FINAL VERSION

BASELINE GEOMORPHIC AND HYDROLOGIC CONDITIONS

Rancho Mission Viejo: Portions of the San Juan and Western San Mateo Watersheds

February 2002

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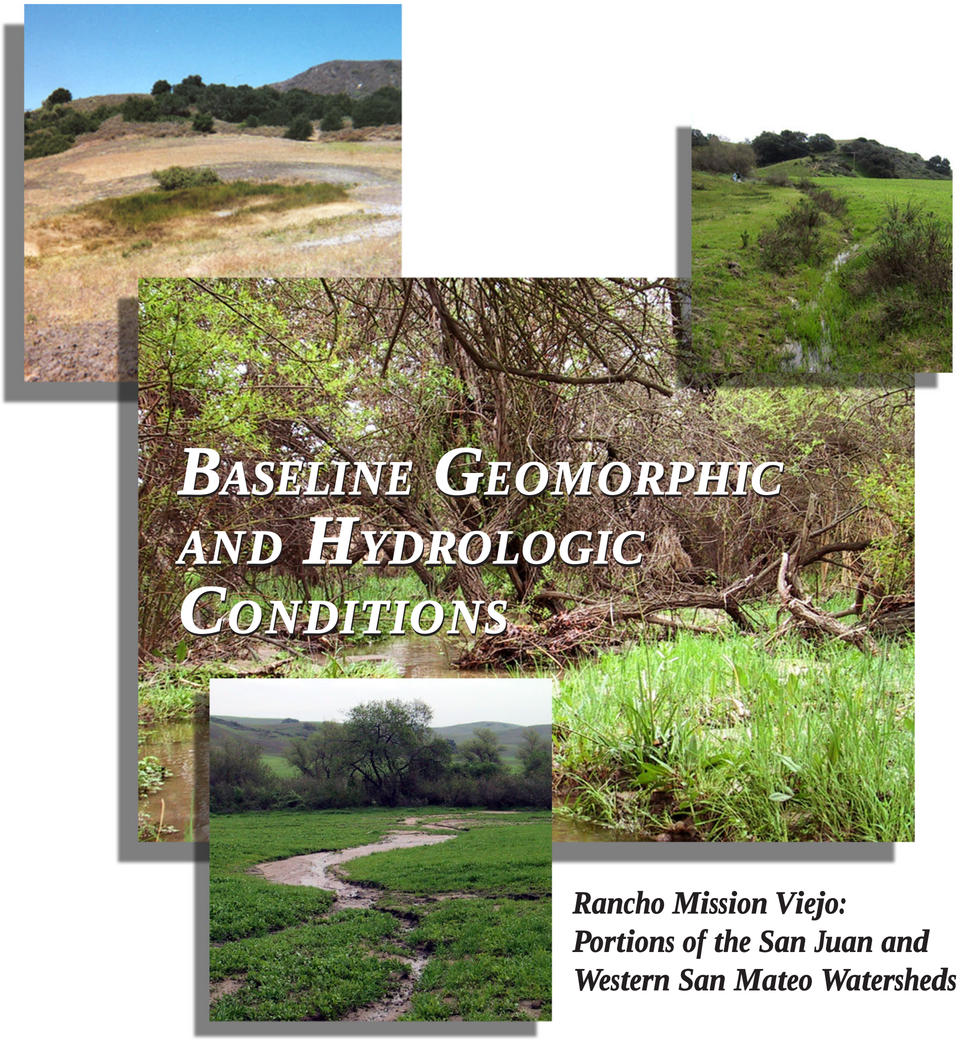

Baseline Geomorphic and Hydrologic Conditions

Rancho Mission Viejo:
Portions of the San Juan and
Western San Mateo Watersheds

Prepared For:

Rancho Mission Viejo
28811 Ortega Highway
P.O. Box 9
San Juan Capastrano, California 92693
Tel: 714.240.3363
Contact: Laura Coley Eisenberg
Richard M. Broming

Prepared By:

PCR Services Corporation
One Venture, Suite 150
Irvine, California 92618
Tel: 949.753.7001
Contact: Eric Stein, Dr.Env., Principal Ecologist

PWA, Ltd.
770 Tamalpais Drive, Suite 401
Corte Madera, California 94925

Balance Hydrologics, Inc.
900 Modoc Street
Berkeley, California 94707-2208

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EXECUTIVE SUMMARY

Federal, State, and local agencies, in cooperation with local landowners are currently engaged in a comprehensive land use and natural resource planning process for the San Juan Creek and western San Mateo Creek watersheds and other adjacent areas located within southern Orange County. This comprehensive planning process includes preparation of a Special Area Management Plan/Master Streambed Alteration Agreement (SAMP/MSAA), a Natural Communities Conservation Plan/Habitat Conservation Plan (NCCP/HCP), a Comprehensive Point and Non-point Source (NPS) Pollution Control Program, and a local entitlement process involving amendments to the County of Orange General Plan and Zoning Ordinance. This comprehensive planning process is intended to coordinate protection of riparian systems and upland habitats, and enable them to be managed over the long-term as part of a single integrated implementation program.

Numerous technical studies and surveys have been conducted during the past several years to support this comprehensive planning effort. Significant data has been gathered by the Corps of Engineers, Department of Fish and Game and the U.S. Fish and Wildlife Service in support of the SAMP/MSAA and NCCP/HCP processes, respectively. The Corps of Engineers has conducted a landscape scale delineation and functional assessment of the streams and riparian zones within the study area. The Corps studies have identified and mapped the extent of potential Corps (and Department of Fish and Game) jurisdiction and ranked the streams in terms of their overall hydrologic, biologic, and biogeochemical integrity. The Corps assessed integrity by dividing the riparian ecosystems into assessment units or "riparian reaches" and assessing each riparian reach using a suite of indicators of ecosystem integrity. Studies conducted for the NCCP/HCP program have mapped the general vegetation communities in the study area and identified areas occupied by sensitive species.

This report summarizes the results of a series of technical baseline studies conducted by Philip Williams and Associates (PWA), Balance Hydrologics (BH), and PCR Services Corporation (PCR) over the past two years. The studies summarized in this report analyze the physical processes and the underlying geomorphology that contribute to the ecologic conditions of the riparian resources in the study area. This report provides insight into the dynamics of the riparian ecosystems and is intended to supplement and complement the information gathered by the landscape scale delineation and functional assessments completed by the Corps of Engineers for the SAMP/MSAA. The report will also supplement the sensitive species and habitats surveys conducted by Dudek & Associates for the NCCP/HCP by providing an understanding of distinctive characteristics and stream systems at a sub-watershed, as well as watershed level. The relationships between hydrologic and geomorphic processes and habitat/lifecycle requirements of sensitive species are considered, but not explicitly addressed in the report, and these relationships will be addressed in detail in a subsequent document focusing on listed aquatic species both within the study area and immediately downstream of the study area.

As indicated above, the focus on this report is on understanding the manner in which the terrains found in the study area affect fundamental processes that alter and shape the study area creek systems and how these terrains respond to different storm events. In order to understand how proposed future changes in land use may result in potential changes in hydrology, it is essential to understand how the relative influence of terrains, soil hydrogroups and land use type on infiltration conditions and runoff can vary depending upon storm event magnitude and also to understand how sub-watersheds, and portions of sub-watersheds, may respond differently to the same storm event. In this way, the Baseline Report analytical approaches are intended to complement the WES studies, so that, taken together, the WES analyses and the methodologies presented in the baseline Report provide a multi-dimensional basis for assessing existing hydrologic and geomorphic conditions throughout the study area, differences in the way different terrains respond to the same hydrologic events, and the effects of proposed changes in land use on hydrologic functions and values at a variety of geographic scales.

The analyses summarized in this report address physical processes and conditions at the watershed and sub-basin scales because this scale of analysis encompasses natural hydrologic, terrains and vegetation features that shape the specific creeks in the study area. The use of the watershed and sub-basin helps create an analytic framework within natural processes can be better understood. Data in this report include direct measurements of processes such as stream network and runoff analyses that can be used to complement the indirect reach indicators selected by WES as part of their functional assessment. It should be understood by the reader that the use of sub-basin as a geographic unit of analysis does not result in the averaging of characteristics across distinctly different portions of a sub-basin. Instead, the use of the sub-basin as the geographic unit of analysis helps provide a scale of assessment that encompasses the distinctive natural hydrologic, terrains and vegetation features within a particular sub-basin that often result in quite different responses to storm events under existing conditions and different responses o future proposed changes in land use.

Thus, the purposes of this report are to: (1) characterize the baseline hydrologic and geomorphic conditions and processes within the study area; (2) identify development and resource management opportunities and constraints associated with hydrologic and geomorphic processes and ecologic conditions at the watershed/landscape scale; and (3) identify key considerations for assessing the potential impacts (including secondary and cumulative impacts) of various development alternatives on hydrologic and geomorphic processes and ecologic conditions. The emphasis throughout this report is to identify and evaluate opportunities at this broader scale which are usually not effectively addressed when planning occurs only at the individual project scale. To achieve these broader purposes, the following analyses were conducted:

Geomorphology and Terrains: The existing and historic land use/land cover, geology, and soils were investigated, mapped, and categorized. This information was used to develop recharge, runoff, and sediment generation characteristics for each sub-basin.

Hydrology: The existing 2-year, 10-year, and 100-year discharges were modeled for each sub-basin and for the overall watersheds. This information was used to identify key considerations relative to the timing and magnitude of flow for each sub-basin.

Sediment Yield and Transport: Expected sediment yields were estimated based on the results of the geomorphology and terrains analysis and a variety of past studies of Southern California watersheds. Sediment transport rates were modeled on a reach-basis and were integrated at the sub-basin and watershed scales. This information was used to identify key sediment production areas, as well as areas of deposition, scour, and key transport reaches. The effect of episodic events on stream stability was also analyzed.

Water Quality: Five existing water quality data sets were analyzed to assess the potential roles that various geomorphic or biologic features of the landscape may be playing in the control and mobilization of key water quality constituents. In addition, an ongoing water quality monitoring program has been initiated to supplement the existing data and provide more detailed baseline information for the San Juan and western San Mateo watersheds.

Shallow Groundwater: Areas where shallow sub-surface water may be important to the integrity of existing aquatic resources. The results of the geomorphology and terrains and the hydrology analyses were used to infer general groundwater flow directions and key recharge areas. This study did not include detailed modeling of groundwater movement or analysis of groundwater quality.

The physical processes analyzed are those that strongly influence the conditions of the riparian ecosystems. As such, the information produced by these studies will help provide an understanding of the long-term dynamic cycles that should be considered during the analysis of future land use alternatives.

The report is organized into seven sections:

<u>Section 1</u> introduces the purposes of the report and provides a framework for the landscape-scale perspective taken in the technical studies. Differences between landscape and site-specific scales of analysis are highlighted and the expected uses of the technical studies are discussed.

<u>Section 2</u> provides information on the general approach and assumptions used for each technical study. Each technical study used a combination of existing data and new

modeling/analysis to provide information on existing conditions in the study area. The approach used for each study was adjusted to accommodate the various scales of analysis (i.e., site specific, sub-basin, and overall watershed), but always included landscape-scale analysis.

Section 3 contains the results of the watershed-scale analyses and provides a discussion of the overall physical, chemical, and biological processes for the study area. The results are organized by watershed (i.e., San Juan and San Mateo) and by topic (i.e., hydrology, geomorphology, sediment transport, water quality, groundwater).

Section 4 summarizes the attributes of the watersheds that are most important from a land use planning perspective. The intent of this Section is to focus the results presented in Section 3 on those issues that are most critical for consideration during the alternatives analysis.

Section 5 contains a discussion of the effect of historic and present land uses on the watersheds. This section emphasizes analysis of areas remaining that are not already developed, entitled, or dedicated as open space. These remaining undeveloped and uncommitted areas are owned primarily by Rancho Mission Viejo (RMV) and are being considered for future land use changes as part of the County's General Plan and Zoning amendment process for the RMV property that is proceeding concurrent with the SAMP/MSAA and NCCP/HCP.

Section 6 provides summaries of the processes occurring in each major sub-basin in the study area and discusses how those processes relate to overall watershed condition. This section also identifies major opportunities and constraints for each sub-basin that should be considered during the alternatives analysis.

Section 7 preliminarily discusses how the analyses contained in this baseline report may be used for subsequent phases of the SAMP/MSAA, NCCP/HCP, water quality management planning, and local entitlement processes. Examples of how each technical study can be applied to each planning/entitlement process are also discussed.

This report is intended to provide a cohesive summary of the various baseline technical studies. The technical studies that are summarized in the report are attached to this report as stand-alone technical appendices.

The models and information summarized in this document will be used to help formulate and analyze alternatives, mitigation measures, and management recommendations. During the next phases of the coordinated planning process, the results of these technical studies will be used to: (1) analyze the effect of alternative land use scenarios on the physical and biological processes of the study area; (2) develop specific approaches, guidelines, and criteria for project design elements and BMPs that would contribute to minimizing the effects of land use changes by maintaining the existing hydrologic, water-quality, and hydrogeologic functions of the watersheds; (3) identify, where practicable, measures necessary to minimize or mitigate the effects of existing uses within the watersheds; and (4) develop specific elements of the aquatic and upland enhancement, restoration and management programs. In addition, during future phases of the coordinated planning process, the results of the landscape-scale analysis will be translated to an area-specific scale to analyze impacts and formulate specific development resource management recommendations.

1.0 INTRODUCTION

1.1 GOALS, OBJECTIVES, AND ORGANIZATION OF REPORT

This report summarizes the results of a series of technical baseline studies on the existing and historic physical processes and conditions in the San Juan Creek watershed and western 18 $mi.^2$ of the San Mateo Creek watershed (upstream and northwest of Camp Pendleton). The technical studies summarized in this baseline conditions report were conducted by Philip Williams and Associates (PWA), Balance Hydrologics (BH), and PCR Services Corporation (PCR), and are intended to complement studies prepared by the U.S. Army Corps of Engineers on the riparian systems in the same study area. Information from studies conducted by Dudek & Associates (Dudek) has also been used to identify preliminary biological considerations.

The studies summarized in this report were conducted in support of the San Juan/San Mateo Special Area Management Plan/Master Streambed Alteration Agreement (SAMP/MSAA), Southern Subregion Natural Communities Conservation Plan/Habitat Conservation Plan (NCCP/HCP), and Comprehensive Point and Non-point Source (NPS) Pollution Control Program. The boundaries of the study area generally coincide with those of the San Juan/San Mateo SAMP/MSAA and southern subregion NCCP/HCP as shown in Figure 1 on page 2. However, as discussed in Sections 5 and 6, the discussion of opportunities and constraints associated with potential changes in future land use focuses on the 25,000 acres owned by Rancho Mission Viejo that are being considered for future land use changes.

The approach, methodology, and inter-relationships between the studies, have been described in detail in the *Work Plan for Hydrology and Geomorphology Studies* (PCR, 2000b) (Work Plan). The specific goals of this Baseline Conditions report are:

1. Characterize the baseline hydrologic and geomorphic conditions and processes of the watersheds.

2. Identify development and resource management opportunities and constraints associated with hydrologic and geomorphic processes and ecologic conditions. The goal is to provide information that may be used in the analysis of the compatibility of various land use scenarios with physical processes and to ensure that proposed development alternatives provide for protection of major wetlands and riparian areas, maintain aquatic resource functions, and address sensitive species needs in terms of hydrology, geomorphology, and water quality.

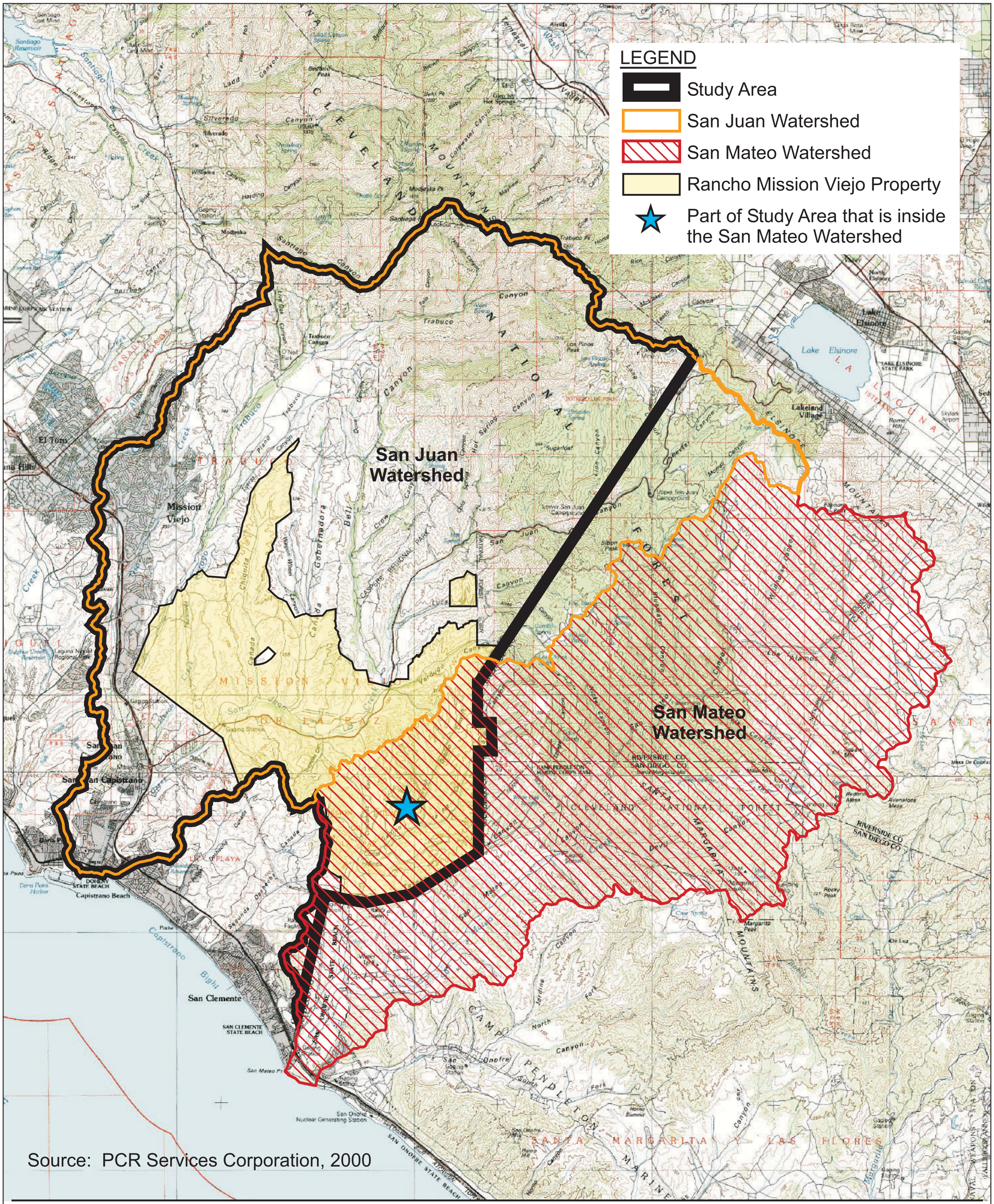

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Figure 1
Baseline Conditions Report
Study Area Boundary

3. Identify key factors and considerations for assessing and mitigating the potential impacts (including secondary and cumulative impacts) of various development alternatives on hydrologic and geomorphic processes at the watershed and sub-watershed scales.

Recommendations resulting from the technical studies may include alternative locations or configurations of proposed future land uses or design features to help protect the integrity of aquatic resources.

As noted previously, this report is intended to complement studies previously completed by the U.S. Army Corps of Engineers for the SAMP (see Section 1.3) and by Dudek & Associates for the NCCP. This report does not assess biological baseline conditions, but does consider known biological constraints and opportunities. Similarly, the relationship between hydrologic and geomorphic processes and habitat and/or lifecycle requirements for aquatic species is not addressed in this report, but will be the focus of a subsequent effort.

Analysis and planning for an approximately 25,000-acre area with a variety of terrains and processes needs to address the particular habitat and hydrological/geomorphic characteristics of sub-watersheds within the larger planning region. Accordingly, this report provides information at both the watershed and sub-basin scales. The general approach and assumptions used for each analysis are described in Section 2. A discussion of the overall physical, and chemical processes and biologic conditions for the San Juan and San Mateo watersheds in Section 3. Section 4 summarizes the attributes of the watersheds that are most important from a land use planning perspective. Section 5 contains a discussion of the effect of historic and present land uses on the watersheds and highlights areas that will be analyzed for potential future land use changes. Section 6 provides summaries of the hydrologic and geomorphic processes occurring in each major sub-basin in the study area, describes how those processes relate to overall watershed condition, and identifies major opportunities and constraints for each sub-basin. Finally, Section 7 introduces how the analysis contained in this baseline report may be used for subsequent phases of the SAMP/MSAA, NCCP/HCP, water quality, and local entitlement processes. This report is intended to provide a cohesive summary of the various technical studies. The complete versions of each technical study are provided as technical appendices to this report.

This report supports the first phase of the coordinated SAMP/MSAA, NCCP/HCP, Water Quality, and local entitlement processes by summarizing the analysis of baseline conditions. The second phase of the coordinated planning process will analyze the effect of several alternative land use scenarios on the physical and biological processes of the watershed[1]. The second phase will also involve development of specific approaches, guidelines, and criteria for project design elements and

[1] *The effect of potential land use changes on hydrologic and geomorphic processes will be assessed in the next phase of the coordinated planning process. This report is not intended to address potential impacts or changes in physical processes, only to summarize baseline conditions.*

Best Management Practices (BMPs) that minimize the effects of land use changes by maintaining the hydrologic, water-quality, and hydrogeologic functions of the watersheds. Specific elements of the aquatic and upland restoration and management programs will also be developed during subsequent phases of this process.

1.2 LANDSCAPE PERSPECTIVE IN ASSESSMENT AND PLANNING

The SAMP/MSAA and NCCP/HCP programs are proactive planning efforts intended to achieve a balance between resource protection and economic development. The stated purpose of the SAMP/MSAA is:

> "to develop and implement a watershed-wide aquatic resource management plan and implementation program, which will include preservation, enhancement, and restoration of aquatic resources, while allowing reasonable and responsible economic activities and development within the watershed-wide study area."

The primary objective of the NCCP/HCP program is:

> "to conserve natural communities and accommodate compatible land use. The program seeks to anticipate and prevent the controversies and gridlock caused by species' listings by focusing on the long-term stability of wildlife and plant communities and including key interests in the process."

The overall goal of the State Non-point Source Program is:

> "to manage NPS pollution, where feasible, at the watershed level, including pristine areas and watersheds that contain water bodies on the CWA [Clean Water Act] section 303(d) list and where local stewardship and site-specific management practices can be implemented through comprehensive watershed protection or restoration plans."

A common theme with all three of these programs is planning and management at the landscape or watershed scale. Watershed scale protection, enhancement, and management of natural resources requires an understanding of the landscape-scale processes that govern the integrity and long-term viability of aquatic and other natural resources.

By taking a landscape perspective in assessment and planning, cumulative impacts and appropriate mitigation measures can be better addressed. Furthermore, the constraints associated with natural resources and processes can be integrated early in the development process. In addition to minimizing impacts, this large-scale perspective facilitates development of a comprehensive preservation, enhancement, and restoration plan that addresses long-term management of natural communities, enhancement of water quality, and flood hazard reduction. This planning process is intended to coordinate protection of riparian wetland systems and upland habitats and enable them to be managed over the long-term as part of a single, integrated implementation program.

A clear distinction must be maintained between the landscape perspective employed in this report and the site-specific perspective typically used in regulatory analyses. This report does not provide detailed information on specific locations; rather, it focuses on overall watershed and sub-watershed processes by evaluating potential cumulative effects and working toward site-specific considerations in the context of the overall watershed processes. This contrasts with the traditional approach of focusing on site-specific effects and attempting to integrate actions at multiple sites to assess cumulative impacts. The approach used in this report (and in subsequent phases of the coordinated planning process) allows a more thorough consideration of potential cumulative impacts and more effectively ensures that overall physical processes in the watersheds are not degraded as a result of the cumulative effect of incremental actions.

This comprehensive planning effort is intended to support applications for state and federal regulatory permits and can be used to assist the federal, state, and local regulatory agencies with their decision-making and permitting authority to protect and enhance upland and aquatic resources and water quality. The overall intent is to develop programmatic approaches for compliance with requirements of the Federal Clean Water Act, State Porter Cologne Act, State Fish and Game Code, and Federal and State Endangered Species Acts, as well as support development of California Environmental Quality Act/National Environmental Policy Act (CEQA/NEPA) documents and the local entitlement process (see Section 1.4).

1.3 RELATIONSHIP OF WORK PLAN STUDIES TO WES AND CRRL REPORT

Accomplishment of this landscape-scale, resource-based planning and management program requires an understanding of the current condition of natural resources and the physical processes that govern their long-term viability. The U.S. Army Corps of Engineers (Corps) Cold Regions Research Laboratory (CRRL) and Waterways Experiment Station (WES) have conducted a landscape scale delineation of aquatic resources (Lichvar et al., 2000) and a landscape scale functional assessment study (Smith, 2000) to characterize and assess the riparian resources in the study area.

The studies summarized in this report do not replace any data produced by the WES and CRRL studies; rather, these studies provide supplemental information in topical areas that are not the focus of the WES and CRRL studies. Together, the two efforts, the WES/CRRL studies and the studies summarized in this report, provide a set of tools for characterizing the existing conditions in the study area and for supporting the identification and analysis of SAMP/MSAA alternatives.

In the context of the future SAMP/MSAA, NCCP/HCP, and GP/zoning alternatives analyses, the results summarized in this report will be used to: (1) help identify areas susceptible or resilient to development impacts; and (2) help develop and analyze land use configuration and design alternatives based on the landscape-scale hydrologic/geomorphological constraints and opportunities. In turn, it is expected that the WES/CRRL study will be used to evaluate the differential effect of the alternatives on riparian integrity, as stated in the third task of their study:

> "The third task is to determine which of several proposed development alternatives will result in the least impact to the overall integrity of riparian ecosystems in the watersheds. This will be accomplished by comparing the baseline ecosystem integrity scores to scores following a 'simulation' of each development scenario. The 'simulations' will be based on the changes that can be expected to occur as a result of each proposed development scenario."

1.4 EXPECTED USE IN SAMP/MSAA, NCCP/HCP, WATER QUALITY, AND LOCAL ENTITLEMENT PROCESSES

A goal of this report is to provide critical information in a landscape-context to support regional and programmatic decisions and authorizations, specifically permits under Sections 401 and 404 of the Federal Clean Water Act, Section 10(a) of the Federal Endangered Species Act, 1600 et seq. streambed alteration agreements pursuant to the California Fish and Game Code Section, and NCCP/HCP plans pursuant to 2800 et seq. of the California Fish and Game Code. The roles of the technical studies (and the associated products) in state and federal permitting and the local entitlement process are explored in the following sections.

1.4.1 Clean Water Act Section 404/SAMP and Section 1600/MSAA

Under the SAMP/MSAA planning process, the WES/CRRL reports and the technical studies summarized in this report will be employed in the Corps 404 "*off-site alternatives analysis*" at a watershed level to provide the analytical framework for identifying land use, reserve design, and management/enhancement alternatives and measures that will reasonably assure the long-term integrity of the significant aquatic resources within the watershed and of watershed and subwatershed functions and processes. Design recommendations resulting from the studies summarized in this report will be used during the "*on-site alternatives analysis*" to ensure that impacts to aquatic resources are avoided, minimized, and mitigated to the maximum extent practicable. The geomorphic terrains analysis will be used to assess potential impacts on hydrologic integrity and drainage density and function and to avoid undesirable changes in recharge, shallow groundwater quality, erosion, and the presence of wetlands. Finally, the output from these studies will be used in conjunction with the WES/CRRL studies and other information concerning habitat and species to establish a regional protection, restoration, and management plan for aquatic resources in the study area, including development of a comprehensive aquatic resource reserve program. The role of each technical study in the on- and off-site alternatives analysis is summarized in Table 1 on page 8.

1.4.2 State and Federal Endangered Species Acts (NCCP and HCP)

The goal of the Southern Subregion NCCP/HCP program is to develop a subregional conservation strategy and management program that would provide for the long-term protection and management of upland and aquatic natural communities and species as part of a single, integrated implementation program. Protection and management of natural communities, and the associated sensitive species, requires consideration of the underlying physical processes that support the targeted natural communities. A primary goal of the technical studies is to understand the physical processes of the watersheds and then use that understanding to develop proposed land use and species/habitat management scenarios that accommodate sensitive species needs over the long term. In particular, the technical studies completed as part of the baseline report will provide information concerning the physical hydrologic processes that will support the following NCCP/HCP objectives:

1. Formulating an effective habitat reserve design that is capable of protecting significant upland and aquatic natural communities and their associated species. This includes providing an understanding of the significance of physical and hydrologic processes, providing opportunities for biological connectivity between source populations of species and with other subregions, and facilitating the evaluation of alternative locations for new development;

2. Identifying upland and aquatic species for regulatory coverage under the State and Federal Endangered Species Acts (ESAs) and NCCP/HCP;

3. Identifying and, if necessary, reconciling competing upland and aquatic resource restoration and adaptive management priorities;

4. Evaluating proposed adaptive management measures within the upland and aquatic natural communities for potential coordination and integration needs/issues; and

5. Identifying and evaluating funding needs and implementation measures that will be needed to support the long-term management of the overall habitat reserve system.

Species listed at the state or federal levels that are present or potentially present in the study area and are dependent upon aquatic resources within the NCCP/HCP subregion include the arroyo toad, least Bell's vireo, southwestern willow flycatcher, and San Diego fairy shrimp. Other aquatic species will be evaluated for designation as "identified" species that would receive regulatory coverage based, in part, on the information generated by this report.

Table 1

Role of Each Technical Project in Completion of Alternatives Analysis

Technical Study	Off-site Alternatives Analysis	On-site Alternatives Analysis
Geomorphic Terrain Analysis	**General constraints and opportunities associated with specific geologic features and soils.**	Runoff characteristics and typical constituents associated with runoff from different soil types.
Stream and Watershed Characterization	**Basic data for other technical studies/provide an overall view of the drainage patterns in the study area.**	Input to the sediment yield and transport analysis/design of stormwater management facilities.
Surface Water Hydrology	Landscape-scale hydrology and flow characteristics of major streams and potential changes in hydrology associated with off-site alternatives.	**Detailed modeling of runoff from proposed projects to design impact minimization and mitigation measures.**
Shallow Groundwater Analysis	**Interactions between hydrodynamics and chemistry of groundwater and surface flow/ dynamics of groundwater dependent wetlands.**	Infiltration rates and design features to mitigate the influence of changes in on-site recharge on water quantity or quality/estimates of groundwater storage and detention.
Surface and Groundwater Quality	Potential pollutant loadings to receiving waters associated with biogenic and anthropogenic sources/intra- and inter-annual variations in loadings.	**Management Measures (under the NPS program) and BMPs that will ensure that water quality standards are met and sensitive species needs are addressed.**
Sediment Analysis	**Major source, sinks, and transport patterns of sediment and effect of alternatives on sediment yield and long-term channel stability.**	Loadings from specific land uses and BMP design features to offset potential effects of development on channel stability.
First Order Stream Function	**Cumulative effect of development alternatives on headwater stream function/strategies to compensate for lost headwater functions.**	Development of project-specific mitigation strategies that address the site-specific contribution of first order streams to overall basin function.

Shaded Boxes	= output of study primarily used for this portion of the analysis (i.e., off-site or on-site alternatives analysis)

Source: PCR Services Corporation, 2000

Although the NCCP/HCP will not directly address ESA issues for lands outside the Southern Subregion boundaries, this report will enable agencies and interested parties to have a better understanding of the relationship between natural communities protection and management within the subregion and downstream areas. Downstream of the NCCP/HCP subregion boundary, in the lower portions of the San Mateo Creek watershed, aquatic resources support the tidewater goby, least Bell's vireo, southwestern willow flycatcher, and potentially the steelhead. The geomorphic terrains analysis will be used to help guide development strategies to avoid and mitigate indirect impacts to sensitive riparian habitat, such as downcutting, bank erosion, and changes in channel forming flows. The sediment yields and transport analysis will be used to evaluate the potential for development-related impacts on sensitive species, such as arroyo toad and least Bell's vireo, as well as potential impacts on lagoon sedimentation (which would be an issue of particular concern with respect to tidewater goby habitat). Analysis of the potential effects of alternative land use scenarios on landscape-scale channel form and process will help ensure that habitat integrity of sensitive species is maintained. Specific impact minimization and mitigation measures will be developed to ensure that proposed development does not directly or indirectly adversely affect the ability of streams to support sensitive species.

1.4.3 Clean Water Act/NPDES Program/Porter Cologne/NPS Control

The federally approved State water quality and NPS programs express a preference for watershed-scale approaches to control point and NPS pollution. The NPS-control Plan achieves this goal by dealing with NPS pollution via 61 Management Measures (MMs). Management measures serve as general guidelines for the control and prevention of polluted runoff and the attainment of water quality goals. Site-specific management practices are then used to achieve the goals of each management measure. Specifically, the Plan:

1. Adopts 61 MMs as goals for six NPS categories (agriculture, forestry, urban areas, marinas and recreational boating, hydromodification, and wetlands/riparian areas/ vegetated treatment systems);

2. Uses a "Three-Tiered Approach" for addressing NPS pollution problems (Tier 1: Self-Determined Implementation of Management Practices [formerly referred to as "voluntary implementation"]; Tier 2: Regulatory Based Encouragement of Management Practices; and Tier 3: Effluent Limitations and Enforcement Actions).

3. Expresses a preference for managing NPS pollution on a watershed scale where local stewardship and site-specific management practices can be implemented through comprehensive watershed protection or restoration plans.

The San Diego Regional Water Quality control board has proposed issuance of a new NPDES permit for discharges of urban runoff in the watersheds of south Orange County (Tentative Order No. 2001-193). The proposed NPDES permit requires preparation of a Watershed Urban Runoff Management Plan (W-URMP) that would require all co-permittees to work cooperatively to assess water quality throughout the watershed and institute land-use planning programs to reduce pollutant runoff to the maximum extent possible. The W-URMP is required , at a minimum to contain the following: mapping of the watershed, an assessment of the water quality of all receiving waters in the watershed, an identification and prioritization of major water quality problems in the watershed, an implementation time schedule of short and long-term recommended activities needed to address the highest priority water quality problem, a mechanism to facilitate collaborative "watershed-based" (i.e., natural resource-based) land use planning, and a short and long-term monitoring and adaptive management program.

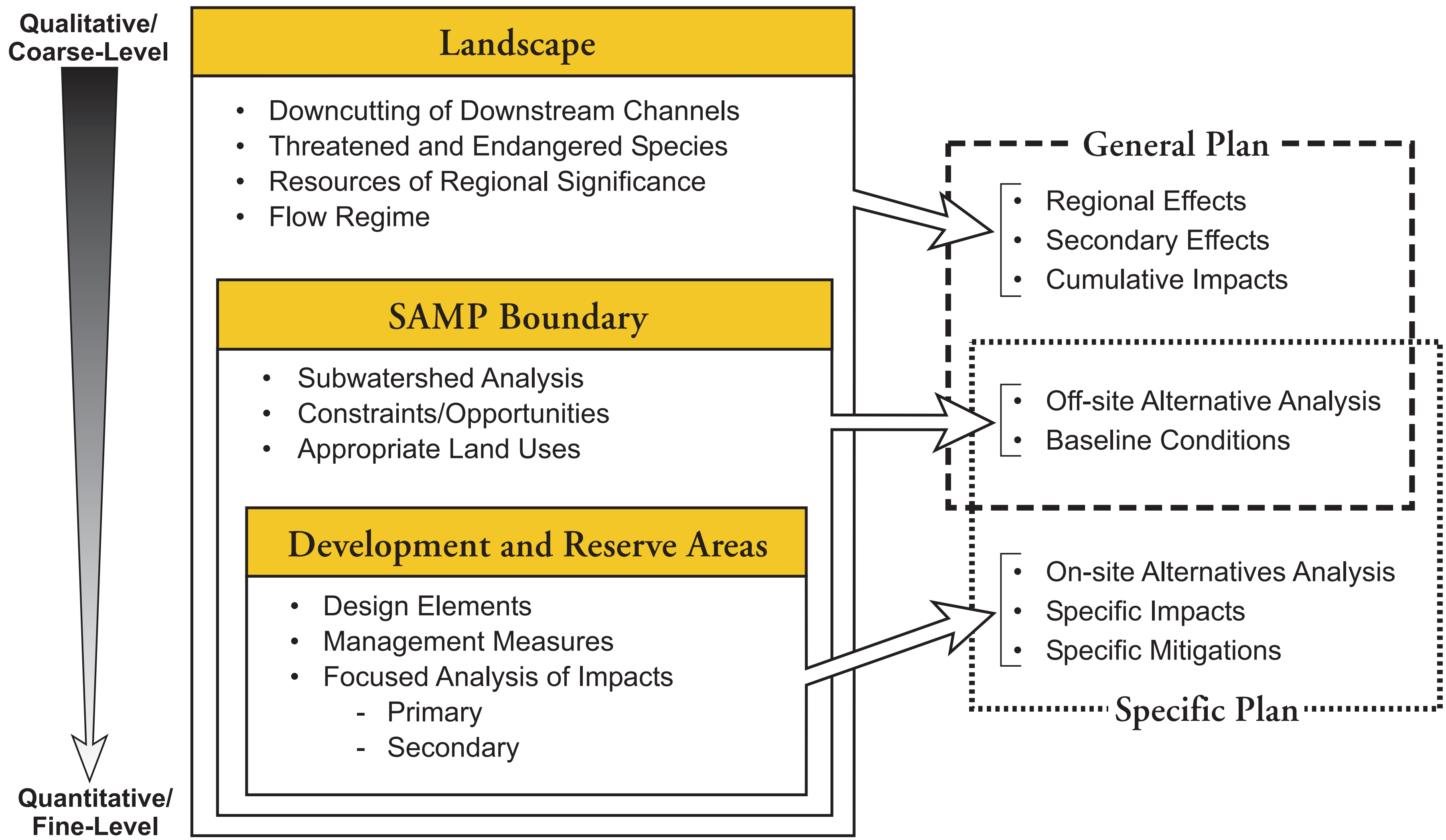
The focus of the technical studies summarized in this report on watershed hydrologic/geomorphic processes is consistent with the watershed emphasis of the NPS and NPDES programs in that the output from the studies will be used to help locate and design proposed developments in a manner that minimizes impacts on the beneficial uses of receiving waters. To the extent feasible, the locations, extent, and configuration of development and open space/habitat reserve areas designated by the SAMP/MSAA and NCCP/HCP will be designed and managed to protect major streams from the effects of new development. Within development areas, design features, buffer requirements, and BMPs will be developed to address both point (i.e., National Pollution Discharge Elimination System) and NPS pollution control issues. The landscape-scale strategies will be consistent with the Watershed URMP requirements of the NPDES permit, while the on-site measures will be consistent with recommended Management Measures in the State NPS Pollution Control Program. The output from the technical studies will be used to help provide the basis for programmatic water quality certification pursuant to the State NPS and San Diego RWQCB programs.

1.4.4 Local Entitlement

Data generated by the technical studies will be used in the design of each new development area to comply with Orange County design requirements for flood hazard assessment. In particular, the work products developed through the surface water hydrology analysis, HEC-1 modeling, will be used to analyze the effect of proposed development on large flood events, particularly the 100-year event. Recommendations for design features and mitigation measures to offset potential hydrologic and sediment impacts of proposed land use changes will be developed. This information may also be used to supplement the existing data produced as part of the Corps of Engineers San Juan Creek watershed study. The Corps watershed study is evaluating potential environmental restoration and flood control projects in the watershed that may be implemented in partnership with the County of Orange.[2]

The contribution of the work plan products to the development of general and specific plans is summarized in Figure 2 on page 12.

[2] *The San Juan Creek watershed study is being administered by the Corps Planning Division. Although it covers some of the same areas as the SAMP/MSAA, it is focused on identifying specific flood control or restoration projects. Unlike the SAMP/MSAA, it is not intended to analyze overall watershed processes and provide management recommendations to maintain the integrity of those processes.*



Source: PCR Services Corporation, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 2
Baseline Conditions Report
Application of Technical Studies to Various Scales of Analysis

2.0 ASSESSMENT APPROACH AND KEY ASSUMPTIONS

The technical studies summarized in this report, evaluated information at three spatial scales. The landscape scale encompasses the entire watersheds from the headwaters to the coast. The intermediate scale includes areas within the boundary of RMV; the finest scale addresses the proposed development or reserve areas (Figure 3 on page 14). The analyses discussed in this report have been undertaken at the first two spatial scales and provide the basis for future analysis at the development or reserve area scale. As such, this report contains large-scale coarse resolution information with further refinement at the sub-watershed level.

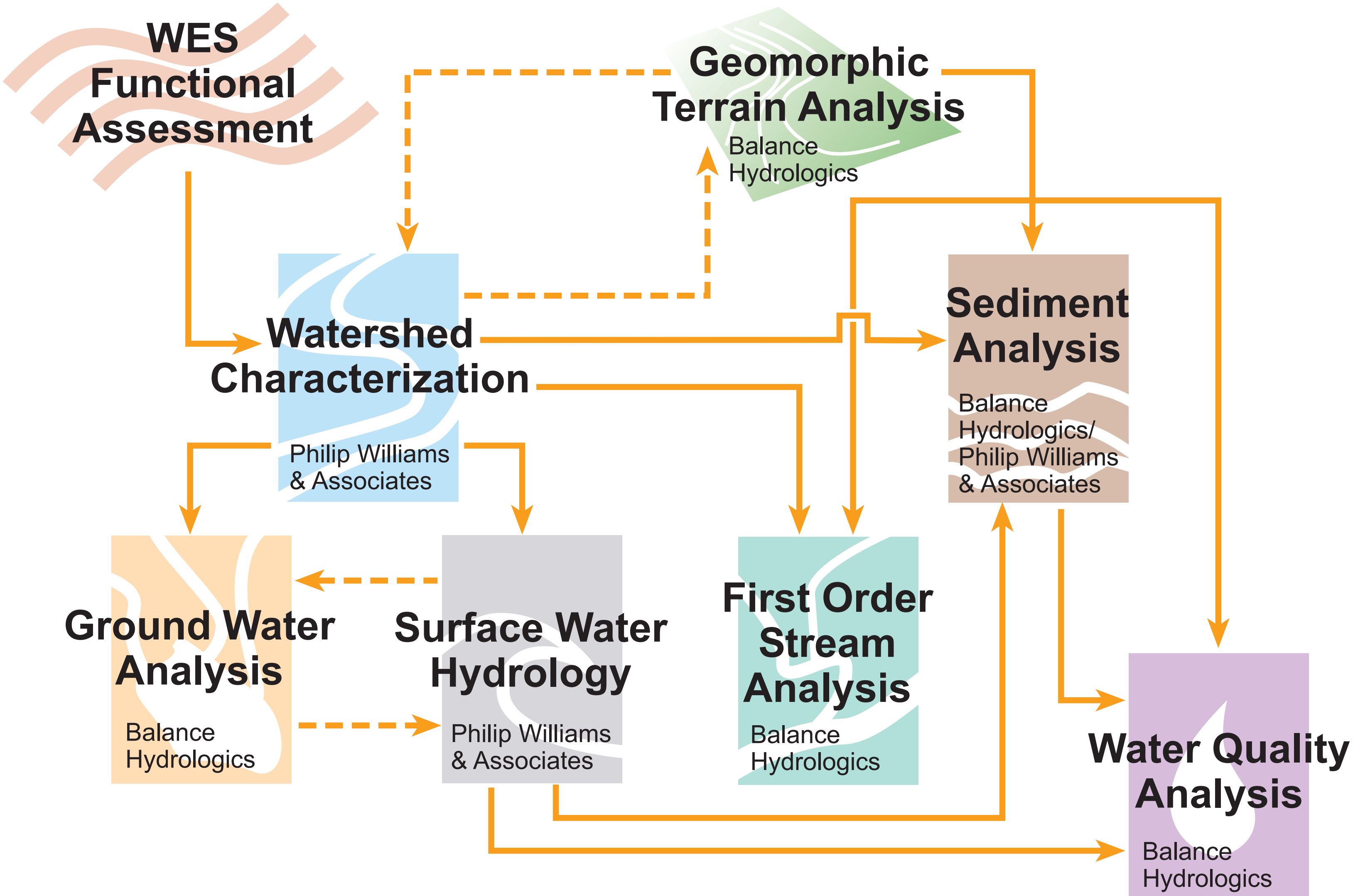
The landscape-scale analyses contained in this report provide information about the constraints and opportunities associated with proposed future land use changes in order to support decision-making at the sub-watershed and programmatic levels. This report will support the off-site alternatives analysis by helping to evaluate the general location, extent, and configuration of alternative development and reserve areas (i.e., tier one of the alternatives analysis process). As the analysis and permitting needs progress to the on-site level, the technical information produced will be refined and applied with higher levels of resolution by analyzing potential changes in physical processes based on specific land use designs.

The methodology used for each of the analyses was specific to the needs of that technical discipline. In all cases, existing data was reviewed and utilized as appropriate and to the maximum extent possible. Because the analyses are intended to provide a landscape scale perspective, methods were geared to optimize this scale of analysis. In several instances, the scale of analysis favored qualitative analysis of processes and patterns over site-specific quantitative evaluations. In some instances, order of magnitude estimates were considered sufficient. In all cases, limitations of the data are disclosed along with the results. The following assumptions were used in all analyses:

1. Approximately 85 percent of the San Mateo creek watershed is outside the study area; therefore, assumptions have been made about land uses outside the study area (primarily on Camp Pendleton) and their influence on overall watershed integrity.[3] In contrast, the majority of the San Juan watershed (downstream of the boundary of the Cleveland National Forest) was directly analyzed by the studies summarized in this report.

2. Although this report focuses on resources subject to the jurisdiction of either the Corps of Engineers or the Department of Fish and Game, non-jurisdictional riparian areas, and

[3] *WES previously evaluated the functional integrity of aquatic resources on Camp Pendleton. This information can be used during the analysis of the cumulative impacts.*



Source: PCR Services Corporation, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 3
Baseline Conditions Report
Relationship Between Technical Studies

"channel-less" valleys (swales) have also been included in the analyses to the extent that they contribute to the biological, hydrologic, or geomorphologic function of the main stream systems. The fundamental unit of analysis for this report is the riparian corridor (as opposed to jurisdictional wetlands), with the focus being on the interaction between upland areas, floodplains, and streams.

The sections below summarize the methods used for investigation of specific disciplines. More detailed information on methodologies can be found in the technical appendices.

2.1 GEOMORPHOLOGY AND TERRAINS

The conditions of aquatic and riparian resources are influenced by land use practices in the contributing watershed. Upland land uses have the potential to affect surface and subsurface flow to wetlands, sediment input to streams and wetlands, and pollutant loading to streams. Increases or decreases in overland flow and sediment generation can alter the physical, chemical, and biological condition of streams. Changes in chemical input to streams can affect the ability to meet overall water quality standards. Sensitivity of wetland and riparian resources to changes in upland land use is determined largely by the geology, soils, and topography found in the contributing watersheds. These three factors can collectively be termed "the terrain" of the watershed.

The analysis of geomorphology and terrains in this report involved primarily a descriptive analysis of the watersheds using existing data on geology, soils, and past and present land uses. In addition, historic data and aerial photos were reviewed to investigate the effect of both natural and anthropogenic land use changes over time. The results of these investigations were used to produce GIS maps showing the constraints and opportunities inherent to each terrain type, such as potential changes in runoff and recharge associated with development in various substrate types. Much of the information on the hydrologic and geomorphic responses of sandy soils to urbanization was based on research conducted in the Pajaro basin in Santa Cruz County by Hecht and Woyshner (1984) and on Karen Prestegaard's 1978 investigations on the effects of urbanization on the coastal regions of northern San Diego County.

2.2 HYDROLOGY

The magnitudes, frequencies, and patterns of surface flow through uplands and within stream channels are the most deterministic factor of the integrity and distribution of wetlands and riparian habitat. Changes in the magnitude or frequency of peak flows for moderate events (i.e., 2-year), channel-forming events (i.e., 5-year or 10-year return interval), or extreme events (i.e., 25-year, 50-year, or 100-year return interval) can affect the long-term viability of riparian habitat and influence the type of community that persists. Increased frequency of high flows (resulting from increased runoff) can destabilize channels and encourage invasion by aggressive non-native plant species. Changes in baseflow can change the physical and biological structure of the stream. Habitat for sensitive species may also be affected by changes in the physical, chemical, or biological condition of the stream that results from alteration of surface water hydrology.

Hydrologic impacts associated with urbanization have been observed and described by several authors. Findings from past research provide a useful context to interpret current hydrologic conditions in the San Juan and San Mateo watersheds, as well as foresee potential impacts due to urbanization. Synthesizing the earlier work of others, Leopold (1968) summarized how increased impervious surfaces in a watershed results in increased stormflow volume, increased stormflow peak discharge, and a reduction in lag time between precipitation and runoff. Estimating the hydrologic impact on a 1 $mi.^2$ watershed, Leopold (1968) estimated that discharge for a given precipitation event would increase roughly 2.5 times if 50 percent of the watershed was urbanized and drained by a storm sewer system. James (1965), Anderson (1970), and Rantz (1971) described how the hydrologic impacts of urbanization are proportionally greater for more frequent interval storm events than larger events where soils saturated beyond their infiltration capacity behave similarly to impervious surfaces (Graf, 1988). More recently, Wong and Chen (1993), used computational models to suggest that increases in flood peaks caused by urbanization are due to increases in impervious areas more than increases in storm sewer networks for basins with variable slopes. Ferguson (1994) focused on stormwater infiltration as the key to solving urban runoff problems.

Researchers have also documented how such changes in hydrologic regime translate to geomorphic changes in stream channel form by altering processes and patterns of sediment erosion, transport, and deposition. Wolman (1967) suggested a cycle whereby urbanizing watersheds have extremely high sediment yields during the construction phase when barren slopes are disturbed and void of vegetation. Following the build-out phase, sediment yields drop to levels below existing conditions as sediment source areas are capped and replaced by urban landscapes. Hammer (1973) concluded that urbanization and its changes in streamflow regimen generally result in enlarged stream channels, with proportionally greater channel enlargement in steeper watersheds. More specific to the Orange County setting of the current report, Trimble (1997) reported how sediment yields in the San Diego Creek watershed increased during a period of urbanization. Trimble (1997) suggested that about two-thirds of this sediment yield was generated from in-channel sediment erosion, with about one-third supplied by upland hillslope sources. Recently, Doyle et al. (2000) used geomorphic assessment techniques (including quantitative measures of shear stress, stream power, and the recurrence interval of bed-mobilizing discharges) to predict channel stability or instability in urbanizing watersheds. A recent compendium of articles published by the Center for Watershed Protection (Schueler and Holland, 2000) offers a comprehensive review of watershed impacts of urbanization and techniques to mitigate such impacts. Although watershed science is a relatively new and emerging discipline, the current baseline report and future planning process for the San Juan and San Mateo creek watersheds benefit from these past studies which provide a framework to understand hydrologic and geomorphic impacts.

2.2.1 Stream Network Analysis

An early step in any watershed analysis is to assess the basic physical and hydrologic characteristics of the drainage basins, also referred to as a stream network analysis. Understanding the composition and spatial arrangement of channels in the watershed is key to understanding streamflow and ecologic conditions. This information also provides input into the subsequent hydrologic and geomorphic analyses.

The stream network for the watersheds was delineated using a multiple-threshold method based upon a digital elevation model (DEM). The created stream network model was validated against field data collected by the WES/CRRL team. The multiple-threshold method is based on the "erosion-threshold" theory (Montgomery and Foufoula-Georgiou, 1994) and predicts the location where channels begin by combining contributing flow areas and slopes of hillsides into a single channel-predicting parameter. The direction of flow is calculated from the DEM using the D8 method, which uses the eight neighboring cells to predict the water flow direction. A single flow direction is specified for every point in the watershed. This technique was applied to the study area at both 30-meter and 10-meter resolutions. In some areas, this method was insufficient to map the channels, and a modified approach was used. In steep areas, where the erosional threshold theory does not apply, a straight tributary source area was used to predict channel locations. For areas of low relief, such as floodplain valleys, mapped channel locations contained in the National Hydrography Dataset were input to the DEM data. These additional steps enabled channel delineations to match observed channels in areas where the DEM alone was not sufficient to predict channels. Finally, the WES/CRRL field-mapped channels were included as channel heads, and their flow paths were traced through the DEM using a calculated flow direction to create complete channels. In this way, all of the WES mapped channels are represented in the resulting stream delineation (see Appendix A).

Descriptive statistics were calculated for the resulting stream network. The number, length, and stream order of channels were calculated for each sub-basin. Drainage density was calculated for each basin by dividing total stream length by the total area of the basin. Additionally, the bifurcation ratio was calculated for each stream order by taking the number of channels for a particular order and dividing by the number of channels of the next highest order. This provides an outline of the stream network's natural structure. Using this information, confluence points where stream orders increase were mapped to highlight important locations in the stream network.

2.2.2 Rainfall-Runoff Analysis

Hydrologic characteristics of the watersheds and sub-basins were analyzed using the Corps' HEC-1 flood hydrograph model, as specified by the Orange County Hydrology Manual (OCHM, 1986). To facilitate the use of OCHM methodology, LAPRE-1 was used in combination with Visual HEC-1. LAPRE-1 is a Los Angeles District Corps pre-processor for HEC-1, customized for hydrologic analysis of Southern California watersheds. The 24-hour balanced design storm specified in the OCHM was used as precipitation input. A watershed GIS database was created to generate and evaluate various input parameters to LAPRE-1 and Visual HEC-1, including sub-basin area, basin roughness, channel lengths, areal rainfall distributions, and SCS runoff curve numbers. Input parameters accounted for existing land use and configuration of the drainage network. Infiltration losses were computed, based on the Natural Resource Conservation Service (NRCS) runoff curve (RI) method. This method incorporates soil characteristics, land use, vegetation, impervious cover, and antecedent moisture conditions to estimate loss rates[4]. The RI scale has a range from 0 to 100, where higher numbers indicate lower infiltration rates. Low loss fractions and maximum loss rates were incorporated into an S-graph unit hydrograph analysis, as specified to Orange County conditions. The model parameters were then used to generate the 2-year, 10-year, and 100-year design storms. Channel routing accounted for all existing hydraulic structures, and followed the Muskingum and Muskingum-Cunge methods. These routing techniques were evaluated and compared to the Convex routing method and considered consistent with the Orange County recommended method.

It should be noted that while HEC-1 is useful for analyzing rainfall-runoff processes in watersheds, the program has several limitations. HEC-1 was designed to model singular storm runoff events, such as the 24-hour Orange County design storm. It is not possible to accurately model two or more consecutive storm events with HEC-1 since the program does not account for dynamic soil moisture and infiltration processes. Even modeling a single storm with two large and distinct rainfall peaks (a "bimodal" storm) is not advisable with HEC-1.[5] The HEC-1 model also tends to over-estimate flows from smaller events, such as the 2-year storm especially in undeveloped catchments. This occurs because HEC-1 uses a relatively simple approach to analyze rainfall, infiltration, and runoff, which does not reflect the true complexities of these processes and SCS

[4] *The land-use, hydrologic soil group, and vegetation mapping used contained classification differences along the county boundaries. These classification differences affected only a small portion of the study area along the western Riverside county boundary. The boundary effects do not significantly impact the hydrologic modeling analysis or its results for two reasons: (a) the classification distinctions across the boundaries are not severe (e.g. difference of one soil hydrogroup or vegetation mapping as Chaparral vs. Narrow Leaf Chaparral) and (b) the hydrologic soil group, land-use, and vegetation data are integrated to develop Runoff Curve Numbers for the individual grid cells of the GIS database, which are then averaged according to hydrologic sub-basins used for the modeling (see Technical Appendix A for a more detailed discussion.)*

[5] *Although HEC-1 does not account for a bimodal storm, it is capable of accurately modeling bimodal runoff patterns that result from basin configuration, drainage network structure, and routing.*

curve numbers tend to be conservative in their estimation on runoff. To address this limitation of HEC-1 for the 2-year event discharges, the OCHM Addendum #1 (1995) was used. In this addendum, input parameters for soil loss and precipitation conditions are calibrated to regionally observed discharge conditions (expected value) taken from seven southern California watersheds under various flow conditions. For the 2-year flows, these guidelines assume higher infiltration than the more conservative “high confidence” approach used for the design of flood control facilities, thereby providing a more realistic discharge baseline that can more accurately depict impacts due to urbanization. In this way, the current hydrology approach is a hybrid which offers county-accepted “high confidence” results for the larger 10-year and 100-year events and 2-year “expected value” results, which are more sensitive to environmental concerns associated with urban-induced hydrogeomorphic changes within the watersheds.

2.2.3 Dry Season Flow Analysis

The quantity and timing of dry season flows can affect riparian resources. Changes in dry season flow can alter the plant community composition of a stream, alter bed-load sediment transport, and result in increased pollutant mobilization. To rigorously evaluate low-flow conditions in a stream, an extended historic record of daily flow conditions is required. To determine whether such records are available, four stream gauges in the study area were investigated,[6] and none contained reliable low-flow records of sufficient duration for a statistically valid analysis.

The historical role of development in increasing dry season flows is well documented (Hammer, 1973; Graf, 1975; Hamilton, 1992; Wong, 1993; Trimble, 1997). A trend analysis was conducted on low-flow data from the urbanized Oso Creek (Crown Valley gauge) basin using the Indicators of Hydrologic Alteration (IHA) program (Richter et al., 1996). The IHA program calculates summary statistics to characterize changes in flow regime resulting from changes in watershed conditions. The analysis of changes in dry-season flows over time for Oso Creek provides useful insight into the potential effects of future land use changes on dry-season flow in the central San Juan and western San Mateo watersheds. Potential effects of proposed development on dry-season flow and design features to minimize these effects will be analyzed during the on-site alternatives analysis.

[6] *Stream gauges investigated were San Juan Creek at La Novia (USGS #11046530), Trabuco Creek at Camino Capistrano (Orange County #5), Trabuco Creek at Del Obispo (USGS #11047300), and Oso Creek at Crown Valley Parkway (Orange County #218).*

2.3 SEDIMENT YIELD AND TRANSPORT

The entrainment, transport, and deposition of sediment in watersheds of coastal southern California occurs according to a cascading system involving upland hillslopes, alluvial stream channels, estuaries, and the coast. These different geomorphic zones within the cascading system variably shed, move, or store sediment. As the principal conduit of sediment transport, the stream channel system dynamically responds to changes in hydrologic conditions across the watershed. Increases or decreases in runoff and sediment delivery to specific reaches can result in shifts in erosional and depositional patterns throughout the drainage network. Additionally, changes in sediment storage functions within the channel create feedbacks which further alter stream geometry and slope and could further destabilize stream behavior.

Sediment yields were estimated, based on a review of a variety of data sources from southern California coastal watersheds. The lines of evidence used included more than 12 previous studies of sediment discharge and locally derived sediment rating curves; observed rates of accumulation in debris basins, reservoirs, and gravel pits; calculated yields based on the Los Angeles District method (LAD) and the Modified Universal Soil Loss Equation (MUSLE); and comparisons with adjoining watersheds having similar sediment-generating influences such as slope, geology, and soils. These sources generated estimated sediment yields that varied by more than 25-fold, so recommendations were made as to the most reliable estimates based on review of the study designs and assumptions used in each study. It should be noted that sediment transport measurements are often inherently inexact, particularly those measurements made during storms or floods. In most cases, it is either not feasible or not worthwhile to obtain additional accuracy. The data may, however, be validated to a level suited to use by applying multiple estimation techniques as was done in this study. Implied precision in sediment data exceeding two or three significant figures is not valid. We have tried to round computations and present values that are not deceptively precise. Discrepancies of up to 5 or 10 percent may arise from this practice and should not be a source of concern.

Storm event-based sediment transport rates and yields were estimated on a reach basis for the studied sub-basins using SAM, a Corps channel design package[7]. Required input to SAM includes average (or effective) hydraulic parameters (discharge rate, flow width, flow depth, energy grade slope, and velocity) and representative sediment parameters (bed-material particle gradation, sediment transport function). Average hydraulic parameters were estimated using an existing HEC-2 model generated by Simons, Li & Associates (SLA, 2000), 10 meter DEM data for the watershed U.S. Geological Survey (USGS), and field data collected by the Waterways Experimentation Station team (Smith, 2000) and Balance Hydrologics. Results from PWA's HEC-1 runoff analysis for the

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[7] *Bedload transport accounts for a small fraction of the overall sediment movement in the watershed, and is a minor factor in shaping stream geomorphology.*

2-year, 10-year, and 100-year discharge events, were used as flow input to SAM. Sediment data from SLA's and WES's fieldwork were utilized, along with estimates of sediment delivery made to the channels by Balance Hydrologics. A representative channel cross-section was developed for selected stream reaches by synthesizing USGS 10-meter digital elevation data with WES channel observations and HEC-2 cross sections from SLA (1999).

SAM has over 19 sediment transport functions available for calculating transport rates. Selecting the appropriate sediment transport function is a crucial decision of the modeling process. For this study, two sediment transport functions were selected, based upon guidelines in the SAM reference manual and comparisons to previous results by SLA (1999) and Vanoni et al. (1980). The Laursen-Madden (LM) function was chosen for its suitability for sand and gravel bed streams, and the Engelund-Hansen (EH) function was initially utilized since it compared well with previous results. The Laursen-Copeland (LC) function was also initially selected because it better represented larger gravel sizes. This was considered more appropriate for places like Bell Canyon. In general, the Laursen-Madden function provides the best estimation of sediment transport for the broadest range of substrate types and topographies. Therefore, for the Baseline Conditions report, PWA emphasized results from the Laursen-Madden sediment transport function. A more detailed explanation of the methodology used in the sediment transport analysis is given in Appendix A.

Since the majority of sediment in this region is generated and transported during infrequent storm events, the effect of episodic events on overall channel stability, long-term sediment yields, erosional processes, and sediment storage in the watershed was evaluated. This analysis was based largely on the results of the terrains analysis and aerial photo interpretation. Ranges of coefficients were generated from the literature that can be applied to the sediment yield and transport results to estimate watershed responses to changes in the frequency or magnitude of episodic events.

2.4 WATER QUALITY

An understanding of the role played by watershed processes in the generation, transport, and assimilation of nutrients and pollutants is critical to informed decision-making that recognizes the combination of characteristics specific to these watersheds. This is especially true, given the diversity of geology, terrains, and land cover within the study area.

The baseline water quality analysis consisted of review, summary, and analysis of five substantial water quality data sets that have been collected within the study area, including data collected by the Orange County Public Facilities and Resources Department (Orange County PFRD). The water quality data collected by others was augmented by a series of field surveys within the study area sub-basins in order to assess the potential roles that various geomorphic and biological features may be playing in controlling the mobilization and cycling of key nutrients and constituents of concern such as nitrogen, phosphorus metals, and sediment. Historical aerial photography was used to put this present-day view of the sub-basins in a context more appropriate to the temporal scale that operates in these highly episodic watersheds. Comparison of the sub-basin characteristics will be used during the alternative analysis to identify the opportunities and constraints that will most directly influence land use planning, permitting processes, and the selection and design of features intended to maintain or enhance water quality.

The information summarized in this baseline conditions report will be augmented by ongoing monitoring of surface water quality. Eleven monitoring stations have been set up for collection of organic and inorganic water quality constituents. Grab samples will be taken during storm events at the beginning of the wet season (ideally during the "first flush" event), in the middle of the wet season, at the end of the season, and twice during the dry season. In addition, continuous analysis (via dataloggers) will occur at four stations. This information will be used to monitor inter- and intra-annual trends and to help detect changes in basic water chemistry such as temperature, pH, and EC (i.e., specific conductance) associated with natural and anthropogenic changes in the watershed. Sediment samples will be analyzed at target locations to determine the contribution of sediment to surface water quality. The results of the ongoing water quality monitoring will be the subject of a future separate report.

2.5 GROUNDWATER

The distribution and condition of aquatic resources is affected by the depth, hydrodynamics, and chemistry of the shallow groundwater (i.e., groundwater that is within the root zone at least seasonally or in the case of mature vegetation, semi-annually). Riparian species, such as willows and cottonwoods, are generally restricted to alluvial soils with shallow groundwater. On coarse substrates in dry regions, early establishment and growth to *Populus* spp. (i.e., cottonwoods) may require water tables within 3 to 6 feet (1 to 2 m) of the surface (Scott et al., 1999). However, *Populus* species have been observed to become established up to 8.5 feet (2.6 m) above the annual low water level (Shafroth et al., 1998; Busch and Smith, 1995). Mature riparian tree species are typically found in settings where the depth to the water table is less than 11.5 feet (3.5 m), but *Populus* spp. have been observed at sites where depth to the water table is 23 to 30 feet (7 to 9 m) (Scott et al., 1999). Changes in either overall depth or duration with which groundwater persists at a certain depth can result in desiccation, narrowing of the riparian zone, or changes in wetland and riparian plant communities. Mount (1995) reported that lowering of groundwater beyond 12 feet (3.7 m) associated with a mining-induced channel incision along Cache Creek in Northern California resulted in pervasive mortality of streamside riparian habitat. Similarly, Smith et al. (1998) reported that cover of phreatophytic shrubs along the Colorado River decreased significantly when groundwater levels drop below 16.4 feet (5 m). Changes in the salinity or pH of shallow groundwater may also adversely affect wetlands or may result in transitions to different community types (e.g., transition from alkali marsh to freshwater marsh or visa versa). For example, Smith et al. (1998) reported that increases in soil electroconductivity along the Colorado River resulted in mortality of willow and cottonwood species and colonization by more salt tolerant species, such as *Tamarix* and *Tessaria*. Slope and seep wetlands and riverine alkali marshes are particularly dependent on perennial or near-perennial sources of shallow groundwater which are strongly affected by the nature of subsurface geology. Finally base flows are affected by subsurface water depth in the contributing watershed.

Information on subsurface hydrodynamics in the San Juan and San Mateo watersheds is sparse, and extensive modeling of groundwater movement is a long, complex, and costly endeavor and therefore is beyond the scope of this study. Consequently, groundwater flow directions and the locations of key recharge areas were inferred from: (a) the results of the terrains analysis, the hydrogeologic conditions, the surface hydrology modeling, and the water quality analysis; and (b) existing well data and bore logs, earlier technical reports on groundwater conditions in the watershed, detailed investigations from the 1960s by the California Department of Water Resources and local water districts, and portions of the San Diego RWQCB Basin Plan. Functional relationships between groundwater and aquatic habitats in the study area were analyzed in light of the inferred relationships. In this report, the discussion of groundwater recharge, movement, and discharge has been integrated with discussions of terrains and surface hydrology, except in instances where groundwater is a significant component of the overall hydrology in a sub-basin (e.g., Cañada Chiquita).

The information summarized in this baseline conditions report will be augmented by ongoing monitoring of groundwater quality. Groundwater sampling will consist of two grab samples from each of four monitoring wells. One sample will be taken during the wet season, the other during the dry season. Samples will be tested for: salinity and major ions, dissolved metals, organics, organophosphates, and carbomate pesticides. In addition, as groundwater data from the TCA and Camp Pendleton become available our understanding of groundwater hydrodynamics in the study area will increase. The results of the ongoing groundwater quality monitoring will be the subject of separate future report.

2.6 RIPARIAN AND WETLAND HABITATS

Numerous biological studies with varying focuses have been conducted in the study area. Work completed for the NCCP/HCP process has mapped habitats and sensitive species locations. The WES/CRRL investigations resulted in mapping of riparian habitats and analysis of the functional integrity of those habitats. Studies conducted by PCR mapped and analyzed the condition of slope wetlands and vernal pool wetlands. The hydrologic and geomorphic processes necessary to support key sensitive species will be addressed in a subsequent report.

This report does not attempt to summarize all the results of the numerous biological investigations that have been conducted in the study area. Instead, the major biological attributes of the watersheds and the sub-basins are summarized and key considerations are provided for analysis of alternative land use scenarios. More detailed information can be found in the WES/CRRL reports, slope wetland and vernal pool reports (PCR) and the NCCP database (Dudek & Associates).

3.0 OVERVIEW OF SAN JUAN AND SAN MATEO CREEK WATERSHEDS

3.1 PHYSICAL SETTING

3.1.1 San Juan Creek Watershed

The San Juan Creek watershed is located in southern Orange County, California. The watershed encompasses a drainage area of approximately 176 $mi.^2$ and extends from the Cleveland National Forest in the Santa Ana Mountains to the Pacific Ocean at Doheny State Beach near Dana Point Harbor. The upstream tributaries of the watershed flow out of steep canyons and widen into several alluvial floodplains. The major streams in the watershed include San Juan Creek, Bell Canyon Creek, Cañada Chiquita, Cañada Gobernadora, Verdugo Canyon Creek, Oso Creek, Trabuco Creek, and Lucas Canyon Creek. Elevations range from over 5,800 feet above sea level at Santiago Peak to sea level at the mouth of San Juan Creek (Corps, 1999).

The San Juan Creek watershed is bounded on the north by the San Diego, Aliso Creek, and Salt Creek watersheds, and on the south by the San Mateo Creek watershed. The Lake Elsinore watershed, which is a tributary of the Santa Ana River watershed, is adjacent to the eastern edge of the San Juan Creek watershed.

3.1.2 San Mateo Creek Watershed

The San Mateo Creek watershed is located in the southern portion of Orange County, the northern portion of San Diego County, and the western portion of Riverside County. The watershed is bounded on the north and west by the San Juan Creek watershed, to the south by the San Onofre Creek watershed, and to the northeast by the Lake Elsinore watershed. San Mateo Creek flows 22 miles from its headwaters in the Cleveland National Forest to the ocean just south of the City of San Clemente. The total watershed is approximately 139 $mi.^2$ and lies mostly in currently undeveloped areas of the Cleveland National Forest, the northern portion of Marine Corps Base Camp Pendleton (MCBCP), and ranch lands in southern Orange County (Lang et al., 1998). Major (named) streams in the watershed include Cristianitos Creek, Gabino Creek, La Paz Creek, Talega Creek, Cold Spring Creek, and Devil Canyon Creek. The study area includes only the portion of the San Mateo Creek drainage within Orange County (approximately 17 percent of the watershed). Elevations range from approximately 3,340 feet above sea level in the mountains of the Cleveland National Forest to sea level at the mouth of San Mateo Creek.

3.2 GEOMORPHIC SETTING

3.2.1 Regional Geology

The San Juan and San Mateo Creek watersheds are located on the western slopes of the Santa Ana Mountains, which are part of the Peninsular Ranges that extend from the tip of Baja California northward to the Palos Verdes peninsula and Santa Catalina Island. The geology of the region is complex and has been dominated by alternating periods of depression and uplift, mass wasting, and sediment deposition (Figure 4 on page 27). Within the watersheds, the Santa Ana Mountains are composed of igneous, metavolcanic, and metasedimentary rocks of Jurassic age and younger. The exposed rocks in the mountainous areas are slightly metamorphosed volcanics, which have been intruded by granitic rocks of Cretaceous age, principally granites, gabbros, and tonalites. Overlying these rocks are several thousand stratigraphic feet of younger sandstones, siltstones, and conglomerates of upper Cretaceous age, composed largely of material eroded from the older igneous and metavolcanic rocks now underlying the Santa Ana Mountains.

Younger sedimentary rocks comprise the bedrock between the Santa Ana Mountains, their foothills, and the Pacific Ocean. Most of the SAMP/MSAA area is underlain by these marine and non-marine sandstones, limestones, siltstones, mudstones, shales, and conglomerates, many of which weather, erode, and/or hold groundwater in characteristic ways. Overlying them are Quaternary stream terrace deposits and Holocene stream channel deposits.

During the past two million years or longer, at least three processes that fundamentally affect structure and process along the major stream channels have affected the two watersheds:

1. Continuing uplift, typically 400 feet or more, which has left at least four major stream terrace levels along the major streams.

2. Downcutting of the main canyons to sea levels, which have fluctuated widely during the global glaciations.[8] The flat valley floors were deposited as sea level rose, leaving often-sharp slope breaks at the base of the existing hillsides and tributary valleys. These materials are geologically young, soft, and prone to incision under certain conditions.

3. Soils formed under climates both warmer/colder and drier/wetter than at present, which led to development of hardpans that have been eroded to form mesas. These hardpan mesas have minimal infiltration and presently channel flows into headwater streams.

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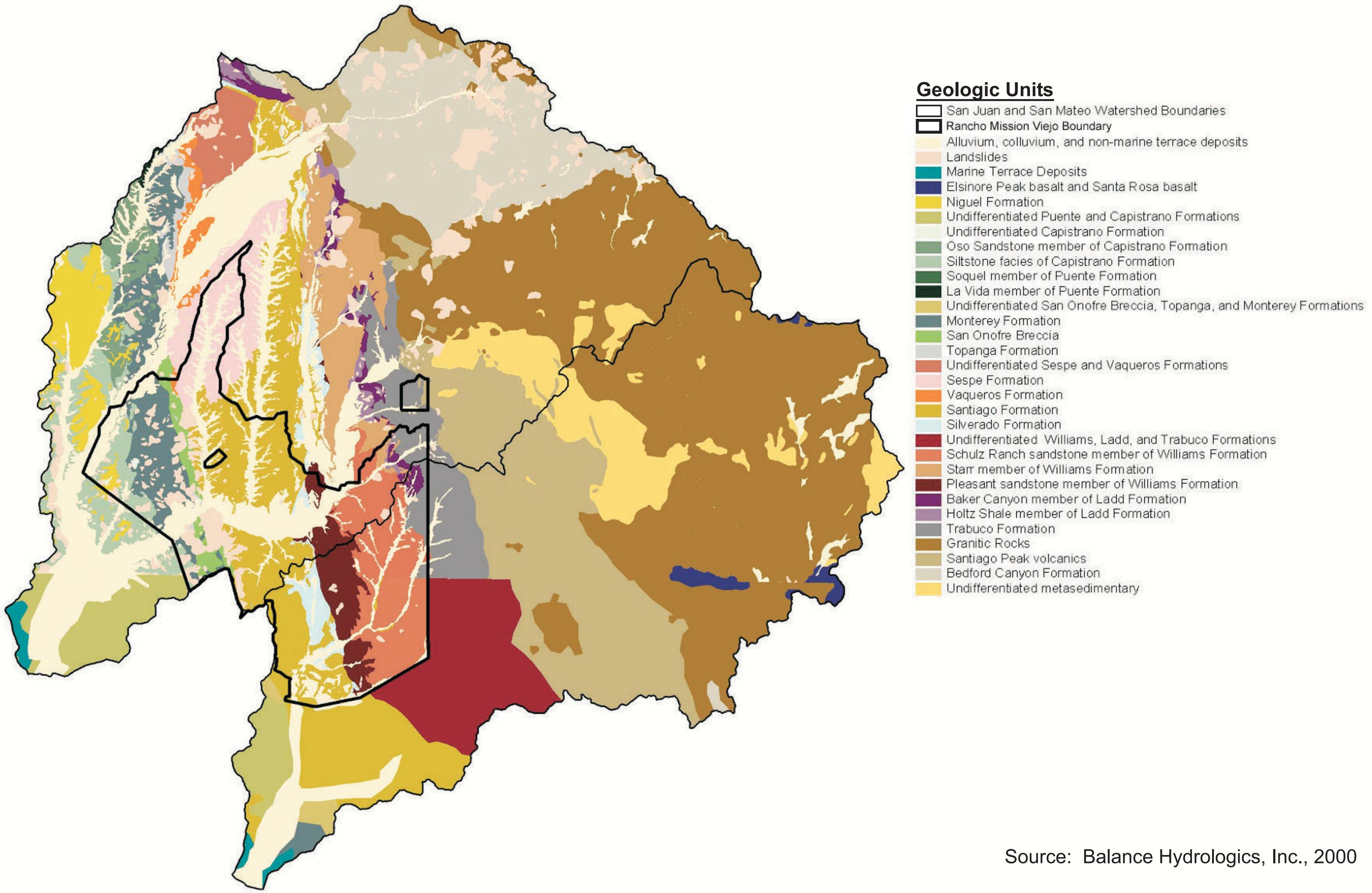
[8] *As recently as 18,000 years ago, sea level was about 380 feet lower, and the shoreline was several miles further west than at present. San Juan, Chiquita, Gobernadora, San Mateo, and Cristianitos Creeks (among others) flowed in valleys 60 to 120 feet lower than at present.*



PCR PWA Balance Hydrologics, Inc.

Figure 4

Baseline Conditions Report

Surficial Geology of Study Area

3.2.2 Terrains

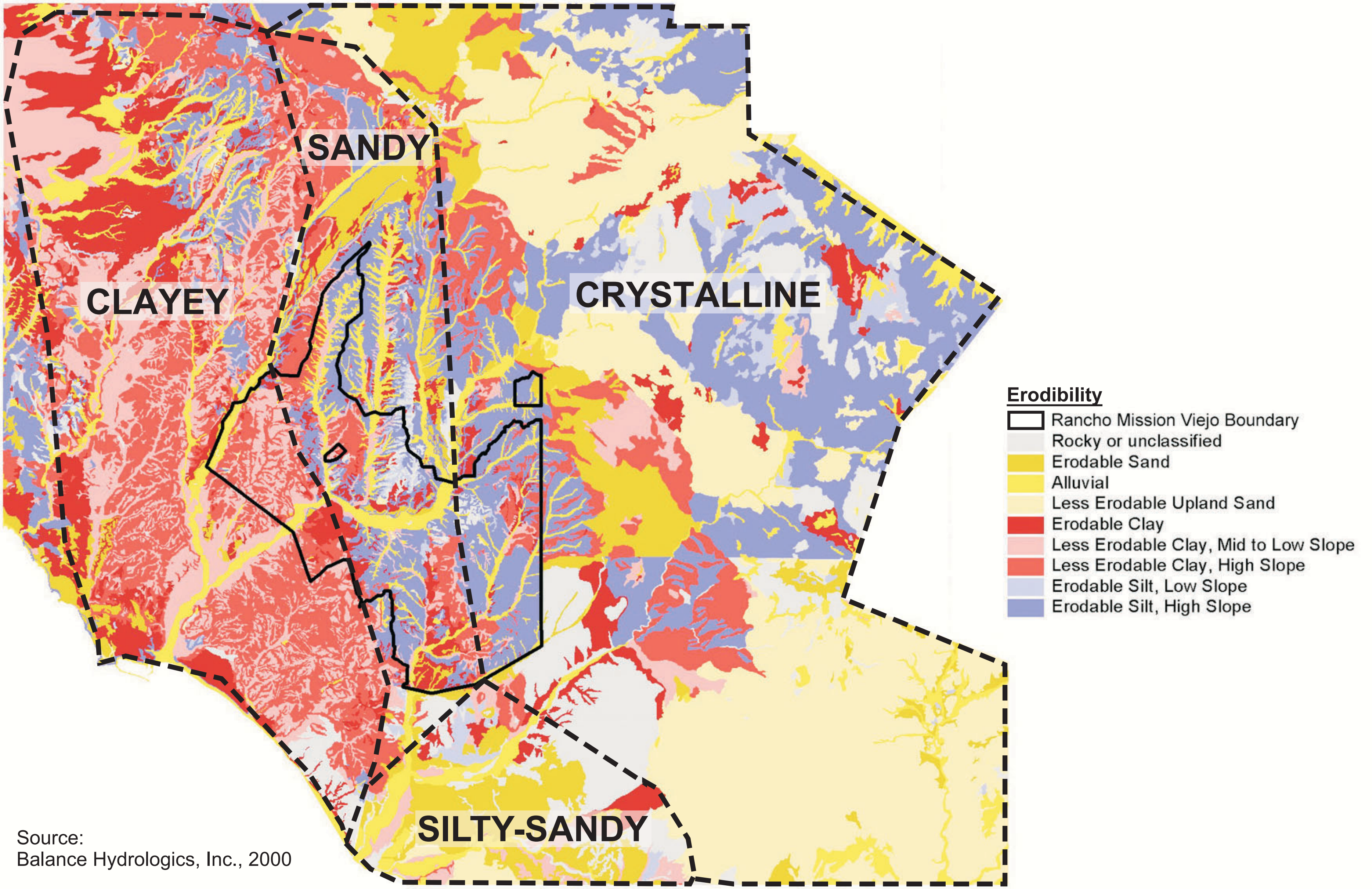
Terrain designations are largely based on soils, geology and topography, as these provide many of the fundamental factors that influence the hydrology and geomorphology characteristic of each terrain. Bedrock is the raw material from which soils are weathered, and, as such, it determines the size and types of particles that will comprise the soil. The resistance of different kinds of bedrock to weathering and erosion also controls the topography of the landscape within a given terrain and, therefore, influences the hydrology of the watersheds and morphology of the drainage networks. Watershed hydrology is also strongly influenced by the climatic patterns typical of Southern California. Climatic factors are discussed in more detail in Section 3.3.1.

There are three major geomorphic terrains found within the San Juan Creek and San Mateo Creek watersheds: (a) sandy and silty-sandy; (b) clayey; and (c) crystalline. These terrains are manifested primarily as roughly north-south oriented bands of different soil types[9] (see Figure 5 on page 29). The soils and bedrock that comprise the western portions of the San Juan Creek watershed (i.e., Oso Creek, Arroyo Trabuco, and the lower third of San Juan Creek) contain a high percentage of clays in the soils. The soils typical of the clayey terrain include the Alo and Bosanko clays on upland slopes and the Sorrento and Mocho loams in floodplain areas. In contrast, the middle portion of the San Juan basin, (i.e., Cañada Chiquita, Bell Canyon, and the middle reaches of San Juan Creek) is a region characterized by silty-sandy substrate that features the Cieneba, Anaheim, and Soper loams on the hillslopes and the Metz and San Emigdio loams on the floodplains. The upstream portions the San Juan Creek watershed, which comprise the headwaters of San Juan Creek, Lucas Canyon Creek, Bell Creek, and Trabuco Creek, may be characterized as a "crystalline" terrain because the bedrock underlying this mountainous region is composed of igneous and metamorphic rocks. Here, slopes are covered by the Friant, Exchequer, and Cieneba soils, while stream valleys contain deposits of rock and cobbley sand. The upland slopes east of both Chiquita and Gobernadora Canyons are unique in that they contain somewhat of a hybrid terrain. Although underlain by deep sandy substrates, these areas are locally overlain by between 2 and 6 feet of exhumed hardpan.

3.2.2.1 Runoff Patterns of Specific Terrains

Runoff patterns typical of each terrain are affected by basin slope, configuration of the drainage network, land use/vegetation, and, perhaps, most importantly the underlying terrain type. Although all three terrains exhibit fairly rapid runoff, undisturbed sandy slopes contribute less runoff than clayey ones because it is easier for water to infiltrate into the coarser substrate. Runoff in

[9] *The different bands of terrain types should be considered as general trends; not every stream is comprised of a single terrain, and inclusions of other soil types occur within each terrain.*



PCR PWA Balance Hydrologics, Inc.

Figure 5
Baseline Conditions Report
Landscape Scale Terrains and Shallow Substrate Erodibility

crystalline terrains tends to be rapid and is highly influenced by the presence and density of coverage of impervious areas of rock outcrop that typify the terrain. As a result, the volume of runoff generated by the same amount and intensity of rainfall in a sandy watershed is generally lower than that generated in a clayey or crystalline watershed. When comparing clayey and crystalline terrains, the former seals and becomes impervious upon saturation, while the latter allows for some infiltration through shallow sands that overlay bedrock. Therefore, runoff in clayey terrains is generally more rapid than in crystalline terrains, not withstanding site-specific differences such as slope and land cover/vegetation.

Expected runoff patterns based on terrains should be distinguished from estimated runoff potential based on soil hydrogroups (see Section 3.4.1.2). Although both provide valid, and typically congruent information, the effect of terrains predominates at low to moderate return interval events (i.e., 2, 5, and 10 year events), while the effect of soil hydrogroups predominate at larger return-interval events (e.g., 25, 50, and 100 year events).

During low to moderate storm events terrains influence the likelihood and extent of channel migration, avulsion, or incision. However, during extreme storm events, the influence of terrains is minimal and runoff is more strongly influenced by soil hydrogroup. For example, a Type C soil in a sandy terrain would produce less runoff during a 5-year event than a Type C soil in a clayey terrain. However, during a larger storm event, runoff from both terrains would be comparable (assuming similar vegetation, slope, and land use).

3.2.2.2 Channel Characteristics of Specific Terrains

Sandy and silt-sandy terrains are generally able to infiltrate larger volumes of water than are clayey and crystalline terrains. As a result: (a) sandy terrains play a vital role in groundwater recharge; (b) undisturbed sandy terrains are typified by lower runoff rates than clayey or crystalline terrains; (c) stream valleys in undisturbed sandy terrains tend to have wide floodplains and are often channel-less; (d) flows tend to persist longer after storms or further into the summer within sandy watersheds; and (e) there is a greater contrast between runoff conditions in undeveloped and urbanized watersheds in sandy terrains than in clayey or crystalline terrains.

Crystalline terrains are typified by narrow, well-defined stream valleys nestled between steep mountainous slopes. Unlike sandy streams that are susceptible to incision, streams in crystalline areas often flow over bedrock and have stable grades. The topography, soils, and hydrography of the crystalline geomorphic terrain are all inherently controlled and influenced by the underlying bedrock.

In Southern California Clayey terrains are also typified by more gentle topography than sandy or crystalline areas. Ridges tend to be lower and broader because the underlying bedrock is often more easily eroded. Clayey terrains also feature streams with fairly well-defined channels that have evolved to handle the higher runoff rates associated with clayey slopes. Clayey terrains are generally less susceptible to many of the environmental problems that plague sandier soils (such as enhanced sediment loading, incision, and headcutting).

Of the three terrains present in the San Juan Creek watershed, streams in sandy terrains are the most vulnerable to channel incision or channel widening associated with land use changes. The two main risks associated with development within sandy terrains are dramatically increased peak discharge and channel incision accompanied by headward erosion. To a certain extent, the two are inherently linked, and both result from the unique erosion and runoff properties of sandy watersheds. Studies have shown that urbanization in sandy watersheds can result in a proportionately greater increase in storm peaks and associated alteration of downstream channel morphology than in more clayey watersheds[10] (Figure 5 on page 29). Sandy terrains are often typified (under undisturbed conditions) by the presence of poorly defined channels along grassy, vegetated valley floors. Increased flood peaks due to urbanization can not only cause channel incision along grassy swales, but channel incision itself further serves to increase flood peaks through enhanced conveyance. The result is an amplified cycle of erosion and downcutting that destroys floodplain interaction, increases sediment yields and the tendency for flooding downstream, and significantly alters habitat.

3.3 HISTORIC CONTEXT

Physical and biological conditions in the watersheds have been affected over time by both natural and anthropogenic forces. Early historical accounts of lower San Juan Creek suggest near-perennial flow, with a freshwater lagoon near the mouth and a "green valley full of willows, alders and live oak, and other trees not known to us" (c.f., Friar Crespi in 1769). Natural events that have helped shaped the current conditions in the watershed include wet and dry cycles, flooding and fires. Anthropogenic effects include changes in patterns of water use, urban development, mining, grazing, and agriculture. The spatial and temporal effect of key historical events is based on not only the scale of the event, but the timing relative to other events. Investigating these patterns can be valuable for understanding natural processes and for long-range planning of future land use changes.

[10] *Differences in the susceptibility of streams in the three terrains to increased runoff are most pronounced for moderate runoff events (e.g. 10 to 25 year events). During extreme runoff events, streams in all three terrains are susceptible to channel incision and headcutting.*

3.3.1 Natural Processes

The geology, topography, and climate of the coastal watersheds of Southern California make them unique among the watersheds in the United States. The Transverse and Peninsular Ranges are intensely sheared and steep due to ongoing uplift and tectonic activity. In addition, these ranges are located close to the coast, resulting in steeper, shorter watersheds than those found in most other portions of the country.

The Mediterranean climate in Southern California is characterized by brief, intense storms between November and March. It is not unusual for a majority of the annual precipitation to fall during a few storms in close proximity to each other. The higher elevation portions of the watershed (typically the headwater areas) typically receive significantly greater precipitation, due to orographic effects. In addition, rainfall patterns are subject to extreme variations from year to year and longer term wet and dry cycles. The combination of steep, short watersheds; brief intense storms; and extreme temporal variability in rainfall result in "flashy" systems where stream discharge can vary by several orders of magnitude over very short periods of time.

3.3.1.1 Wet and Dry Cycles

Wet and dry cycles, typically lasting up to 15 to 20 years, are characteristic of southern California. The region presently appears to be emerging from a wetter-than-normal cycle of years beginning in 1993. Previously, five consecutive years of sub-normal rainfall and runoff occurred in 1987 through 1991.

Prior droughts of recent note include the brief, "hard" droughts of 1976 to 1977 and 1946 to 1951. Previous notable wet periods of the recent past were observed in 1937 to 1944 and 1978 to 1983. An unusually protracted sequence of generally dry years began in 1945 and continued through 1977. [11] During this period, rainfall was approximately 25 percent below the average for the prior 70 years (Reichard, 1979; Lang et al., 1998). Both recharge and (especially) sediment transport were diminished to even greater degrees. Although wet years did occur during this period, dry conditions were sufficiently persistent to lower groundwater levels and contract the extent of riparian corridors. In many areas, landslide activity was much less than during strings of wet years. Throughout Chiquita and Gobernadora canyons, many of the channel segments that may have cut across debris aprons formed by the 1938 floods and subsequent wet years may have re-filled during this period. At a broader regional scale, the 33 years of below-average rainfall, recharge, and sediment entrainment coincided with the post-war period of especially intensive hydrologic data collection, resulting in underestimates of hydrologic activity. Most of the hydrologic design studies

[11] *Inman and Jenkins have classified the time period between 1948 and 1977 as a relatively dry cycle and the period of October 1977 to the present as a relatively wet cycle.*

performed in southern Orange County were based on data collected between the years of 1960 through 1985, when rainfall, recharge, and sediment yields were below longer-term norms. Therefore, they may not account for variations in flow and sediment associated with long-term climate trends.

3.3.2 Floods

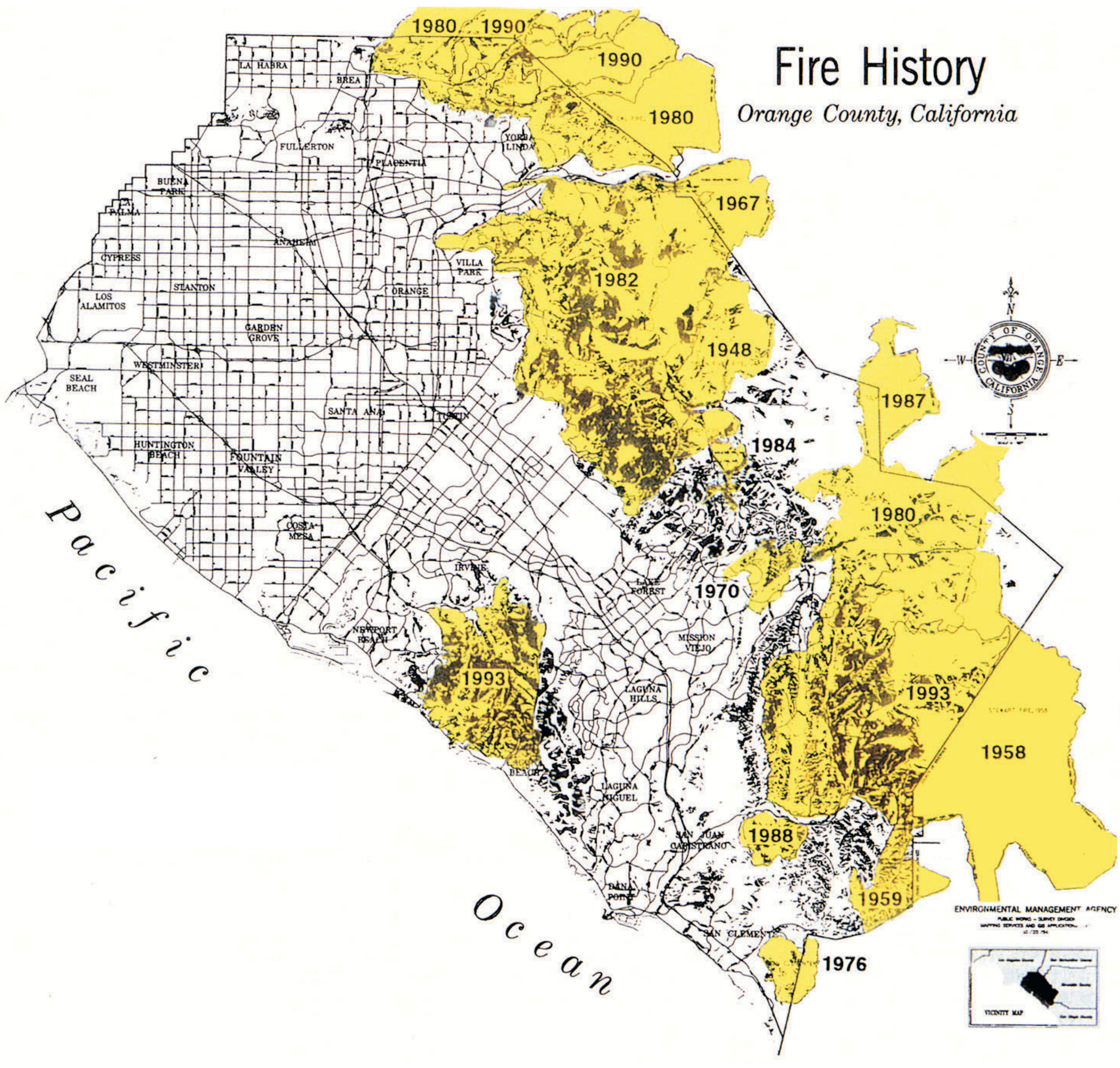
Major floods are a necessary component of riparian ecosystems in that they serve to re-establish ("reset") the plant communities by scouring older vegetation, establishing new areas of bare substrate, and facilitating dispersal of disturbance-adapted riparian plant species. Furthermore, major floods alter the location, continuity, and supply of sediment and large organic matter to the channel networks.

Major, flood-related disturbance of the channel and riparian systems may be expected with mean recurrences of 10 to 20 years. Large floods occurred in coastal southern California in 1907, 1916, 1937, 1938, 1969, 1978, 1983, 1993, 1995, and 1998. Historical accounts of the 1916 flood indicate that San Juan Creek extended fully across the valley downstream from the mission and what is now Highway 5 (Corps, 1999). Peak runoff values were estimated to be in the range of 104 to 151 (cfs/mi.^{2}) for Aliso, Trabuco, San Juan, and San Onofre Creeks, and 234 cfs/mi.^{2} for Laguna Creek at Laguna Beach in a more clay-rich watershed.[12] No data are available for either flood from San Mateo Creek or its major tributaries. The February 1969 peak flows were long-duration events, which eventually generated peak flows of 22,400 cfs at the La Novia gauging station in San Juan Capistrano, the highest reported prior to general urbanization in the watershed. The January and March 1995 events led to peaks of 15,200 cfs and 25,600 cfs, respectively, the latter being the largest flow recorded on San Juan Creek. Five distinct major crests were observed in February 1998, with a peak flow of 17,000 cfs.

3.3.3 Watershed Scale Fires

Nearly all portions of the two watersheds have been subject to watershed-scale fires from one to three times (and in limited areas, four or five times) during the past century (Fife, 1979; Stephenson and Calcarone, 1999) (Figure 6 on page 34 shows the recent fire history for Orange County). The primary hydrologic effects of the fires are sharp increases in sediment yields and often aggradation in the channel downstream (see Section 3.4.2). It should be noted that not all areas falling within a mapped fire periphery have actually been burnt. Generally, north-facing slopes and riparian corridors are much less likely to burn, and other areas may be affected only by a

[12] *Substantially higher peaks were observed February 6, 1937, in the Aliso (230 cfs/mi.^{2}) and Trabuco (255 cfs/mi.^{2}) watershed during what is described as a minor regional storm; San Juan Creek conveyed 80 cfs/mi.^{2} during the 1937 storm.*



Source: County of Orange, Environmental Management Agency, 1994

PCR PWA Balance Hydrologics, Inc.

N
No scale

Figure 6
Baseline Conditions Report
Fire History

rapidly moving (and less destructive) ground fire. Pockets of soil and vegetation which have survived for many decades (or perhaps centuries) without high-intensity burning occur throughout the two watersheds.

Fires can result in shifts or changes in the vegetation community. Coastal sage scrub is generally considered to be relatively resilient to disturbance. However, frequent or intense fires may result in temporary to long-term increases in grassland species. In extreme instances frequent or intense fires may result in a type-conversion from sage scrub to grassland. Such a conversion may decrease infiltration and increase runoff and erosion into streams that drain the burned sub-basins.

The combination of fire, followed by high rainfall runoff shortly thereafter, can be one of the most significant sequences of events that shape the riparian corridors. This series of events can result in mobilization of large sediment stores that significantly alter the geometry and elevation of downstream channels. Much of the eastern San Juan watershed was last burned in 1959. The combination of this fire and the subsequent 1969 floods (described above) may have resulted in considerable deposition within the channels and floodplains, which have subsequently incised for many years.

3.3.4 Grazing

Large portions of both watersheds have been grazed at varying intensities over the last two hundred years. The exact effects of grazing remain unclear. The season-long, -continuous grazing over many years associated with traditional grazing practices was likely responsible for conversion of much of the uplands in the watershed from native grasses and scrub to non-native annual grassland. However, Heady (1968, 1977) suggested that large native herbivores present prior to European colonization might have been an important factor in grassland formation and ecology. Edwards (19XX) also notes "-observation and experiment world-wide are increasingly showing that large grazing-browsing-trampling mammals and native grasslands are coevolved." Therefore, some level and intensity of seasonal grazing may be necessary and beneficial to maintaining native grasses. Edwards (19XX) postulates that livestock grazing can be ecologically beneficial, if specific strategies are devised on the basis of site-by-site needs. Because native plant communities are typically associated with higher infiltration than non-native grasses, grazing induced conversion of ground cover was likely accompanied by increased runoff and erosion. Lower infiltration rates in the surrounding watershed may have also resulted in a decrease in the depth of shallow subsurface water. Decreases in shallow subsurface water can affect baseflow and width of riparian zones.

Intensive grazing within riparian corridors has been associated with suppression of riparian habitat and trampling of stream banks. The lack of established woody vegetation combined with direct disturbance from cattle could destabilize streams and make them more susceptible to erosion and incision. Therefore, the current width, depth, and geometry of the creeks in the study area may have been influenced by the cumulative influence of long term grazing on the uplands and the stream corridors.

3.4 HYDROLOGY

3.4.1 San Juan Creek Watershed

3.4.1.1 Drainage Network

Hydrologically, the San Juan watershed can be organized into three regions: the western portion of the watershed with the highly developed Oso Creek sub-basin and the moderately developed Trabuco Creek sub-basin; the relatively undeveloped sub-basins of the central San Juan watershed (i.e., Cañada Chiquita, Cañada Gobernadora, Bell Canyon, Lucas Canyon, Trampas Canyon and Verdugo Canyon); and the steeper eastern headwater canyons. The drainage density of the entire watershed is 10 mi/mi.^{2}. This value is somewhat low compared to other published reports (Strahler, 1968; Schumm, 1956), which suggest average drainage densities for various geomorphic settings, including southern California, of between 20 to 30 mi/mi.^{2}. Geologic, soil, and basin configuration issues (as discussed above) may all contribute to this lower-than-expected drainage density value. In the San Juan Creek watershed, many tributary valleys are comprised of sandy terrains and, as such, include swales that do not have a clearly defined channel form (i.e., channel-less swales). Omitting these swales from the calculated surface drainage network also reduces the drainage density of San Juan Creek watershed. Stream network maps and a discussion of important stream network parameters for each of the sub-basins are presented in Technical Appendix A.

3.4.1.2 Infiltration

Infiltration was estimated using the USDA hydrologic soil group classification. This standard USDA classification is based upon estimated runoff potential based upon soil properties that influence runoff. Soils are classified into hydrologic soil groups A, B, C, or D, depending upon infiltration rates measured when the soils are thoroughly wet. A-type soils have the highest infiltration rates while D-type soils have the lowest infiltration potential. In general, Type A soils contain a higher proportion of coarser textures (sand and gravel) and/or have a deeper soil profile. These conditions result in good drainage with higher rates of water transmission into the subsurface. In contrast, Type D soils are likely to contain a less permeable restricting clay layer, or are shallow, and this results in slower rates of water transmission into the subsurface. Conditions for B and C type soils are intermediate to A and D type soils. Table 2 on page 37 defines each soil type

Table 2

Orange County Hydrologic Soil Type Descriptions

Type A	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands and gravels. These soils have a high rate of water transmission.
Type B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
Type C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
Type D	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

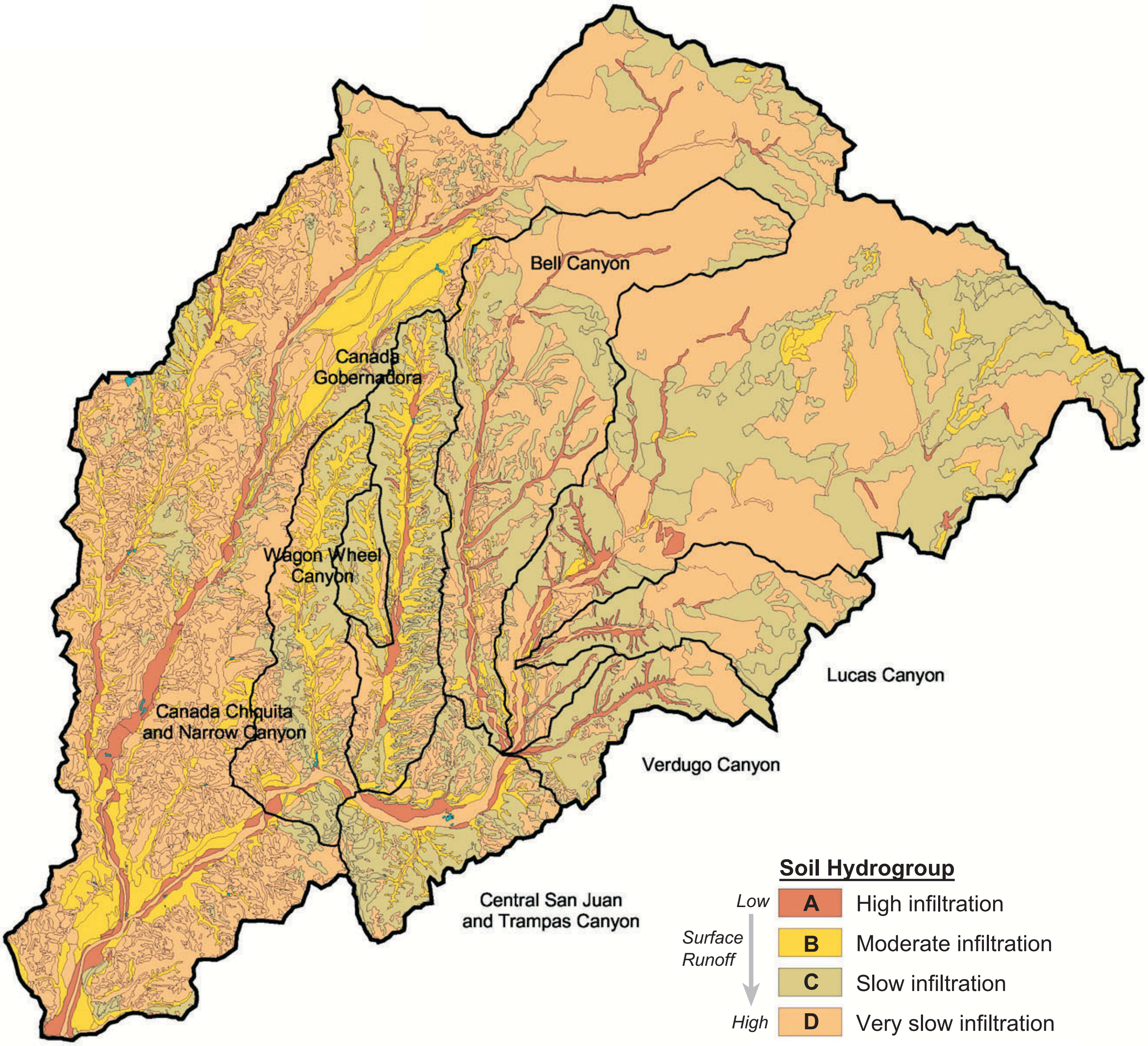
Source: USDA, September 1978

according to the OCHM. The distribution of hydrologic soil groups in the San Juan watershed is shown in (Figure 7 on page 38).[13]

It is important to note that permeability rates from the USDA-SCS Soil Survey hydrogroups are not the same thing as loss rates used in the HEC-1 runoff modeling process. Loss rates for the studied sub-basins are given in Tables 3-2 and 3-3 of Appendix A to the Baseline Conditions report. Loss rates represent the amount of precipitation that is "lost" to other processes and is not available to generate runoff. Loss rates include not only infiltration into the soil (represented by soil hydrogroup), but also vegetation cover, land-use classification, and percent impervious surface.

Overall, infiltration in the San Juan watershed is relatively low, due to the prominence of poorly infiltrating soils (e.g., 79.8 percent of the watershed in underlain by soil types C or D) and the significant proportion of development in the western watershed. However, there are significant pockets of the watershed, particularly in the central watershed, which do have more permeable soils and offer better potential infiltration. Following the methods described in the OCHM, SCS runoff curve numbers were assigned to synthesize the effect of soil type, land use, vegetation, and infiltration processes and provide an integrated overall "hydrologic loss" rate. Note, for the analysis

[13] *A discussion of the influence of terrains vs. soil hydrogroups on runoff patterns is provided in Section 3.2.2.1.*



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 7
Baseline Conditions Report
Distribution of Hydrologic Soil Groups for San Juan Watershed

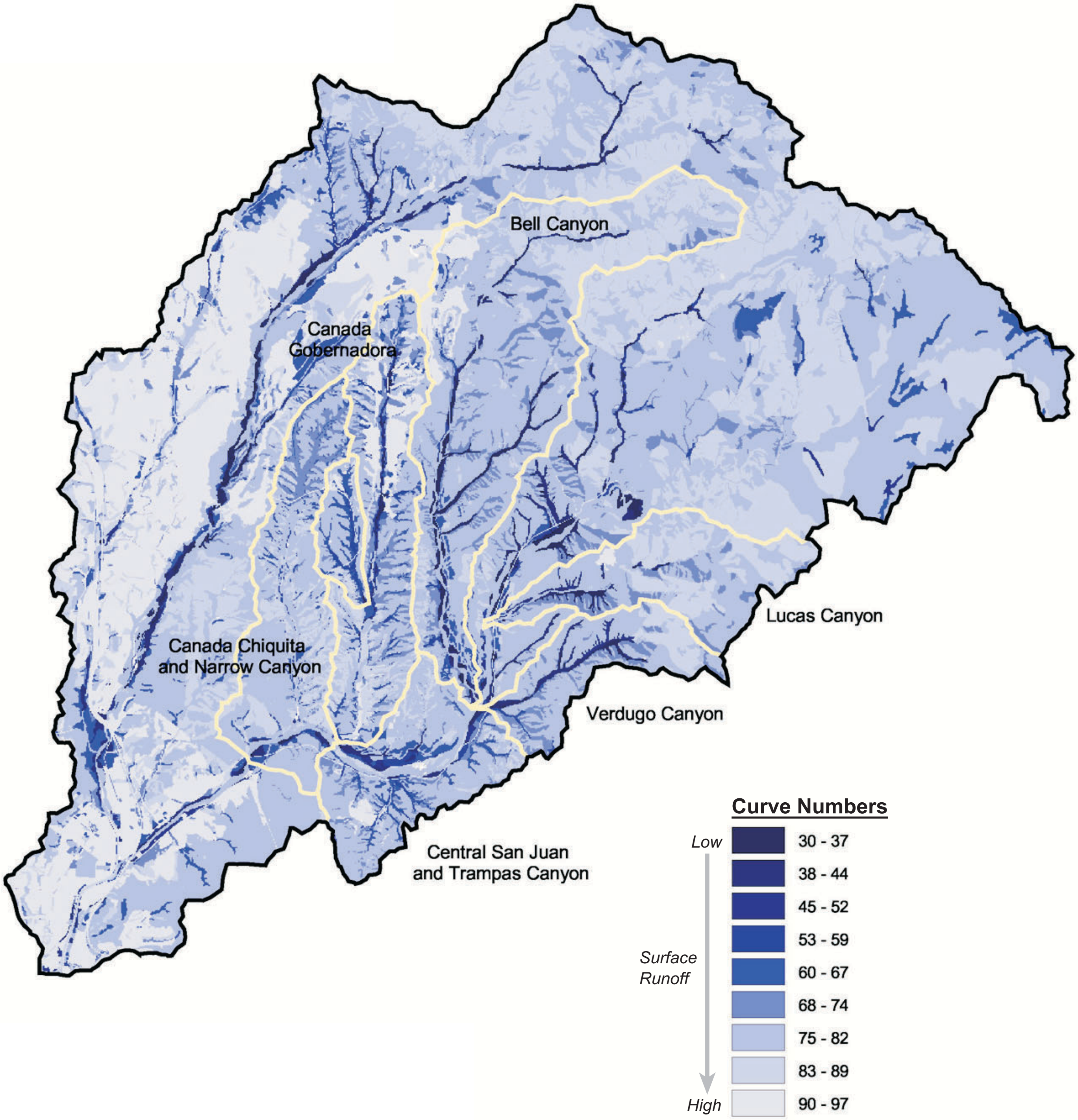
of 2-year events, loss rates were set at 0.6 in/hr, as indicated in the Addendum to the OCHM (1995). Figure 8 on page 40 and Table 3 on page 41 display the distribution of SCS runoff curve numbers for the San Juan watershed. Assigned runoff curve numbers range from 30 to 97, with an area-averaged curve number of 80.5 for the whole watershed. The majority of the watershed (91 percent) was characterized by higher curve numbers between 70 and 97. For modeling purposes, higher curve numbers result in a greater proportion of rainfall becoming surface runoff (i.e., less infiltration). The highly developed western watershed, as well as the northern portion of Cañada Gobernadora, have the highest runoff curve numbers. Lower curve numbers occur mostly along riparian corridors and alluvial valley floors. Arroyo Trabuco, Wagon Wheel Canyon, Cañada Gobernadora, Bell Canyon, Lucas Canyon, Verdugo Canyon, and the Central San Juan catchments all contain zones of lower curve numbers along their valley bottoms. Based on a spatial GIS analysis of these runoff curve numbers, loss rates were calculated and incorporated into the HEC-1 model.

3.4.1.3 Storm Event Runoff

The 2-year, 10-year, and 100-year storm events were analyzed using the HEC-1 model of the San Juan Creek watershed. Figure 9 through Figure 11 on pages 42 through 44, respectively, show hydrographs at four locations in the watershed for each event.[14] Peak flows for the four locations are summarized in Table 4 on page 45.

Certain notable trends are observable in the modeling results from Figure 9 through Figure 11 on pages 42 through 44, respectively. For the 2-year event, peak runoff from the western, more urbanized, Trabuco and Oso sub-watersheds occurs earlier than peak flows along the main San Juan Creek in the central watershed upstream of Horno Creek. The shape of the hydrographs from the more urbanized Oso and Trabuco sub-watersheds is steeper, or flashier, for both the rising and falling limbs of the 2-year hydrograph. As the magnitude of the modeled events increases for the 10-year and 100-year events, the earlier arrival and "flashiness" of peak runoff from the Oso and Trabuco sub-basins is less pronounced. The more rapid arrival of peak flows from the western watershed occurs for two reasons. Flow distances from the western tributaries are somewhat shorter to the lower San Juan watershed than from the areas to the east. Secondly, the western watershed is more urbanized than the eastern watershed. Impervious surfaces in these urban areas shed runoff much more quickly than more pervious areas to the east, and the hydrograph peak occurs earlier. Peaks from the different sub-regions of the watershed combine to produce a hydrograph with a

[14] *The four locations are as follows: San Juan Creek upstream of Horno Creek (approximately the location of the USGS streamflow gauge at La Novia Street); Oso Creek upstream of the Trabuco Canyon confluence; Trabuco Creek upstream of the Oso Creek Confluence; and San Juan Creek at the Pacific Ocean. Taken together, these locations provide a good representation of hydrologic events at the watershed scale.*



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

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0 1 2 Miles

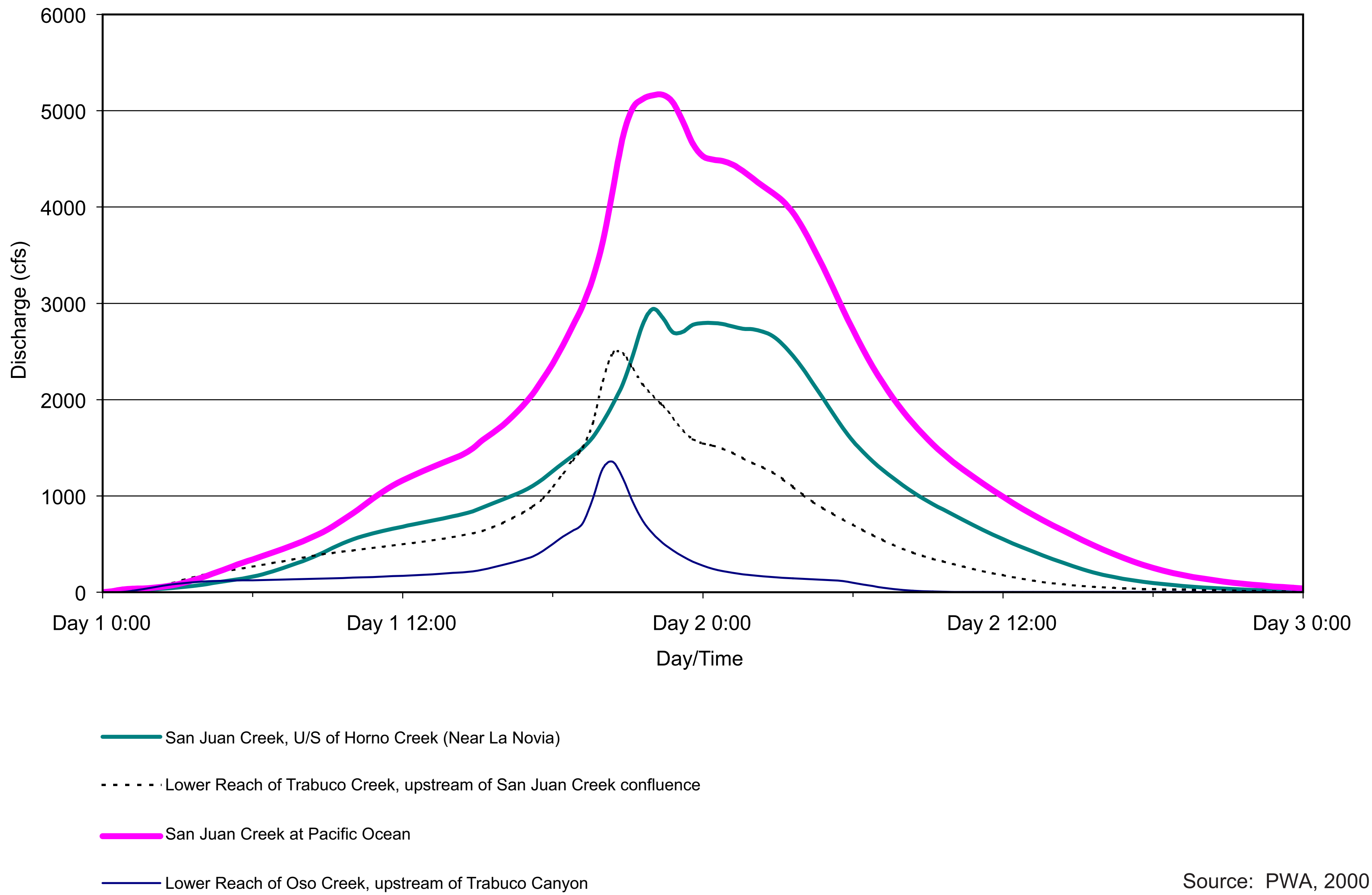
Figure 8
Baseline Conditions Report
Distribution of SCS Curve Numbers
for San Juan Watershed

Table 3

San Juan Watershed Physical Characteristics

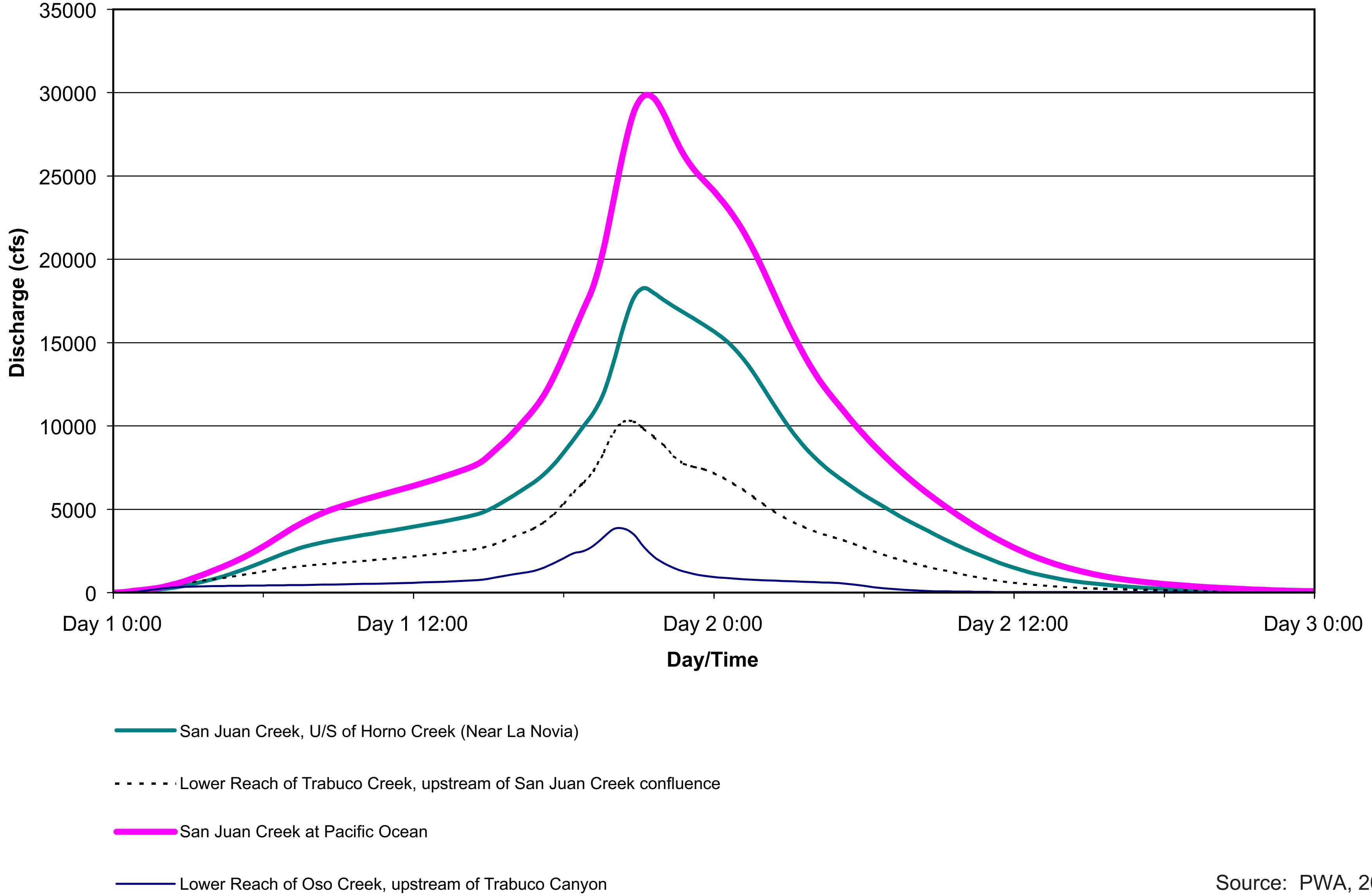
Sub-Watershed Region	Area (mi.^{2})	Area as % of Upstream WS Area	Length (mi)	Elevation (ft)		Percentage Area with Hydrologic Soil Group				Area-Averaged Curve Number (AMC II)	Impervious Area (%) of Total Sub-Basin
				Max	Min	A	B	C	D		
Lucas Canyon	7.17	14.31%	7.99	3,022	430	3.62	0.17	48.57	47.64	78.60	0.20
Verdugo Canyon	4.80	6.21%	6.02	2,487	358	8.30	1.25	61.81	28.63	74.80	0.05
Bell Canyon	5.12		5.47	4,485	1,178	1.94	0.00	9.15	88.91	82.30	0.00
	9.10		6.86	3,061	584	3.41	2.95	43.29	50.34	78.80	7.44
	6.35		8.86	2,405	358	8.12	5.64	45.83	40.41	74.00	0.02
Area Averages	20.57	28.42%				4.50	3.05	35.58	56.87	78.20	3.30
Cañada Gobernadora	2.99		3.17	1,237	656	3.43	35.25	54.36	6.96	79.50	29.84
	2.93		4.31	1,050	390	7.37	27.82	60.71	4.11	76.50	12.05
Wagon Wheel Canyon	1.77		3.49	1,063	390	0.69	30.59	62.96	5.76	74.50	1.77
	3.40		4.01	797	230	4.40	19.89	38.90	36.81	79.40	0.26
Area Averages	11.08	11.58%				4.33	27.83	52.67	15.16	77.88	11.59
Cañada Chiquita	4.58		5.59	1,168	358	0.00	36.55	41.89	21.56	77.70	0.35
	4.66		3.82	656	154	3.27	14.95	31.65	50.13	79.20	1.72
Area Averages	9.24	8.80%				1.65	25.65	36.73	35.98	78.49	1.04
Central San Juan Catchments	7.42	8.77%	4.48	892	230	6.07	12.08	52.62	29.24	75.90	3.14
Entire Watershed	175.97	100.00 %				4.74	15.42	27.80	52.04	80.50	21.84

Source: PWA, 2000



PCR PWA Balance Hydrologics, Inc.

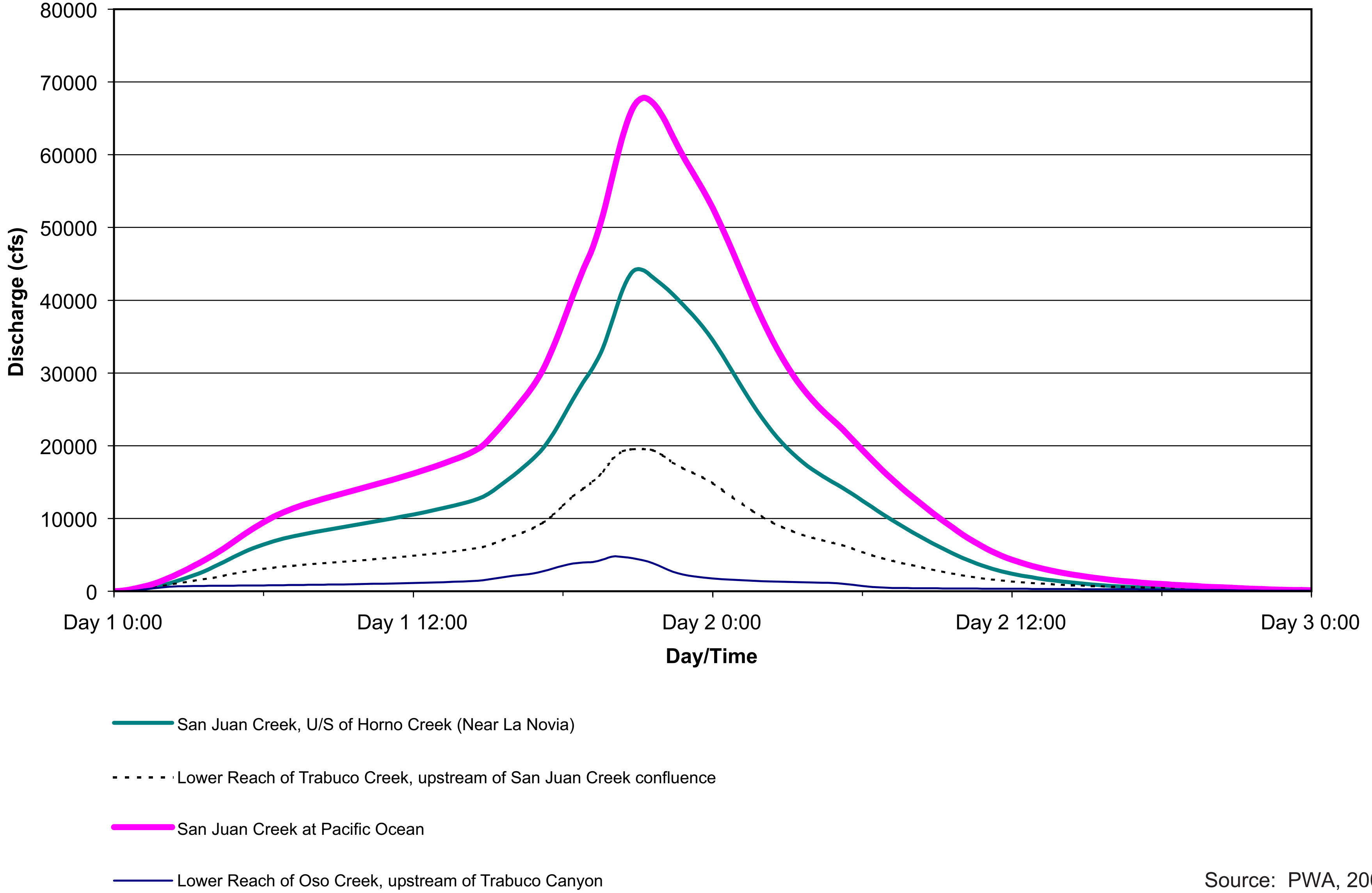
Figure 9
Baseline Conditions Report
2-Year Event Hydrographs
for San Juan Watershed



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 10
Baseline Conditions Report
10-Year Event Hydrographs
for San Juan Watershed



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 11
Baseline Conditions Report
100-Year Event Hydrographs
for San Juan Watershed

Table 4

Summary of Peak Flows (CFS), San Juan Watershed

Watershed Location	2-Year Event		10-Year Event		100-Year Event	
	(cfs)	(cfs/mi.^{2})	(cfs)	(cfs/mi.^{2})	(cfs)	(cfs/mi.^{2})
Oso Creek, upstream of Trabuco Creek	1,490	92	4,650	286	6,180	380
Lower Trabuco Creek, upstream of San Juan	2,560	47	10,600	194	20,040	366
San Juan Creek, upstream of Horno Creek	2,940	27	18,280	167	44,120	403
San Juan Creek at Pacific Ocean	5,170	29	29,820	169	67,820	385

Source: PWA HEC-1 Analysis, 2000

sustained high peak flow of 67,820 cfs for the 100-year event. The shape of the hydrograph is indicative of the longer, more sustained hydrologic response time for all regions of the San Juan watershed during the 100-year event.

Total runoff volumes and runoff per unit area for San Juan Creek at the Pacific Ocean are shown in above for the three modeled events. Runoff volume per unit area is generally higher for the overall San Juan Creek watershed than it is for the individual sub-basins because the individual sub-basins of the central watershed are generally undeveloped. Increased runoff from the more developed western portions of the watershed increases the overall watershed-averaged runoff volumes. (See Table 5 on page 46).

In general, absolute peak flow rates and volumes are greatest from the largest sub-basins: Bell Canyon in the San Juan watershed and Gabino Canyon in the San Mateo watershed (see Figure 12 on page 47). Peak flows and runoff volumes per unit area are fairly similar for the sub-basins within each watershed (see Figure 13 on page 48). However, discharge per unit area is generally greater for the sub-basins of the San Mateo watershed than for the San Juan watershed. This pattern reflects the steeper slopes and crystalline terrains found in the San Mateo watershed, which are expected to produce larger peaks flows per unit area. Within the San Juan watershed runoff volumes per unit area are lowest for the Chiquita, Gobernadora, and central San Juan sub-basins, which have the sandiest terrains and the highest infiltration rates (i.e., highest relative proportion of Type A and Type B soils). Gobernadora has slightly higher peak flows per unit area than would be expected, given the inherent properties of the sub-basin; this likely results from (1) the upstream development, which acts to increase volume and decrease time of concentration; and (2) from the hardpan layer which covers much of the upslope areas in the sub-basin. Hydrologic and sediment transport conditions in these individual sub-basins are described in further detail in Section 6.

Table 5

Storm Event Runoff Volumes, San Juan Watershed at the Pacific Ocean

Event	Total Runoff Volume (acre-feet)	Runoff Volume per Unit Area (acre-feet/mile^2)
2- Year	6,410	36
10-Year	31,040	176
100-Year	70,800	402

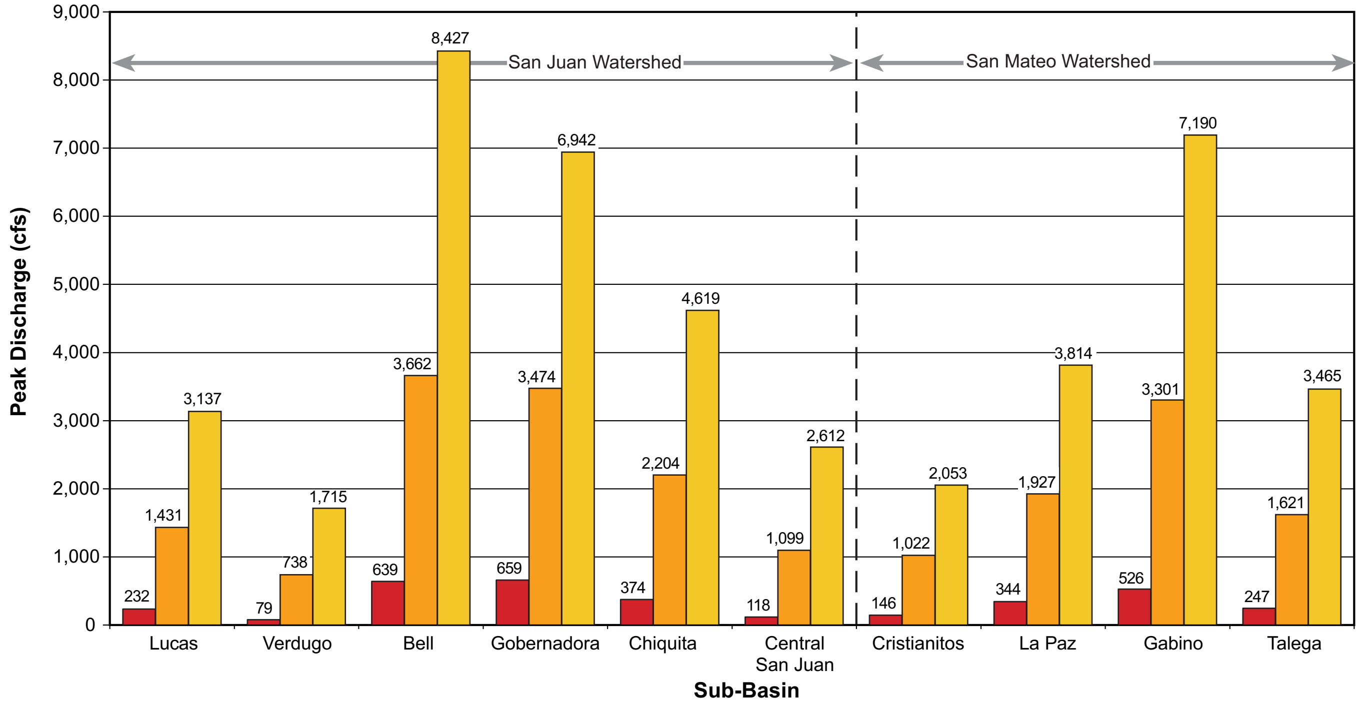
Source: PWA HEC-1 Analysis, 2000

3.4.1.4 Comparisons with Previous Hydrologic Studies

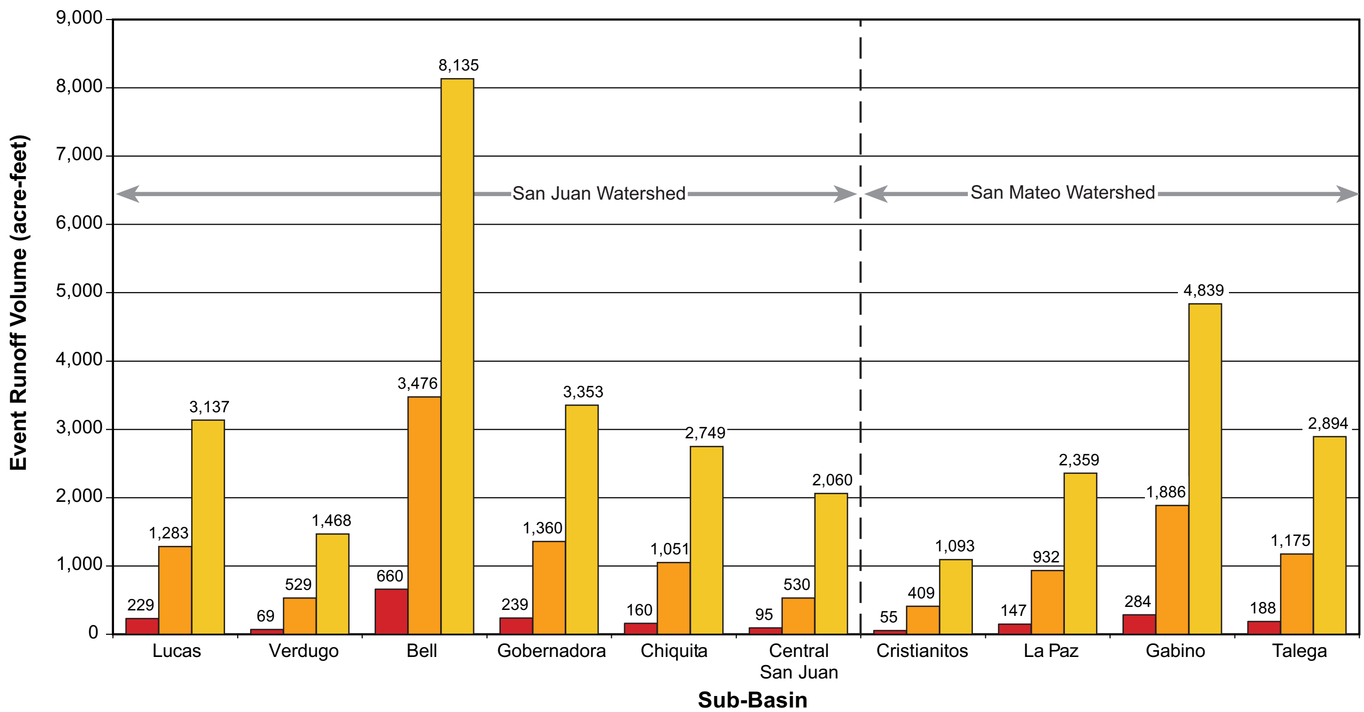
Previous hydrologic studies of the San Juan watershed have been completed by Rivertech (1987), Simons, Li & Associates (SLA, 1999), and the USGS (1993). Rivertech (1987) calculated 100-year peak discharges in the San Juan Creek watershed for future development conditions. Rivertech estimated 100-year flows (high-confidence) for Trabuco Creek, Oso Creek, and the main stem of San Juan Creek upstream to Long Canyon, using AES software following the Orange County Hydrology Manual (OCHM, 1986). In general, the results of the 2000 PWA analysis of existing conditions compare closely with the 1987 Rivertech estimates of future conditions. This result is not unexpected, as many of the "future" land use conditions assumed by Rivertech in 1987 are, in fact, existing land use conditions in 2000.

SLA (1999) recently performed a flood frequency analysis, HEC-1 rainfall-runoff analysis, low flow analysis, sediment yield and transport analysis, and groundwater assessment in support of the San Juan Creek watershed management study being conducted by the Planning Division of the U.S. Army Corps of Engineers, Los Angeles District. The SLA project analyzed the entire San Juan Creek Watershed, including Oso and Trabuco Creeks, and calculated discharge-frequency relationships for two gauged locations: San Juan Creek at La Novia Street and Trabuco Creek at Camino Capistrano. Historical flow data from these two gauges and the HEC Flood Frequency Program were used to create discharge-frequency relationships.

In general, SLA followed the methods outlined in the OCHM to formulate its HEC-1 model. However, to refine its model it adjusted basin roughness parameters so the estimated peak flow rates from HEC-1 would match with calculated peak flows from the discharge-frequency analysis. As a result, peak-flow values from its HEC-1 analysis are identical to results from its discharge-frequency analysis. A more standard model calibration process involves comparing HEC-1 generated hydrographs from a known precipitation event to actual stream flow data from the same storm event. The SLA technique assumes that a design rainfall event of a given return frequency would produce a discharge event of equal return frequency, which may not always be a valid assumption.



Part A: Peak Discharge for Selected Sub-Basins



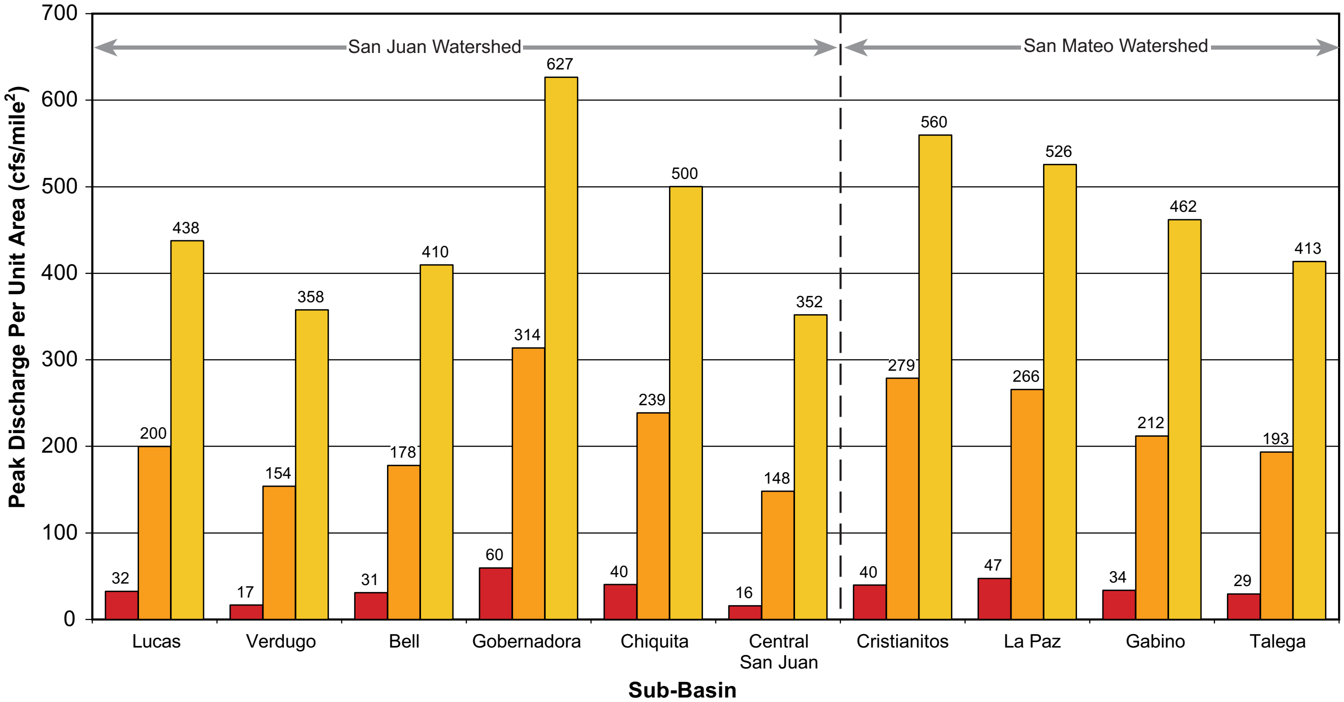
Part B: Event Runoff Volume for Selected Sub-Basins

Source: PWA, 2000

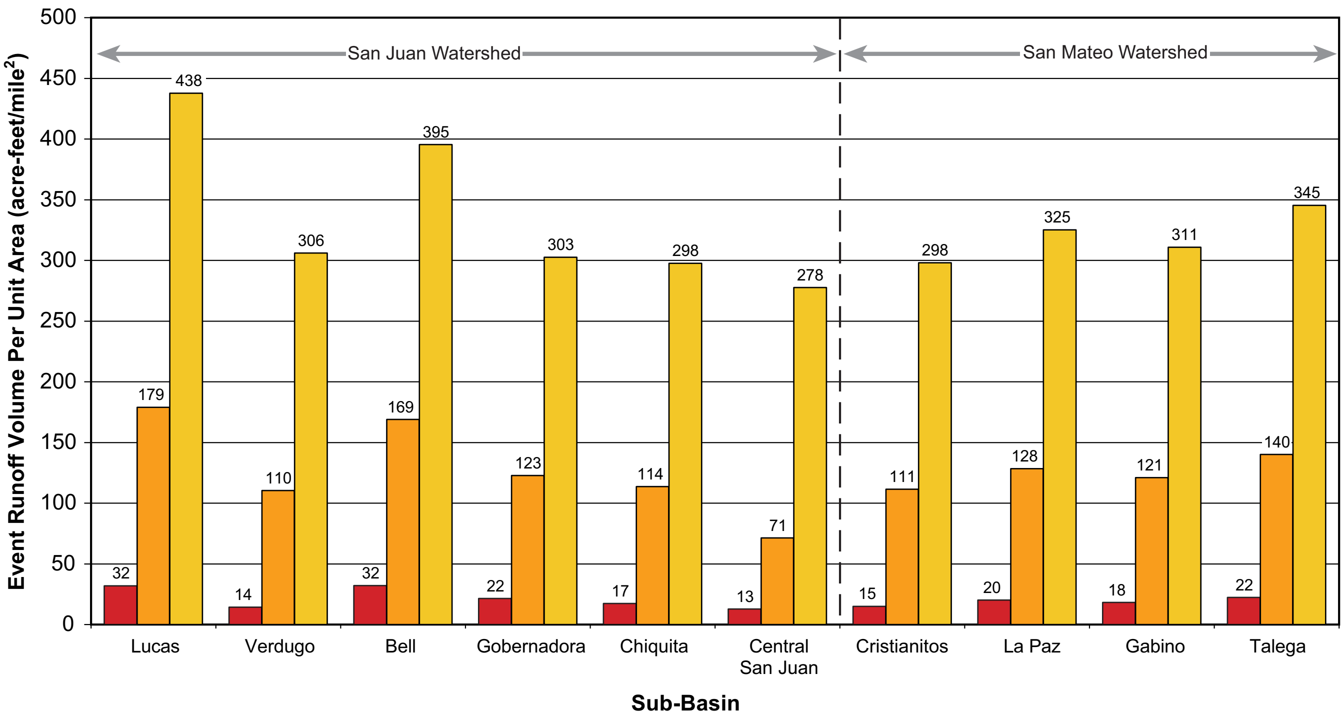
2-Year 10-Year 100-Year

PCR PWA Balance Hydrologics, Inc.

Figure 12
Baseline Conditions Report
Peak Discharge and Event Runoff Volume for Selected Sub-Basins



Part A: Peak Discharge per Unit Area for Selected Sub-Basins



Part B: Event Runoff Volume per Unit Area for Selected Sub-Basin

Source: PWA, 2000

2-Year 10-Year 100-Year

PCR PWA Balance Hydrologics, Inc.

Figure 13
Baseline Conditions Report
Peak Discharge per Unit Area and Event Runoff Volume per Unit Area for Selected Sub-Basins

Additionally, SLA reported peak flows as “expected values” and not the more standard “high confidence values.” Expected value estimates typically assume lower antecedent moisture conditions and, therefore, produce lower predicted runoff and associated stream flow than the high confidence values. If SLA had used high confidence values, as required by the OCHM (and used by PWA), its predicted discharges would have been significantly higher. Consequently, SLA’s peak flow numbers are not directly comparable to Orange County design values and are generally lower than Rivertech’s “high confidence” values (see on page 50).

Results of the current PWA analysis were also compared to discharge values for the San Juan watershed based on USGS regional regression equations. Because most of the watershed is undeveloped, the USGS *rural* regression was used to calculate peak flows for the overall watershed. Discharge values based on the USGS regional regression method (rural) were the lowest of all approaches. This is not surprising, as these USGS regional rates do not reflect developed land conditions and are, therefore, not entirely appropriate for the semi-developed San Juan watershed. A comparison of the calculated 100-year discharge values from PWA (2001), Rivertech (1987), SLA (1999), and the USGS regional regression approach are shown in Table 6 on page 50.

In general, the results of the PWA analysis compare closely with Rivertech’s estimates for the Oso Creek, Trabuco Creek, and San Juan Creek at La Novia locations. Despite this general agreement at upstream locations, at the Pacific Ocean river mouth, 100-year results by PWA are somewhat higher than Rivertech. When considered per unit area, PWA’s estimated 100-year discharge for the entire San Juan Creek watershed (67,820 cfs) equates to roughly 385 cfs/mi.^{2} (see Table 4 on page 45). This value plots below enveloping curves for maximum recorded floods for Pacific slope basins and is similar to values recorded for the March 1938 flood events on the Santa Ana River and the Tujunga Creek tributary of the Los Angeles River (see Figure 2-Figure 14, Technical Appendix A). For the current PWA analysis, the coincidental timing of hydrographs, where flows from the Oso, Trabuco, and central San Juan sub-basins arrive to the lower San Juan Creek region at roughly the same time for the 100-year event may account for the higher PWA runoff numbers at the ocean (Figure 11 on page 44). Other potential sources for this discrepancy are found in the use of different sub-basin delineations, routing parameters, land use designations, and modeling software by the two studies. Nevertheless, within the bounds of error associated with hydrologic models, there is reasonably close agreement between peak flow estimates generated by Rivertech and PWA.

3.4.2 San Mateo Creek Watershed

3.4.2.1 Drainage Network

The 133.2 mi.^{2} San Mateo Creek watershed has two principal drainage systems that join in the lower stream valley, 2.7 miles upstream of the ocean. The focus area of the SAMP/MSAA

Table 6

Comparison of Estimated 100-Year Discharges (CFS), San Juan Creek Watershed

Location	Rivertech [a]	SLA [b]	USGS [c]	PWA [d]
Oso Creek at confluence with Trabuco Creek	6,700	5,400	4,580	6,180
Trabuco Creek at confluence with San Juan Creek	22,600	18,700	12,500	20,040
San Juan Creek at La Novia Street Bridge	40,600	36,100	22,300	44,120
San Juan Creek at the Pacific Ocean	59,500	53,300	33,000	67,820

[a] *Rivertech (1987), "high confidence" values based on ultimate development conditions.*
[b] *Simons, Li & Associates (1999), "expected values" based on frequency-magnitude relations.*
[c] *USGS (1993), regional regression approach based upon rural (undeveloped) conditions.*
[d] *PWA (2001), HEC-1 based on undeveloped conditions following OCHM, 1986.*

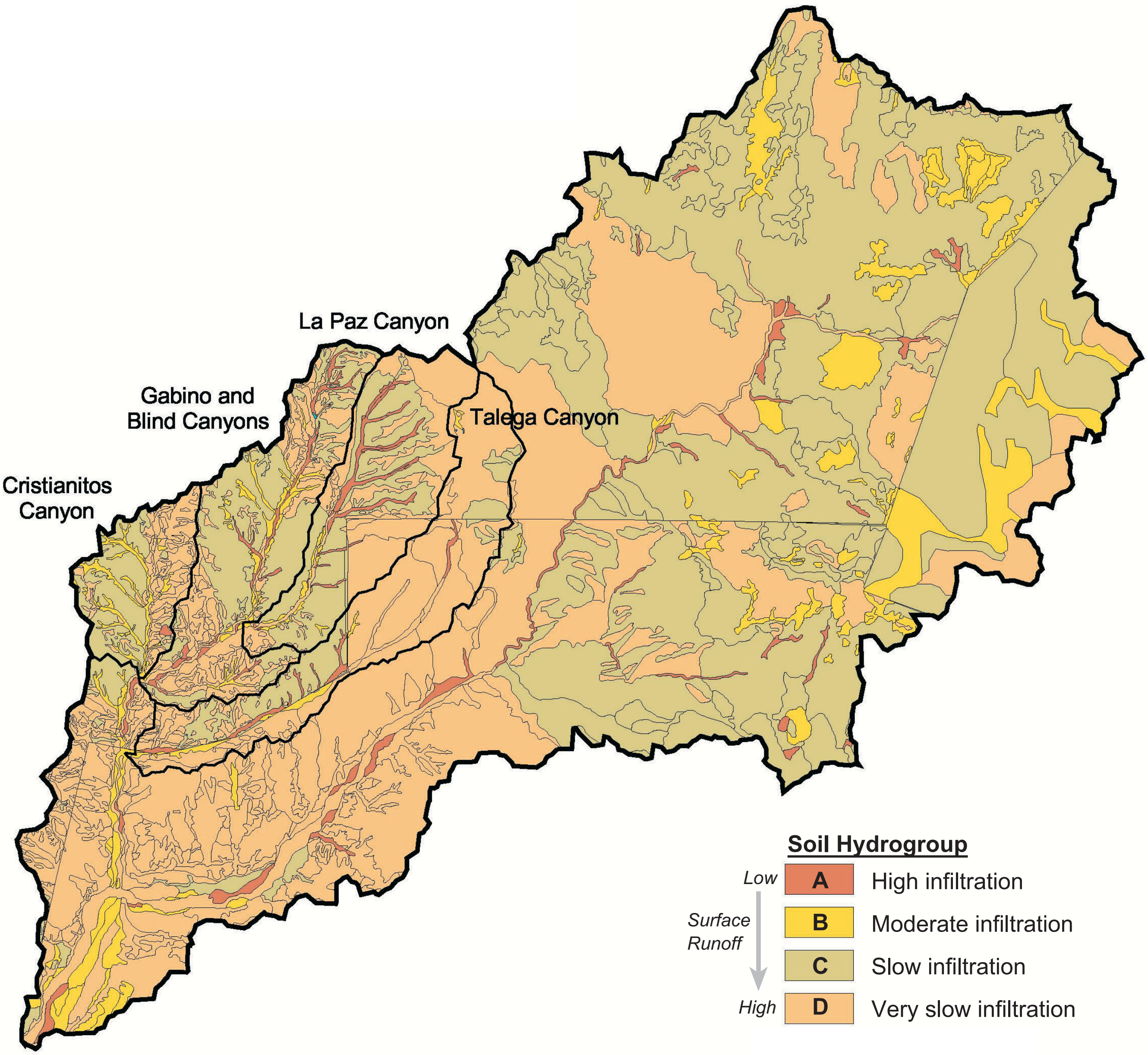
Source: PCR Services Corporation, 2001

analysis is the western watershed north of the main stem of San Mateo Creek. The sub-basins of interest include La Paz, Gabino, Cristianitos, Blind, and Talega Canyons upstream of the Cristianitos and San Mateo creek confluence. Approximately 17 percent of the total runoff in the San Mateo Creek basin emanates from these tributaries (Carlson, pers. comm., 2000).

The predicted drainage density for the San Mateo watershed is 8 mi/mi.^{2}. Since the WES/CRRL study only mapped the portion of the San Mateo watershed within the SAMP/MSAA study area, complete calibration of the basin channel mapping was not possible. However, the predicted channel networks and drainage densities for the northwestern portion of the watershed (within the area mapped by WES/CRRL) have comparable accuracy to those in the San Juan Creek watershed. These results are discussed in the sub-basin analysis found in Section VI of this report (beginning on page 99) and presented more fully in Technical Appendix A.

3.4.2.2 Infiltration

Infiltration was estimated using the USDA hydrologic soil group classification as described in Section 3.4.1.2 (see Figure 14 on page 51). Overall, infiltration in the San Mateo watershed is relatively low due to the prominence of poorly infiltrating soils (e.g., 89.8 percent of the watershed is underlain by soil types C or D). However, there are pockets of the watershed, particularly in the upper western watershed, which do have more permeable soils and offer higher infiltration. Using the OCHM methods, SCS runoff curve numbers were assigned to synthesize the effect of soil type, land use, vegetation, and infiltration processes and offer an integrated overall "hydrologic loss" rate. Note, for the analysis of 2-year events, loss rates were set at 0.6 in/hr, as indicated in the Addendum to the OCHM (1995). Figure 15 on page 52 and Table 7 on page 53 displays the distribution of SCS



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

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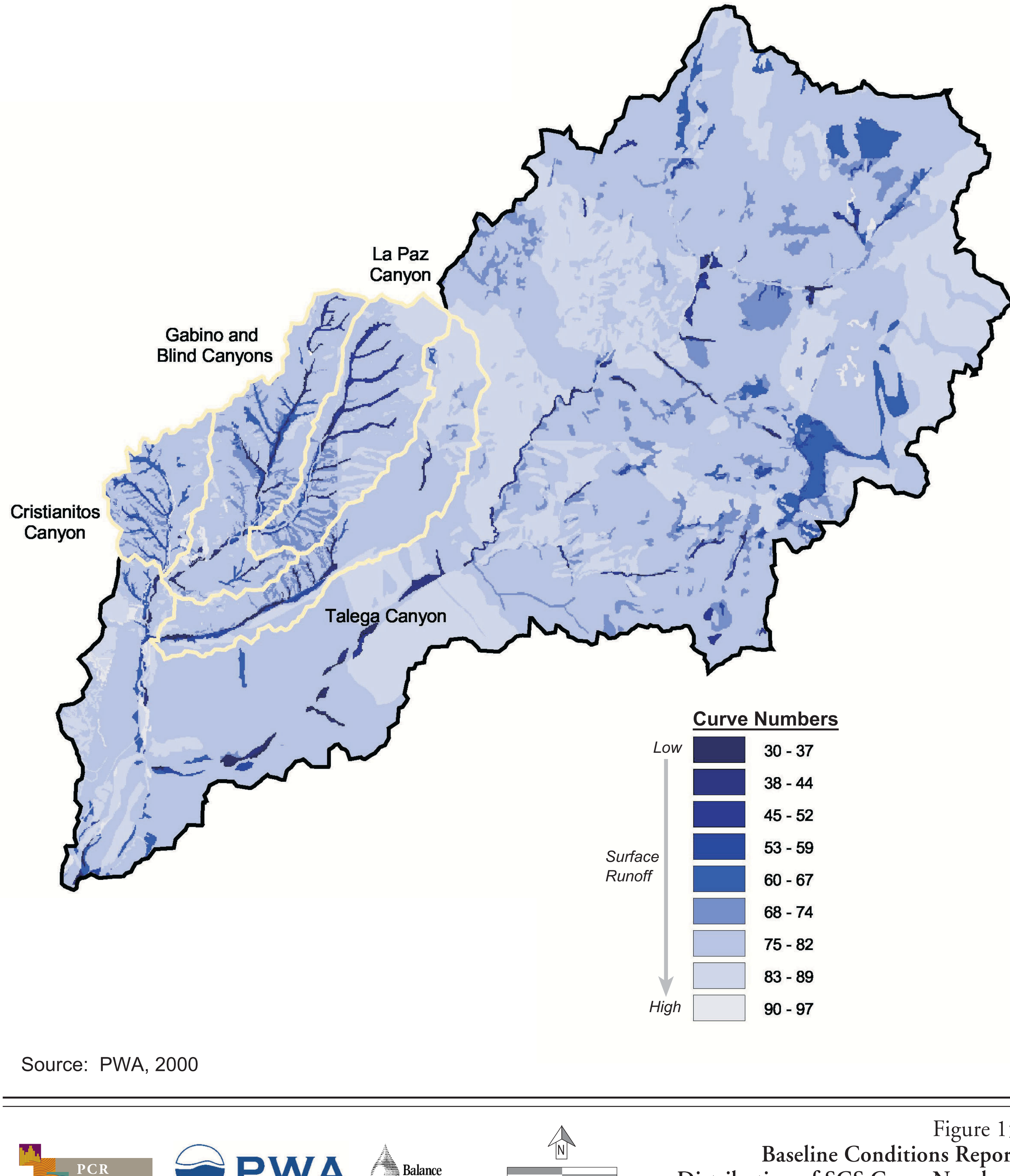
0 1 2 Miles

Figure 14
Baseline Conditions Report
Distribution of Hydrologic Soil Groups
for San Mateo Watershed



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 15
Baseline Conditions Report
Distribution of SCS Curve Numbers
for San Mateo Watershed

Table 7

San Mateo Watershed Physical Characteristics

Sub-watershed Region	Area (mi.^{2})	Length (mi)	Elevation (ft) max	Elevation (ft) min	Percentage Area with Hydrologic Soil Group A	B	C	D	Area-averaged Curve Number (AMC II)	Impervious Area (%)
La Paz Canyon	7.25	6.8	2,497	436	6.70	1.72	43.77	47.81	77.0	0.03
Upper Gabino Canyon	5.03	5.82	1,923	436	5.59	7.68	55.72	31.02	74.9	0.00
Lower Gabino Canyon with Blind Canyon	3.28	4.02	1,050	282	3.46	2.54	33.99	60.00	78.4	1.67
Upper Cristianitos Canyon	3.67	3.69	1,007	282	0.63	12.86	43.86	42.66	77.2	< 1.00
Talega Canyon	8.38	10.08	2,438	177	2.91	2.63	18.83	75.63	79.2	0.55
Entire Watershed	133.28	28.81	3,412	0	1.92	8.29	49.31	40.48	78.7	3.917

Source: PWA HEC-1 Analysis, 2000

runoff curve numbers for the San Mateo watershed. Assigned runoff curve numbers range from 31 to 97, with an area-averaged curve number of 78.7 for the whole watershed. The majority of the watershed (93 percent) was characterized by higher curve numbers between 70 and 97. Higher curve numbers result in a greater proportion of rainfall becoming surface runoff. The lower valley zones and riparian corridors along Cristianitos, Gabino, La Paz, and Talega canyons, as well as some reaches along the main San Mateo Creek upstream, include several areas of lower curve numbers. Based on a spatial GIS analysis of these runoff curve numbers, loss rates were calculated and incorporated into the HEC 1 model.

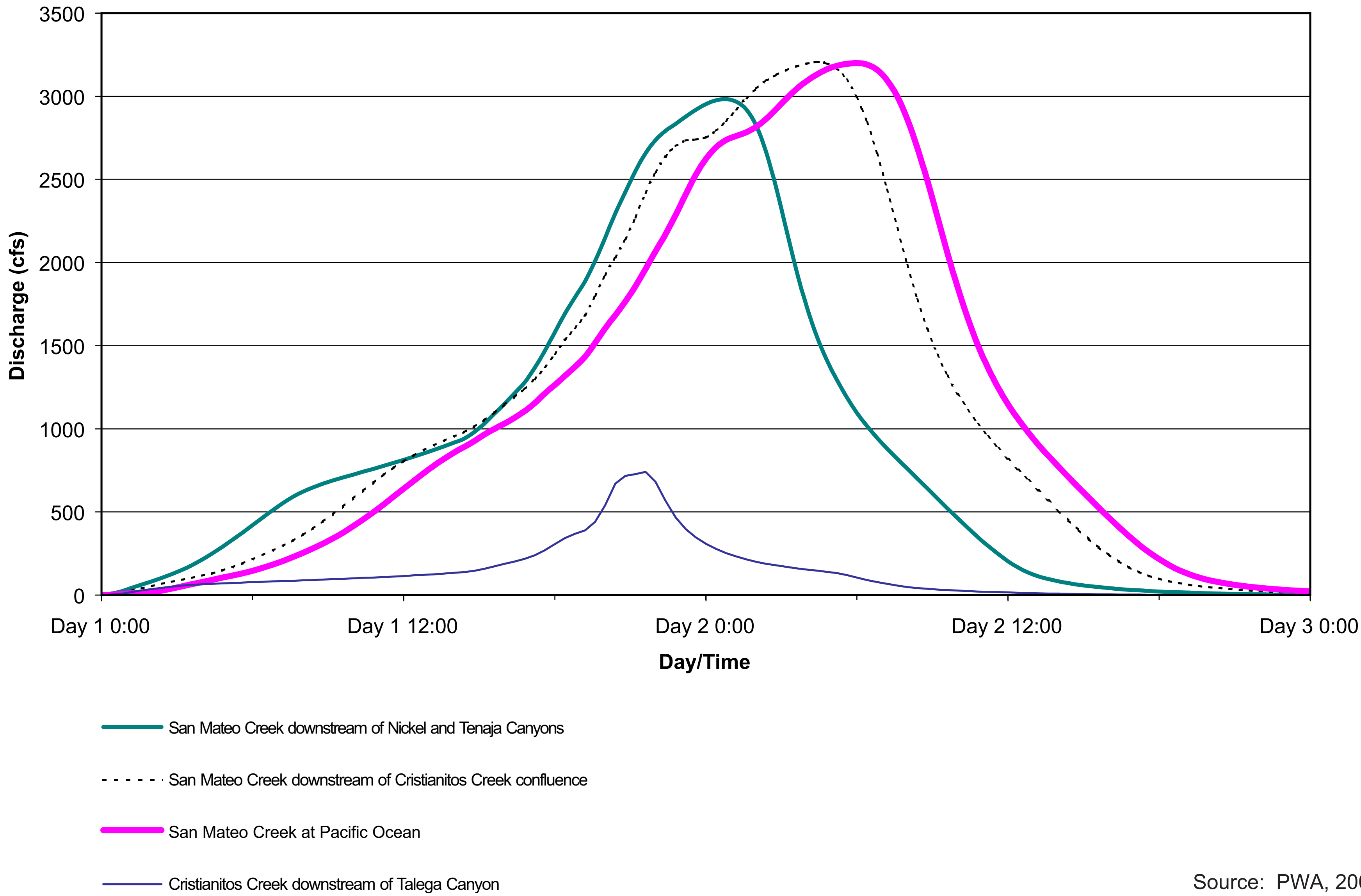
3.4.2.3 Storm Event Runoff

The 2-year, 10-year, and 100-year storm events were analyzed using the HEC-1 model of the San Mateo Creek watershed. Figure 16 through Figure 18 on pages 55 through 57, respectively, show hydrographs at four locations in the watershed for each event.[15] Peak flows for the four locations are summarized in Table 8 on page 58.

Several things are notable about the predicted hydrographs. In general, the hydrographs show the characteristic pattern of a large watershed, increasing in peak discharge and time of peak as they move downstream through the watershed. Flows from Cristianitos Creek, the most significant western tributary to San Juan Creek, join the main San Mateo channel prior to the passing of peak flows in the main San Mateo channel for all three events. As a result, contributing flows from Cristianitos Creek help sustain flows for the overall San Mateo watershed at the Pacific Ocean, where peak flows have a relatively long duration. The long duration is also reflective of the relatively un-urbanized condition of most of the watershed. Runoff rates tend to increase and decline much less rapidly in natural watersheds than in urbanized watersheds. Unlike the San Juan watershed to the north that contains large urbanized areas with impervious surfaces, the event hydrographs for the undeveloped San Mateo Creek do not exhibit heightened or accelerated flows.

Total runoff volumes and runoff per unit area for San Mateo Creek at the Pacific Ocean are shown in Table 9 on page 58 for the three modeled events. The individual sub-basins of the western San Mateo watershed have generally higher infiltration conditions and less runoff per unit area than the overall San Mateo watershed rates. Interestingly, for the 10-year and 100-year events, runoff volume per unit area for the relatively undeveloped San Mateo watershed is comparable to the more developed San Juan watershed to the north. However, as discussed in Section 3.4.1.3, peak discharge per unit area for the San Mateo sub-basins is generally higher than for the San Juan sub-

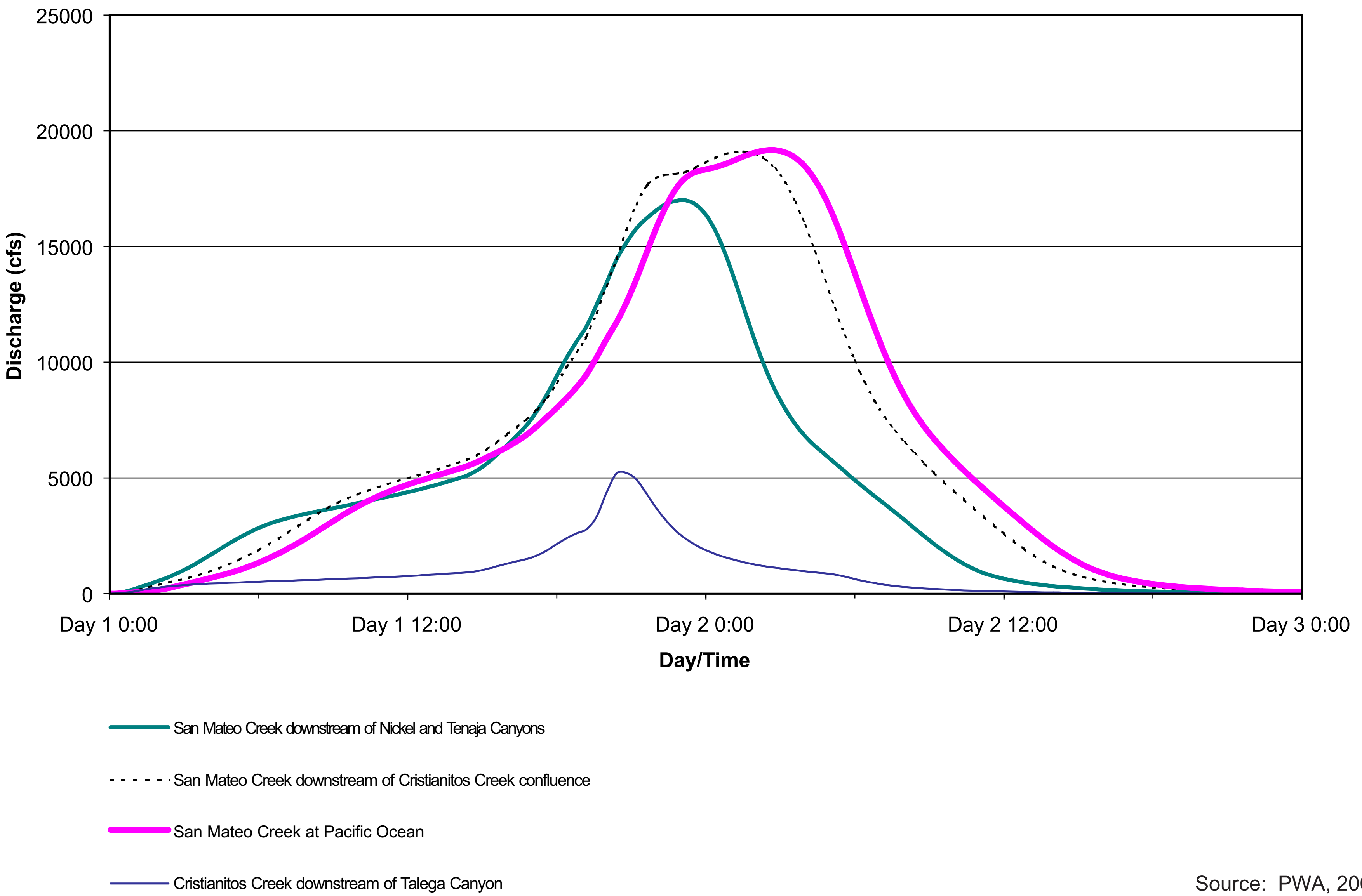
[15] *The four locations are as follows: San Mateo Creek downstream of the Nickel Canyon and Tenaja canyons; San Mateo Creek downstream of Cristianitos Creek; Cristianitos Creek downstream of Talega Canyon; and San Mateo Creek at the Pacific Ocean. These locations provide a good representation of hydrologic events at the watershed scale.*



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

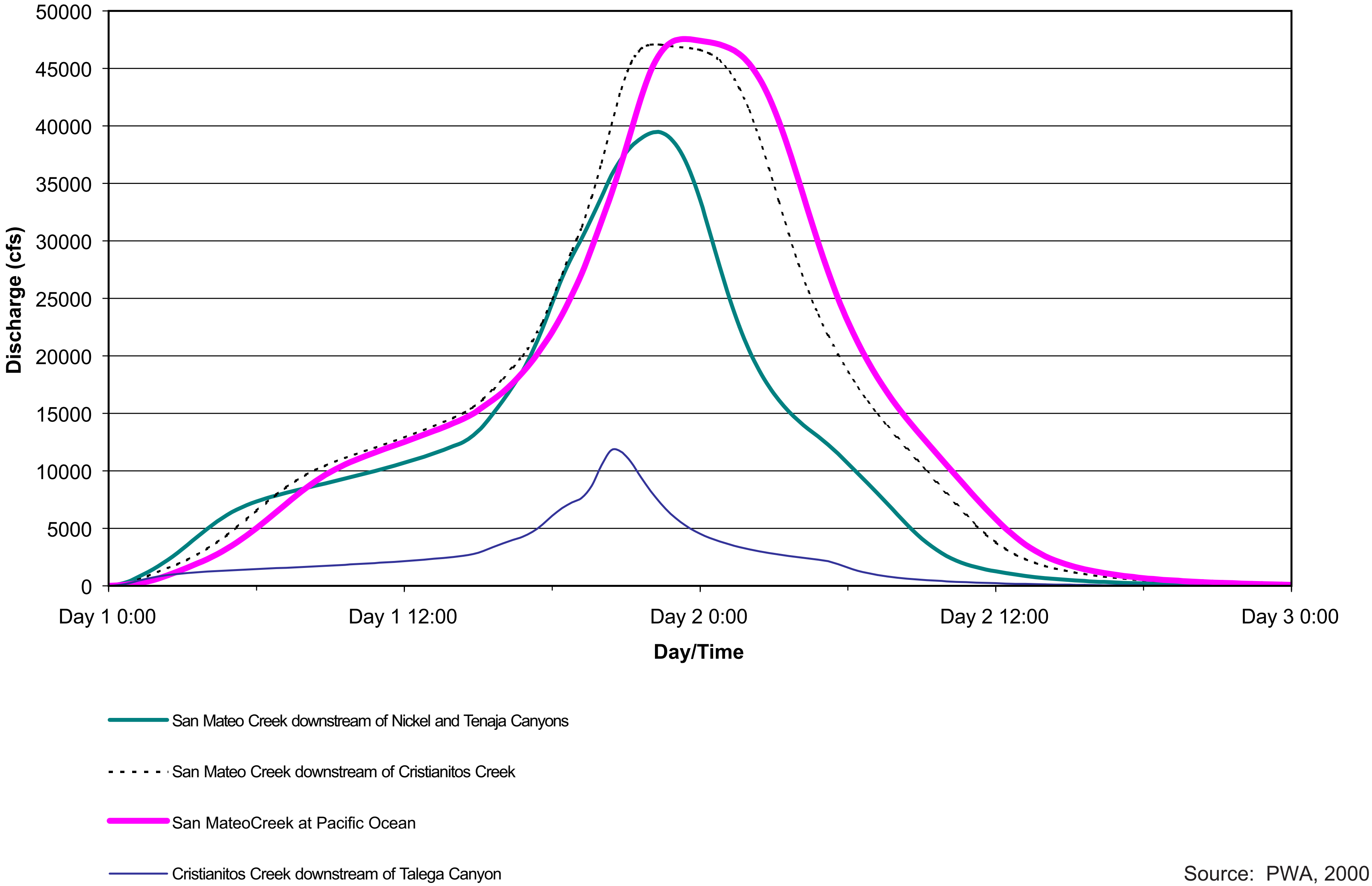
Figure 16
Baseline Conditions Report
2-Year Event Hydrographs
for San Mateo Watershed



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 17
Baseline Conditions Report
10-Year Event Hydrographs
for San Mateo Watershed



PCR PWA Balance Hydrologics, Inc.

Figure 18
Baseline Conditions Report
100-year Event Hydrographs
for San Mateo Watershed

Table 8

Summary of Peak Flows (CFS), San Mateo Watershed

Watershed Location	2-Year Event		10-Year Event		100-Year Event	
	(cfs)	(cfs/mi.^{2})	(cfs)	(cfs/mi.^{2})	(cfs)	(cfs/mi.^{2})
Cristianitos Creek at Talega Canyon	740	27	5,220	189	11,800	427
San Mateo Creek at Nickel/Tenaja Canyons	2,980	37	16,990	211	39,440	489
San Mateo Creek downstream of Cristianitos Creek	3,200	25	19,100	148	47,070	366
San Mateo Creek at Pacific Ocean	3,200	24	19,160	144	47,530	357

Source: PWA HEC-1 Analysis, 2001

Table 9

Storm Event Runoff Volumes, San Mateo Watershed at the Pacific Ocean

Event	Total Runoff Volume (acre-feet)	Runoff Volume per Unit Area (acre-feet/mi.^{2})
2-Year	4,550	34
10-Year	24,970	187
100-Year	59,100	443

Source: PWA HEC-1 Analysis, 2000

basins due to differences in terrain and slope between the two watersheds (see Figure 13 on page 48). In comparing runoff and discharge between the San Mateo sub-basins, the absolute discharges are highest for the Gabino sub-basin due to its large area; however, discharge per unit area is slightly higher for Cristianitos and La Paz primarily due to their shape and predominance of poorly infiltrating soils (see Figure 12 and Figure 13 on page 47 and on page 48, respectively). Hydrologic and sediment transport conditions in these individual sub-basins are described in further detail below in Section 6.

Unlike the San Juan Creek watershed, we have been unable to locate any previous hydrologic modeling studies completed for the San Mateo Creek watershed. Therefore, no comparisons can be made at this time.

3.4.3 Low Flow Conditions

The potential effect of urbanization on low-flow conditions was investigated by analyzing the Oso Creek sub-basin as an example of what could potentially happen in other parts of the San

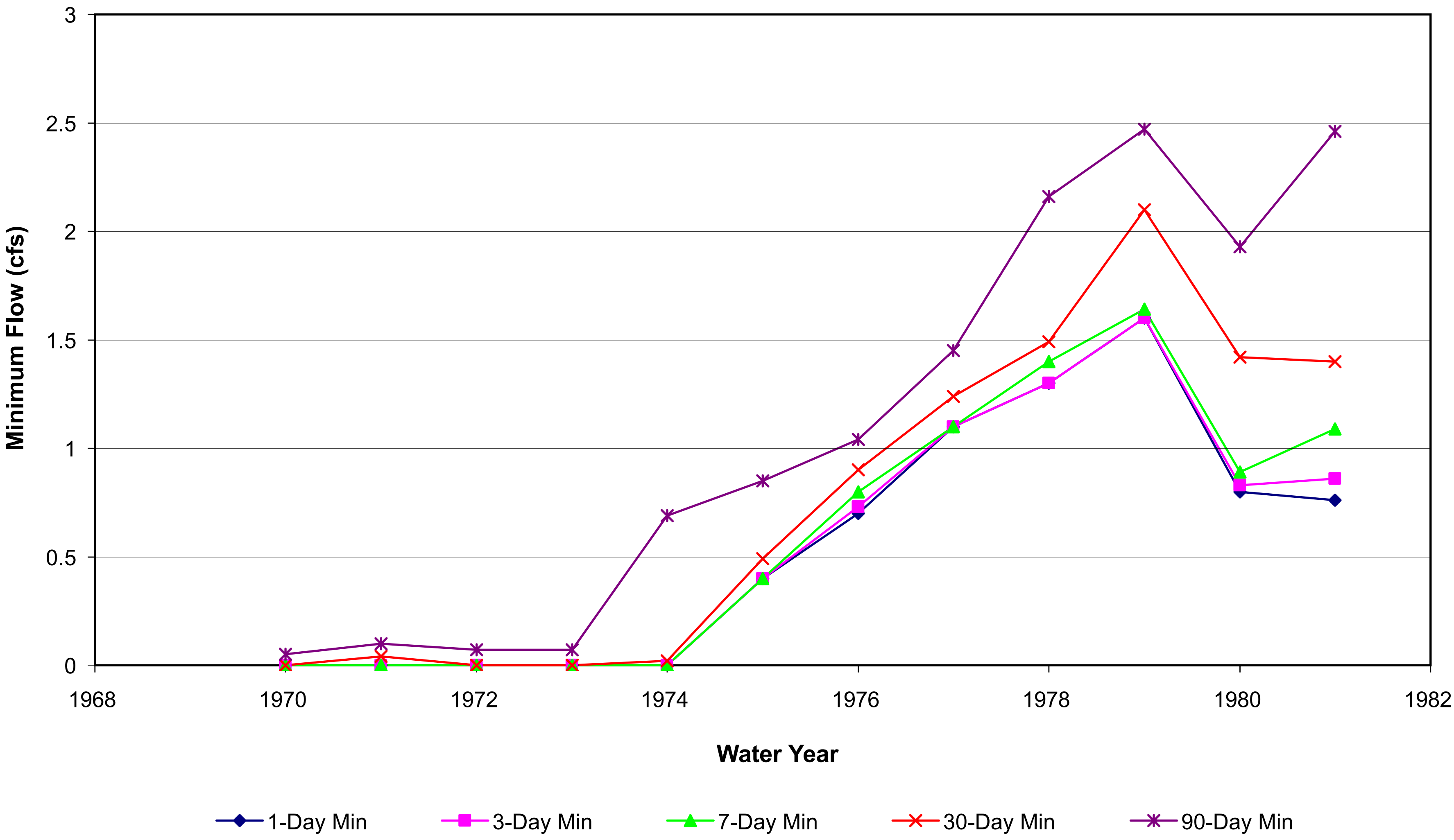
Juan or San Mateo Creek watersheds if similar land use transformations were to occur. The results of the trend analysis conducted for Oso Creek show that annual minimum stream flows and mean summer flows consistently increased over time as the basin progressively developed (see Figure 19 and Figure 20 on page 60 and on page 61, respectively). Annual minimum stream flows, average summer daily stream flows, and annual base-flows all increased during the 12-year period of increased urbanization. The correlation between percentage of watershed area developed and percentage increase in mean July flows is shown in Figure 21 on page 62. The relationship observed in the Oso Creek sub-basin is consistent with the findings of Hamilton (1992) that indicate that urbanization increases dry season low flow discharge in arid climates. The effect of upstream development on dry season flows is currently observable in the northern portion of the Cañada Gobernadora sub-basin, where the Coto de Caza development has increased the magnitude and persistence of low flows to the central Cañada Gobernadora watershed. The potential biotic impacts associated with these changes in low-flow conditions may include a shift in the plant species composition of the wetland and riparian areas in response to changes in extent and duration of saturation, as well as changes in water chemistry (e.g., salinity, alkalinity). In addition, faunal habitats may shift to support species more dependent on persistent moisture than intermittent flow conditions.

The effect of increased urbanization on low-flow conditions will vary, based on the underlying terrains. In general, the sandy terrains of the central San Juan watershed will be more susceptible to increased low flow associated with urbanization. In contrast, crystalline terrains found in the eastern San Juan and portions of the San Mateo watershed have intrinsically low infiltration rates. Therefore, the proportionate increase in low flow associated with urbanization in these areas may be less than in the sandy portions of the study area. Impacts to low-flow conditions will be used as a criterion to evaluate potential land use alternatives in a future phase of work, as well as during the on-site alternatives analysis. Analysis of potential changes in low flow will be more meaningful once future land use changes are better defined.

3.5 SEDIMENT PROCESSES

3.5.1 Sediment Yield

Sediment yield is the result of all of the erosive processes that take place in a watershed. Rates of erosion in coastal southern California are among the highest in the world, and in the semi-arid environment of Southern California, more sediment is typically shed from upland slopes than can be transported by stream networks (Mount, 1995). Floodplains and stream valleys, therefore, serve as areas of sediment deposition and temporary storage. Erosion rates tend to increase with both the seasonality of rainfall and the tendency toward relatively large, infrequent storms (c.f., Wells, 1981). Hillslopes are episodically subjected to fire and channels tend to periodically incise

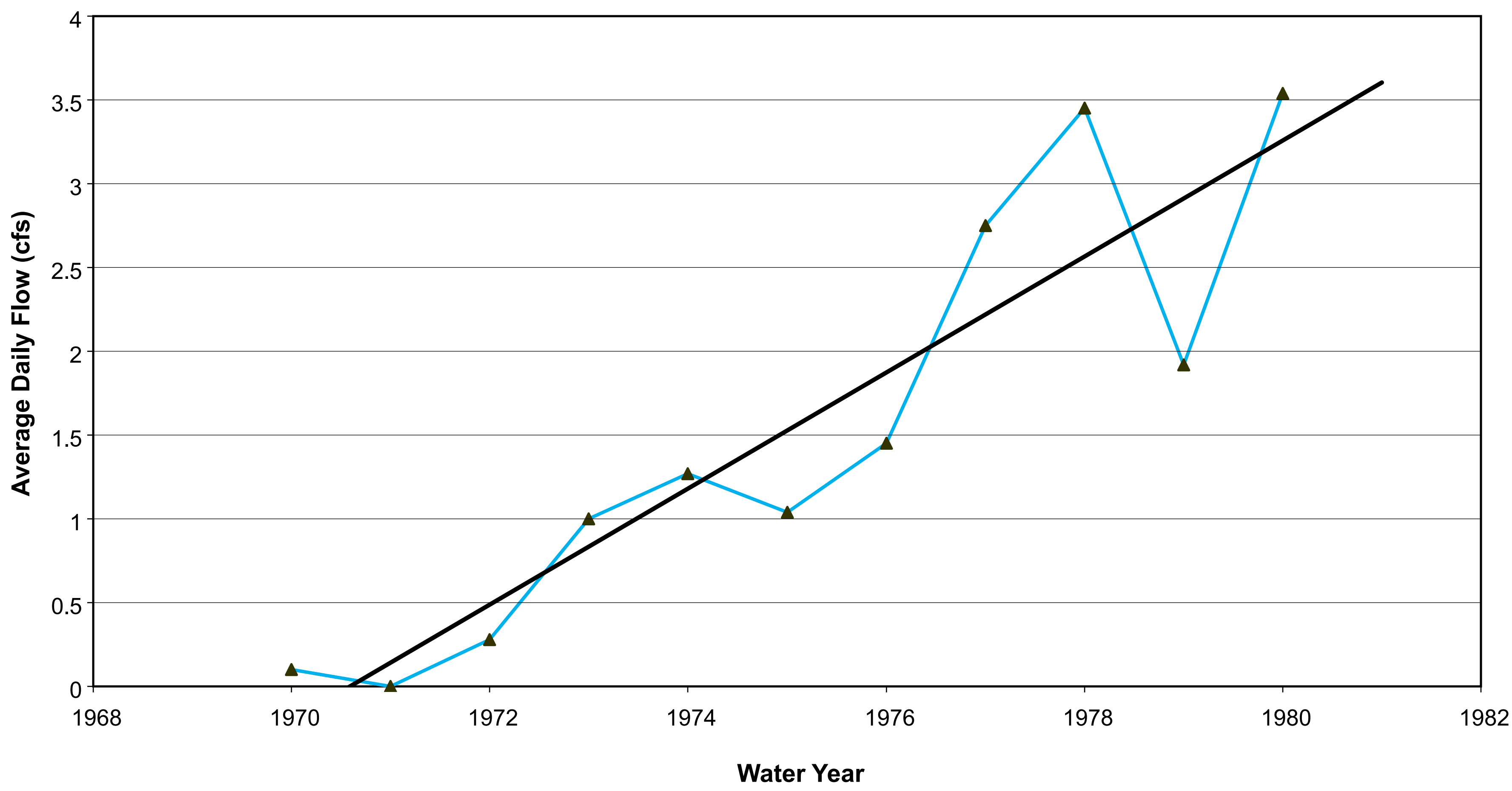


Source: PWA, 2000

Note: No data available after 1981

PCR PWA Balance Hydrologics, Inc.

Figure 19
Baseline Conditions Report
Annual Minimum Streamflows vs. Time
for Oso Creek

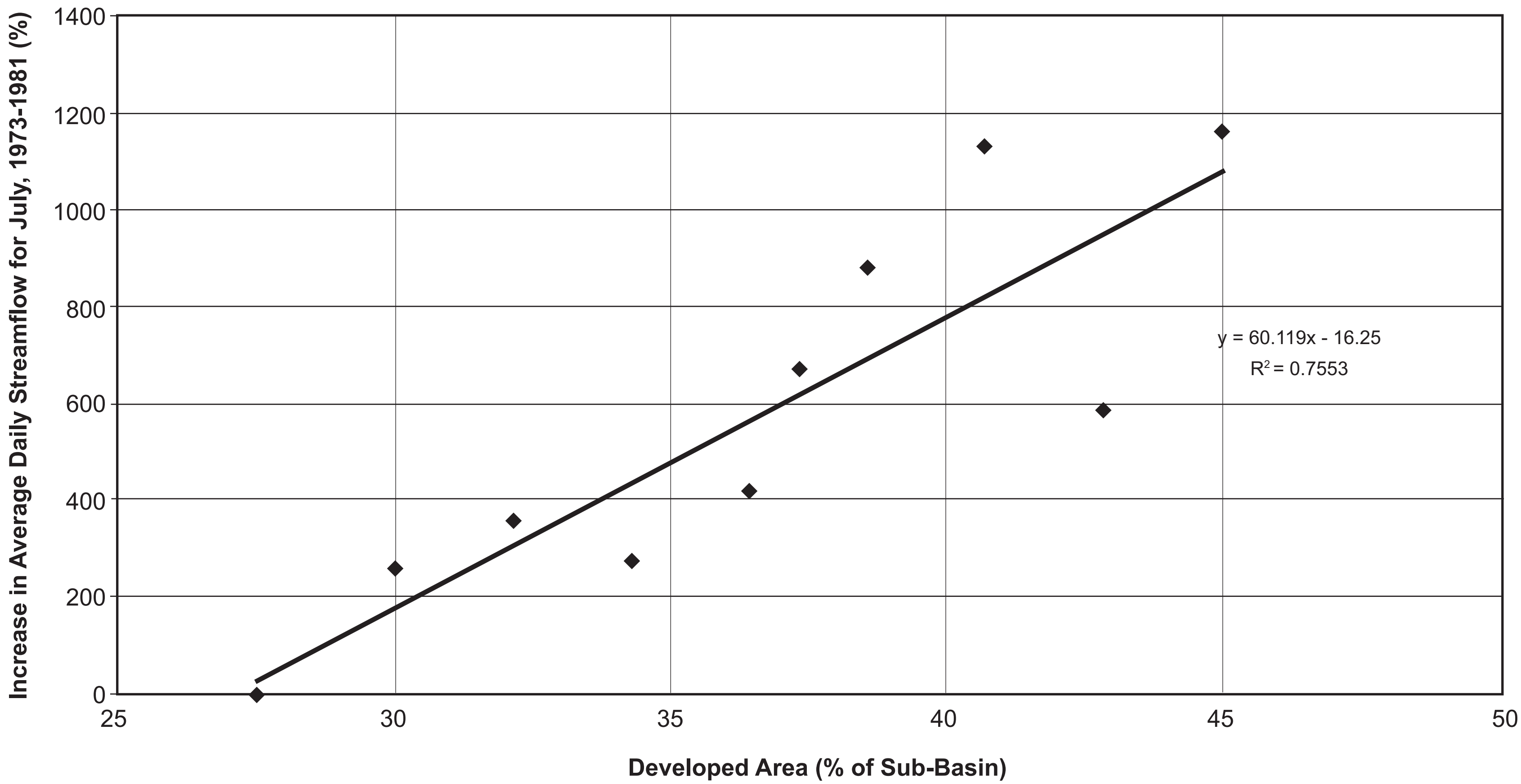


Source: PWA, 2000

Note: Data is July monthly mean of average daily streamflows.

PCR PWA Balance Hydrologics, Inc.

Figure 20
Baseline Conditions Report
Mean Daily Stream Flow for the Month of July vs. Time for Oso Creek



Source: PWA, 2000

Figure 21
Baseline Conditions Report
Developed Area vs. Increase in Average Daily Streamflow for Oso Creek

into their valley floors, processes that may generate most of the sediment yielded by some watersheds.

Many factors affect sediment yield. Among the most significant are geology, topography, rainfall, vegetation, multi-year wet and dry climatic cycles, fires, floods, landslides, and land use. Of these factors, fires, floods, and landslides are all episodic events that interact with the geology, topography, vegetation, and land use to affect the volume and timing of sediment delivery in the study area.

Sediment yields for the San Juan and San Mateo watersheds were estimated from existing data on measured sediment discharge in San Juan Creek and other creeks in the region, estimates of upland sediment yield rates in southern California, and application of the Corps of Engineers LAD debris method and the MUSLE.

Using measurements of streamflow and suspended sediment discharge, as well as estimates of bedload sediment discharge based on the modified Einstein method, Kroll and Porterfield (1969) estimated that long-term total sediment discharge for the San Juan drainage basin between 1931 and 1968 was approximately 1,230 tons per $mi.^2$ per year. This value is believed to underestimate total sediment yield from the watershed because: (a) it is an estimate of the sediment that is actually transported by the streams rather than the total amount of sediment provided to them; and (b) the data from which long term sediment yields were extrapolated were collected during two years that did not experience significant floods. Because most sediment is moved during extreme events, such as relatively large floods, this last point is key.

Taylor (1981) developed a catchment sediment yield model based on data from 36 water conservation reservoirs, flood control reservoirs, and debris basins throughout Southern California. Taylor's model estimates sediment yield using the relationship:

$$DR = \alpha L^{\beta} A^{\gamma}$$

Where:

DR = denudation rate, equivalent to the volume of accumulated sediment divided by the total erosional area in the drainage and the number of years over which the accumulation took place.

L = a topographic variable that reflects the dominant land type, defined as mountains, hills, or plains. Mountainous drainages have the highest denudation rates. Hill areas have lower rates, and on plains, measured denudation rates are extremely small.

A = a factor that takes into account the size of the basin, as studies have shown that there is a decrease in denudation rate as basin size increases.

α, β, and γ = fitted coefficients computed for each of 24 hydrographic drainage units defined by the study.

Taylor's denudation rates, expressed as base sediment yield rates, for the sub-watersheds in the San Juan and San Mateo drainages are shown in Table 10 on page 65 and Table 11 on page 67, respectively. Computed denudation rates are highest in the mountainous crystalline areas, where projected sediment yields are almost 6,000 tons per $mi.^2$ per year. Within the foothills, projected base sediment yield rates range from approximately 2,500 to 3,100 tons per $mi.^2$ per year. The foothill denudation rates calculated by Taylor are approximately twice the average annual sediment load for San Juan Creek estimated by Kroll. This difference may be attributable to the fact that: (a) denudation rates represent the amount of material available to streams for transport rather than the amount that they are actually able to move on a regular basis; (b) as discussed previously, Kroll may underestimate sediment transport during large storms; and (c) sediment sampling and calculation of yearly sediment budgets by Kroll do not appear to include the bedload sediment being transported.[16]

The sediment yields estimated based on the LAD and MUSLE methods are expressed as cubic yards per $mi.^2$ for specific design discharge events, including the 2-year, 25-year, 50-year, 100-year, 200-year, and 500-year floods, making direct comparison with historical measured or estimated sediment yields obtained from other sources difficult. Computed sediment yields based on the LAD method were 145 and 10,270 tons per $mi.^2$ for the 2-year to 100-year floods in the San Juan watershed and 640 and 14,840 tons per $mi.^2$ for the same design storms in the Arroyo Trabuco watershed. Sediment yield estimates obtained using the MUSLE method were 71 and 7,800 tons per $mi.^2$ in the San Juan watershed for the 2-year and 100-year floods and 200 and 8,900 tons per $mi.^2$ in the Arroyo Trabuco watershed for the same design storms. Yields calculated using the MUSLE and LAD methods for the 25-year and 50-year events are within a similar range of baseline sediment yields estimated by Taylor's denudation rate formula. Table 12 on page 68 provides a comparison of estimated sediment yields in the San Juan watershed using the techniques discussed above.

For all methods, calculated sediment yields that attempt to quantify the amount of material available for stream transport exceed estimates and measurements of transported sediment loads by more than a factor of 2. This may accurately reflect the condition of watersheds in an arid environment, where far more material is weathered and eroded than can typically be conveyed to and transported by local stream systems.

---

[16] *Sediment yield associated with episodic events is the most significant factor in the overall sediment budget for southern California coastal watersheds. Bedload transport accounts for a small fraction of the overall sediment movement in the watershed, and is a minor factor in shaping stream geomorphology.*

Table 10

Base Sediment Yields And Particle Size Distributions, San Juan Creek Watershed

							Particle Size Distribution					
							Suspended Load		Bedload			
Stream	**Major Geologic (Unit(s))**	**Weathers to** [a]	**Streambed Characteristics**	**Transport Characteristics**	**Base Sediment Yield Rate** [b] **(mm/year)**	**Base Sediment Yield Rate (tons/sq mi/year)**	**Clay/Silt**	**Sand**	**Sand**	**Gravel**	**Cobble**	**Percent Bedload**
Oso			sand, silt, clay	supply limited	0.35	2,491	high	high	high	v. low	v. low	15 to 25
	Niguel Sandstone	clayey and sandy silt										
	Capistrano Siltstone	clayey silt, expansive clay, some sand										
Trabuco			gravel, sand, silt, clay	transport limited	0.35	2,491	high	high	high	med	low	10 to 20
	Bedford Canyon Metamorphics	sand, silt, clay, pebbles										
	Santiago Peak Volcanics	angular pebbles and clay										
	Sespe and Vaqueros Sandstone and Conglomerate	clay, silt, sand, gravels										
	Old channel deposits	clay, silt, sand, gravels cobbles										
	Monterey Shale	silt and clay										
	San Onofre Breccia	silt, sand, gravels, cobbles										
	Niguel Sandstone	clayey and sandy silt										
	Capistrano Siltstone	clayey silt, expansive clay, some sand										
Chiquita			sand, some silt	supply limited	0.41-0.45	2,918 to 3,202	high	high	high	v. low	v. low	5
	Sespe Sandstone and Conglomerate	clay, sand, gravels										
	Santiago Sandstone, Siltstone, Claystone	clayey sand										
	San Onofre Breccia	silt, sand, gravels, cobbles										
Gobernadora			sand, silt, clay	supply limited	0.41	2,918	high	high	high	low	v. low	5 to 10
	Sespe Sandstone and Conglomerate	sand, silt, clay; minor gravels										
	Santiago Sandstone, Siltstone, Claystone	clayey sand										
Bell			cobbles, gravels, sand	transport limited	0.38	2,704	med	med	med	high	high	50 to 60
	Bedford Canyon Metamorphics	sand, silt, clay, pebbles										
	Starr Fanglomerate and Sandstone	silt with pebbles and cobbles										
	Santiago Sandstone, Siltstone, Claystone	clayey sand										
Upper San Juan			bedrock, gravels	supply limited	0.84	5,978	low	high	med	med	high	60 to 80
	granitic	sand or smaller w/ large boulders										
	meta-sedimentary	sand, silt, clay, pebbles										
	Santiago Peak Volcanic	angular pebbles and clay										
	Trabuco Conglomerate	sand, cobbles, boulders										
	Starr Fanglomerate and Sandstone	silt with pebbles and cobbles										
Verdugo			cobbles, gravels, sand, silt	transport limited	0.44	3,131	med	high	high	med	high	50 to 60
	Trabuco Conglomerate	sand, cobbles, boulders										
	Starr Fanglomerate and Sandstone	silt with pebbles and cobbles										

Table 10 (Continued)

Base Sediment Yields And Particle Size Distributions, San Juan Creek Watershed

							Particle Size Distribution					
							Suspended Load		Bedload			
Stream	**Major Geologic (Unit(s))**	**Weathers to [a]**	**Streambed Characteristics**	**Transport Characteristics**	**Base Sediment Yield Rate [b] (mm/year)**	**Base Sediment Yield Rate (tons/sq mi/year)**	**Clay/Silt**	**Sand**	**Sand**	**Gravel**	**Cobble**	**Percent Bedload**
TRAMPAS			sand, silt, clay (?)	supply limited			low	high	high	v. low	v. low	40 to 50
	Shultz Ranch Sandstone	sand and silt										
	Santiago Sandstone	sand and clay										
	Monterey Shale	silt and clay										
	San Onofre Breccia	silt, sand, gravels, cobbles										
LUCAS			cobbles, gravels, sand, silt	transport limited	0.44	3,131	low	med	low	high	high	50 to 60
	Trabuco Conglomerate	sand, cobbles, boulders										
	Starr Fanglomerate and Sandstone	silt with pebbles and cobbles										
	Shultz Ranch Sandstone	sand and silt										

[a] *Gravels are 2 to 64 mm. Pebbles are a subset of larger gravels (16 to 64 mm). Cobbles are 64 to 256 mm (2.5 to 10 inches). Boulders are larger.*

[b] *Sediment yield rates presented are based on Taylor (1981) and should be revised to reflect a more refined understanding of local conditions. Data are presented as calculated to allow replication; readers should be aware that these values should be read to no more than two significant figures.*

Source: Balance Hydrologics, 2000

Table 11

Base Sediment Yields and Particle Size Distributions, San Mateo Creek Watershed

							Particle Size Distribution					
							Suspended Load		Bedload			
	Stream	**Major Geologic (Unit(s))** [a]	**Weathers to**	**Streambed Characteristics**	**Base Sediment Yield Rate** [b] **(mm/year)**	**Base Sediment Yield Rate (tons/ mi.^{2}/year)**	**Clay/Silt**	**Sand**	**Sand**	**Gravel**	**Cobble**	**Percent Bedload**
Within Study Area	CRISTIANITOS	Santiago Sandstone, Siltstone, Claystone	clayey sand	sand, silt, clay,	0.48	3,416	high	high	high	low	low	40 to 50
Within Study Area	GABINO	Williams Sandstone, Conglomerate Shultz Ranch Sandstone Santiago Sandstone, Siltstone, Claystone	sand, silt, gravels sand and silt clayey sand	sand, silt, gravel, cobbles	0.42	2,989	med	med	med	med	med	50 to 60
Within Study Area	LA PAZ	Trabuco Conglomerate Williams Sandstone, Conglomerate Shultz Ranch Sandstone Santiago Sandstone, Siltstone, Claystone	gravels, cobbles, boulders, sand sand, silt, gravels sand and silt clayey sand	sand, silt, gravel, cobbles	0.42	2,989	med	med	med	med	low	50 to 70
Beyond Study Area	TALEGA	volcanics and meta-volcanics Williams Sandstone, Conglomerate Santiago Sandstone, Siltstone, Claystone Capistrano Siltstone, Sandstone	sand, silt, clay, gravels, cobbles sand, silt, gravels clayey sand clay, silt, sand		0.39	2,775	high	?	?	high	?	20 to 40
Beyond Study Area	DEVIL CANYON	granodiorite volcanics and meta-volcanics	sand or smaller with large boulders sand, silt, clay, gravels, cobbles	bedrock, gravel, sand	0.35	2,490	med	high	high	high	high	30 to 50
Beyond Study Area	LOWER SAN MATEO (south of confluence with Cristianitos)	mid-Miocene marine upper Miocene marine Pleistocene marine terrace	sand, silt, clay silt and clay sand, silt, clay; minor cobbles, gravels	sand, silt, cobble, gravel (sandiest near mouth)	0.35	2,490	high	high	low	low	v. low	20 to 40
Beyond Study Area	UPPER SAN MATEO	upper Cretaceous marine Santiago Sandstone, Siltstone, Claystone	sand, silt, clay clayey sand	bedrock, gravel, sand, silt	0.35	2,490	low	high	med	med	high	20 to 40

[a] *Taylor classified Devil Canyon and Upper San Mateo as "hills" rather than "mountains," which leads to an anomalously low base sediment yield. We have increased estimated denudation rates from 0.30 to 0.35 mm/yr.*

[b] *Sediment yield rates presented are based on Taylor (1981) and should be revised to reflect a more refined understanding of local conditions. Data are presented as calculated to allow replication; readers should be aware that these values should be read to no more than two significant figures.*

Source: Baseline Hydrologics, 2000

Table 12

Comparison of Sediment Yield Estimates

Watershed	County	Author	Dominant Substrate Type	Method	Time Period	Sediment Type (tons/ mi.^{2})	Comments
San Juan	Orange	Kroll & Porterfield	crystalline & sedimentary	rating curve applied to gauging record	1931-1968	1,230	based on measurements taken during 1967-1968
San Juan	Orange	Taylor	crystalline & sedimentary	calculated denudation rate	—	1,500 to 6,000	highest in mountainous areas, lower in foothills
San Juan	Orange	SLA	crystalline & sedimentary	LADB	—	4,350 to 6,850	indicated range is Q25 to Q50 with no burn
San Juan	Orange	SLA	crystalline & sedimentary	MUSLE	—	3,000 to 5,000	indicated range is Q25 to Q50
Arroyo Trabuco	Orange	SLA	crystalline & sedimentary	LADB	—	5,700 to 9,950	indicated range is Q25 to Q50 with no burn
Arroyo Trabuco	Orange	SLA	crystalline & sedimentary	MUSLE	—	3,000 to 5,500	indicated range is Q25 to Q50
San Diego	Orange	OCPFRD	crystalline & sedimentary	sampled sediment transport	1983-1998	1,800	suspended sediment only
San Diego	Orange	OCPFRD	crystalline & sedimentary	debris basin sediment removal	1983-1998	395	low trap efficiency

Source: Balance Hydrologics, 2000

3.5.2 Episodicity

In Central and Southern California, up to 98 percent of the amount of sediment moved in any single decade is often mobilized during one or two intense flow events (Knudsen et al., 1992), a conclusion that is supported by estimates of sediment discharge in Arroyo Trabuco and in San Juan Creek near San Juan Capistrano over a period extending from 1932 to 1968 (Kroll and Porterfield, 1969). The amount of sediment mobilized during an intense flow event is governed by available sources in the watershed, landform, and time since the last major fire.[17] Major sediment stores and expected fire frequencies are discussed below.

Rotational slumps, block glides, and soil slips have all been observed and mapped in different portions of the San Juan and San Mateo Creek watersheds. Residual bedrock landslide debris covers more than 3.7 $mi.^2$ within the San Juan Creek watershed alone, and it has been estimated that more than one billion tons of landslide debris are ready for transit down this drainage area during a major flood event (Vanoni et al., 1980).

Landslides cover more than one-third of the Cristianitos fault zone area, and composite slides as great as 630 acres are present. Although impressive in aerial extent and important from a geotechnical perspective, these large bedrock slides are likely geologically-old relict features thought to contribute less sediment to streams than do shallow failures on much steeper slopes.

West of the fault zone, the landscape is comprised mostly of low hills that terminate at a broad, wave cut terrace formed by marine erosion at the coastline. This area is not marked by extensive landslides because capping deposits help to protect the underlying bedrock, and stream erosion is not significantly active near the coast. Landslides in the hills between the coastal terrace and the Cristianitos fault are prevalent and consist mainly of bedrock failures that generally occur along the slopes of streams as discrete units or as aprons of coalescing slides. Although earth movement is common in these areas, localized slides probably do not contribute significantly to episodic sediment yields, unless they impinge directly into the channel, but rather contribute to baseline sediment yields.

East of the fault zone, landslides cover less than 1 percent of the area. More importantly, from the perspective of sediment yield, the area east of the fault zone has a propensity for the occurrence of mud-debris flows, notably in the Trabuco and Williams Formations. During periods of extended rainfall, such as during the 1969 floods, mud-debris flows emanating from the heads of steep canyons were commonplace (Morton, 1974). Failures occurred mostly in accumulations of slopewash or colluvial debris that lay somewhat perched high and at the heads of narrow, steep drainage channels above alluvial valleys. When these materials became saturated, they were

[17] *An estimated 70 percent of all sediment production in California's chaparral is triggered by fire (Wells, 1981).*

mobilized en masse. The steeper and straighter the channel, the farther the material flowed, picking up additional rock debris, mud, and vegetation in the process (Morton, 1974).

Factors that account for the estimated effects of fire on sediment yield are based on several studies that describe changing sediment rating curves and yields following large fires (for example, DeBano, 1998; Roberts et al., 1984; Hecht et al., 1983; Hecht, 1981; Glysson, 1977; Brown and Jackson, 1973). After reviewing the available field evidence, we conclude that post-fire sediment yields from the subwatersheds of the SAMP/MSAA area may be best predicted from base rates of sediment transport by using multipliers of 10, 7, 4, 2, 1.5, and 1 for the first through sixth winter following the fire. For watersheds of 2 to 20 mi.^{2}, multipliers of 12, 7, 3, 1.5, and 1 times the base rate may be used to estimate sediment yields during the first five winters following the fire. These factors assume that the burn periphery covers 100 percent of the watershed, although (as is typical) large areas of unburned vegetation remain on north and east facing slopes or adjoining the riparian zones. For watersheds smaller than 2 mi.^{2}, a briefer and more extreme set of multipliers might be used, such as 15, 5, 1.5, and 1, with base rates of sediment yield resuming after 3 to 4 years; existing research, however, is probably not sufficient to support any particular set of multipliers.[18]

3.5.3 In-Channel Sediment Transport

Peak sediment transport rates were calculated using the SAM model[19] for each major sub-basin in the study area for the 2-year, 10-year, and 100-year discharge events. Peak transport rates per unit area were also calculated for each of the sub-basins. The Laursen-Madden transport function was used to generate sediment transport rates for general comparison purposes and for use in the alternatives analysis. This transport function has been shown to be a reliable estimate of sediment transport across basins of various substrate types. Technical Appendix A provides a discussion of the validity of using this transport function as well as a detailed comparison and sensitivity analysis of the various sediment transport functions. It should be noted that these rates represent the capacity for the system to transport sediment and may not describe actual sediment transport rates. Actual sediment transport is determined by both transport capacity and sediment supply (see terrains discussion above).

[18] *Watersheds smaller than 2 mi.^{2} (1,280 acres) may not have sufficient alluvial development to develop a consistent sediment rating curve. Hence, these factors should be used only for comparisons of alternatives and other planning applications, not for design. The approximation given in the text is most valid for the larger small watersheds and least valid for those smaller than a mi.^{2}.*

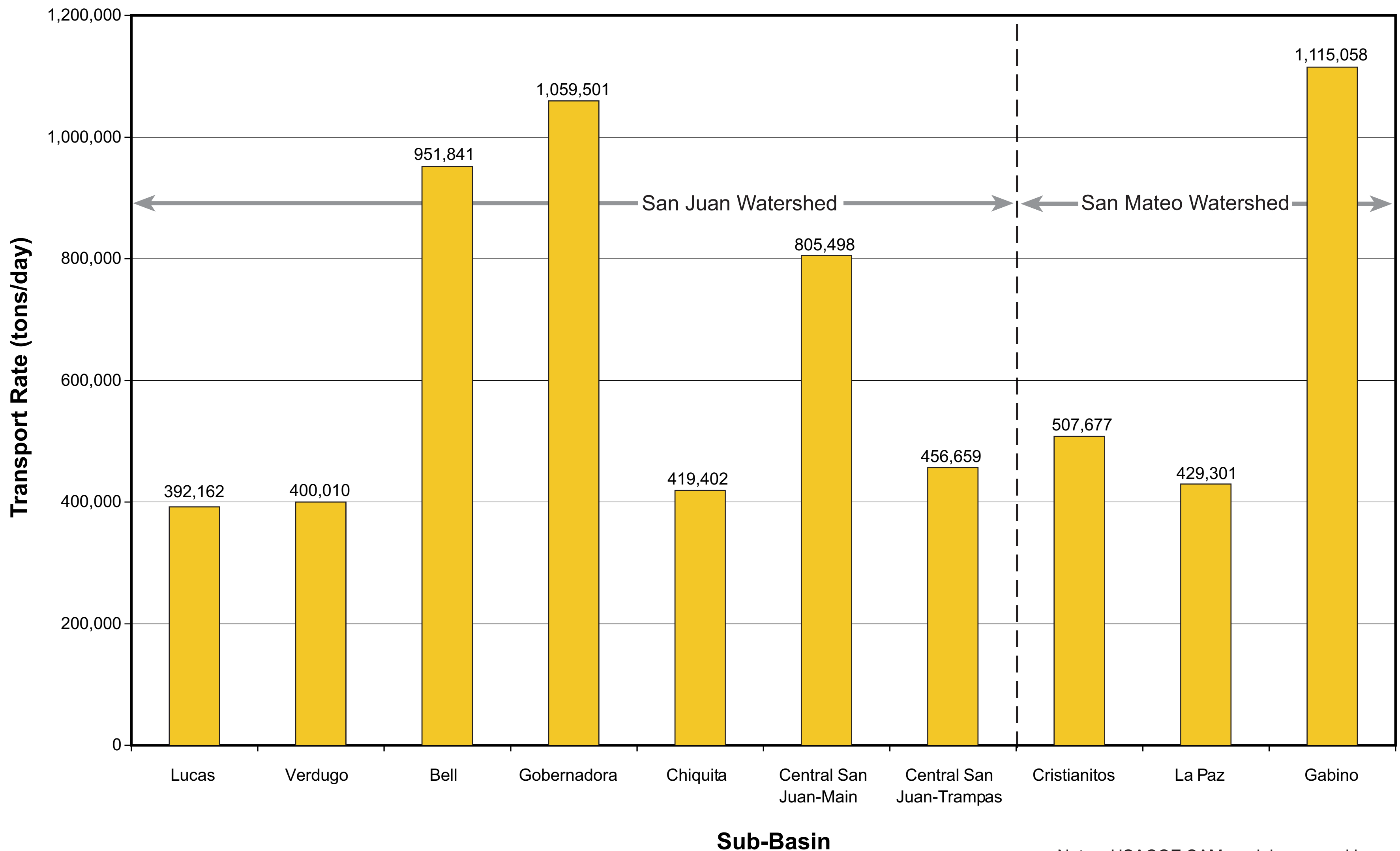
[19] *The Laursen-Madden (LM), Laursen-Copeland (LC), and Engelund-Hansen (EH) sediment transport functions were used within the SAM application. In general, the Laursen-Madden (LM) function is most suitable for sand and gravel bed streams and is a general all purpose function suitable for comparison across basins with various substrate types.*

3.5.3.1 San Juan Watershed

Absolute peak sediment transport capacities for each major sub-basin during the 100-year flow event are compared in Figure 22 on page 72. Transport rates are given at the most downstream end of each sub-basin. For the Laursen-Madden transport function, Cañada Gobernadora and Bell Canyon had the highest absolute sediment transport rates in the San Juan watershed. This result is likely explained by the relatively large size of these two canyons (11.08 $mi.^2$ and 20.57 $mi.^2$ respectively), although Cañada Gobernadora also has a relatively high transport capacity per unit area (see Figure 23 on page 73). After Bell Canyon and Cañada Gobernadora, the main stem of the Central San Juan Creek sub-basin had the next highest absolute sediment transport rate. Peak transport rates from Lucas Canyon were the lowest of the San Juan Creek watershed sub-basins.

Transport rates per unit area at the most downstream reach of each sub-basin for a 100-year flow event are shown in Figure 23 on page 73. Since these rates are independent of sub-basin size, they reflect sediment shedding properties, integrating factors of channel geometry, runoff rates, and geology. For the Laursen-Madden transport function, Trampas Canyon had the highest transport rates per unit area of any of the studied sub-basins entering San Juan Creek. Cañada Gobernadora, Verdugo Canyon, and Lucas Canyon had the next highest transport capacities per unit area. Transport rates per unit area are likely highest for Trampas Canyon, due to steep channel slopes at the basin mouth, transportable sediment sizes, and a small drainage area. In many ways, Trampas Canyon is different from the other studied sub-basins, which are larger canyon systems that occupy broader valleys. Trampas Canyon is more representative of the steeper headwater systems of the San Juan watershed where sediment yields are much higher. Conversely, sediment yields per unit area for the main San Juan channel are the lowest. More detailed sediment transport results for each sub-basin are presented in Section 6 and in Technical Appendix A.

Calculated sediment yields for the 2-year, 10-year, and 100-year storm events are shown in Figure 24 on page 74. These results essentially represent the potential volume of sediment delivered to the main stem of San Juan Creek from each of the tributary sub-basins during various magnitude storm events. In general, average annual measures of sediment yield estimated by Balance Hydrologics (see Table 12 on page 68) are consistent with the absolute transport rates for a 2-year storm event estimated by PWA. Bell Canyon exhibited the highest sediment yield to San Juan Creek. This is not surprising, since Bell is the largest of the sub-basins and produced relatively high transport rates. The main stem of the Central San Juan sub-basin, Gobernadora, Trampas, and Lucas Canyons also produced relatively high yields. Cañada Chiquita produced the lowest yields of the San Juan watershed sub-basins. Figure 25 on page 75 shows sediment yields per unit area. Trampas Canyon has the highest yields per area. This is consistent with the results for transport rates described above for this steep, small tributary catchment. Of the studied canyon sub-basins, Verdugo Canyon had the highest yield per unit area.

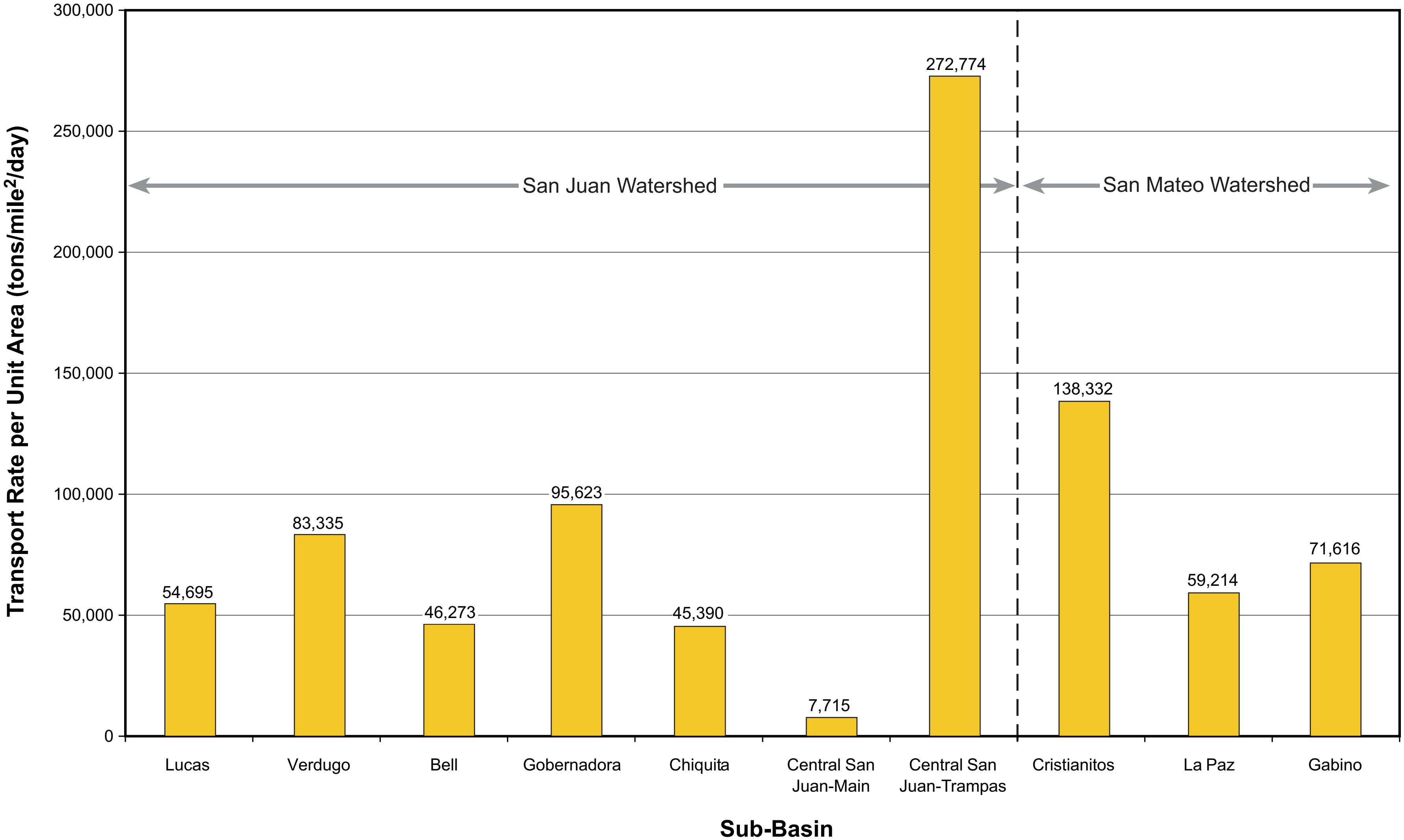


Source: PWA, 2000

Notes: USACOE SAM model was used in analysis based on Laursen (Madden) transport function.

PCR PWA Balance Hydrologics, Inc.

Figure 22
Baseline Conditions Report
Peak 100-Year Sediment Transport Rates for San Juan and San Mateo Watersheds

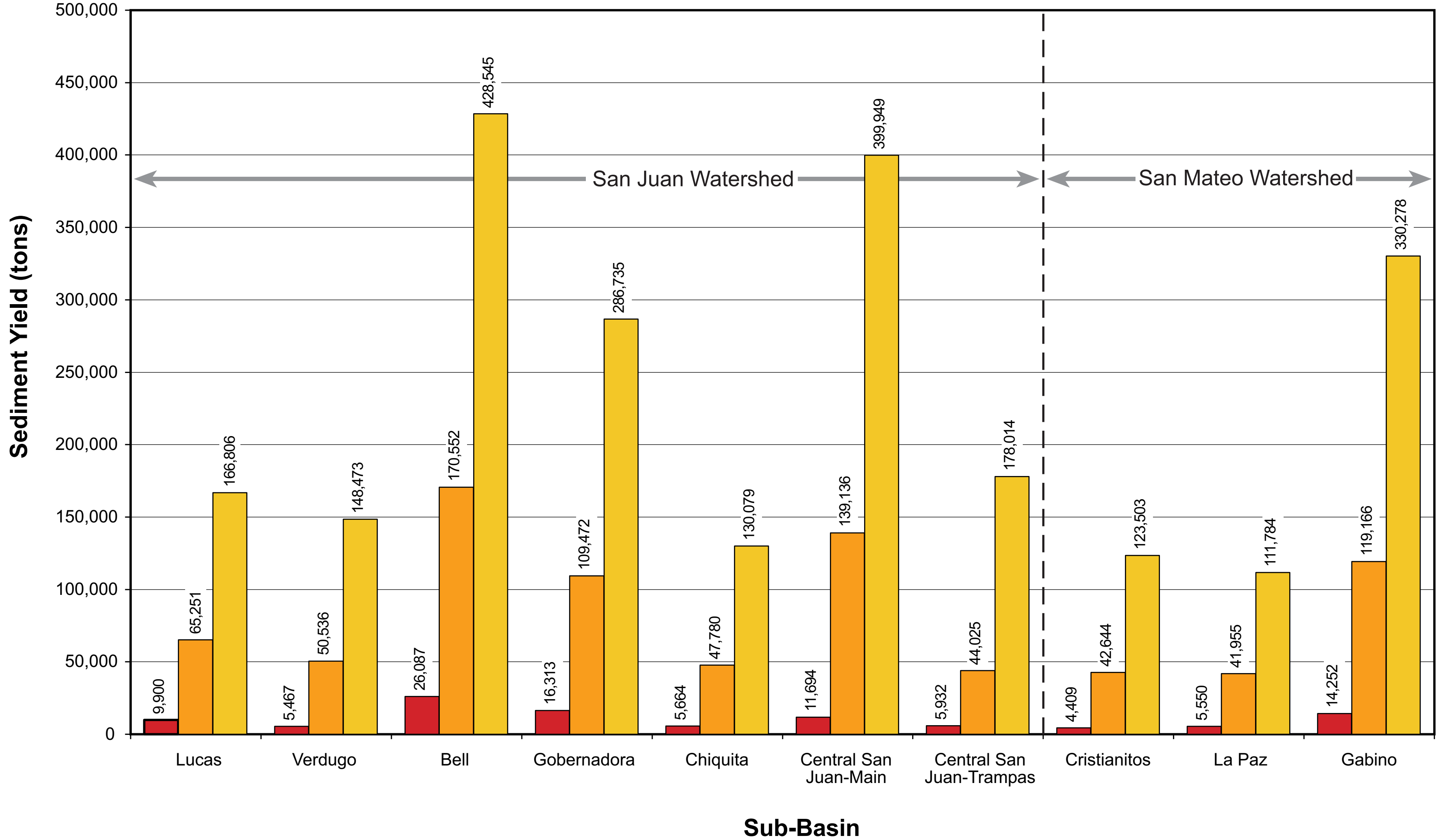


Source: PWA, 2000

Notes: USACOE SAM model was used in analysis based on Laursen (Madden) transport function.

PCR PWA Balance Hydrologics, Inc.

Figure 23
Baseline Conditions Report
Peak 100-Year Sediment Transport Rate per Unit Area for San Juan and San Mateo Watersheds



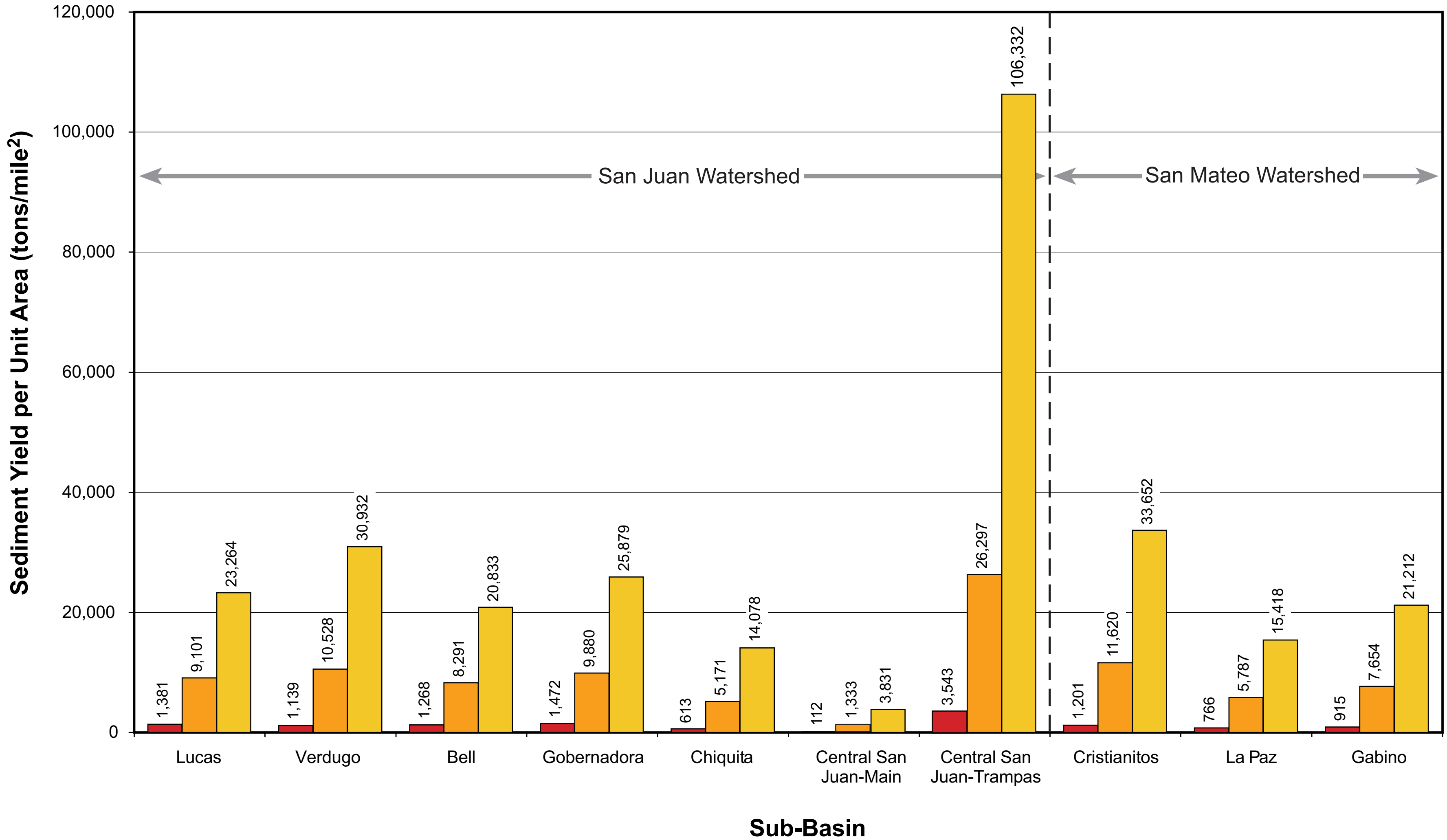
Source: PWA, 2000

2-Year 10-Year 100-Year

Notes: USACOE SAM model was used in analysis based on Laursen (Madden) transport function.

PCR PWA Balance Hydrologics, Inc.

Figure 24
Baseline Conditions Report
Sediment Yield for
2-Year, 10-Year, and 100-Year Discharges



Source: PWA, 2000

Notes: USACOE SAM model was used in analysis based on Laursen (Madden) transport function.

PCR PWA Balance Hydrologics, Inc.

Figure 25
Baseline Conditions Report
Sediment Yield per Unit Area for 2-Year, 10-Year, and 100-Year Discharges

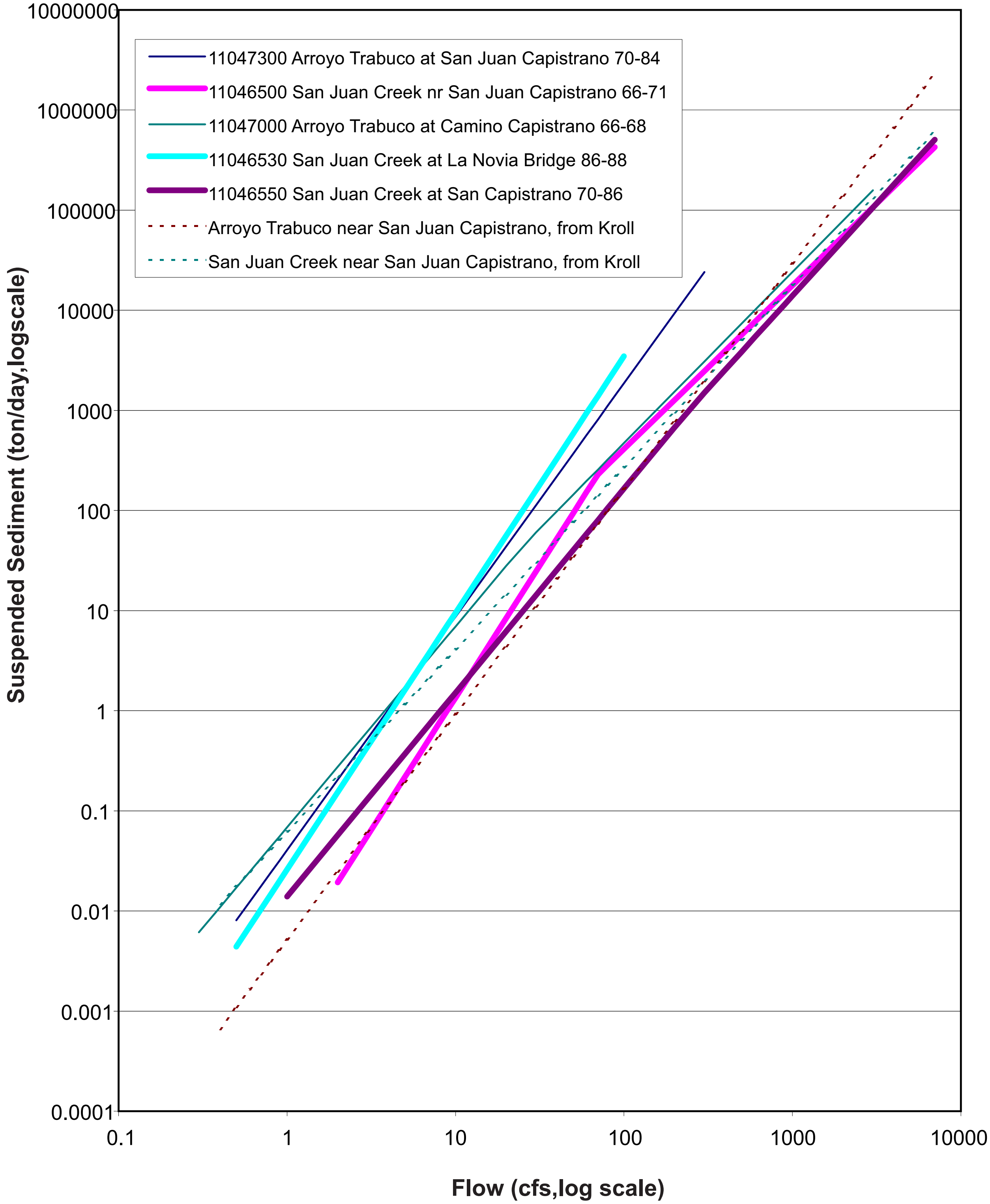
Based on the in-channel yield results, sediment mass balances were calculated for the four modeled reaches of the main stem of San Juan Creek to assess if the reaches were erosional or depositional. Upstream sediment input to San Juan Creek, from the upper watershed above Lucas Canyon, was estimated using results from BH. Although the magnitude of results varies somewhat for the two sediment transport functions (i.e., Laursen-Madden and Laursen-Copeland), both functions indicate a general pattern of deposition in three of the four modeled reaches during large flood events. The most downstream reach was predicted to be slightly erosional during extreme flood events. The delivery of sediment from the canyon sub-basins to the main San Juan Creek channel likely plays a significant role in this depositional pattern observed in the three upstream reaches.

3.5.3.2 San Mateo Watershed

In the San Mateo Creek watershed, Gabino Canyon (upstream of the Cristianitos Creek confluence) was calculated to have the highest sediment transport capacity (see Figure 22 on page 72). This absolute rate is the highest of all modeled sub-basins in the San Juan and San Mateo watersheds and is similar in magnitude to rates calculated for Gobernadora and Bell Canyons in the San Juan watershed. Transport rates calculated for La Paz and Cristianitos Canyons are the lowest in of the modeled San Mateo sub-basins and are similar to values calculated for Lucas and Verdugo canyons. The Upper Cristianitos sub-basin (3.67 mi.^{2}) had the highest transport capacity per unit area of the three modeled San Mateo sub-basins (see Figure 23 on page 73). The basin's per unit area transport rate surpasses rates calculated for all other sub-basins except Trampas Canyon. This implies that the hydrology, geology, and geomorphology of Upper Cristianitos Creek are conducive to transporting sediment. The transport capacity per unit area of Gabino Canyon is intermediate between estimated rates for La Paz and Cristianitos Canyons. Of the modeled sub-basins in the San Mateo Creek watershed, La Paz Canyon had the lowest transport rates per unit, only slightly higher than those for Lucas Canyon.

Calculated sediment yields at the mouth of the sub-basins for the 2-year, 10-year, and 100-year storm events are shown in Figure 24 on page 74. This figure illustrates that the Gabino Canyon sub-basin exhibits the highest sediment yield of the three San Mateo sub-basins. This is most likely due to the somewhat larger size of Gabino Canyon, relative to the Upper Cristianitos and La Paz sub-basins. Although the Upper Cristianitos sub-basin is half the size of the La Paz sub-basin, its relatively high rate of sediment transport per unit area (see Figure 23 on page 73) resulted in total sediment yields that were slightly higher than those from the La Paz sub-basin for the 10-year and 100-year events.

Figure 26 on page 77 shows the sediment rating curves developed for several streams of the San Juan and San Mateo watersheds. In comparing yield figures or sediment rating curves for different basins, it is important to keep in mind differences between the basins in the primary factors



Source: Balance Hydrologics, Inc., 2000

PCR PWA Balance Hydrologics, Inc.

Figure 26
Baseline Conditions Report
Suspended Sediment Rating Curve for Streams of the San Juan and San Mateo Watersheds

that affect sediment yields and transport, including precipitation regime, geology and soils, relief, bank and bed stability, drainage area, type of stream (i.e., alluvial or bedrock), tectonic setting, and fire and land use history of the basin. Of particular interest are subwatersheds underlain by Monterey shale, which have steeply sloping sediment rating curves. This diatomaceous, chalky rock weathers quickly and yields high quantities of sediments at all flows. Very little sand is produced from this geologic type. In contrast, the crystalline bedrock sediment yield is highly episodic. At most flows it will produce few sediments, however, at extremely high flows and/or after fires it yields high quantities of sediments. In general, suspended sediment discharge in San Mateo Creek is generally less than in San Juan Creek for all measured flows. One factor that may contribute to the lower suspended sediment discharge in San Mateo Creek is the absence of Monterey shale in the drainage geology. This diatomaceous rock that underlies 10 percent of the drainage area in San Juan Creek is known to yield high quantities of sediment as it weathers. Another factor contributing to the lower rate of suspended sediment transport in San Mateo is the smaller drainage area size.

3.6 WATER QUALITY

Pollutant pathways and cycles within settings as diverse as the San Juan and San Mateo Creek watersheds can be complex. Constituents of concern in these watersheds include temperature, turbidity, nutrients (primarily nitrogen and phosphorus), metals, and pesticides (primarily diazanon and chloropyrofos). Although the biogeochemical relationships that govern the fate of different constituents can be complicated, it is important to note that a number of generalizations are possible regarding the effect of the environmental setting and the terrains on water quality. These generalizations, if applied in the proper context, can provide a framework within which to understand monitoring data and to develop strategies for water quality management.

In general, pollutants are transported and sometimes transformed into other compounds with storm water runoff. They are either in dissolved form, particulate form, or are adsorbed to other particles in the water (clays, colloids, etc.). The availability of particulates and pH affect the distribution of pollutants between dissolved and bound forms. Therefore, land use characteristics that promote infiltration and slow the flow of water allowing sediments to settle or filter out are the main factors that control pollutant mobility.

Geology can also have a direct impact on specific water quality constituent concentrations. For example, the Monterey shale bedrock, which occurs in several of the San Juan Creek sub-basins, has been reported to be a source of high levels of phosphate (Dickert, 1966) and certain metals, such as cadmium (Majmundar, 1980).

Terrains can influence the mobilization, loading, and cycling of pollutants. Some general water quality characteristics of the major terrains in the study area are:

- **Sandy terrains**. Sandy terrains generally favor infiltration of rainfall and therefore have the potential to direct pollutants mobilized in low to moderate rainfall events into sub-surface pathways, with little or no actual biogeochemical cycling taking place in surface waters. Sequestered in sands, pollutants have the opportunity to degrade and attenuate via contact with soils and plants in the root/vadose zones before passage to groundwater or mobilization and transport to surface waters during larger storm events.

- **Silty terrains**. Silty terrains are characterized by higher runoff rates and tend to favor surface water pathways more than sandy terrains (but less than clayey terrains). Silty substrates can also be a significant source of turbidity (i.e., fine sediments). Conversely, the finer sediments derived from the silty substrates promote the transport of metals and certain pesticides in particulate form. This makes them less-readily available in first and second-order stream reaches, but potentially allows transport to higher order streams and subsequent deposition over long distances.

- **Clayey terrains**. Clayey terrains are characterized by very high rates of surface runoff during low and moderate storm events. Although clay soils are generally quite resistant to erosion, they can be very significant sources of turbidity during extreme rainfall events when erosion occurs and/or headcutting or incision within the streambed begins.

- **Crystalline terrains**. Crystalline terrains are common only in the uppermost reaches of the San Juan and San Mateo Creek systems where development and agricultural activities are absent. Similar to clayey terrains and in contrast to sandy terrains, during low to moderate rainfall events, primary pollutant pathways will be in surface water flow, leading to the potential for rapid mobilization and transport of constituents. Unlike clayey terrains, however, the crystalline substrates may be relatively poor in the finer particles that cause turbidity. Like all terrain types, extreme events will likely result in the mobilization and transport of all sizes of sediments from these areas.

3.6.1 Analysis of Existing Water Quality Data for the San Juan Watershed

Orange County has collected a significant amount of water quality data for San Juan Creek since the 1950s.[20] The bulk of recent water quality monitoring data in the San Juan Creek watershed was collected by the Orange County PFRD in the 1990's at three sampling points that allow for a generalized comparison among land use and terrain types. The sampling points are: (a) the main stem of San Juan Creek at La Novia bridge in San Juan Capistrano has a large drainage area that includes all terrain types and contains diverse land uses; (b) the main stem of San Juan Creek at Caspers Regional Park (approximately 10 miles upstream of San Juan Capitstrano) represents runoff

[20] *Concurrent discharge measurements were not taken at the time of sampling for much of the data, creating some limitations on its use.*

from primarily open space coastal scrub and chaparral on crystalline terrains; and (c) the Oso Creek sample location represents mostly urban land uses on clayey terrains.

The data for the key nutrients (nitrate, ammonia, and phosphate) monitored by Orange County is summarized in Table 13 on page 81. This table includes statistical summaries for the measured concentrations of these nutrients as a function of the 3-day antecedent rainfall measured at the Tustin rain gauge.[21] It is important to note that the measured nutrient concentrations, especially during dry periods, were at or below the detection limit for one of more of these constituents. In this case, the detection limit values were used in the statistical summaries. For this reason, any conclusions about absolute nutrient concentrations at low levels should be considered tentative. The disaggregation of the data was carried out in an effort to identify patterns of nutrient mobility as a function of rainfall, which is generally considered the primary mobilizing event within any low-elevation watershed that is not influenced by snow-melt runoff.

3.6.1.1 Nitrates and Phosphates

Several observations can be made on the basis of this data, as well as the historical data which is included in Appendix B:

- The data suggest that there are one or more significant sources of nitrogen loading between the Caspers and La Novia monitoring stations. It is not possible with the available data to ascertain the sources of the additional loading, but it may include factors such as the location of several nursery operations downstream of the Caspers site, development on San Juan tributaries (e.g., Coto de Caza on Cañada Gobernadora), and

[21] *Rainfall data from the Tustin gauge was chosen due to the completeness of the data and the relative proximity of the gauge to the watershed. The gauge is operated by the Orange County PFRD and is located northwest of the water quality stations on San Juan and Oso Creeks. Additionally, the gauge is located at an elevation (and, thus, mean annual rainfall) similar to the monitored watersheds. It is reasonable to assume that storm patterns and relative intensities observed at Tustin will be generally representative of conditions within the San Juan, Arroyo Trabuco, and Oso Creek sub-watersheds. Additional insight could be gained with precipitation data collected, and especially stream discharge data, collected within these basins.*

Table 13

Summary Of Water Quality Data Measured by the Orange County Public Facilities and Resources Department as Function of Antecedent Rainfall, WY 1991 To WY 1999

3-Day Rainfall [a]	Caspers Regional Park # of Samples	Caspers Regional Park Mean	Caspers Regional Park Median	La Novia # of Samples	La Novia Mean	La Novia Median	Oso Creek/Mission Viejo # of Samples	Oso Creek/Mission Viejo Mean	Oso Creek/Mission Viejo Median
Nitrate Concentrations (mg/l NO_3 as N)									
0.00	32	0.1	0.1	43	0.3	0.2	10	0.9	1.0
0.01-0.50	10	0.2	0.1	21	0.5	0.5	23	1.2	1.3
0.51-1.00	6	0.9	0.1	15	1.2	1.2	15	1.2	1.2
1.00-1.50	1	0.7	0.7	7	1.5	1.7	15	1.4	1.3
>1.50	0	n.d.	n.d.	5	0.4	0.4	18	1.0	0.8
Ammonia Concentrations (mg/l NH_3 as N)									
0.00	31	0.1	0.1	42	0.1	0.1	10	0.9	1.0
0.01-0.50	9	0.4	0.1	20	0.1	0.1	23	1.2	1.3
0.51-1.00	5	2.5	0.5	14	0.1	0.1	15	1.2	1.2
1.00-1.50	1	0.5	0.5	7	0.3	0.6	15	1.4	1.3
>1.50	0	n.d.	n.d.	5	0.1	0.1	18	1.0	0.8
Phosphate Concentrations mg/l PO_4 as P)									
0.00	31	0.1	0.1	43	0.1	0.1	10	0.7	0.6
0.01-0.50	9	0.4	0.1	21	0.2	0.2	23	0.4	0.3
0.51-1.00	5	3.4	3.6	15	0.6	0.4	15	0.7	0.5
1.00-1.50	1	1.0	1.0	7	0.7	0.7	15	0.7	0.6
>1.50	0	n.d.	n.d.	5	0.5	0.5	18	1.0	0.5
Zinc Concentrations (Total Zn mg/l)									
0.00	11	23	22	12	28	16	10	68	63
0.01-0.50	9	77	23	17	52	20	23	61	49
0.51-1.00	7	87	100	18	48	32	15	87	92
1.00-1.50	1	38	38	7	51	43	14	135	58
>1.50	0	n.d.	n.d.	5	30	24	18	58	54

[a] *Sum of three-day rainfall in inches as measured at the Orange County PFRD gauge in Tustin.*

n.d. = *no data*

Source: Balance Hydrologics, 2000

the large amount of grassland in the sub-basins below Caspers.[22] There is insufficient reliable data to determine whether a similar situation exists with regard to phosphate loadings between the two sites.

Figure 27, Part A on page 83 illustrates the relationship between measured nitrate concentrations at La Novia and 3-day antecedent rainfall. There are strong indications that nitrate is introduced into the lower San Juan Creek system by a mechanism that generally increases proportionally with precipitation up to 1.50 inches of 3-day rainfall. Regression analysis of the relationship between nitrate concentrations and 3-day antecedent rainfall up to 1.50 inches yielded an r-squared value of 0.42. Given the natural variability in the data and the small sample size, this correlation is considered meaningful. This relationship can be further examined by plotting the sampled nitrate concentrations as a function of mean daily discharge as measured at the USGS gauge (see Figure 27, Part B on page 83). The latter figure gives a better indication of the relative saturation of the watershed at the time of sampling. The data are consistent with N mobilization either through direct transport by surface storm water runoff or by the displacement of nitrate-rich groundwater into the stream system. The cluster of points at higher discharge rates likely represents the baseline nitrate loading associated with rainfall, since most rainfall would be running off under these saturated watershed conditions and nitrate assimilation by the biota would be relatively insignificant.[23]

- The monitoring results for phosphate at La Novia indicate that there is a tendency to higher phosphate levels with increases in both 3-day antecedent rainfall and discharge. These relationships are presented graphically in Figure 28, Parts A and B on page 84. The r-squared value for the relationship between phosphate concentrations and 3-day antecedent rainfall is 0.28. This weak correlation likely results from differences in the point during the season in which samples were collected. Because phosphate is typically transported in the bound form with particulates, the amount of seasonal rainfall (and runoff) that occurred prior to the sampling affects phosphate concentration by affecting the amount of sediment mobilization. Nevertheless, the apparent relationship between phosphate and rainfall/discharge is consistent with erosion being the primary contributor of phosphorus loading. Unfortunately, not enough samples were collected at Caspers to ascertain whether this observation applies to the watershed as a whole or only to that portion below Bell Canyon.

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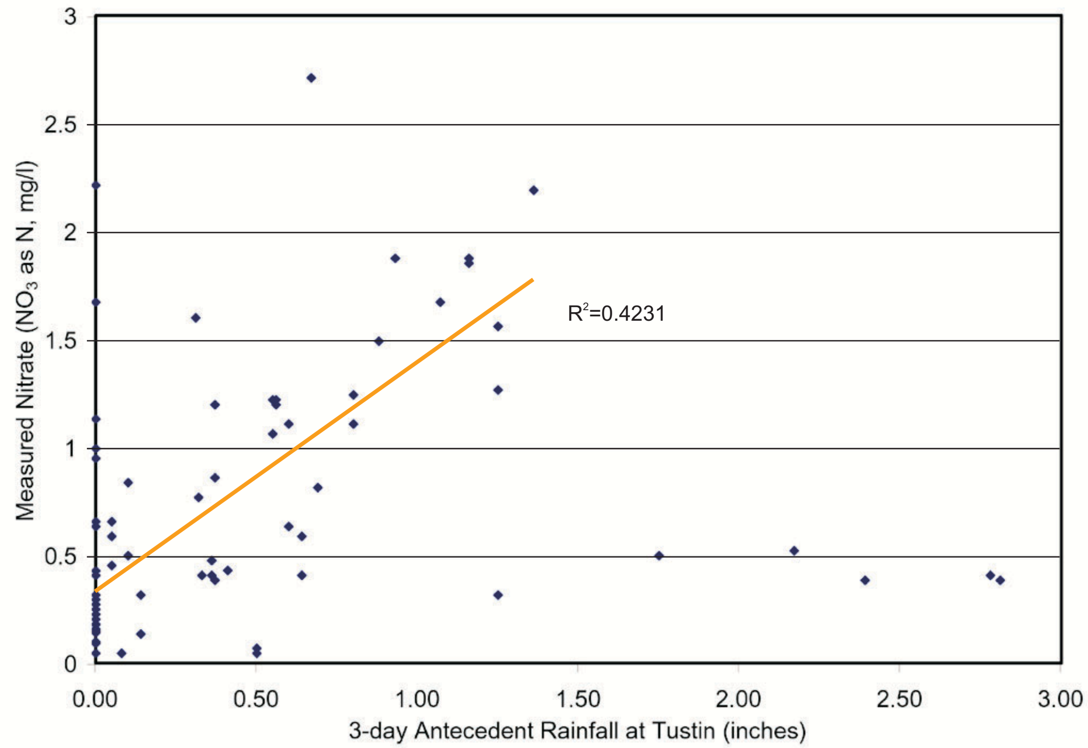
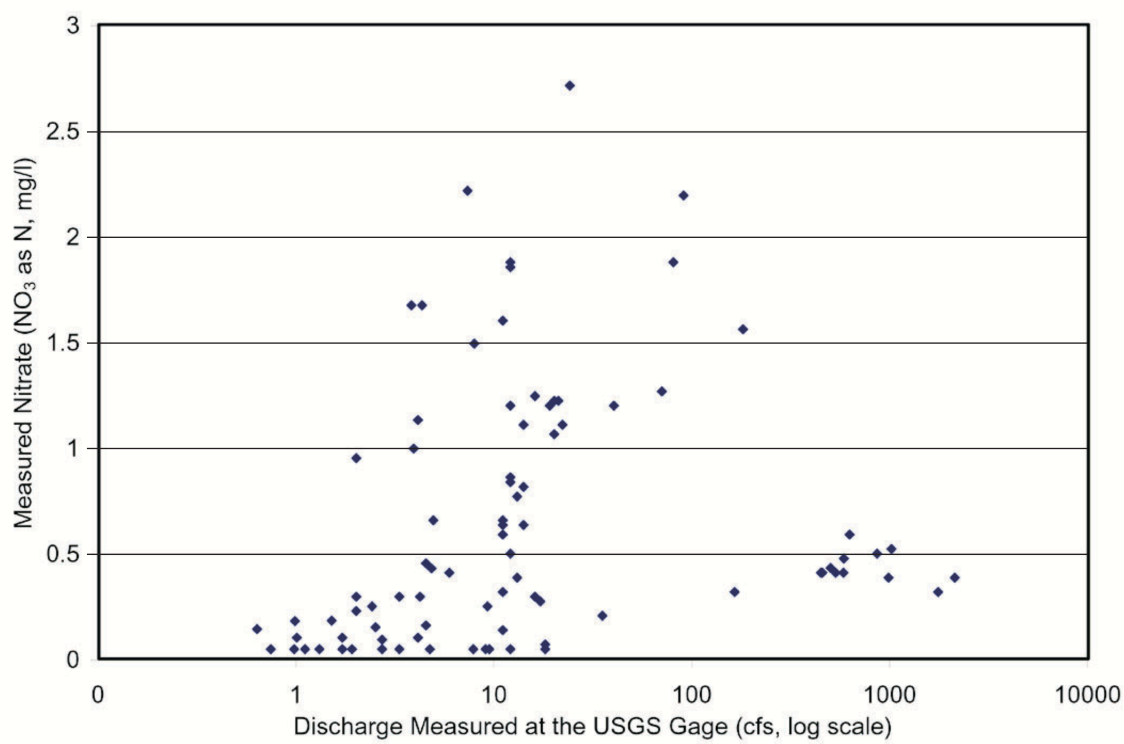
[22] Grasslands (both native and non-native) have been shown to contribute relatively high loadings of nitrogen in studies carried out in several locations. One obvious potential contributing factor is the fact that grasslands are ideal for livestock grazing with the associated potential for N mobilization from animal wastes. Additionally, grassland soils are typically roughly 4 to 5 percent nitrogen by weight, and this N is available to rainfall passing over or through these soils.

[23] A background nitrate concentration of 0.4 mg/L in rainfall would be consistent with studies in other locations in the nation. For example, Betson (1978) measured a nitrate plus nitrite concentration of 0.47 mg/L in rainfall at Knoxville, Tennessee.



Part A: Nitrate Concentrations vs. Antecedent Rainfall

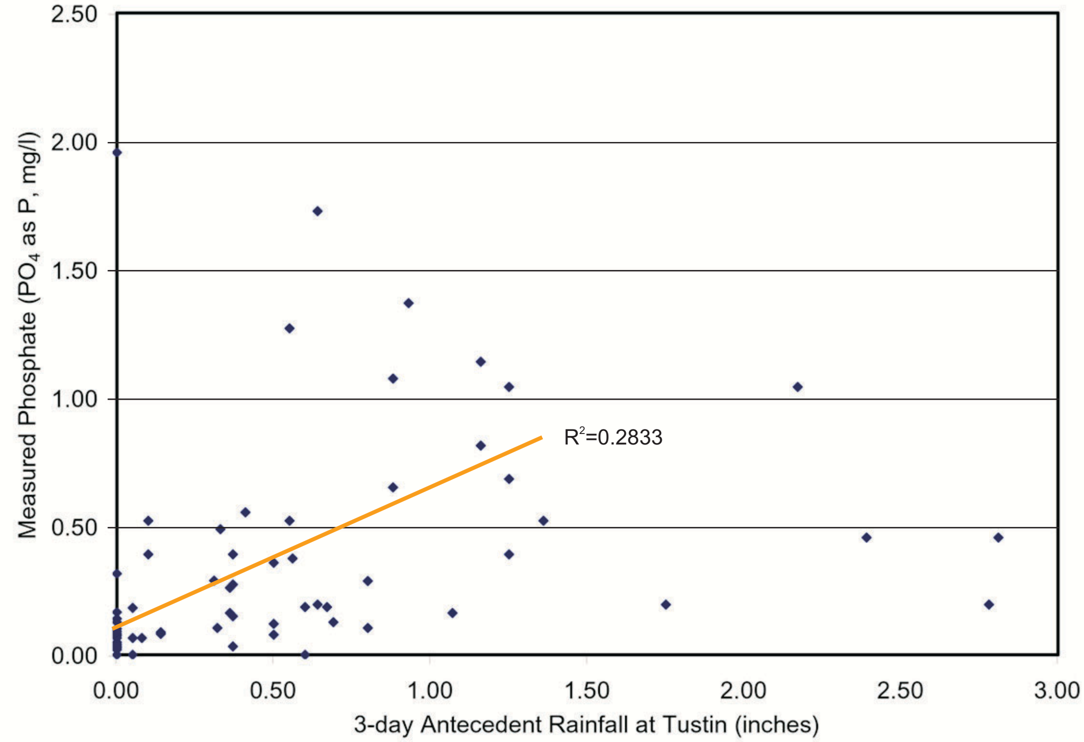


Part B: Nitrate Concentrations vs. Discharge

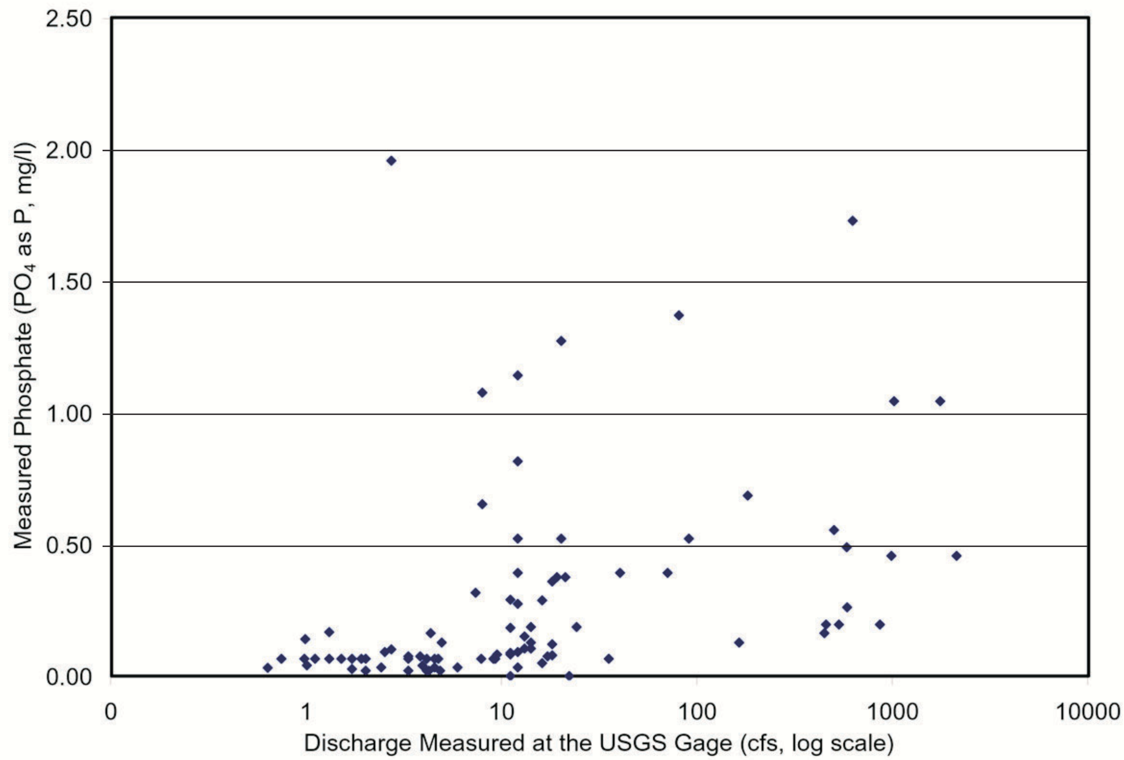
Source: Balance Hydrologics, Inc., 2000

PCR PWA Balance Hydrologics, Inc.

Figure 27
Baseline Conditions Report
Nitrate Concentrations for
San Juan Creek at La Novia



Part A: Phosphate Concentrations vs. Antecedent Rainfall



Part B: Phosphate Concentrations vs. Discharge

Source: Balance Hydrologics, Inc., 2000

PCR PWA Balance Hydrologics, Inc.

Figure 28
Baseline Conditions Report
Phosphate Concentrations for
San Juan Creek at La Novia

- It is possible that channel incision can be a contributing factor to both nitrogen and phosphorus loading in the San Juan system. The link between channel incision and phosphorus loading is relatively straightforward: Erosion of channel and floodplain terrace material can release significant quantities of stored phosphates. The link to nitrogen loading may be less readily apparent and centers around the potential for changes to groundwater inflows to stream reaches as the channel bed degrades. Deeper groundwater is often enriched in nitrate. As a stream incises, it dewaters adjacent aquifers from progressively greater depths thereby increasing the nitrogen loading in the surface waters under baseflow conditions,

The ratio of available nitrogen to available phosphorus within a water body often has an important regulating effect on the growth of aquatic plants and animals.[24] The monitoring data support the contention that these systems are generally nitrogen limited (i.e., N/P ratio < 10)[25]. One notable exception is found for San Juan Creek at La Novia.

Figure 29 on page 86 illustrates the N/P ratio at this monitoring location as a function of discharge. In this case, it appears that the San Juan system is nitrogen limited at both very low and very high flow rates. Intermediate flow rates correspond with the period when the nitrate concentrations have increased (with increasing rainfall as discussed above) but phosphate levels have yet to increase significantly. Once discharge increases, with the associated general tendency to increase phosphate levels, nitrogen once again becomes the limiting nutrient. Interestingly, even though the overall Nitrogen values in the more urbanized Oso Creek sub-watershed are higher, phosphate levels are still high enough to lead to nitrogen limitation.

3.6.1.2 Zinc

Monitoring carried out by the Orange County PFRD in the 1990s in San Juan Creek included analysis of several metals: cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), silver (Ag), and zinc (Zn). The results are reported in Appendix B.[26] In waters with typical pH levels of 7 to 8, as found in San Juan Creek, metals are most likely to be found in their particulate phase. Therefore, one can assume that the more bio-available dissolved fraction will have a much

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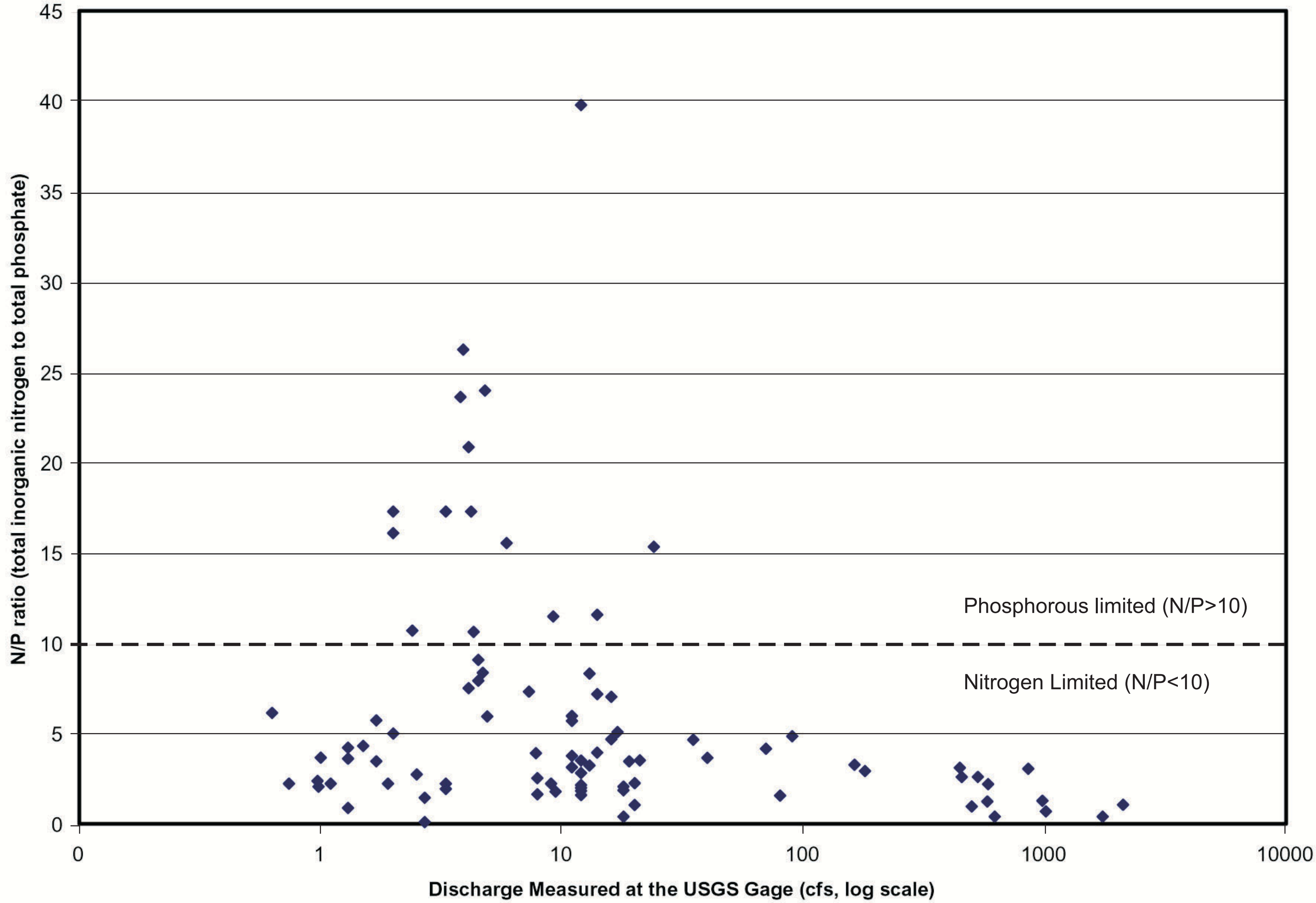
[24] Aquatic organisms, such as algae, require carbon, nitrogen, and phosphorus to fuel their basic metabolic processes. If one of these elements is present at low concentrations in the environment, it may become a limiting factor in their growth. The nitrogen/phosphorus ratio (N/P) is often used to indicate which element is limiting, with ratios below 10 indicating that nitrogen is limiting and ratios above 10 indicating that phosphorus is limiting.

[25] It should be noted that the threshold of N/P < 10 is generalized from a wide range of aquatic systems. The actual level in the SAMP watersheds may vary with location, time of year and particular species being considered.

[26] The analyses were primarily conducted on unfiltered samples, meaning that the reported values represent the total metal concentration that includes both the dissolved and particulate fractions.



Source: Balance Hydrologics, Inc., 2000

PCR PWA Balance Hydrologics, Inc.

Figure 29
Baseline Conditions Report
Nitrogen/Phosphorous Ratios vs. Discharge
for San Juan Creek at La Novia

lower concentration. Because metals are typically found in their particulate form and are, therefore, transported in the same manner as sediments, it is unlikely that significant metal transport will occur during dry weather, as the majority of sediment transport occurs during storm events. An initial examination of the San Juan Creek monitoring data shows that, with the notable exception of zinc, most metals are found in concentrations below the detection limit. The zinc data are summarized in Table 13 on page 81 and Figure 30 on page 88. Several observations can be made on the basis of this data:

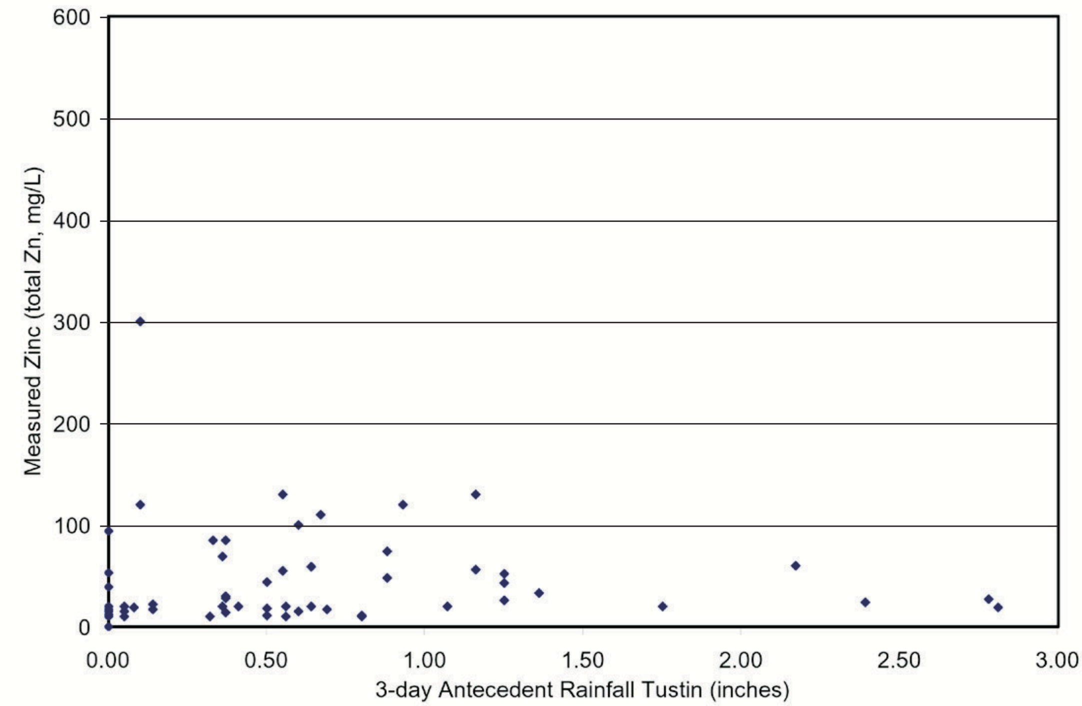
- The data do not indicate a significant difference in zinc concentrations between the Caspers and La Novia monitoring stations. This suggests that equivalent zinc sources are found both upstream and downstream of the Caspers site. Such sources likely include galvanized metal products (e.g., steel culverts), automobile tire wear, roof drainage, and natural mineral weathering.

- Zinc mobility with rainfall. The relationship between measured zinc concentrations and 3-day antecedent rainfall suggest that zinc concentrations increase with increasing rainfall until approximately 1 inch of 3-day cumulative antecedent rainfall is reached, at which point zinc concentrations begin to decrease (see Figure 30, Part A on page 88). This response is further illustrated the relationship between measured zinc concentrations and daily flow, which shows that the highest levels of zinc occur at flows between 10 and 100 cfs (see Figure 30, Part B on page 88). This pattern can be explained by a background loading of zinc, as seen at low flows. As discharge increases, sediments are mobilized and transported downstream with the associated particulate metals. At the highest flows, zinc concentrations decrease as a result of dilution from rainwater and removal of contaminated sediments from the system.

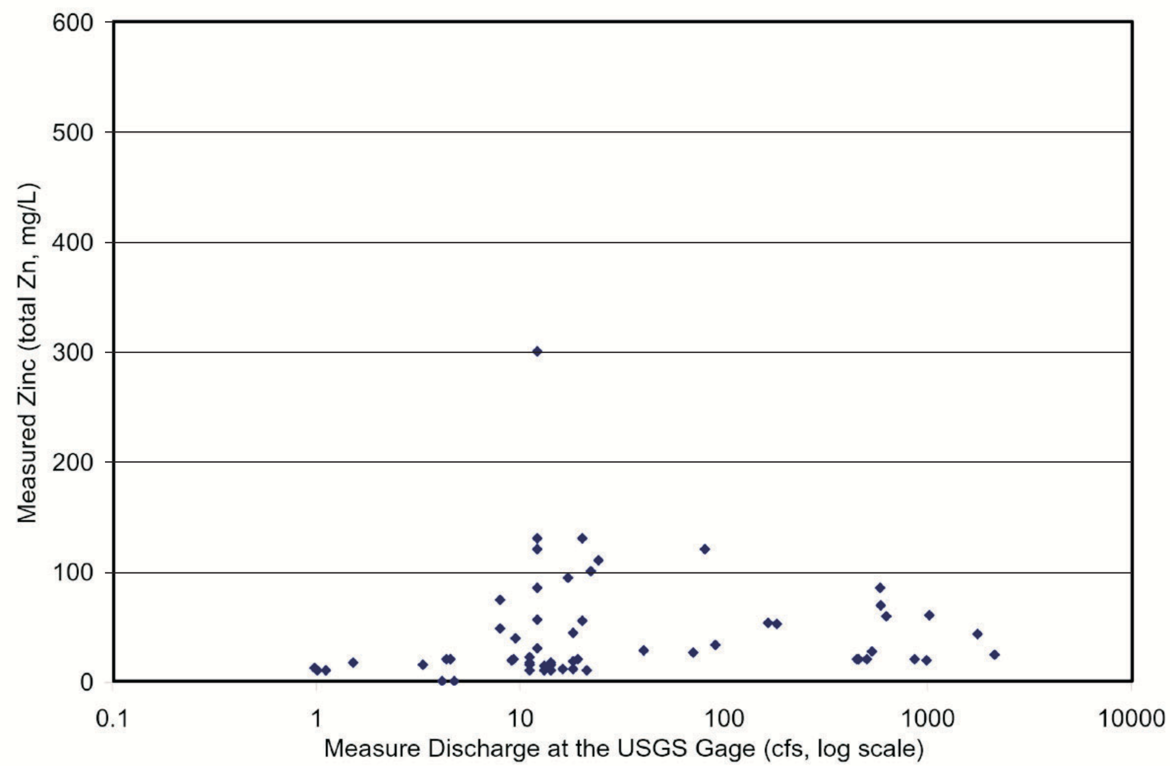
- Total zinc concentrations in water samples collected from San Juan Creek range from below the detection limit to 420 µg/L (measured at Caspers Regional Park on November 15, 1993). As a point of comparison, the monitoring results indicate that, on several occasions, zinc concentrations surpassed the 120 mg/L criteria (for both acute and chronic levels) that have been established for priority toxic pollutants under the California Toxics Rule. In general, we would expect the dissolved fraction of total zinc to have much lower concentrations than particle-bound fractions.

3.6.1.3 Total Dissolved Solids

During the 1960's, surface water samples were analyzed for total dissolved solids (TDS) as part of an effort to locate drinking water sources in the San Juan Creek watershed. The TDS sampling consisted of a bulk parameter that measured dissolved salts, in this case primarily sodium (Na^+), calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^+), chloride (Cl^-), sulfate (SO_4^-), bicarbonate (HCO_3^-), and silica (SiO_2) in water. Sources of these constituents include both natural weathering of



Part A: Zinc Concentrations vs. Antecedent Rainfall



Part B: Zinc Concentrations vs. Discharge

Source: Balance Hydrologics, Inc., 2000

PCR PWA Balance Hydrologics, Inc.

Figure 30
Baseline Conditions Report
Zinc Concentrations for
San Juan Creek at La Novia

bedrock and soils as well as anthropogenic sources from agriculture and urbanization. The data set suggests that TDS concentrations in San Juan Creek increase from 200 mg/L at its upper reaches to over 1,000 mg/L in the lower reach. Given the minimal urbanization of the watershed in the 1960's, this 500 percent increase in TDS is likely the result of: (a) inputs from sub-basins that drain highly erodible substrates such as Monterey Shale (e.g., Cañada Chiquita and Oso Creek); (b) irrigation return flows in Oso Creek, Cañada Chiquita and Cañada Gobernadora; and (c) evaporative processes that concentrate salts in the water column throughout the length of San Juan Creek. These data suggest that high TDS is indicative of a baseline condition for the lower San Juan watershed.

3.6.1.4 Bacteria

Frequent, but spatially limited bacteria monitoring data is available for the lower reaches of San Juan Creek under a program carried out by the South East Regional Reclamation Agency (SERRA). These data indicate persistently high counts of total and fecal coliform (FC), and enterococcus (EC), both at the mouth of San Juan Creek and upstream of the Latham Treatment Plant. The RWQCB water quality objective for contact recreation of 200/ml of total bacteria (log mean over 30-day period) is consistently exceeded. However, the water quality objective for non-contact recreation of 2000/ml of total bacteria is generally attained at the upstream monitoring site. For calendar year 2000 the log mean fecal coliform concentration at Del Obispo Park was roughly 300/ml. The U.S. EPA guidelines for enterococci that are cited in the Basin Plan (151/ml for infrequently used freshwater areas) was met on only roughly one-third of the samples taken over recent years at the upstream Del Obispo Park monitoring site. The log mean enterococci concentration for calendar year 2000 was approximately 540/ml.

It is important to note that both the SERRA monitoring sites are located at the most downstream reaches of San Juan Creek, within and below extensive urbanized areas. The sources of these bacterial contaminants cannot be ascertained with existing data.

3.6.2 Analysis of Existing Water Quality Data for the San Mateo Watershed

Unfortunately, there is limited available comparable baseline data for San Mateo Creek. Limited water quality data from various studies (Lang et al.1998) were compiled. However, these studies contained no samples that were analyzed for metals, and the five samples analyzed for nutrients were all collected on the same day (March 17, 1997) without corresponding discharge measurement (see Appendix B). The ability to analyze baseline water quality conditions for the San Mateo Watershed would be furthered if the monitoring data collected on the Marine Base Camp Pendleton were available for review.

Additional and ongoing water quality monitoring is currently being conducted by Rivertech Inc. for Rancho Mission Viejo. The sampling plan, begun in early 2001, calls for a comprehensive analysis of both storm event and dry weather samples collected from nine locations within the SAMP/MSAA study area, including two sites within the San Mateo Creek watershed (Cristianitos and Gabino Creeks). This data is supplemented by continuous monitoring of temperature, conductivity, dissolved oxygen, pH and flow at four stations (including Cristianitos Creek). Data already collected is not yet available for analysis. However, it will be an important resource for future updates to this report.

As part of the San Diego Basin Plan, Region IX of the Water Quality Control Board has designated beneficial uses (pursuant to Section 303 of the CWA) for San Juan and San Mateo Creek. These designated beneficial uses for these two watersheds are defined and listed in Table 14 on page 91. In addition, applicable water quality standards established by Region 9 of RWQCB and by the State Water Board under the California Toxics Rule are summarized in Table 15 on page 92.

3.7 GROUNDWATER

The vast majority of the San Juan and San Mateo watersheds is underlain by semi-consolidated sandstones and by alluvial and terrace sediments derived from the sandstones that have the capacity to store groundwater (Williams, 1969; Morton, 1970). Several of the bedrock geologic units in the central portion of the San Juan watershed are moderately sandy and largely uncemented, affording significant opportunities for infiltration and groundwater storage. In this portion of the watershed, the sandy deposits in the floodplain and stream valleys are permeable and therefore, can be a major source of groundwater recharge to both local and regional aquifers. Clay portions of the watershed and areas with geologic units composed of siltstones, shales, and mudstones, contain few beds of water-bearing sandy sediments. These areas also tend to have the highest groundwater salinity because negatively charged clay particles are often coated with ions that are released into the groundwater.

Weathered and fractured crystalline rocks yield moderate amounts of water sustaining springs and baseflows, commonly in the more mountainous upper portions of the two watersheds and their neighboring basins. These flows support some of the more significant and continuous bands of riparian vegetation. They are typically the least mineralized and highest quality of the groundwaters in both watersheds, and their contributions to baseflows are often significant in maintaining water quality in the alluvial aquifers downstream within levels suitable for aquatic habitat functions.

Table 14

Designated Beneficial Uses for San Juan and San Mateo Creek Watersheds per San Diego Basin Plan Watershed

Description of Use	San Juan Creek Watershed	San Mateo Creek Watershed
Agricultural Supply (AGR)—Includes uses of water for farming, horticulture, or ranching, including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.	Yes	
Industrial Service Supply (IND)—Includes uses of water for industrial activities that do not depend primarily on water quality, including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, or oil well re-pressurization.	Yes	
Contact Water Recreation (REC-1)—Includes uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and SCUBA diving, surfing, white water activities, fishing, or use of natural hot springs.	Yes	
Non-Contact Water Recreation (REC-2)—Includes the uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tidepool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.	Yes	Yes
Warm Freshwater Habitat (WARM)—Includes uses of water that support warm water ecosystems, including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.	Yes	Yes
Cold Freshwater Habitat (COLD)—Includes uses of water that support cold water ecosystems, including, but not limited to, preservation and enhancement of aquatic habitats, vegetation, fish or wildlife, including invertebrates.	Yes	
Wildlife Habitat (WILD)—Includes uses of water that support terrestrial ecosystems, including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.	Yes	Yes
Rare, Threatened, or Endangered Species (RARE)—Includes uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under state or federal law as rare, threatened, or endangered.	[a]	Yes (lower reaches only)

[a] *Although the San Juan Creek watershed supports endangered species, such as the arroyo toad, the San Diego Water Board has not designated RARE as a beneficial use for this watershed.*

Source: San Diego Water Quality Control Board

Table 15

California RWQCB Region 9 and CTR Standards and Objectives Applicable to the Quality of Water in the SAMP Study Area

Constituent	Units	California Drinking Water Standards [a]	Basin Plan Objectives [b]	California Toxics Rule [f] (CMC) [g]	California Toxics Rule [f] (CCC) [h]
Inorganic Chemicals					
Aluminum	mg/L	1	--	--	--
Antimony	mg/L	0.006	--	--	--
Arsenic	mg/L	0.05	--	0.34	0.15
Asbestos	MFL	7	--	--	--
Barium	mg/L	1	--	--	--
Beryllium	mg/L	0.004	--	--	--
Boron	mg/L	-- [c]	0.75	--	--
Cadmium	mg/L	0.005	--	0.0043	0.0022
Chromium	mg/L	0.05	--	0.016	0.011
Chloride	mg/L	none	250	--	--
Copper	mg/L	1.3	--	0.013	0.009
Cyanide	mg/L	0.2	--	--	--
Fluoride	mg/L	2	1	--	--
Iron	mg/L	0.3	0.3	--	--
Lead	mg/L	0.015	--	0.065	0.0025
Manganese	mg/L	0.05	0.05	--	--
Mercury	mg/L	0.002	--	--	--
Nickel	mg/L	0.1	--	0.47	0.52
Nitrate+Nitrite (as N)	mg/L	10	-- [e]	--	--
Nitrite (as N)	mg/L	1	--	--	--
Selenium	mg/L	0.01	--	--	0.005
Silver	mg/L	0.05	--	0.0034	--
Sodium	%	-- [c]	60	--	--
Sulfate	mg/L	250, 500	250	--	--
Thallium	mg/L	0.002	--	--	--
Zinc	mg/L	5	--	0.12	0.12

Table 15 (Continued)

California RWQCB Region 9 and CTR Standards and Objectives
Applicable to the Quality of Water in the SAMP Study Area

Constituent	Units	California Drinking Water Standards [a]	Basin Plan Objectives [b]	California Toxics Rule [f] (CMC) [g]	California Toxics Rule [f] (CCC) [h]
Others					
pH	pH Units	6.5-8.5	6.5-8.5	--	--
Specific Conductance	(µs)	900, 1600	--	--	--
Total dissolved solids	mg/L	500	500	--	--
Ammonia (as N)	mg/L	30	-- [4]	--	--
Fecal coliform bacteria	MPN/100m	log mean <20	--	--	--

[a] *Maximum contaminant levels established by the DHS, from Title 22 of the California Code of Regulations, April 2000. Where two values are shown, they represent the "recommended" and "mandatory" values.*
[b] *Concentrations not to be exceeded more than 10 percent of the time during any one year period.*
[c] *No primary drinking water standards have been established for boron or sodium. At elevated concentrations, these constituents may constrain plant or crop growth.*
[d] *Un-ionized ammonia concentrations exceeding 0.0025 mg/L can be toxic.*
[e] *Biostimulating constituents.*
[f] *California Toxics Rule (CTR) freshwater aquatic life criteria.*
[g] *Criteria Maximum Concentration (CMC) equals the highest concentration to which aquatic life can be exposed for a short period of time.*
[h] *Criteria Continuous Concentration (CMC) equals the highest concentration to which aquatic life can be exposed for an extended (4-days) period of time.*

Source: Balance Hydrologics, Inc., 2001

There are three shallow alluvial basins that sustain perennial or near-perennial stream flow in the San Juan Creek Watershed. These basins are located in Chiquita Canyon above the "Narrows", Chiquita Canyon below the "Narrows," and Gobernadora Canyon. These alluvial basins are all recharged primarily by ground water emanating from the adjoining bedrock aquifers. The shallow alluvial aquifers of the Gobernadora and Chiquita valleys are partially isolated from the San Juan aquifer via a "damming effect" resulting from the presence of fine-grained lake-bed deposits which underlay their lower reaches.

At the landscape scale, most of the riparian and aquatic habitats have at least transient reliance on groundwater. The exception to this would be in Chiquita and Gobernadora Canyons, which contain some of the largest areas of sandy soils and the greatest volumes of aquifer storage. The low permeability lake-bed deposits in these canyons form sand wedges that help sustain shallow groundwater levels in the lower half mile of the Chiquita and Gobernadora Canyons. These shallow groundwater conditions are an important component of maintenance of riparian habitat in these areas.

Slope wetlands in the study area are also sustained by groundwater. Approximately half of the slope wetlands are sustained by water emanating directly from landslides, while others may be supported by groundwater stored in the Santiago formation that is upwelling along bedrock fractures and faults. Generally, both the yields and the quality of groundwater vary considerably over the course of a season. More detailed analysis of the slope wetlands is provided in the *Slope Wetland Functional Assessment* (PCR, 2000a); detailed analysis of groundwater in the study area is provided in Appendix C.

3.8 BIOLOGICAL RESOURCES

A total of 16 vegetation types have been mapped within the San Juan and San Mateo watersheds (Holland, 1986; OCHCS, 1992). A diversity of vegetation typifies most of these two watersheds. Riparian woodlands and forests occur along most portions of the stream corridors. Some of the major stands of riparian vegetation can be found in the following areas: San Juan and Trabuco to the confluence with Oso Creek; Cañada Gobernadora tributaries; Bell Canyon; and many of the tributaries to San Juan and San Mateo creeks. Dispersed sections of riparian vegetation occur along Oso, Horno, and Cañada Chiquita Creeks. The slopes along these corridors are dominated by coastal sage scrub or chaparral communities. With increasing elevation, chaparral communities replace coastal sage. Coastal sage scrub is restricted to xeric, south facing slopes. Oak woodlands and forest become common in the upper reaches of the watersheds on north-facing slopes and along drainages. In several parts of the watersheds, increased urbanization has eliminated the natural vegetation.

According to the WES/CRRL studies, the study area contains approximately 3,080 acres of aquatic and riparian resources, and 1,252 miles of intermittent and ephemeral drainages. Based on the Corps' planning level delineation, approximately 1,871 acres of aquatic and riparian resources would be considered subject to Corps jurisdiction under Section 404 of the Clean Water Act, within the bank full and active flood areas (i.e., CRRL Rating 1). Of these 1,871 acres, approximately 996 acres of riparian habitat would be considered Corps jurisdictional wetlands (Lichvar et al., 2000). The remaining 1,209 acres of aquatic and riparian resources may or may not be subject to Corps jurisdiction and would need to be delineated using a routine jurisdictional determination/wetland delineation procedure. The specific extent of CDFG jurisdiction will be determined at a later time using routine site-specific jurisdictional determination methods. However, the information contained in the CRRL landscape-scale delineation should provide a strong foundation for determining the extent of CDFG jurisdiction.

Dominant aquatic habitat types in the study area are southern willow scrub and mule fat scrub. Southern sycamore riparian woodland and southern coast live oak woodland are also common, especially in the San Mateo Creek watershed. There are also isolated instances of alkali marsh, slope wetlands, and vernal pools, primarily in the San Juan Creek watershed. The functional integrity of the riverine and non-riverine resources were evaluated by WES (Smith, 2000) and PCR (2000a), respectively, and are discussed in companion reports.

3.8.1 San Juan Creek Watershed

The San Juan Creek watershed within the study area supports a variety of habitats. The predominant habitats are coastal sage scrub (12,255 acres or 34 percent of the study area), chaparral (8,448 acres or 23 percent), grassland (4,193 acres or 11 percent), agriculture (3,572 acres or 10 percent) and riparian (2,703 acres or 7 percent, as mapped in the generalized NCCP/HCP vegetation database). Other natural habitats include oak woodland (844 acres), forest (449 acres), open water (176 acres), marsh (14 acres), cliff and rock (9 acres), streams (7 acres), and vernal pools (5 acres). Developed land comprises 2,789 acres (7 percent), and disturbed habitat comprises 756 acres (2 percent).

Riparian woodlands and forests occur along most of the stream courses in the study area. The type of riparian forest along the drainages of the San Juan watershed varies based on elevation, geology, and hydroregime. San Juan Creek itself is a broad riverine complex in certain reaches, has intermittent to near-perennial flow, and is dominated by willow-cottonwood riparian forests. Perennial streams such as Cañada Chiquita and Cañada Gobernadora contain communities typical of more hydric conditions and include sections that support alkaline marsh and meadow wetlands. The valley floors of Cañada Chiquita and Gobernadora have been subjected to extensive agriculture and grazing, and little native vegetation remains on the valley floor beyond that found within the riparian zone. Tributaries to the east and further up in the watershed, such as Verdugo and Bell Canyons, are drier, have coarser substrates, and typically support sycamore-cottonwood riparian forests.

The San Juan Creek watershed supports a large variety of sensitive species (see Table 16 on page 96). The resident gnatcatcher population is considered one of the core populations of the species in southern California. The least Bell's vireo occurs primarily in two locations in the watershed; approximately eight pairs occur in Canada Gobernadora within the Gobernadora Ecological Restoration Area (GERA) and a significant population has been documented to occur in Arroyo Trabuco. Populations of vireo in the watershed have generally been increasing over the last decade. The arroyo toad population is relatively small in the middle to lower portions of San Juan Creek, but larger populations occur in Bell Canyon and upper San Juan Creek.

Table 16

Sensitive Species in the San Juan Creek Watershed

Common Name	*Scientific Name*
State or Federally Listed Species	
California gnatcatcher	*Polioptila californica*
arroyo toad	*Bufo californicus*
least Bell's vireo	*Vireo bellii pusillus*
thread-leaved brodiaea	*Brodiaea filifolia*
Sensitive Fauna	
Cooper's hawk	*Accipiter cooperii*
white-tailed kite	*Elanus leucurus*
long-eared owl	*Asio otus*
rufous-crowned sparrow	*Aimophila ruficeps*
yellow warbler	*Dendroica petechia*
California horned lark	*Eremophila alpestris actia*
Mountain lion	*Puma concolor*
southwestern pond turtle	*Clemmys marmorata pallida*
San Diego horned lizard	*Phrynosoma coronatum blainvillei*
orange-throated whiptail	*Cnemidophorus hyperythrus beldingi*
coastal western whiptail	*Cnemidophorus tigris multiscutatus*
northern red-diamond rattlesnake	*Crotalus ruber ruber*
western patch-nosed snake	*Salvadora hexaplepis virgultea*
two-striped garter snake	*Thamnophis hammondii*
western spadefoot toad	*Scaphiopus hammondi*
red-shouldered hawk	*Buteo lineatus*
great horned owl	*Bubo virginianus*
cactus wren	*Campylorhynchus brunneicapillus*
grasshopper sparrow	*Ammodramus savannrum*
yellow-breasted chat	*Icteria virens*
SD desert woodrat	*Neotoma lepida intermedia*
mule deer	*Odocoileus hemionus*
Sensitive Plants	
salt spring checkerbloom	*Sidalcea neomexicana*
Catalina mariposa lily	*Calochortus catalinae*
Coulter's saltbush	*Atriplex coulteri*
beaked spikerush	*Eleocharis rostellata*
Coulter's matilija poppy	*Romneya coulteri*
southern tarplant	*Centromadia [Hemizonia] parryi* ssp. *australis*
intermediate mariposa lily	*Calochortus weedii* var. *intermedius*
many-stemmed dudleya	*Dudleya multicaulis*
Palmer's grapplinghook	*Harpagonella palmeri*
mud nama	*Nama stenocarpa*

Source: Dudek & Associates, 1999

3.8.2 San Mateo Creek Watershed

The portion of the San Mateo watershed within the study area supports a variety of natural habitats. The predominant habitats are coastal sage scrub (3,876 acres or 32 percent of the study area), grassland (3,166 acres or 26 percent), and chaparral (2,808 acres or 23 percent). Riparian habitat (as mapped in the generalized NCCP/HCP vegetation database) comprises 1,089 acres (9 percent). The remaining habitat/land cover is comprised of agriculture (3 acres), developed land (491 acres), disturbed habitat (233 acres), woodland (100 acres), forest (160 acres), open water (3 acres), streams (6 acres), marsh (0.6 acre), and cliff and rock (5 acres).

The San Mateo watershed is dominated by sycamore and oak woodland riparian forests. The canyons in the San Mateo watershed tend to be steeper and narrower than those in the San Juan watershed. Consequently, substrates are coarser, with many of the streams dominated by rock and cobbles. The upper portions of Gabino and La Paz watersheds have been subject to intensive grazing, and many of the riparian zones are somewhat denuded. Landslides have facilitated expression of groundwater in some sections of the watershed, promoting development of isolated patches of alkaline marsh plant communities. The lower portion of the watershed flows through MCBCP has been subjected to some agricultural, recreational, and military uses.

The upper San Mateo watershed supports a large variety of sensitive species (see Table 17 on page 98). With the exception of the arroyo toad, which is abundant in Talega Creek, none of these species occurs in great numbers within the study area. However, the least Bell's vireo occurs in large numbers downstream in San Mateo Creek. It also is notable that the southern steelhead and the federally listed endangered tidewater goby occur in the San Mateo Creek watershed; however, they occur outside the SAMP/MSAA study area.[27] Detailed discussion of the integrity of the riverine and non-riverine aquatic resources in the study area can be found in the WES study (Smith, 2000) and the PCR analysis (PCR, 2000a), respectively.

[27] *The National Marine Fisheries Service (NMFS) is currently reviewing the status of the southern steelhead in San Mateo Creek.*

Table 17

Sensitive Species in the Upper San Mateo Creek Watershed

Common Name	*Scientific Name*
State or Federally Listed Species	
California gnatcatcher	*Polioptila californica*
least Bell's vireo	*Vireo bellii pusillus*
arroyo toad	*Bufo californicus*
thread-leaved brodiaea	*Brodiaea filifolia*
Sensitive Fauna	
Cooper's hawk	*Accipiter cooperii*
rufous-crowned sparrow	*Aimophila ruficeps*
grasshopper sparrow	*Ammodramus savannrum*
long-eared owl	*Asio otus*
great horned owl	*Bubo virginianus*
red-shouldered hawk	*Buteo lineatus*
cactus wren	*Campylorhynchus brunneicapillus*
white-tailed kite	*Elanus leucurus*
California horned lark	*Eremophila alpestris actia*
yellow-breasted chat	*Icteria virens*
southwestern pond turtle	*Clemmys marmorata pallida*
western spadefoot toad	*Scaphiopus hammondi*
orange-throated whiptail	*Cnemidophorus hyperythrus beldingi*
coastal western whiptail	*Cnemidophorus tigris multiscutatus*
northern red-diamond rattlesnake	*Crotalus ruber ruber*
San Diego horned lizard	*Phrynosoma coronatum blainvillei*
western patch-nosed snake	*Salvadora hexaplepis virgultea*
two-striped garter snake	*Thamnophis hammondii*
San Diego desert woodrat	*Neotoma lepida intermedia*
mule deer	*Odocoileus hemionus*
mountain lion	*Puma concolor*
Sensitive Plants	
Catalina mariposa lily	*Calochortus catalinae*
prostrate spineflower	*Chorizanthe procumbens*
mesa brodiaea	*Brodiaea jolonensis*
upright burhead	*Echinodorus beteroi*
San Diego County viguiera	*Viguiera lanciniata*
vernal barley	*Hordeum intercedens*
chaparral beargrass	*Nolina cismontane*
western dichondra	*Dichondra occidentalis*
Fish's milkwort	*Polygala cornuta* var. *fishiae*
intermediate mariposa lily	*Calochortus weedii* var. *intermedius*
many-stemmed dudleya	*Dudleya multicaulis*
Palmer's grapplinghook	*Harpagonella palmeri*
mud nama	*Nama stenocarpa*

Source: Dudek & Associates, 1999

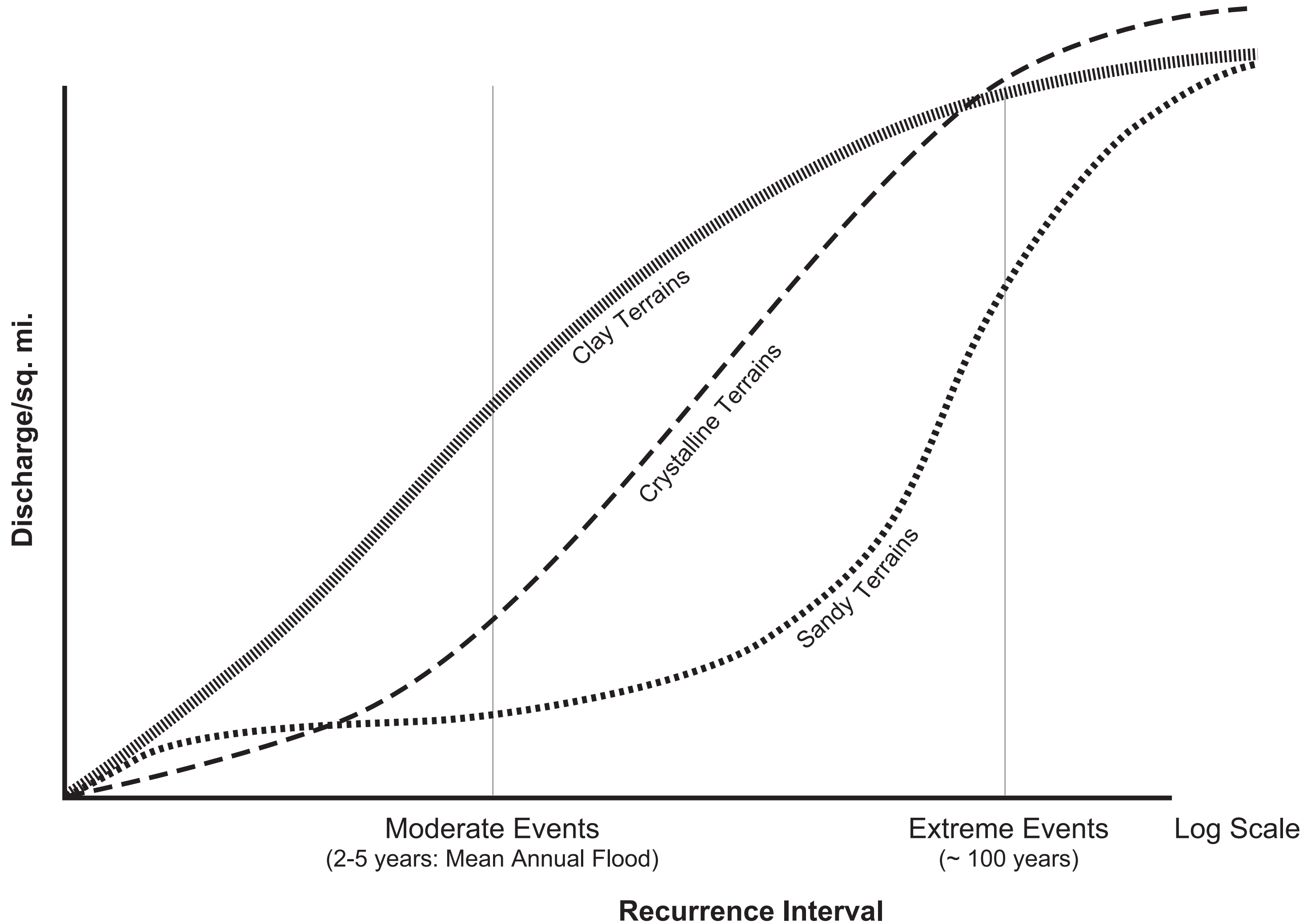
4.0 SUMMARY OF WATERSHED ATTRIBUTES/REGIONAL CONTEXT

The technical analyses summarized in this report provide an overview of the physical processes and biological conditions of the San Juan and upper San Mateo creek watersheds and provides information for land use planning at the watershed scale. The major attributes of the watershed that should be considered during land use planning include the underlying geology, patterns of runoff, interaction of groundwater with surface hydrology, sediment processes, historic land uses and existing water quality. Following is a summary of how these major attributes can be incorporated into decisions regarding future land use.

4.1 GEOMORPHOLOGY AND TERRAINS

The SAMP/MSAA study can be divided into three major geomorphic terrains which are manifested as north-south running zones through the watersheds: clayey, sandy, and, crystalline. The runoff patterns and susceptibility of the channels to incision are influenced by the soils and subsoils that are characteristic of each terrain. The western portions of the study area (i.e., Oso Creek, Arroyo Trabuco, and the lower third of San Juan Creek) are predominately clayey terrains. The central portion of the study area (i.e., Chiquita, Bell, and the middle reaches of San Juan Creek) is underlain by sandy or silty-sandy substrates. This is reflected by drainage densities that are lower than other coastal watersheds in southern California and by channel-less tributary valleys that are characterized by swales that are hydrologically connected to the main stem creek, but lack true bed and bank structure. The eastern portion of the study area (i.e., Lucas Canyon, Gabino, La Paz, Cristianitos, and Talega Creeks) is underlain by crystalline rocks (granitic or partly metamorphosed volcanic in origin) which have developed slopes and soils that are both shallow and sandy. The slopes east of both Chiquita and Gobernadora Canyons are unique in that they contain somewhat of a hybrid terrain. Although underlain by deep sandy substrates, they are locally overlain by between 2 and 6 feet of exhumed hardpan.

Although all three terrains exhibit fairly rapid runoff, undisturbed sandy slopes contribute less runoff than clayey ones because it is easier for water to infiltrate into the coarser substrate. Runoff in crystalline terrains tends to be rapid and is highly influenced by the presence and density of coverage of impervious areas of rock outcrop that typify the terrain. As a result, the volume of runoff generated by the same amount and intensity of rainfall in a sandy watershed is generally lower than that generated in a clayey or crystalline watershed. A schematic illustration of the effect of major terrains on peak flows is provided in Figure 31 on page 100.



Source: PCR Services Corporation and Balance Hydrologics, Inc., 2001

PCR PWA Balance Hydrologics, Inc.

Figure 31
Baseline Conditions Report
Generalized Effects of Major Terrains on Peak Flow

The differences in runoff patterns between terrains provide opportunities for the land use planning process. In clayey and crystalline terrains, the difference in runoff response between an urbanized and a natural condition is much less pronounced than in sandy terrains (i.e., clayey watersheds generally do not experience as dramatic an increase in post-urbanization runoff as sandy watersheds). Consequently, channels in clayey and crystalline terrains are generally more resistant to erosion, incision, and headcutting than sandy ones, if appropriate runoff management measures are implemented.[28] Crystalline terrains are characterized by shallow bedrock with an overlying layer of sandy substrate; therefore, they typically allow for higher infiltration rates than clayey terrains, which seal and become impervious upon saturation. Therefore, in clayey terrains, it may be preferable to situate development on the ridge tops and maintain vegetated buffers adjacent to the stream corridors.

Unless stabilized by riparian vegetation, streams in sandy terrains are generally the least stable and, therefore, the most susceptible to channel incision or channel widening associated with changes in land use. Studies have shown that urbanization in sandy watersheds can result in a more marked proportionate increase in storm peaks and associated alteration of downstream channel morphology than in more clayey watersheds. Therefore, in sandy terrains, management of post-development runoff is critical. The least damaging development prescription would be to provide ample set backs from the streams in order to retain the infiltration capacity of the valley floor and cluster residential uses on the hillslopes or ridges while avoiding the main tributary swales. Because the effect of markedly increased flow in sandy watersheds following urbanization has been observed to be inversely proportional to the size of the watershed, placing development atop ridges in sandy terrains above small, vulnerable sub-watersheds soils must be accompanied by adequate detention/infiltration (which could occur in the adjacent swales). Such management will decrease the risk of erosion, incision, and downcutting of lower order drainages on the slopes below the development.

Although these generalized patterns can guide land use planning at a watershed scale, the specific characteristics of a given sub-basin should direct planning at the site-specific scale. For example, while the eastern slopes and ridges of Chiquita and Gobernadora are generally sandy, the ridges are locally capped by hard clay layers that geologists interpret to be ancient subsoils. These areas receive rainfall and generate extremely rapid runoff, especially during large storm events. Runoff from these hardpan caps is rapid even during moderate sized storms, presently forming numerous gullies at the heads of individual tributary valleys before it percolates into the sandy soils further downslope. In the context of the entire study area, the hydrologic effects of development can be minimized if sited, to the extent feasible, in areas that already yield low-infiltration and high runoff patterns. However, in all terrains, sensitive biological communities or habitats should be

[28] *Oso Creek is located in an area dominated by clayey terrain. However, the magnitude of urbanization, uncontrolled increases in runoff, and floodplain encroachment have exceeded the resilience of the channel and resulted in extreme channel incision.*

avoided to the maximum extent possible and runoff from developed area should be managed and floodplain integrity maintained in order to help maintain the geomorphic and biologic integrity of the streams.

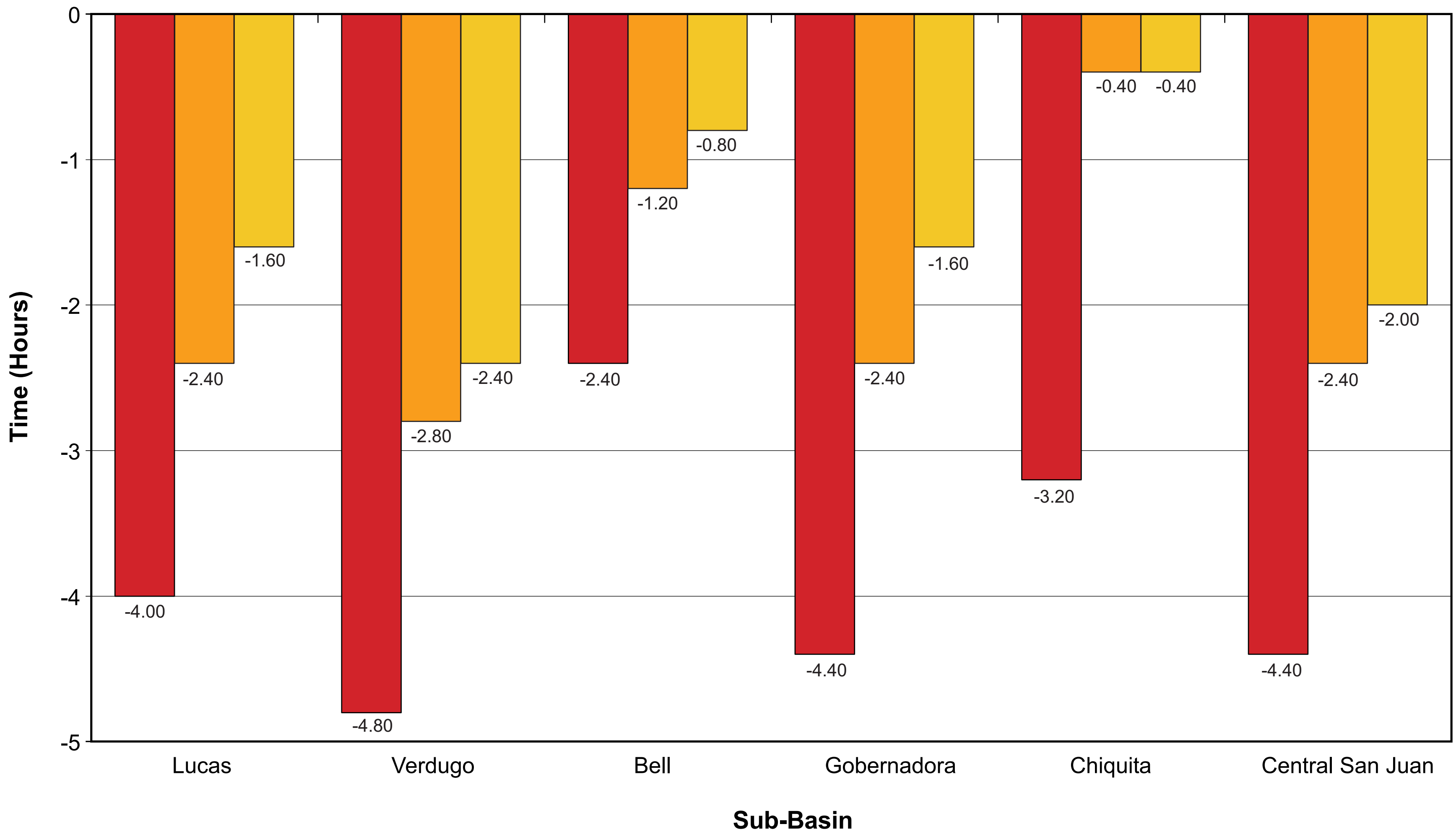
The terrains reflect the properties of the underlying geologic formations, parent materials to the soils. While most of the rock units which form sandy terrains do occur elsewhere in Orange County, they outcrop to a much greater extent in the San Juan and San Mateo watersheds, where they are predominant landscape-shaping influences in some of the larger sub-basins. The SAMP/MSAA provides an opportunity to develop approaches and guidelines consistent with the properties of these distinct and unfamiliar substrates rather than using traditional criteria that are likely to prove ineffective or even harmful to habitat functions in these soils and watersheds.

4.2 SURFACE HYDROLOGY

Both the San Juan and San Mateo watersheds are generally characterized by slow infiltration rates relative to adjacent watersheds. For example, review of existing data for the Santa Margarita and San Luis Rey watersheds shows that these two watersheds have a higher percentage of Type B soils than the San Juan and San Mateo watersheds (Steinitz et al, 1996). Therefore the San Juan and San Mateo watersheds would be considered more slowly infiltrating areas than the Santa Margarita and San Luis Rey (in general). Compared with the San Mateo watershed, San Juan contains approximately 10 percent less coverage with poorly infiltrating soils (i.e., C and D soil hydrogroups). In contrast, the steep crystalline terrains of the San Mateo watershed exhibit rapid runoff and relatively lower infiltration capacity.

Significant differences can be found within the watersheds at the sub-basin scale. Within the San Juan watershed, Chiquita and Gobernadora Canyons possess broad valleys of relatively higher infiltrating sandy soils. However, as noted above, the slopes above portions of Gobernadora are characterized by B soils that are overlain by several feet of hardpan that, if undisturbed, cause this area to respond more like a C or D soil

The composite hydrograph for 2-year, 10-year, and 100-year flows in San Juan Creek at flows the ocean are 5,170 cfs, 29,280 cfs, and 67,280 cfs, respectively. For San Mateo watershed, the predicted 2-year, 10-year, and 100-year flows at the ocean are 3,200 cfs, 19,160 cfs, and 47,530 cfs, respectively. Predicted flows in the San Mateo watershed are between 21 percent and 24 percent lower than those in the San Juan watershed, which is consistent with the 24 percent size difference between the two watersheds (i.e., 133 mi.^{2} vs. 176 mi.^{2}). Several things are notable about the hydrologic modeling results. First, peak flows from the western portion of the watershed arrive in the lower San Juan watershed more rapidly than peak flows from the central and eastern portions of the watershed (see Figure 32 on page 103). Peak flows from Oso Creek and Trabuco Creek



Source: PWA, 2000

Notes: A negative value indicates that the sub-basin peak flow arrives at the confluence with the main stem of San Juan Creek before the peak flow of San Juan Creek itself. A positive value indicates that the sub-basin peak flow arrives at the confluence after the peak flow of San Juan Creek.

PCR PWA Balance Hydrologics, Inc.

Figure 32
Baseline Conditions Report
Sub-Basin Peak Flow Timing Relative to the Main Stem of San Juan Creek

arrive at the main stem of San Juan Creek approximately 2.8 hours before flows from the central and eastern portions of the watershed (as represented by the hydrograph for San Juan Creek upstream of Horno Creek). The more rapid arrival of peak flows from the western watershed occurs for three reasons: (a) Flow distances from the western tributaries are somewhat shorter to the lower San Juan watershed than from the areas to the east; (b) The western watershed is more urbanized than the eastern watershed. Impervious surfaces in these urban areas shed runoff much more quickly than more pervious areas to the east, and the hydrograph peak occurs earlier; (c) The central portion of the San Juan watershed contains higher infiltrating sandy areas that act to attenuate runoff to the main stem of San Juan Creek.

In a planning context, it is important to be aware of the relationship between the timing of peak flows along the main stem creek relative to those of the sub-basins. The goal should be to not alter the runoff interactions between the main stem and sub-basin creeks to a level that results in coincident flood peaks, thereby exacerbating the effects of urbanization on downstream hydrology. As a general rule, land planning should attempt to maintain the function of the existing channel network and minimize floodplain constriction in major tributary valleys.

The potential effect of urbanization on low-flow conditions was investigated by analyzing the Oso Creek sub-basin as an example of what could potentially happen in other parts of the San Juan or San Mateo Creek watersheds if similar land use transformations were to occur. The results of the trend analysis conducted for Oso Creek show that annual minimum stream flows and mean summer flows have consistently increased over time as the basin progressively developed. The effect of upstream development on dry season flows is currently observable in the northern portion of the Cañada Gobernadora sub-basin, where the Coto de Caza development has increased the magnitude and persistence of low flows to the central Cañada Gobernadora watershed.

Wet and dry cycles in southern California typically last for 15 to 20 years, with major floods that act to "reset" the riparian plant communities occurring every 10 to 20 years. The long-term implications of these wet and dry cycles on groundwater levels, width of riparian zones, and landslide activity (which increases sediment delivery to the streams) must be accounted for during future land use planning.

4.3 GROUNDWATER

The vast majority of the San Juan and San Mateo watersheds are underlain by alluvial and alluvial-terrace aquifers that have the capacity to store groundwater. Unlike many of the other portions of southern Orange County, the sandy portions of the central San Juan watershed are moderately permeable and provide significant groundwater recharge opportunities. These areas should be taken into account during the land planning process. Maximizing infiltration especially in sandy terrains could also have the effect of minimizing changes in surface runoff and water quality associated with increasing impervious surfaces. At the landscape scale, most of the riparian and aquatic habitats have at least transient reliance on groundwater. Of particular import are Chiquita and Gobernadora Canyons, which contain some of the greatest volumes of alluvial-aquifer storage and contain riparian zones that depend on contact with groundwater year-round. In these watersheds, maintenance of shallow groundwater with appropriate water chemistry is an important component of maintenance of riparian habits.

These areas also support most of the slope wetlands in the area of study, all of which are sustained by groundwater. Approximately half of the slope wetlands are sustained by water emanating directly from landslides, while the other half are sustained by deeper bedrock aquifers with the water being merely conveyed through landslides. Because landslides are more localized features than the bedrock aquifers, both the yields and the quality of groundwater vary considerably over the course of a season. In contrast, flows that are sustained by deeper bedrock aquifers tend to be more consistent in terms of both yield and quality. Groundwaters originating within the landslides and other slope deposits are locally significant because they sustain wetlands; however, they have little role in supporting the larger, continuous riparian and aquatic systems.

4.4 SEDIMENT PROCESSES

Like many arid systems, sediment yields in the San Juan and San Mateo watersheds generally exceed the transport capacity of the streams. Some of the less steep sub-basins are supply limited, but this is not the general trend for the watersheds. Consequently, San Juan and San Mateo creeks are generally depositional during large flow events. Approximately 80 percent of long-term sediment yields are produced during a few episodic events. Calculated potential average annual sediment yields for the San Juan watershed range from 1,500 to 6,000 tons/mi.^{2}. Using the LAD and MUSLE methods, predicted yields in San Juan Creek during a 100-year event range from 7,800 to 10,270 tons/mi.^{2}. Base sediment yields may increase by factors of approximately 10, 7, 4, and 2 in the first four years following a major fire. In all cases, calculated sediment yields exceed estimated transport capacities by more than a factor of two. Furthermore, the estimated sediment yields do not account for the estimated one billion tons of landslide debris that could be mobilized during a major flood-fire sequence.

Calculated peak sediment transport rates indicate that in the San Juan Creek watershed, Bell and Cañada Gobernadora Canyons represent the largest sediment contribution to San Juan Creek. Cañada Gobernadora has recently exhibited increased sediment transport; however, this is likely due to the construction of Coto de Caza, as opposed to a natural phenomenon. In-channel sediment generation resulting from incision in lower Cañada Gobernadora also contributes to high sediment yield from this sub-basin. Of the sub-basins within the study area of the San Mateo watershed, the Gabino sub-basins had the highest absolute transport capacity, while the Cristianitos sub-basin had the highest transport rate per unit area. Suspended sediment discharge in San Mateo Creek is generally less than in San Juan Creek for all measured flows. One factor that may contribute to the lower suspended sediment discharge in San Mateo Creek is the presence of less-erosive crystalline terrain in the basin geology. This diatomaceous rock that underlies 10 percent of the drainage area in San Juan Creek is known to yield high quantities of sediment as it weathers. Another factor contributing to low yields of suspended sediment in San Mateo is the smaller drainage basin size.

A key element of any effective sediment management plan will be avoiding the creation of major new sources (or sinks) of sediment. New sources can include either new locations or mobilizing sediment through accelerating processes that have been recently inactive in the landscape (e.g., landslides). The most common new source of sediment in a developing landscape is in-channel sediment generation associated with channel incision. Avoiding incision and channel widening are among the most promising approaches to managing sediment yields. Channel incision can increase sediment yields, often by 3 to 7 times, and can persist over a period of 2 to 3 decades. Non-incised, unchanneled reaches, such as portions of middle and upper Chiquita Canyon (as well as most of its tributaries), and middle Gobernadora are important opportunities to maintain existing channel configurations, principally through maintaining existing riparian woodlands plus keeping water tables up and changes in peak flows down, to the degree feasible.

Although avoiding inducing new sediment-generating locations or processes is the most promising approach to managing sediment yields, it should be coupled with land use planning that maintains sediment transport processes through designated channel reaches without interruption or in-stream modifications. This strategy not only will help ensure channel stability, but also will help sustain suitable habitat for sensitive species, such as the southwestern arroyo toad. As with management of hydrologic processes, it is important to remember that sediment yields can vary widely over time due to episodic events and long-term climatic cycles; land use designs must take these cycles into account.

4.5 WATER QUALITY

Water quality constituents of concern in the study watersheds include temperature, turbidity, nutrients (primarily nitrogen and phosphorus), metals, and pesticides (primarily diazinon and chloropyrifos). A significant amount of water quality data has been collected for San Juan Creek since the 1950s. However, most of this data was for nutrients and bacteria and was collected during high-flow events. Unfortunately, there is limited available comparable baseline data for San Mateo Creek. Four water quality monitoring locations have been initiated as part of the baseline data collection for the SAMP/MSAA and should provide useful information.

The data collected along San Juan Creek suggest that there are one or more significant sources of nitrogen loading between the Caspers and La Novia monitoring stations. It is impossible to ascertain the sources of the additional loading, but it may include factors such as the location of several nursery operations downstream of the Caspers site, development on San Juan tributaries (e.g., Coto de Caza on Cañada Gobernadora), and the large amount of grassland in the sub-basins below Caspers. Nitrate measurements at La Novia show a trend of increasing concentration with increased stream discharge, from 0 to approximately 100 cfs (where nitrate concentration = 2.5 to 3.0 mg/l). At higher discharges, nitrate concentration decreases until it drops to background levels at a discharge of approximately 1,000 cfs. These data are consistent with N mobilization either through direct transport by surface storm water runoff or by the displacement of nitrate rich groundwater into the stream system. Nitrogen levels at higher discharge rates reflect the effects of complete washout and subsequent dilution and watershed saturation. The monitoring data for phosphate at La Novia indicate that there is a tendency to higher phosphate levels with increasing stream discharge. This relationship is consistent with erosion being the primary contributor of phosphorus loading via phosphate adsorbed to particulates.

The streams in the San Juan Creek watershed appear to be generally nitrogen limited (i.e., N/P ratio < 10). However, for San Juan Creek at La Novia, the N/P ratio is a function of stream discharge. At both very low and very high flow rates, the San Juan system is nitrogen-limited. However, at intermediate flow rates, the nitrate concentrations have increased (with increasing discharge as discussed above) but phosphate levels have yet to increase significantly, resulting in a transient condition where phosphate is the limiting nutrient. The general pattern of nitrogen being the limiting nutrient implies that algal primary productivity within the San Juan Creek watershed could generally be reduced most effectively by reducing phosphorus loadings to the streams. Similarly, primary productivity would likely be impacted more by increases in nitrogen loadings than by increases in phosphorus.

Orange County PFRD has monitored several metals in San Juan Creek since the early 1990s. The Orange County data is a composite of both dissolved and particulate phases; however, in waters with typical pH levels of 7 to 8, as found in San Juan Creek, metals are most likely to be found in their particulate phase. Therefore, one can assume that the more bio-available dissolved fraction will have lower concentrations than the particulate phase. Because metals are typically found in their particulate form and are, therefore, transported in the same manner as sediments, it is unlikely that significant metal transport will occur during dry weather, as the majority of sediment transport occurs during storm events. An initial examination of the San Juan Creek monitoring data shows that, with the notable exception of zinc, most metals are found in concentrations below the detection limits.

Monitoring data for zinc at La Novia show that the highest levels of zinc occur at flows between 10 and 100 cfs. This pattern likely results from increased sediment mobilization with higher rainfall and stream discharge, increasing the concentration of particle-bound zinc in San Juan Creek. At the highest flows, zinc concentrations decrease as a result of dilution from rainwater and removal of contaminated sediments from the system. The monitoring results indicate that, on several occasions, zinc concentrations surpass both the acute and chronic toxicity objectives for fresh surface waters (21 μg/L and 23 μg/L) set by other Regional Water Quality Boards in California (RWQCB, 1995). It is not clear whether the zinc originates from anthropogenic origins, or if reflects higher naturally occurring concentrations of zinc in the Monterey Shale or other sediment-generating geologic units which outcrop just upstream of this station.

Bacterial monitoring at the mouth of San Juan Creek indicates persistently high counts of total and fecal coliform (FC), and enterococcus (EC). Total bacterial counts frequently exceed 200/ml, which is the RWQCB objective for contact recreation. For calendar year 2000 the log mean fecal coliform concentration at Del Obispo Park was roughly 300/ml. The log mean enterococci concentration for calendar year 2000 was approximately 540/ml. These monitoring stations are located at the most downstream reaches of San Juan Creek, within and below extensive urbanized areas. Although the sources of these bacterial contaminants cannot be ascertained with existing data, future land use changes in the upper watershed will need to protect against additional loadings that may exacerbate the existing bacterial contamination problems in the lower San Juan Creek watershed.

Pollutant pathways and cycles within the San Juan and San Mateo Creek watersheds can be generalized based upon critical characteristics of sub-basin terrain types. Sandy terrains typically favor infiltration, mobilizing pollutants in subterranean pathways with little or no biogeochemical cycling taking place in surface waters. Silty terrains have higher runoff rates and often contribute fine sediments (that have the ability to adsorb metals and pesticides) to downstream waterways. Clayey terrains are characterized by very high surface runoff rates and therefore play only a minor role in groundwater processes. Although typically resistant to erosion, clay soils can be a significant source of turbidity where incision occurs. Crystalline terrains have high runoff rates during larger storms and, in a natural state, produce much of the sediment and eroded soil that moves down the creeks.

Pollutants may travel with storm water or dry season runoff in either the dissolved or particulate phases. Therefore, a series of water quality management features (i.e., a “treatment train”) may be the most appropriate strategy to control all potential sources of water quality impairment. This “treatment train” should involve a combination of land use and management features, such as promotion of infiltration, retention facilities, series of water quality wetlands, and streamside buffers.

4.6 BIOLOGICAL RESOURCES

A total of 16 vegetation community types are mapped within the San Juan and San Mateo watersheds (Holland, 1986; OCHCS, 1992). The study area contains approximately 3,080 acres of aquatic and riparian resources. Riparian woodlands and forests occur along most portions of the stream corridors. Some of the major stands of riparian vegetation can be found in the following areas: San Juan to the confluence with Oso Creek, Cañada Gobernadora tributaries, Bell Canyon, and many of the tributaries to San Juan and San Mateo creeks. Dispersed sections of riparian vegetation occur along Oso, Horno, and Cañada Chiquita Creeks. The slopes along these corridors are dominated by coastal sage scrub or chaparral communities. With increasing elevation, chaparral communities replace coastal sage. Coastal sage scrub is restricted to xeric, south facing slopes. Oak woodlands and forest become common in the upper reaches of the watersheds on north-facing slopes and along drainages. The study area also contains slope wetlands, concentrated mainly along the toe of slopes in Chiquita Canyon and several vernal pool complexes in the middle portion of the San Juan Creek watershed.

Multiple sensitive species inhabit the San Juan and San Mateo watersheds. Of particular note are resident gnatcatcher populations in Chiquita Canyon that are considered one of the core populations in Southern California. Portions of San Mateo watershed and Bell Canyon support large numbers of southwestern arroyo toad. Least Bell's vireo are associated with a number of riparian systems in the study area and could increase as the species continues to recover. Consideration of watershed-scale physical processes, as discussed above, will be critical to ensuring the long-term integrity of the biological resources of the study watersheds. Protection and management of habitat for sensitive species, such as the arroyo toad and least Bell's vireo, will depend on maintenance of channel stability, adequate channel-floodplain interaction, appropriate buffers adjacent to riparian zones, key groundwater recharge areas, appropriate sediment transport patterns, and control of pollutant loading to major tributaries and the main stem creeks.

5.0 LAND USES

The extent of the study area available for future land use planning has been affected by both historic land use practices and existing commitments. The historical patterns of changing human activities in the San Juan and San Mateo basins have been described in prior reports (Corps, 1999a; KEA, 1998; Lang et al., 1998). The following sections are intended to highlight changes or activities of the past 60 years which continue to affect the channels or watersheds. Existing land use commitments are summarized to help focus subsequent analysis on areas available for future land use changes.

5.1 HISTORIC LAND USE PRACTICES

Several historic land use practices have affected both the linear and lateral extent of the riparian zones along the streams in the study area. These include grazing, agriculture, mining, groundwater use, and urbanization.

Cattle-grazing and cutting of the riparian woodlands for fuel and timber have reduced the extent of streamside vegetation. As has been the case in most of the western United States, grazing has resulted in trampling of streamside vegetation and shifted the distribution streamside vegetation to favor more non-native species. At the watershed-scale, consistent, intense and prolonged grazing facilitates a transition of upland vegetation from native grasses and scrub to non-native, annual grasses. The latter are associated with much lower infiltration and higher runoff than native plant communities. Increased runoff and erosion from grazed upland landscapes, in combination with grazing of streamside vegetation, have probably contributed to changes in the geometry and depth of the creeks in the study area and decreased the width of the riparian corridors. Intentional clearing for fields and pastures continued into the middle of the twentieth century, most notably in Cañada Chiquita and Gobernadora (Aguirre, pers. comm., 2000) and probably in Cristianitos and lower Gabino Canyons.

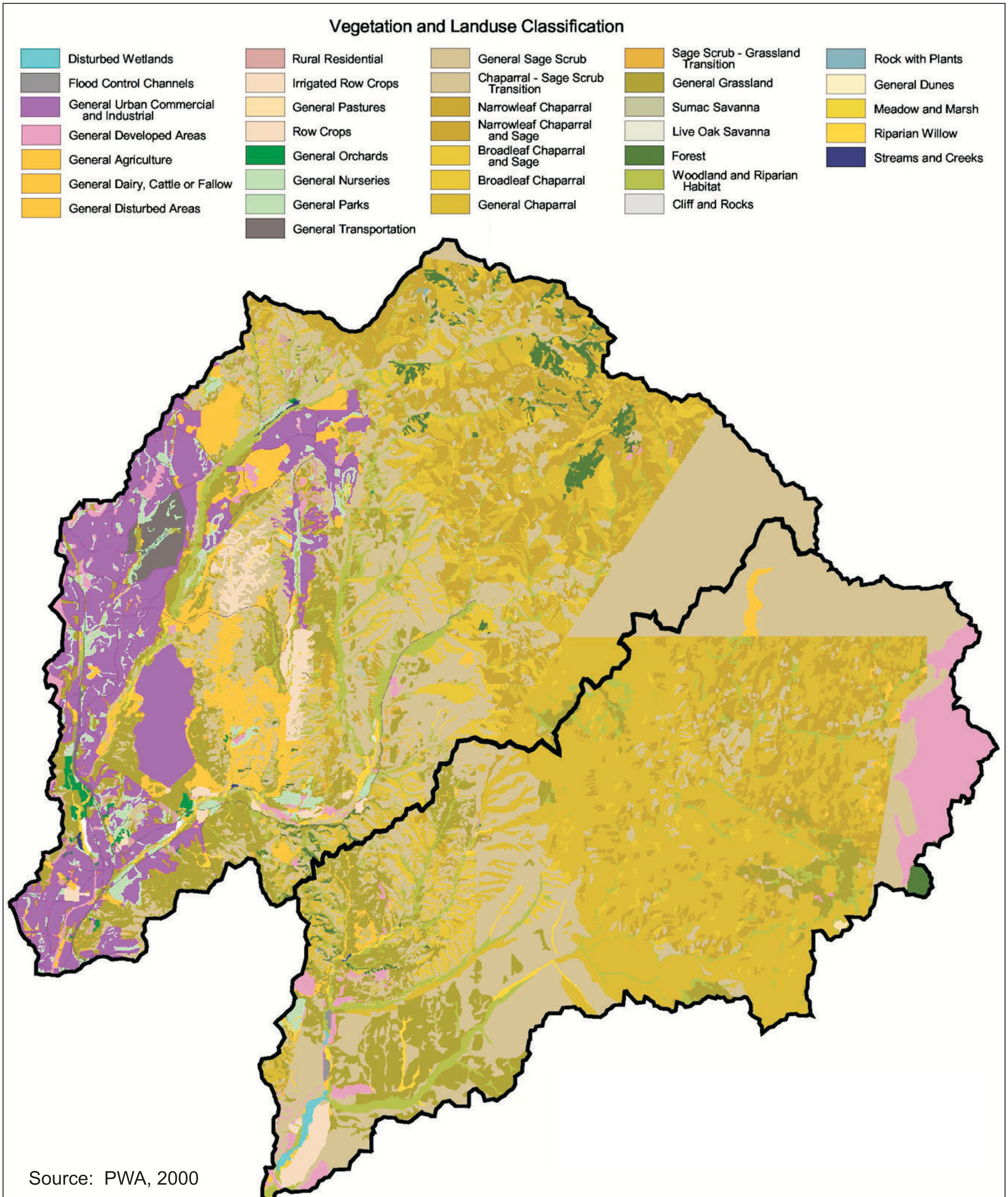
Mining has occurred in the watershed during the past 60 years, gradually declining in extent and scope. Commercial sand and gravel operations have been concentrated primarily along upper Arroyo Trabuco (Livingston & Graham) and in San Juan Creek near the Bell Canyon confluence (Conrock/Calmat). Both facilities have been inactive for at least the past five years, and neither is likely to be re-established. In-channel mining may have had a substantial role in narrowing the riparian woodland and inducing downcutting, notably in Oso, Trabuco, and San Juan Creek between Lucas and Chiquita Canyons. High-quality glass sand continues to be mined from the Los Trancos sub-basin and is expected to continue through 2014. The facility includes a large settling basin that acts to decrease peak flows from this sub-watershed. This retention associated with this basin may be retarding bank retreat along Trampas Canyon, which has been fully incised since the 1938 floods, if not earlier. Numerous day pits have been excavated in upland areas at various locations in the San Juan and San Mateo watersheds, with activity generally ceasing by 1950 or earlier. These pits may provide seasonal habitat for avifauna, but probably have little effect on hydrology or sediment processes in adjacent streams.

Groundwater pumping in the early part of the twentieth century (through the 1930s) led to seasonal or multi-year draw-down of groundwater levels, compounding the effects of the 1929 to 1935 dry period (Browning, 1934; KEA, 1998). However, by 1963, Orange County made the decision to base future land uses in the southern part of the county on purchases of imported water from the State Water Project and the Colorado River Aqueduct. This decision limited the long-term effect of alluvial groundwater withdrawals to approximately 3,000 to 3,500 acre feet per year pumped by RMV. The San Juan Basin Authority currently pumps groundwater from the aquifers of the lower San Juan Basin; however, high salinity constrains which portions of the aquifer can be used and limits withdrawals. The San Mateo alluvial aquifer has been operated primarily to meet irrigation needs for the past 60 years. Use of groundwater for water supply in adjoining units of Camp Pendleton has been increasing intermittently. Pumping from this aquifer is thought to be met in part from increased deep percolation of runoff in San Mateo Creek and its tributaries, decreasing the length of channel available to sustain riparian vegetation (Lang et al., 1998).

Commercial nurseries and agricultural operations have existed for at least 50 years and continue to exist in the San Juan Creek watershed. These operations contribute increased runoff to San Juan Creek that may contain nitrates, phosphates, and other pesticide-related compounds. In summary, the conditions of the riparian zones in the study area today are a result of both natural processes and cycles and over 60 years of land use practices.

5.2 EXISTING LAND USES

The study area includes both developed and undeveloped areas, with major urban development beginning in the early 1970s (see Figure 33 on page 112). In the San Juan Creek watershed, the Dove Canyon subdivision introduced medium-density residences into the middle Bell Canyon watershed during the early 1970s. The Coto de Caza project introduced full urban infrastructure into the middle one-third of the Cañada Gobernadora watershed during the early- to mid-1980s; the project has expanded and intensified during the late 1990s. Tesoro High School, presently (2000) under construction in the middle Chiquita watershed, serves both of these communities and nearby projects along the Oso Parkway corridor. Rancho Santa Margarita, Trabuco Canyon, Robinson Ranch, and the Ladera projects have resulted in urbanization of much of the Oso and Arroyo Trabuco sub-watershed. The lower San Juan Creek watershed is occupied by



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 33
Baseline Conditions Report
Generalized Land Use and Vegetation
for San Juan and San Mateo Watersheds

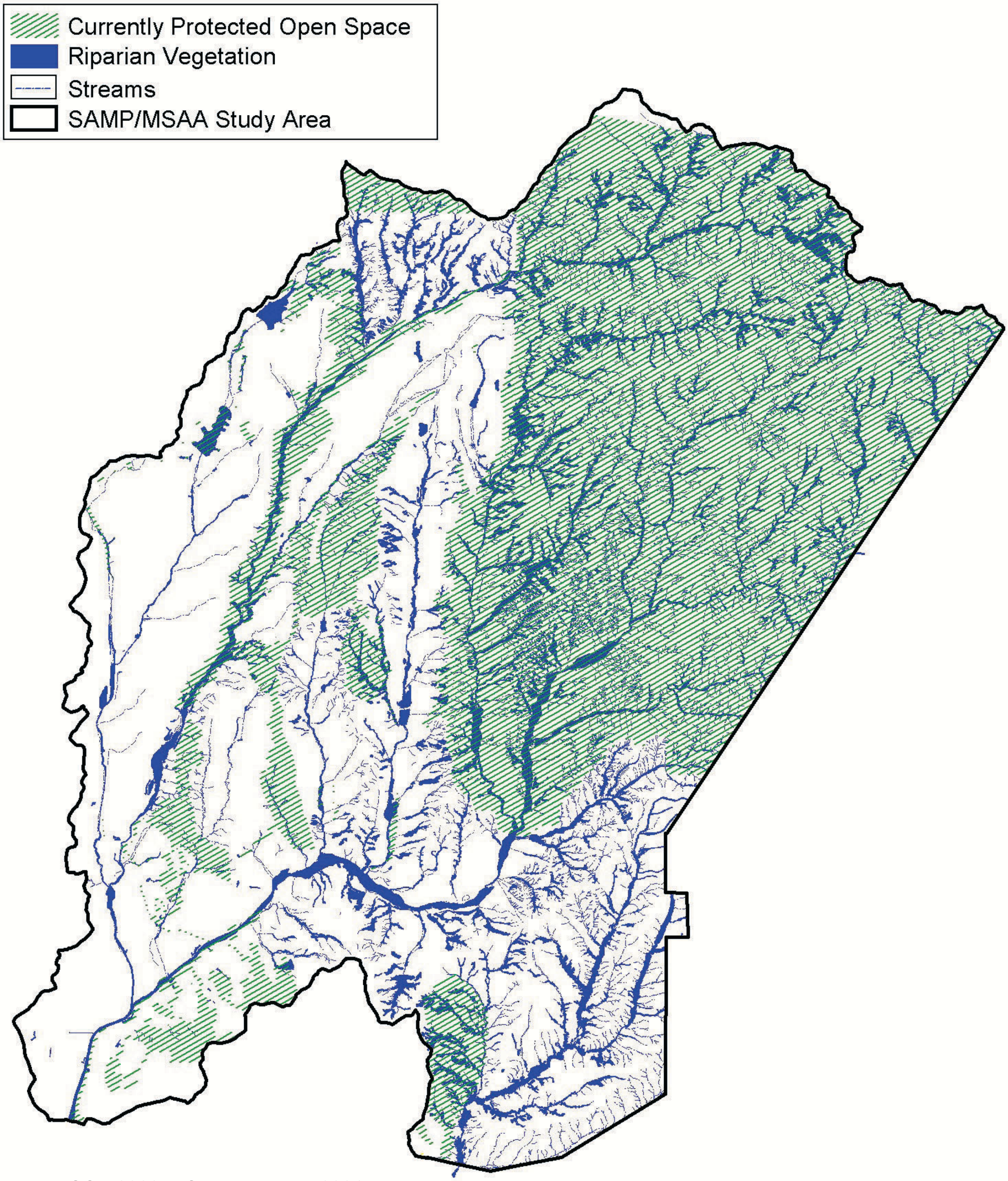
the cities of San Juan Capistrano and Mission Viejo. The majority of upper San Mateo Creek watershed remains undeveloped. However, portions of the upper watershed and most of the lower watershed are occupied by Camp Pendleton Marine Corps Base. Lands owned by the Marine Corps are subject to military, agricultural, and recreation activities.

Significant portions of the watersheds are protected as open space, including the Cleveland National Forest, which occupies the majority of the upper watersheds. The middle portion of Arroyo Trabuco is within O'Neill Regional Park. Caspers Wilderness Park covers portions of Bell Canyon and the middle reaches of San Juan Creek. Other protected areas in the San Juan Creek watershed include the Upper Chiquita Canyon Conservation Area, Chiquita Ridge Open Space, Tijeras Creek Open Space, Cañada Gobernadora Mitigation and Reserve area, Thomas Riley Park, Starr Ranch and the Ladera Ranch Open Space. The Rancho Mission Viejo Conservancy is adjacent to both the San Juan and San Mateo Creek watersheds. This area contributes to overall ecology of the region, but drains into the Segunda Deshecha watershed. Overall, approximately 40 percent of the watershed areas are currently protected as open space (see Figure 34 on page 114).

5.3 AREAS AVAILABLE FOR FUTURE LAND USE CHANGES

By the year 2025, Orange County will see increases in population, employment, and housing. According to Orange County Growth Projections 2000 (OCP, 2000), the official demographic data adopted by the County of Orange, Orange County's population will increase by 19 percent from 2,853,757 to 3,416,037. Employment is projected to increase by 36 percent or 30,000 jobs per year. Using SCAG's target 1.44-jobs/housing ratio for Orange County, 13,039 dwelling units per year (a total of 308,809 units) are needed to house this projected increase in employees. However, housing growth is expected to increase by only 14 percent or 5,513 dwelling units per year (137,819 total units). Therefore, a deficit of 7,526 housing units per year (170,990 total units) will result.

Rancho Mission Viejo is the largest private landholding in the study area. RMV owns the only significant areas that are not already developed entitled or dedicated as open space. To help address the projected housing shortage in Orange County, RMV is proceeding with a local entitlement process, concurrent with the SAMP/MSAA and NCCP/HCP, to gain development approvals for those portions of the ranch not set aside for open space purposes. Therefore, RMV lands are the focus of the SAMP/MSAA and NCCP/HCP planning process. The remainder of this baseline conditions report will focus on analysis of lands on RMV that are available for consideration for future development. The overall goal is to allow for sensible development in a manner that minimizes overall impacts and does not result in significant adverse impacts (incrementally or cumulatively) on the biological and physical condition and processes of the watersheds.



Source: ACOE 2000, PCR and EDAW 2001

PCR PWA Balance Hydrologics, Inc.

Figure 34
Baseline Conditions Report
Riparian Vegetation in Existing Protected Open Space

6.0 SUB-BASIN SUMMARY AND CONSIDERATIONS FOR FUTURE LAND USE

Although the sub-basins in the San Juan and San Mateo Creek watersheds are hydrologically and biologically connected, each major sub-basin has somewhat unique or distinctive attributes. Understanding these attributes is essential in a planning context and can help identify key considerations during the alternative analysis process.

The review of existing land uses in Chapter 5 concluded that the only lands available for significant land use changes are on RMV. Other areas in the San Juan and San Mateo watersheds are not available for consideration for future land use changes because they are committed to open space preservation, developed, or currently under development. In the San Juan watershed, the areas that are available for consideration for future land use changes include portions of Chiquita, Gobernadora (including Wagon Wheel), Verdugo, and Central San Juan Creek (including Trampas Canyon). In the San Mateo watershed, available areas include portions of Gabino (including Blind Canyon), La Paz, Upper Cristianitos, and Talega (see Figure 35 on page 116). This chapter will summarize the major characteristics of these sub-basins and provide some major opportunities and constraints that should be considered during the evaluation of both off-site and on-site alternatives for the SAMP/MSAA, development of various reserve designs for the NCCP/HCP, and design of watershed-scale water quality features. The hydrologic and sediment transport characteristics of the major sub-basins are compared in Sections 3.4 and 3.5, respectively (see Figures 11, 12, 21-24, 31 and Tables 3, 7, 10, 11).

6.1 SAN JUAN CREEK WATERSHED

6.1.1 Cañada Chiquita

6.1.1.1 Overview of Sub-basin Characteristics

Cañada Chiquita is the northwestern-most full sub-basin in the SAMP/MSAA study area. With a catchment of 9.24 $mi.^2$ it is aligned north-to-south. Local relief (from ridgetop to channel) gradually increases southward in this watershed, reaching a maximum of about 500 feet. Cañada Chiquita is the downstream-most major tributary before the confluence of Trabuco Creek, near Mission San Juan Capistrano. Approximately 60 percent of the San Juan watershed lies upstream of the confluence with Cañada Chiquita.

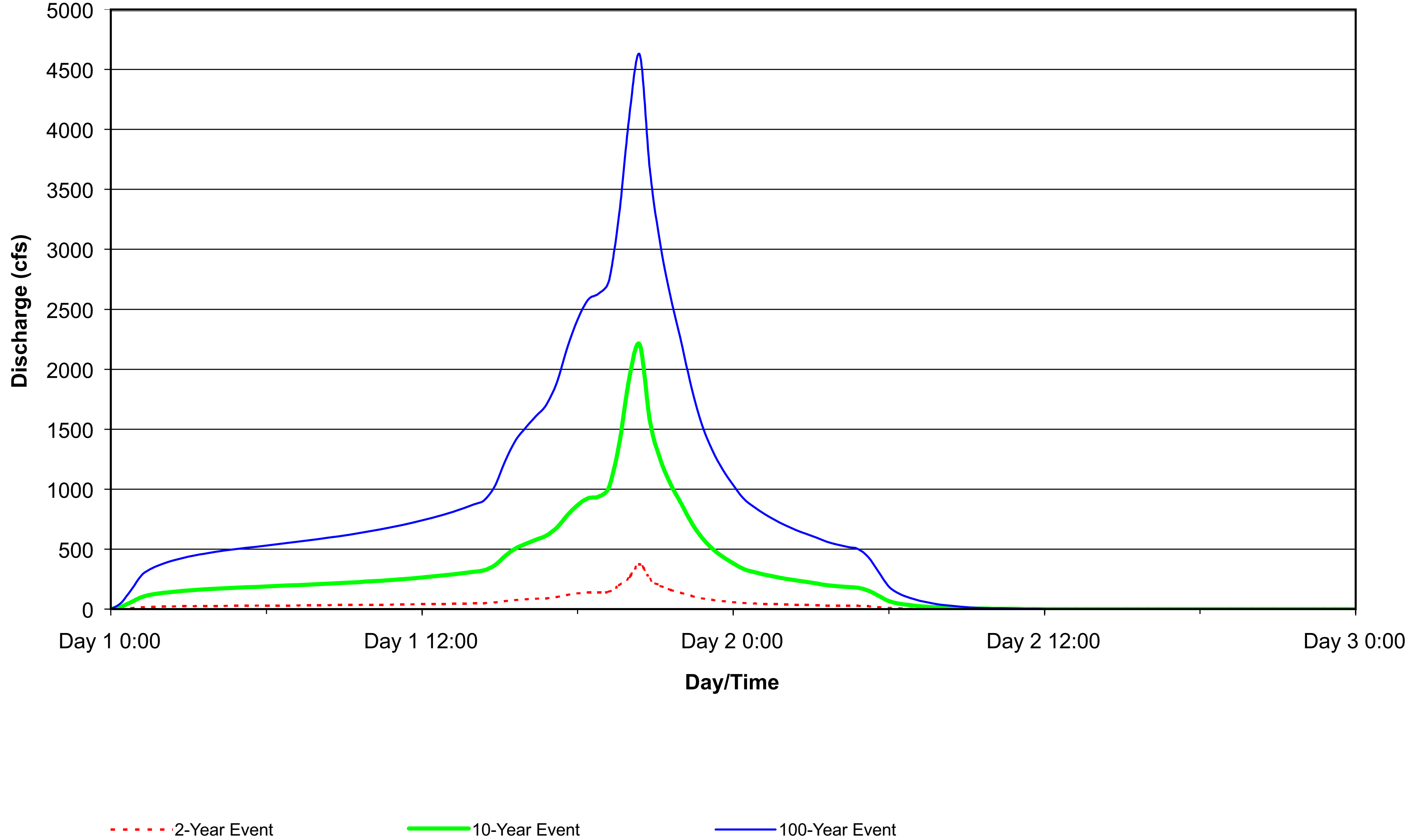
Figure 35
Baseline Conditions Report
Sub-Basin Watersheds for
San Juan and San Mateo

The Cañada Chiquita drainage basin is underlain by bedrock of the Monterey, San Onofre, Topanga, Sespe, and Santiago formations. The lower portion of the sub-basin is underlain primarily by the Santiago formation. The Cristianitos fault zone runs through the vertical extension of Chiquita Canyon. Faulting associated with the major portion of the Cristianitos Fault Zone results in highly variable bedding within the bedrock along the southern half of the east side of the canyon. The surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and landslide deposits. Several large bedrock landslide complexes occur along and adjacent to the Cristianitos fault system, especially west of the fault zone (Morton, 1974). These larger landslides are located within the southwestern one-third of the drainage basin and appear to have failed along weak, sheared bedrock associated with the Cristianitos fault system.[29] These large landslides are likely remnants of the glacial ages, when the dimate was wetter and Cañada Chiquita was 50 to 100 feet deeper than the present-day valley floor.

Cañada Chiquita is a fifth order stream at its confluence with San Juan. There are 470 first order drainages within this sub-basin that represent about 47 percent of the total stream length within the sub-basin. The drainage density of this watershed is lower than comparably sized sub-basins in the region, and many of the lateral valleys are channel-less swales. The terrains of Cañada Chiquita are considered to be primarily sandy, and as such the sub-basin generally has high infiltration capacity. This is especially true in the long channel-less swales, which contain deep sandy terrace deposits. This sub-watershed is primarily underlain by soils from three hydrologic groups: B (25.7 percent), C (36.7 percent), and D (36.0 percent). The dominant land use is agriculture (approximately 40 percent of the sub-basin), with developed lands accounting for less than 2 percent of the sub-basin.

The relatively high proportion of permeable soils and low percentage of developed area result in Cañada Chiquita presently having a moderate- to low-runoff response to precipitation events compared to the other sub-basins analyzed. The high infiltration rates also contribute to the perennial nature of Chiquita Creek. The hydrographs for the 2-year, 10-year, and 100-year events display a rapid singular peak between equally shaped rising limbs and falling limbs (see Figure 36 on page 118). Peak flows exiting Cañada Chiquita occur approximately 24 minutes before the San Juan Creek peak at its confluence with Cañada Chiquita for both the 10-year and 100-year events. Peak flows from Cañada Chiquita do not have a significant impact on the magnitude of peak flows in San Juan Creek at the confluence and downstream. Relative runoff volumes for Chiquita are also relatively low at present with the sub-basin contributing 4 percent and 6 percent of the runoff volume to San Juan Creek at their confluence, while occupying approximately 9 percent of the watershed area at that point. Peak flows from Cañada Chiquita are also approximately 4 percent to 6 percent of peak flows in San Juan Creek at the confluence. For the three events modeled, Cañada

[29] *Review of available geologic literature indicates this fault systems is not considered active, pursuant to the guidelines of the Alquist-Priolo Earthquake Fault Zone Map.*



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 36
Baseline Conditions Report
2-Year, 10-Year, and 100-Year Event Hydrographs
for Cañada Chiquita

Chiquita produced between 42 percent and 74 percent as much runoff on a per-acre basis as the average for the San Juan Creek watershed as a whole. However, during extreme flow events (i.e., 50-year or 100-year storms), the infiltration capacity of the soils may be exceeded (partially due to shallow groundwater), and during such major storm events, the soils may behave like poorly infiltrating Class C and D soils.

Below the "narrows" in middle Chiquita Canyon, soils are predominantly sands, silts, and clays. Above the narrows, the soils contain slightly more gravels and cobbles. The sandy substrates mean that the main creek is prone to incision under altered hydrologic regimes. Several active headcuts are present in Chiquita Creek, and the channel is presently incising in several locations. Continued channel incision will increase the sediment generation for the sub-basin by increasing in-channel sediment generation. The Chiquita sub-basin provides some of the lowest sediment yields and transport rates of the sub-basins analyzed in the San Juan watershed and produces substantially less sediment than the neighboring Gobernadora Canyon. However, during episodic events, sediment stored in the lateral channel-less swales may be mobilized and transported to the main portion of Chiquita Creek and further downstream.

The underlying Monterey shale bedrock, prevalence of grassland valleys, and the presence of a relatively high proportion of clay terrain in the valley floor means that nitrogen and phosphorus loadings from this sub-basin are likely quite high, with limited capacity for assimilation within the watershed itself. This may be especially true for phosphorus loadings given the presence of the Monterey formation and evidence of channel incision. Both metals and any pesticides would tend to move in particulate forms.

Chiquita Creek is one of the few naturally perennial streams in the watershed. Water likely flows from the ridge tops toward the valley bottom along subsurface impermeable layers and comes to the surfaces at changes in topography or where substrates of differing transmissivities intersect (i.e., where terrace deposits intersect floodplain alluvial deposits). The valley bottom is characterized by shallow sub-surface water for long portions of the year. This water daylights at the toe of the valley wall in several locations, supporting a series of slope wetlands.

The perennial nature and subsurface water movement in Chiquita Canyon support riparian habitats, freshwater and alkaline marsh, and slope wetlands. The majority of Chiquita Creek is southern willow riparian forest and willow scrub with pockets of alkaline marsh. The middle portions of Chiquita Creek (below Oso Parkway) support a mixture of southern willow scrub and coast live oak riparian woodland. The riparian canopy is mostly intact, but the soils and understory vegetation does exhibit some impacts from cattle-grazing. In areas where the creek has incised (up to 15 vertical feet), connection with the floodplain has been lost and overbank flow seldom occurs. Lateral canyons support primarily California live oak and scrub oak woodlands. The majority of the slope wetlands in the study area occur in the lower portion of Chiquita Canyon. These perennially moist wetlands occur in series along the toe of the slopes (primarily on the east side) and may provide refugia or act as stepping-stones for several taxa of animals. Chiquita Ridge contains several vernal pools including the largest pool in Orange County that supports the federally listed endangered Riversidean fairy shrimp and San Diego fairy shrimp. The slopes and ridges adjacent to the main creek are dominated by coastal sage scrub that supports one of the largest populations of California gnatcatcher in the study area.

6.1.1.2 Summary of Sub-Basin Opportunities and Constraints

Cañada Chiquita includes significant riparian habitat, slope wetlands, vernal pools, a gnatcatcher population, and sources of groundwater recharge. However, the main stem creek is incising in several locations. Specific opportunities and constraints are as follows:

- The sandy substrates have a high susceptibility to erosion and gully formation if runoff is increased to the channel network;
- Channel-less swales, primarily on the east side of the creek, are likely important infiltration areas, but are susceptible to erosion and incision;
- Runoff volumes per unit area are moderate to low (due to high infiltration), but peak flow is relatively high (due to the shape of the sub-basin) when compared to the other San Juan sub-basins;
- Groundwater recharge, especially through the tributary swales, is likely important to maintaining the hydrology of the slope wetlands along the margins of the valley;
- Existing channel incisions and headcuts represent risks of continued channel degradation if runoff is not managed appropriately.
- Existing channel incisions present restoration opportunities, including restoration of floodplain connections and overbank flows along Chiquita Creek; and
- The existing gnatcatcher population in this sub-basin is part of a larger “core population” of gnatcatchers present in the San Juan Creek watershed.

6.1.2 Cañada Gobernadora

6.1.2.1 Overview of Sub-Basin Characteristics

The 11.10 $mi.^2$ Cañada Gobernadora sub-basin is an elongated valley that is aligned north to south. At 9.7 miles, it is the longest watercourse in the San Juan Creek watershed and represents about 11.6 percent of the total watershed area upstream of the Cañada Gobernadora and San Juan Creek confluence.

The geology, soils, and resultant terrains in Cañada Gobernadora are extremely complex. The sub-basin has the lowest percentage of Class D (low infiltrating) soils of any of the sub-basins analyzed and is underlain by geologic formations associated with shallow aquifers. The upper portion of the sub-basin (mainly beyond the RMV boundary) is underlain by the Sespe Formation, while the lower portion of the sub-basin (within the RMV boundary) is underlain by the Santiago Formation. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides.[30] Consequently, Cañada Gobernadora contains some of the highest potential infiltration areas in the study area. This is especially true in the valley floor, which is characterized by deep alluvial deposits with interbedded clay lenses that support seasonally shallow groundwater. However, the sandy and silty substrates on many of the hill slopes and ridges in the sub-basin are overlain by several feet of exhumed hardpan or contain exposed rock outcrops. These areas presently exhibit rapid runoff comparable to Class D soils.

Runoff patterns in Cañada Gobernadora are influenced by the shape of the watershed, the underlying soils and geology, and upstream development in Coto de Caza. In the northern portion of the sub-basin, upstream of the Wagon Wheel confluence, the main valley is drained by a fifth order channel for most of its length. Downstream of the confluence with Wagon Wheel, Gobernadora becomes a sixth order system until it joins San Juan Creek further downstream. More than 30 third order channels, and six fourth order streamcourses converge on the main Cañada Gobernadora channel from the western and eastern side slopes. The overall drainage density is approximately 9 $mi/mi.^2$ for the combined basins, which share 500 first order channels. First order drainages represent about 45 percent of the total stream length, whereas fifth and sixth order drainages comprise 8.6 percent of total channel length. Due to the elongated configuration of this basin, first order streams are proportionally less of the total stream length than in some of the other sub-basins like Verdugo, Lucas, or Bell Canyons. In addition, many of the tributaries are channel-less swales. These areas represent high infiltration zones that likely convey stream runoff to the main-stem of Cañada Gobernadora and only exhibit surface connection following extreme runoff events. These infiltration zones may also contribute to baseflow and the perennial nature of Cañada Gobernadora.

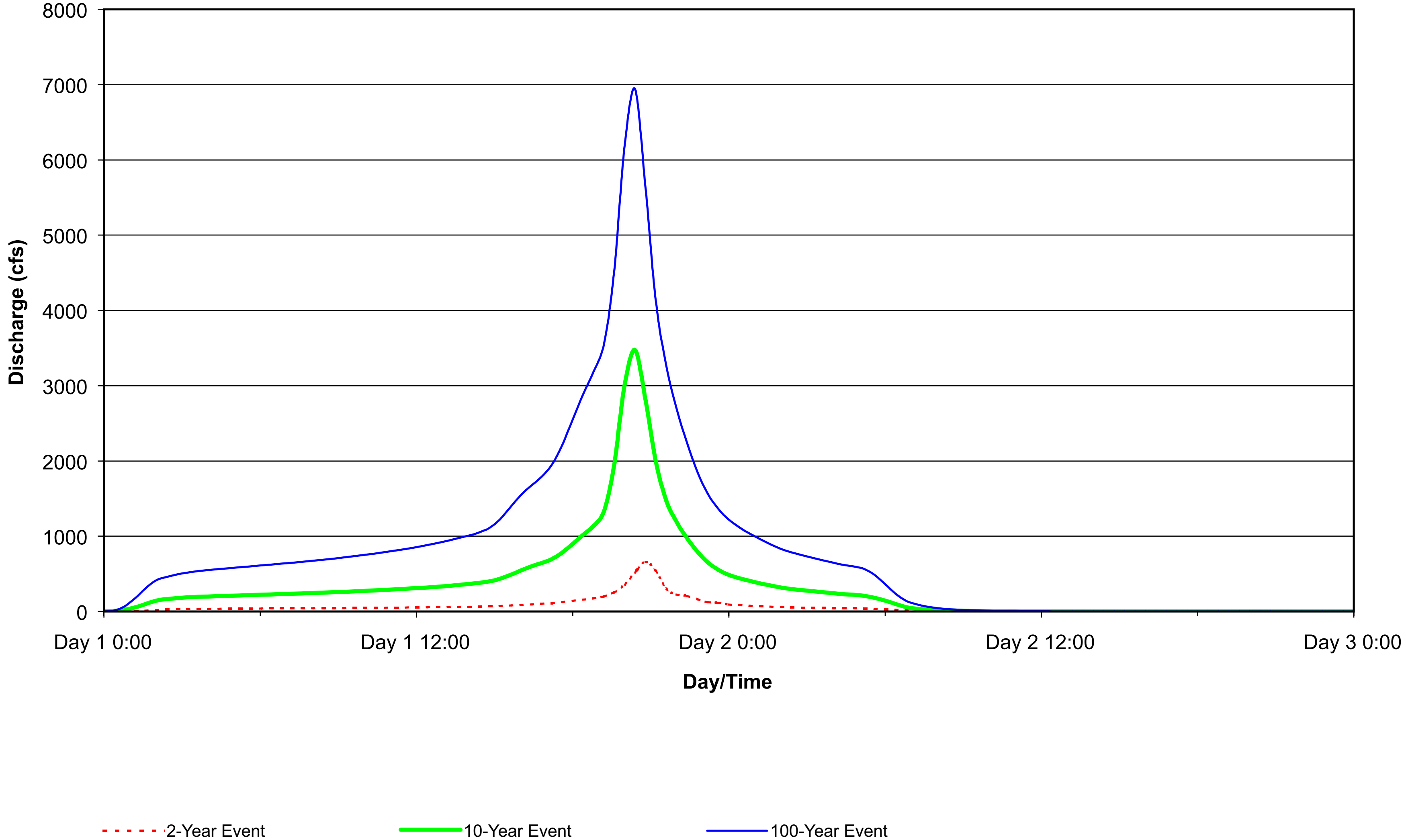
Runoff volumes and peak flows from Cañada Gobernadora are relatively high in comparison to the other San Juan sub-basins presented. Cañada Gobernadora contributes about 8 percent of the runoff volume to San Juan Creek at their confluence while it occupies approximately 11.6 percent of the watershed area at that point. For the three events modeled, Cañada Gobernadora produced

[30] *Review of aerial photographs and available geologic maps indicate that the landslides located within the project boundaries are shallow and of relatively limited aerial extent.*

approximately 62 to 75 percent as much runoff on a per-acre basis as the average for the San Juan Creek watershed as a whole. However, runoff response is rapid as indicated by 2-year, 10-year, and 100-year hydrographs that display rapid singular peaks with similarly shaped rising limbs and falling limbs (see Figure 37 on page 123). This pattern results from the long, thin shape of the sub-basin; the impervious hardpan and bedrock outcrops; and the relatively greater proportion of developed areas in this sub-basin (particularly in the northern basin). Peak flows from Cañada Gobernadora arrive at San Juan Creek approximately 4.4 hours, 2.4 hours, and 1.6 hours prior to the passing of peak flows along San Juan for the 2-year, 10-year, and 100-year events, respectively. Although this represents a substantial time separation, peak flows from Cañada Gobernadora do have a recognizable impact on peak flows in San Juan Creek at the confluence and downstream due to the relatively large size of the peak flow from the canyon.

Cañada Gobernadora is predominantly underlain by sands and silts and has the potential to generate relatively high amounts of sediment where the surface is disturbed and channelized. Currently, high sediment yields (mainly from the disturbed upper portion of the sub-basin outside the RMV boundary) result in a transport limited system with yields and transport rates (both absolute and per unit area) for Cañada Gobernadora that are the highest of any sand-dominated sub-basin. Sediment yield and transport rates are comparable to the Verdugo sub-basin, which is a steeper and coarser substrate basin, and absolute sediment transport is second only to the larger Bell Canyon sub-basin. In recent years, natural sediment sources have been augmented by sediment runoff from graded slopes in the developing areas of the upper sub-basin (outside the RMV boundary). Much of the sediment generated from the upstream development in Coto de Caza deposits in the lower portion of the canyon, typically within the riparian zone.

Pollutant transport within the Cañada Gobernadora sub-basin is quite complicated with different pathways dominating by location and even season. Much of the watershed lands in the middle and lower reaches are underlain by the permeable Santiago sandstone. Therefore, early in the winter it is reasonable to assume that most rainfall infiltrates, and that groundwater pollutant pathways are predominant. The presence of sandy apron deposits at the mouth of side canyons can locally encourage infiltration. Where the channel is aggrading, there is a greater connectivity with the floodplain and more possibilities for the riparian corridor to play a role in assimilating constituents of concern. However, surface water pathways likely predominate in the lower reaches due to incision that has led to a loss of channel-floodplain connectivity and the presence of heavy clays that bring groundwater to the surface. This sub-basin is likely a significant source of both nitrogen and phosphorus loadings, from grasslands/agriculture, urbanization in the upper reaches with minimal use of BMPs and the presence of large nursery operations. Conditions favor the transport of metals and pesticides in particulate form.



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 37
Baseline Conditions Report
2-Year, 10-Year, and 100-Year Event Hydrographs for Cañada Gobernadora at Confluence with San Juan Creek

Along with Chiquita, Cañada Gobernadora is the only portion of the study area where shallow subsurface water plays an important role in the ecology of the aquatic resources. The Santiago formation that predominates the lower portion of the sub-basin is associated with lateral groundwater flow along interfaces between thinly interbedded impermeable clay and permeable sand (Morton, 1974). This creates areas of shallow groundwater in the valley bottom and the lower portion of some of the lateral swales. The shallow groundwater (along with urban runoff from upstream development) contributes to the perennial nature of Cañada Gobernadora. In addition, several of the tributaries to Cañada Gobernadora, such as Wagon Wheel and Sulfur Canyons, support wetlands along faults or fracture zones that cut the sands of the Sespe formation, releasing water stored in the sandstone.

The broad floodplain valley bottom and shallow groundwater found in Cañada Gobernadora allow the creek to support relatively dense riparian habitat. The lowest portion of the main creek (upstream from the confluence with San Juan Creek) has been restored and enhanced as mitigation for authorized impacts to riparian habitats in other areas of Orange County. This portion of the creek supports dense thickets of willow scrub, open water, and emergent marsh. An area adjacent to the middle portion of the creek has recently been utilized to create emergent wetlands as mitigation for impacts in other locations. Over time, this area is expected to develop to a matrix of willow scrub, emergent marsh, and woodland communities that will increase the overall width of the riparian zone in this location. Upstream of the confluence with Wagon Wheel Canyon, the stream contains a mix of southern willow riparian and sycamore-willow woodland to the boundary with Coto de Caza. Several of the major tributaries to Cañada Gobernadora support mature oak woodland with coarser substrate streambeds.

6.1.2.2 Summary of Sub-Basin Opportunities and Constraints

Cañada Gobernadora includes significant riparian habitat and sources of groundwater recharge. Specific opportunities and constraints are as follows:

- Because much of the slopes and ridges are currently covered with a hardpan cap, they exhibit low infiltration rates and rapid runoff patterns.
- The swales and valley bottom are underlain by deep alluvial deposits that function as important infiltration/recharge areas. At the same time, infiltration capacity in the valley bottom and swales may be limited by high groundwater levels.
- Peak runoff per unit area is the among the highest of any sub-basin studied as a result of existing upstream development and the presence of hardpan caps on the slopes and ridges that increase overall basin runoff.

- The timing of the peak flows in Cañada Gobernadora and San Juan Creek at the confluence with San Juan Creek does not produce coincident peaks.

- The lower portion of Cañada Gobernadora receives excessive sediment input from the upstream development of Coto de Caza. Sediment generation will likely be replaced by increased clear-water flow as construction in Coto de Caza is completed. However, the clear water flow may exacerbate existing channel incision thereby increasing sediment delivery to downstream areas.

- The sub-basin contains high loadings of both nitrogen and phosphorus from agriculture nursery's and upstream development.

- The valley floor currently contains swales, ponds, wetlands, and buffers that help partially assimilate nutrient loadings from upstream areas before they reach Cañada Gobernadora or San Juan Creek thereby providing water quality benefits to these receiving waters. However, the role of the riparian zone in nutrient assimilation is reduced where channel incision has isolated the creek from the floodplain.

- The riparian habitat associated with Cañada Gobernadora and the major oak-woodland tributaries provide important aquatic buffers. The floodplain area adjacent to the main portion of the creek provides good opportunities for additional restoration/mitigation efforts.

- The lower portion of Cañada Gobernadora supports a population of least Bell's vireo.

6.1.3 Verdugo

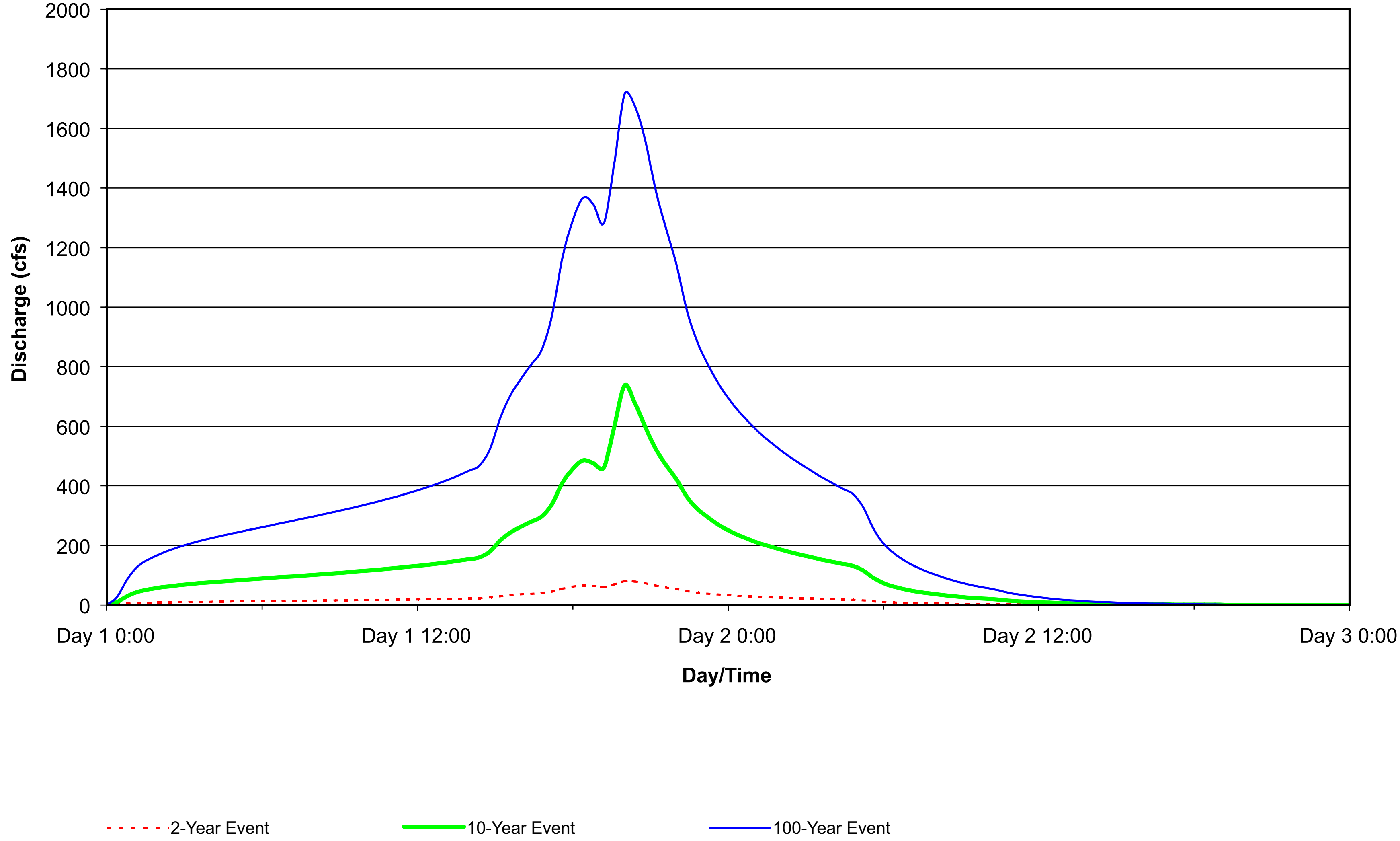
6.1.3.1 Overview of Sub-basin Characteristics

The 4.80- $mi.^2$ Verdugo Canyon watershed has roughly an east-west orientation with several tributary channels entering the main valley stream from the north and south. The sub-basin is underlain by bedrock of the Williams, Ladd, and Trabuco formations and the Santiago Peak Volcanics. Approximately one-half to two-thirds of the Verdugo Canyon drainage basin lies within the project boundary. Within the boundaries of the project, the underlying bedrock consists of the Schulz Ranch and Starr members of the Williams formation, the Holz Shale and Baker Canyon members of the Ladd Formation, and the Trabuco formation. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace, deposits and a few landslides. The landslides located within the project boundaries are shallow and of relatively limited areal extent.

Drainage density for the sub-basin varies spatially, with an average density of 13 mi/mi.^{2}. The eastern headwaters of Verdugo Canyon have a lower drainage density, while the area north of Verdugo Creek in the central canyon area has a higher drainage density. This increased drainage density likely reflects the geologic substrate beneath the central Lucas and Verdugo basins. Overall, 562 first order drainages are delineated in the Verdugo Canyon sub-basin. Similar to Lucas Canyon, these first order reaches comprise about 51 percent of the total stream length in the basin. Verdugo Canyon is a fifth order stream system at its confluence with the main San Juan channel, immediately downstream of Bell Canyon.

Verdugo Canyon had one of the highest predicted infiltration rates of any of the sub-basins studies in the San Juan watershed. This results from the undeveloped condition of the sub-basin, the relatively high proportion of Type A (8.3 percent) soils (compared to other sub-basins), and relatively low proportion of Type D soils (28.6 percent) compared to other sub-basins in the watershed. The hydrographs for Verdugo Creek show two distinct, peaks with a smaller, yet distinct peak, occurring prior to the main peak of the hydrograph (see Figure 38 on page 127). This shape is characteristic of the hydrographs for Lucas Canyon, Verdugo Canyon, and the Central San Juan catchments, and likely results from the shape of the precipitation hyetograph modeled for this portion of the watershed. Peak flows from Verdugo Creek arrive at San Juan Creek approximately 2.4 hours, 2.8 hours, and 4.8 hours before the flow in San Juan Creek for the 2-year, 10-year, and 100-year event, respectively. Therefore, peak flows from Verdugo Canyon do not significantly increase peak flows in San Juan Creek at the confluence or downstream. Runoff volumes and peak flows from Verdugo Canyon are relatively small, as is expected given the high infiltration rates in the sub-basin. Verdugo Canyon contributes less than 4 percent of the runoff volume to San Juan Creek at its confluence with Verdugo Canyon, while it occupies approximately 6.2 percent of the watershed area at that point. Peak flows from Verdugo Canyon are also less than 4 percent of the total peak flows in San Juan Creek at the confluence. Verdugo Canyon produced less runoff on a per-acre basis than four out of the five other San Juan sub-basins analyzed. Only the central San Juan catchments had lower runoff per-area values.

Verdugo Canyon, along with Lucas and Bell Canyons, constitute the more silty portions of the San Juan Creek watershed, with upper portions of the sub-basins containing crystalline terrains. These areas are characterized by coarser substrates, shallower soils, and steeper slopes than Chiquita or Gobernadora. The combination of substrate type and slope results in Verdugo Canyon having the highest sediment transport rate per unit area of any of the sub-basins in San Juan Creek watershed. Sediment yield for Verdugo is second behind Bell Canyon. Like many of the steep silty and crystalline areas of the study area, much of the sediment in Verdugo is mobilized during episodic events and, when mobilized, has the potential to have substantial effect on sediment delivery and on the geomorphology of the downstream areas.



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 38
Baseline Conditions Report
2-Year, 10-Year, and 100-Year Event Hydrographs for Verdugo Canyon at Confluence with San Juan Creek

The large quantities of highly erodible soils in the Verdugo sub-basin can be expected to provide a source of phosphorus loading to San Juan Creek. Nitrogen loading from the sub-basin is expected to be low given that only six percent of the watershed is covered with grasslands, there are limited anthropogenic sources, and little channel incision. The terrains and steep slope of Verdugo Canyon likely results in direct nutrient and pollutant pathways to surface waters. The existence of an intact riparian corridor implies that there is potential for sequestration of constituents of concern within floodplain terraces, with increased amounts of organic carbon available to augment nitrogen cycling. Speciation is expected to favor the transport of metals and pesticides (were any to be present) in an adsorbed form.

The biological resources of Verdugo Canyon are also similar to those found in Bell or Lucas Canyon. The streams are predominantly coarse substrate with southern coast live oak riparian woodland, surrounded by sage scrub and chapparal. These areas are more similar to habitats found in the upper San Mateo watershed than to those found in Chiquita and Gobernadora. Because groundwater is less prevalent than in Chiquita or Gobernadora, the habitats are more mesic than the willow riparian habitats found in those sub-basins. The narrowness of the canyon results in high biological interaction between the habitats of the floodplain and the adjacent uplands.

6.1.3.2 Summary of Sub-Basin Opportunities and Constraints

Verdugo Canyon contains riparian habitat and possesses important sediment generation and transport processes. Specific opportunities and constraints are as follows:

- Verdugo Canyon contains significant riparian habitat and resources within a relatively narrow (i.e., geologically confined) floodplain.
- Verdugo Canyon is an important infiltration area within the watershed.
- Because Verdugo Canyon exhibits low relative discharge and low runoff volume and the peak flows lag behind those of San Juan Creek, it does not significantly contribute to runoff in the main stem of San Juan Creek.
- Verdugo Canyon provides an important source of sediments to downstream areas.

6.1.4 Central San Juan (including Trampas)

6.1.4.1 Overview of Sub-Basin Characteristics

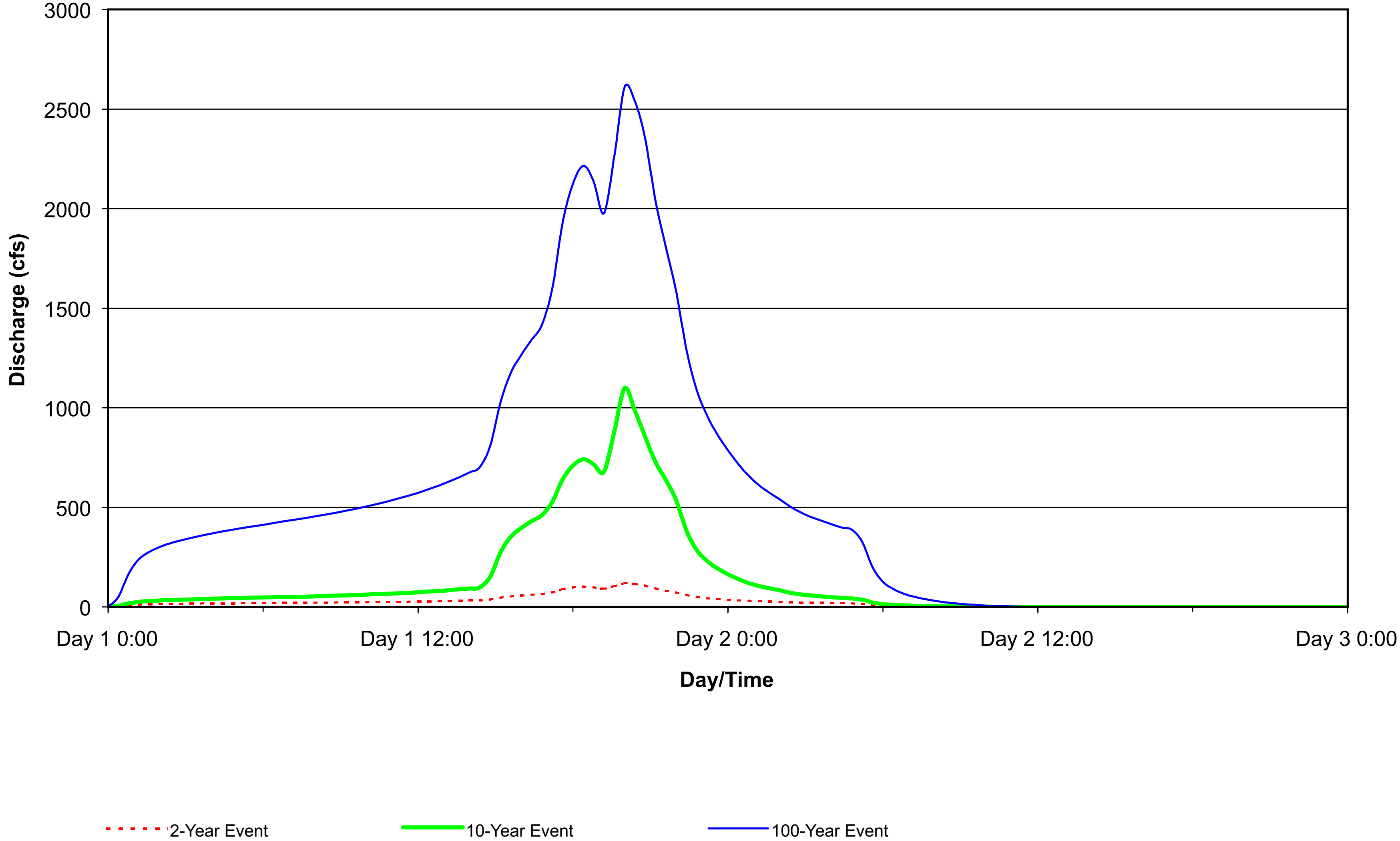
In the central portion of the San Juan watershed, about 10 to 12 miles upstream from the coast, there is a 7.4- $mi.^2$ area (between the mouths of Cañada Gobernadora and Bell Canyon upstream) that contains several small tributary drainages which feed directly into the main stem of

San Juan Creek. The area surrounding the Color Spot Nursery drains directly southward into the main San Juan system and, as such, is not part of either the Gobernadora or Bell Canyon sub-basins. This triangular area is drained by two third order creeks and one fourth order stream. On the south side of San Juan Creek, Trampas Canyon and two unnamed fourth order streams drain steep terrain directly to San Juan Creek. The central portion of the main stem of San Juan Creek, downstream of Bell, Lucas, and Verdugo Canyons, consists of a meandering river with several floodplain terraces in a wide valley bottom.

The Central San Juan and Trampas Canyon drainage basin is underlain by bedrock of the Santiago, Silverado, and Williams formations. Bedding within the bedrock of the Santiago, Silverado, and Williams formations is near horizontal to gently dipping. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides. There are two large landslide complexes located south of San Juan Creek along the western boundary of the drainage basin. In addition, two Late Quaternary fault systems, the Cristianitos and the Mission Viejo faults, trend through this drainage basin. The Cristianitos fault trends approximately northwest–southeast along the western boundary of the drainage basin south of San Juan Creek. Two branches of the Mission Viejo fault trend approximately north-south through the eastern portion of the drainage basin. Review of available geologic literature indicates these fault systems are not considered active pursuant to the guidelines of the Alquist-Priolo Earthquake Fault Zone Map.

The majority of the central San Juan sub-basin area is underlain by soils of hydrologic groups C (52.6 percent) and D (29.2 percent). Of the six sub-basins studied in the watershed, the Central San Juan catchments had nearly the highest maximum loss rate, second only to Lucas Canyon. This is likely reflective of the shallow slope and broad floodplain valley that facilitates infiltration.

Multiple tributary inputs result in hydrographs for the Central San Juan catchments characterized by two distinct and one subtle peak (see Figure 39 on page 130). This sub-basin differs from the other studied sub-basins in that the other sub-basins typically consist of a single canyon whose discharge joins San Juan Creek at a single confluence. The effects of these discharges on San Juan Creek occur primarily at the confluence point. By contrast, within the Central San Juan catchments sub-basin, effects of the surface runoff will be distributed in numerous locations along the reach of the main San Juan Creek channel. Therefore, it is difficult to establish a direct relationship between land use patterns in specific catchments and the effect on runoff patterns in San Juan Creek. For this reason, the results that characterize the runoff from this sub-basin and the effect of this runoff upon the flows in San Juan Creek discussed below should be interpreted cautiously.



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 39
Baseline Conditions Report
2-Year, 10-Year, 100-Year Event Hydrographs for Central San Juan Catchments

In the Central San Juan catchments, peak flows from the tributaries occur approximately 4.4 hours, 2.4 hours, and 2.0 hours before the San Juan Creek peak flows through this area for the 2-year, 10-year, and 100-year events, respectively. Partially due to this difference in peak timing, and also due to the moderate rates and volumes or runoff from this sub-basin, peak flows from the Central San Juan catchments do not have a significant impact on peak flows in San Juan Creek at the confluence and downstream. In absolute terms, runoff volumes and peak flows from the Central San Juan catchments are among the lowest of the six San Juan sub-basins studied. For all three events, the Central San Juan catchments contribute between 2 percent and 5.5 percent of the runoff volume to San Juan Creek at their confluence, while they occupy approximately 8.8 percent of the watershed area at that point. Peak flows from the Central San Juan catchments are approximately between 3.5 percent and 5.5 percent of peak flows in San Juan Creek at the confluence. For the three events modeled, the Central San Juan catchments produced between 24 percent and 69 percent as much runoff on a per-acre basis as the average for the San Juan Creek watershed as a whole, and peak discharge per unit area was among the lowest of the San Juan sub-basins. These low runoff values are likely due to the large proportion of undeveloped areas in the sub-basin, particularly along the central San Juan Creek floodplain, and the small size of the sub-basin in comparison to the other reported sub-basins. Low sub-basin slopes and a broader sub-basin shape may also reduce runoff by increasing infiltration.

The central portion of San Juan Creek is most important as a sediment transport reach. All the catchments that drain into this portion of San Juan Creek together produce a comparable amount of sediment as the Chiquita Canyon sub-basin. In addition, due to its size, there is a substantial amount of bedload transport that occurs along the central portion of San Juan Creek. However, the yield per unit area for the central catchments is the lowest of any area studied in the San Juan watershed. Like Cristianitos Creek, the central portion of San Juan functions as a sediment conduit between the major sediment-producing sub-basins and downstream areas. The nature of the soils in the central San Juan tributaries favors the relatively rapid mobilization of constituents into surface water flows and ready transport of pollutants out of the central sub-basins (e.g., Trampas Canyon) and into the main stem of San Juan Creek. The combination of predominant grasslands, erodible soils, and anthropogenic sources means that the sub-basins can be expected to generate relatively large nitrogen and phosphorus loadings for their size and may be a contributor to the increases in nutrient concentrations between Caspers Regional Park and La Novia that is evident in the Orange County PFRD monitoring program. However, some of the constituents may be sequestered (at least seasonally) within the permeable alluvial aquifers of San Juan Creek. High loads of fine sediment and particulates should favor the adsorbed phases of heavy metals and pesticides.

The central portion of San Juan Creek has intermittent to near perennial flow that is supported by alluvial groundwater that is near the surface, at least seasonally. The riparian habitats and pool and ponds depend on sufficient duration of shallow groundwater. This groundwater is recharged from sub-basins higher in the watershed and is conveyed in the alluvium through the central portion of San Juan Creek.

Agricultural and developed lands cover approximately 12 percent of the land in this sub-basin, with the nurseries being a key component of the land use. On the north side of San Juan Creek, above the Color Spot nursery, there are two major tributaries of note. The first bisects the site beginning as a moderate- to high-gradient, scrub-oak – dominated riparian zone in a chaparral matrix. As the gradient decreases, the sinuosity increases, and the stream corridor supports mature oak woodland. The lowest portion of the stream transitions into a 3-foot-deep-by-5-foot-wide incised channel, characterized by mule fat scrub habitat. The substrate of the stream is dominated by rock and boulders indicating a high energy system where the stream condition is controlled by episodic high velocity flows that convey a lot of debris from the upper watershed. The second drainage feature on the north side of the creek flows out of a canyon to into a manmade impoundment. The upper portion of the stream consists of high gradient, scrub-oak dominated riparian habitat in a chaparral matrix, similar to the main canyon. As this stream flows toward the impoundment, the slope flattens and the vegetation community transitions into southern-willow riparian habitat, with an understory dominated by *Scirpus* spp. and *Baccharis salicifolia* (mule fat). Although not occupied at present, the structure and composition of the lower portion of the drainage appears to be suitable for occupation by least Bell's vireo or southwestern willow flycatcher. The pond at the terminus of this drainage is impounded by a road fill and lacks any substantive fringing wetland vegetation.

The area along Radio Tower Road, on the south side of San Juan Creek, contains representatives of all the major wetland types in the study area: riverine, alkali marsh, slope wetlands, vernal pool, and lacustrine fringe wetlands. The riverine areas on the site are generally high-gradient, low-order streams characterized as steep canyons dominated by sycamore or willow riparian forest. Portions of the drainages appear to have perennial flow, probably associated with groundwater discharge and areas of heavy soils (i.e., relatively high clay content).

Two portions of the site were found to contain slope wetlands associated with localized slumps that result in groundwater discharge. The first area has formed in a small slump adjacent to the main dirt road traversing the site, while the second area is above a corral and contains two slope wetlands. A natural spring has been altered to create a stock pond, and a 240-foot-long-by-45-foot-wide slope wetland has formed in, association with the spring and pond. A second slope wetland is located approximately 200 feet west of the spring, in association with a cut in the slope. Both slope wetlands are saturated at or near the surface for the majority of the year. The site contains three distinct areas that support vernal pools. All the pools have recently been documented to support both the San Diego and the Riversidean fairy shrimp. Several manmade stockponds in this areas support fringing lacustrine wetlands. These ponds provide year-round habitat for amphibians (including bullfrogs) and waterfowl. All upland areas have been heavily grazed and are dominated by non-native grasslands.

Sand, hard rock, and minerals have been mined from Trampas Canyon over the last 50 years. A lake in the abandoned quarry pit dominates this sub-basin. The lake is steep-sided, relatively deep, and does not appear to support any aquatic resources of note. The surrounding uplands are dominated by ruderal vegetation and contain minimal habitat value. Consequently, there are minimal resources of import associated with this drainage area.

The middle reach of the main stem of San Juan Creek is a broad, meandering stream with several floodplain terraces. The creek supports a mosaic of southern willow riparian woodland, mule fat scrub, open water, and sand bars. The adjacent terraces support coast live oak woodland and southern sycamore riparian woodland. The creek has relatively coarse substrate and high topographic complexity, with a variety of secondary channels, pits, ponds, and bars. An abandoned aggregate mining pit has been filling in over the last several years and supports an open water and emergent marsh community. The southwestern arroyo toad is known to occur in the middle reaches of San Juan Creek, but the bullfrog population associated with the old mining pit may affect the population size.

6.1.4.2 Summary of Sub-Basin Opportunities and Constraints

The Central San Juan catchments support a suite of aquatic resources and provide important sediment transport capacity, and arroyo toads have been observed using this area. Specific opportunities and constraints are as follows:

- The area along Radio Tower Road contains a diversity of wetland types in close proximity to each other, thereby increasing heterogeneity of the landscape from an aquatic resources perspective.
- The Trampas Canyon sub-basin is severely degraded and contains minimal aquatic resources of note.
- Most of the Central San Juan catchments are in sandy terrains that provide good infiltration capacity. However, these terrains are susceptible to adverse impacts associated with increased erosion and sediment production to San Juan Creek.
- The central portion of San Juan Creek provides important sediment transport capacity. If not properly addressed, increases in the velocity or volume of discharge could result in increased channel sediment generation and resultant channel incisions.
- High nitrogen and phosphorus loadings are expected from the tributary sub-basins of central San Juan Creek.
- Arroyo toad habitat is present that provides connectivity to toad populations in Caspers Park. However, this reach of San Juan Creek does not appear to support large resident

populations of arroyo toad. Opportunities to manage the habitat in this reach and control exotic predators will be coordinated through the NCCP/HCP.

6.2 SAN MATEO CREEK WATERSHED

6.2.1 Gabino

6.2.1.1 Overview of Sub-basin Characteristics

Gabino Canyon is underlain primarily by bedrock of the Williams Formation (Pleasants sandstone and Schulz Ranch members), along with the Santiago, Silverado, Ladd (Baker Canyon member), and Trabuco formations. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides. The Mission Viejo fault trends north-south through the southwestern portion of the drainage basin. Although not considered active, this fault affects the terrains and subsurface water movement in the canyon.

The Gabino sub-basin is underlain by clayey and crystalline terrains that generally produce higher runoff volumes per unit area than sandier areas. However, compared to other crystalline terrains in the study area, Gabino Canyon has the highest infiltration capacity of any of the analyzed sub-basins in the San Mateo watershed.[31] Approximately 56 percent of the upper sub-basin is underlain by Type C soils, with 31 percent of the upper basin having the least permeable Type D soils. Infiltration capacity is somewhat lower in the lower portion of the sub-basin and Blind Canyon, with D-type soils being predominant.

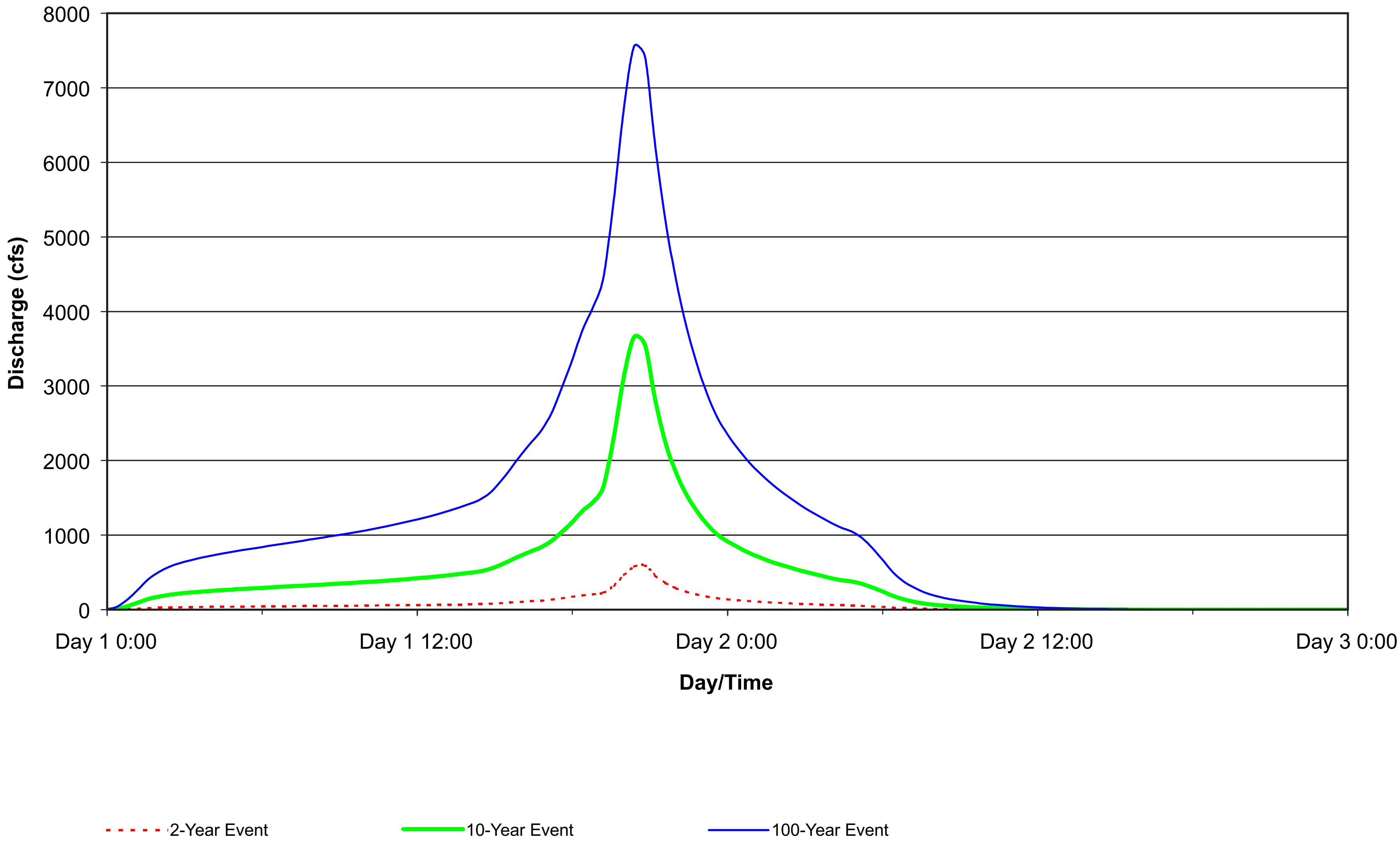
Gabino Canyon is 8.3 $mi.^2$ and approximately 10 miles long. Along with Talega Canyon, it is the largest sub-basin in the upper San Mateo watershed. Its size, along with its position high in the watershed, and steep terrain produce the highest absolute peak flows and runoff volumes in the upper San Mateo watershed. The crystalline terrains and position in the watershed also result in relatively high drainage density. The 1,274 first order drainages within the Gabino sub-basin account for approximately 51 percent of the stream miles in the sub-basin. At its confluence with La Paz, Gabino Creek is a sixth order stream, until it joins Cristianitos Canyon further downstream. In absolute terms, peak flow rates and volumes at the mouth of Gabino Canyon are at least four times greater than flows entering from the neighboring upper Cristianitos sub-basin, which is a considerably smaller watershed area. However, Gabino Canyon has lower runoff per unit area than either La Paz or Talega Canyons, reflecting the somewhat higher infiltration capacity than these other sub-basins. The simulated hydrographs for Gabino Canyon have a similar shape to the La Paz Canyon hydrographs, with a single distinct peak that rises and falls relatively rapidly. The rising

[31] *Runoff volumes in Gabino Canyon are higher than those for the sandier areas of the San Juan watershed.*

limb of the hydrograph is steeper than the falling limb. This shape is indicative of a somewhat flashy responsive watershed and may be attributable to the crystalline terrain, as well as the shape and slope of the watershed (see Figure 40 on page 136). Flows exiting Gabino Canyon peak about 1.2 hours, 0.8 hours, and 0.4 hours after peak flows have exited the upper Cristianitos sub-basin (upstream of the Gabino confluence) for the 2-year, 10-year, and 100-year events respectively. Interestingly, for the 2-year and 10-year events, storm peaks are somewhat attenuated between the Upper Gabino/La Paz confluence upstream and the Gabino/Cristianitos confluence downstream. This is not the case for the 100-year event, whereby the downstream location has higher peak flows. The proximity of timing of peak flows during more extreme events results in peak flows from Gabino Canyon having the potential to directly add to peak flows in Cristianitos Canyon at the confluence, significantly increasing the downstream hydrograph.

Gabino Canyon was calculated to have the highest sediment yield and transport rate of any sub-basin analyzed in the San Mateo watershed. These high yields are partially attributable to the size of the sub-basin; however, the transport rate per unit area is also high, second only to the Cristianitos sub-basin. Cobbles and other larger particles comprise the majority of sediment produced in this sub-basin; however, unlike La Paz, sand comprises a substantial portion of the sediment produced. The relatively high proportion of underlying sandy substrates (compared to the rest of the crystalline areas in the study area) likely contributes to the high sediment yield predicted for Gabino Canyon. Incision of the channel in the reaches just upstream of the confluence with La Paz also is a likely source of sediment. However, a significant portion of the sediment production is probably associated with erosion caused by historic grazing. Conversion of native habitat to non-native grassland, along with continued grazing, appears to have resulted in extensive gully formation adjacent to Gabino Creek and resultant increases in sediment delivery to downstream areas. A critical feature of the sediment transport characteristics of Gabino Canyon is that most of the sediment is mobilized during extreme episodic events, when the topography, unstable upland soils, and substrate types contribute to produce large quantities of sediment. This sediment is probably very important to downstream channel structure and provides habitat for sensitive species in the middle and lower watershed.

The high proportion of grasslands in the upper watershed represents a potential source of high nitrogen loadings. Similarly phosphate loadings are expected to be moderate, mainly associated with erosion in the upper watershed. Incision in the upper reaches of Gabino Canyon and the naturally confined floodplain in the lower reaches mean that assimilation of nitrate and phosphate loadings are expected to be low to moderate within the riparian floodplain. Baseline metal loadings should be relatively low under existing conditions with most metals transported in particulate form.



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 40
Baseline Conditions Report
2-Year, 10-Year, and 100-Year Event Hydrographs for Gabino Canyon at Confluence with Cristianitos Creek

Groundwater is probably not a significant component of the aquatic ecosystems in the Gabino sub-basin. The channel is typically dry by May or June of even wet years. However, localized groundwater discharge was observed at several active headcuts in the upper watershed. Therefore, there may be localized areas (or sub-surface lenses) that provide localized shallow groundwater. Because the bedrock beneath Gabino Creek is comprised mainly of old, tightly consolidated sediments, any groundwater discharged would have above average specific conductance (i.e., higher salinity).

The dominant habitat types in the upper portion of Gabino Canyon, above the confluence with La Paz Creek, is southern coast live oak riparian woodland. The adjacent uplands are primarily ruderal grasslands with sage scrub on the hillslopes. The upper watershed has been heavily grazed and is incised in places with vegetation that has been cropped or trampled. The riparian zone varies in width from relatively narrow to relatively wide and is well developed (depending on the intensity of grazing). Historically, the stream probably migrated through the floodplain, but now is confined by headcutting and incision processes. In some reaches this incision is in excess of ten feet and appears to have intercepted subsurface flow. A manmade lake/stockpond in upper Gabino canyon, informally known as "Jerome's Pond," captures water from Gabino Creek and three unnamed tributaries. The pond can be characterized as a hemi-marsh mix of open water and bulrush (*S. californicus*). Where Gabino creek flows into the stockpond, there is a delta dominated by mule fat scrub. The pond outlets into a tributary that supports willow riparian habitat and eventually joins the main flows of Gabino Creek. Above the pond, the tributaries are a mix of oak riparian and broad floodplain sycamore habitats. Portions of these tributaries exhibit slumping and erosion, probably resulting from grazing impacts, perhaps in conjunction with fires. A major unnamed tributary flows into Gabino Creek just upstream of its confluence with La Paz Creek. The natural drainage pattern of this tributary has been substantially altered over time by mining activities, including the creation of a series of artificial ponds.

Lower Gabino Creek (below the confluence with La Paz), middle Gabino Creek, and La Paz Creek support structurally diverse, mature oak and southern sycamore riparian woodland with dense chaparral on the adjacent slopes. The center of the stream has a rock cobble substrate overlain by areas of shallow alluvial deposits that support mule fat scrub. The floodplain and riparian zones in the lower sub-basin are confined by the geology of the valley, but contain high topographic complexity (including bars and ponds that were inundated during our site visit), an abundance of coarse and fine woody debris, leaf litter, and a mosaic of plant communities. In many years, the creek flows through the late spring and seasonal pools persist in some locations, but seldom through the summer.

Blind Canyon is a major tributary watershed to Gabino and, as such, was analyzed as part of the lower Gabino system. Blind Canyon is a high gradient, coarse substrate stream, dominated by sycamore and oak riparian gallery forest with a mule fat-dominated understory. The stream contains good topographic complexity, leaf litter, and coarse and fine woody debris. There are numerous high gradient, low order tributaries to Blind Canyon on the site. Some contain scrub oak-dominated riparian forest, others are unvegetated swales. Several of the tributaries appear to pond seasonally at naturally occurring grade changes, but do not exhibit any features of slope wetlands.

6.2.1.2 Summary of Sub-Basin Opportunities and Constraints

Gabino Canyon contains mature oak and sycamore riparian woodlands and provides an important source of sediment to downstream areas. Specific opportunities and constraints are as follows:

- The Gabino sub-basin has a high drainage density and high number of confluence points;
- The floodplain of Gabino Creek is narrow and geologically confined;
- Gabino Canyon provides important sediment yields, though these yields may currently be in excess of natural conditions.
- The crystalline soils in the sub-basin are less sensitive to increases in runoff than sandy soils in other areas, and the lower portion of Gabino Creek has the ability to attenuate increased flows. This pattern is reflected in the hydrographs for the sub-basin (see Figure 40 on page 136).
- The combination of grazing and underlying soils has resulted in incision of upper Gabino Creek (and the associated increase in in-stream sediment production). Remediation of existing upland erosion implementation of a grazing management program and revegetation would improve the current channel instability and reduce sediment loading to the lower watershed over the long term.
- The oak and sycamore gallery forests of lower Gabino Creek represent some of the highest quality riparian habitat in the study area. In addition, portions of upper Gabino Creek supports degraded alkali marsh habitat. This area has high restoration potential, if the channel incision is stabilized.
- A major tributary on the north side of the lower reach of Gabino Canyon has been substantially altered and presents significant restoration opportunities.
- Gabino Creek supports a population of the federally-listed endangered arroyo toad.

6.2.2 La Paz

6.2.2.1 Overview of Sub-Basin Characteristics

La Paz Creek is the major tributary drainage to Gabino Creek, and the two sub-basins share many common characteristics. Approximately two-thirds of the 7.3 mi.^{2} La Paz sub-basin is within the RMV boundary. The La Paz Canyon drainage basin is underlain by bedrock of the Williams and Trabuco formations and the Santiago Peak Volcanics. Within the boundaries of RMV, the underlying bedrock consists of the Schulz Ranch member of the Williams formation and the Trabuco formation. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides.

La Paz creek is a lengthy, fifth order stream and has several fourth order parallel drainages joining it from the eastern hillslopes. Like most of the sub-basins in the upper San Mateo watershed, the steep crystalline terrains produce high drainage density and multiple confluence points. The sub-basin includes 575 first order and 110 second order drainages and has a drainage density of 10 mi/ mi.^{2}. The longest watercourse is approximately 6.8 miles. First order drainages comprise 54 percent of the total streamcourse length in the basin. The narrow western strip of La Paz Canyon is characterized by short, second order streams which drain from the dividing ridge with Upper Gabino Canyon and feed into the main La Paz channel. The fourth order confluence points in the eastern tributaries are associated with dense stands of oak and sycamore woodland and may represent zones of relatively high geomorphic and habitat function.

Runoff and infiltration patterns are similar to those predicted for Gabino Canyon, but at a lower magnitude due to the smaller size of the sub-basin. Runoff per unit area is greater for La Paz Canyon than for Gabino Canyon. This difference results from the fact that the headwaters of La Paz Canyon are approximately 800 feet higher than those of Gabino. The higher portions of the sub-basin receive greater rainfall due to orographic effects. In addition, the upper portions of La Paz Canyon have a high proportion of crystalline terrains and class D soils. Therefore, the portions of La Paz Canyon that receive the most rainfall have the highest expected runoff volumes, resulting high runoff per unit are for the sub-basin as a whole.

The calculated infiltration and loss rates fall in the middle of the calculated range for the reported San Mateo watershed sub-basins. These mid-range rates reflect a balance between poor infiltrating soils in an undeveloped watershed. The majority of the sub-basin is underlain by soils of hydrologic groups C (43.8 percent) and D (47.8 percent) and the sub-basin is nearly entirely undeveloped (99.6 percent). Agricultural and developed lands (mostly roads) cover approximately 0.4 percent of the sub-basin. Therefore, only a very tiny fraction of the basin is impervious to infiltration. Predicted hydrographs for La Paz Canyon display a single distinct peak that rises and falls relatively rapidly. The rising limb of the hydrograph is steeper (convex) than the falling limb (concave). This shape is indicative of a somewhat flashy responsive watershed and may be attributable to the relatively high proportion of low-permeability soils in the watershed. The timing of peak flows is identical to the peak time for upper Gabino Canyon at its confluence with La Paz Canyon. This is not surprising considering that the Upper Gabino Canyon and La Paz Canyon drainages are very similar in size and shape. As a result, peak streamflow from La Paz Canyon directly contributes to increasing peak discharge at Gabino Canyon and further downstream. Runoff per unit area for La Paz Canyon is between 61 percent and 73 percent of the average for the entire San Mateo watershed for the 2-year, 10-year, and 100-year events.

Predicted sediment yields and transport rates for La Paz Canyon are the lowest of any of the sub-basins analyzed in the San Mateo watershed. Rates and yields are comparable to those of the upper Cristianitos sub-basin, which is approximately half the size of La Paz. The low yields may be partially due to the relatively large proportion of very coarse substrates (i.e., large cobbles and boulders) produced from La Paz Canyon. These coarse substrates are likely mobilized very infrequently during large-scale episodic events, at which time they play a significant role in reshaping the geomorphology of the lower portions of the watershed. Groundwater is not a significant contributing factor to the ecology of the riparian systems in the La Paz sub-basin.

Existing nitrogen loadings in the La Paz sub-basin should be relatively low. The lack of well-developed floodplain structure likely limits the ability of the sub-basin to store phosphates and fairly significant quantities are probably mobilized and transported to the main stem of the San Mateo during high flow events. Background metal loadings are likely to be relatively low, with metal speciation favoring particulate forms

La Paz Creek supports dense stands of structurally diverse, mature coast live oak and southern sycamore riparian woodlands. The riparian zones are confined by the geology of the valley, but contain high topographic complexity (including bars and ponds that are inundated late into the spring), an abundance of coarse and fine woody debris, leaf litter, and a mosaic of understory plant communities. In the upper reaches of the sub-basin, the streams are narrow and form tight mosaics with the chaparral and sage scrub of the adjacent uplands. The rock and cobble substrate type that dominates the streambed is reflective of the slope and geologic setting of the sub-basin. Portions of the streams that convey seasonal high velocity flows also retain water for extended periods of time in shallow depressions within the active channel. The seasonal depressions, combined with the open bars and variety of plant communities, likely provide many niches and support complex and inter-related communities.

6.2.2.2 Summary of Sub-Basin Opportunities and Constraints

La Paz Canyon opportunities and constraints are similar to those for Gabino Canyon and include the following:

- The La Paz sub-basin has a high drainage density and high number of confluence points;
- The floodplain of La Paz Creek is narrow and geologically confined;
- La Paz Canyon provides important sediment yields; and
- The oak and sycamore gallery forests of La Paz Creek represent some of the highest quality riparian habitat in the study area.

6.2.3 Cristianitos

6.2.3.1 Overview of Sub-basin Characteristics

The 3.7 mi.^{2} Cristianitos Canyon drainage basin (upstream of the confluence with Gabino Creek) is underlain by bedrock of the Santiago and Silverado formations. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits, and a few landslides.

The upper Cristianitos Canyon is a fifth order network with a calculated drainage density of 8 mi/ mi.^{2}. Compared with other sub-basins of this study, the upper Cristianitos watershed has a more rounded, or pear-shaped, configuration. Additionally, the headwater areas are not as steep as many of the other sub-basins. These conditions reflect the physiographic and geologic setting of the upper Cristianitos basin just south of the dividing ridge with the San Juan watershed. As a result of this setting, third and fourth order tributary arms are distributed fairly evenly and have similar lengths. There are 187 first order drainages that account for nearly half of the basin's total stream length.

The majority of the Cristianitos sub-basin is underlain by poorly infiltrating soils of hydrologic groups C (43.9 percent) and D (42.7 percent). However, compared to other sub-basins of the San Mateo watershed studied, the upper Cristianitos Canyon also contains a relatively large portion of the better infiltrating soil group B (12.9 percent). The relatively high proportion of Type B soils and the minimal development in the sub-basin produce relatively high infiltration rates relative to the other reported sub-basins within the San Mateo watershed.[32]

The more gently sloping shape of the headwaters of this drainage, high infiltration rates, and a drainage network which dampens flow peaks results in a less "flashy" hydrograph than observed in other sub-basins of the upper San Mateo watershed. The hydrograph for Cristianitos Canyon has a broader base with lower flow rates. As noted in Section 6.2.1.1, the peak time for Cristianitos is

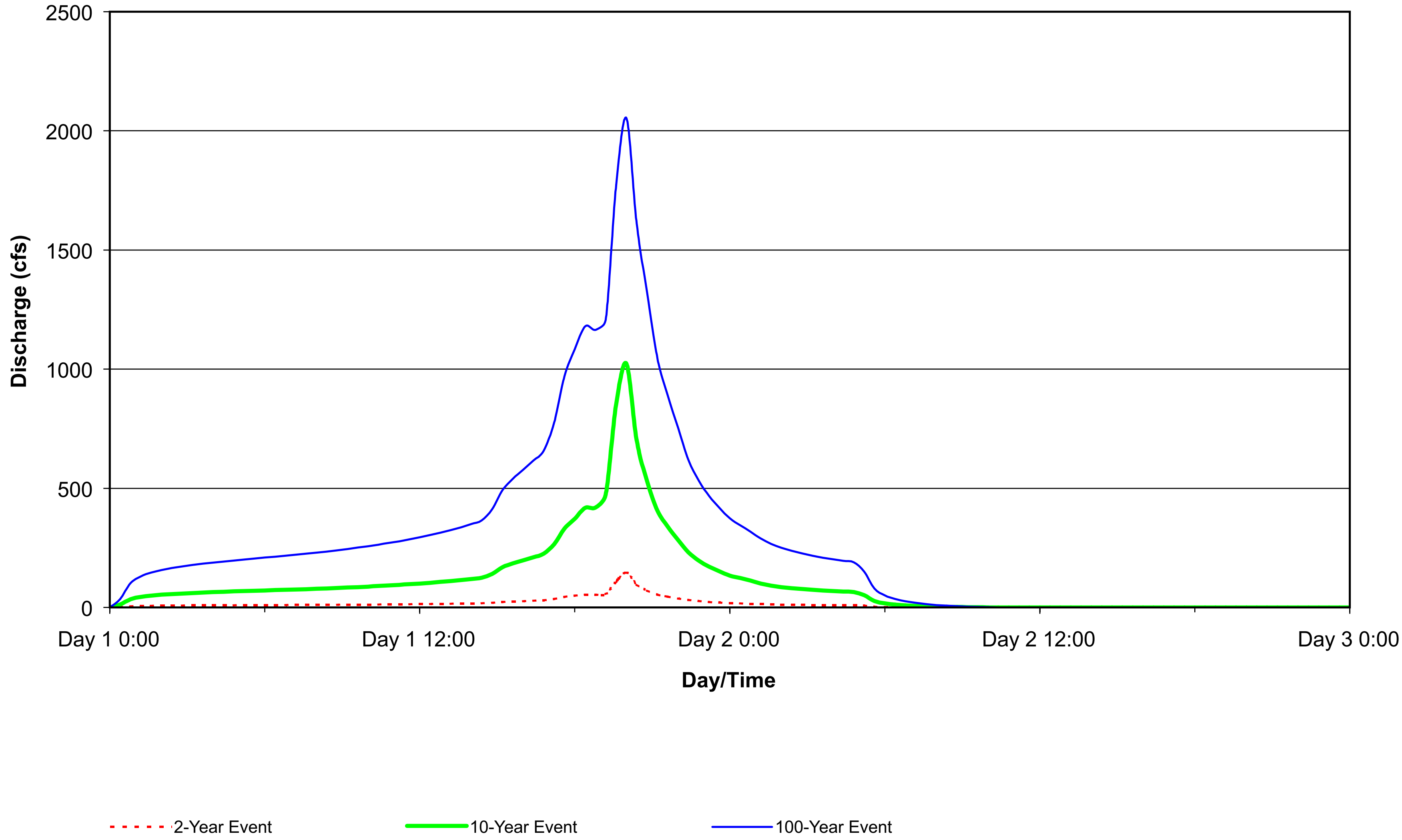
[32] *Runoff volumes in Cristianitos Canyon are higher than those for the sandier areas of the San Juan watershed.*

identical to the peak time for Gabino Canyon at their confluence. Therefore, peak flows from Gabino Canyon and Cristianitos Canyon combine simultaneously at the confluence, and this significantly increases the hydrograph downstream (see Figure 41 on page 143). In absolute terms, runoff volumes and peak flows from Cristianitos Canyon are the lowest of the studied San Mateo sub-basins, primarily due to the smaller size of this sub-basin. In terms of peak discharge per unit area, upper Cristianitos had the highest rates for the 10-year and 100-year events of the studied San Mateo sub-basins. This higher result for peak discharge per unit area may be somewhat surprising, considering Cristianitos Canyon had more favorable soil and infiltration conditions than the other studied San Mateo sub-basins. It is believed that routing conditions in the Cristianitos Canyon sub-basin, which is the least elongated of the San Mateo sub-basins, enhance flow concentration and generate larger peak flows per unit area. In terms of runoff per unit area, values from Cristianitos Canyon are lower than the other studied sub-basins, only between 43 and 67 percent of the average for the entire San Mateo watershed.

The substrate type in Cristianitos Creek is primarily sands and silts, with a significant portion of clays. However, the lower portion of Cristianitos Creek appears to be actively incising. Review of aerial photographs shows that prior to the extreme flow event of 1938, the reach of Cristianitos Creek upstream from the confluence of Gabino Creek was little more than a swale and seems to have incised 8 to 15 feet since that time. This portion of the creek is likely susceptible to further incision, and associated in-channel sediment generation, during extreme flow events. Sediment transport rate per unit area for the Cristianitos sub-basin is the highest of any San Mateo sub-basin studied. However, because of the small size of the Cristianitos sub-basin, the gross sediment yield and transport rate is the lowest of the studies sub-basins. From a sediment processes perspective, Cristianitos Creek is probably most important as a transport reach, conveying material generated higher in the watershed to downstream areas. Continued incision would interfere with this function.

Pollutant transport and cycling likely occurs predominately within surface waters. The extent of grasslands in the sub-basin strongly suggests that nitrogen loading is currently high, while the high erosion potential indicates that the mobilization of phosphorus sources may be equally high. Metal loadings to the sub-basin are likely low at present and most metal transport can be expected in the particulate form.

Aquatic resources in the Cristianitos sub-basin consist of both riverine and lacustrine (associated with abandoned clay pit mines and stockponds) systems. The upper portions of the sub-basin consist of a ridge or spine with canyons on both sides. These canyons are steep and narrow and contain well-developed, mature oak riparian woodland in a matrix of intact chaparral and coastal sage scrub. Although the total jurisdictional area associated with these drainages may be small, their structure, position in the landscape (in the headwaters), and juxtaposition with intact upland plant communities results in high functioning upland/wetland ecosystems. Cristianitos



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 41
Baseline Conditions Report
2-Year, 10-Year, and 100-Year Event Hydrographs for Cristianitos Canyon at Confluence with Gabino Canyon

Creek, below an existing stockpond, is a meandering stream that contains alkali marsh communities mixed with willow and mule fat. However this reach is actively incising. Reaches just upstream of Gabino Creek have near-perennial flow, apparently supported by discrete loci of groundwater discharge. The persistent saturation has facilitated development of well-structured hydric soils, and as the gradient flattens, there is a moderate width floodplain associated with the stream. This area supports the highest diversity of wetland species of any of the San Mateo sub-basins studied.

There are several lacustrine wetlands in the sub-basin associated with abandoned clay pits or stockponds. In general, these areas appear to be functioning as intact wetlands. They contain a mix of open water and emergent marsh vegetation. Most are surrounded by a mix of sage scrub and grasslands. One of the stockponds on the lower end of Cristianitos Creek has a stream dominated by mule fat scrub draining into it. The ponds generally appear to have low turbidity and are being used by fish, invertebrates, amphibians, and birds. A large, abandoned claypit exists near the southern boundary of the sub-basin. This pit is approximately 80 to 100 feet deep and dominated by open water with a narrow fringe of emergent marsh habitat. This large, abandoned pit is blue-green in color, and it does not appear to be functioning as a viable ecosystem. Adjacent uplands in the sub-basin have a percentage of clay soils and may support sensitive plant populations.

6.2.3.2 Summary of Sub-Basin Opportunities and Constraints

Cristianitos Canyon includes a significant riparian-upland habitat matrix, alkaline marsh areas, and transport capacity through the system. Specific opportunities and constraints are as follows:

- The upper portion of the sub-basin contains high-quality oak riparian/upland complexes. This matrix of habitat types likely provides high overall biodiversity as an upland-riparian unit.
- The alkali marsh wetlands within the middle portion of the sub-basin are considered regionally significant. The hydrology of lower Cristianitos Creek is not fully understood; however, the dependence of this site on groundwater means that activities in the watershed may affect this resource.
- The riparian zone of Cristianitos Creek likely provides connective function between the upper watershed resources and areas downstream (off Rancho Mission Viejo property).
- Cristianitos Creek has been actively incising since 1938 and is likely susceptible to further incision and associated in-channel sediment generation. This area represents a restoration opportunity.

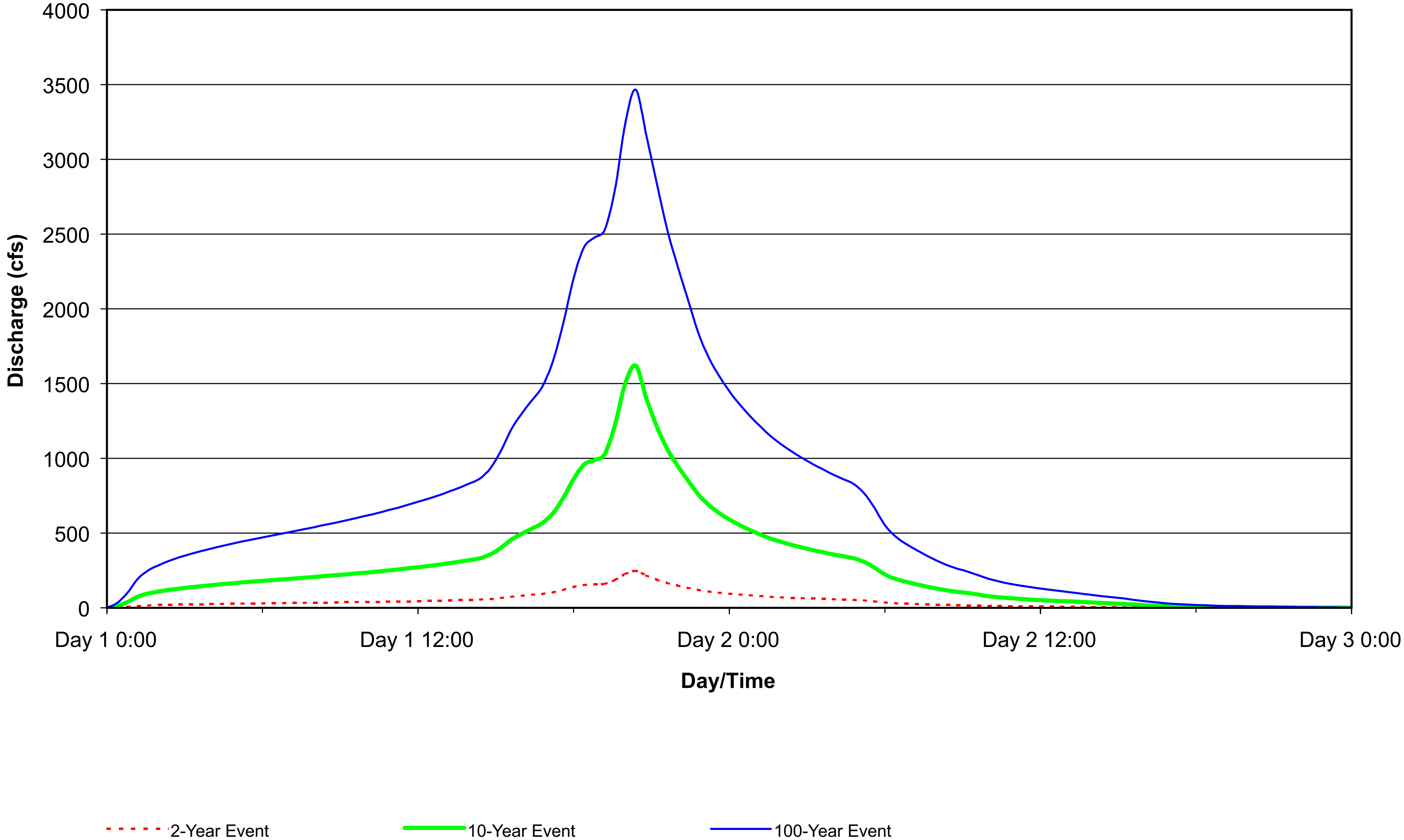
- The sediment transport capacity of Cristianitos Creek is important as a means to ensure that materials produced in the upper watershed are delivered to downstream areas.

6.2.4 Talega

6.2.4.1 Overview of Sub-Basin Characteristics

The Talega Canyon drainage straddles the boundary of Rancho Mission Viejo and Camp Pendleton. The basin is underlain by bedrock of the Santiago, Silverado, Williams, and Trabuco formations and the Santiago Peak Volcanics. Approximately one-third to one-half of the Talega Canyon drainage basin lies within the project boundary, most of which is occupied by the existing TRW facilities. Within the boundaries of RMV, the underlying bedrock consists of the Santiago and Silverado formations and the Pleasants sandstone and Schulz Ranch members of the Williams formations. Surficial geologic units within the project boundaries consist of alluvium, colluvium, nonmarine terrace deposits and a few landslides.

Talega Creek is a fifth order system where it meets Cristianitos Canyon, downstream of the Gabino Confluence. The 8.3 $mi.^2$ sub-basin has a drainage density of 9 mi/ $mi.^2$, with 501 first order channels. The Talega Canyon sub-basin is extremely elongated, with the longest watercourse over 10.1 miles. The majority of the sub-watershed is underlain by soils of hydrologic groups C (18.8 percent) and D (75.6 percent). Talega Canyon has the highest proportion of poorer infiltrating Type D soils of any of the other sub-basins analyzed in the San Mateo watershed. When considered as a percentage of total storm event rainfall, hydrologic losses in Talega Canyon were the lowest of all reported San Mateo sub-watersheds, for all three modeled storm events. Overall, the low loss rates calculated for Talega Canyon indicate that infiltration rates within the sub-basin are also low, relative to the other reported sub-basins. Although the hydrographs for Talega Creek have a pronounced peak, they are relatively broad (see Figure 42 on page 146). This shape may be attributable to the elongated geometry of the Talega Canyon sub-basin, which tends to attenuate the flood wave as it travels through the sub-basin. While upper tributaries contribute runoff to the main trunk stream, lower tributaries have already conveyed their runoff out of the sub-basin. As a result, elongated basins like Talega Canyon can have dampened hydrographs. In absolute terms, runoff volumes and peak flows from Talega Canyon are in the upper-middle of the range compared to other reported San Mateo sub-basins. Talega Canyon contributes about 33 percent of the runoff volume to Cristianitos Creek at their confluence while it occupies approximately 28.76 percent of the upstream watershed area at that point. Peak flows from Talega Canyon are approximately 25 percent of peak flows in Cristianitos Creek at the confluence. In terms of runoff per unit area, Talega Canyon produced between 66 percent and 78 percent as much runoff on a per-acre basis as the average for the San Mateo Creek watershed as a whole. Talega Canyon is an interesting contrast between runoff peaks which are relatively low and runoff volumes which are relatively high. Higher runoff volumes are generated due to the high proportion of poorly draining soils. However,



Source: PWA, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 42
Baseline Conditions Report
2-Year, 10-Year, and 100-Year Event Hydrographs for Talega Canyon at Confluence with Cristianitos Creek

the elongated shape of the sub-basin and long routing distance reduces the magnitude of peak flow rates. Peak discharge rates are attenuated as they travel downstream through the sub-basin.

The lack of available data and the fact that a significant portion of the basin is outside the study area (in Camp Pendleton) prevented analysis of sediment yield or transport rates for this sub-basin.

Nitrogen loading from the Talega sub-basin should be relatively low given the existing land use and cover. However, the potential for generating large amounts of fine sediments indicates that Talega can be a significant source of phosphates. Historical aerial photography shows that a well-vegetated floodplain has often been absent, suggesting that the riparian corridor may play a relatively minor role in cycling of pollutants. However, some sequestration may occur in pockets where sandy substrates are found. Metal partitioning should heavily favor transport in the less biologically available particulate forms.

The riparian zones of Talega Creek are similar to those found in upper Cristianitos and Lower Gabino Creeks. Substrate is rock/cobble dominated with sandbars forming in depositional areas. The riparian habitat consists of dense stands of structurally diverse, mature coast live oak and southern sycamore riparian woodlands. Center portions of the creek support mule fat scrub and open sand bar habitat. The riparian zones are confined by the geology of the valley, but contain high topographic complexity, an abundance of coarse and fine woody debris, leaf litter, and a mosaic of understory plant communities. The creek contains shallow pools that retain water into the late spring and early summer. Some of the highest concentrations of southwestern arroyo toad in the San Mateo watershed are located along Talega Creek.

6.2.4.2 Summary of Sub-Basin Opportunities and Constraints

Talega Canyon includes high quality riparian habitat and a major arroyo toad population. Specific opportunities and constraints are as follows:

- The floodplain of Talega Creek is narrow and geologically confined.
- Talega Creek provides significant sediment yields.
- Talega Creek contains habitat supporting a “core population” of arroyo toads, including adjacent upland habitat and requisite sediment processes.
- The oak and sycamore gallery forests of Talega Creek represent some of the highest quality riparian habitat in the study area.

7.0 MAKING USE OF THE BASELINE CONDITIONS ANALYSIS

Completion of the analysis of baseline hydrologic, geomorphic, and biologic conditions in the San Juan and upper San Mateo Watersheds culminates the first phase of the coordinated SAMP/MSAA, NCCP/HCP, water quality, and local entitlement process. The subsequent phases of this coordinated planning process will: (1) analyze the effect of several proposed land use scenarios on the physical and biological processes of the study watersheds; (2) involve development of specific approaches, guidelines, and criteria for project design elements and BMPs that minimize the effects of land use changes by maintaining the hydrologic, water-quality, and hydrogeologic functions of the watersheds; (3) identify, where practicable, measures necessary to minimize or mitigate the effects of existing uses within the watersheds, but beyond the limits of the study area; and (4) develop specific elements of the aquatic and upland restoration and management programs.

The models and information developed as part of the assessment of baseline conditions will be used during the next phases of the planning process in a predictive manner to evaluate potential impacts and identify impact minimization measures, mitigation measures, and management recommendations. Application of the studies summarized in this Baseline Conditions Report to the SAMP/MSAA, NCCP/HCP, Comprehensive Water Quality Management Plan, and Local Entitlement processes are discussed in detail in Section 1.4 of this report. Examples of how each technical study will be applied to each planning/entitlement process are discussed below. This list is not inclusive, but meant to provide initial recommendations regarding application of the studies. In most cases, specific application of the technical studies will provide input to multiple environmental programs. When considering the application of the technical studies, it is important to be cognizant of the landscape scale and associated spatial accuracy of these studies. Many aspects of the studies affect the resolution and accuracy of the analysis, including field data collection, digitization and photo interpretation, coordinate registration, distortion in images (photos), and precision of the models. In general, the studies are appropriate for use during the alternatives analysis phase. However, certain design applications or detailed impact analyses may require more rigorous analysis.

7.1 APPLICATION OF THE TERRAINS ANALYSIS

SAMP/MSAA – The terrains analysis has identified areas that are conducive to recharge, susceptible to erosion and/or gully formation, and currently possess rapid runoff characteristics. This information will be used during the off-site alternatives analysis to site projects in a manner that has the least overall effect on physical processes in the watersheds, consistent with the overall project purpose. During the on-site alternatives analysis, the terrains analysis will be used to develop design features that minimize or mitigate impacts, in consideration of the intrinsic properties of the landscape.

NCCP/HCP – The terrains analysis will be used to provide recommendations for recharge areas that would help support existing or proposed riparian habitat that may be suitable for least Bell's vireo or southwestern willow flycatcher. Terrains information will also be used to develop management recommendations to: (1) minimize erosion or excessive sediment generation that could affect channel stability; and (2) provide mitigation for impacts to habitat for the arroyo toad or other aquatic species.

Water Quality – Analysis under the SAMP/MSAA and NCCP/HCP, relative to management of sediment generation and optimization of recharge, will also be used as part of the water quality control program to minimize and/or mitigate increases in sedimentation and turbidity by siting development in appropriate areas.

Local Entitlement – The soil and geologic characterizations in the terrains analysis will be used to support siting and design recommendations for specific projects, such as the location of specific structures, basins, and roads.

7.2 APPLICATION OF THE HYDROLOGIC ANALYSIS

SAMP/MSAA – During the off-site alternatives analysis, the results of the hydrologic analysis will be used to evaluate potential changes in flow regimes associated with the various development alternatives and discuss how these potential changes could affect the long-term integrity of wetland and riparian habitats and related species. During the on-site alternatives analysis, these studies will be used to provide recommendations for design features and mitigation measures to offset potential impacts of proposed land use changes. The effect of episodic events on channel stability will be evaluated, and routing of stream flows will be considered during selection of aquatic resource reserve areas to take advantage of natural attenuations of peak flows.

NCCP/HCP – The hydrologic models will be used to analyze the potential effects of land use changes to hydrologic characteristics that may affect the ability of riparian zones to support both sensitive and non-sensitive species. Characteristics to be analyzed include baseflow, annual storm flows, and extreme events.

Water Quality – The hydrologic analysis will provide information for development of stormwater management plans (including formulation of a "treatment train") and Management Measures for control of NPS pollution. These studies will be used to determine appropriate locations, sizes, and designs of water quality control facilities and features, such as basins and swales.

Local Entitlement – The hydrologic analysis will be used to provide input into detailed design of stormwater conveyance systems, detention, and retention facilities for each development area. The relationship of peak flow timing between tributaries and the main stem creeks will be considered during the design of development areas to avoid coincident peaks in downstream areas.

7.3 APPLICATION OF THE SEDIMENT ANALYSIS

SAMP/MSAA – Results of the sediment analysis will be used to evaluate potential impacts of development alternatives on sediment yield, long-term stability and integrity of streams and associated riparian habitat, and the role of floodplains as sediment sources or sinks. During the off-site alternatives analysis, this information will be used to provide guidance on the location of proposed development and reserve areas in a manner that maintains important sediment processes. During the on-site alternatives analysis, these studies will be used to develop design features that maintain appropriate sediment yields and transport rates in the major watercourses. In addition, the sediment analysis will be used to help design restoration strategies for streams that are currently incising.

NCCP/HCP – Analysis of sediment transport and associated stream stability will be used in the NCCP/HCP to ensure that sediment delivery and transport rates are managed in a way that protects aquatic habitats against channel degradation, restores currently degraded streams, and is protective of habitat for sensitive species, such as the arroyo toad. Sediment transport information will also be used to address downstream effects on sediment delivery to sensitive species habitat outside the study area.

Water Quality – The sediment yield and transport models will be used to address rates of sediment entry into channels during both the construction and post-development phases. BMPs and MMs under the NPS Pollution Control program will be developed to manage sediment delivery to streams. Results of the sediment analysis will also be used to help determine appropriate buffer widths adjacent to streams.

Local Entitlement – The sediment analysis will be used to address channel capacity and competence issues, relative to floodflow and sediment conveyance. These studies will also be used in the design and determination of maintenance needs for proposed flood control facilities. Design features (e.g., setbacks, basins, buffers) will accommodate both high frequency and episodic sediment yields.

7.4 APPLICATION OF WATER QUALITY STUDIES

SAMP/MSAA **–** Analysis of existing water quality constituents and potential future water quality loadings will be used to develop recommendations regarding riparian or wetland areas that could be avoided and/or enhanced. It will also be used to identify areas that could function as both habitat areas and water quality features.

NCCP/HCP **–** The water quality analysis will be used to evaluate the potential impacts of runoff associated with proposed land use changes on tolerances of aquatic habitats and NCCP/HCP-identified species, such as the arroyo toad.

Water Quality and Local Entitlement **–** The collection of both dry and wet season water quality data that has been initiated as part of the baseline conditions analysis will be continued. This information will establish the baseline condition for development of water quality control strategies for proposed developments. The water quality analysis will include an investigation of pollutant loadings to receiving waters under different development alternatives. Following this analysis, appropriate BMPs and general urban runoff MMs will be developed to meet State NPS Pollution Control Requirements.

7.5 APPLICATION OF THE GROUNDWATER ANALYSIS

SAMP/MSAA **–** Information on potential groundwater recharge areas will be used in the selection of development and reserve areas to help provide sufficient shallow subsurface water to support riparian habitats. In areas where perennialization may be of concern, potential recharge areas or other factors will be identified to ensure appropriate baseflow levels are maintained.

NCCP/HCP **–** The groundwater analysis will be used to identify recharge areas that may contribute to the function of adjacent streams that contain sensitive species or habitats.

Water Quality **–** The groundwater analysis will be used to develop appropriate infiltration basins that will be a component of the management of urban runoff in a manner that protects water quality and other beneficial uses of the main receiving waters.

Entitlement **–** The groundwater analysis will be used to help locate and design infiltration strategies (i.e., basins, swales, strips) within proposed development areas.

7.6 APPLICATION OF THE BIOLOGICAL RESOURCES ANALYSIS

SAMP/MSAA – During the off-site alternatives analysis, results of all the baseline technical studies will be used in conjunction with biological data collected as part of the NCCP/HCP, WES/CRRL studies, slope wetlands analysis, and vernal pool analysis to evaluate the areal and functional impact of proposed land use changes. This analysis will include analysis of the effect of upland land use changes on adjacent aquatic resources. During the on-site alternatives analysis phase, the biological analyses will be used to develop impact avoidance, minimization, and mitigation measures. These studies will also be used to prioritize aquatic resource preservation and restoration areas and to develop the aquatic resources restoration and management program.

NCCP/HCP – Application of the biological resources analysis to the NCCP/HCP will be similar and, in most cases, overlap application to the SAMP/MSAA. In addition, the relationship between physical processes and needs of sensitive species will be analyzed. A subsequent report on the hydrologic and geomorphic needs of listed species will be developed that links the known habitat and life history requirements of listed species to the physical processes in the San Juan and San Mateo Creek watersheds. The report will provide management recommendations for long-term management of sensitive species at the watershed and sub-watershed scales. The analysis for the NCCP/HCP will also include more attention to management of upland resources than that for the SAMP/MSAA.

Water Quality – The biological resources analysis will be used to provide recommendations for integration of wetlands and riparian areas, including buffers, into the comprehensive water quality management program.

Local Entitlement – Results of the biological resources analysis under the SAMP/MSAA and NCCP/HCP will be used to document satisfaction of local mitigation requirements under CEQA.

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Balance Hydrologics, Inc.

Technical Appendix A

Baseline Hydrologic Conditions
San Juan & Upper San Mateo Watersheds

Prepared for: **Rancho Mission Viejo**

May 30, 2001

Prepared by:

PWA

PHILIP WILLIAMS & ASSOCIATES

CONSULTANTS IN HYDROLOGY

PWA
PHILIP WILLIAMS & ASSOCIATES, LTD
CONSULTANTS IN HYDROLOGY

May 30, 2001

Richard M. Broming
28811 Ortega Highway
P.O. Box 9
San Juan Capistrano, CA 92693

RE: **Baseline Hydrology Report**
PWA Ref. # 1393

Dear Richard:

Enclosed is PWA's baseline hydrology report for conditions in the San Juan and San Mateo watersheds. This report serves as Technical Appendix A to the comprehensive team report, *Baseline Biologic, Hydrologic, and Geomorphic Conditions* (PCR, 2001). Together, the team report, this PWA Appendix, and the other studies conducted by team members support the San Juan/San Mateo Special Area Management Plan (SAMP), Southern Sub region Natural Communities Conservation Plan/Habitat Conservation Plan (NCCP/HCP), and Comprehensive Point and Non-point Source Pollution Control Program (NPS) for lands owned by Rancho Mission Viejo.

This baseline hydrologic information provides a foundation for identifying land use, reserve design, and management/enhancement alternatives and measures during subsequent *off-site and on-site* alternatives analyses. This foundation is a key to avoiding, minimizing, and mitigating impacts to aquatic resources to the maximum extent practicable.

The contents of the PWA Appendix include: a brief description of the project area's physical setting; a description of the approach and methods used for the hydrology analysis; watershed overview results for the San Juan and San Mateo drainage basins; more detailed hydrology results for 10 individual sub-basin areas; and results from in-channel sediment transport modeling.

PWA will support the team presentation of the *Baseline Report* and this Appendix in the coming weeks and will be available to discuss our results and their implications as needed. Conducting such studies as this one are important steps towards making good land management decisions. We at PWA appreciate the

Rancho's commitment to preserving the heritage and natural resources of the San Juan and San Mateo watersheds within the framework of your development objectives.

Sincerely,

Kenneth M. Schwarz, Ph.D. Project Director	Jeffrey P. Haltiner, Ph.D. Principal in Charge

Cc: Laura Eisenberg
Tom Staley
Eric Stein

Baseline Hydrologic Conditions of San Juan and Western San Mateo Creek Watersheds

Prepared for

Rancho Mission Viejo

Prepared by

Philip Williams & Associates, Ltd.

May 30, 2001

PWA Ref. # 1393

Services provided pursuant to this Agreement are intended solely for the use and benefit of the Rancho Mission Viejo.

No other person or entity shall be entitled to rely on the services, opinions, recommendations, plans or specifications provided pursuant to this agreement without the express written consent of Philip Williams & Associates, Ltd., 770 Tamalpais Drive, Suite 401, Corte Madera, California 94925.

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1. INTRODUCTION

1.1 BASELINE HYDROLOGY STUDIES AND THE SAMP/NCCP PROCESS

This report presents findings from hydrologic analyses conducted by Philip Williams & Associates, Ltd. (PWA) in the San Juan Creek and the upper San Mateo Creek watersheds of southern Orange County, California. PWA conducted several technical studies to provide an assessment of baseline conditions in support of the San Juan/San Mateo Special Area Management Plan (SAMP), Southern Sub region Natural Communities Conservation Plan/Habitat Conservation Plan (NCCP/HCP), and Comprehensive Point and Non-point Source Pollution Control Program (NPS) for lands owned by Rancho Mission Viejo. The boundaries of the study area generally coincide with those of the San Juan/San Mateo SAMP and southern sub-region NCCP (Figure 1-1). In addition to PWA's research, studies of baseline physical and ecologic conditions by Balance Hydrologics (BH), Dudek & Associates (Dudek), and PCR Services Corporation (PCR) are summarized in a comprehensive team report, *Baseline Biologic, Hydrologic, and Geomorphic Conditions* (PCR, 2001). The approach, methodology, and inter-relationships between the studies are described in detail in the *Work Plan for Hydrology and Geomorphology Studies* (PCR, 2000) (Work Plan).

The SAMP and NCCP/HCP programs are proactive planning efforts intended to achieve a balance between resource protection and economic development. The stated purpose of the SAMP is:

> "to develop and implement a watershed-wide aquatic resource management plan and implementation program, which will include preservation, enhancement, and restoration of aquatic resources, while allowing reasonable and responsible economic activities and development within the watershed-wide study area."

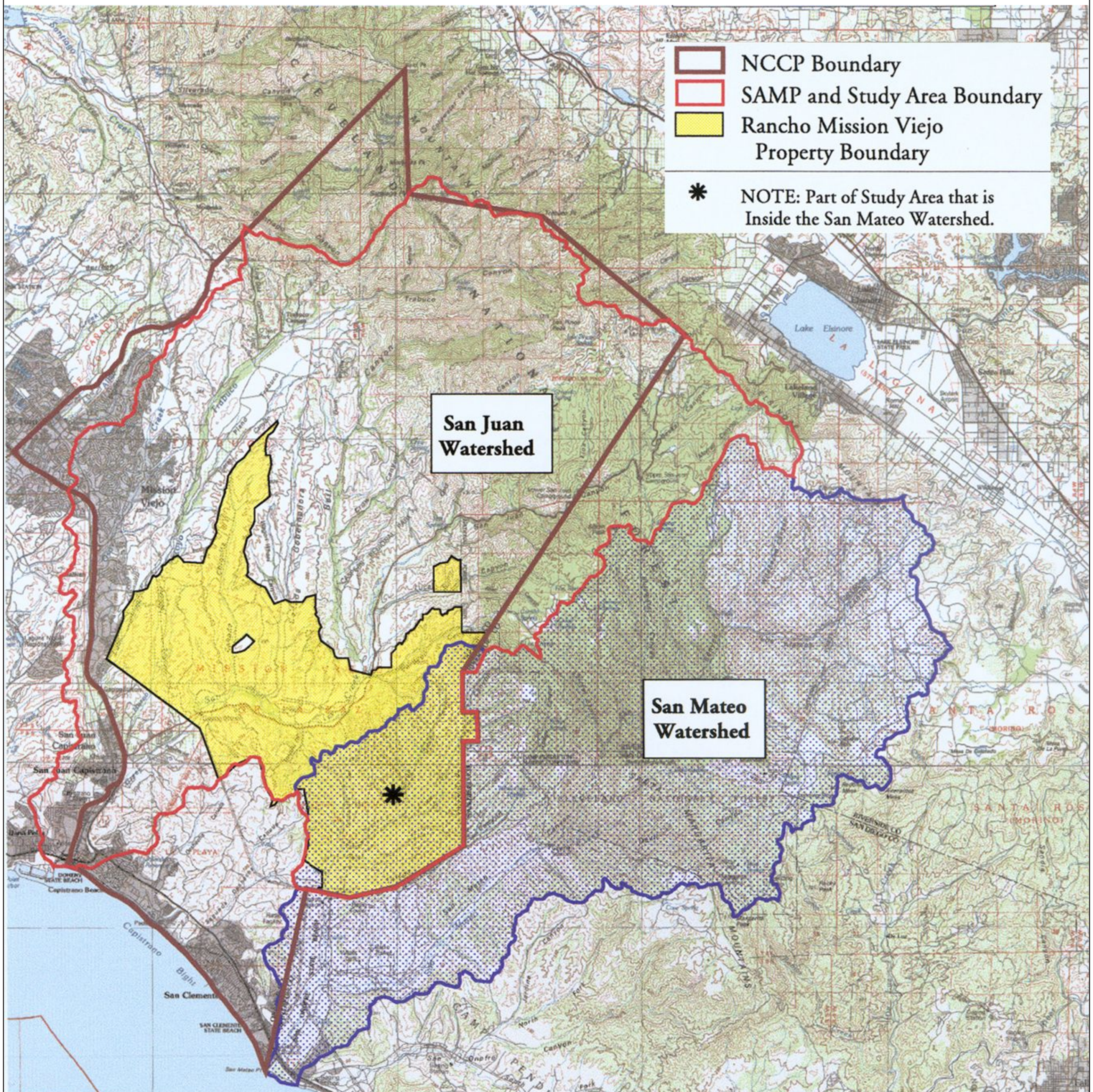
The primary objective of the NCCP/HCP program is:

> "to conserve natural communities and accommodate compatible land use. The program seeks to anticipate and prevent the controversies and gridlock caused by species' listings by focusing on the long-term stability of wildlife and plant communities and including key interests in the process."

The overall goal of the State Non-point Source Program is:

> "to manage NPS pollution, where feasible, at the watershed level, including pristine areas and watersheds that contain water bodies on the CWA section 303(d) list and where local stewardship and site-specific management practices can be implemented through comprehensive watershed protection or restoration plans."

A common theme with all three of these programs is planning and management at the landscape or watershed scale. Watershed scale protection, enhancement and management of natural resources requires an understanding of the landscape-scale processes that govern the integrity and long-term viability of aquatic and



Source: PCR Services Corporation, 2000

Figure 1-1
Baseline Conditions Report
Study Area Boundary

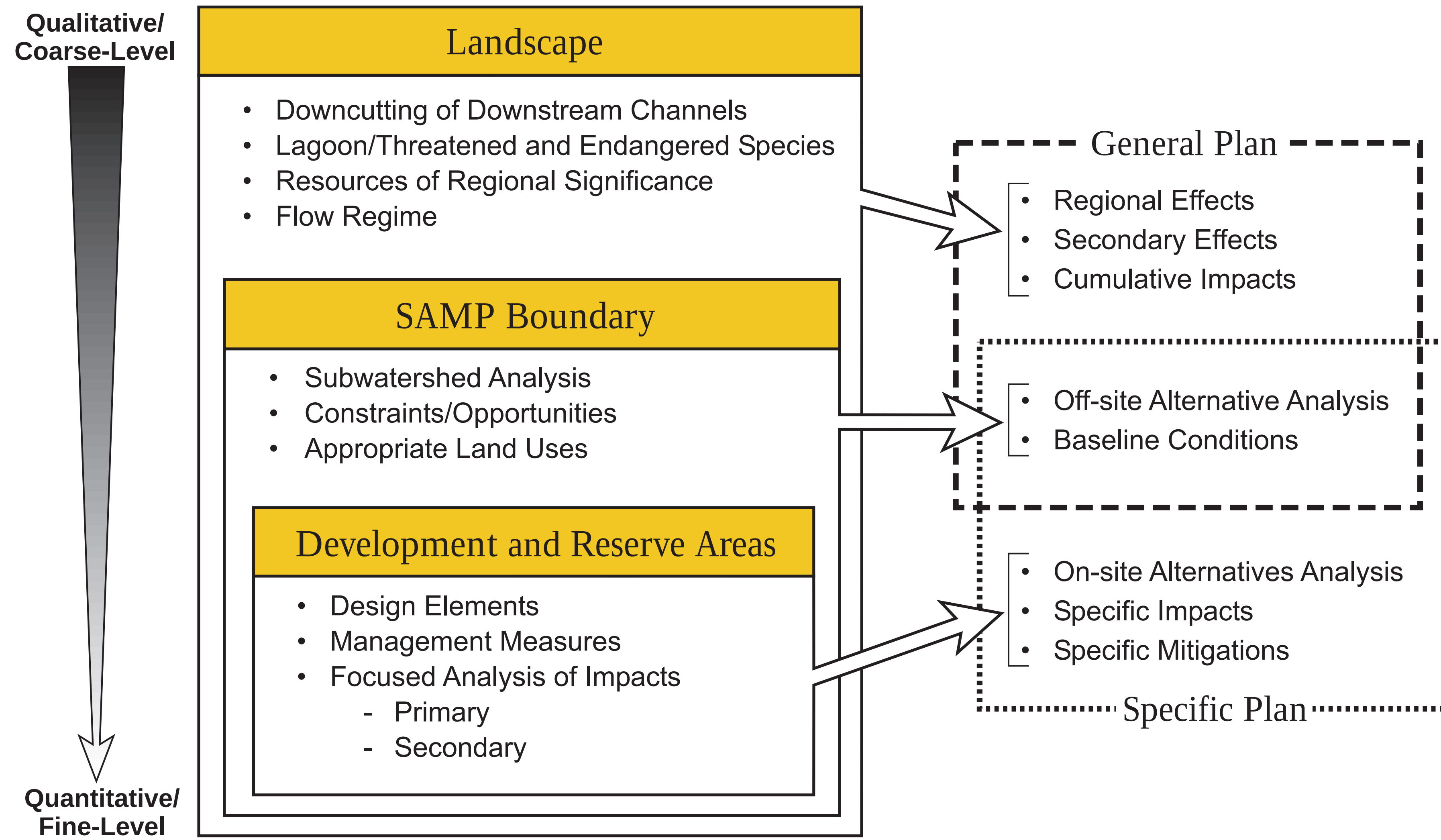
other natural resources. By taking a landscape perspective in assessment and planning, cumulative impacts can be better addressed. Furthermore, the constraints associated with natural resources and processes can be integrated early in the development process. In addition to minimizing impacts, this large-scale perspective facilitates development of a comprehensive preservation, enhancement, and restoration plan that addresses long-term management of natural communities, enhancement of water quality improvement, and flood hazard reduction. This planning process is intended to coordinate protection of riparian systems and upland habitats, and enable them to be managed over the long-term as part of a single integrated implementation program. Accomplishment of this large-scale resource-based planning and management program requires an understanding of not only the current condition of natural resources, but also the physical processes that govern their long-term viability.

This comprehensive planning effort is intended to support applications for state and federal regulatory permits and can be used to assist the federal, state, and local regulatory agencies with their decision making and permitting authority to protect upland and aquatic resources and water quality. The overall intent is to develop programmatic approaches for compliance with requirements of the Federal Clean Water Act (Sections 401 and 404), Federal and State Endangered Species Acts, State Porter Cologne Act, State Fish and Game Code (Sections 1601-1603), NCCP plans pursuant to 2800 et seq. of the California Fish and Game Code, as well as support development of CEQA/NEPA documents and the local entitlement process.

1.2 GOALS, SCALE OF ANALYSIS, AND ORGANIZATION OF REPORT

The goal of this report is to assess baseline hydrologic conditions in the San Juan and San Mateo watersheds. This information will provide a foundation for identifying land use, reserve design, and management/enhancement alternatives and measures for a subsequent "*off-site alternatives analysis*" phase of work. Following the off-site analysis, the baseline hydrology studies will also be used to guide design recommendations during an "*on-site alternatives analysis*". The purpose of these alternatives analyses is to ensure that impacts to aquatic resources are avoided, minimized, and mitigated to the maximum extent practicable. In addition, through the local entitlement process, the baseline hydrology will be used in the design of new development areas to comply with Orange County design requirements for flood hazard assessment. In particular, results of the rainfall-runoff hydrographic analysis will be used to analyze potential effects of proposed development on flood events. Recommendations for design features and mitigation measures to offset potential hydrologic and sediment impacts of proposed land use changes will be developed. This current information may also be used to supplement existing data produced for the Corps of Engineers San Juan Creek watershed studies (KEA, 1998; SLA, 1999).

As described above, this report provides information to support planning and decision-making processes at three different spatial scales (Figure 1-2). At the regional landscape scale, the hydrology studies will assist planning efforts to manage cumulative impacts and regional effects across a 25,000-acre area containing a variety of terrains and processes. Within the SAMP/RMV boundaries (Figure 1-1), hydrologic studies are more focused towards understanding the particular behavior of individual sub-basins within the larger watersheds. At this intermediate sub-basin scale, hydrology and sediment transport results, in addition to geomorphology and ecology findings (PCR, 2001), are used to identify



Source: PCR Services Corporation, 2000

PCR PWA Balance Hydrologics, Inc.

Figure 1-2
Baseline Conditions Report
Application of Technical Studies
to Various Scales of Analysis

habitat conditions, opportunities and constraints, and appropriate land uses. At the scale of the reserve or development parcel, hydrology and sediment transport findings support identifying appropriate hydrogeomorphic design concepts, habitat requirements, and site-specific impacts and mitigation. Accordingly, this report provides information at both the watershed and sub-basin scales. Hydrologic support for the reserve and development parcel scale will be further developed as needed based on the baseline findings.

Following this introduction, which includes a brief description of the project area's physical setting, this report includes four additional technical sections. In Section 2, the approach and methods used for the hydrology analysis are described (Section 2.2) with watershed overview results for the San Juan (Section 2.3) and San Mateo (Section 2.4) drainage basins. In Section 3, hydrology results for six individual sub-basin areas (Lucas Canyon, Verdugo Canyon, Bell Canyon, Cañada Gobernadora, Cañada Chiquita, and Central San Juan Catchments) are discussed. Descriptions of the drainage network, infiltration conditions, and storm event runoff conditions are given for each sub-basin. Section 4 is structured similarly to Section 3, but includes results from the four studied sub-basins of the western San Mateo watershed (La Paz Canyon, Gabino Canyon, Upper Cristianitos Canyon, and Talega Canyon). Section 5 presents the in-channel sediment transport analysis and includes: an introduction to the SAM modeling approach (Section 5.2); presentation of sediment transport rates, sediment yields, and sediment mass balances for the individual sub-basins and watersheds (Sections 5.3 and 5.4); a sensitivity analysis (Section 5.4); and a comparison to other studies (Section 5.6). A list of participating PWA staff and references are offered in Sections 6 and 7 respectively.

1.3 PHYSICAL SETTING OF PROJECT AREA

1.3.1 Locations, Topography, and Streams

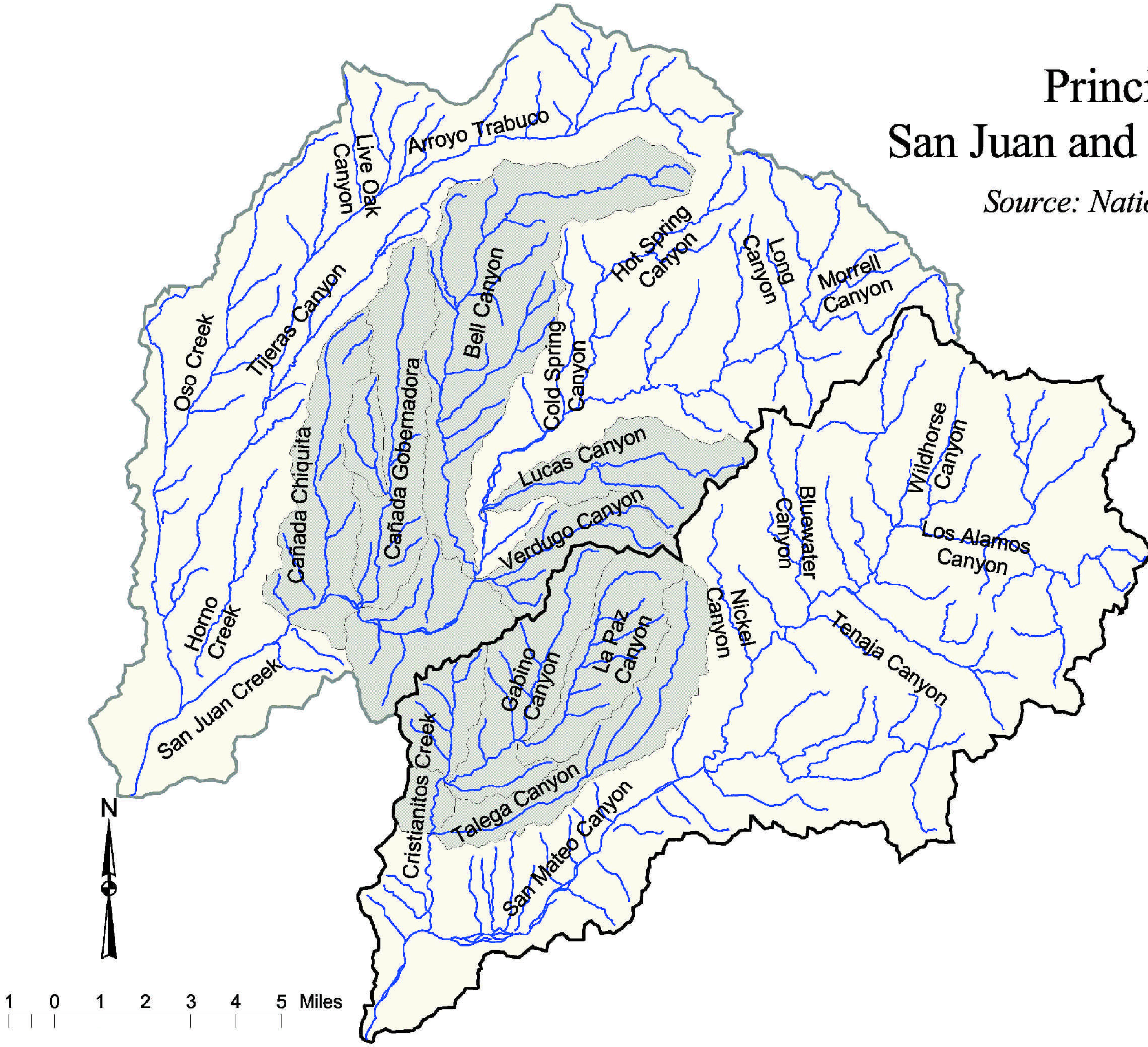
The San Juan Creek watershed is located in southern Orange County, California. The watershed encompasses a drainage area of approximately 176 square miles, and extends from the Cleveland National Forest in the Santa Ana Mountains to the Pacific Ocean at Doheny State Beach near Dana Point Harbor. The upstream tributaries of the watershed flow out of steep canyons. As the streams flow, they coalesce and widen out into several alluvial floodplains. The major streams in the watershed include San Juan Creek, Bell Canyon Creek, Canada Chiquita, Canada Gobernadora, Verdugo Canyon Creek, Oso Creek, Trabuco Creek, and Lucas Canyon Creek (Figure 1-3). Elevations range from 5,687 feet at Santiago Peak to sea level at the mouth of San Juan Creek (Figure 1-4). The San Juan Creek Watershed is bounded on the north by the San Diego, Aliso Creek, and Salt Creek watersheds, and on the south by the San Mateo Creek watershed. The Lake Elsinore watershed, which is a tributary of the Santa Ana River watershed, is adjacent to the eastern edge of the San Juan Creek watershed.

The San Mateo Creek watershed is located in the southern portion of Orange County, the northern portion of San Diego County, and the western portion of Riverside County. The watershed is bounded on the north and west by the San Juan Creek watershed, to the south by the San Onofre Creek watershed, and to the northeast by the Lake Elsinore watershed. San Mateo Creek flows 22 miles from its headwaters in the

Figure 1-3

Principal Streams
San Juan and San Mateo Watersheds

Source: National Hydrography Dataset



Note: Shaded areas are individual sub-basins studied in detail for Baseline Conditions Report

Light border - San Juan Basin
Dark border - San Mateo Basin

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Cleveland National Forest to the ocean just south of the City of San Clemente. The total watershed is approximately 139 square miles, and lies mostly in currently undeveloped areas of the Cleveland National Forest, the northern portion of Marine Corps Base Camp Pendleton (MCBCP), and ranch lands in southern Orange County (Lang, 1998). Principal (named) streams in the watershed include Cristianitos Creek, Gabino Creek, La Paz Creek, Talega Creek, Cold Spring Creek and Devil Canyon Creek (Figure 1-3). The SAMP study area includes only the portion of the San Mateo Creek drainage within Orange County. Elevations range from approximately 3,340 feet above sea level in the mountains of the Cleveland National Forest to sea level at the mouth of San Mateo Creek (Figure 1-4).

1.3.2 Regional Geology, Geomorphology, and Terrains

The topics of geology and geomorphology for the baseline conditions analysis are described more thoroughly in the Baseline Conditions report (PCR, 2001) and in other supporting technical appendices by Balance Hydrologics (2001). The following introduction is based on the findings of those studies.

The San Juan and San Mateo Creek watersheds are located on the western Pacific slopes of the Santa Ana Mountains, which are part of the Peninsular Ranges. Within the watersheds, the Santa Ana Mountains are composed of igneous and metasedimentary rocks of Jurassic age and younger. The exposed rocks in the mountainous areas are slightly metamorphosed volcanics, which have been intruded by granitic rocks of Cretaceous age, principally granites, gabbros, and tonalites. Overlying these rocks are several thousand stratigraphic feet of younger sandstones, siltstones, and conglomerates of upper Cretaceous age, composed largely of material eroded from the older igneous and metasedimentary rocks now underlying the Santa Ana Mountains. Younger sedimentary rocks comprise the bedrock between the Santa Ana Mountains, their foothills, and the Pacific Ocean.

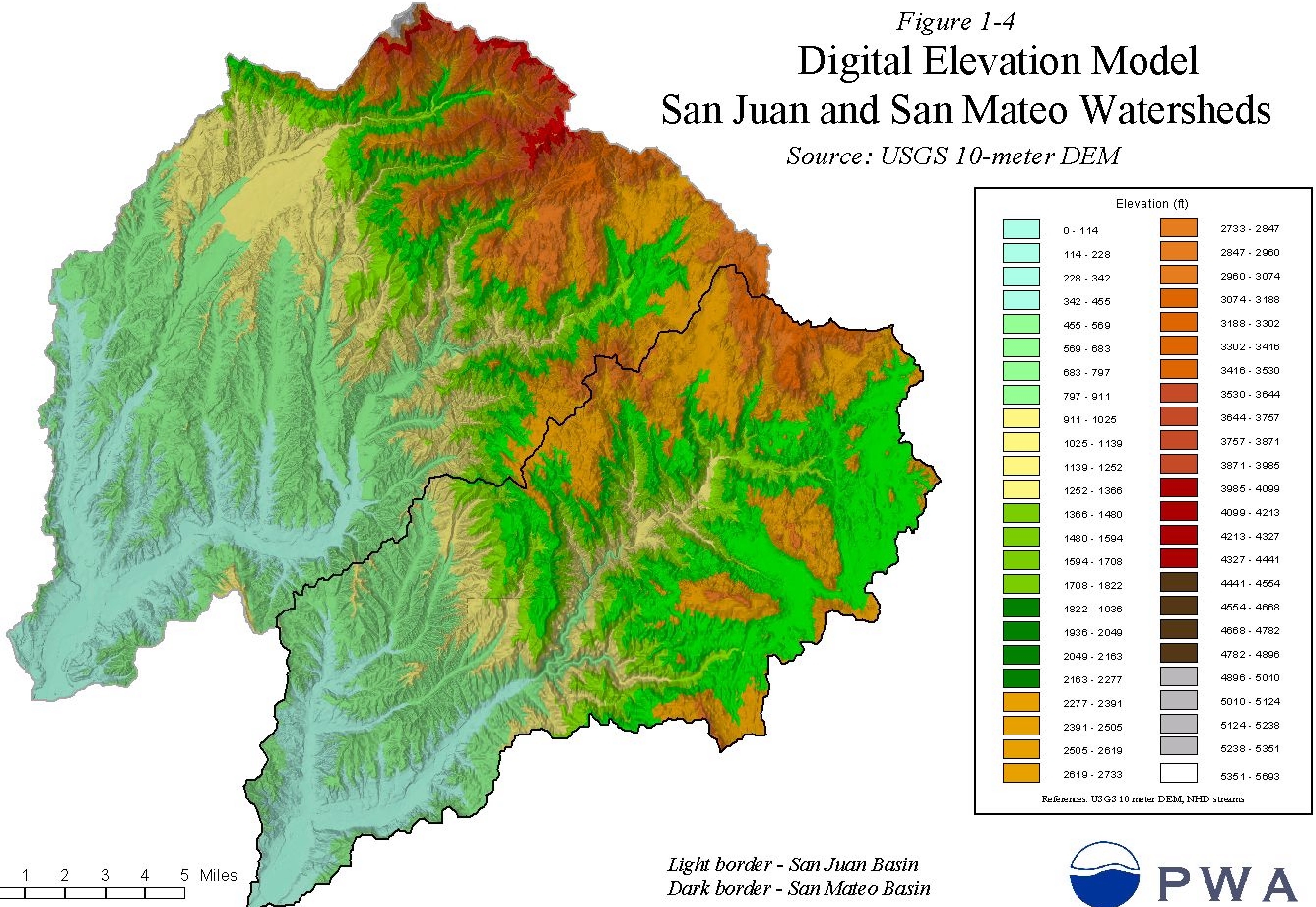
These marine and non-marine sandstones, limestones, siltstones, mudstones, shale, and conglomerates, many of which weather, erode, and/or hold groundwater in characteristic ways, underlie most of the SAMP area. Overlying them are Quaternary stream terrace deposits, and Holocene stream channel deposits. Tectonic uplift during the Quaternary has left at least four major stream terrace levels along the major streams. Within this tectonic framework, eustatic sea level changes have caused channel downcutting in the main canyons as streams adjusted to lower base levels. With rising sea levels, deposition occurred on valley floors, which often left sharp slope breaks at the base of the existing hillsides and tributary valleys. These recent valley deposits are geologically young, soft, and prone to incision under certain conditions. Soils formed under climates both warmer/colder and drier/wetter than at present. Along some of the canyon ridges, hardpans developed which currently direct flows into headwater streams.

According to analysis and interpretation by Balance Hydrologics (2001), there are three major geomorphic terrains found within the San Juan Creek and San Mateo Creek watersheds: (a) sandy, (b) clay, and (c) crystalline. These terrains are manifested primarily as roughly north-south oriented bands of different soil types (Figure 1-5). The soils and bedrock that comprise the western portions of the San Juan Creek watershed (i.e., Oso Creek, Arroyo Trabuco, and the lower third of San Juan Creek), contain a high percentage of clays in the soils. In contrast, the middle portion of the San Juan basin (i.e., Canada

Figure 1-4

Digital Elevation Model
San Juan and San Mateo Watersheds

Source: USGS 10-meter DEM



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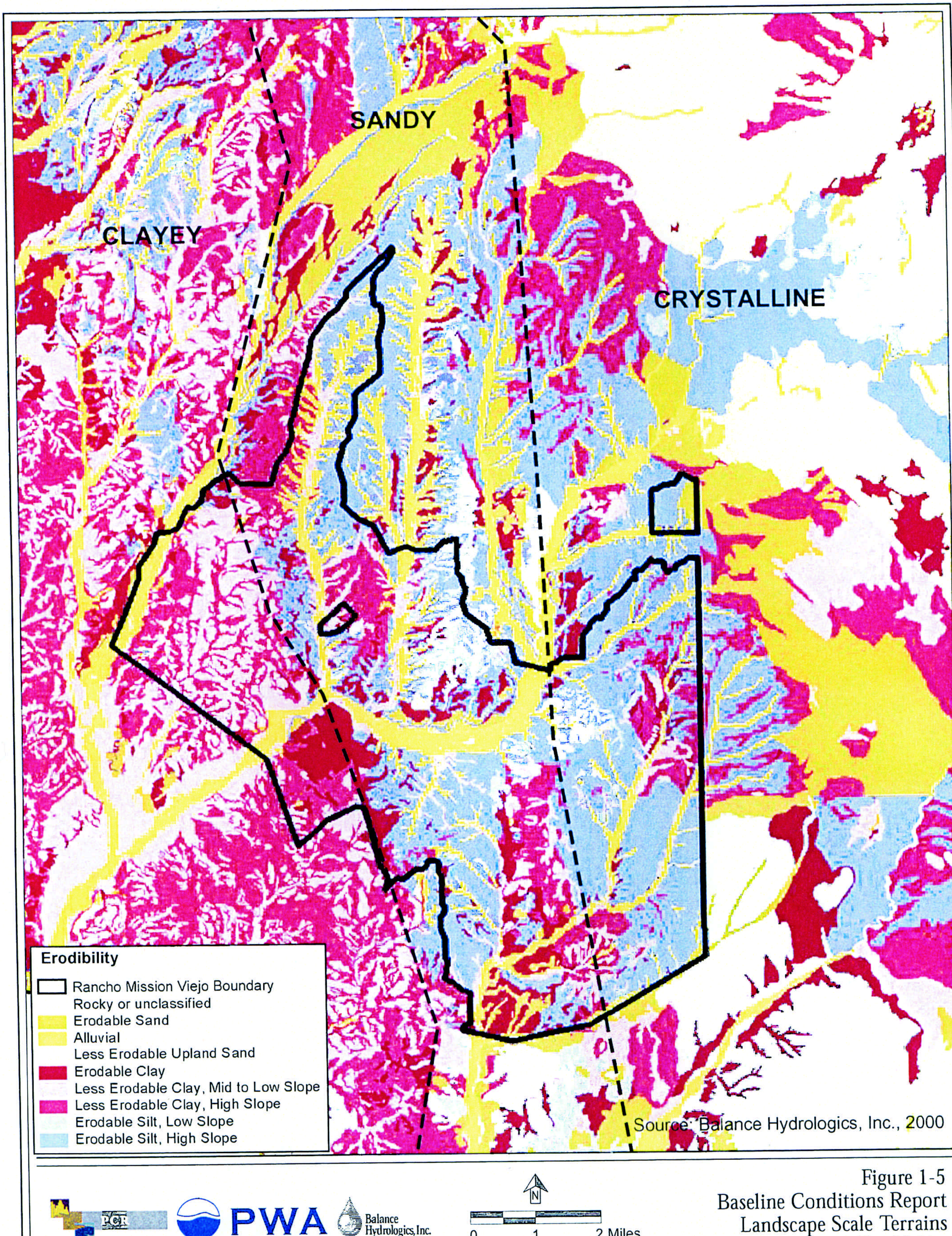


Figure 1-5
Baseline Conditions Report
Landscape Scale Terrains
and Shallow Substrate Erodibility

Chiquita, Bell Canyon, and the middle reaches of San Juan Creek) is a region characterized by sandy substrate. The upstream portions the San Juan Creek watershed, which comprise the headwaters of San Juan Creek, Lucas Canyon Creek, Bell Creek, and Trabuco Creek, may be characterized as a "crystalline" terrain because the bedrock underlying this mountainous region is composed of igneous and metamorphic rocks. Gobernadora Canyon is unique in that it is somewhat of a hybrid terrain. Although underlain by deep sandy substrates, it is overlain by between 2 and 6 feet of exhumed hardpan.

There are important hydrologic distinctions between sandy, clay, and crystalline terrains. Although all three terrains exhibit fairly rapid runoff, undisturbed sandy slopes contribute less runoff than clay hillslopes because it is easier for water to infiltrate into the coarser substrate. Runoff in crystalline terrains tends to be rapid, and is highly influenced by the presence and density of coverage of impervious areas of rock outcrop that typify the terrain. As a result, the volume of runoff generated by the same amount and intensity of rainfall in a sandy watershed is generally lower than that generated in a clay or crystalline watershed.

Once runoff is concentrated in stream valleys and floodplains, sandy terrains are able to infiltrate larger volumes of water than are clay and crystalline terrains. As a result, (a) sandy terrains play a vital role in groundwater recharge, (b) undisturbed sandy terrains are typified by lower runoff rates than clay or crystalline terrains, (c) stream valleys in undisturbed sandy terrains tend to have wide floodplains and are often channel-less, and (d) there is a greater contrast between runoff conditions in undeveloped and urbanized watersheds in sandy terrains than in clay or crystalline terrains. In contrast, narrow, well-defined stream valleys nestled between steep mountainous slopes typify crystalline terrains. Unlike sandy streams that are susceptible to incision, streams in crystalline areas often flow over bedrock and have stable grades. The topography, soils, and hydrography of the crystalline geomorphic terrain are all inherently controlled and influenced by the underlying bedrock. Clay-dominated terrains are also typified by more gentle topography than sandy or crystalline areas. Ridges tend to be lower and broader because the underlying bedrock is often more easily eroded. Clay terrains also feature streams with fairly well defined channels that have evolved to handle the higher runoff rates associated with clay slopes. Clay-dominated terrains are generally less susceptible to many of the environmental problems that plague sandier soils (such as enhanced sediment loading, incision and headcutting).

2. WATERSHED HYDROLOGY

2.1 INTRODUCTION

The magnitude, frequency, and pattern of surface flow through uplands and within stream channels is likely the most deterministic factor of the integrity and distribution of wetlands and riparian habitat. Changes in the magnitude or frequency of peak flows for more frequent events (i.e., 2-year return interval), more moderate events (i.e., 10-year return interval) or extreme events (i.e., 100-year return interval) can affect the long-term viability of riparian habitat and influence the type of community that persists. Increased frequency of high flows (resulting from increased runoff) can destabilize channels and encourage invasion by aggressive non-native plant species. Changes in baseflow (i.e., perennialization of historically intermittent or ephemeral streams) can change the physical and biological structure of the stream. Habitat for sensitive species may also be affected by changes in the physical, chemical, or biological condition of the stream that results from alteration of surface water hydrology. As such, a careful analysis of baseline hydrology conditions of the San Juan and San Mateo Watersheds was conducted. This baseline analysis will be used to evaluate hydrologic impacts of land-use alternatives in a subsequent phase of work. This chapter includes a description of the techniques used for the hydrology analysis (Section 2.2) and overview results for the San Juan (Section 2.3) and San Mateo (Section 2.4) drainage basins for issues of the stream network, infiltration, storm event runoff, and low flow conditions.

Hydrologic impacts associated with urbanization have been observed and described by several authors. Findings from past research provides a useful context to interpret current hydrologic conditions in the San Juan and San Mateo watersheds as well as insight to anticipate potential impacts due to urbanization. Synthesizing the earlier work of others, Leopold (1968) summarized how increased impervious surfaces in a watershed results in increased stormflow volume, increased stormflow peak discharge, and a reduction in lag time between precipitation and runoff. Estimating the hydrologic impact on a 1 mi^2 watershed, Leopold (1968) estimated that for a given precipitation event, discharge would increase roughly 2.5 times if 50% of the watershed was urbanized and drained by a storm sewer system. James (1965), Anderson (1970), and Rantz (1971) described how the hydrologic impacts of urbanization are proportionally greater for more frequent interval storm events than larger events where soils saturated beyond their infiltration capacity behave similarly to impervious surfaces (Graf, 1988). More recently, Wong and Chen (1993) used computational models to suggest that increases in flood peaks caused by urbanization are due to increases in impervious areas more than increases in storm sewer networks for basins with variable slopes. Ferguson (1994) focused on stormwater infiltration as the key to solving urban runoff problems.

Researchers have also documented how such changes in hydrologic regime translate to geomorphic changes in stream channel form by altering processes and patterns of sediment erosion, transport, and deposition. Wolman (1967) suggested a cycle whereby urbanizing watersheds have extremely high sediment yields during the construction phase when barren slopes are disturbed and void of vegetation. Following the build-out phase, sediment yields drop to levels below existing conditions as sediment source areas are capped and replaced by urban landscapes. Hammer (1973) concluded that urbanization and its changes in streamflow regimen generally result in enlarged stream channels, with proportional greater channel enlargement in steeper watersheds. More specific to the Orange County setting of the current report, Trimble (1997) reported how sediment yields in the San Diego Creek watershed increased during a period of urbanization. Trimble (1997) suggested that about two-thirds of this sediment yield was generated from in-channel sediment erosion with about one-third supplied by upland hillslope sources. Recently, Doyle et al (2000) used geomorphic assessment techniques (including quantitative measures of shear stress, stream power, and the recurrence interval of bed-mobilizing discharges) to predict channel stability or instability in urbanizing watersheds. A recent compendium of articles published by the Center for Watershed Protection (Schueler and Holland, 2000) offers a comprehensive review of watershed impacts of urbanization and techniques to mitigate such impacts. Although watershed science is a relatively new and emerging discipline, the current baseline report and future planning process for the San Juan and San Mateo creek watersheds benefit from these past studies which provide a framework to understand hydrologic and geomorphic impacts.

2.2 APPROACH

2.2.1 Stream Network Analysis

Mapping the composition and spatial arrangement of channels in a watershed is a key initial task to assess the basic physical and hydrologic qualities of the drainage basin. The identified stream network provides a foundation to better understand potential impacts to streamflow, sediment transport, and geomorphic conditions. This mapped channel network also provides a baseline to evaluate potential ecologic impacts, particularly in reference to headwater streams. The hydro-geomorphic function and habitat role of headwater streams in the San Juan and San Mateo watersheds is not addressed in this hydrology report but is discussed in the overall Baseline Conditions Report (PCR, 2001).

The stream network for the watersheds was delineated using a multiple threshold method based upon a topologically correct digital elevation model (DEM). This analysis was completed within a Geographical Information System (GIS), using channel data from the U.S. Army Corps of Engineers – Waterways Experimentation Station (USACE WES/CRRL), topographic and channel data from the U.S. Geological Survey (USGS), and field data collected by PWA. The created stream network model was validated against field data collected by the WES/CRRL team. The multiple threshold method is based on the "erosion-threshold" theory (Montgomery and Foufoula-Georgiou, 1994) and predicts the location where channels begin by combining contributing flow areas and slopes of hillsides into a single channel-predicting parameter. The direction of flow is calculated from the DEM using the D8 method, which uses the eight neighboring cells to predict the water flow direction. A single flow direction is specified for every point in the watershed. This technique was applied to the study area at both 30-meter and 10-meter resolutions.

In some areas this method was insufficient to map the channels and a modified approach was used. In steep areas, where the erosional threshold theory does not apply, a straight tributary source area was used to predict channel locations. For areas of low relief, such as floodplain valleys, mapped channel locations contained in the National Hydrography Dataset were input to the DEM data. These additional steps enabled channel delineations to match observed channels in areas where the DEM alone was not sufficient to predict channels. Finally, the WES/CRRL field-mapped channels were included as channel heads, and their flow paths were traced through the DEM using a calculated flow direction to create complete channels. In this way, all of the WES mapped channels are represented in the resulting stream delineation. This composite method requires a number of input parameters, including the ground slopes used to identify the appropriate method, and the two thresholds used for channel prediction (the erosional threshold, and the tributary area threshold). Values for these parameters were selected based on PWA field data and by comparing the predicted channels to locations of known channels.

Descriptive statistics were calculated for the resulting stream network. The number, length, and stream order of channels were calculated for each sub-basin. Drainage density was calculated for each basin by dividing total stream length by the total area of the basin. Additionally, the bifurcation ratio was calculated for each stream order by taking the number of channels for a particular order and dividing by the number of channels of the next highest order. This provides an outline of the stream network's natural structure. Using this information, confluence points where stream orders increase were mapped to highlight important locations in the stream network.

2.2.2 Rainfall-Runoff Analysis

2.2.2.1 Overview and Methods

Since measured streamflow rates are only available at a few locations in the project area, computer models, which relate precipitation events to predicted runoff, were used to assess baseline flow conditions. The Army Corps of Engineers HEC-1 flood hydrograph model was utilized with input parameters as specified by the Orange County Hydrology Manual (OCHM, 1986). To facilitate the use of OCHM methodology, LAPRE-1 was used in combination with Visual HEC-1. LAPRE-1 is a Los Angeles District USACE pre-processor for HEC-1, customized for hydrologic analysis of southern California watersheds. A watershed GIS database was created to generate and evaluate various input parameters to LAPRE-1 and Visual HEC-1, including sub-basin area, basin roughness, channel lengths, area rainfall distributions, and SCS runoff curve numbers. Data generated from the GIS is described in following sections.

It should be noted that while HEC-1 is useful for analyzing rainfall-runoff processes in watersheds, the program has several limitations. HEC-1 was designed to model singular storm runoff events such as the 24-hr Orange County design storm. It is not possible to accurately model two or more consecutive storm events with HEC-1 since the program does not account for dynamic soil moisture and infiltration processes. Even modeling a single storm with two large and distinct rainfall peaks (a "bimodal" storm) is not advisable with HEC-1. This limitation was not an issue in following OCHM methods since the OCHM design storm has a distinct singular rainfall peak.

The HEC-1 model also tends to over-estimate flows from smaller events, such as the 2-year storm. This occurs because HEC-1 uses a relatively simple approach to analyze rainfall, infiltration, and runoff, which does not reflect the true complexities of these processes. To address this limitation of HEC-1 for the 2-year event discharges, PWA followed the Orange County Hydrology Manual Addendum #1 (1995). Input parameters for soil loss and precipitation conditions were calibrated to regionally observed discharge conditions (expected value). For the 2-year flows, these guidelines provide a more realistic discharge baseline that can more accurately depict impacts due to urbanization. In this way, the current PWA hydrology approach is a hybrid, which offers county accepted 'high confidence' results for the larger 10- and 100-year events and 2-year results, which are more sensitive to environmental concerns, associated with urban-induced hydrogeomorphic changes within the watersheds.

While acknowledging these limitations, HEC-1 still offers a valuable method to assess potential impacts of land use changes. The current HEC-1 results provide an existing conditions baseline upon which relative changes in peak flows and volumes arising from post-project conditions can be evaluated.

2.2.2.2 Sub-Basin Delineation

The first step in formulating rainfall-runoff models for the San Juan Creek and San Mateo Creek Watersheds was to delineate appropriate sub-basins within the watersheds. Sub-basins allow localized watershed characteristics (such as soil type, vegetation cover, and channel geometry) to be described in more detail and allow hydrographs to be calculated at various points within a watershed. The effect of local land-use changes within the watershed can therefore also be evaluated on the sub-basin scale.

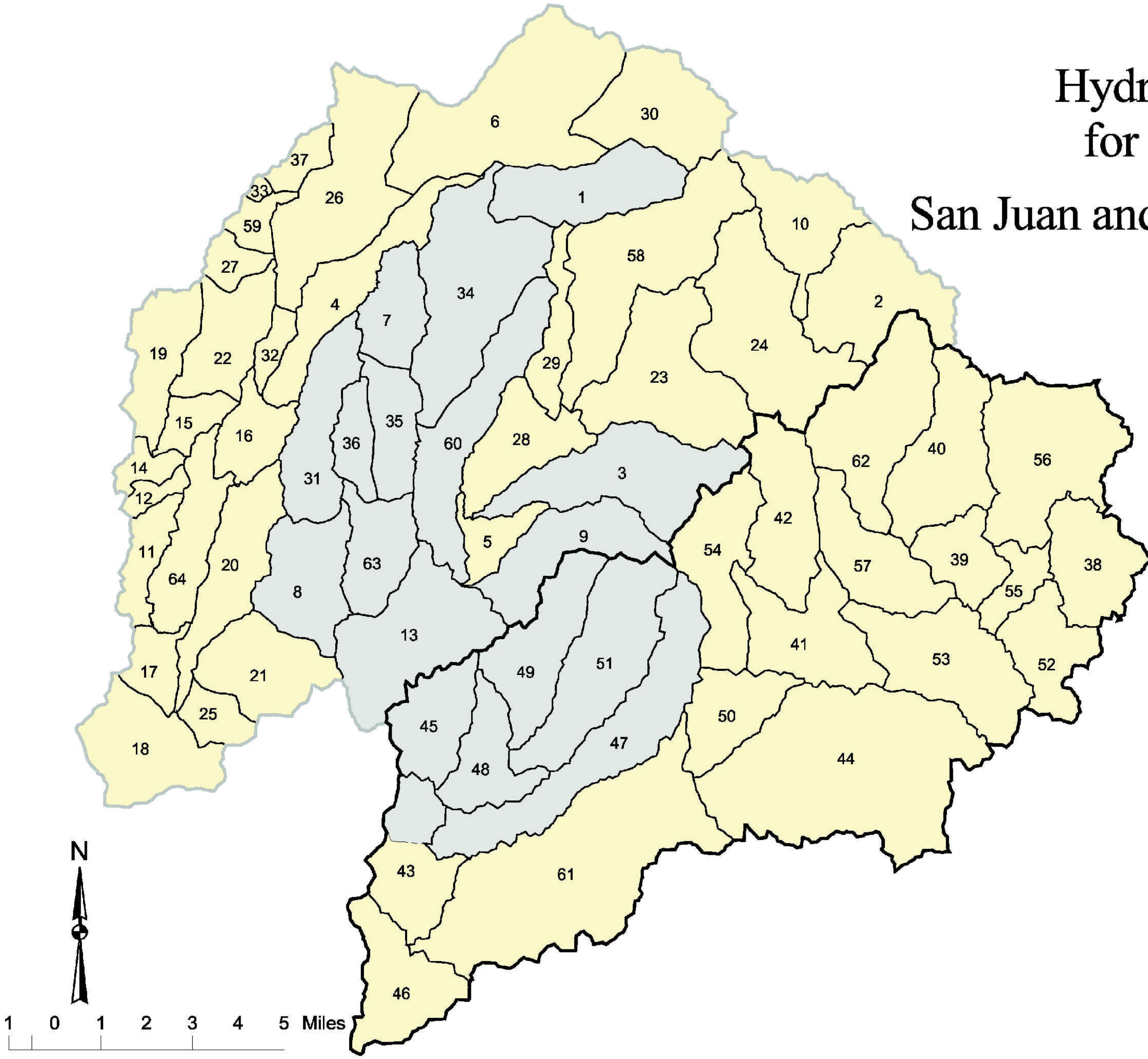
Sub-basins were delineated using the project GIS and guidelines from the OCHM. Key areas in each watershed were designated as sub-basins, including Cañada Gobernadora, Cañada Chiquita, Central San Juan Creek, Upper Cristianitos Creek, and Bell, Lucas, Verdugo, Talega, La Paz, and Gabino Canyons. Remaining sub-basin areas were delineated based on logical topographic features, hydraulic structures (such as reservoirs and flood control channels), and the OCHM guideline that the largest sub-basin should be no greater than four times the area of the smallest sub-basin (OCHM, 1986, K-2).

Once sub-basins were delineated, sub-basin areas were calculated in the GIS. Hydrologic sub-basins for the San Juan and San Mateo watersheds are shown in Figure 2-1. Hydrologic parameters including calculated sub-basin areas, as well as, watercourse lengths, loss rates, slopes, sub-basin roughness conditions, and runoff curve numbers are listed in Tables 2-1 and 2-2 for the San Juan and San Mateo sub-basins.

figure 2-1

Hydrologic Sub-basins for Runoff Analysis

San Juan and San Mateo Watersheds



Note: Shaded areas are individual sub-basins studied in detail for Baseline Conditions Report

Light border - San Juan Basin
Dark border - San Mateo Basin

PWA

Table 2-1 Hydrologic Parameters for the San Juan Creek Watershed, Year 2000 Conditions

		Areas				Soils					Watercourse Lengths							
		Sub-basin		Upstream Drainage		Low Loss Fraction			Maximum Loss Rate (in/hr)		Longest		To Centroid		Slope	Sub-basin		LAPRE-1
GIS Sub-basin	HEC-1 Node	(mi^2)	(acres)	(mi^2)	(acres)	2-year	10-year	100-year	2-year	10-year & 100-year	(mi)	(ft)	(mi)	(ft)	(ft/mi)	Roughness n-value	Average Curve Number (AMC II)	S-graph Type
1	SJ1	5.12	3276	5.12	3277	0.590	0.314	0.062	0.600	0.208	5.47	28862	2.68	14154	605.0	0.050	82.3	Mountain
2	SJ2	6.18	3955	6.18	3955	0.675	0.373	0.079	0.600	0.243	6.23	32898	2.26	11921	280.1	0.045	77.4	Mountain
3	SJ3	7.17	4586	50.11	32070	0.729	0.435	0.109	0.599	0.231	7.99	42179	4.35	22963	324.4	0.050	78.6	Mountain
4	TC4	4.67	2987	30.38	19443	0.664	0.416	0.119	0.447	0.190	7.07	37324	3.42	18039	130.9	0.040	83.2	Valley Undeveloped
5	SJ5	1.70	1086	51.81	33158	0.860	0.595	0.203	0.591	0.245	2.84	14994	1.29	6809	321.2	0.040	74.3	Foothill
6	TC6	11.04	7067	16.51	10566	0.640	0.358	0.082	0.597	0.218	8.87	46859	6.13	32348	528.6	0.050	80.3	Mountain
7	SJ7	2.99	1912	2.99	1914	0.732	0.488	0.156	0.421	0.189	3.17	16737	1.35	7148	183.2	0.025	79.5	Valley Undeveloped
8	SJ8	4.66	2982	104.91	67142	0.799	0.515	0.141	0.590	0.233	3.82	20193	1.70	8958	131.2	0.040	79.2	Valley Undeveloped
9	SJ9	4.80	3069	56.61	36230	0.844	0.568	0.181	0.600	0.249	6.02	31810	2.88	15200	353.4	0.050	74.8	Mountain
10	SJ10	4.39	2812	4.39	2810	0.604	0.320	0.062	0.599	0.226	5.21	27518	2.81	14816	448.2	0.050	80.5	Mountain
11	OC11	2.00	1280	16.28	10419	0.607	0.382	0.117	0.351	0.136	3.68	19405	1.74	9182	87.5	0.025	84.4	Valley Developed
12	OC12	0.73	467	14.29	9146	0.459	0.249	0.054	0.213	0.081	1.51	7974	0.59	3140	193.4	0.020	90.9	Valley Developed
13	SJ13	7.42	4747	84.59	54138	0.851	0.578	0.181	0.581	0.243	4.48	23649	1.84	9718	148.0	0.040	75.9	Valley Undeveloped
14	OC14	1.00	642	13.56	8678	0.487	0.272	0.062	0.237	0.086	1.36	7172	0.49	2566	256.0	0.020	89.9	Valley Developed
15	OC15	1.41	905	8.98	5747	0.442	0.245	0.059	0.181	0.070	2.99	15808	1.65	8727	141.4	0.020	90.7	Valley Undeveloped
16	TC16	2.53	1618	32.91	21062	0.670	0.430	0.144	0.511	0.196	2.96	15628	1.31	6898	162.9	0.030	81.5	Valley Undeveloped
17	TC17	1.70	1090	54.79	35066	0.596	0.369	0.109	0.305	0.139	2.98	15713	1.38	7271	131.2	0.025	85.0	Valley Developed
18	SJ18	5.34	3418	175.97	112621	0.557	0.327	0.081	0.298	0.121	4.52	23865	2.31	12205	129.2	0.025	87.4	Valley Developed
19	OC19	3.57	2287	12.55	8032	0.442	0.236	0.049	0.180	0.066	4.76	25117	2.58	13610	112.4	0.025	91.4	Valley Developed
20	SJ20	4.81	3075	4.81	3078	0.678	0.399	0.085	0.531	0.192	6.33	33429	3.37	17815	130.1	0.050	85.0	Valley Undeveloped
21	SJ21	4.59	2940	109.50	70080	0.676	0.415	0.106	0.449	0.170	4.37	23076	1.81	9556	240.2	0.040	83.7	Valley Developed
22	OC22	3.95	2531	7.56	4838	0.364	0.192	0.046	0.129	0.048	4.13	21806	1.62	8530	174.0	0.025	93.0	Valley Undeveloped
23	SJ23	7.83	5013	27.29	17466	0.700	0.402	0.089	0.600	0.225	5.99	31606	2.73	14413	385.9	0.050	80.0	Mountain
24	SJ24	8.88	5685	19.46	12454	0.643	0.352	0.072	0.599	0.226	4.48	23651	1.59	8374	426.3	0.050	79.9	Mountain
25	SJ25	1.53	981	115.84	74138	0.709	0.450	0.128	0.468	0.180	2.46	12991	1.26	6656	297.4	0.030	81.9	Valley Developed
26	TC26	8.30	5315	24.81	15878	0.706	0.451	0.138	0.514	0.208	6.98	36831	4.08	21549	226.2	0.040	80.7	Mountain
27	0C27	1.16	742	3.61	2310	0.495	0.279	0.063	0.174	0.075	1.72	9070	0.78	4138	185.3	0.020	89.5	Valley Developed
28	SJ28	4.01	2565	42.95	27488	0.865	0.608	0.222	0.590	0.248	4.36	23001	2.23	11768	274.9	0.050	72.8	Mountain
29	SJ29	2.17	1391	38.94	24922	0.760	0.469	0.125	0.599	0.236	5.08	26835	2.22	11738	519.6	0.050	78.0	Mountain
30	TC30	5.46	3497	5.46	3494	0.605	0.322	0.066	0.600	0.222	4.49	23716	2.27	12006	545.6	0.050	80.4	Mountain
31	SJ31	4.58	2928	4.58	2931	0.840	0.552	0.153	0.598	0.257	5.59	29538	2.46	12966	144.9	0.045	77.7	Foothill
32	TC32	0.90	576	25.71	16454	0.754	0.538	0.238	0.489	0.210	2.48	13082	1.23	6500	136.4	0.030	73.7	Valley Undeveloped
33	OC33	0.20	128	1.35	864	0.457	0.255	0.061	0.221	0.084	0.60	3187	0.32	1687	255.4	0.025	90.5	Valley Undeveloped
34	SJ34	9.10	5823	14.22	9101	0.763	0.482	0.135	0.555	0.214	6.86	36241	3.48	18360	360.9	0.050	78.8	Mountain
35	SJ35	2.93	1872	5.91	3782	0.809	0.551	0.181	0.528	0.240	4.31	22731	2.10	11109	153.2	0.045	76.5	Valley Undeveloped
36	SJ36	1.77	1133	7.68	4915	0.867	0.603	0.198	0.589	0.259	3.49	18441	1.86	9844	192.6	0.045	74.5	Foothill
37	OC37	1.15	735	1.15	736	0.774	0.501	0.146	0.578	0.215	2.29	12092	0.95	5038	257.9	0.030	79.8	Mountain
58	SJ58	9.48	6066	36.77	23533	0.648	0.362	0.081	0.600	0.225	8.45	44605	4.64	24521	404.7	0.050	80.3	Mountain
59	OC59	1.10	706	2.45	1568	0.422	0.231	0.060	0.181	0.074	2.17	11463	0.91	4810	255.4	0.020	91.2	Valley Developed
60	SJ60	6.35	4066	20.57	13165	0.855	0.584	0.198	0.600	0.245	8.86	46766	4.75	25102	231.1	0.050	74.0	Mountain
63	SJ63	3.40	2173	11.08	7091	0.799	0.514	0.139	0.598	0.247	4.01	21151	2.33	12277	141.7	0.040	79.4	Foothill
64	TC64	3.90	2495	36.80	23552	0.645	0.416	0.138	0.407	0.169	5.57	29409	2.53	13343	99.0	0.035	82.3	Foothill

Table 2-2 Hydrologic Parameters for the San Mateo Creek Watershed, Year 2000 Conditions

		Areas				Soils					Watercourse Lengths							
		Sub-basin		Upstream Drainage		Low Loss Fraction			Maximum Loss Rate (in/hr)		Longest		To Centroid		Slope			
GIS Sub-basin	HEC-1 Node	(mi^2)	(acres)	(mi^2)	(acres)	2-year	10-year	100-year	2-year	10-year & 100-year	(mi)	(ft)	(mi)	(ft)	(ft/mi)	Sub-basin Roughness n-value	Average Curve Number (AMC II)	LAPRE-1 S-graph Type
38	SM38	4.29	2748	4.29	2748	0.556	0.283	0.049	0.323	0.135	3.85	20335	1.65	8737	119.3	0.030	82.9	Valley Developed
39	SM39	2.72	1739	20.65	13213	0.718	0.422	0.109	0.600	0.252	3.37	17810	1.47	7753	393.9	0.050	77.1	Mountain
40	SM40	5.99	3833	26.64	17047	0.673	0.373	0.081	0.600	0.248	5.54	29276	2.71	14334	366.3	0.045	78.0	Mountain
41	SM41	5.28	3382	55.64	35612	0.774	0.472	0.120	0.600	0.242	4.66	24590	1.95	10282	450.9	0.050	78.1	Mountain
42	SM42	5.16	3300	50.36	32230	0.651	0.355	0.070	0.600	0.218	5.26	27776	2.67	14111	602.5	0.050	81.5	Mountain
43	CC43	4.56	2916	32.18	20593	0.774	0.483	0.124	0.556	0.199	4.39	23180	2.10	11066	141.2	0.040	81.0	Valley Undeveloped
44	SM44	16.46	10535	80.65	51616	0.734	0.430	0.104	0.600	0.245	9.48	50077	4.78	25237	207.9	0.050	77.8	Mountain
45	CC45	3.67	2347	19.24	12313	0.848	0.562	0.162	0.600	0.236	3.69	19501	1.64	8666	196.3	0.040	77.2	Valley Undeveloped
46	SM46	4.65	2977	133.28	85300	0.786	0.493	0.126	0.569	0.217	4.60	24288	2.26	11939	129.8	0.035	80.6	Valley Undeveloped
47	CC47	8.38	5363	27.62	17677	0.778	0.483	0.127	0.597	0.217	10.08	53235	5.34	28198	224.2	0.040	79.2	Mountain
48	CC48	3.28	2102	15.57	9966	0.820	0.532	0.149	0.590	0.223	4.02	21250	1.51	7957	190.8	0.040	78.4	Valley Undeveloped
49	CC49	5.03	3221	5.03	3221	0.865	0.591	0.190	0.600	0.247	5.82	30740	2.68	14145	255.3	0.045	74.9	Mountain
50	SM50	3.50	2240	64.19	41082	0.769	0.471	0.117	0.600	0.227	4.30	22692	1.91	10071	418.3	0.050	79.9	Mountain
51	CC51	7.25	4643	7.25	4643	0.821	0.537	0.157	0.600	0.237	6.80	35893	3.46	18266	303.1	0.045	77.0	Mountain
52	SM52	3.70	2365	3.70	2365	0.630	0.341	0.072	0.488	0.201	3.86	20356	2.04	10784	143.0	0.035	79.1	Valley Developed
53	SM53	6.84	4380	45.20	28930	0.734	0.434	0.112	0.600	0.252	5.54	29244	2.79	14746	255.9	0.040	76.3	Valley Undeveloped
54	SM54	5.05	3230	60.69	38842	0.662	0.365	0.076	0.600	0.226	5.70	30116	3.10	16355	354.3	0.050	80.3	Mountain
55	SM55	1.64	1048	9.63	6161	0.686	0.384	0.083	0.600	0.245	3.48	18371	1.88	9922	316.8	0.035	78.8	Mountain
56	SM56	8.30	5312	17.93	11474	0.683	0.383	0.088	0.565	0.242	5.92	31283	3.22	16976	274.7	0.040	77.0	Mountain
57	SM57	4.55	2914	38.36	24550	0.705	0.409	0.096	0.600	0.234	3.75	19823	1.12	5917	446.5	0.050	79.5	Mountain
61	SM61	15.80	10114	96.45	61730	0.791	0.495	0.124	0.596	0.208	9.93	52445	4.97	26216	172.1	0.040	80.4	Valley Undeveloped
62	SM62	7.17	4590	33.81	21636	0.670	0.369	0.078	0.600	0.248	5.82	30752	2.97	15686	359.9	0.050	77.9	Mountain

2.2.2.3 Precipitation Parameters

Precipitation parameters were calculated according to OCHM methods. For each sub-basin, PWA calculated point precipitation depth data for the modeled return intervals (2-year, 10-year, and 100-year) and the durations specified in the OCHM (5-minute, 30-minute, 1-hour, 3-hour, 6-hour, and 24-hour durations). Due to tendency of the HEC-1 model to over-estimate 2-year runoff rates (as discussed above), PWA followed methods outlined in the OCHM Addendum No. 1 (OC, 1995) to adjust standard 2-year point rainfall amounts by a factor of 0.7. According to the Addendum, this adjustment yields runoff results that are "expected" values instead of the "high-confidence" values resulting from standard OCHM methods. Expected values provide a more realistic representation of 2-year peak runoff rates and are specifically appropriate for evaluating mitigation requirements associated with proposed development activities (OC, 1995, p.3).

Also, point precipitation amounts were adjusted to account for non-mountainous and mountainous areas in the watersheds. As specified in the OCHM, different point precipitation values were used for sub-basins below elevation 2,000 feet (non-mountainous) and sub-basins above elevation 2,000 feet (mountainous). Area averaging was used to calculate appropriate point precipitation values for sub-basins with both mountainous and non-mountainous areas. Calculated point precipitation depths are shown in Table 2-3.

Table 2-3 Point Precipitation Values, Non-mountainous and Mountainous Areas

Duration	Point Precipitation (inches)					
	Non-mountainous Areas			Mountainous Areas		
	2-year	10-year	100-year	2-year	10-year	100-year
5 minutes	0.13	0.34	0.52	0.18	0.50	0.78
30 minutes	0.28	0.72	1.09	0.32	0.84	1.34
1 hours	0.37	0.95	1.45	0.46	1.22	1.94
3 hours	0.62	1.59	2.43	0.94	2.48	3.96
6 hours	0.85	2.20	3.36	1.46	3.87	6.19
24 hours	1.44	3.68	5.63	2.67	7.05	11.27

Source: OCHM, 1986, B-9 and OCHM Addendum No. 1.

Point precipitation depth data were input to LAPRE-1, the Los Angeles Army Corps of Engineers HEC-1 pre-processor, which scaled the data according to sub-basin area to obtain areal precipitation depths, and then formulated a 24-hour design rainstorm for each sub-basin according to OCHM methods (OCHM, 1986, B-11).

2.2.2.4 Infiltration Parameters

Infiltration is the process by which surface water percolates into the sub-surface soil and groundwater column. Infiltration is an important hydrologic process because it governs groundwater recharge, soil moisture storage, and surface water runoff. As modeled by HEC-1, infiltration is one of several processes represented by a withdrawal of a portion of total storm precipitation that could generate surface runoff. Other processes that subtract precipitation from storm runoff (cumulatively referred to as "losses" in HEC-1) include vegetation interception, surface depression storage, and evapotranspiration. Losses are subtracted from actual precipitation to yield effective precipitation, the amount of precipitation available for runoff. According to OCHM methods, losses are computed using two parameters: the low loss fraction (F*), and the maximum loss rate (Fp). Losses are computed as proportional to the low loss fraction and precipitation intensity (F* x Precipitation Intensity) unless they exceed the maximum loss rate. If computed losses exceed the maximum loss rate, losses are assumed to equal Fp.

Hydrologic soil type, vegetation cover, land-use classification, and percent impervious conditions are considered in determining F* and Fp. These data were assembled into the project GIS. Hydrologic soil groups are shown in Figure 2-2, and vegetation and land-use are shown in Figure 2-3 for the San Juan and San Mateo watersheds. Vegetation and land-use data were obtained from previous studies (Figure 2-4) conducted by the Waterways Experimentation Station (WES, 2000), the San Diego Association of Governments (SANDAG 1990, 1995), Dudek/Jones and Stokes (1993), and Harvard (1990).

Soils were classified according to standard USDA descriptions that reflect estimated runoff potential based on soil properties. Soils are grouped according to infiltration rates measured when the soils are thoroughly wet. Soils are classified into four hydrologic soil groups (A, B, C, or D), where A-type soils have the highest infiltration rates and D-type soils have the lowest infiltration potential. Table 2-4 defines hydrologic soil types according to the Orange County Hydrology Manual (1986).

Table 2-4 Orange County Hydrologic Soil Type Descriptions

Type A	Low runoff potential. Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands and gravels. These soils have a high rate of water transmission.
Type B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
Type C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
Type D	High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Source: OCHM, 1986, C-2.

Following OCHM methods, maximum loss rates (Fp) were calculated for each sub-basin. In general, maximum loss rate is determined according to soil hydrologic group, as shown in Table 2-5. These maximum loss rates were used in computing 10-year and 100-year runoff. However, in computing 2-year runoff a maximum loss rate of 0.6 inches/hour was used for all soil types, as specified in the OCHM Addendum No. 1 (OC, 1995). This higher Fp value helps to correct the tendency of HEC-1 to overestimate 2-year runoff rates, as explained previously. For the 10-year and 100-year models, weighted average maximum loss rates were calculated for each sub-basin (Tables 2-1, 2-2) according to the proportion of each soil hydrologic group within the sub-basin. Impervious areas were taken into consideration in calculating Fp values.

figure 2-2

Hydrologic Soil Groups
San Juan and San Mateo Watersheds

Source: USDA/NRCS

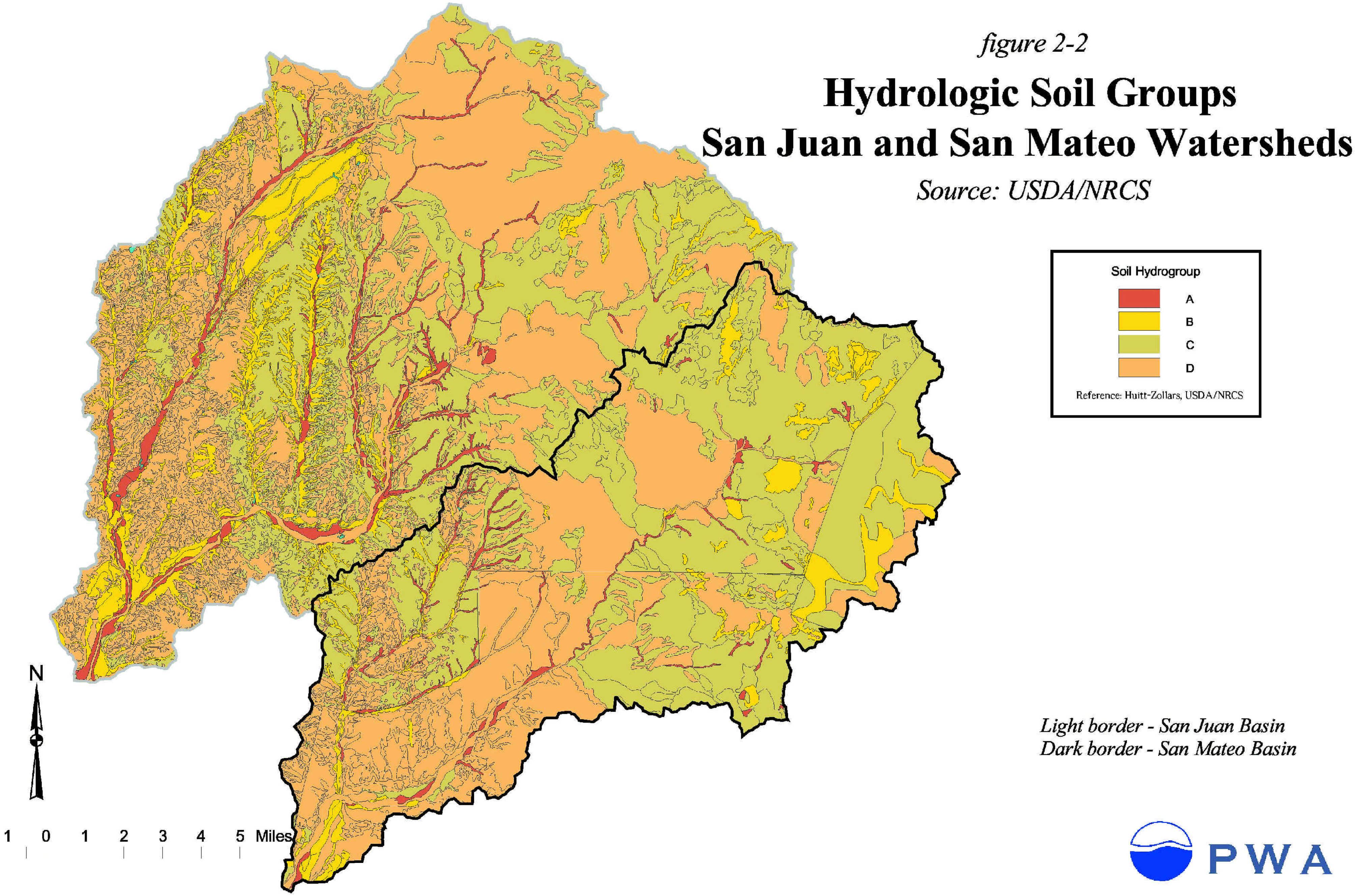
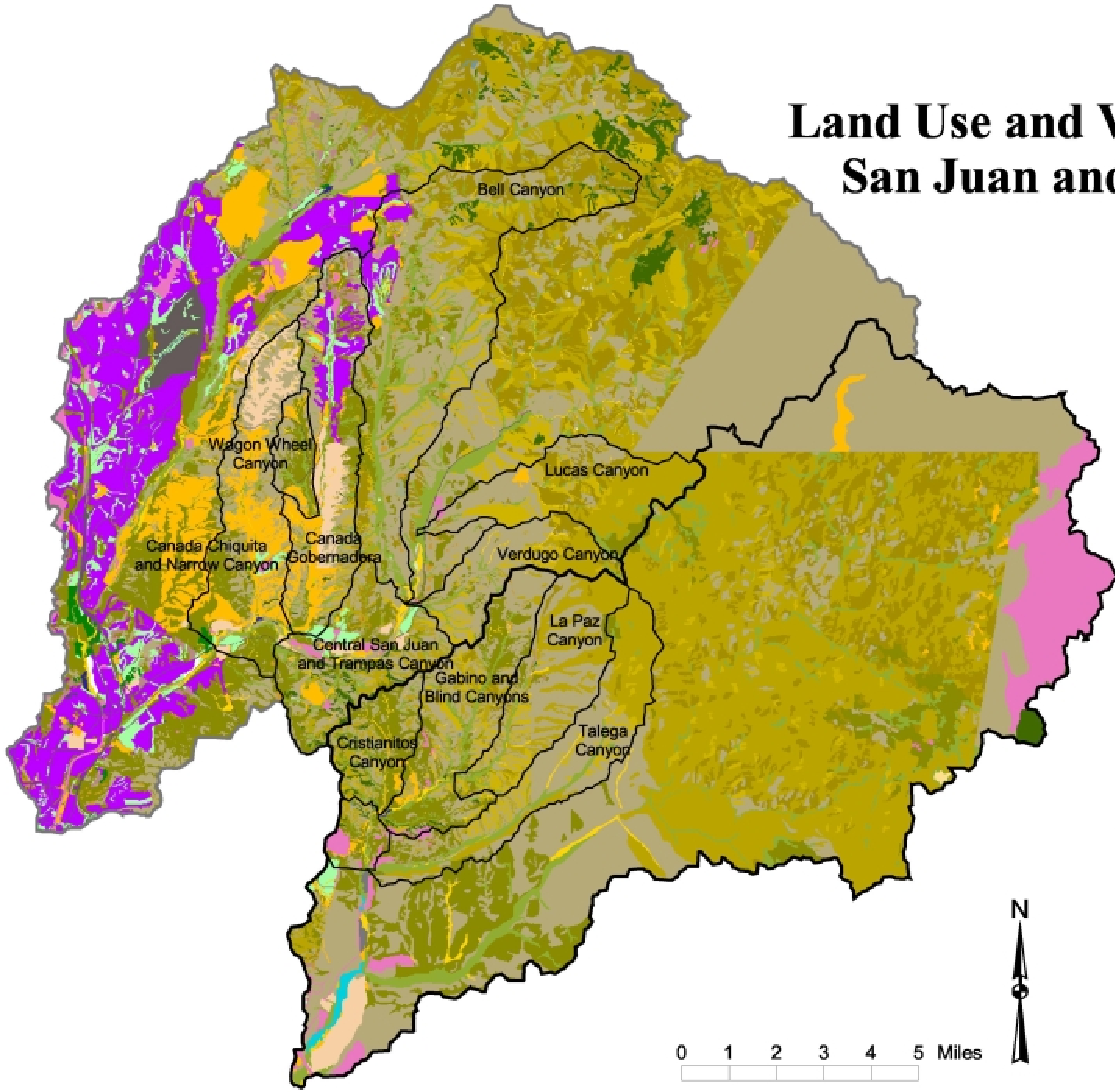


figure 2-3

Land Use and Vegetation Classifications
San Juan and San Mateo Watersheds



Vegetation and Landuse Classification

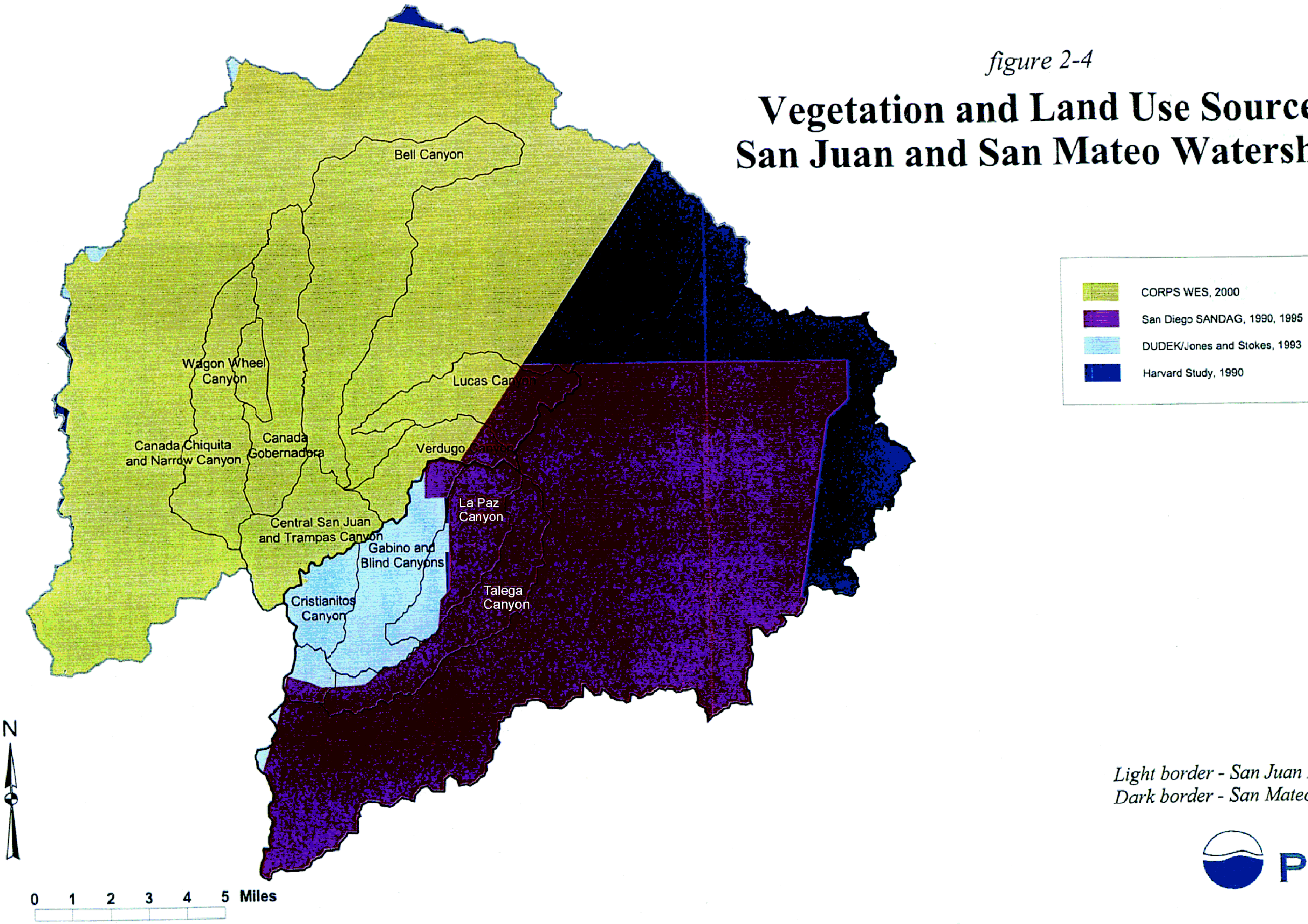
- Disturbed Wetlands
- Flood Control Channels
- General Urban Commercial and Industrial
- General Developed Areas
- General Agriculture
- General Dairy, Cattle or Fallow
- General Disturbed Areas
- Rural Residential
- Irrigated Row Crops
- General Pastures
- Row Crops
- General Orchards
- General Nurseries
- General Parks
- General Transportation
- General Sage Scrub
- Chaparral - Sage Scrub Transition
- Narrowleaf Chaparral
- Narrowleaf Chaparral and Sage
- Broadleaf Chaparral and Sage
- Broadleaf Chaparral
- General Chaparral
- Sage Scrub - Grassland Transition
- General Grassland
- Sumac Savanna
- Live Oak Savanna
- Forest
- Woodland and Riparian Habitat
- Cliff and Rocks
- Rock with Plants
- General Dunes
- Meadow and Marsh
- Riparian Willow
- Streams and Creeks

Light border - San Juan Basin
Dark border - San Mateo Basin

PWA

figure 2-4

Vegetation and Land Use Sources
San Juan and San Mateo Watersheds



Light border - San Juan Basin
Dark border - San Mateo Basin

PWA

Table 2-5 Maximum Loss Rates (Fp) for 10- and 100-year events

Soil Hydro-group	A	B	C	D
Fp (inches/hour)	0.40	0.30	0.25	0.20

Source: OCHM, C-13.

Low loss fractions were computed for each sub-basin following OCHM methods. As described in the OCHM, the Natural Resource Conservation Service (NRCS) runoff index (RI), or curve number, method forms the basis for computing low loss fractions. The RI scale has a range from zero to 100, where higher numbers indicate lower infiltration rates. RI's or curve numbers (CN) were assigned to different areas in the watersheds based on vegetation cover, land-use, soil hydro-group, and antecedent moisture conditions.

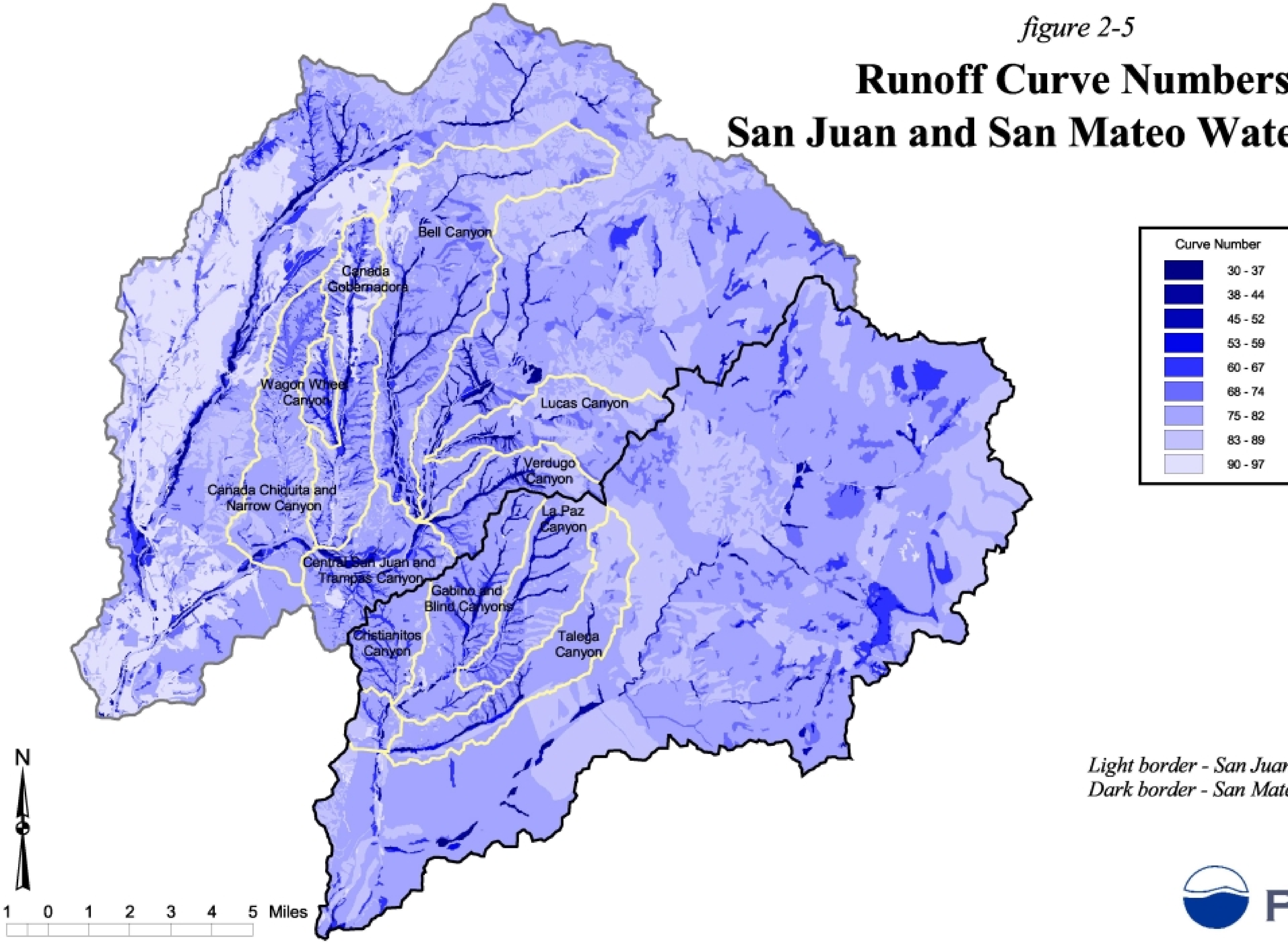
This was accomplished by creating a cross-reference matrix (Table 2-6) and performing a two-layer GIS analysis. Each land-use cell in the GIS database was identified as being *natural, agricultural*, or *developed*. If the ground cover cell was "developed" then the land-use layer took precedence and the vegetation layer was ignored. In contrast, if the cell was "natural" or "agricultural", then the assigned vegetative cover became the active land cover type. In this way, each grid cell in the watershed GIS database was assigned a specific land cover code, a soil type, and a runoff curve number (Table 2-6). The three general land-use distinctions are classified further into 39 specific types in Table 2-6. Natural (*or undeveloped*) lands are divided into particular plant communities where differences in canopy cover and density influences assigned runoff curve numbers. Figures C-2 and C-3 in the OCHM (OCHM, 1986, C-5) were referenced to assign curve numbers according to vegetation, land-use, and soil type. Developed regions are classified according to the density of their development and given different runoff curve numbers. For example, rural residential areas have lower runoff curve numbers than single-family residential zones (Table 2-5). Impervious areas were assigned a curve number of 98 (OCHM, 1986, C-7). Runoff curve numbers for the San Juan and San Mateo watersheds are shown in Figure 2-5.

In undeveloped areas, hydrologic soil type strongly influences runoff generation. For many of the land-uses classes in Table 2-6, D-type soils often have twice as high of a runoff curve number as the A-type soils. In developed areas with more impervious surfaces the relative influence of soil-type is dampened. In general, "fair" conditions were assumed for the quality of the land coverage in designating the runoff curve values. Where "fair" cover conditions were not available for a particular land type, averages were taken between "good" and "poor" conditions to approximate "fair" cover conditions. For the 2-year event, the intermediate antecedent moisture condition (AMC) II was used according to the guidelines of the OCHM Addendum No. 1 (1995). For the 10-year event AMC II was also used, and for the 100-year event AMC III (the wettest initial soil condition) was used.

Runoff curve numbers from each cell of a sub-basin (Figure 2-5) were averaged to provide a singular sub-basin value as input to the hydrologic model (Tables 2-1, 2-2). Although, spatial detail is lost through this aggregation process, this GIS procedure represents an analytical improvement in the accuracy of the rainfall-runoff modeling. Sub-basin runoff curve numbers varied from 72.8 to 93.0 for the 64 sub-basins of the two watersheds. Based on these composite curve numbers, a low loss fraction was calculated for each sub-basin. Together, low loss fractions and maximum loss rates were input to LAPRE-1, and used to calculate precipitation losses and effective precipitation for each sub-basin and each storm event. Effective precipitation was then used in HEC-1 to calculate runoff.

figure 2-5

Runoff Curve Numbers
San Juan and San Mateo Watersheds



Light border - San Juan Basin
Dark border - San Mateo Basin

PWA

Table 2-6 PWA Land Use / Vegetation Cover Classification, Curve Numbers and Basin n-values

PWA Category and Sub-categories			PWA Code	Examples from WES Description	OCHM Source Cover Type(s)	Curve Number for Soil Types				Baisn n value
						A	B	C	D	
Natural (1)	Dunes (101)	General Dunes	10101	Dune Habitats; S. Coastal Foredunes; S. Dune Scrub	Open Brush - good	41	63	75	81	0.03
	Sage Scrub (102)	General Sage Scrub	10201	Scrub Habitats; Southern Coastal Bluff Scrub; Maritime Succulent Scrub; Venturan-Diegan Transitional Sage Scrub; Southern Catus Scrub; Chenopod Scrub; Riveridian Coastal Sage Scrub; Flood Plain Sage Scrub	Open Brush - average fair and good	44	65	76	82	0.03
		Sage Scrub - Grassland Transition	10202	Sage Scrub-Grassland Ecotone; Mixed Sage Scrub - Grassland	average Open Brush - fair and Grass - fair	48	68	78	84	0.03
	Chaparral (103)	General Chaparral	10301	Chaparral Habitats; Southern Mixed Chaparral; Mixed Montane Chaparral; Nolina Chaparral; Toyon-Sumac	average Broadleaf Chaparral - fair and Narrowleaf Chaparral - fair	48	68	78	84	0.03
		Chaparral - Sage Scrub Transition	10302	Coastal Sage-Chaparral Scrub Ecotone	Chaparral and Sage	45	66	77	83	0.03
		Broadleaf Chaparral	10303	Ceanothus Chaparral; Scrub Oak Chaparral; Manzanita Chaparral	Broadleaf Chaparral - average fair and good	36	60	73	80	0.035
		Broadleaf Chaparral and Sage	10304	Scrub Oak-Sagebrush; Scrub Oak-Sage Scrub	average Open Brush - fair and Broadleaf Chaparral - fair	43	65	76	82	0.035
		Narrowleaf Chaparral	10305	Chamise Chaparral	Narrowleaf Chaparral - fair	55	72	81	86	0.03
		Narrowleaf Chaparral and Sage	10306	Chamise-Sagebrush; Chamise-Sage Scrub; Maritime Chaparral-Sagebrush; Maritime Chaparral-Sage Scrub; S. Maritime Chaparral	average Open Brush - fair and Narrowleaf Chaparral - fair	51	69	79	85	0.03
		Live Oak Chaparral	10307	Interior Live Oak Chaparral	average Broadleaf Chaparral - fair and Woodland/Grass - fair	42	64	76	82	0.04
	Grassland (104)	General Grassland	10401	Grassland Habitats; Annual Grass; Elymus Grassland; Souther Coastal Needlegrass; Mixed Perennial Grass; Ruderal; Deergrass	Grass - average fair and good	44	65	77	82	0.04
		Sumac Savanna	10402	Sumac Savanna	average Grass - fair and Broadleaf Chaparral - fair	45	66	77	83	0.04
		Live Oak Savanna	10403	Coast Live Oak Savanna	Average Grass - fair and Woodland/Grass - fair	47	67	78	83	0.04
	Woodland and Forest (105)	Woodland and Riparian Habitat	10501	Riparian Habitats; Riparian Herb; S. Sycamore; S. Coast Live Oak; S. Arroyo Willow; S. Black Willow; S. Cottonwood-Willow; White Alder; Canyon Live Oak; Woodland Habitats	Woodland - average fair and good	31	58	72	78	0.05
		Riparian Willow	10502	Southern Willow Scrub; Mulfat Scrub	Average Open Brush - fair and Woodland - fair	41	63	75	81	0.05
		Forest	10503	Forest Habitats	Woodland/Grass - average fair and good	39	62	75	81	0.05
	Wetlands and Watercourses (106)	Meadow and Marsh	10601	Vernal Pools, Seeps and Wet Meadows; Marsh Habitats	Meadows/Cienegas - good	30	58	71	78	0.04
		Streams and Creeks	10602	Intermittent Streams; Ephemeral Drainages	verage Open Brush - fair and Grass - fa	48	68	78	84	0.03
		Flood Control Channels	10603	Flood Control Channels	average Open Brush - fair and Grass - fair with 50% impervious	73	83	88	91	0.02
	Cliff and Rock Habitats (107)	Cliff and Rocks	10701	Cliff and Rock Outcrops	Barren	78	86	91	93	0.05
		Rock with Plants	10702	Vascular Plants in Rock Habitats	average Barren and Open Brush - fair	62	76	84	88	0.05
Agricultural (2)	General Agriculture (201)	General Agriculture	20101	Agriculture; Other Agriculture	average Fallow, Legumes/Close Seeded, Row Crops, Small Grains	67	78	85	89	0.2
	Row Crops (202)	Row Crops	20201	Dryland Field Crops	average Pasture/Dryland - fair and Small Grains	59	73	82	86	0.2
		Irrigated Row Crops	20202	Irrigated Row and Field Crops	avergae Pasture/Irrigated - fair and Row Crops and Small Grains	62	75	83	87	0.2
	Dairy and Cattle or Fallow (203)	General Dairy, Cattle or Fallow	20301	Dairies/Stockyards/Stables	Fallow	77	86	91	94	0.03
	Orchards (204)	General Orchards	20401	Vineyards and Orchards	Orchards/Evergreen - average fair and good	39	62	75	81	0.1
	Nurseries (205)	General Nurseries	20501	Nurseries	Orchard/Evergreen - good with 15% impervious	43	64	76	82	0.025
	Pastures (206)	General Pastures	20601		average Pasture/Dryland - fair and Pasture Irrigated - fair	47	67	78	83	0.03
Developed (3)	General Developed Areas (301)	General Developed Areas	30101	Developed Areas; Non-urban industrial/commercial/institutional; Other Developed Areas	Residential/Commercial with 50% impervious	65	77	84	87	0.02
		Residential / Commercial	30102			32	56	69	75	0.02
		Impervious Areas	30103			98	98	98	98	0.01
	Residential (302)	Rural Residential	30201	Rural residential	Chaparral and Sage with 10% impervious	50	69	79	85	0.025
		Single Family Residential	30202		Residential/Commercial with 40% impervious	58	73	81	84	0.025
		Multiple Family Residential	30203		Residential/Commercial with 75% impervious	82	88	91	92	0.02
	Urban Commercial and Industrial (303)	General Urban Commercial and Industrial	30301	Urban	Residential/Commercial with 90% impervious	91	94	95	96	0.015
	Transportation (304)	General Transportation	30401	Transportation	Residential/Commercial with 95% impervious	95	96	97	97	0.015
	Parks (305)	General Parks	30501	Parks and Ornamental Plantings	Turf - fair with 15% impervious	52	70	80	84	0.025
Other (9)	Disturbed Areas (901)	General Disturbed Areas	90101	Disturbed Areas	Barren	78	86	91	93	0.04
		Disturbed Wetlands	90102		average Meadows/Cienegas - fair and Barren	65	78	86	89	0.03

NOTES:
1) Basin n-values revised 8th September 2000

2.2.2.5 Synthetic Unit Hydrograph Parameters

The unit hydrograph method is a means of calculating the time distribution of runoff during a rainfall event. A unit hydrograph is a hydrograph with a volume of 1 inch of storm runoff for a given rainstorm in a given watershed. In calculating a unit hydrograph, the watershed factors affecting the time distribution of runoff (watershed area, shape, slope and land-use) are assumed to be constant for a given watershed. There are several methods that can be used to calculate unit hydrographs, including the Snyder method, Clark's method, the SCS method, and the S-graph method.

The OCHM specifies that the unit hydrograph method be used to calculate runoff hydrographs in Orange County watersheds larger than 640 acres or one square mile. The OCHM also specifies that the unit hydrograph should be derived using the S-curve method. LAPRE-1 provides a useful means of calculating the unit hydrograph for a given watershed and event based on OCHM methods. Input parameters required by LAPRE-1 include basin factor (n), length of the longest watercourse (L), length of watercourse to the centroid of the watershed (L_{ca}), average watershed slope (S), and S-graph type (mountain, foothill, valley: developed, or valley: undeveloped). These parameters are listed in Tables 2-1 and 2-2.

The GIS database compiled for the two watersheds was used to determine LAPRE-1 unit hydrograph input parameters for each sub-basin. Basin roughness factors (n) were determined according to descriptions in Figure E-2 of the OCHM (1986). As described, channel and land cover characteristics are the most important factors in determining basin n-values. Low basin factors (0.015 to 0.025) apply to areas where some proportion of the drainage system has been channelized, and where land cover includes impervious areas, grasses, and scattered brush. Moderate basin factors (0.030 to 0.050) apply to areas where the drainage system is primarily natural, and where land cover includes grasses, brush, and trees. A high basin factor (0.200) applies to regions with no channeled drainage system and particularly dense land cover. Tables 2-1 and 2-2 include basin factors selected for each modeled sub-basin in the two watersheds.

Watercourse lengths and slopes for each sub-basin were calculated using the Digital Elevation Model (DEM) of watershed topography and various GIS calculation routines. Length of the longest watercourse (L) was defined as the longest flow distance between any point in the sub-basin the downstream sub-basin concentration point. L was found using a GIS routine that calculated the flow distance between the mouth of San Juan or San Mateo Creek at the Pacific Ocean and every DEM grid point in the sub-basin, and then returned the longest and shortest of these lengths. Invariably, the longest distance was to a point on the watershed divide of the sub-basin and shortest distance was to the sub-basin concentration point. L was calculated as the difference between these two lengths. Calculated L-values for key sub-basins are shown in Tables 2-1 and 2-2.

Length of watercourse to the centroid (L_{ca}) was measured in a similar manner to L. A GIS routine was used to identify the centroid grid point for each sub-basin. Flow distances between the centroid point and the mouth of the creek and the sub-basin concentration point and the mouth of the creek were calculated and subtracted to obtain L_{ca}. Average sub-basin slope (S) was computed as the overall slope between the sub-basin concentration point and the point on the sub-basin flow divide farthest from the concentration point. Calculated sub-basin slopes and L_{ca} distances are shown in Tables 2-1 and 2-2.

In addition to these parameters, an S-graph type was assigned to each sub-basin for calculation of a unit hydrograph in LAPRE-1. OCHM criteria for assigning an S-graph to a watershed area are shown in Table 2-7.

Table 2-7 Criteria for Assigning an S-graph to a Watershed Area

S-graph Type	Criteria
Mountain	Watersheds characterized by natural channels with numerous plunging flow reaches and lodged boulders/debris.
Foothill	Watersheds characterized by natural channels that are sharply incised in canyon bottoms, i.e., overbank flows are confined near the defined channels.
Valley: Undeveloped	Natural watersheds characterized by channels that are not sharply incised, i.e., where overbank flows may spread widely from the defined channel.
Valley: Developed	Watersheds characterized by prismatic channels that provide conveyance of T-year peak flows.

Source: OCHM, 1986, E-7.

PWA used data from several different sources (project GIS database; SLA, 1999; WES, 2000; U.S. ACOE Los Angeles District, 1999) to evaluate key sub-basin characteristics and assign an S-graph according to OCHM criteria. Characteristics evaluated include land-use, percent of area developed, land slopes, and length of incised channel. Tables 2-1 and 2-2 include S-graph types assigned to each sub-basin.

Together, the parameters described in this section (basin factor, length of the longest watercourse, length of watercourse to the centroid of the watershed, average watershed slope, and S-graph type) were used in LAPRE-1 to calculate unit hydrographs for each sub-basin and each storm event.

2.2.2.6 Routing and Hydraulic Structure Parameters

Because a multiple sub-basin approach was required to model the large San Juan and San Mateo Watersheds, it was also necessary to use routing reaches in the HEC-1 model to represent portions of certain channels. For the developed western portion of the San Juan Watershed (along Oso Creek) it was also necessary to simulate several hydraulic structures, including reservoirs and detention basins. Figures 2-6 and 2-7 illustrate the HEC-1 node networks for the modeled San Juan and San Mateo creek watersheds. Routing reaches are identified in these figures by trapezoidal shapes, representing channel cross-sections. Hydraulic structures are identified by triangles. Sub-basins in Figures 2-6 and 2-7 can be geographically cross-referenced with the sub-basin delineations of Figure 2-1.

In the San Juan Watershed, where surveyed cross-sectional data was available from a HEC-RAS hydraulics model (SLA, 1999), the Muskingum-Cunge routing method was used. In HEC-1, this method incorporates channel cross-sectional geometry information, a reach length and slope, and data on channel roughness. Reach lengths and slopes were calculated using the watershed GIS. For open channels an average eight-point cross-section based on HEC-RAS model geometry was used. Roughness values were also obtained from the HEC-RAS model. Culvert geometry was used for routing reaches in culverts. Routing data for those San Juan reaches modeled with the Muskingum-Cunge method are shown in Table 2-8.

Table 2-8 Muskingum-Cunge Routing Data, San Juan Watershed

Sub-Basin #	HEC-1 Reach Name	Channel Type	Reach Length (Feet)	Energy Grade Slope	Roughness (n), Left Overbank	Roughness (n), Channel	Roughness (n), Right Overbank
8	ERSJ8	Natural	3,853	0.0077	0.035	0.030	0.035
8	LRSJ8	Natural	6,137	0.0075	0.035	0.030	0.035
11	ROC11a	Concrete	9,503	0.0064	0.035	0.015	0.035
11	ROC11b	Natural	5,001	0.0049	0.035	0.030	0.035
12	ROC12	Concrete	3,337	0.0098	0.035	0.020	0.035
13	RSJ13	Natural	19,617	0.0065	0.035	0.030	0.035
14	ROC14	Armored	3,099	0.0074	0.035	0.020	0.035
15	ROC15	Natural	9,603	0.0092	0.035	0.030	0.035
16	RTC16	Natural	12,037	0.0114	0.045	0.040	0.045
17	RTC17a	Natural	6,317	0.0095	0.035	0.030	0.035
17	RTC17b	Concrete	5,831	0.0095	0.016	0.016	0.016
18	RSJ18	Concrete	18,105	0.0009	0.016	0.016	0.016
21	RSJ21	Natural	13,235	0.0079	0.040	0.030	0.040
22	ROC22a	Natural	9,284	0.0166	0.035	0.028	0.035
22	ROC22b	Natural	5,108	0.0166	0.035	0.028	0.035
25	ERSJ25	Natural	3,391	0.0039	0.035	0.030	0.035
25	LRSJ25	Natural	2,335	0.0084	0.035	0.030	0.035
25	NRSJ25	Natural	3,327	0.0069	0.035	0.030	0.035
27	ROC27	Concrete Pipe	6,137	0.0166	0.014	0.014	0.014
32	RTC32	Natural	11,442	0.0198	0.045	0.040	0.045
33	ROC33	Natural	2,818	0.0198	0.035	0.030	0.035
35	RSJ35	Natural	18,413	0.0144	0.035	0.025	0.035
59	ROC59a	Concrete Pipe	4,167	0.0150	0.014	0.014	0.014
59	ROC59b	Concrete Pipe	2,381	0.0150	0.014	0.014	0.014
63	RSJ63	Natural	15,818	0.0102	0.035	0.030	0.035
64	RTC64	Natural	22,416	0.0083	0.040	0.035	0.040

Source: PWA GIS Analysis, 2000; SLA, 2000 HEC-RAS model.

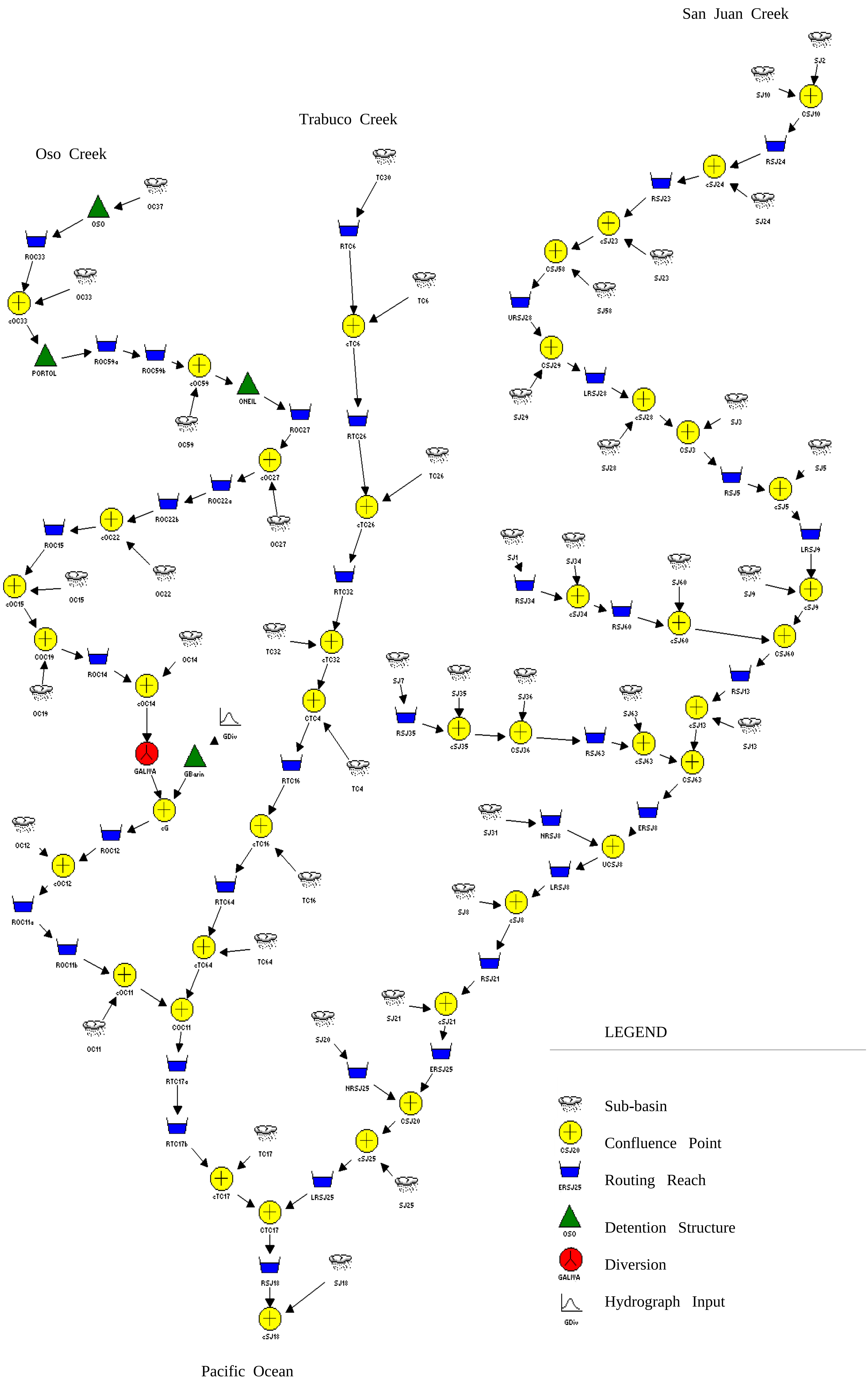


figure 26

HEC-1 Node Network
San Juan Watershed

1393 SAMP San Juan.cdr

P W A

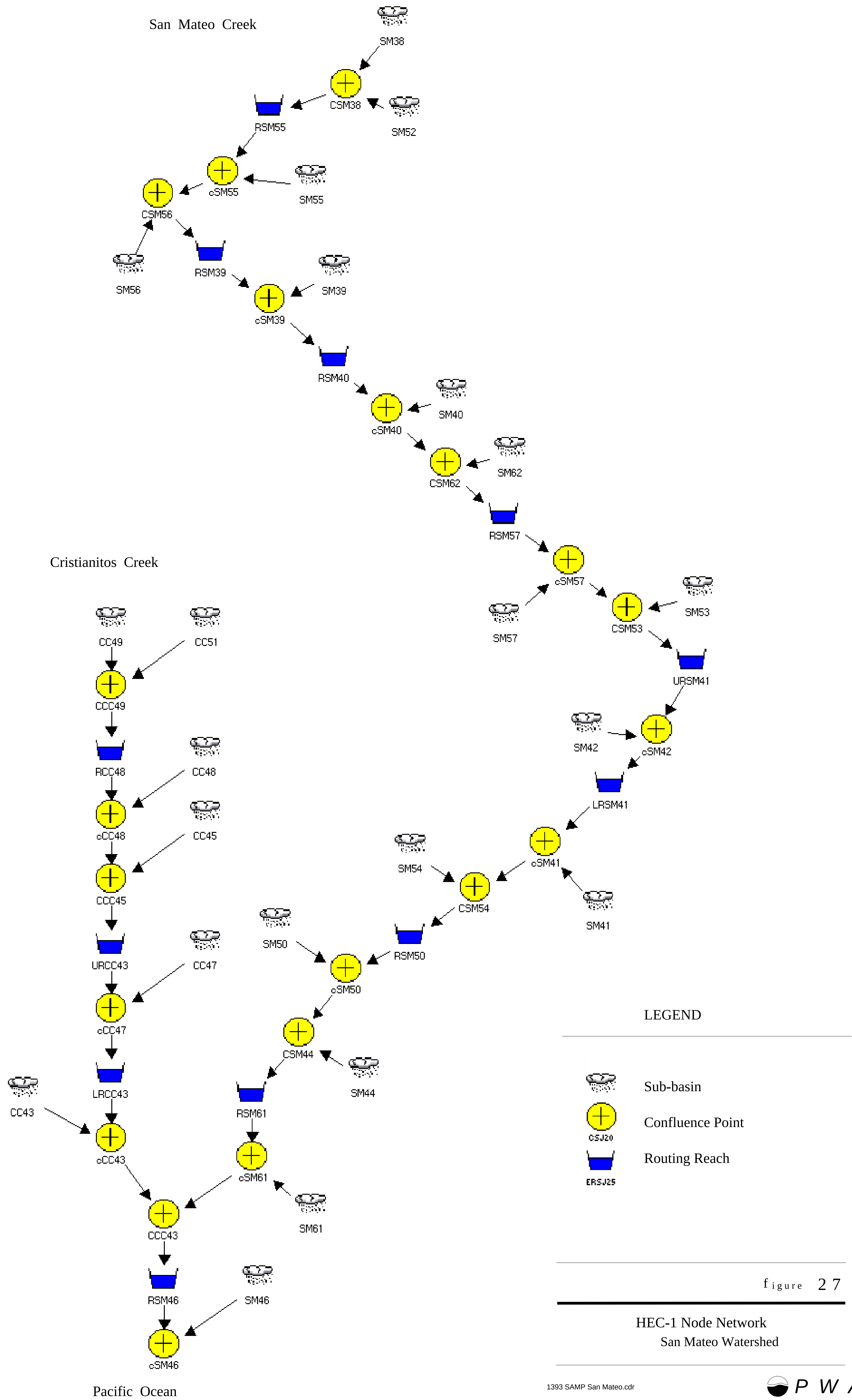


figure 27

HEC-1 Node Network
San Mateo Watershed

1393 SAMP San Mateo.cdr

P W A

In the areas of the San Juan Watershed where HEC-RAS model data was not available, the Muskingum routing method was used. Muskingum routing was also used for the entire San Mateo Watershed HEC-1 model. Muskingum routing requires the calculation of three parameters for use in the model: K, NSTPS, and X. K is an estimate of the travel time through the routing reach. K was calculated using an estimate of flood wave velocity and channel length calculated from GIS. X is a weighting parameter that ranges between 0.0 and 0.5. NSTPS is the number of computational sub-reaches within the routing reach and may be calculated by dividing K by the computation interval of the model (24 minutes). Table 2-9(a-b) shows Muskingum routing parameters used in the HEC-1 models.

The OCHM specifies that streamflow routing calculations, when necessary, should be performed using the convex routing technique. However, it also states that other routing techniques may be acceptable if results of these techniques are comparable to those obtained using convex routing. Since convex routing is not available in the HEC-1 program, PWA used Muskingum and Muskingum-Cunge routing techniques, as previously described. However, to satisfy the requirements of the OCHM, PWA applied the convex routing technique (as outlined in the OCHM) to several routing reaches in the San Juan Creek watershed model for 100-year conditions and compared with Muskingum routing results. The same inflow hydrograph for a given reach was routed by the Muskingum method in HEC-1 and the convex method using spreadsheet calculations. The percentage differences between the two outflow hydrographs were calculated for each time step of the hydrographs. Table 2-10 shows and example of the results of the comparison for reach RSJ60. Table 2-11 summarizes average percentage difference results for all reaches compared, for flows greater than 10 cfs.

Table 2-9a Muskingum Routing Parameters, San Juan Creek and San Mateo Creek Watershed

San Juan Creek Watershed										
Sub-Basin #	HEC-1 Reach Name	2-Year Event			10-Year Event			100-Year Event		
		K (Hours)	X	NSTPS	K (Hours)	X	NSTPS	K (Hours)	X	NSTPS
RSJ5	5	0.7	0.3	2	0.6	0.2	2	0.4	0.1	1
RTC6	6	2.4	0.3	8	1.8	0.2	7	1.4	0.1	6
NRSJ8	8	0.9	0.3	3	0.7	0.2	2	0.5	0.1	2
LRSJ9	9	0.2	0.3	1	0.1	0.2	1	0.1	0.1	1
RSJ23	23	2.1	0.3	7	1.6	0.2	6	1.3	0.1	5
RSJ24	24	1.2	0.3	4	0.9	0.2	3	0.7	0.1	3
RTC26	26	2.0	0.3	7	1.5	0.2	6	1.2	0.1	5
LRSJ28	28	1.7	0.3	5	1.2	0.2	4	1.0	0.1	4
URSJ28	28	0.2	0.3	1	0.1	0.2	1	0.1	0.1	1
RSJ34	34	2.6	0.3	9	2.0	0.2	7	1.6	0.1	7
RSJ60	60	2.0	0.3	6	1.5	0.2	5	1.2	0.1	5

Table 2-9b Muskingum Routing Parameters, San Juan Creek and San Mateo Creek Watershed

San Mateo Creek Watershed										
Sub-Basin #	HEC-1 Reach Name	2-Year Event			10-Year Event			100-Year Event		
		K (Hours)	X	NSTPS	K (Hours)	X	NSTPS	K (Hours)	X	NSTPS
RSM55	55	0.8	0.3	2	0.6	0.2	2	0.5	0.1	2
RSM39	39	1.0	0.3	3	0.7	0.2	2	0.6	0.1	2
RSM40	40	0.3	0.3	1	0.2	0.2	1	0.2	0.1	1
RSM57	57	0.9	0.3	3	0.7	0.2	2	0.6	0.1	2
URSM41	41	0.6	0.3	2	0.5	0.2	1	0.4	0.1	1
LRSM41	41	1.1	0.3	3	0.8	0.2	3	0.7	0.1	3
RSM50	50	1.5	0.3	5	1.1	0.2	4	0.9	0.1	4
RSM61	61	4.2	0.3	14	3.2	0.2	12	2.5	0.1	11
RCC48	48	1.0	0.3	3	0.7	0.2	2	0.6	0.1	2
URCC43	43	0.7	0.3	2	0.5	0.2	1	0.4	0.1	1
LRCC43	43	1.2	0.3	4	0.9	0.2	3	0.7	0.1	3
RSM46	46	1.7	0.3	5	1.3	0.2	5	1.0	0.1	4

Source: PWA calculations, 2001.

Table 2-10 Comparison of Muskingum and Convex Routing Techniques for Reach RSJ60, San Juan Creek Watershed

Muskingum Routing Outflow (cfs)	Convex Routing Outflow (cfs)	%-Difference	Muskingum Routing Outflow (cfs)	Convex Routing Outflow (cfs)	%-Difference	Muskingum Routing Outflow (cfs)	Convex Routing Outflow (cfs)	%-Difference
0.0	0.0	0.0 %	2185.2	2185.3	0.0 %	704.5	765.6	8.7 %
0.6	0.0	-100.0 %	2360.5	2342.5	-0.8 %	594.7	658.7	10.8 %
6.4	0.0	-100.0 %	2552.5	2534.8	-0.7 %	509.7	574.8	12.8 %
29.2	45.7	56.3 %	2770.5	2747.6	-0.8 %	443.4	497.4	12.2 %
82.2	105.0	27.8 %	3033.9	3008.7	-0.8 %	389.2	438.5	12.7 %
164.4	177.1	7.7 %	3355.3	3342.0	-0.4 %	342.8	380.1	10.9 %
260.9	260.0	-0.3 %	3721.3	3674.0	-1.3 %	302.0	337.0	11.6 %
360.9	348.5	-3.4 %	4093.2	3999.7	-2.3 %	266.2	293.9	10.4 %
464.3	449.3	-3.2 %	4445.5	4325.3	-2.7 %	234.6	259.9	10.8 %
569.5	548.8	-3.6 %	4822.8	4834.9	0.3 %	206.8	228.1	10.3 %
668.2	632.4	-5.4 %	5327.5	5355.7	0.5 %	181.4	199.0	9.7 %
752.2	716.0	-4.8 %	5956.3	5789.8	-2.8 %	157.3	171.9	9.3 %
819.7	778.3	-5.0 %	6493.5	6188.9	-4.7 %	134.0	147.0	9.7 %
874.3	837.0	-4.3 %	6728.8	6398.4	-4.9 %	112.7	126.3	12.0 %
920.3	886.9	-3.6 %	6695.4	6404.6	-4.3 %	94.8	106.2	12.0 %

Table 2-10 (continued)

Muskingum Routing Outflow (cfs)	Convex Routing Outflow (cfs)	%-Difference	Muskingum Routing Outflow (cfs)	Convex Routing Outflow (cfs)	%-Difference	Muskingum Routing Outflow (cfs)	Convex Routing Outflow (cfs)	%-Difference
960.9	931.6	-3.0 %	6537.9	6341.5	-3.0 %	80.1	91.7	14.4 %
997.8	973.3	-2.5 %	6291.5	6073.0	-3.5 %	68.0	77.2	13.5 %
1032.1	1010.2	-2.1 %	5914.5	5800.5	-1.9 %	57.7	66.4	15.1 %
1064.8	1046.6	-1.7 %	5420.9	5354.0	-1.2 %	48.9	56.1	14.7 %
1096.7	1080.2	-1.5 %	4894.3	4907.6	0.3 %	41.5	47.9	15.3 %
1128.2	1113.7	-1.3 %	4410.0	4509.8	2.3 %	35.2	40.7	15.6 %
1159.6	1146.2	-1.2 %	3989.7	4124.6	3.4 %	29.9	34.5	15.3 %
1191.0	1178.5	-1.0 %	3627.1	3786.6	4.4 %	25.3	29.4	16.2 %
1222.5	1210.7	-1.0 %	3316.7	3485.1	5.1 %	21.4	24.6	15.1 %
1254.2	1242.8	-0.9 %	3056.7	3212.8	5.1 %	18.2	21.2	16.6 %
1286.1	1275.1	-0.9 %	2842.2	2998.6	5.5 %	15.4	17.7	14.9 %
1318.5	1307.8	-0.8 %	2663.6	2790.0	4.7 %	13.0	15.0	15.6 %
1351.6	1340.9	-0.8 %	2510.6	2630.7	4.8 %	10.7	12.3	15.0 %
1385.5	1375.1	-0.7 %	2375.5	2471.4	4.0 %	8.6	10.2	17.6 %
1420.3	1409.4	-0.8 %	2253.4	2340.9	3.9 %	6.9	8.2	19.7 %
1456.3	1446.0	-0.7 %	2141.2	2214.5	3.4 %	5.4	6.6	21.9 %
1493.7	1482.6	-0.7 %	2036.9	2101.7	3.2 %	4.2	5.3	25.3 %
1532.8	1522.3	-0.7 %	1938.6	1996.5	3.0 %	3.2	4.0	26.7 %
1573.9	1562.8	-0.7 %	1841.5	1883.4	2.3 %	2.2	2.9	32.5 %
1617.2	1606.4	-0.7 %	1733.8	1759.2	1.5 %	1.4	1.9	39.0 %
1663.4	1652.6	-0.6 %	1602.2	1629.9	1.7 %	0.7	1.4	98.6 %
1713.0	1701.4	-0.7 %	1447.7	1478.0	2.1 %	0.3	0.8	228.9 %
1767.1	1755.7	-0.6 %	1286.7	1326.0	3.1 %	0.1	0.6	880.3 %
1830.5	1815.1	-0.8 %	1131.7	1177.5	4.0 %	0.01	0.4	4661.5 %
1914.8	1924.8	0.5 %	982.0	1029.1	4.8 %			
2032.8	2034.6	0.1 %	836.9	894.7	6.9 %	**Average %-Difference** (Q > 10 cfs) =		**4.1 %**

Source: PWA analysis, 2001.

Table 2-11 Average Between Muskingum and Convex Routing Techniques for Selected Routing Reaches in San Juan Creek Watershed

Routing Reach	Average %-Difference (Q > 10 cfs)
RTC6	7.0 %
RTC26	3.6 %
RSJ24	0.6 %
RSJ23	5.7 %

Table 2-11 (continued)

Routing Reach	Average %-Difference (Q > 10 cfs)
URSJ28	0.1 %
LRSJ28	2.3 %
RSJ5	-0.7 %
LRSJ9	0.2 %
RSJ34	9.3 %
RSJ60	4.1 %
NRSJ8	-0.3 %

Source: PWA analysis, 2001.

The comparison between the Muskingum and Convex routing methods indicates that the two techniques produce very similar results. As shown in Table 2-11, the average percentage difference between outflow hydrographs, for flows greater than 10 cfs, was less than 10% for all reaches tested, and was less than 5% for the majority of reaches. This indicates that the two routing methods produced very comparable results and that PWA's selected routing methods are a reasonable alternative to the Convex method specified in the OCHM.

In addition to the routing reaches described, four detention facilities were modeled on Oso Creek in the San Juan Watershed: Oso Reservoir, Portola Basin, O'Neil Basin, and the Galivan Basin. Data to model these four facilities in HEC-1 was taken from SLA (1999).

Oso Reservoir, Portola Basin, and O'Neil Basin are standard detention basin facilities. Therefore, the modeling approach for these basins in HEC-1 is simply to use the detention routine, which requires stage-storage and stage-discharge data that describe the geometry of the basins. An initial storage condition for each facility is also required in HEC-1. Since these three detention facilities have been in place for some time, the stage-storage and stage-discharge data describing basin geometry is well established. These data are presented in Table 2-12, as described in SLA (1999). The facilities were assumed to be approximately empty as an initial condition in the HEC-1 models.

Table 2-12 Stage-Storage and Stage-Discharge Data

Oso Reservoir			Portola Detention Basin			O'Neil Detention Basin		
Volume (acre-feet)	Stage (Feet)	Discharge (cfs)	Volume (acre-feet)	Stage (Feet)	Discharge (cfs)	Volume (acre-feet)	Stage (Feet)	Discharge (cfs)
0	880	0	0	780	0	0	706	0
160	900	1	3	785	110	1	707	77
400	910	2	5	790	140	4	710	134
700	915	140	12	795	160	25	715	190
1,300	925	142	30	800	170	114	720	230
2,050	935	144	65	805	180	328	729	284
2,450	940	147	120	810	190	375	730	369
3,450	950	149	210	815	205	520	735	1,120
3,451	955	150	240	816	400	650	739	1,863
4,500	960	1,900	260	817	1,200	678	740	2,044
4,750	963	3,875	275	818	3,000	803	744	2,785

Source: SLA, 1999, Table 2

The Galivan Basin is a side-spillway detention facility that diverts flow from Oso Creek during peak flow conditions, but does not divert during lower flows. HEC-1 cannot adequately model the complex hydraulics of such a facility with the standard detention routine. Therefore, PWA took a different approach to modeling Galivan Basin that incorporated externally calculated hydraulic data from Orange County as reported by SLA. PWA's approach was to model Galivan Basin in HEC-1 using two components: 1) a diversion, and 2) a detention basin.

The diversion simulates flow out of the creek, over a diversion weir, and into the basin during peak flow periods. Discharge over the diversion weir is correlated to discharge in the creek. This discharge relationship was estimated based on Orange County hydraulic modeling results and was presented in SLA (1999). PWA used this discharge relationship to model the diversion component of Galivan Basin in HEC-1 (Table 2-13).

Table 2-13 Diversion Discharge Relationship, Galivan Basin

Discharge in Oso Creek (cfs)	0	3,500	4,000	5,000	7,000	9,000	10,000	29,000
Discharge Diverted (cfs)	0	0	350	1,300	3,000	4,700	4,800	4,800

Source: SLA, 1999, Table 23

The second component, the detention basin, simulates routing through the basin and back into the channel downstream through the basin outlet structure. As inflow to the detention basin, a hydrograph was specified that retrieves flow previously diverted from the creek. Detention basin elevation-storage and elevation-outflow characteristics were estimated based on Orange County hydraulic modeling results (Table 2-14). HEC-1 results from PWA's approach to modeling Galivan Basin compared well with Orange County hydraulic modeling results.

Table 2-14 Estimated Elevation-Storage and Elevation-Outflow Characteristics, Galivan Basin

Elevation (Feet)	Storage (Acre-feet)	Outflow (cfs)
253.80	0.000	0.0
254.02	1.153	0.0
254.62	2.721	0.0
254.89	3.406	0.0
255.21	5.021	0.0
255.40	6.177	0.0
255.85	8.800	0.0
256.00	9.800	16.0
256.15	10.700	24.2
256.90	15.200	43.5
257.65	20.000	58.0
258.02	22.361	65.0
258.35	26.500	70.0
259.50	43.650	102.0
261.00	64.650	125.0
262.00	78.000	140.0

Source: PWA analysis (2000) of Orange County hydraulic modeling data.

2.2.3 Low Flow Analysis

The quantity and timing of dry season flows can be determining factors for riparian resources. Changes in dry season flow can not only alter the plant community composition of a stream, but also can alter channel stability, and result in increased pollutant mobilization. To rigorously evaluate low-flow conditions in a stream, an extended historic record of daily flow conditions is required. Four stream gauges in the study area were investigated[1] and none contained reliable low flow records of sufficient duration for a statistically valid analysis.

Although data limitations precluded a complete statistical analysis of baseline low-flow conditions, the historical role of development in increasing dry season flows is well documented (Hamilton, 1992). A trend analysis was conducted on low-flow data from the urbanized Oso Creek (Crown Valley gauge) basin using the IHA program (Richter et al., 1996). The IHA software calculates 34 summary statistics to characterize changes in flow regime resulting from changes in watershed conditions (such as urbanization or construction of a dam). The results of the IHA analysis for Oso Creek provide useful insight into the potential effects of future land use changes on dry-season flow in the central San Juan and western San Mateo watersheds. Potential effects of proposed development on dry-season flow and design features to minimize these effects will be analyzed during the on-site alternatives analysis.

2.3 SAN JUAN WATERSHED OVERVIEW

2.3.1 Drainage Network

Hydrologically, the San Juan watershed can be organized into three regions: the western portion of the watershed with the highly developed Oso Creek sub-basin and the moderately developed Trabuco Creek sub-basin; the relatively undeveloped sub-basins of the central San Juan; and the steeper eastern headwater canyons. The valleys and hillslopes of the central San Juan Basin (Canada Chiquita, Canada Gobernadora, Bell Canyon, Lucas Canyon, Trampas Canyon and Verdugo Canyon) are the focus of much of this report, whereas the western developed areas and the eastern headwaters are not primary assessment areas. These central sub-basins encompass 59.3 mi^2, which represent 33.7% of the total San Juan watershed area (176 mi^2). Figure 2-8 depicts the surface stream network of the entire San Juan Creek watershed as calculated by the multiple threshold (WES/CRRL calibrated) method described above in Section 3.2.1. Downstream of the Bell Canyon confluence, San Juan Creek is a seventh order stream as it flows 15.2 mi to the Pacific Ocean. Other large (sixth order) confluences occur at the junctions of Canada Gobernadora and Arroyo Trabuco further downstream. First order channels represent about 50% of the total length of stream channel in the watershed; this was consistent with findings for individual sub-basins (see below).

The drainage density of the entire San Juan watershed is 10 mi/mi^2, which is consistent with drainage densities calculated for the individual sub-basins described below. This value is somewhat low compared to other published reports (Strahler 1968, Schumm 1956), which suggest average drainage densities for

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[1] *Stream gauges investigated were San Juan Creek at La Novia (USGS #11046530), Trabuco Creek at Camino Capistrano (Orange County #5), Trabuco Creek at Del Obispo (USGS #11047300), and Oso Creek at Crown Valley Parkway (Orange County #218).*

various geomorphic settings including southern California (~20-30 mi/mi^2). Geologic, soil, and basin configuration issues (PCR, 2001) may all contribute to this lower than expected drainage density value. In the San Juan Creek watershed, many tributary valleys are comprised of sandy terrains and contain swales that do not have a clearly defined channel form. Omitting these channel-less swales from the surface drainage network reduces the calculated drainage density of San Juan Creek watershed. Another factor for the low drainage densities may be explained by the chosen methodology, which used field verification of actual channels to calibrate the predicted drainage network. Historically, measures of drainage density were often made using only 1:24,000 topographic maps and, unlike this study, were not based on field observed channel conditions. Stream network parameters and maps are presented for each of the sub-basins and discussed below.

2.3.2 Infiltration

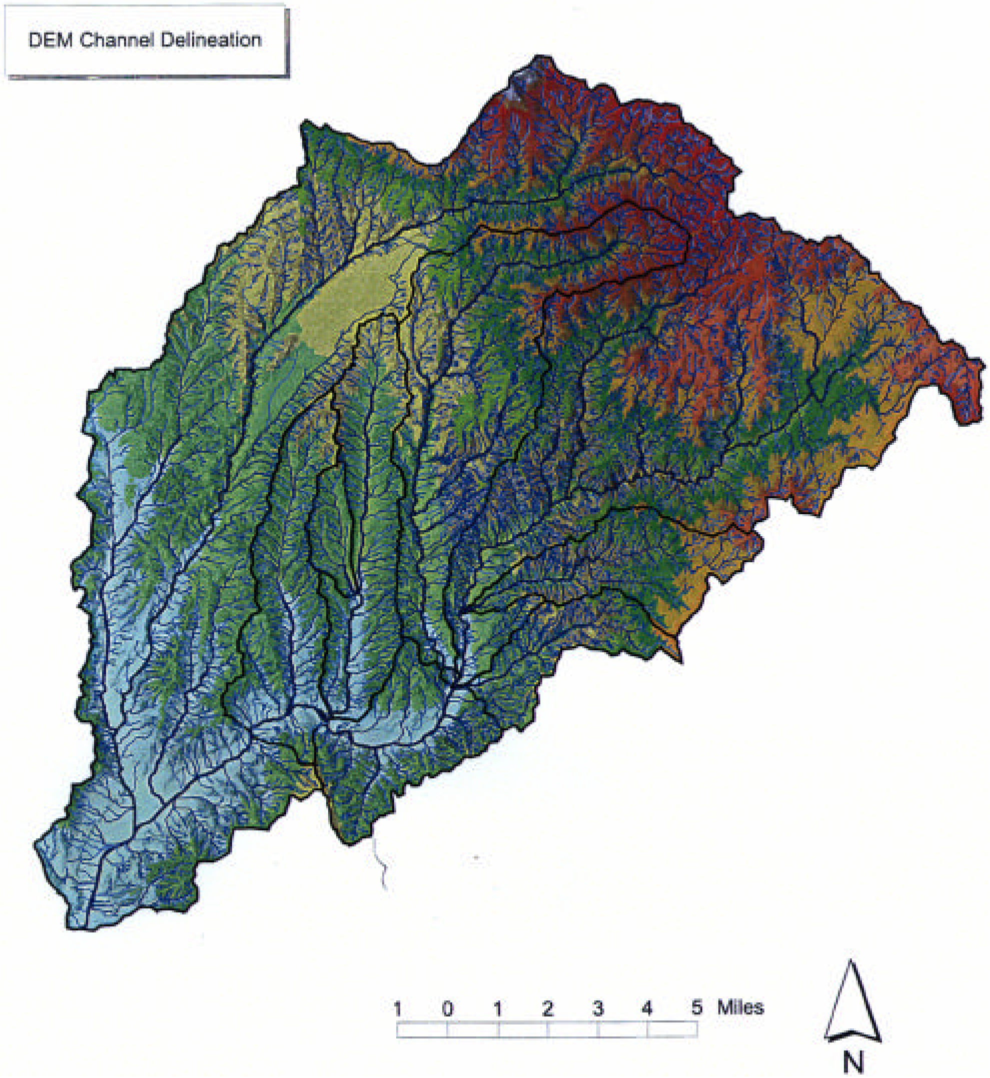
As described above, infiltration is the process by which surface water percolates into the sub-surface soil and groundwater column. In HEC-1, infiltration rates are computed based on the NRCS runoff index method which incorporates soil characteristics, land use, vegetation, impervious cover and antecedent moisture conditions to estimate loss rates. The distribution of hydrologic soil groups in the San Juan watershed is shown above in Figure 2-2. GIS analysis indicates that the majority of the watershed is underlain by soils of hydrologic groups B (15.4%) C (27.8%) and D (52.0%) (Section 3, Table 3-1). This distribution is weighted more heavily toward the poorly infiltrating C and D soils. When viewed as a whole, the San Juan Creek watershed soils do not offer high infiltration potential. However, in the central sub-basins, which are described in greater detail below, the relative proportion of better infiltrating soils is generally higher.

The distribution of land-use and vegetation classes for the San Juan watershed is shown in Figure 2-3. As indicated, much of the watershed is undeveloped (61.5%), while approximately 28.9% of the watershed is developed (Section 3, Table 3-1). As discussed above, most of the development is concentrated in the Oso and Trabuco tributaries of the western watershed, and the northern half of the Canada Gobernadora sub-basin. A high percentage of the land surface of these urbanized regions is impervious to runoff. Overall, approximately 22% of the entire San Juan watershed is impervious surface areas (Section 3, Table 3-2). Various agricultural land uses occur mostly in Canada Chiquita, southern Canada Gobernadora, and the central San Juan catchments. Agriculture represents 6.3% of the total watershed area. The predominant vegetation communities in the San Juan watershed are coastal sage scrub and chaparral with corridors of riparian vegetation occurring along the primary creek paths (Figure 2-3).
Based on the OCHM methods, SCS runoff curve numbers (Figure 2-5) were used in hydrologic modeling of the San Juan watershed to synthesize the effect of soil type, land-use, vegetation, and infiltration processes and provide an integrated overall “loss” rate. Assigned runoff curve numbers range from 30 to 97, with an area-averaged curve number of 80.5 for the entire San Juan watershed.

The majority of the watershed (91%) was characterized by higher curve numbers between 70 and 97. For modeling purposes, higher curve numbers result in a greater proportion of rainfall becoming surface runoff. In many ways the runoff curve number map of Figure 2-5 is a synthesis of the land-use, vegetation, and soil type maps (Figures 2-2, 2-3). The highly developed western San Juan watershed, as well as, the northern portion of Canada Gobernadora has the highest runoff curve numbers. The darker blue tones of Figure 2-5 indicate areas with lower curve numbers.

figure 2-8

Channel Network
San Juan Basin

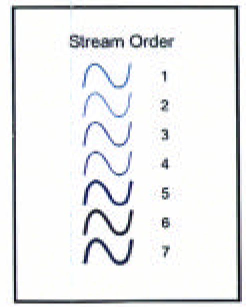


Channel Network Statistics

Basin Area = 112,548 acres
Drainage Density = 10 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	11024	425	4683383	5.49
2	2008	1175	2359413	3.01
3	667	1779	1186870	4.83
4	138	4387	605430	5.31
5	26	11255	292628	5.2
6	5	43278	216388	5
7	1	88573	88573	

Total Stream Length: 1786.5 mi



PWA

These areas occur mostly along riparian corridors and alluvial valley floors. Arroyo Trabuco, Wagon Wheel Canyon, Canada Gobernadora, Bell Canyon, Lucas Canyon, Verdugo Canyon, and the Central San Juan Catchments all contain zones of lower curve numbers along their valley bottoms. Based on a spatial GIS analysis of these runoff curve numbers, loss rates were calculated and incorporated into the HEC-1 model. For the 2-year event, loss rates were input to the HEC-1 model according to parameters regionally calibrated to measured flow data (Addendum No. 1 of the OCHM, 1995). Loss rates were calculated for the entire San Juan watershed, and for the individual sub-basins (Table 2-1).

Overall, infiltration in the San Juan watershed is relatively low due to the prominence of poorly infiltrating soils and the significant proportion of development in the western watershed. However, there are significant pockets of the watershed, particularly in the central watershed, which do have more permeable soils and offer better infiltration.

2.3.3 Storm Event Runoff

The 2-year, 10-year, and 100-year storm events were analyzed using a constructed HEC-1 model of the San Juan Creek watershed (Figure 2-6). Figure 2-9 shows predicted hydrographs for the 2-, 10-, and 100-year events at Pacific Ocean river mouth. Figures 2-10, 2-11, and 2-12 show hydrographs at four locations in the watershed for each event. The four locations are as follows: San Juan Creek upstream of Horno Creek (approximately the location of the USGS streamflow gage at La Novia Street); Oso Creek upstream of the Trabuco Canyon confluence; Trabuco Creek upstream of the Oso Creek Confluence; and San Juan Creek at the Pacific Ocean. Taken together these locations provide a good representation of hydrologic events at the watershed scale. Peak flows for the four locations are summarized in Table 2-15.

Table 2-15 Summary of Peak Flows, San Juan Watershed

	2-year Event		10-year Event		100-year Event	
Watershed Location	**(cfs)**	**(cfs/ mile^2)**	**(cfs)**	**(cfs/ mile^2)**	**(cfs)**	**(cfs/ mile^2)**
Oso Creek upstream of Trabuco Creek	1,490	92	4,650	286	6,180	380
Lower Trabuco Creek, upstream of San Juan	2,560	47	10,600	194	20,040	366
San Juan Creek, upstream of Horno Creek	2,940	27	18,280	167	44,120	403
San Juan Creek at Pacific Ocean	5,170	29	29,820	169	67,820	385

Source: PWA HEC-1 Analysis, 2001

Certain notable trends are observable in the modeling results from Figures 2-10 through 2-12. For the 2-year event, peak runoff from the western, more urbanized, Trabuco and Oso sub-watersheds occurs earlier than peak flows along the main San Juan Creek in the central watershed upstream of Horno Creek. The shape of the hydrographs from the more urbanized Oso and Trabuco sub-watersheds is steeper, or flashier, for both the rising and falling limbs of the 2-year hydrograph. As the magnitude of the modeled events increases for the 10-year and 100-year events, the earlier arrival and "flashiness" of peak runoff from the Oso and Trabuco sub-basins is less pronounced.

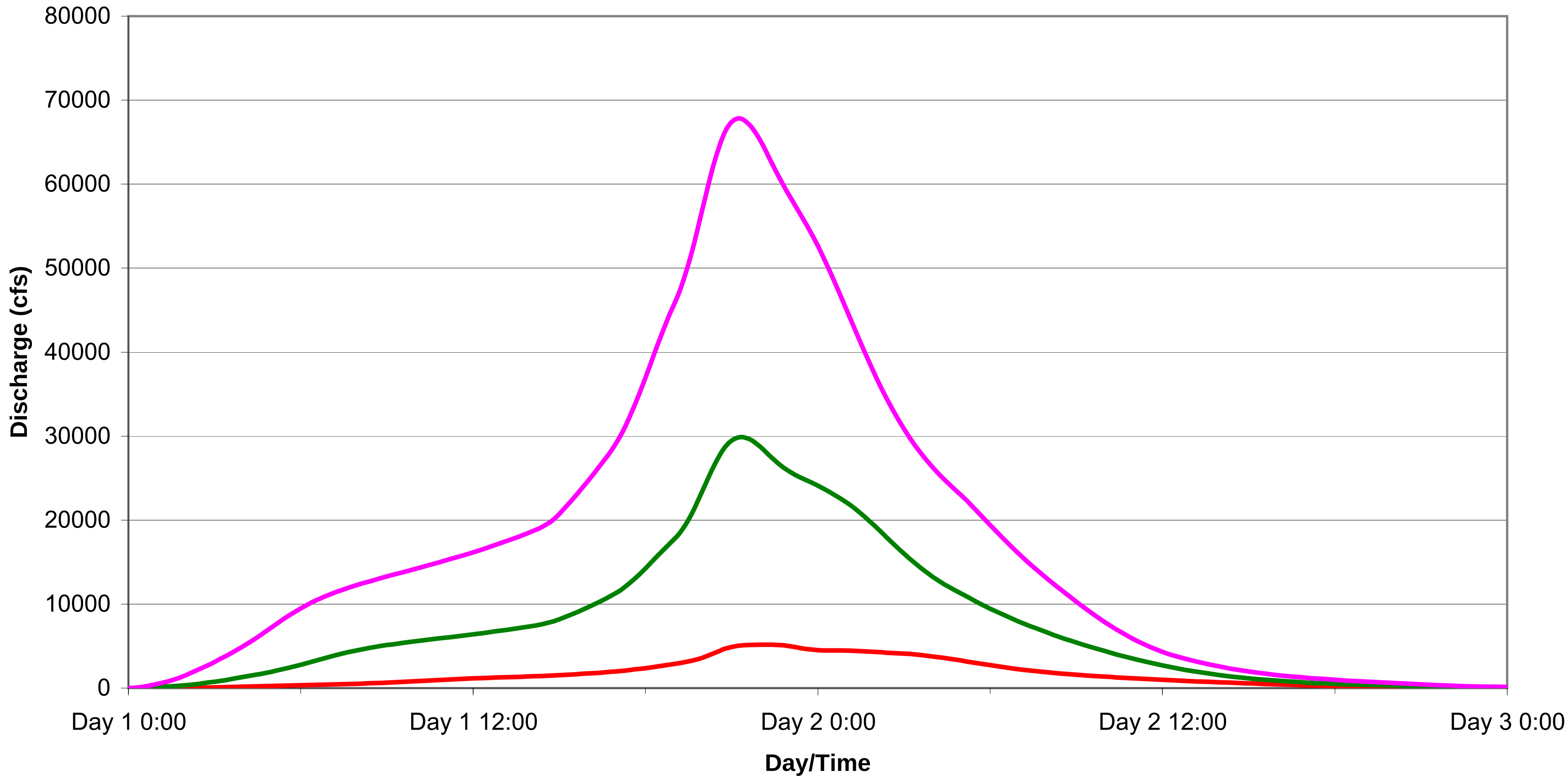


Figure 2-9

South Orange County SAMP
San Juan Creek at the Pacific Ocean
San Juan Creek Watershed

PWA PWA#: 1393

San Juan 2-10-100 same scale 2.xls SJ 2, 10, & 100-yr chart 6/23/2004 3:21 PM

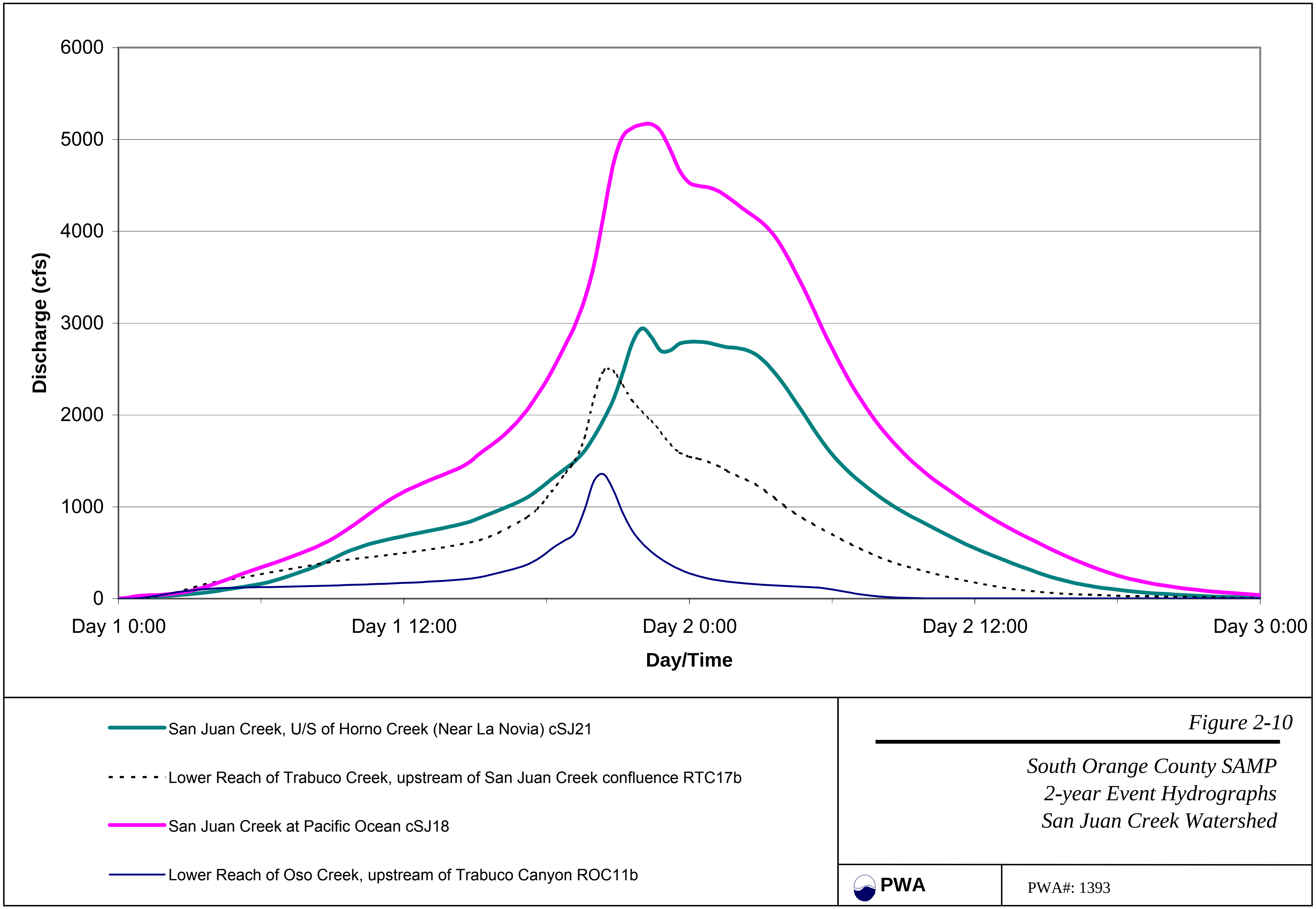


Figure 2-10

South Orange County SAMP
2-year Event Hydrographs
San Juan Creek Watershed

PWA

PWA#: 1393

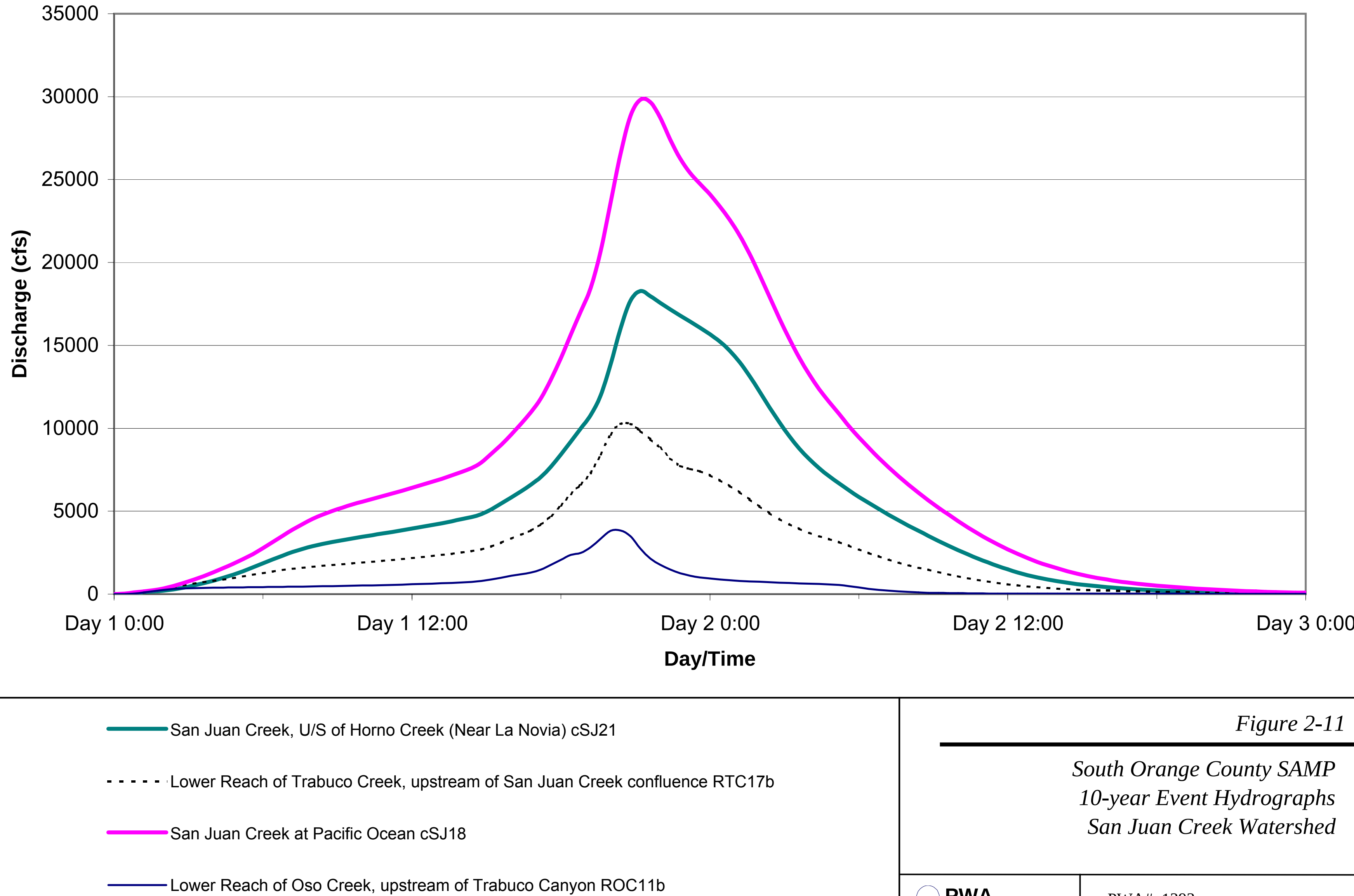


Figure 2-11

South Orange County SAMP
10-year Event Hydrographs
San Juan Creek Watershed

PWA

PWA#: 1393

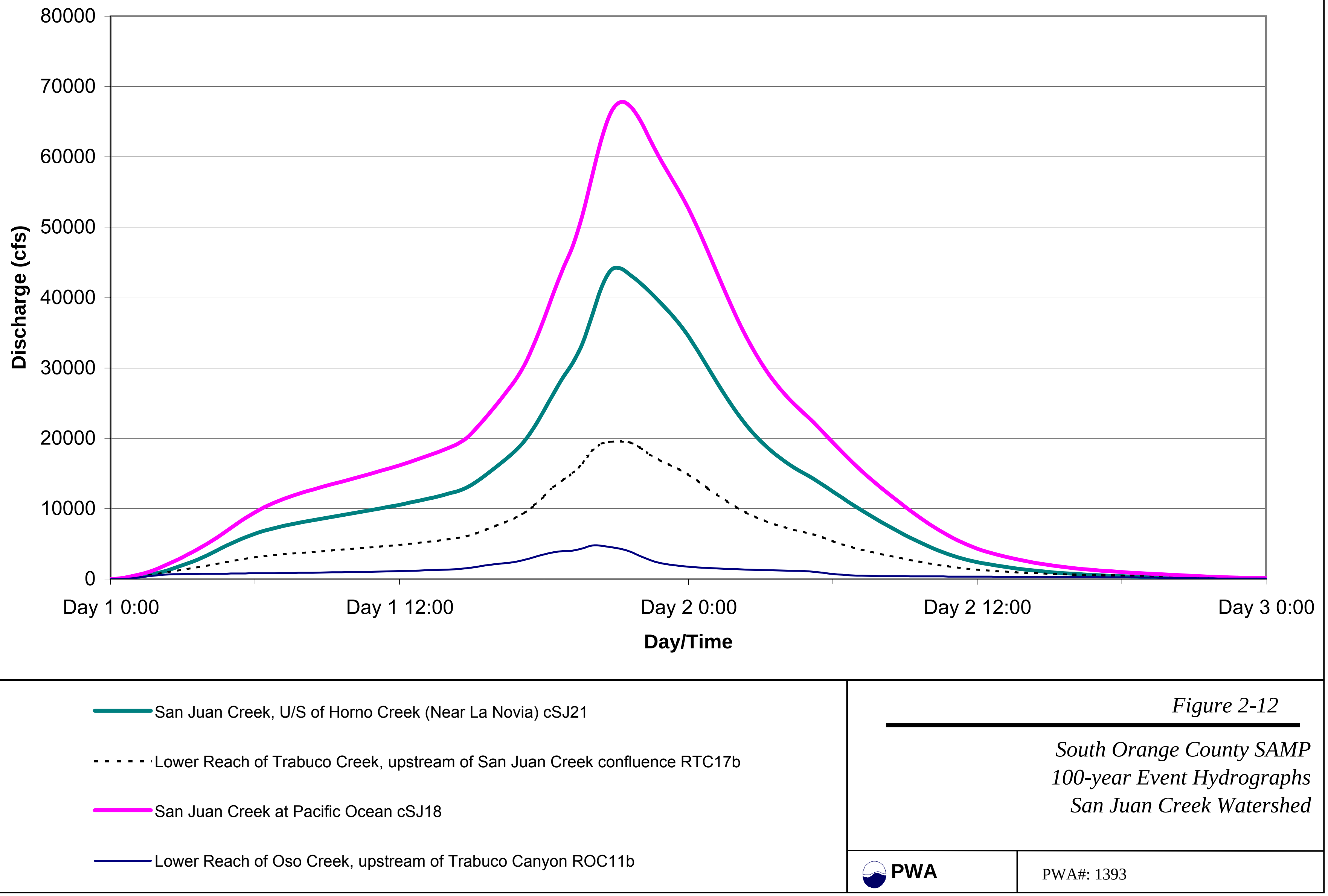


Figure 2-12

South Orange County SAMP
100-year Event Hydrographs
San Juan Creek Watershed

PWA PWA#: 1393

Total runoff volumes at the Pacific Ocean outlet of the San Juan watershed are shown in Table 2-16 for the three modeled events. Runoff volume per unit area is also included for reference. Runoff volume per unit area is generally higher for the overall San Juan Creek watershed than it is for the individual sub-basins because these individual sub-basins of the central watershed are generally undeveloped (Section 3, Table 3-1). Increased runoff from the more developed western regions raises the overall watershed-averaged values presented in Table 2-16.

Table 2-16 Storm Event Runoff Volumes, San Juan Watershed at the Pacific Ocean

Event	Total Runoff Volume (acre-feet)	Runoff Volume per Unit Area (acre-feet/mile^2)
2-year	6,410	36
10-year	31,040	176
100-year	70,800	402

Source: PWA HEC-1 Analysis, 2000.

Hydrologic and sediment transport conditions in the individual sub-basins of the San Mateo watershed are described in greater detail below in Sections 3 and 4.

2.3.4 Comparison with Previous Hydrology Studies

Previous hydrologic studies of the San Juan watershed have been completed by Rivertech (1987), Simons, Li & Associates (SLA, 1999), and the USGS (1994). Rivertech (1987) calculated 100-year peak discharges in the San Juan Creek watershed for future development conditions. Rivertech estimated 100-year flows (high-confidence) for Trabuco Creek, Oso Creek, and the main stem of San Juan Creek upstream to Long Canyon, using AES software following the Orange County Hydrology Manual (OCHM, 1986). Rivertech's modeling of future conditions in 1987 was based on future agricultural zoning in much of the central San Juan watershed at that time. Therefore, the difference in land use conditions and runoff between 'existing' conditions in 2001 and 'future' conditions from 1987 are considered to be small.

SLA (1999) recently performed a flood frequency analysis, HEC-1 rainfall-runoff analysis, low flow analysis, sediment yield and transport analysis, and groundwater assessment in support of the San Juan Creek watershed management study being conducted by the Planning Division of the U.S. Army Corps of Engineers, Los Angeles District. The SLA project analyzed the entire San Juan Creek Watershed, including Oso and Trabuco Creeks, and calculated discharge-frequency relationships for two gauged locations: San Juan Creek at La Novia Street and Trabuco Creek at Camino Capistrano. Historical flow data from these two gauges and the HEC Flood Frequency Program were used to create discharge-frequency relationships (Table 2-17).

Table 2-17 Summary of San Juan Creek Watershed Discharge-Frequency Relationships

Flood Return Period (Years)	Discharge at (cfs)	
	Trabuco Creek at Camino Capistrano (Orange County #5)	**San Juan Creek at La Novia (USGS #11046530)**
2	99	479
5	744	2,940
10	1,930	6,770
20	4,010	12,700
50	8,670	24,400
100	14,000	36,400
500	34,600	75,500

Source: SLA, 1999

In general, SLA followed the methods outlined in the OCHM to formulate their HEC-1 model. However, to refine their model they adjusted basin roughness parameters so the estimated peak flow rates from HEC-1 would match with calculated peak flows from the discharge-frequency analysis (Table 2-17). As a result, peak-flow values from their HEC-1 analysis are identical to results from their discharge-frequency analysis.

A more standard model calibration process involves comparing HEC-1 generated hydrographs from a known precipitation event to actual stream flow data from the same storm event. The SLA technique assumes that a design rainfall event of a given return frequency would produce a discharge event of equal return frequency, which may not always be a valid assumption. Additionally, SLA reported peak flows as “expected values,” and not the more standard “high confidence values.” Expected value estimates typically assume lower antecedent moisture conditions and therefore, produce lower predicted runoff and associated stream flow than the high confidence values. SLA’s peak flow numbers are therefore not directly comparable to Orange County design values and are generally lower than Rivertech’s “high confidence” values.

Besides examining results from previous studies by Rivertech (1987) and SLA (1999), PWA checked peak discharge values for the San Juan watershed based on USGS regional regression equations. USGS-NFF software, obtained from USGS Water Resources Investigations Report #94-4002 was used for these calculations. Regression equations were available for urban developed conditions and for rural or undeveloped areas. The rural regression equation was applied to the undeveloped portions of the watershed. In developed areas in the western watershed, the urban regression was not entirely appropriate due to the presence of reservoirs and detention basins. Because the urban regression wasn’t applicable and because most of the watershed is undeveloped, the USGS rural regression was used to calculate peak flows for the overall watershed. As a result, the USGS regression 100-year discharge values are lower than estimates from the other studies and the current PWA work. Table 2-18 shows peak flows, for various flood frequencies, at the La Novia crossing and at the Pacific Ocean using the USGS regional regression equations.

Table 2-18 San Juan Creek Watershed Peak Flows*

Flood Return Period (Years)	Discharge (cfs)	
	San Juan Creek at La Novia (USGS #11046530)	San Juan Creek at the Pacific Ocean
2	461	648
5	2,040	2,940
10	4,210	6,120
25	9,610	14,100
50	15,400	22,800
100	22,300	33,000
500	52,500	78,300

**Calculated from USGS Regional Regression Equations, 1994.*

A comparison of the calculated 100-year discharge values from PWA (2001), Rivertech (1987), SLA (1999), the USGS regional regression approach are shown in (Table 2-19). Discharge values based on the USGS regional regression method (rural) were the lowest of all approaches. This is not surprising as these USGS regional rates do not reflect developed land conditions and are therefore not entirely appropriate for the semi-developed San Juan watershed.

Table 2-19 Comparison of Estimated 100-Year Discharges (cfs), San Juan Creek Watershed

Location	Rivertech [a]	SLA [b]	USGS [c]	PWA [d]
Oso Creek at confluence with Trabuco Creek	6,700	5,400	4,580	6,180
Trabuco Creek at confluence with San Juan Creek	22,600	18,700	12,500	20,040
San Juan Creek at La Novia Street Bridge	40,600	36,100	22,300	44,120
San Juan Creek at Pacific Ocean	59,500	53,300	33,000	67,820

[a] *Rivertech (1987), "high confidence" values based on ultimate development conditions.*
[b] *Simons Li & Associates (1999), "expected values" based on frequency-magnitude relations.*
[c] *USGS (1994), regional regression approach based upon rural (undeveloped) conditions.*
[d] *PWA (2001), HEC-1 based on undeveloped conditions following OCHM, 1986.*

In general, the results of the PWA analysis compare closely with Rivertech's estimates for the Oso Creek, Trabuco Creek, and San Juan Creek at La Novia locations. Despite this general agreement at upstream locations, at the Pacific Ocean rivermouth, 100-year results by PWA are somewhat higher than Rivertech. For the current PWA analysis, the coincidental timing of hydrographs, where flows from the Oso, Trabuco, and central San Juan sub-basins arrive to the lower San Juan Creek region at roughly the same time for the 100-year event may account for the higher PWA runoff numbers at the ocean (Figure 2-12). Other potential sources for this discrepancy are found in the use of different sub-basin delineations, routing parameters, land-use designations, and modeling software by the two studies. Nevertheless, within the bounds of error associated with hydrologic models, there is reasonably close agreement between peak flow estimates generated by Rivertech and PWA. SLA's "expected value" peak flow numbers are generally lower and not directly comparable to Rivertech's and PWA's "high confidence" values which are based on standard Orange County design procedures.

In Figure 2-13, enveloping curves of historical peak discharges in southern California are presented for both Pacific slope and interior basins. This figure is taken from the Riverside County Flood Control and Water Conservation District (RCFCWCD) Hydrology Manual (1978). When considered per unit area, PWA's estimated 100-year discharge for the entire San Juan Creek watershed (67,820 cfs) equates to roughly 385 cfs per square mile (Table 2-15). This value plots below the enveloping curve for maximum recorded floods for Pacific slope basins and is similar to values recorded for the March 1938 flood events on the Santa Ana River and the Tujunga Creek tributary of the Los Angeles River.

PWA (2001) and Rivertech (1987) results are compared along the length of San Juan Creek in Figure 2-14 and for individual sub-basin canyons in Figure 2-15. Since both studies employed similar techniques following the OCHM methodology, the general agreement in results could be expected. As described above, the divergence in results towards the ocean is likely due to routing conditions, whereby peak flows from the Oso, Trabuco, and San Juan channels occur at similar times in the current PWA analysis. Further upstream along the main San Juan Creek channel, the two studies agree very closely. Results for individual sub-basins indicate that PWA values are generally lower than Rivertech at the sub-basin scale. Many of the individual sub-basins shown in Figures 2-14 and 2-15 are presented in greater detail in Section 3.

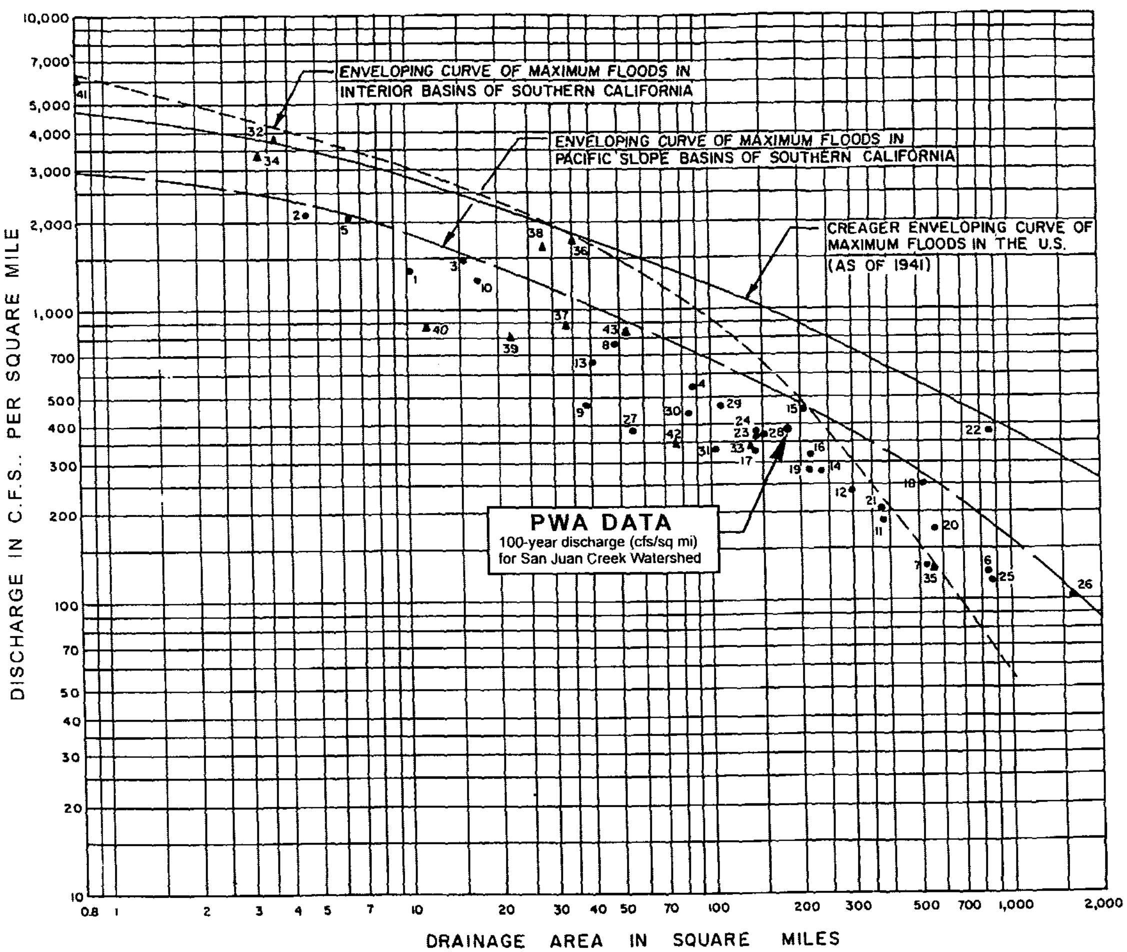
2.3.5 Low Flow Data Sources and Analysis

In addition to understanding storm flows, recognizing baseline low flow conditions in the San Juan Creek watershed is very important in terms of maintaining functioning habitat. In several watersheds in coastal southern California, urbanization has increased the magnitude and persistence of low-flows (particularly in the summer dry season) by increasing impervious surfaces and dry season releases of imported water (Hamilton, 1992). It is difficult to quantify baseline low flow conditions in semi-arid watersheds with episodic runoff like San Juan Creek. To rigorously evaluate low-flow conditions in a stream, an extended historic record of daily flow conditions is required. A statistical analysis (using a computer program like IHA, Richter et al., 1996) can then be performed to systematically describe a stream's flow regime.

2.3.5.1 Low Flow Gauge Record

To assess the quality of low-flow data available, PWA reviewed the reliability of four stream gages in the San Juan Creek Watershed: San Juan Creek at La Novia (USGS #11046530), Trabuco Creek at Camino Capistrano (Orange County #5), Trabuco Creek at Del Obispo (USGS #11047300), and Oso Creek at Crown Valley Parkway (Orange County #218). Based on this data review and discussions with agencies operating the gages, we determined that there is insufficient data of adequate quality to conduct a statistically valid low-flow analysis using a program like IHA.

A representative of the USGS field office in Orange County acknowledged that consistent and reliable low-flow data is not available from the San Juan Creek at La Novia Bridge gage (USGS #11046530) because the creek is wide and sandy at the gage location allowing the low-flow channel to change positions often. The changing position of the low-flow channel was not consistently tracked by the gage's measuring device. Therefore, historic low-flow data for this gage is deemed only "fair" by the USGS (pers. comm. Al Caldwell, USGS Field Office, Orange County, Sept. 2000) and not valid for low-flow analysis. The USGS confirmed that high flow data from this gage is of better quality since the entire channel width is inundated during large flow events.



RECORDED OR ESTIMATED PEAK DISCHARGES OF RECORD

	STREAM & LOCATION	DRAINAGE AREA (SQUARE MILES)	PEAK DISCHARGE (INCLUDES DEBRIS) C.F.S.	DATE
● —	SOUTHERN CALIF.-PACIFIC SLOPE BASINS			
1	CUCAMONGA CREEK NEAR UPLAND	10.1	14,100	25 JAN 1969
2	DAY CREEK NEAR ETIWANDA	4.6	9,450	25 JAN 1969
3	DEVIL'S CANYON ABOVE COGSWELL DAM	15.4	23,000	2 MAR 1938
4	EAST FORK SAN GABRIEL RIVER NEAR CAMP BONITA	88.2	46,000	2 MAR 1938
5	FISH CREEK NEAR DUARTE	6.4	13,000	25 JAN 1969
6	LOS ANGELES RIVER AT LONG BEACH	832	102,000	25 JAN 1969
7	LOS ANGELES RIVER AT LOS ANGELES	514	87,000	3 MAR 1938
8	LYTLE CREEK NEAR FONTANA	47.9	35,900	25 JAN 1969
9	MILL CREEK NEAR YUCAIPA	38.1	18,100	2 MAR 1938
10	SAN ANTONIO CREEK NEAR CLAREMONT	16.9	21,400	2 MAR 1938
11	SAN DIEGO RIVER NEAR SANTEE	377	70,200	27 JAN 1916
12	SAN DIEGUITO RIVER NEAR BERNARDO	299	72,100	27 JAN 1916
13	SAN GABRIEL RIVER AT COGSWELL DAM	40.4	26,900	2 MAR 1938
14	SAN GABRIEL RIVER AT FOOTHILL BLVD	230	61,800	2 MAR 1938
15	SAN GABRIEL RIVER AT SAN GABRIEL DAM	202	90,000	2 MAR 1938
16	SAN GABRIEL RIVER BELOW MORRIS DAM	211	65,700	2 MAR 1938
17	SAN JACINTO RIVER BELOW NORTH FORK NEAR SAN JACINTO	141	45,000	16 FEB 1927
18	SAN LUIS REY RIVER AT BONSALL	512	128,000	23 FEB 1891
19	SAN LUIS REY RIVER NEAR MESA GRANDE	209	58,600	27 JAN 1916
20	SAN LUIS REY RIVER AT OCEANSIDE	557	95,600	27 JAN 1916
21	SAN LUIS REY RIVER NEAR PALA	373	75,300	27 JAN 1916
*22	SANTA ANA RIVER AT AGUA MANSA	855	320,000	22 JAN 1862
23	SANTA ANA RIVER NEAR MENTONE	144	52,300	2 MAR 1938
24	SANTA ANA RIVER NEAR MENTONE	144	53,700	23 FEB 1891
25	SANTA ANA RIVER AT RIVERSIDE NARROWS	858	100,000	2 MAR 1938
26	SANTA CLARA RIVER NEAR SATICOY	1595	165,000	25 JAN 1969
27	SANTA YSABEL CREEK NEAR MESA GRANDE	53.9	21,100	27 JAN 1916
28	TUJUNGA CREEK BELOW HANSEN DAM	150	54,000	3 MAR 1938
29	TUJUNGA CREEK NEAR SUNLAND	106	50,000	3 MAR 1938
30	TUJUNGA CREEK AT TUJUNGA DAM (INFLOW)	81.4	35,000	3 MAR 1938
31	WEST FORK SAN GABRIEL RIVER AT CAMP RINCON	102	34,000	2 MAR 1938
▲ —	SOUTHERN CALIF.-INTERIOR BASINS			
32	CAMERON CREEK NEAR TEHACHAPI	3.59	13,500	30 SEP 1932
33	DEEP CREEK NEAR HESPERIA	137	46,600	2 MAR 1938
34	LITTLE SAN GORGONIO CREEK NEAR BEAUMONT	3.23	11,000	25 FEB 1969
35	MOJAVE RIVER NEAR VICTORVILLE	530	70,600	2 MAR 1938
36	PINE TREE CANYON 12 MILES NORTH OF MOJAVE	35	59,500	12 AUG 1931
37	PINE TREE CREEK NEAR MOJAVE	33.5	30,000	23 AUG 1961
38	SACRAMENTO WASH NEAR NEEDLES	27	43,000	17 AUG 1939
39	SAN GORGONIO RIVER NEAR BANNING	21.2	17,000	2 MAR 1938
40	SNOW CREEK NEAR PALM SPRINGS	11	9,500	FEB 1927
41	UPPER WILLOW SPRINGS CANYON NEAR MOJAVE	0.81	4,900	30 SEP 1932
42	WEST FORK MOJAVE RIVER NEAR HESPERIA	74.8	26,100	2 MAR 1938
43	WHITEWATER RIVER ABOVE WHITEWATER	51.4	42,000	2 MAR 1938

NOTES:

*1. Because of the extreme variation of this value from the other data, this point was disregarded in construction of the enveloping curve for California.

2. References for flow estimates are USGS Water Supply Papers and Bibliography item No. 13.

RCFC & WCD
HYDROLOGY MANUAL

figure 2-13

Enveloping Curves of Peak Discharges in Southern California

Source: Riverside County Hydrology Manual

Proj. # 1393SAMP

PWA

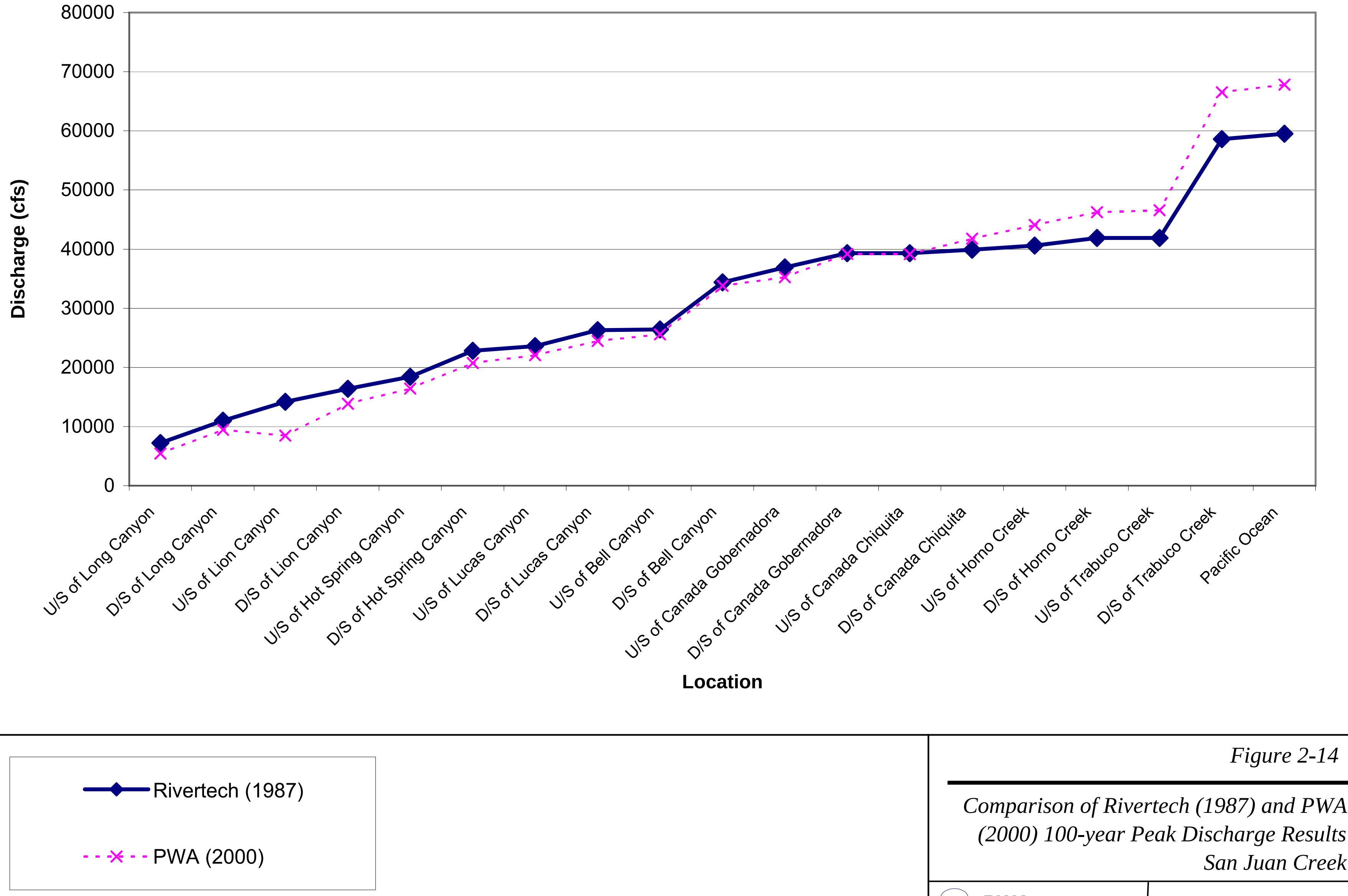


Figure 2-14

Comparison of Rivertech (1987) and PWA (2000) 100-year Peak Discharge Results
San Juan Creek

PWA PWA#: 1393

nmawer 6/23/2004
1393 Rivertech Results Comparison.xls

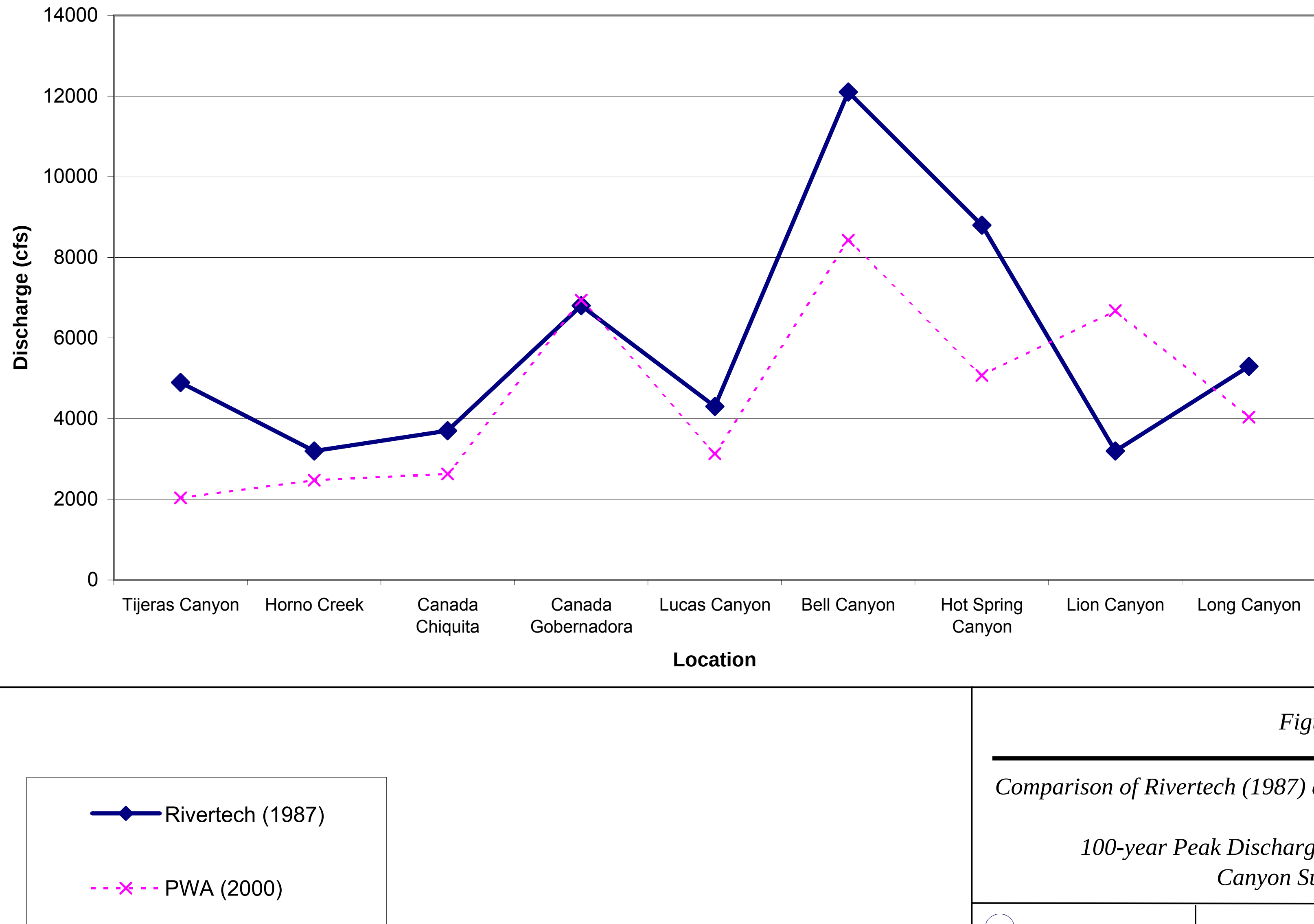


Figure 2-15

Comparison of Rivertech (1987) and PWA (2000)
100-year Peak Discharge Results
Canyon Sub-basins

PWA PWA#: 1393

nmawer 6/23/2004
1393 Rivertech Results Comparison.xls

Low-flow data from the Trabuco Creek at Del Obispo gage (USGS #11047300) is potentially more useful than from the La Novia Bridge gage. Prior to 1990, operators had problems establishing a consistent rating curve for the Del Obispo gage due to channel erosion. Data from this period is likely not very reliable (personal comm. Al Caldwell, USGS Field Office, Orange County, Sept, 2000). In 1990 a concrete grade stabilizer was installed, making data collected from this gage since 1990 more reliable. However, the USGS only has data from October 1995 to 30 September 1999 currently available, a record too short for adequate statistical low-flow analysis. Furthermore, since the gage measures flow from a portion of the watershed that has become steadily more developed since the 1960s, the flow record would not represent stationary baseline conditions.

Data from the Trabuco Creek at Camino Capistrano gage (Orange County #5) was determined to be unreliable. According to County representatives this gage has not been used in three years due to a poor rating curve, attributable in part to its position immediately downstream of a bridge pier. The County characterized data from this gage as marginal. Data from the Oso Creek at Crown Valley Parkway gage (Orange County #218) dates back to 1969 and was characterized as solid by the County. However, like the Trabuco Creek gages, this Oso Creek gage measures flow from a portion of the watershed that has become steadily more developed since the 1960s. In 1964 urban areas covered approximately 5% of the Oso Creek watershed. In 2000 approximately 90% of the watershed is urban. For this reason, the flow record from the Crown Valley Parkway gage does not likely represent a statistically stationary condition and therefore is not useful for characterizing baseline low-flow conditions.

Given the lack of reliable low-flow data from the four primary stream gages in the watershed, PWA researched alternative data sources that would provide the most useful characterization of low-flows in the watershed. Balance Hydrologics (Balance) measured field flow conditions between November 16, 1999 and June 6, 2000. Flow measurements were generally visual estimates taken at various locations spread throughout the Central San Juan watershed. Flow estimates ranged from 0.1 gallons per minute (gpm) in small tributary creeks to 40 cubic feet per second (cfs) in the main channel of San Juan Creek. Dry creek beds were observed throughout the observation period at various locations. The level of accuracy for all of the measurements was judged to be poor by Balance. These measurements are useful for gaining an intuitive feel for the low-flow regime in the watershed. However, because they represent a single snap-shot in time and because the accuracy of the measurements is poor, they are not useful for quantitatively establishing baseline low-flow conditions in the watershed.

In addition to searching for primary low-flow data sources, PWA reviewed the recent low-flow analysis conducted by Simons, Li & Associates (SLA, 1999). SLA used data from three of the primary stream gages in the San Juan Creek watershed (San Juan Creek at La Novia, Trabuco Creek at Camino Capistrano, and Oso Creek at Crown Valley Parkway) to plot flow non-exceedance frequencies for the range of measured flows at each gage. To account for the progressive development that has occurred in the watershed (especially in the Trabuco and Oso Creek sub-basins), and its effect on low-flows, SLA used only data collected since 1980. It was assumed that this data reasonably described current baseline conditions in the watershed. However, continuing development in the watershed since 1980 makes it difficult to use this data as a statistical baseline for analyzing low-flow conditions. As described in the SLA report (Table 2-20), there have been significant increases in urban area in the watershed since 1980. Therefore, low-flow conditions have not remained statistically consistent since 1980.

Table 2-20 Urbanization Over Time in the San Juan Creek Watershed

Year	Percentage of Watershed Urbanized			
	San Juan Creek (122 square miles)	**Trabuco Creek (38 square miles)**	**Oso Creek (16 square miles)**	**Total Watershed (176 square miles)**
1964	3%	2%	5%	3%
1974	7%	6%	30%	9%
1988	10%	20%	60%	18%
1990	20%	40%	80%	32%
2000	22%	45%	90%	35%
2050	30%	60%	95%	48%

Source: SLA, 1999

2.3.5.2 Historical Low Flow Trend Analysis

Although a complete statistical analysis of baseline low-flow conditions could not be established for the entire San Juan watershed due to lack of data, the historical role of development to increase low-flows was observed for the Oso Creek tributary in the San Juan watershed. PWA conducted a trend analysis on flow data from Oso Creek (Crown Valley Parkway gage) between the years 1969 and 1981. This trend analysis was conducted using the IHA program mentioned previously. The IHA software calculated 34 statistics to characterize the overall stream flow regime. As a result, clear trends in the data emerged which indicated the influence of urbanization in raising low-flows.

Some of the results of the trend analysis conducted for Oso Creek are shown in Figures 2-16 through 2-21. These figures show that low-flows have consistently increased over time as the Oso Creek watershed progressively developed (Table 2-18). Annual minimum stream flows (Figure 2-16), average June, July, and August daily stream flows (Figures 2-17, 2-18, and 2-19), and annual base-flows (Figure 2-20) all increased during this 12-year period of increased urbanization. The trends seen in Figures 2-16 through 2-20 are not adjusted for annual climatic variability. In Figure 2-21, the correlation between percentage of watershed area developed and percentage increase in mean July flows shows the effect of watershed development on dry season flows. The relationship shown in Figure 2-21 is consistent with findings by Hamilton (1992) that indicate that urbanization increases dry season low flow discharge.

An increase in low flows, as observed at Oso Creek, could potentially happen in other parts of the San Juan Creek Watershed if similar land-use transformations were to occur. This process has recently been observed in the northern portion of the Canada Gobernadora sub-basin, where the Coto de Caza development has increased the magnitude and persistence of low flows to the central Canada Gobernadora watershed. The potential biotic impacts associated with these changes in low flow conditions are discussed in the comprehensive Baseline Conditions Report (PCR, 2001). Impacts to low flow conditions will be used as a criterion to evaluate potential land use alternatives in a future phase of work.

2.4 SAN MATEO WATERSHED OVERVIEW

2.4.1 Drainage Network

Like the San Juan Creek watershed, the San Mateo Creek watershed (133.2 mi^2) drains the westward Pacific slope of the southern Santa Ana Mountains (Figure 1-4). The focus area of the SAMP baseline analysis is within the tributary valleys of Cristianitos Creek in the western watershed (Figure 2-1). Cristianitos Creek drains southward and joins the main stem of San Mateo Creek 2.7 mi upstream of the ocean outlet. The sub-basins of interest upstream of the Cristianitos and San Mateo creek confluence include La Paz, Gabino, Upper Cristianitos, Blind, and Talega Canyons. These sub-basins are highlighted in gray in Figures 1-3 and 2-1.

As described above, the predicted stream network was verified with the WES channel mapping results. The WES mapping program was focused towards the western portion of the San Mateo watershed. As in the case of the San Juan basin, network analysis methods were chosen to mimic in detail the WES channel delineations. Therefore, the predicted channel network in the area of focus in the western watershed is likely accurate (Figure 2-22), while some of the stream channels in the eastern (upper) San Mateo watershed may be less reliable. Likewise, overall basin statistics, which reflect the upper eastern watershed, may not be as accurate as the individual statistics for the western sub-basin (presented below). The calculated drainage density of the entire San Mateo watershed would likely be higher than the predicted 8 mi/mi^2 value had a more complete basin channel mapping been utilized for the network calibration. In contrast, the drainage density values (presented below in Chapter 3) for the named sub-basins of the western watershed, which used the available WES channel maps, are considered more accurate.

2.4.2 Infiltration

The distribution of hydrologic soil groups A, B, C, or D, in the San Mateo Creek watershed is shown in Figure 2-2. This standard USDA classification is based upon estimated runoff potential based upon soil properties that influence runoff. GIS analysis indicates that the majority of the watershed is underlain by poorer infiltrating soils of hydrologic groups C (49.3%) and D (40.5%) (Table 3-4). Viewed as a whole, the San Mateo Creek watershed does not offer particularly high infiltration potential. However, in some of the western sub-basins, the relative proportion of better infiltrating A and B-type soils is higher.

The land-use and vegetation distributions for the San Mateo watershed are shown in Figure 2-3. The majority of the watershed is undeveloped (89.7%) and a small fraction is developed (7.9%) or used for agriculture (1.3%) (Chapter 3, Table 3-4). As seen in Figure 2-3, most of the watershed is covered in sage, chaparral, grassland, or woodland. Agricultural lands represent a small portion of the watershed (1.3%) and occur mostly in the lower Cristianitos and San Mateo stream valleys. Developed areas include some light industrial and residential areas both inside and outside of the marine base in the lower watershed. Overall, only about 4% of the entire San Mateo watershed is impervious to runoff.

According to OCHM methods, SCS runoff curve numbers were used in hydrologic modeling of the San Mateo Creek watershed to synthesize the effect of soil type, land-use, vegetation, and infiltration processes and offer an integrated overall “loss” rate. The distribution of SCS runoff curve numbers for the San Mateo watershed is shown in Figure 2-5). Assigned runoff curve numbers range from 31 to 97, with an area-averaged curve number of 78.7 for the entire watershed. The majority of the San Mateo Creek watershed (93%) was characterized by higher curve numbers between 70 and 97. Higher curve numbers result in a greater proportion of rainfall becoming surface runoff. In many ways the runoff curve number map of Figure 2-5 is a synthesis of the land-use, vegetation, and soil type maps (Figures 2-2, 2-3). The lower valley zones and riparian corridors along Cristianitos, Gabino, La Paz, and Talega canyons, as well as some reaches along the main San Mateo Creek upstream, include several areas of lower curve numbers. Based on a spatial GIS analysis of these runoff curve numbers, loss rates were calculated and incorporated into the HEC-1 model. For the 2-year event, loss rates were input to the HEC-1 model according to parameters regionally calibrated to measured flow data (Addendum No. 1 of the OCHM, 1995). Loss rates were calculated for the entire San Mateo watershed, and for the individual sub-basins (Table 2-1).

Overall, infiltration in the San Mateo watershed is relatively low due to the prominence of poorly infiltrating soils. However, there are pockets of the watershed, particularly in the upper western watershed, which do have more permeable soils and offer higher infiltration.

2.4.3 Storm Event Runoff

The 2-year, the 10-year, and the 100-year storm events were analyzed using the HEC-1 model of the San Mateo Creek watershed. Hydrologic sub-basins used for the HEC-1 modeling analysis are shown in Figure 2-1 and the HEC-1 node map is seen in Figure 2-7. Figure 2-23 shows overall 2-, 10-, and 100-year storm hydrographs at the mouth of San Mateo Creek at the Pacific Ocean. Figures 2-24, 2-25, and 2-26 show hydrographs at four locations in the watershed for each event. The four locations are as follows: San Mateo Creek downstream of the Nickel Canyon and Tenaja canyons; San Mateo Creek downstream of Cristianitos Creek; Cristianitos Creek downstream of Talega Canyon; and San Mateo Creek at the Pacific Ocean. These locations provide a good representation of hydrologic events at the watershed scale. Peak flows for the four locations are summarized in Table 2-21.

Table 2-21 Summary of Peak Flows, San Mateo Watershed

Watershed Location	2-year Event		10-year Event		100-year Event	
	(cfs)	(cfs/mile^2)	(cfs)	(cfs/mile^2)	(cfs)	(cfs/mile^2)
Cristianitos Creek at Talega Canyon	740	27	5,220	189	11,800	427
San Mateo Creek d/s of Nickel/Tenaja canyons	2,980	37	16,990	211	39,440	489
San Mateo Creek d/s of Cristianitos Creek	3,200	25	19,100	148	47,070	366
San Mateo Creek at Pacific Ocean	3,200	24	19,160	144	47,530	357

Source: PWA HEC-1 Analysis (2001).

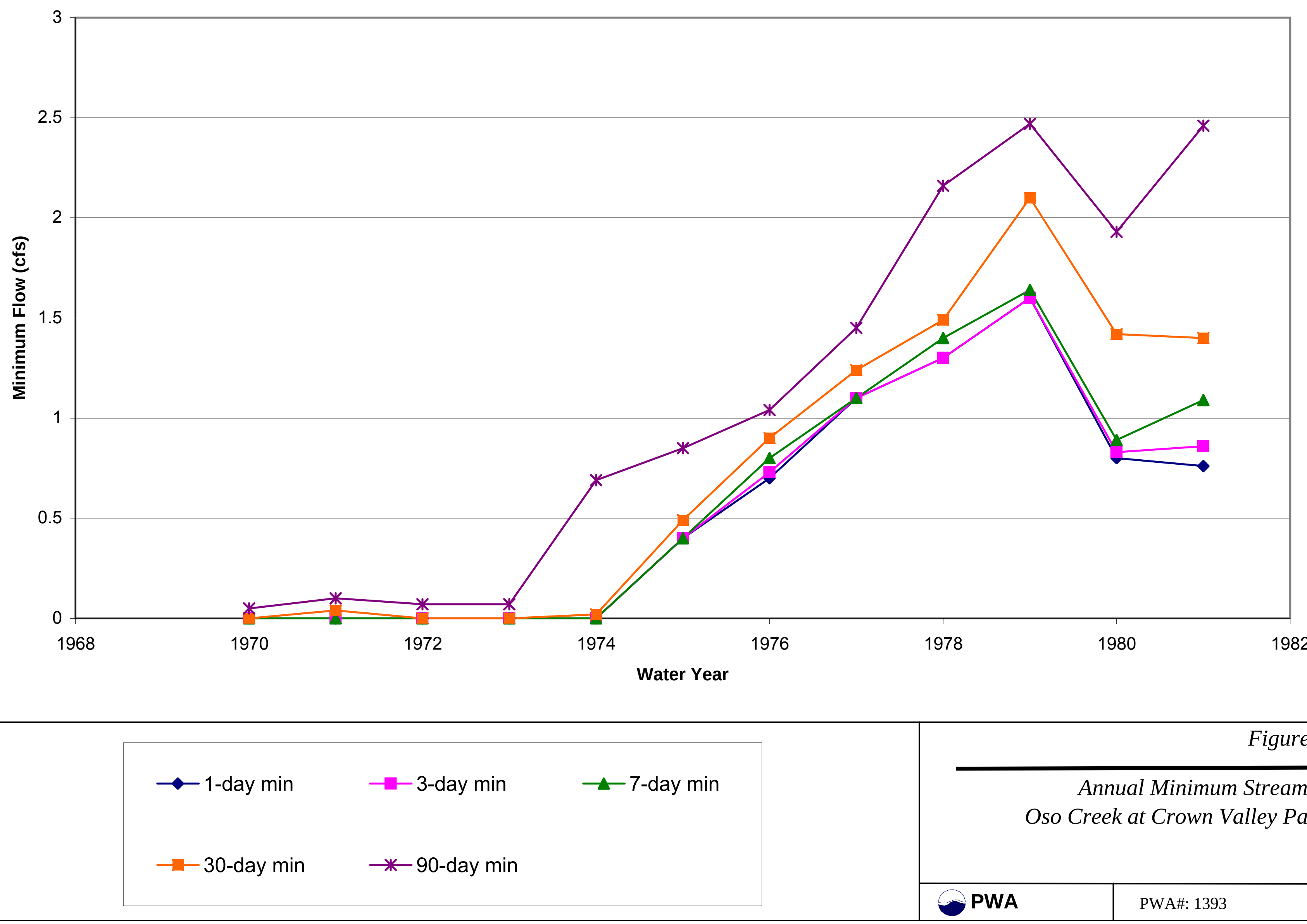


Figure 2-16

Annual Minimum Stream-flows
Oso Creek at Crown Valley Parkway

PWA | PWA#: 1393

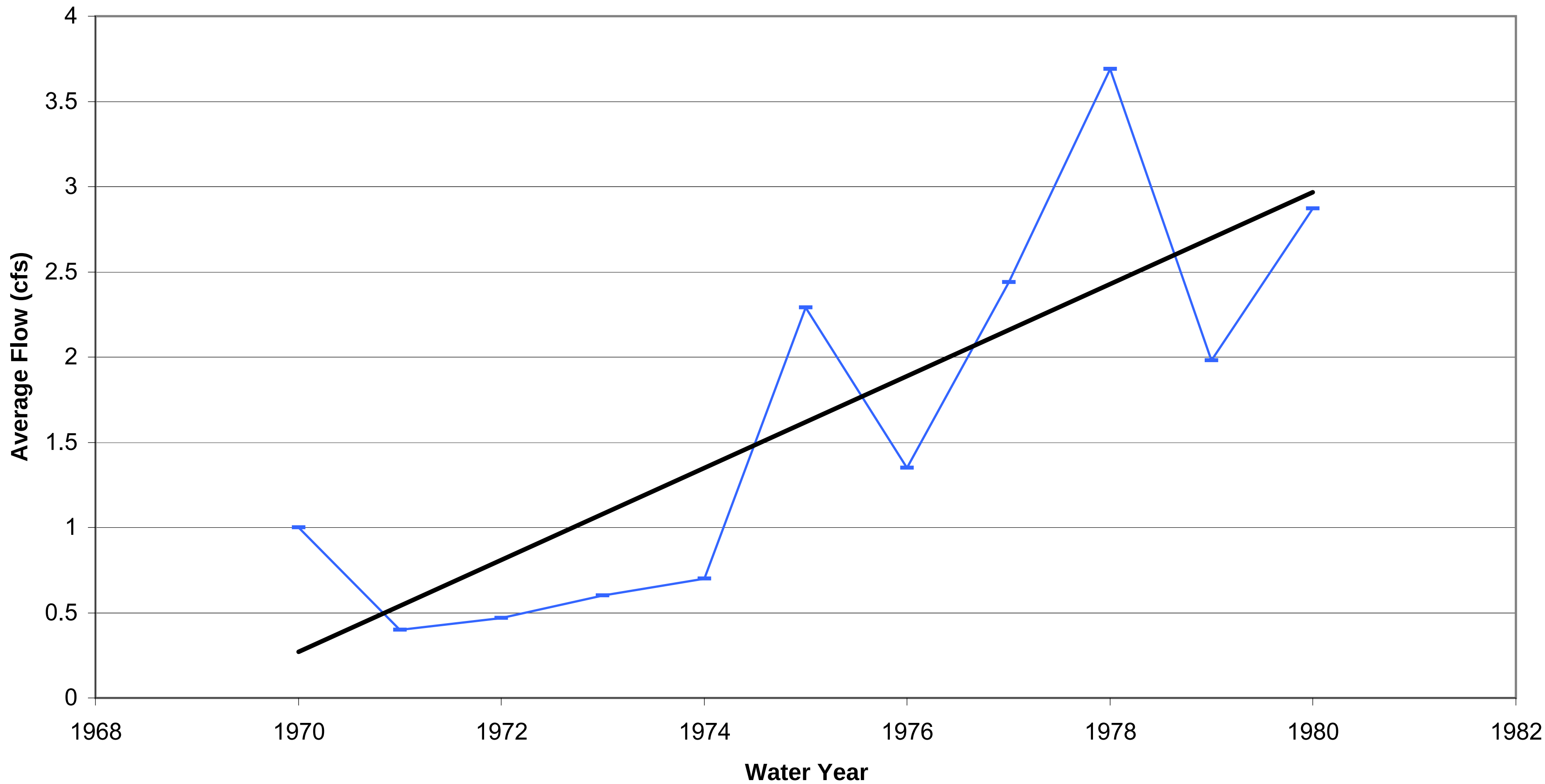


Figure 2-17

June Monthly Mean of Average Daily Stream Flow
Oso Creek at Crown Valley Parkway

PWA | PWA#: 1393

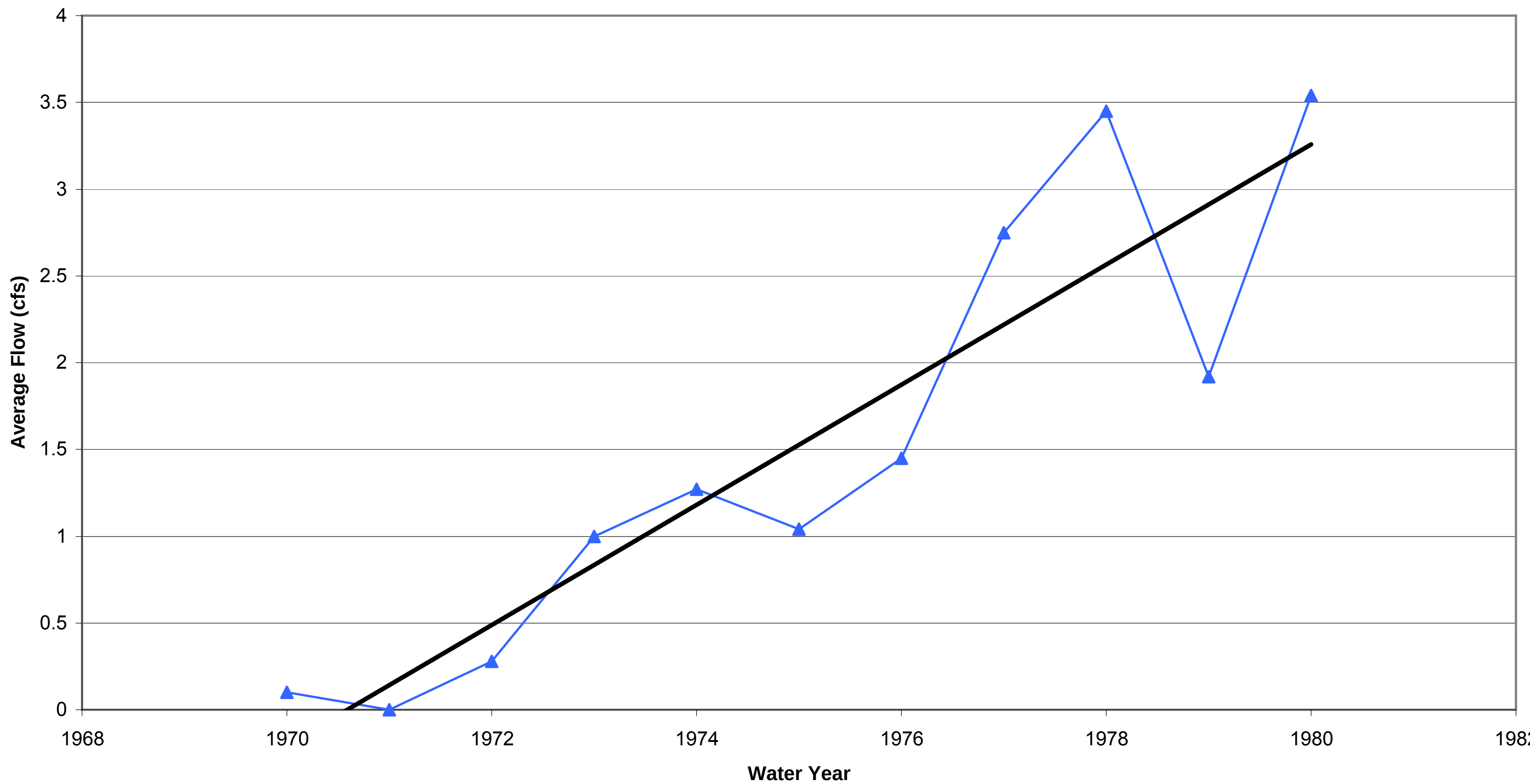


Figure 2-18

July Monthly Mean of Average Daily Stream Flow Oso Creek at Crown Valley Parkway

PWA | PWA#: 1393

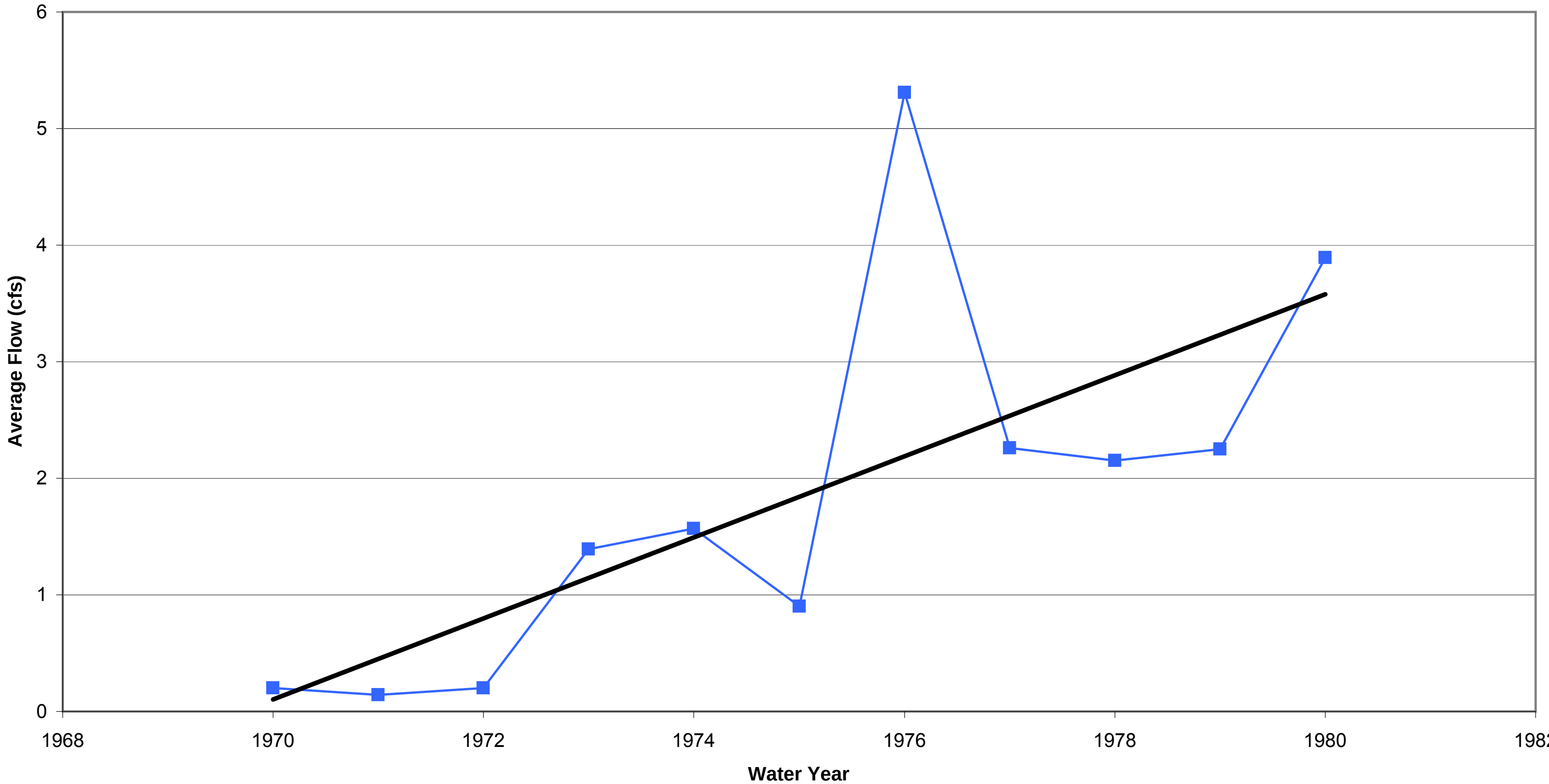


Figure 2-19

August Monthly Mean of Average Daily Stream Flow
Oso Creek at Crown Valley Parkway

PWA | PWA#: 1393

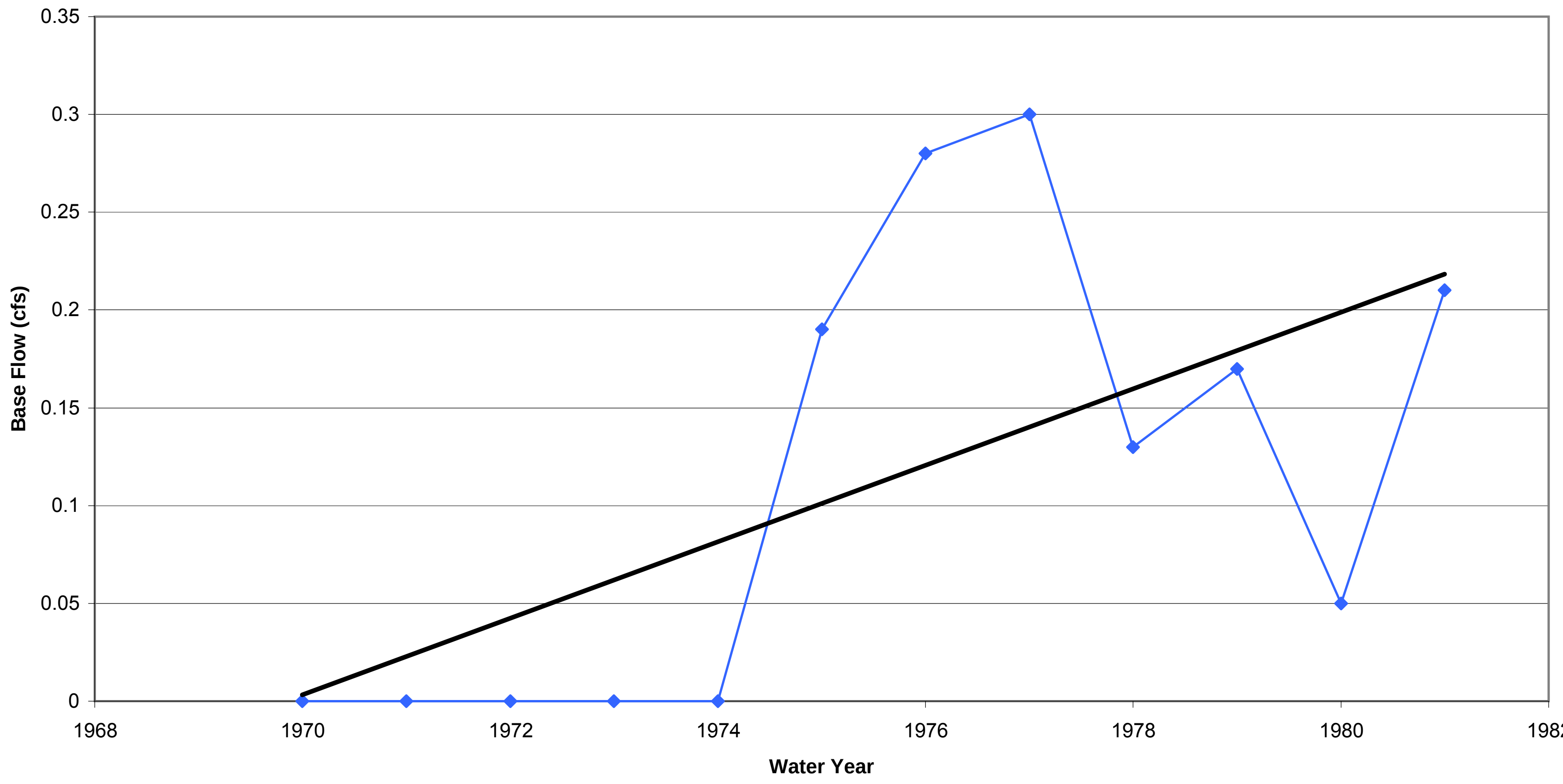


Figure 2-20

Annual Base Flows
Oso Creek at Crown Valley Parkway

PWA | PWA#: 1393

1393 SAMP\t\Baseline Report\FiguresResults\Low Flow\Oso Creek IHA Results.xls

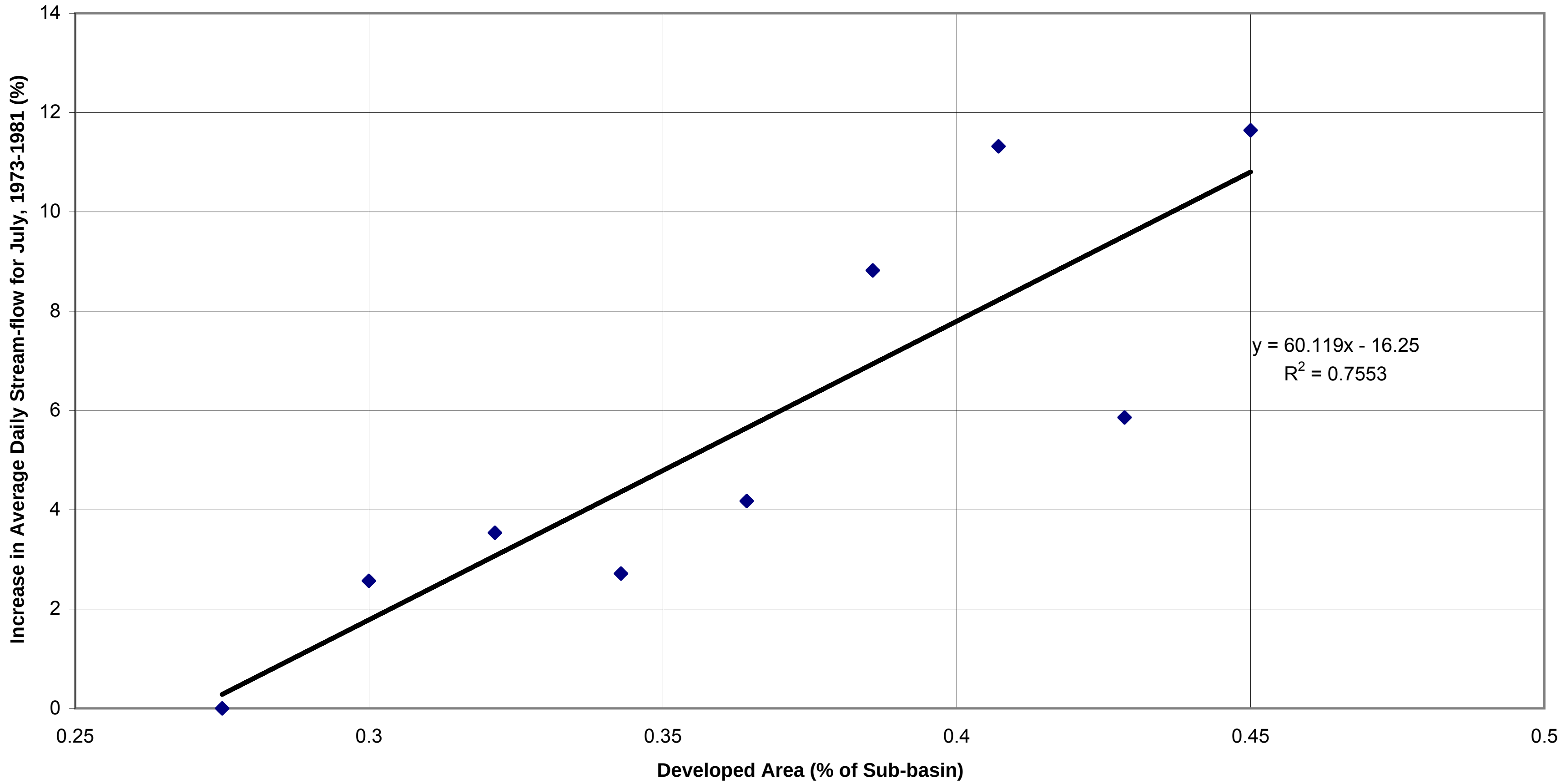


Figure 2-21

%-Developed Area Versus %-Increase in Average Daily Stream-flow in July, 1974 - 1981 Oso Creek at Crown Valley Parkway

PWA PWA#: 1393

1393 SAMP\t\Baseline Report\FiguresResults\Low Flow\Oso Creek IHA Results.xls

Several things are notable about these hydrologic results. In general, the hydrographs show the characteristic pattern of a large watershed with increases in peak discharge and time of peak moving downstream through the watershed. Flows from the Crisitianitos Creek tributary join the main San Mateo channel prior to the passing of peak flows in the main San Mateo channel for all three events. This earlier arrival of Cristianitos flows is most pronounced for the 2-year event and less pronounced for the 10- and 100-year events sequentially. As a result, contributing flows from Cristianitos Creek help sustain flows for the overall San Mateo Watershed at the Pacific Ocean, where peak flows have a relatively long duration. The long duration is also reflective of the relatively un-urbanized condition of most of the watershed. Runoff rates tend to increase and decline much less rapidly in natural watersheds than in urbanized watersheds. In contrast to the results from the San Juan watershed with its large urbanized areas, the event hydrographs for San Mateo Creek do not seem to be heightened or accelerated due to urban development. Discharge rates per unit area for the San Mateo Creek watershed can be compared to the recorded values shown in Figure 2-13.

Total runoff volumes at the Pacific Ocean outlet of the San Mateo watershed are shown in Table 2-22 for the three modeled events. Runoff volume per unit area is also included for reference. Runoff volumes per unit area are higher for the overall San Mateo Creek watershed than for the individual sub-basins described below in Section 3. These individual sub-basins of the western San Mateo watershed have generally higher infiltration conditions and less runoff per unit area than the overall San Mateo watershed rates. Interestingly, for the 10-year and 100-year events, runoff volume per unit area is greater for the relatively undeveloped San Mateo watershed than the more developed San Juan watershed to the north (Table 2-22).

Unlike the San Juan Creek watershed, there have been no previous hydrologic modeling studies completed for the San Mateo Creek watershed. Therefore, no direct comparisons can be made at this time. Hydrologic and sediment transport conditions in the individual sub-basins of the San Mateo watershed are described in greater detail below in Sections 3 and 4.

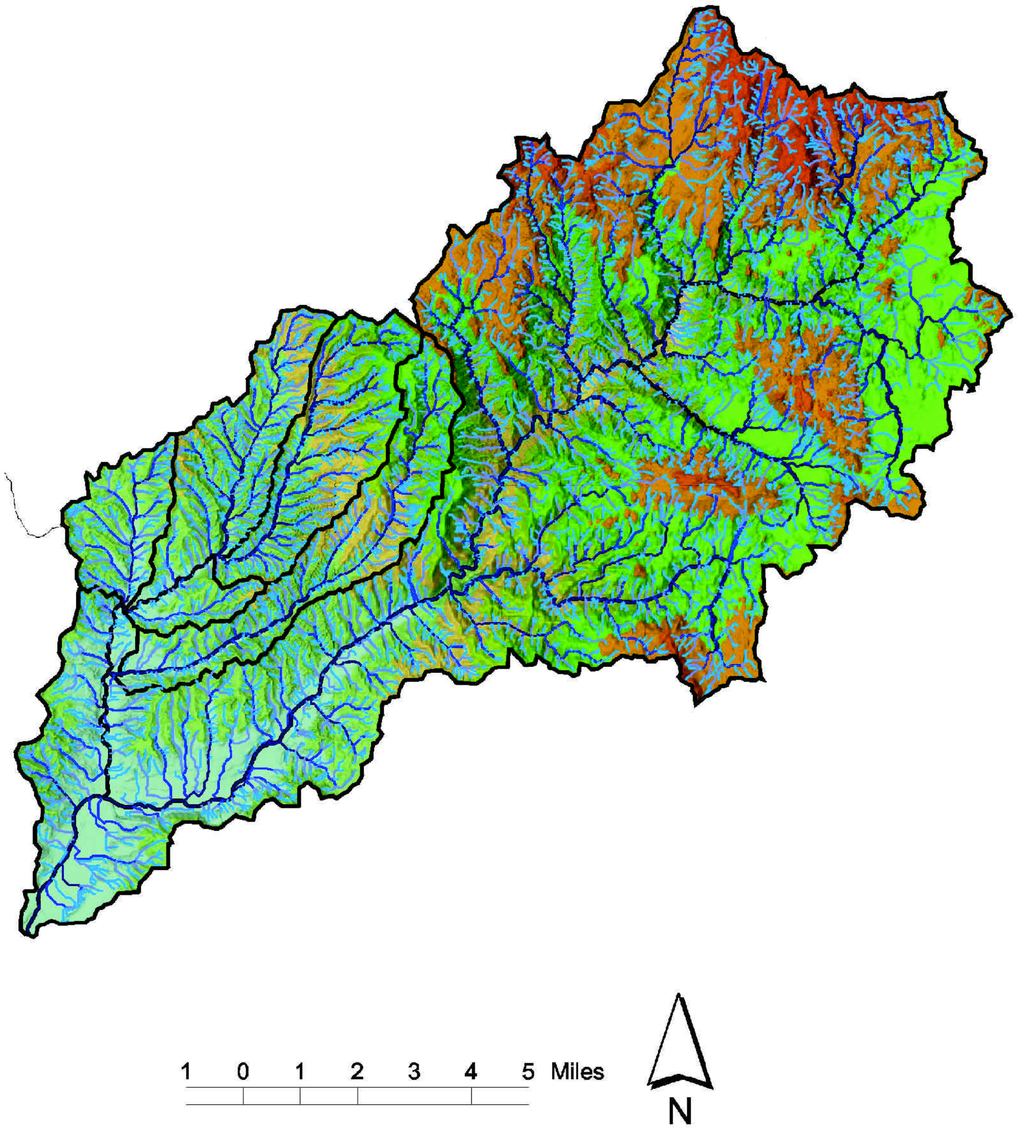
Table 2-22 Storm Event Runoff Volumes, San Mateo Watershed at the Pacific Ocean

Event	Total Runoff Volume (acre-feet)	Runoff Volume per Unit Area (acre-feet/mile^2)
2-year	4,550	34
10-year	24,960	187
100-year	59,090	443

Source: PWA HEC-1 Analysis (2000).

figure 2-22

Channel Network
San Mateo Basin



Channel Network Statistics

Basin Area = 85,242 acres
Drainage Density = 8 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	5822	501	2919042	5.63
2	1034	1442	1491342	2.86
3	362	2208	799206	4.96
4	73	5006	365404	5.46
5	16	13112	209787	4
6	4	19173	76693	4
7	1	95810	95810	

Total Stream Length: 1128.3 mi

Stream Order

1
2
3
4
5
6
7

PWA

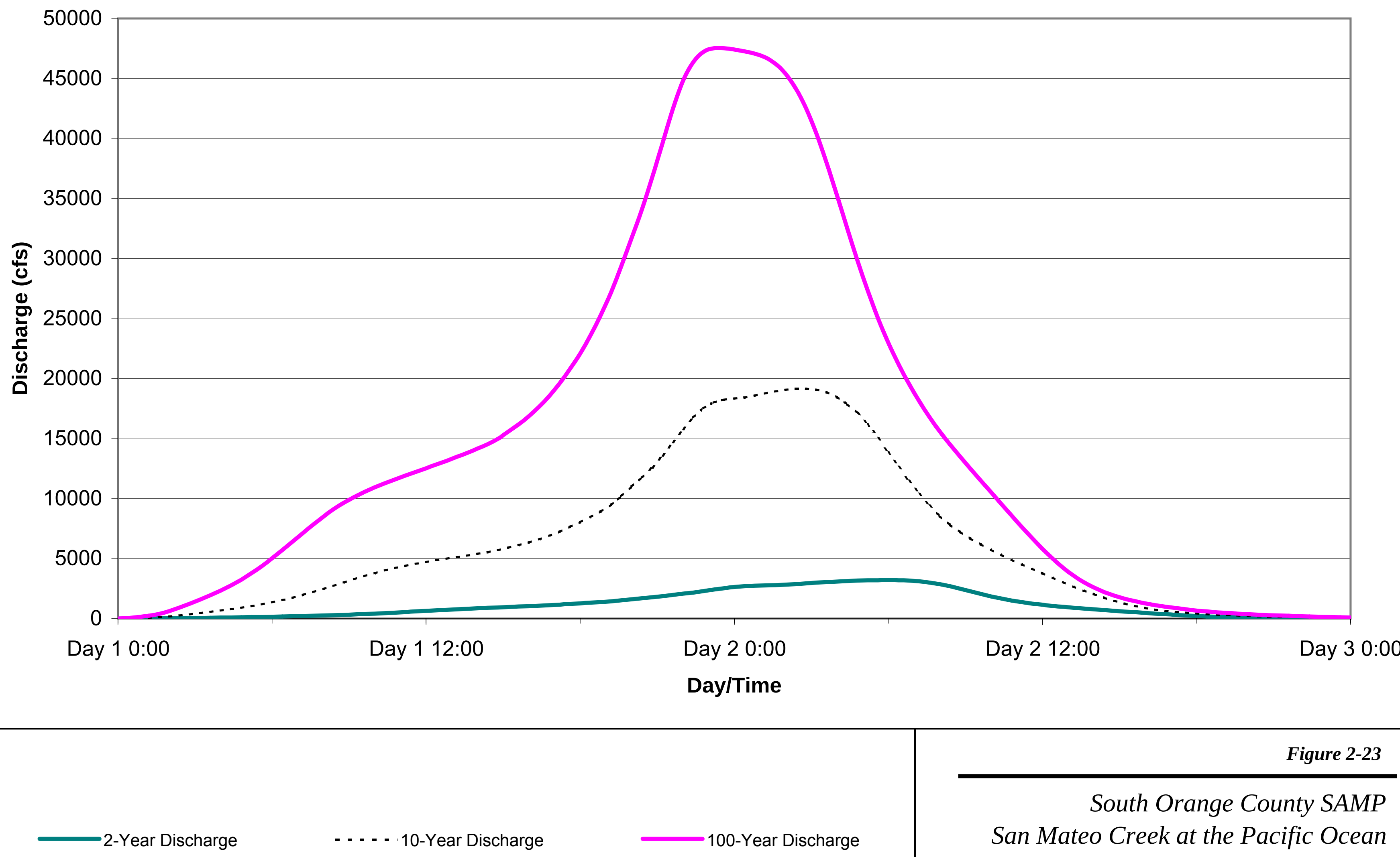


Figure 2-23

South Orange County SAMP
San Mateo Creek at the Pacific Ocean
San MateoCreek Watershed

PWA PWA#: 1393

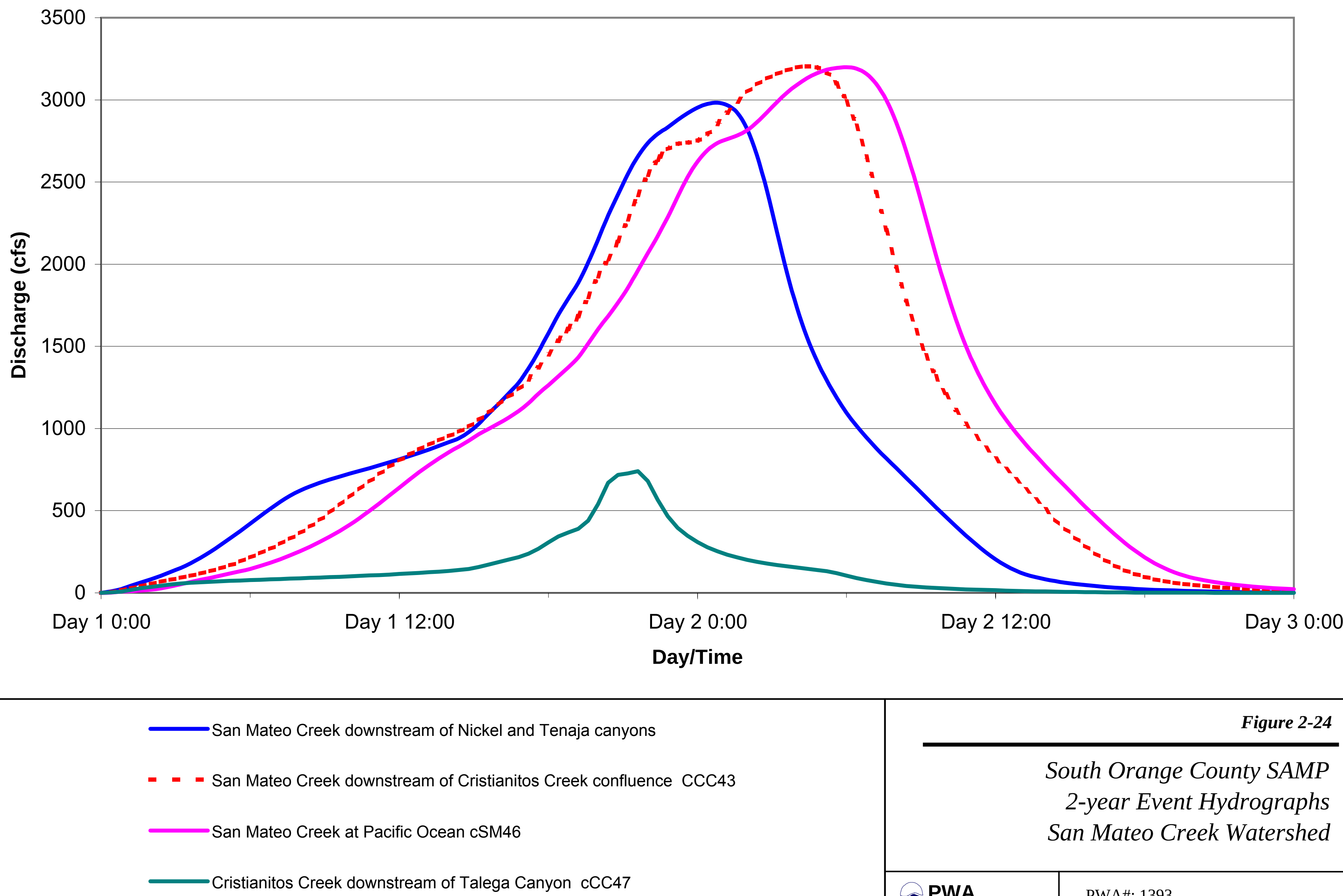


Figure 2-24

South Orange County SAMP
2-year Event Hydrographs
San Mateo Creek Watershed

PWA

PWA#: 1393

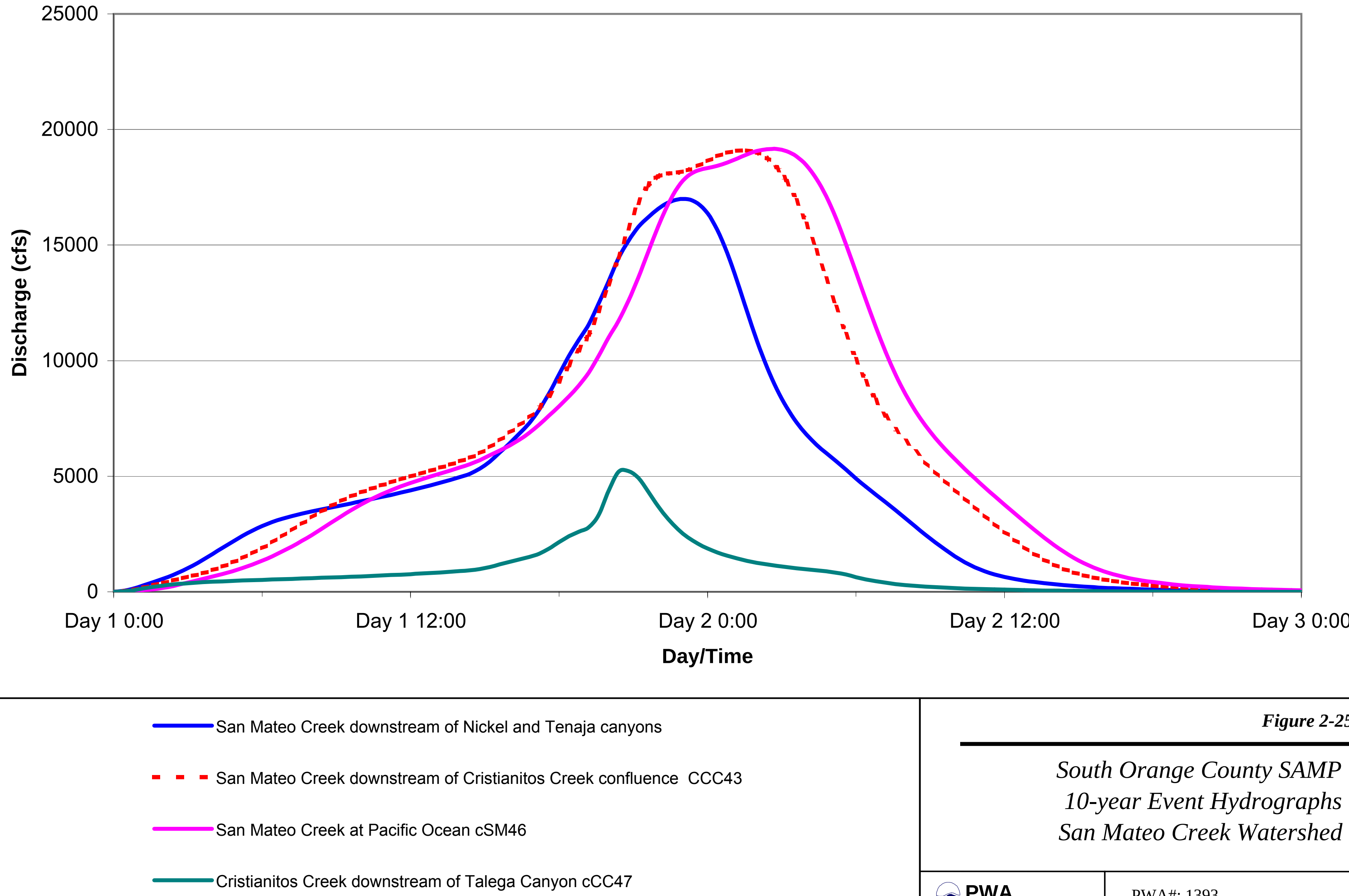


Figure 2-25

South Orange County SAMP
10-year Event Hydrographs
San Mateo Creek Watershed

PWA PWA#: 1393

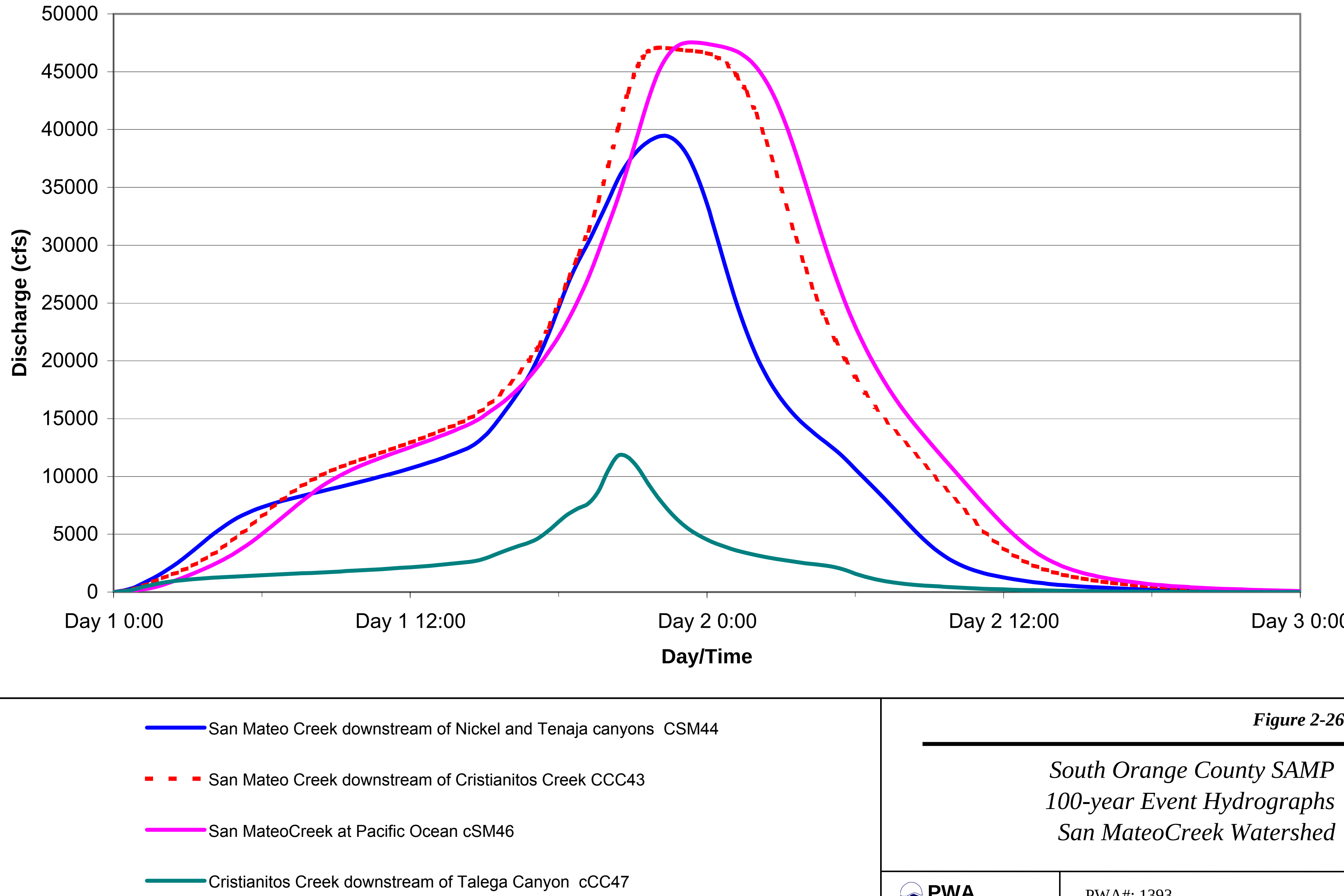


Figure 2-26

South Orange County SAMP
100-year Event Hydrographs
San MateoCreek Watershed

PWA | PWA#: 1393

3. HYDROLOGY OF INDIVIDUAL SAN JUAN & SAN MATEO CREEK SUB-BASINS

3.1 INTRODUCTION TO INDIVIDUAL SUB-BASINS

Stream network, infiltration, and storm event runoff conditions for individual sub-basins of the San Juan and San Mateo Creek watersheds were analyzed in greater detail than the watershed overviews presented above in Section 2. Results for these individual canyons are presented in Sections 3.2 and 3.3 below. Prior to reviewing these individual results it is useful to present summary comparison tables and graphs for the sub-basins.

In Tables 3-1 through 3-6, physical characteristics (including basin geometry, soil, and land-use conditions), infiltration and precipitation parameters, peak discharge and runoff volume parameters and results are given for the studied sub-basins of the San Juan and San Mateo Creek watersheds. These tables are referenced repeatedly in the subsequent discussions of Sections 3.2 and 3.3. In Figures 3-1 and 3-2 peak discharge rates and peak discharge per unit area are plotted for the 10 sub-basins. Peak flow rates are greatest from the largest sub-basins such as Bell Canyon in the San Juan watershed and Gabino Canyon in the San Mateo watershed. In terms of discharge per unit area (Figure 3-2), Cañada Gobernadora in the San Juan watershed and Upper Cristianitos Canyon in the San Mateo watershed had the highest rates of the studied sub-basins. For storm event volume (Figure 3-3), the larger Bell and Gabino canyons shed the most runoff. Runoff volumes per unit area (Figure 3-4) are fairly equitable, with Lucas and Bell canyons having the highest rates.

Table 3-7 indicates the times at which peak flows exited the sub-basins. Times along the main San Juan Creek at the confluence with the various sub-basins are also given for reference. Since the studied sub-basins of the San Mateo watershed were all tributaries to Cristianitos Creek, comparative peak times along the main San Mateo channel are not examined. Figure 3-5 illustrates that Lucas, Verdugo, Bell, Gobernadora, Chiquita, and the Central San Juan catchments all experienced their peak flow rates prior to the passing of peak flow along the main San Juan Creek.

3.2 SAN JUAN CREEK WATERSHED

3.2.1 Lucas Canyon

3.2.1.1 Drainage Network

The Lucas Canyon sub-basin (7.17 mi^2) is located in the eastern-central portion of the San Juan watershed (Figure 3-6). The central valley and main stream course of this sub-basin is oriented along an east-west axis while most tributary channels enter Lucas Canyon from the north or south. The longest continuous watercourse of the sub-basin is approximately 6 miles. The Lucas Canyon and San Juan Creek confluence occurs roughly 1.5 miles upstream of the Bell Canyon and Verdugo Canyon outlets.

Table 3-1 San Juan Creek Watershed Physical Characteristics Including Basin Geometry, Soil, and Land-use Conditions

	Sub-basin Name					Elevation (ft)			Percentage Area with Hydrologic Soil Group				Percentage Area by Land Cover			
Sub-watershed Region	GIS	HEC-1	Area (mi^2)	Area as % of Upstream WS Area	Length[1] (mi)	max.	min.	Slope[2] (ft/mi)	A	B	C	D	Undeveloped	Agricultural	Developed	Other
Lucas Canyon	3	SJ3	7.17	14.31%	7.99	3022	430	324.45	3.62	0.17	48.57	47.64	98.48	0	0.37	1.15
Verdugo Canyon	9	SJ9	4.80	6.21%	6.02	2487	358	353.43	8.30	1.25	61.81	28.63	99.88	0	0.07	0.04
Bell Canyon	1	SJ1	5.12		5.47	4485	1178	604.99	1.94	0	9.15	88.91	100.00	0	0	0
	34	SJ34	9.10		6.86	3061	584	360.88	3.41	2.95	43.29	50.34	87.16	0.05	10.71	2.08
	60	SJ60	6.35		8.86	2405	358	231.14	8.12	5.64	45.83	40.41	99.93	0	0.06	0.01
Area Averages			*20.57*	*28.42%*					*4.50*	*3.05*	*35.58*	*56.87*	*94.30*	*0.02*	*4.75*	*0.93*
Canada Gobernadora	7	SJ7	2.99		3.17	1237	656	183.19	3.43	35.25	54.36	6.96	46.55	1.78	49.42	2.24
	35	SJ35	2.93		4.31	1050	390	153.18	7.37	27.82	60.71	4.11	53.07	28.88	15.03	3.02
(Wagon Wheel Canyon)	36	SJ36	1.77		3.49	1063	390	192.56	0.69	30.59	62.96	5.76	84.12	8.57	1.86	5.44
	63	SJ63	3.40		4.01	797	230	141.69	4.40	19.89	38.90	36.81	56.74	31.17	0.07	12.02
Area Averages			*11.08*	*11.58%*					*4.33*	*27.83*	*52.67*	*15.16*	*57.40*	*19.03*	*17.62*	*5.96*
Canada Chiquita	31	SJ31	4.58		5.59	1168	358	144.86	0	36.55	41.89	21.56	51.97	47.43	0.37	0.24
	8	SJ8	4.66		3.82	656	154	131.25	3.27	14.95	31.65	50.13	62.14	34.21	3.64	0
Area Averages			*9.24*	*8.80%*					*1.65*	*25.65*	*36.73*	*35.98*	*57.10*	*40.76*	*2.02*	*0.12*
Central San Juan Catchments	13	SJ13	7.42	8.77%	4.48	892	230	147.96	6.07	12.08	52.62	29.24	84.79	6.15	5.66	3.40
Entire watershed	-	-	175.97	100.0%	31.05	5682	0	112.42	4.74	15.42	27.80	52.04	61.49	6.27	28.92	3.32

[1] Length of longest watercourse
[2] Average slope of longest watercourse

Table 3-2 San Juan Creek Watershed Infiltration and Precipitation Parameters

Sub-watershed Region	Sub-basin Name GIS	Sub-basin Name HEC-1	Area (mi^2)	Area as % of Upstream WS Area	Percentage Area with Curve Number in Range (AMC II) 30-39	40-49	50-59	60-69	70-79	80-89	90-97	Area-averaged Curve Number (AMC II)	Low Loss Fraction 2-year*	10-year	100-year	Impervious Area (%)	Maximum Loss Rate 2-year* (in/hr)	Maximum Loss Rate 10 & 100 (in/hr)	Incident Precipitation 2-year* (in)	Incident Precipitation 10-year (in)	Incident Precipitation 100-year (in)	Precipitation Losses 2-year* (in)	2-year* (%)	10-year (in)	10-year (%)	100-year (in)	100-year (%)
Lucas Canyon	3	SJ3	7.17	14.31%	1.75	1.64	0.20	0.18	45.85	49.20	1.18	78.6	0.7244	0.4352	0.1087	0.20	0.5988	0.2312	1.85	4.81	7.56	1.35	72.97	2.01	41.77	0.81	10.73
Verdugo Canyon	9	SJ9	4.80	6.21%	2.73	5.50	0.53	0.76	60.37	30.03	0.08	74.8	0.8440	0.5678	0.1812	0.05	0.5997	0.2486	1.47	3.78	5.82	1.24	84.35	2.05	54.36	1.04	17.80
Bell Canyon	1	SJ1	5.12		1.51	0.37	0.05	0.00	11.02	87.04	0.00	82.3	0.5899	0.3137	0.0623	0.00	0.6000	0.2084	2.39	6.27	9.98	1.37	57.32	1.84	29.26	0.60	6.00
	34	SJ34	9.10		2.62	0.78	0.41	1.14	42.55	42.92	9.58	78.8	0.7627	0.4820	0.1346	7.44	0.5530	0.2142	1.57	4.07	6.29	1.17	74.52	1.80	44.14	0.81	12.89
	60	SJ60	6.35		6.24	1.86	1.00	4.50	48.02	38.39	0.00	74.0	0.8548	0.5836	0.1984	0.02	0.5999	0.2447	1.45	3.73	5.71	1.22	84.14	2.00	53.68	1.09	19.01
Area Averages			20.57	28.42%	3.46	1.01	0.50	1.90	36.39	52.50	4.24	78.20	0.75	0.47	0.14	3.30	0.5792	0.2222	1.74	4.51	7.03	1.24	73.21	1.87	43.38	0.84	13.07
Canada Gobernadora	7	SJ7	2.99		1.40	0.51	3.41	11.25	42.62	10.54	30.27	79.5	0.7319	0.4884	0.1564	29.84	0.4210	0.1889	1.43	3.67	5.61	1.00	69.93	1.54	42.04	0.81	14.36
	35	SJ35	2.93		3.01	0.86	4.58	5.70	51.15	21.01	13.69	76.5	0.8092	0.5513	0.1808	12.05	0.5277	0.2400	1.43	3.65	5.59	1.11	77.62	1.79	49.05	0.94	16.90
(Wagon Wheel Canyon)	36	SJ36	1.77		0.29	0.22	7.53	18.16	55.53	13.04	5.24	74.5	0.8668	0.6028	0.1982	1.77	0.5894	0.2588	1.43	3.65	5.58	1.19	83.22	1.97	54.01	1.04	18.60
	63	SJ63	3.40		0.32	0.12	2.44	6.58	36.75	51.23	2.56	79.4	0.7987	0.5139	0.1392	0.26	0.5984	0.2475	1.42	3.63	5.56	1.11	78.17	1.71	47.07	0.74	13.32
Area Averages			11.08	11.58%	1.32	0.44	4.08	9.46	45.14	26.17	13.40	77.88	0.79	0.53	0.16	11.59	0.5305	0.2315	1.43	3.65	5.58	1.09	76.61	1.73	47.34	0.86	15.39
Canada Chiquita	31	SJ31	4.58		0	0	0.73	6.53	59.84	32.29	0.61	77.7	0.8403	0.5524	0.1527	0.35	0.5979	0.2566	1.43	3.66	5.60	1.16	81.12	1.80	49.12	0.80	14.37
	8	SJ8	4.66		1.40	0.51	3.41	11.25	42.62	10.54	30.27	79.2	0.7990	0.5147	0.1405	1.72	0.5897	0.2332	1.34	3.43	5.25	1.07	79.85	1.73	50.45	0.74	14.02
Area Averages			9.24	8.80%	0.70	0.26	2.08	8.91	51.15	21.31	15.58	78.49	0.82	0.53	0.15	1.04	0.5938	0.2448	1.38	3.55	5.42	1.11	80.48	1.76	49.79	0.77	14.19
Central San Juan Catchments	13	SJ13	7.42	8.77%	0.65	1.96	3.77	9.21	52.31	28.51	3.58	75.9	0.8512	0.5776	0.1810	3.14	0.5812	0.2427	1.35	2.52	5.29	1.15	85.19	1.40	55.70	0.95	17.88
Entire watershed	-	-	175.97	100.00%	1.72	1.21	1.24	4.45	27.15	39.70	24.53	80.5	-	-	-	21.84	-	-	1.74	4.48	7.05	1.17	67.24	1.71	38.17	0.73	10.35

*2-year loss rates and precipitation adjusted according to the Orange County Hydrology Manual Addendum No. 1 (OCHM, 1995).

Table 3-3 San Juan Creek Watershed Peak Discharge and Runoff Parameters and Results

Sub-watershed Region	Sub-basin Name		Area	Total	Total U/S Area	% of Total U/S Watershed Area	Length[1]	Basin n-value	Lag Time	Time of Peak Discharge (Day hh:mm from	Peak Discharge					
											2-year		10-year		100-year	
	GIS	HEC-1	(mi^2)	Area (mi^2)	(mi^2)		(mi)		(hr)		(cfs)	(%)[2]	(cfs)	(%)[2]	(cfs)	(%)[2]
Lucas Canyon	3	SJ3	7.17	7.17	50.11	14.31%	7.99	0.050	1.00	Day 1 20:24	232	12.04	1431	13.50	3137	12.82
Verdugo Canyon	9	SJ9	4.80	4.80	77.18	6.21%[7]	6.02	0.050	0.76	Day 1 20:00	79	4.06	738	6.73	1715	6.71
Bell Canyon	1	SJ1	5.12				5.47	0.050	0.64	Day 1 20:00	559	-	2355	-	4398	-
	34	SJ34	9.10				6.86	0.050	0.88	Day 1 20:00	618	-	3298	-	6953	-
	60	SJ60	6.35	20.57	72.38	28.42%	8.86	0.050	1.24	Day 1 22:24	639	24.96	3662	25.36	8427	24.94
Canada Gobernadora	7	SJ7	2.99				3.17	0.025	0.48	Day 1 19:36	368	-	1608	-	2727	-
	35	SJ35	2.93				4.31	0.045	1.75	Day 1 20:00	449	-	2234	-	4051	-
(Wagon Wheel Canyon)	36	SJ36	1.77				3.49	0.045	0.92	Day 1 20:00	551	-	2845	-	5225	-
	63	SJ63	3.40	11.08	95.67	11.58%	4.01	0.040	1.83	Day 1 20:48	659	24.48	3474	21.53	6942	17.72
Canada Chiquita	31	SJ31	4.58				5.59	0.045	2.82	Day 1 20:24	281	-	1566	-	3036	-
	8	SJ8	4.66				3.82	0.040	1.67	Day 1 21:36	95	-	705	-	1624	-
		SJ31+SJ8	9.24	9.24	104.91	8.80%	9.41			Day 1 20:24	374	13.11	2204	12.44	4619	10.75
Central San Juan Catchments	13	SJ13	7.42	7.42	84.59	8.77%[6]	4.48	0.040	0.82	Day 1 20:00	118	4.55	1099	7.45	2612	7.41
Entire watershed	-	-	175.97	175.97	175.97	100.00%	31.05	-	0.83[4]	Day 1 21:12	5,165	100	29,817	100	67,817	100

Sub-watershed Region	Increase in Peak Discharge of Channel Downstream						Runoff Volume						Runoff Volume per Unit Area					
	2-year		10-year		100-year		2-year		10-year		100-year		2-year		10-year		100-year	
	(cfs)	(%)[2]	(cfs)	(%)[2]	(cfs)	(%)[2]	(ac.ft.)	(%)[2]	(ac.ft.)	(%)[2]	(ac.ft.)	(%)[2]	(ac.ft. / mi^2)	(%)[3]	(ac.ft. / mi^2)	(%)[3]	(ac.ft. / mi^2)	(%)[3]
Lucas Canyon	113	5.86	875	8.25	2413	9.87	229	10.14	1,283	11.27	3,137	12.08	32	87.83	179	101.50	438	108.81
Verdugo Canyon	29	1.47	323	2.95	1049	4.10	69	2.94	529	4.38	1,468	5.26	14	39.55	110	62.57	306	76.07
Bell Canyon	603	23.57	3475	24.06	8217	24.32	660	21.95	3,476	22.34	8,135	22.57	32	88.20	169	95.80	395	98.30
Canada Gobernadora	107	3.98	1393	8.63	3954	10.09	239	7.15	1,360	7.80	3,353	8.09	22	59.22	123	69.60	303	75.22
(Wagon Wheel Canyon)																		
Canada Chiquita	168	5.89	1617	9.13	3839	8.93	160	4.57	1,051	5.68	2,749	6.22	17	47.59	114	64.50	298	73.99
Central San Juan Catchments	27	1.04	531	3.60	2057	5.84	95	3.06	530	3.29	2,060	5.41	13	35.14	71	40.49	278	69.03
Entire watershed	-	-	-	-	-	-	6,406	100	31,041	100	70,797	100	36	100.00	176	100.00	402	100.00

(1) Length of longest watercourse
(2) As a percentage of value for San Juan Creek watershed at confluence with the sub-watershed (inclusive)
(3) As percentage of entire San Juan watershed
(3) Mean value for all sub-basins in watershed
(4) At mouth of San Juan Creek, HEC-1 node cSJ18
(6) Does NOT include Gobernadora
(7) Includes Bell

Table 3-4 San Mateo Creek Watershed Physical Characteristics Including Basin Geometry, Soil, and Land-use Conditions

Sub-watershed Region	Sub-basin Name		Area (mi^2)	Length(1) (mi)	Elevation (ft)		Slope(2) (ft/mi)	Percentage Area with Hydrologic Soil Group				Percentage Area by Land Cover			
	GIS	HEC-1			max.	min.		A	B	C	D	Undeveloped	Agricultural	Developed	Other
La Paz Canyon	51	CC51	7.25	6.80	2497	436	303.08	6.70	1.72	43.77	47.81	99.63	0.07	0.31	0
Upper Gabino Canyon	49	CC49	5.03	5.82	1923	436	255.27	5.59	7.68	55.72	31.02	99.99	0	0.01	0
Lower Gabino Canyon with Blind Canyon	48	CC48	3.28	4.02	1050	282	190.76	3.46	2.54	33.99	60.00	93.13	0	3.34	3.52
Upper Cristianitos Canyon	45	CC45	3.67	3.69	1007	282	196.32	0.63	12.86	43.86	42.66	97.23	0	0	2.77
Talega Canyon	47	CC47	8.38	10.08	2438	177	224.20	2.91	2.63	18.83	75.63	98.91	0	1.09	0
Entire watershed	-	-	133.28	28.81	3412	0	87.91	1.92	8.29	49.31	40.48	89.71	1.29	7.88	1.12

(1) Length of longest watercourse

(2) Average slope of longest watercourse

Table 3-5 San Mateo Creek Watershed Infiltration and Precipitation Parameters

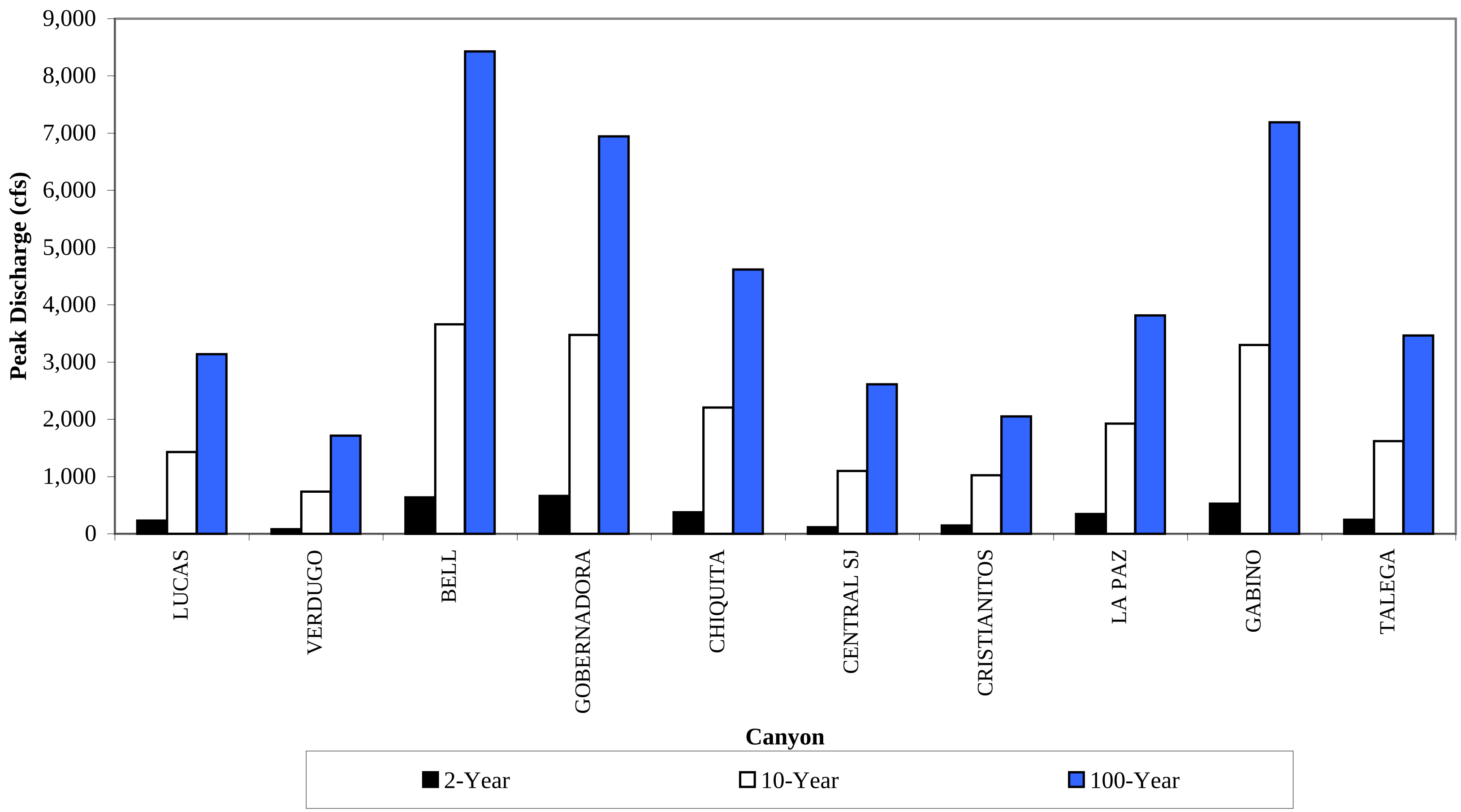
Sub-watershed Region	Sub-basin Name		Area (mi^2)	Percentage Area with Curve Number (AMC II) in Range							Area-averaged Curve Number (AMC II)	Low Loss Fraction			Impervious Area (%)	Maximum Loss Rate		Incident Precipitation			Precipitation Losses					
																2-year*	10 & 100	2-year*	10-year	100-year	2-year*		10-year		100-year	
	GIS	HEC-1		30-39	40-49	50-59	60-69	70-79	80-89	90-97		2-year*	10-year	100-year		(in/hr)	(in/hr)	(in)	(in)	(in)	(in)	(%)	(in)	(%)	(in)	(%)
La Paz Canyon	51	CC51	7.25	0.56	6.10	0.73	1.02	43.85	47.75	0	77.0	0.8213	0.5368	0.1571	0.03	0.5998	0.2369	1.51	3.88	5.97	1.19	78.81	1.87	48.25	0.89	14.83
Upper Gabino Canyon	49	CC49	5.03	2.25	3.34	2.25	5.36	54.61	32.18	0	74.9	0.8653	0.5911	0.1903	0.00	0.6000	0.2467	1.43	3.66	5.60	1.19	83.22	1.90	52.05	0.99	17.71
Lower Gabino Canyon with Blind Canyon	48	CC48	3.28	1.19	1.86	0.39	2.18	37.53	53.71	3.14	78.4	0.8198	0.5319	0.1492	1.67	0.5900	0.2227	1.41	3.62	5.53	1.13	80.14	1.75	48.52	0.79	14.29
Upper Cristianitos Canyon	45	CC45	3.67	0	0.11	3.10	9.23	46.32	39.51	1.72	77.2	0.8476	0.5616	0.1617	0	0.6000	0.2360	1.41	3.60	5.51	1.18	83.69	1.86	51.61	0.86	15.54
Talega Canyon	47	CC47	8.38	1.95	0.96	1.80	0.81	23.54	70.93	0	79.2	0.7780	0.4829	0.1268	0.55	0.5967	0.2167	1.55	3.99	6.16	1.19	76.77	1.80	45.05	0.76	12.35
Entire watershed	-	-	133.28	0.61	1.14	0.80	4.51	43.23	48.94	0.77	78.7	-	-	-	3.917	-	-	1.88	4.91	7.72	1.35	71.81	1.99	40.40	0.78	10.16

*2-year loss rates and precipitation adjusted according to the Orange County Hydrology Manual Addendum No. 1 (OCHM, 1995).

Table 3-6 San Mateo Creek Watershed Peak Discharge and Runoff Parameters and Results

Sub-watershed Region	Sub-basin Name		Area	Length[1]	Basin n	Lag Time	Time of Peak Discharge	Peak Discharge			Peak Discharge Per Unit Area (cfs/mi^2)			Runoff Volume			Runoff Volume per Unit Area					
								2-year	10-year	100-year	2-year	10-year	100-year	2-year	10-year	100-year	2-year		10-year		100-year	
	GIS	HEC-1	(mi^2)	(mi)	value	(hr)	(hrs)	(cfs)	(cfs)	(cfs)	(cfs/mi^2)	(cfs/mi^2)	(cfs/mi^2)	(ac.ft.)	(ac.ft.)	(ac.ft.)	(ac.ft. / mi^2)	(%)[2]	(ac.ft. / mi^2)	(%)[2]	(ac.ft. / mi^2)	(%)[2]
La Paz Canyon	51	CC51	7.25	6.80	0.045	0.853	Day 1 20:00	344	1,927	3,814	47	266	526	147	932	2359	20	59	128	69	325	73
Upper Gabino Canyon	49	CC49	5.03	5.82	0.045	0.809	Day 1 20:00	235	1,419	2,765	47	282	549	78	563	1484	15	45	112	60	295	66
Lower Gabino Canyon with Blind Canyon	48	CC48	3.28	4.02	0.040	0.648	Day 1 20:00	161	992	1,936	49	302	590	60	390	996	18	53	119	64	304	68
Gabino Canyon Upstream of Christianitos		cCC48	15.57				Day 1 21:12	526	3,301	7,190	34	212	462	284	1886	4839	18	53	121	65	311	70
Upper Cristianitos Canyon	45	CC45	3.67	3.69	0.040	0.653	Day 1 20:00	146	1,022	2,053	40	279	560	55	409	1093	15	44	111	59	298	67
Talega Canyon	47	CC47	8.38	10.08	0.040	1.292	Day 1 20:24	247	1,621	3,465	29	193	413	188	1175	2894	22	66	140	75	345	78
Entire watershed	-	cSM46	133.28	28.81	-	0.78 [3]	Day 2 2:48	3,199	19,159	47,525	24	144	357	4,553	24,961	59,087	34	100	187	100	443	100

(1) Length of longest watercourse.
(2) As percentage of San Mateo watershed values.
(3) Mean value for all sub-basins in watershed.



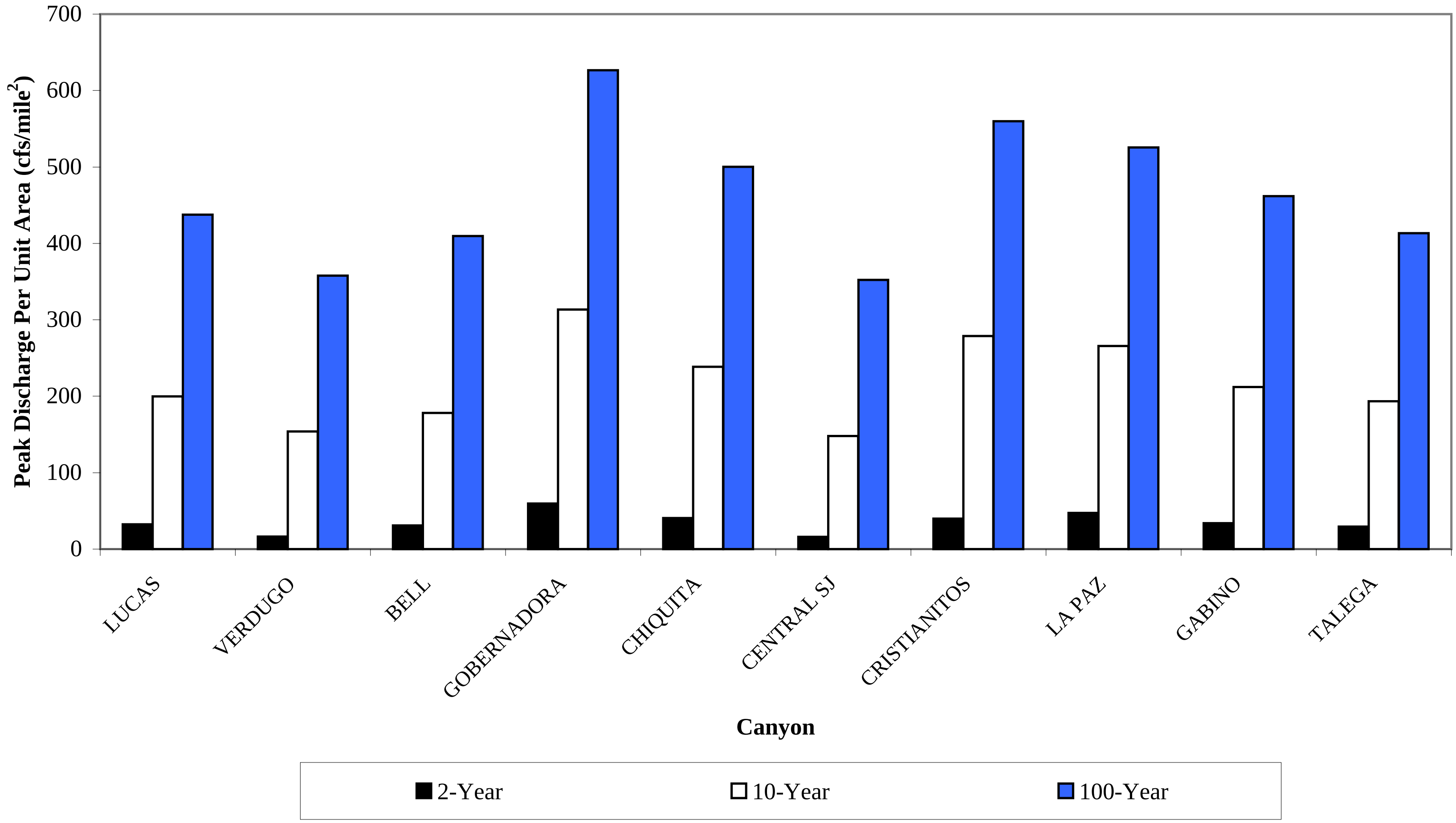
Source: PWA (2000) Analysis.
Notes:

Figure 3-1

Peak Discharge Summary
San Juan & San Mateo Creek Watersheds

PWA

PWA #:1393



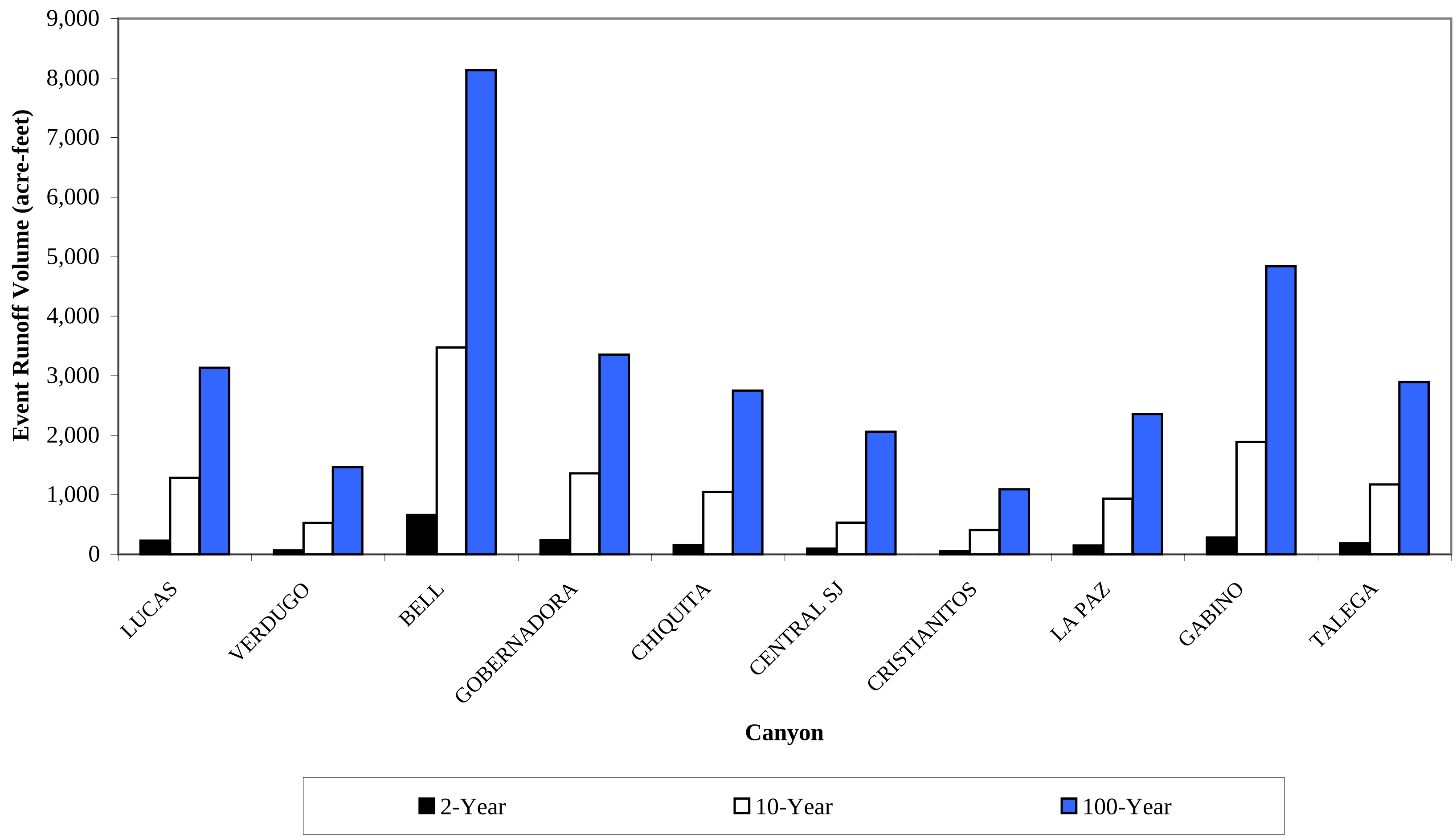
Source: PWA (2000) Analysis.
Notes:

Figure 3-2

Peak Discharge Per Unit Area
San Juan & San Mateo Creek Watersheds

PWA

PWA #:1393



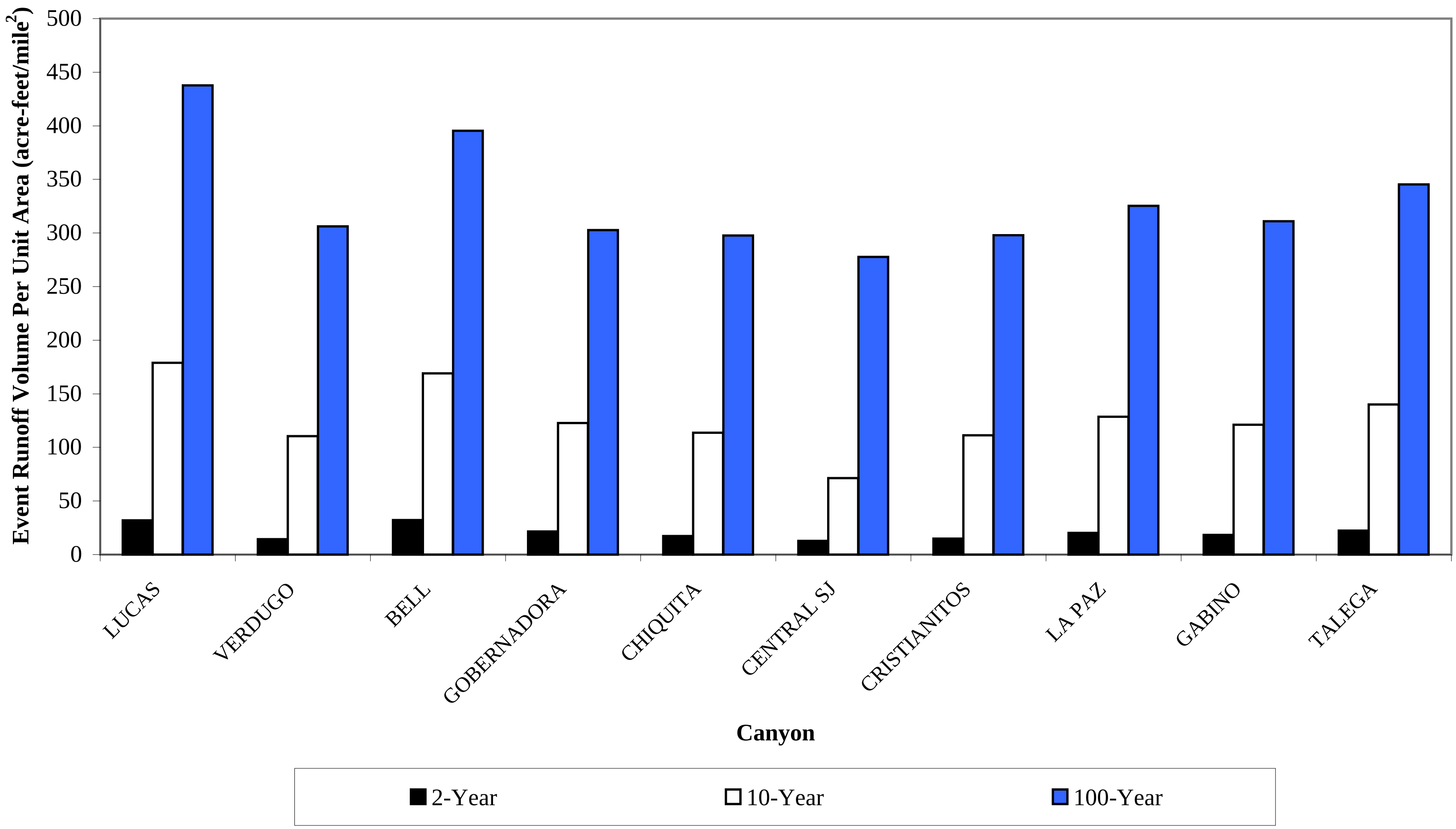
Source: PWA (2000) Analysis.
Notes:

Figure 3-3

Event Runoff Volume Summary
San Juan & San Mateo Creek Watersheds

PWA

PWA #:1393



Source: PWA (2000) Analysis.
Notes:

Figure 3-4

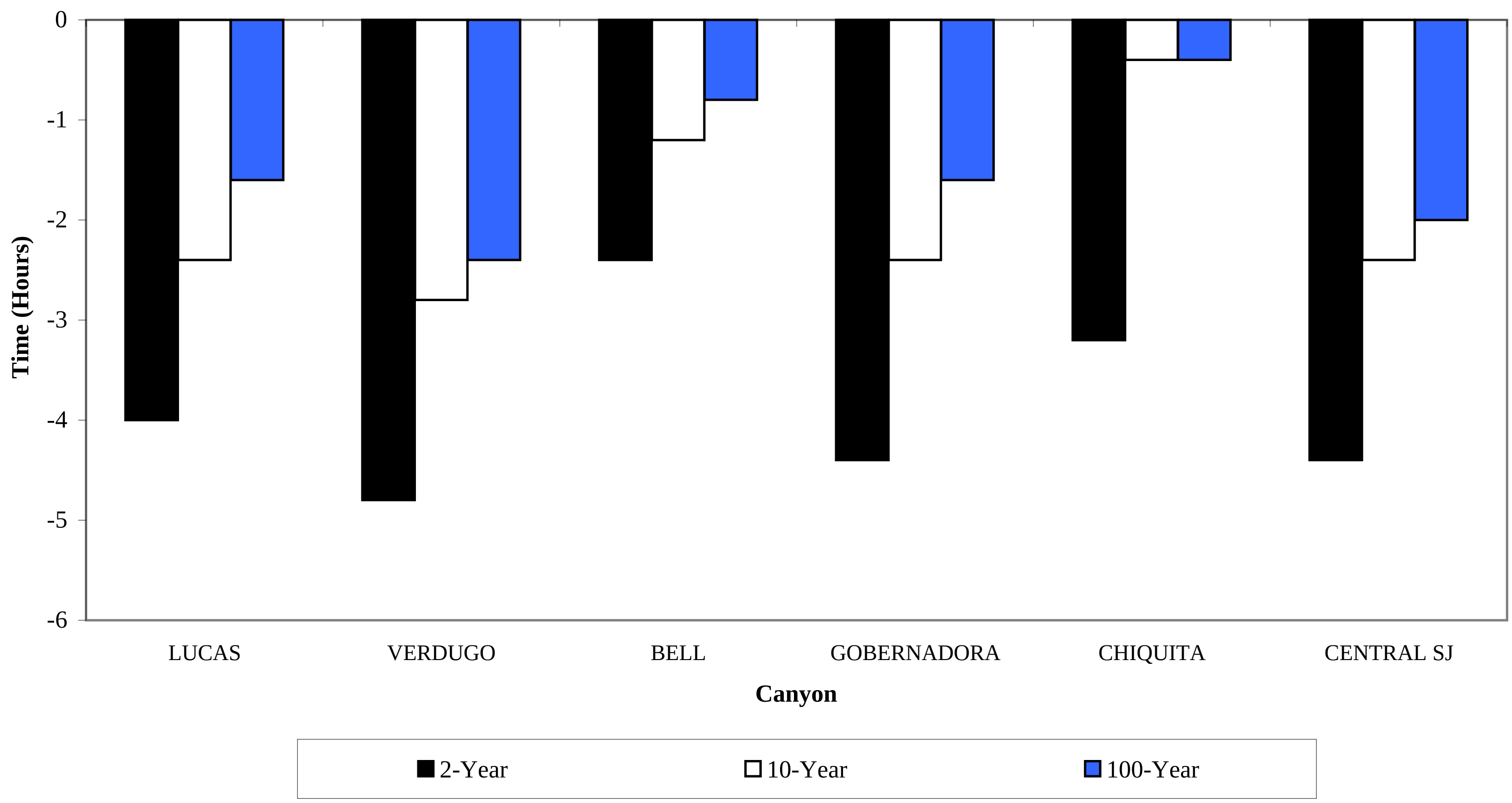
Event Runoff Volume Per Unit Area
San Juan & San Mateo Creek Watersheds

PWA

PWA #:1393

Table 3-7 Peak Flow Timing

Sub-basin	Peak Flow Time (DAY # HH:MM from beginning of event)			San Juan Watershed: Main Stem Peak Flow Time @ Sub-basin Confluence (DAY # HH:MM)			San Juan Watershed: Sub-basin Peak Timing Relative to Main Stem (Hours)		
	2-year	10-year	100-year	2-year	10-year	100-year	2-year	10-year	100-year
LUCAS	Day 1 20:24	Day 1 20:24	Day 1 20:24	Day 2 0:24	Day 1 22:48	Day 1 22:00	-4.00	-2.40	-1.60
VERDUGO	Day 1 20:00	Day 1 20:00	Day 1 20:00	Day 2 0:48	Day 1 22:48	Day 1 22:24	-4.80	-2.80	-2.40
BELL	Day 1 22:24	Day 1 21:36	Day 1 21:12	Day 2 0:48	Day 1 22:48	Day 1 22:00	-2.40	-1.20	-0.80
GOBERNADORA	Day 1 20:48	Day 1 20:24	Day 1 20:24	Day 2 1:12	Day 1 22:48	Day 1 22:00	-4.40	-2.40	-1.60
CHIQUITA	Day 1 20:24	Day 1 20:24	Day 1 20:24	Day 1 23:36	Day 1 20:48	Day 1 20:48	-3.20	-0.40	-0.40
CENTRAL SJ	Day 1 20:00	Day 1 20:00	Day 1 20:00	Day 2 0:24	Day 1 22:24	Day 1 22:00	-4.40	-2.40	-2.00
SAN JUAN @ PACIFIC	Day 1 22:24	Day 1 21:12	Day 1 21:12	N/A	N/A	N/A	N/A	N/A	N/A
CRISTIANITOS	Day 1 20:00	Day 1 20:00	Day 1 20:00						
LA PAZ	Day 1 20:00	Day 1 20:00	Day 1 20:00						
GABINO	Day 1 21:12	Day 1 20:48	Day 1 20:24						
TALEGA	Day 1 20:24	Day 1 20:24	Day 1 20:24						
SAN MATEO @ PACIFIC	Day 2 6:00	Day 2 2:48	Day 1 23:12						



Source: PWA (2000) Analysis.
Notes: A negative value indicates that the sub-basin peak flow arrives at the confluence with the main stem of San Juan Creek *before* the peak flow of San Juan Creek itself. A positive value indicates that the sub-basin peak flow arrives at the confluence *after* the peak flow of San Juan Creek.

Figure 3-5

Sub-basin Peak Flow Timing Relative to the Main Stem of San Juan Creek

PWA

PWA #:1393

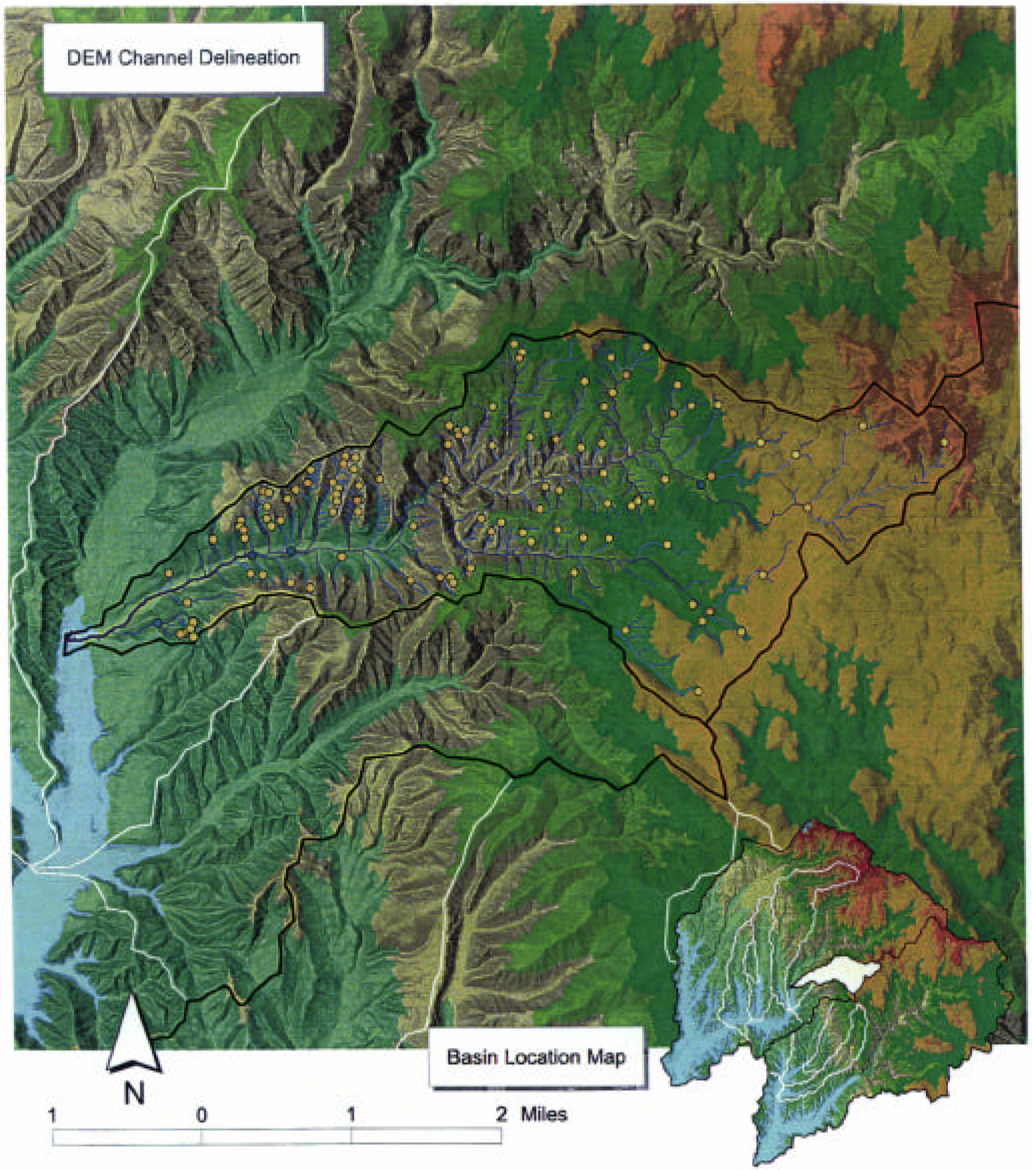


figure 3-6

Channel Network Lucas Canyon

Channel Network Statistics

Basin Area = 4,583 acres
Drainage Density = 9 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	474	394	186709	4.94
2	96	936	89820	5.33
3	18	2772	49897	6
4	3	7557	22672	3
5	1	7594	7594	

Total Stream Length: 67.6 mi

Stream Order

1
2
3
4
5
6
7

Order Increment Points

2
3
4
5
6
7

PWA

Within the entire San Juan watershed, the Lucas Canyon sub-basin, like other basins near it, represents a transition to the steeper and more rugged upper regions of the San Juan drainage. Lucas Canyon's area represents about 14.3% of the San Juan watershed area (51.81 mi^2) upstream of the Lucas Canyon and San Juan Creek confluence.

Lucas Canyon is a fifth order basin at its canyon mouth along the main San Juan corridor. The main valley stream channel extends upstream eastward into parallel fourth and third order segments. Many second and third order side-valley tributaries enter the main valley from the north side of the canyon. A clustering of second and third order confluence points occurs in the lower western section of the sub-basin. Confluence points are distributed more evenly in the middle reaches of the basin and distributed sparsely in the upper portions of the sub-basin. The low number of channels in the upper basin results from the absence of mapped WES channels in this region. As a result, actual drainage densities are expected to be slightly higher than the calculated 9 mi/mi^2 measure. Overall, there are 474 first order channels in Lucas Canyon which comprise over 52% of the total channel length in the basin.

The hydrology of Lucas Canyon was analyzed as part of the San Juan watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2 above. This canyon is represented by sub-basin 3 in Figure 2-1 and node SJ3 in the HEC-1 network in Figure 2-6. The sections below describe important hydrologic characteristics and processes of the Lucas Canyon sub-basin. Estimated runoff values based upon the HEC-1 analysis are presented.

3.2.1.2 Infiltration

As previously discussed, according to HEC-1, the rate of infiltration within a watershed area is generally related to the soil types, vegetation types, and land-use distribution in the watershed. The soil type distribution within Lucas Canyon is shown in Figure 2-2. As reported in Table 3-1, GIS analysis indicates that the majority of the sub-basin is underlain by soils of hydrologic groups C (48.6%) and D (47.6%). Soils in these classes are poorer infiltrators than soils in classes A or B. The land-use and vegetation distributions for Lucas Canyon are shown in Figure 2-3. As indicated in Table 3-1, Lucas Canyon is nearly entirely undeveloped (98.5%). Developed lands (mostly roads) cover approximately 0.4% of the sub-basin. Therefore, only a very tiny fraction of the basin is impervious to infiltration. The predominant vegetation types in the sub-basin are sage and chaparral (Figure 2-3).

According to OCHM methods, SCS runoff curve numbers were used in hydrologic modeling of the sub-basin to synthesize the effect of soil type, land-use, vegetation, and infiltration processes and offer an integrated overall "loss" rate for the sub-basin. Assigned runoff curve numbers range from 31 to 97 in Lucas Canyon, with an area-averaged curve number of 78.6. The vast majority of the sub-basin (95%) was characterized by curve numbers between 70 and 89. Based on these curve numbers, loss rates were calculated for the sub-basin and incorporated into the HEC-1 model. The maximum loss rate for Lucas Canyon was calculated to be 0.23 inches/hour for the 10- and 100-year events, and .60 inches/hour for the 2-year event. Total precipitation losses for the 2-, 10-, and 100-year storm events are also reported in Table 3-2.

Calculated loss rates for Lucas Canyon are relatively low in comparison to the other San Juan watershed sub-basins described in this report. When considered as a percentage of total storm event rainfall, losses in Lucas Canyon were smaller than losses in all six reported San Juan sub-watersheds for all three modeled storm events (except for Bell Canyon and Cañada Gobernadora during the 2-year event). Overall, the low loss rates calculated for Lucas Canyon indicate that infiltration rates are also relatively low in this sub-basin. This is likely a result of the relatively high proportion of poorly draining soils. Lucas Canyon has a relatively high proportion of class-D soils and a relatively low proportion of class-A and class-B soils.

3.2.1.3 Storm Event Runoff

The 2-year, 10-year, and 100-year storm hydrographs were calculated for the outlet of Lucas Canyon using the HEC-1 hydrologic model (Figure 3-7). The storm event hydrographs all display a smaller yet distinct peak which occurs before the main peak of the hydrograph. This is especially pronounced for the 10-year and 100-year hydrographs. This shape is characteristic of the hydrographs in the southeastern portion of the San Juan Creek watershed (Lucas Canyon, Verdugo Canyon, and the Central San Juan catchments), and is more likely attributable to the shape of the precipitation hyetograph modeled for this portion of the watershed rather than physical conditions (like basin shape or tributary relationships) in the sub-basins.

The second notable feature of the Lucas Canyon hydrographs relates to the timing of runoff. Peak flows occur at 20:24 hours following the onset of precipitation. Runoff exiting Lucas Canyon peaks 4.0, 2.4, and 1.6 hours (for the 2-, 10-, and 100-year events respectively) prior to the arrival of peak flows on the main San Juan Creek peak at the Lucas Canyon confluence (Figure 3-5). Peak flows from Lucas Canyon have a moderate impact (6-10% increase) on peak flows in San Juan Creek at the confluence and downstream relative to the size of the sub-basin (Figures 3-8, 3-9, 3-10, Table 3-3).

In comparison to the other relatively undeveloped sub-basins presented, runoff volumes and peak flows per unit area from Lucas Canyon are high (Figures 3-2, 3-4). Lucas Canyon produced approximately the same runoff on a per-acre basis as the average for the San Juan Creek watershed as a whole (Table 3-3). This runoff per-area rate is quite high considering that Lucas Canyon is undeveloped while much of the western San Juan watershed is highly developed. This result may be explained by the comparatively low permeability of soils in Lucas Canyon sub-basin discussed above. For all three runoff events, Lucas Canyon contributes between 10% and 12% of the runoff volume to San Juan Creek at their confluence and it occupies approximately 14% of the total watershed area at that point (Table 3-3). Peak flows from Lucas Canyon are approximately 13% of peak flows in San Juan Creek at the confluence (the 10-year peak flow from Lucas Canyon was calculated at 1431 cfs). Overall, for the three flood events modeled, runoff from Lucas Canyon had a significant impact on the overall San Juan Creek hydrograph downstream of the confluence of the two streams.

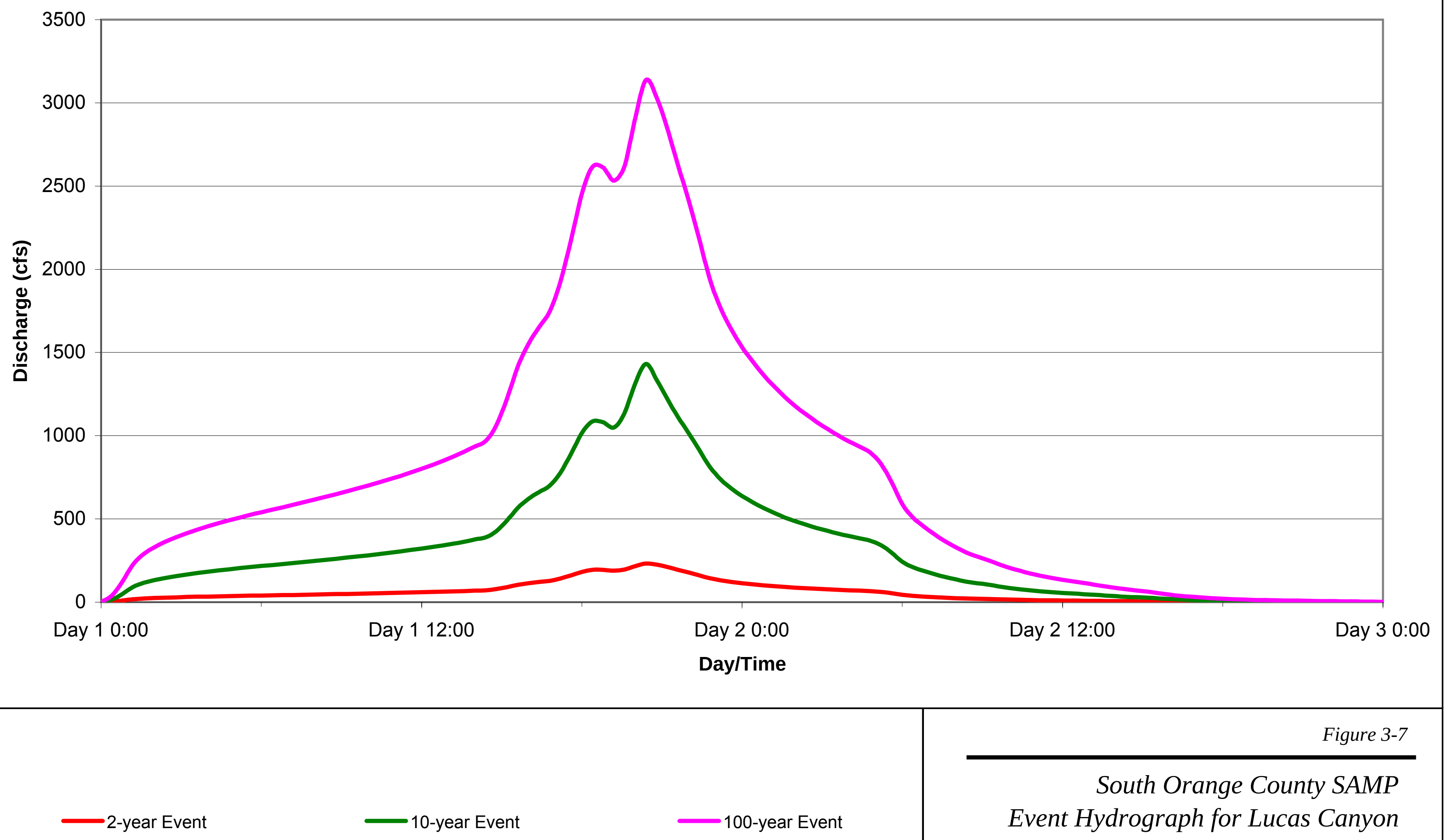
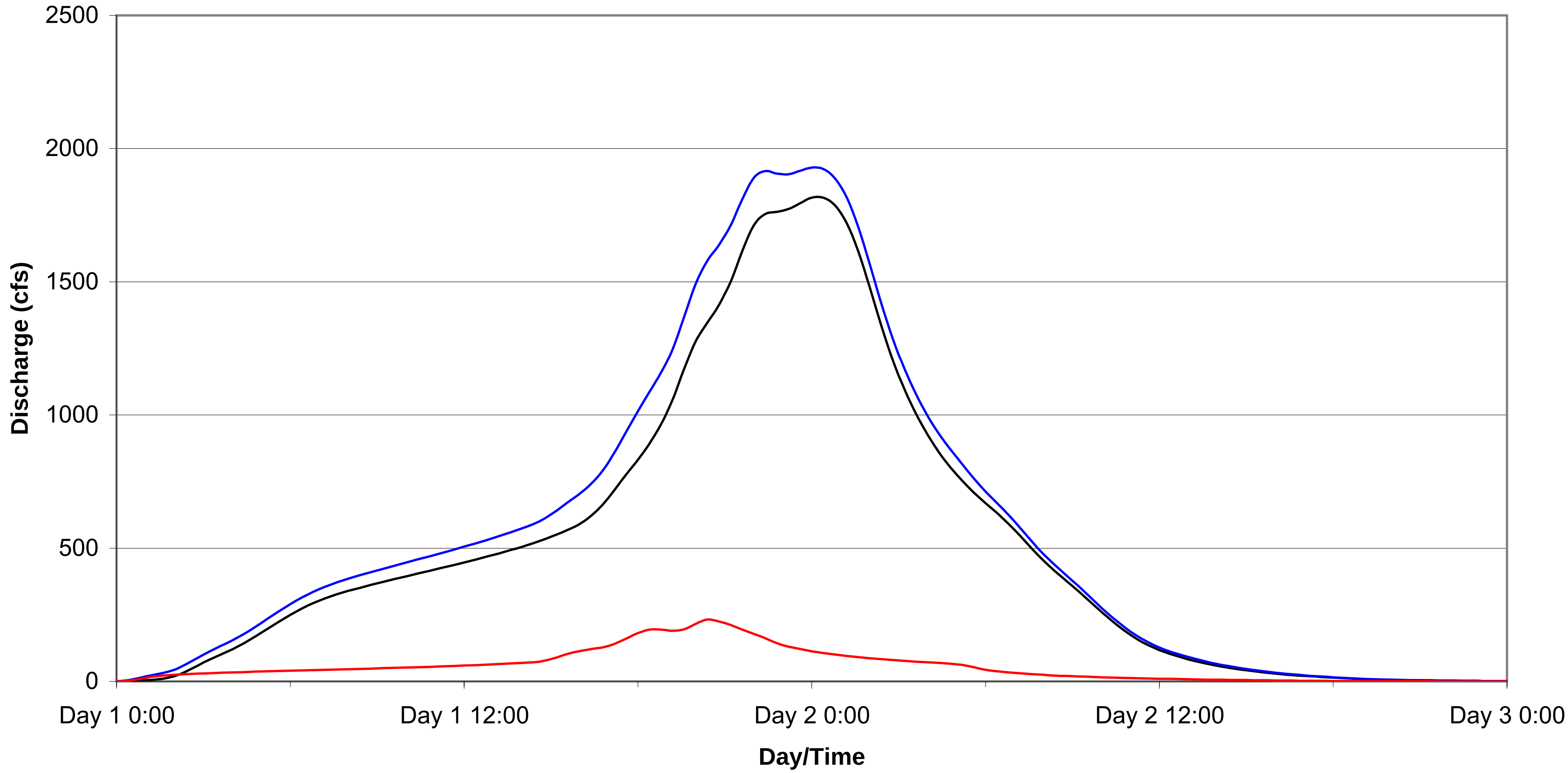


Figure 3-7

South Orange County SAMP
Event Hydrograph for Lucas Canyon
at Confluence with San Juan Creek

PWA PWA#: 1393



San Juan Creek U/S of Lucas Canyon cSJ28

San Juan Creek D/S of Lucas Canyon CSJ3

Discharge (cfs), Lucas Canyon at confluence with San Juan Creek SJ3

Figure 3-8

South Orange County SAMP
2-year Event San Juan Creek
Confluence at Lucas Canyon

PWA PWA#: 1393

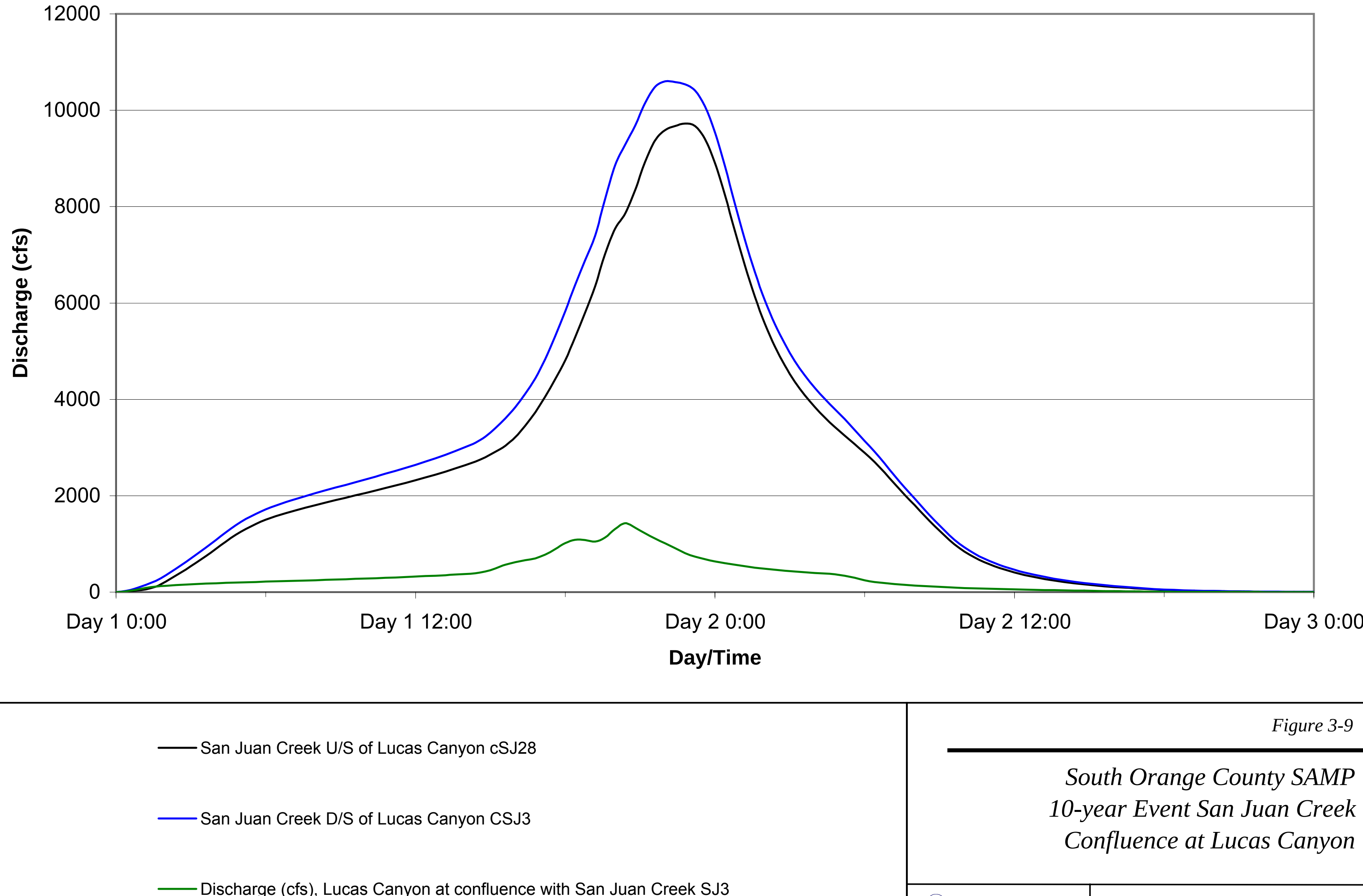


Figure 3-9

South Orange County SAMP
10-year Event San Juan Creek
Confluence at Lucas Canyon

PWA

PWA#: 1393

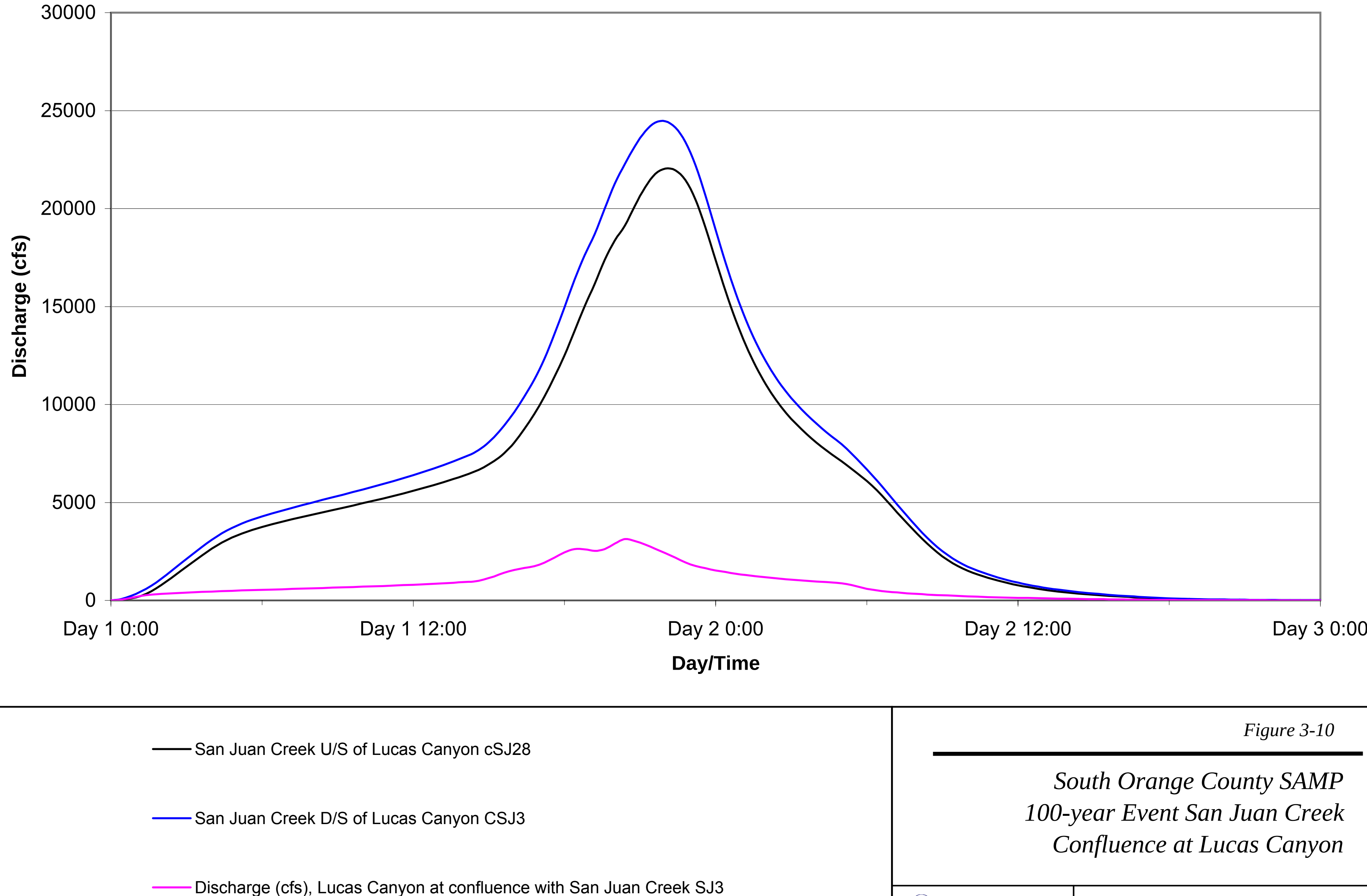


Figure 3-10

South Orange County SAMP
100-year Event San Juan Creek
Confluence at Lucas Canyon

PWA | PWA#: 1393

3.2.2 Verdugo Canyon

3.2.2.1 Drainage Network

The Verdugo Canyon (4.80 mi^2) sub-basin is located in the eastern central portion of the San Juan basin, just south of the Lucas Canyon basin (Figure 3-11). Similar to Lucas Canyon, the Verdugo Canyon watershed has roughly an east-west orientation with several tributary channels entering the main valley stream from the north and south. The longest continuous watercourse is 8 miles. Verdugo Canyon is a fifth order stream system at its confluence with the main San Juan channel, immediately downstream of Bell Canyon. Verdugo Canyon's area represents about 6.2% of the San Juan watershed area (77.2 mi^2) upstream of the Verdugo Canyon and San Juan Creek confluence. It is roughly 14.5 mi downstream to the Pacific Ocean along the route of San Juan Creek.

Compared to Lucas Canyon, a more complete WES channel mapping for Verdugo Canyon results in a higher drainage density value of 13 mi/mi^2 for the network. Order-incremental confluence points are found throughout the basin, although (as in the case of Lucas Canyon) the eastern headwaters of Verdugo Canyon have a lower drainage density. An area with a higher concentration of order-incremental confluence points is observed north of Verdugo Creek in the central canyon area. This area of higher drainage density is aligned with, but just south of, the region in Lucas Canyon noted above with a higher drainage density. This increased drainage density likely reflects the geologic substrate beneath the central Lucas and Verdugo basins. Overall, 562 first-order channels are delineated in the Verdugo Canyon sub-basin. Similar to Lucas Canyon, these first-order reaches comprise about 51% of the total stream length in the basin.

The hydrology of Verdugo Canyon was analyzed as part of the San Juan watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2 above. This canyon is represented by sub-basin 9 in Figure 2-1 and node SJ9 in the HEC-1 network in Figure 2-6. The following sections describe important hydrologic characteristics and processes of the Verdugo Canyon sub-basin. Estimated runoff values based upon the HEC-1 analysis are offered and illustrated.

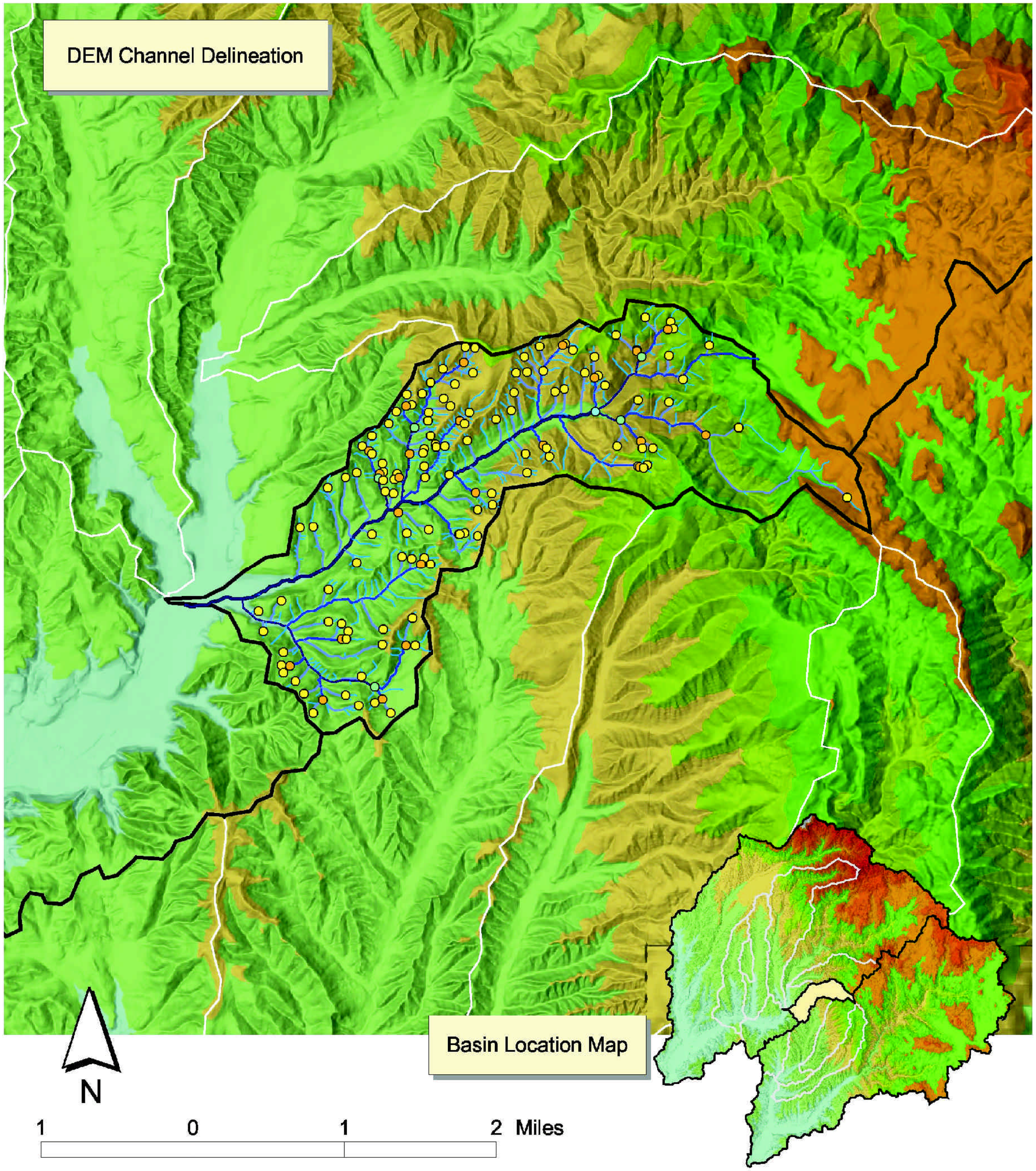
3.2.2.2 Infiltration

The soil type distribution within Verdugo Canyon is shown in Figure 2-2. GIS analysis, summarized in Table 3-1, indicates that the majority of the Verdugo Canyon sub-basin is underlain by soils of hydrologic groups C (61.8%) and D (28.6%). Soils in these classes are poorer infiltrators, however the distribution of soil types in Verdugo Canyon (including 8.3% class A soils) suggests that this sub-basin has a higher proportion of better infiltrating (A and B) soils in comparison to Lucas Canyon to the north. The land-use and vegetation distributions for Verdugo Canyon are shown in Figure 2-3 above. Verdugo Canyon is undeveloped (99.9%), with developed lands (consisting mostly of roads) cover less than 0.1% of the sub-basin (Table 3-1). The predominant vegetation types in the sub-basin are sage and chaparral (Figure 2-3).

Assigned curve numbers range from 31 to 95 in Verdugo Canyon with an area-averaged curve number of 74.8 (Figure 2-5). The majority of the sub-basin (90%) has areas with curve numbers between 70 and 89.

figure 3-11

Channel Network
Verdugo Canyon



Channel Network Statistics

Basin Area = 3,067 acres
Drainage Density = 13 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	562	288	161768	4.53
2	124	6675	83698	4.59
3	27	1600	43204	5.40
4	5	2740	13699	5.00
5	1	17009	17009	

Total Stream Length: 60.5 mi

Stream Order

1
2
3
4
5
6
7

Order Increment Points

2
3
4
5
6
7

PWA

Based on these curve numbers, loss rates were calculated for the sub-basin and incorporated into the HEC-1 model. The maximum loss rate for Verdugo Canyon was calculated to be 0.25 inches/hour for the 10- and 100-year events and 0.60 inches/hour for the 2-year event. Total precipitation losses for the 2-, 10-, and 100-year storm events are also reported in Table 3-2.

Calculated loss rates for Verdugo Canyon are relatively higher than the other San Juan watershed sub-basins described in this report. When considered as a percentage of total storm event rainfall, losses in Verdugo Canyon were second only to losses in the Central San Juan Catchments, for all three modeled storm events. Overall, the relatively high loss rates calculated for Verdugo Canyon indicate that infiltration rates are also relatively higher in this sub-basin. This results from the undeveloped condition of the sub-basin and the higher proportion of type-C and type-A soils compared to other sub-basins in the watershed.

3.2.2.3 Storm Event Runoff

Three storm hydrographs were calculated for the outlet of Verdugo Canyon using the HEC-1 hydrologic model (Figure 3-12). Each of the 2-year, 10-year, and 100-year hydrographs display a smaller yet distinct peak which occurs prior to the main peak of the hydrograph. As described above, this shape is characteristic of the hydrographs for Lucas Canyon, Verdugo Canyon and the Central San Juan catchments, and likely results from the shape of the precipitation hyetograph modeled for this portion of the watershed.

The second notable feature of the Verdugo Canyon hydrographs relates to the timing of runoff. Peak flows occur at 20:00 hours following the onset of precipitation (Table 3-7). This peak time is approximately 2.4, 2.8, and 4.8 hours before San Juan Creek peaks at its confluence with Verdugo Canyon for the 2-, 10-, and 100-year events respectively (Figure 3-5). Therefore, peak flows from Verdugo Canyon didn’t significantly increase peak flows in San Juan Creek at the confluence or downstream. Verdugo Canyon peak flows enter into the main San Juan stream before peak flows occur on San Juan Creek at this location (Figures 3-13, 3-14, 3-15).

Runoff volumes and peak flows from Verdugo Canyon are relatively small in absolute terms (Figures 3-1, 3-3) and intermediate when measured per unit area (Figures 3-2, 3-4). Verdugo Canyon contributes approximately 5% of the runoff volume to San Juan Creek (at its confluence with Verdugo Canyon) during a 100-year event. This volume estimate is generally in line with the fact that Verdugo Canyon occupies approximately 6.2% of the watershed area at that point in the watershed (Table 3-3). Peak flows from Verdugo Canyon are less than 4% of the total peak flows in San Juan Creek at the confluence. The 10-year peak flow from Verdugo Canyon was calculated at 738 cfs. Verdugo Canyon produced less peak runoff on a per-acre basis than 4 out of the 5 other San Juan sub-basins analyzed for the 2-year and 10-year events (Figure 3-2). Only the central San Juan catchments had lower runoff per-area values. Verdugo Canyon had significantly less runoff on a per-acre basis than the average for the entire San Juan Creek watershed (Table 3-3). These results may be explained by the lack of development and favorable infiltration conditions in the Verdugo Canyon sub-basin.

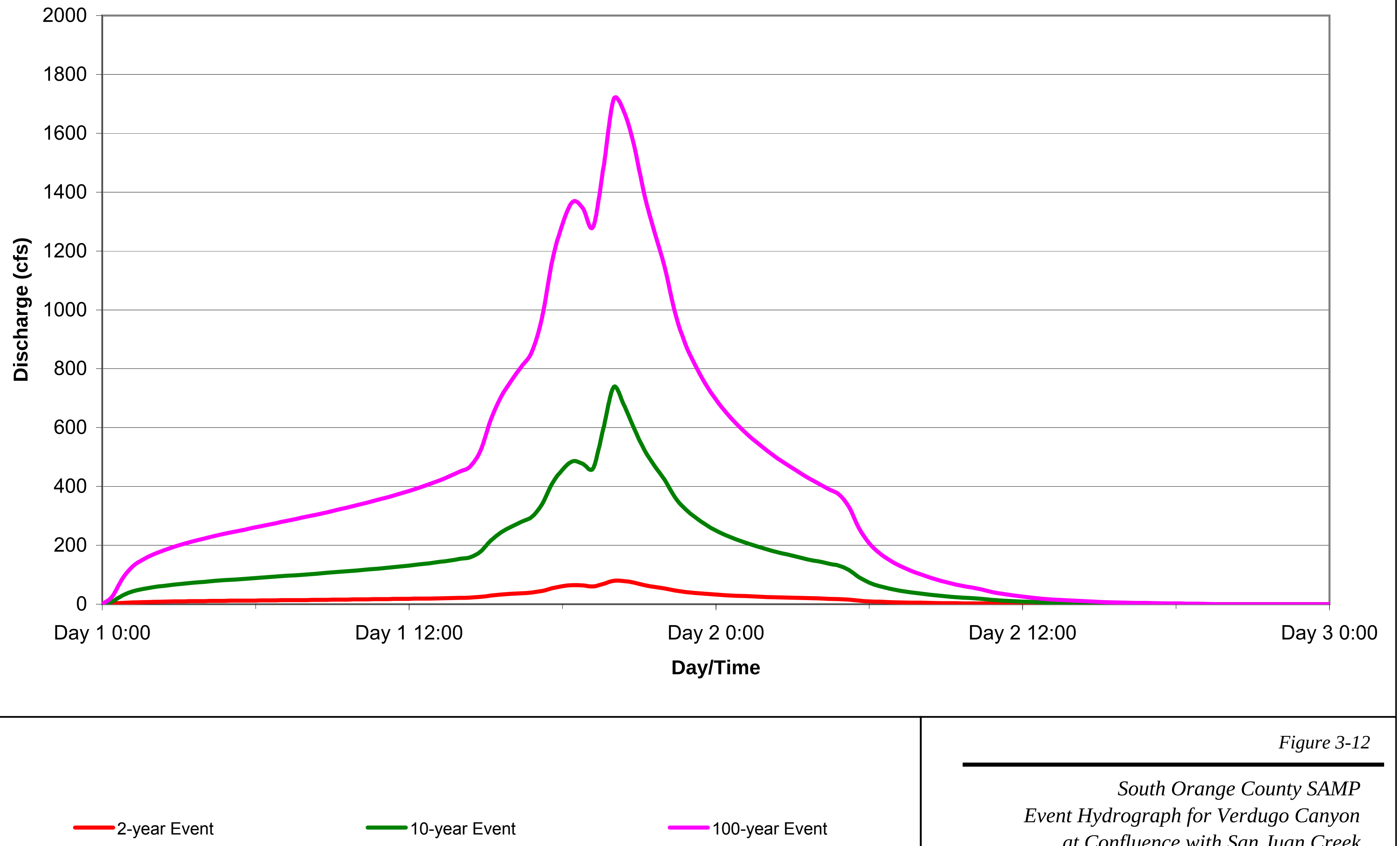
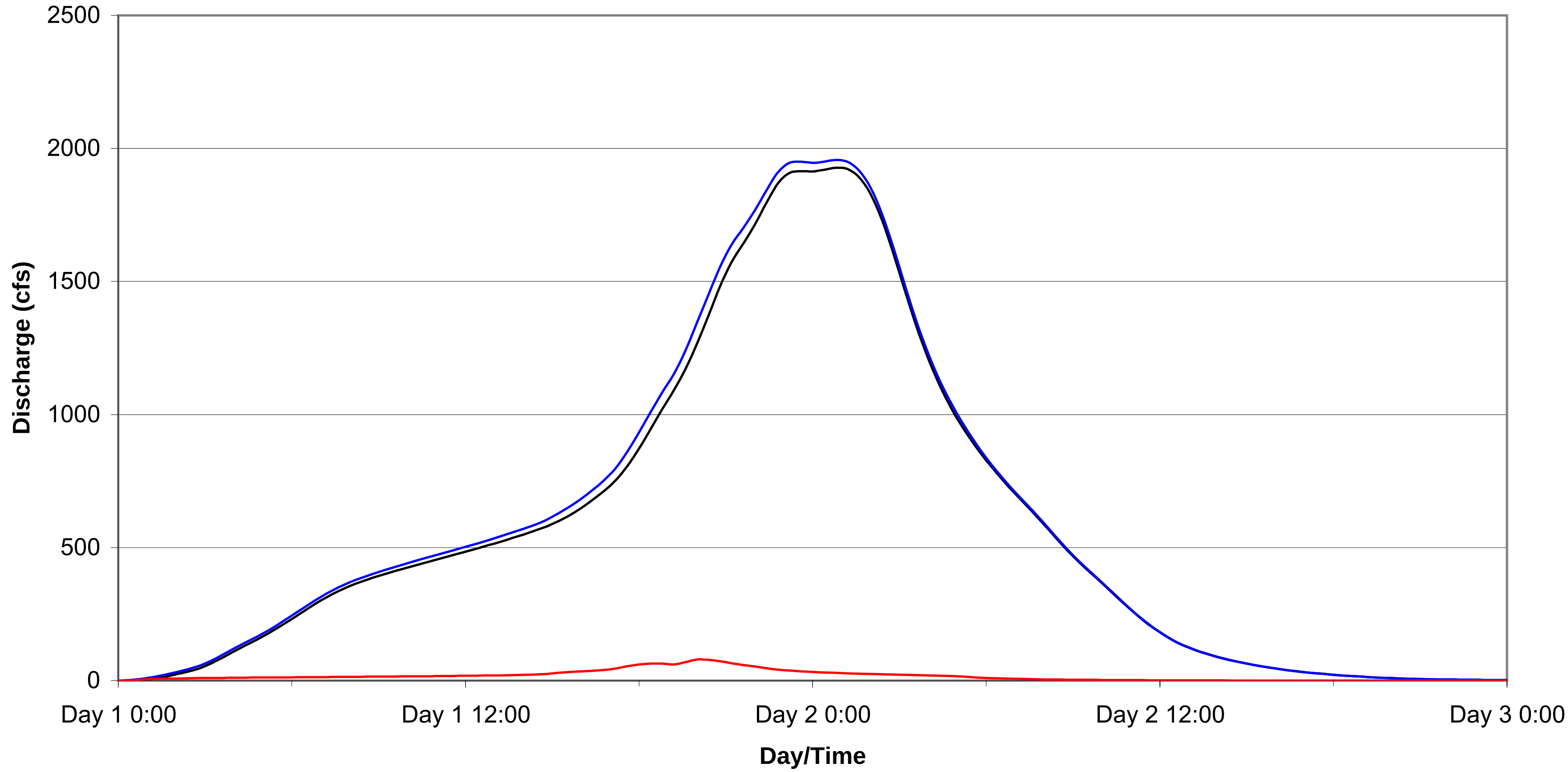


Figure 3-12

South Orange County SAMP
Event Hydrograph for Verdugo Canyon
at Confluence with San Juan Creek

PWA

PWA#: 1393



San Juan Creek U/S of Verdugo Canyon LRSJ9

San Juan Creek D/S of Verdugo Canyon cSJ9

Discharge (cfs), Verdugo Canyon at confluence with San Juan Creek SJ9

Figure 3-13

South Orange County SAMP
2-year Event San Juan Creek
Confluence with Verdugo Canyon

PWA

PWA#: 1393

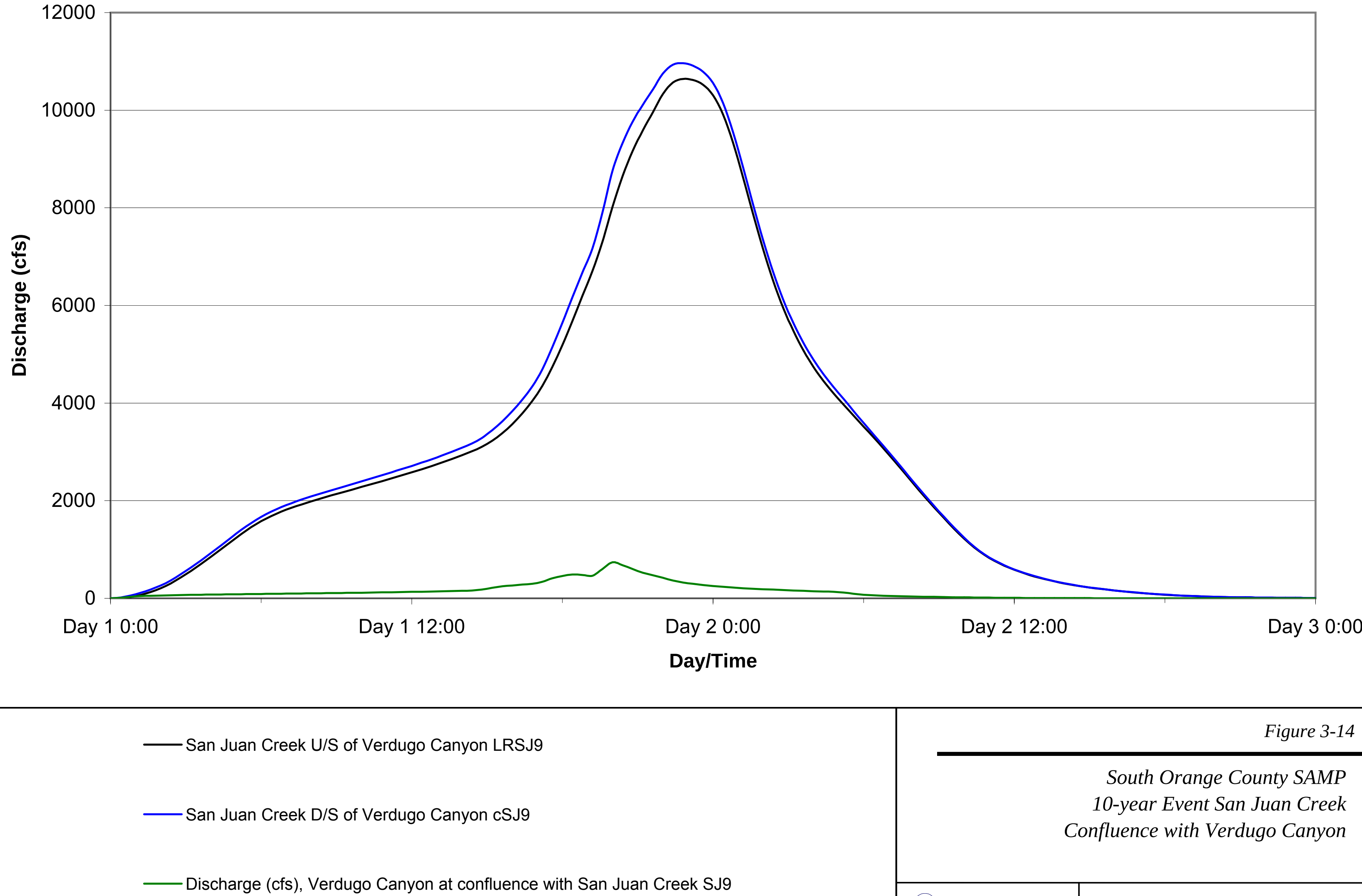


Figure 3-14

South Orange County SAMP
10-year Event San Juan Creek
Confluence with Verdugo Canyon

PWA

PWA#: 1393

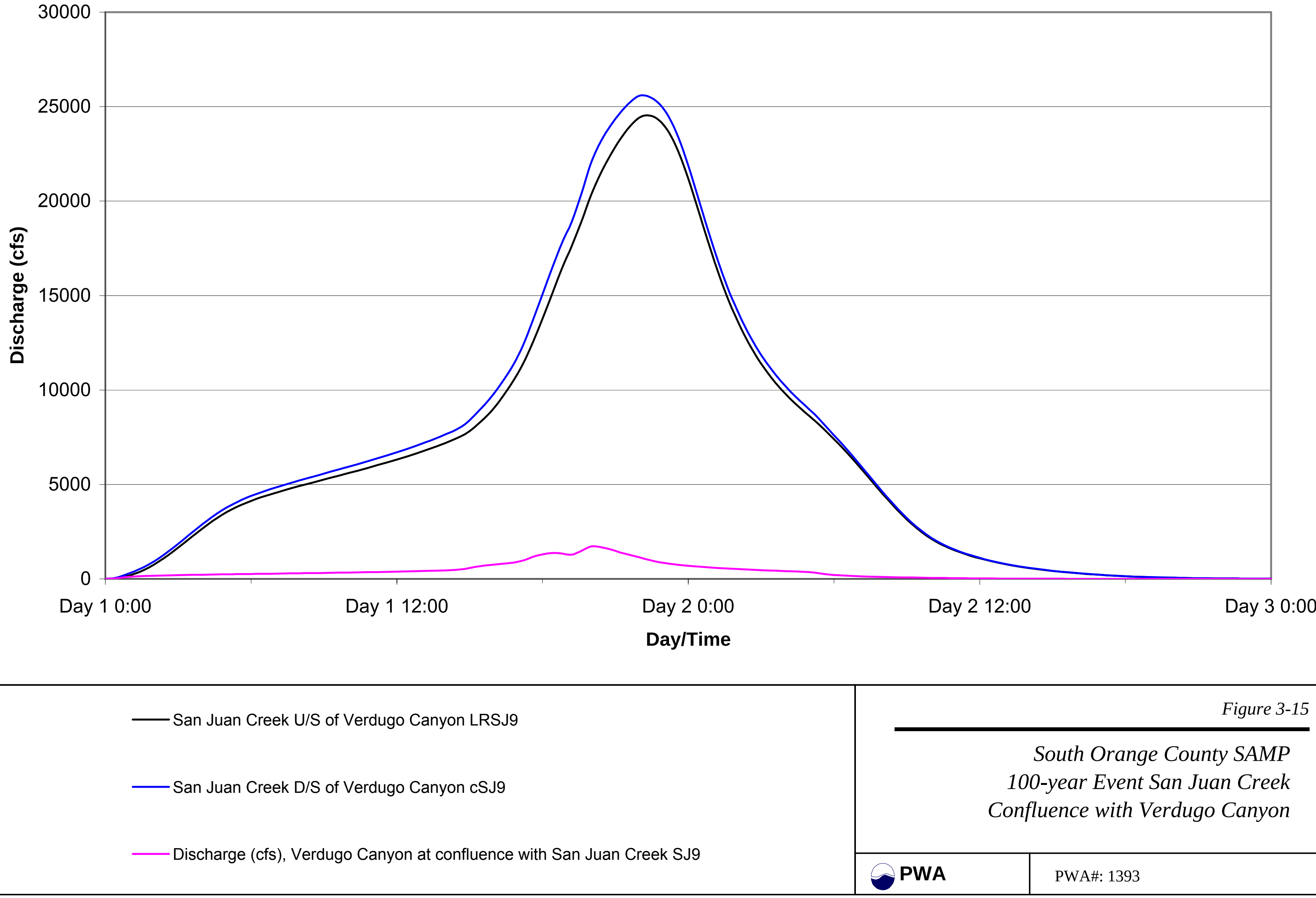


Figure 3-15

South Orange County SAMP
100-year Event San Juan Creek
Confluence with Verdugo Canyon

PWA

PWA#: 1393

Overall, for the three flood events modeled, runoff from Verdugo Canyon had only a minor impact on the overall San Juan Creek hydrograph downstream of the confluence of the two streams. As explained above, this relatively small downstream effect is due to early peak times and proportionally smaller peak flows and runoff volumes from Verdugo Canyon than from most of the other sub-basins examined in this report.

3.2.3 Bell Canyon

3.2.3.1 Drainage Network

Bell Canyon (20.57 mi^2) is a large sixth order sub-basin in the central San Juan watershed (Figure 3-16). The Bell Canyon and San Juan confluence is 12.62 mi upstream of the coast. Bell Canyon's area represents about 28.4% of the San Juan watershed area (72.38 mi^2) upstream of the Bell Canyon and San Juan Creek confluence. The mouth of Bell Canyon enters San Juan Creek immediately upstream of Verdugo Canyon and about 1.5 mi downstream of Lucas Canyon.

Bell Canyon has an interesting configuration in that its central north-south arm is roughly parallel and similar in orientation to the other north-south valleys (Chiquita Canyon and Canada Gobernadora) to the west. However, the upper portion of Bell Canyon veers sharply to the east into the steeper terrain of the older substrate (Figure 1-5). The dividing ridge between Bell Canyon and Canada Gobernadora is relatively narrow and does not supply as many tributary channels as the eastern portion of the Bell Canyon sub-basin. Bell canyon is the largest sub-basin unit in this study and has one of the highest computed drainage densities at 13 mi/mi^2. Many of the second and third-order incremental confluence points are concentrated in lower Crow Canyon and in the un-named tributary immediately south of Crow Canyon. Of the 257 total miles of stream within this basin, the higher fifth and sixth order streams account for about 4% of total stream length while the first order segments represent 55% of total stream length. The longest continuous stream length in the sub-basin is 15 miles.

The hydrology of Bell Canyon was analyzed as part of the San Juan watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2. This canyon is represented by sub-basins 1, 34, and 6 of Figure 3-1 and nodes SJ1, SJ34, and SJ60 in the HEC-1 network of Figure 2-6. The following sections describe important hydrologic characteristics and processes of the Bell Canyon sub-basin. Estimated runoff values based upon the HEC-1 analysis are presented.

3.2.3.2 Infiltration

The soil type distribution within the Bell Canyon sub-basin is shown in Figure 2-2. GIS analysis indicates (Table 3-1) that the majority of the sub-basin is underlain by soils of hydrologic groups C (35.6%) and D (56.9%). Soils in these classes are poor infiltrators. Compared to the other sub-basins studied in the San Juan Watershed, Bell Canyon has the largest proportion of class-D soils. The land-use and vegetation distributions for Bell Canyon are shown in Figure 2-3. The predominant vegetation types in the sub-basin are sage and chaparral. The majority of Bell Canyon is undeveloped (94.3%), developed (or other) lands cover only about 5.7% of the sub-basin (Table 3-1). Approximately 3.3% of the basin is impervious to infiltration. According to OCHM methods, SCS runoff curve numbers (Figure 2-5) were used in hydrologic modeling of the sub-basin to integrate the effect of soil type, land-use, and vegetation on overall "loss" processes in the sub-basin, which include infiltration. Assigned runoff curve numbers

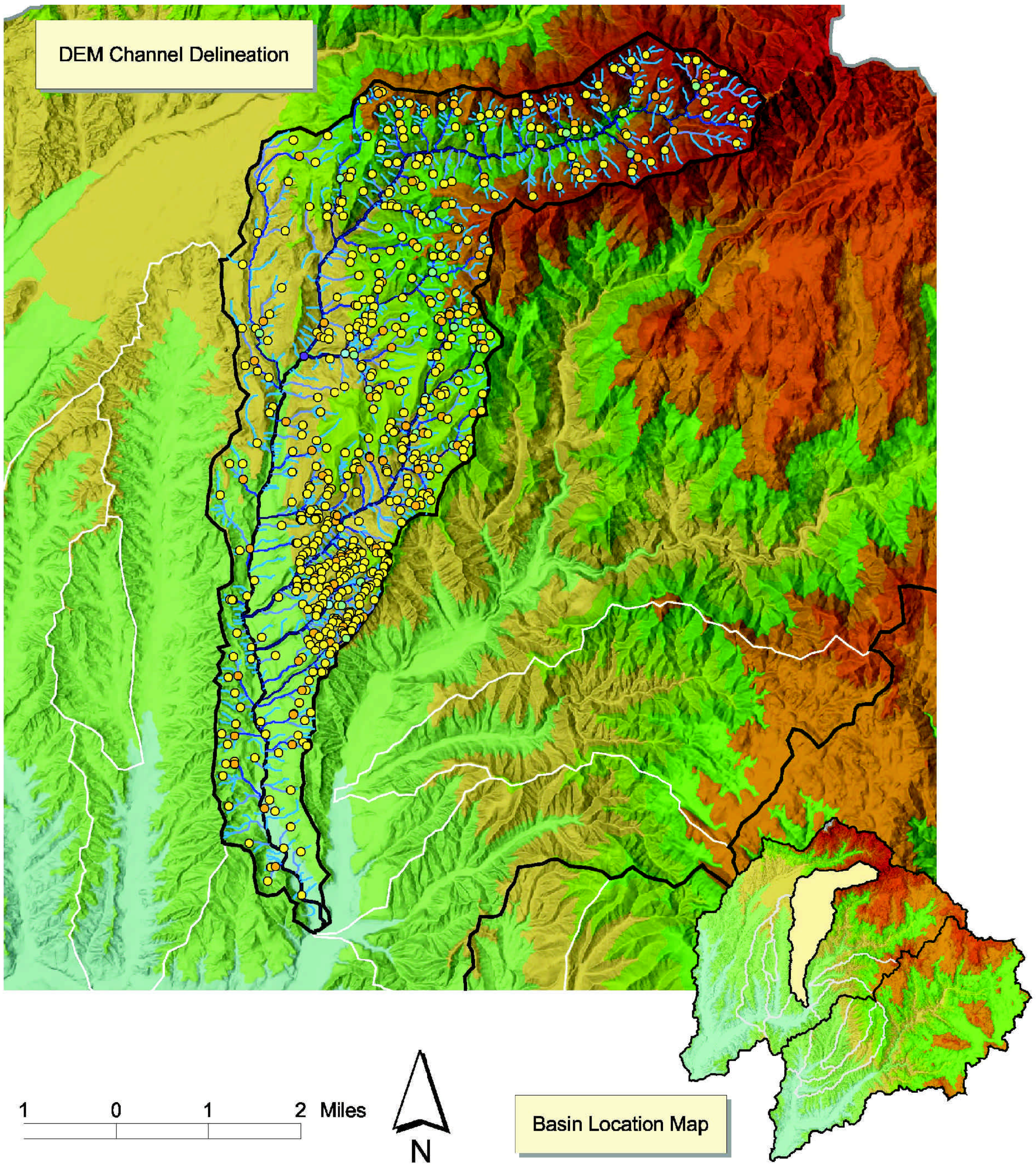


Figure 3-16

Channel Network
Bell Canyon

Channel Network Statistics

Basin Area = 13,156 acres
Drainage Density = 13 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	2552	295	752057	
2	541	550	297741	4.72
3	101	1531	154635	5.36
4	19	3116	59195	5.32
5	4	13663	54650	4.75
6	1	37904	37904	4

Total Stream Length: 256.9 mi

Stream Order

1
2
3
4
5
6
7

Order Increment Points

2
3
4
5
6
7

PWA

range from 31 to 97 in Bell Canyon. A large majority of the sub-basin (88.9%) was characterized by higher curve numbers between 70 and 89. The area-averaged curve number of 78.2 for the Bell Canyon sub-basin is slightly less than Lucas Canyon (78.6) and greater than Verdugo Canyon (74.8). Based on these curve numbers, loss rates were calculated for the sub-basin and incorporated into the HEC-1 model. The area-averaged maximum loss rate for Bell Canyon was calculated to be 0.22 inches/hour for the 10- and 100-year events and 0.58 inches/hour for the 2-year event. Total precipitation losses for the 2-, 10-, and 100-year storm events are also reported in Table 3-2.

Although there is considerable variability of loss rates within the Bell Canyon sub-watershed, average loss rates for Bell Canyon are relatively low compared to the other San Juan watershed areas described in this report. Of the six sub-basins analyzed, Bell Canyon had the lowest maximum 10- and 100-year loss rate. When considered as a percentage of total storm event rainfall, losses in Bell Canyon were lower than losses in all but one of the six other sub-basins. Lucas Canyon had lower loss rates than Bell Canyon for the 10-year and 100-year events. Overall, the low loss rates calculated for Bell Canyon indicate that infiltration rates are also low in this sub-watershed. This is likely a result of the high proportion of poorly draining soils. As stated above, Bell Canyon has the highest proportion of class-D soils of the analyzed San Juan sub-basins.

3.2.3.3 Storm Event Runoff

Three storm hydrographs were calculated for the outlet of Bell Canyon using the HEC-1 hydrologic model (Figure 3-17). There are several relevant features displayed in these hydrographs. Most apparent, the hydrographs display a rapid singular peak. This shape is characteristic of the hydrographs in the central portion of the San Juan Creek watershed (Bell Canyon, Cañada Gobernadora, and Cañada Chiquita), and is more likely attributable to the shape of the precipitation hyetograph modeled for this portion of the watershed than physical conditions (like basin shape or tributary relationships) in the sub-basins. The steep hydrographs for the 10- and 100-year events indicate that the characteristics of the sub-basin may cause a rapid runoff response. This may be due to the high proportion of poorer infiltrating soils in the Bell Canyon basin compared to the other sub-basins investigated.

A second notable characteristic of the Bell Canyon hydrographs is that peak flows occur at 22:24, 21:36, and 21:12 hours following the beginning of precipitation for the 2-, 10-, and 100-year storms respectively (Table 3-7). This peak occurs approximately 2.4 hours prior to peak discharge in San Juan Creek at the Bell Canyon confluence for the 2-year event and 1.2 and 0.8 hours prior to the 10- and 100-year events (Figure 3-5). This suggests that Bell Canyon has a quick runoff response time despite its large size and elongated basin shape.

Peak flow rates from Bell Canyon represent about 25% of peak flows in San Juan Creek at the confluence (Figures 3-18, 3-19, 3-20). The 10-year peak flow from Bell Canyon was calculated at 3662 cfs. Peak flows in San Juan Creek increase by approximately 24% due to contributing flows from Bell Canyon (Table 3-3).

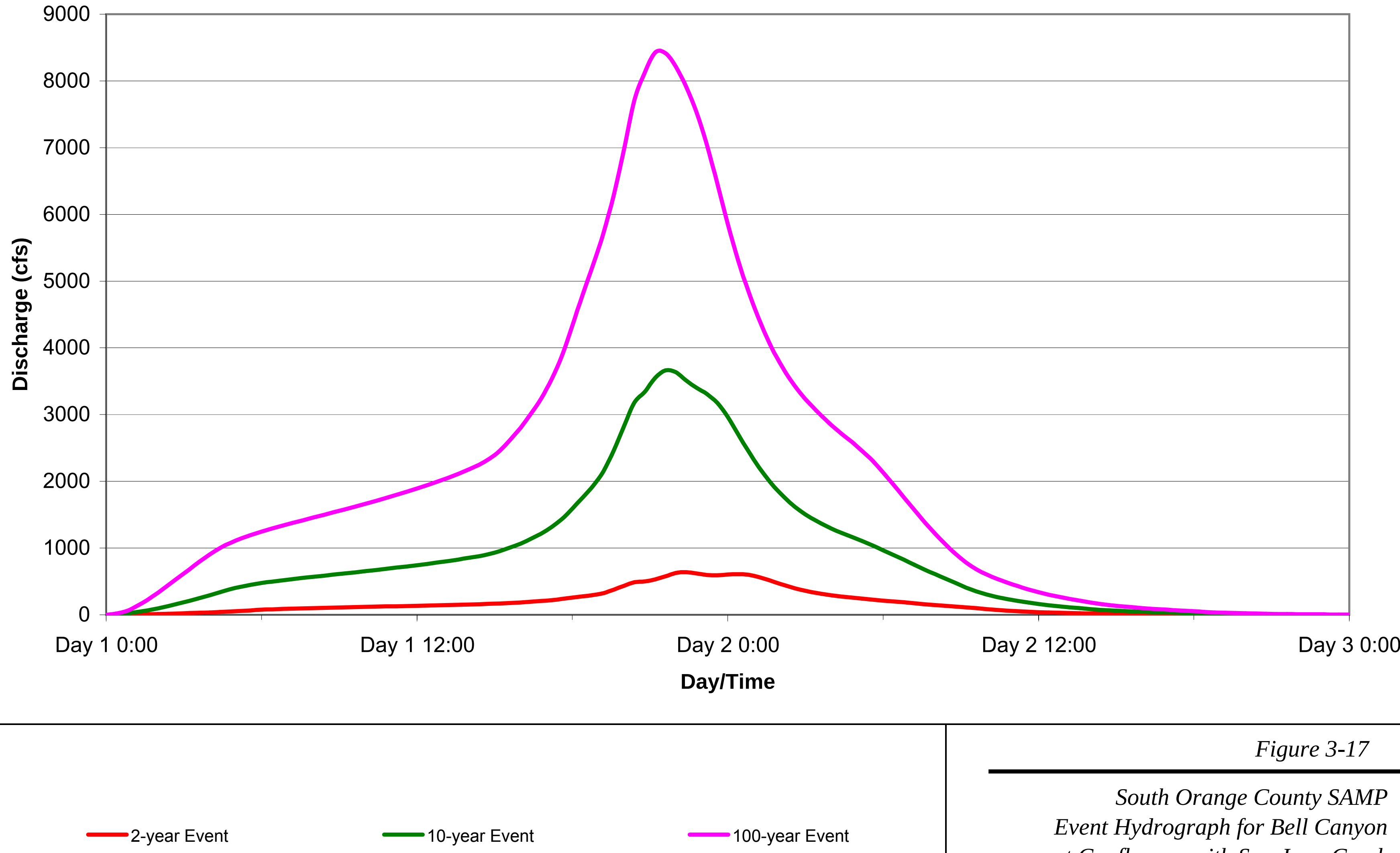


Figure 3-17

South Orange County SAMP
Event Hydrograph for Bell Canyon
at Confluence with San Juan Creek

PWA PWA#: 1393

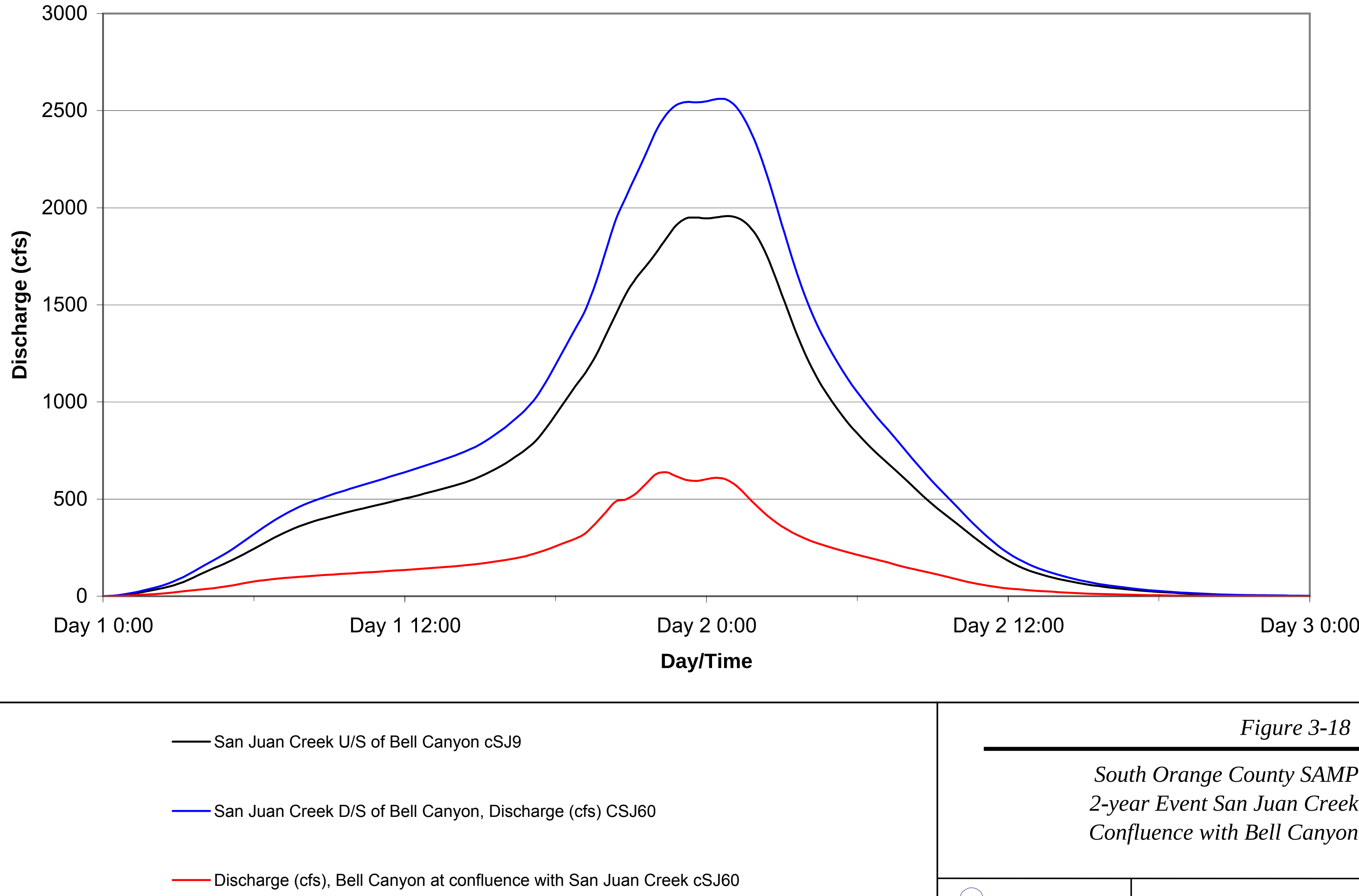
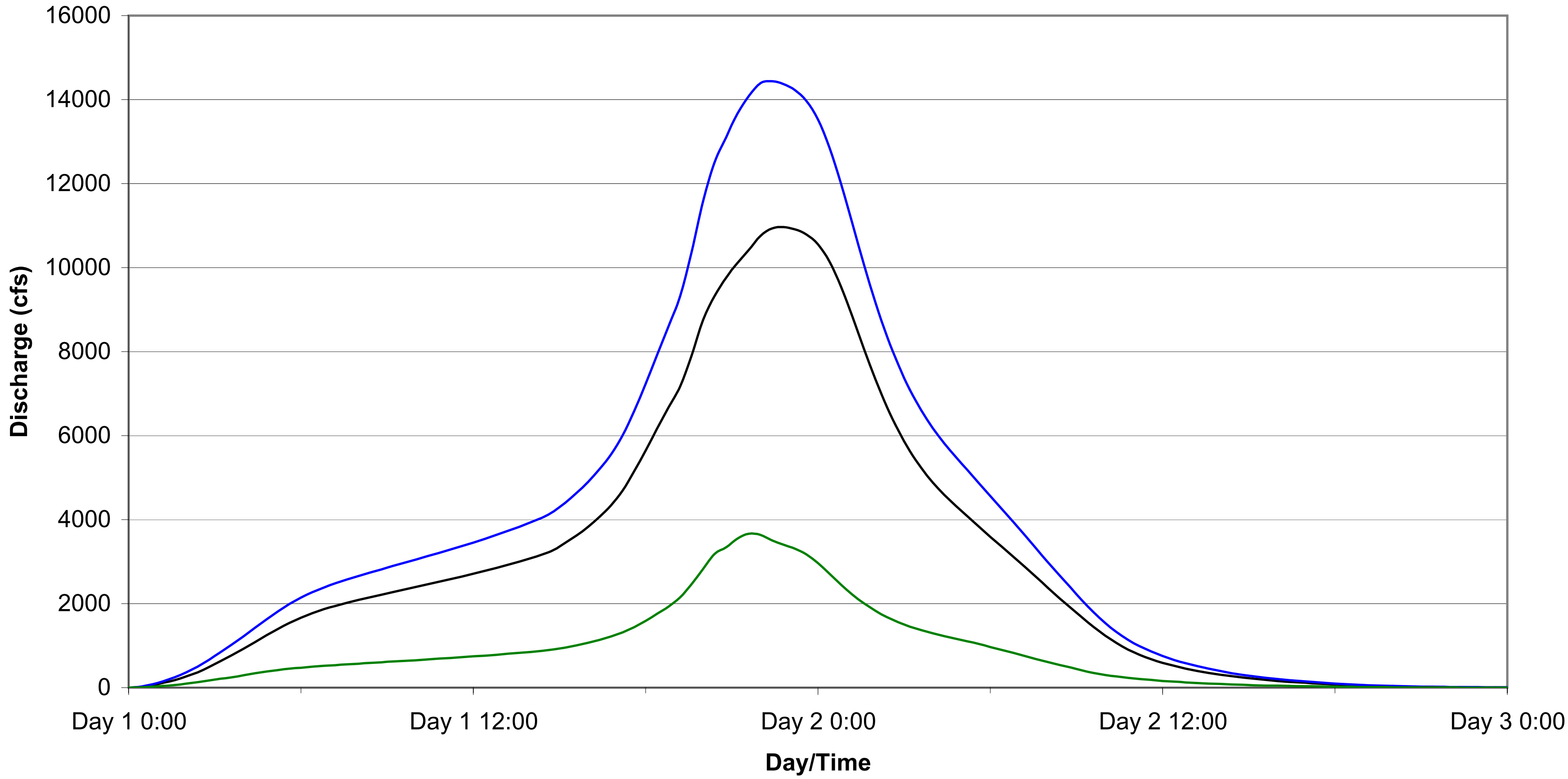


Figure 3-18

South Orange County SAMP
2-year Event San Juan Creek
Confluence with Bell Canyon

PWA PWA#: 1393



San Juan Creek U/S of Bell Canyon cSJ9

San Juan Creek D/S of Bell Canyon, Discharge (cfs) CSJ60

Discharge (cfs), Bell Canyon at confluence with San Juan Creek cSJ60

Figure 3-19

South Orange County SAMP
10-year Event San Juan Creek
Confluence with Bell Canyon

PWA PWA#: 1393

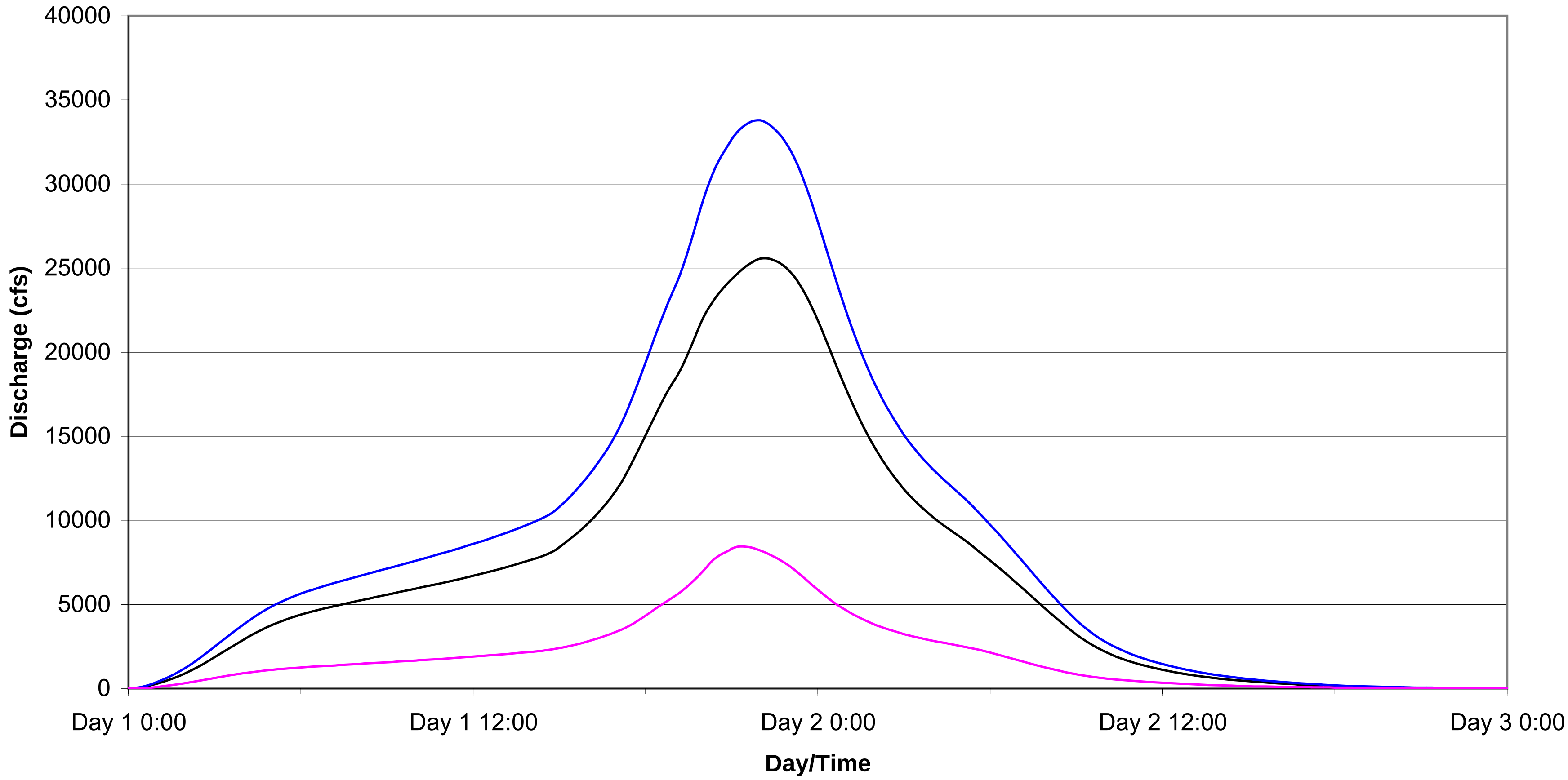


Figure 3-20

South Orange County SAMP
100-year Event San Juan Creek
Confluence with Bell Canyon

PWA

PWA#: 1393

Had peak flow times between the main San Juan channel and the Bell Canyon sub-basin coincided, the relative influence of Bell Canyon on San Juan flows would have been even more pronounced. In absolute terms, runoff volumes and peak flows from Bell Canyon are higher than all other San Juan sub-basins presented. As shown in Table 3-3, for all three events Bell Canyon contributes approximately 22% of the runoff volume to San Juan Creek at their confluence while it occupies 28.4% of the watershed area at that point.

For the three events modeled, Bell Canyon produced approximately the same runoff volume on a per-acre basis as the average for the San Juan Creek watershed as a whole (Table 3-3, Figure 3-4). This is significant since almost the entire Bell Canyon sub-basin is undeveloped while much of the western San Juan watershed is highly developed. The comparatively greater proportion of poorer infiltrating soils in the Bell Canyon sub-basin likely explains these high per-area runoff rates. It should be noted that runoff from different parts of Bell Canyon is not uniform due to the varied characteristics of the sub-basin.

Overall, runoff from Bell Canyon had a significant impact on the overall San Juan Creek hydrograph downstream of the confluence of the two streams. Although peak timing was not coincident, the large volume of water draining from Bell Canyon strongly influences flow in San Juan Creek. Furthermore, the magnitude of peak flows and runoff volumes from Bell Canyon is proportionally larger than for most of the other sub-basins examined in this report.

3.2.4 Cañada Gobernadora

3.2.4.1 Drainage Network

The Cañada Gobernadora sub-basin (11.1 mi^2) is an elongated north-south oriented valley (Figure 3-21) that is similar in drainage form to Cañada Chiquita to the west and Bell Canyon to the east. The longest watercourse in the sub-basin is approximately 9.7 miles. Cañada Gobernadora’s area represents about 11.6% of the San Juan watershed area (95.67 mi^2) upstream of the Canada Gobernadora and San Juan Creek confluence. In the northern portion of the sub-basin, upstream of the Wagon Wheel confluence, the main valley is drained by a fifth order channel for most of its length. The Wagon Wheel sub-basin (1.8 mi^2) contributes a fifth-order segment from the west to the main Canada Gobernadora stream system. Downstream of this confluence, the main stem becomes a sixth-order system until it joins San Juan creek further downstream. More than 30 third order channels, and six fourth order streams converge on the main Canada Gobernadora channel from the western and eastern side slopes. The overall drainage density is approximately 9 mi/mi^2 for the combined basins, which share 500 first order channels. First order channels represent about 45% of the total stream length, whereas fifth and sixth order channels comprise 8.6% of total channel length. Due to the elongated configuration of this basin, first order streams are proportionally less of the total stream length than in some of the other sub-basins like Verdugo, Lucas, or Bell Canyons.

The event based rainfall-runoff hydrology of Cañada Gobernadora was analyzed as part of the San Juan watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2 above. This area is represented by sub-basins 7, 35, and 63 in Figure 2-1 and nodes SJ7, SJ35, and SJ63 in the HEC-1 network in Figure 2-6. The Wagon Wheel Canyon tributary is represented by sub-basin 35 and HEC-1 node SJ35. The following paragraphs describe important hydrologic characteristics and processes of the Bell Canyon sub-basin. Estimated runoff values based upon the HEC-1 analysis are described.

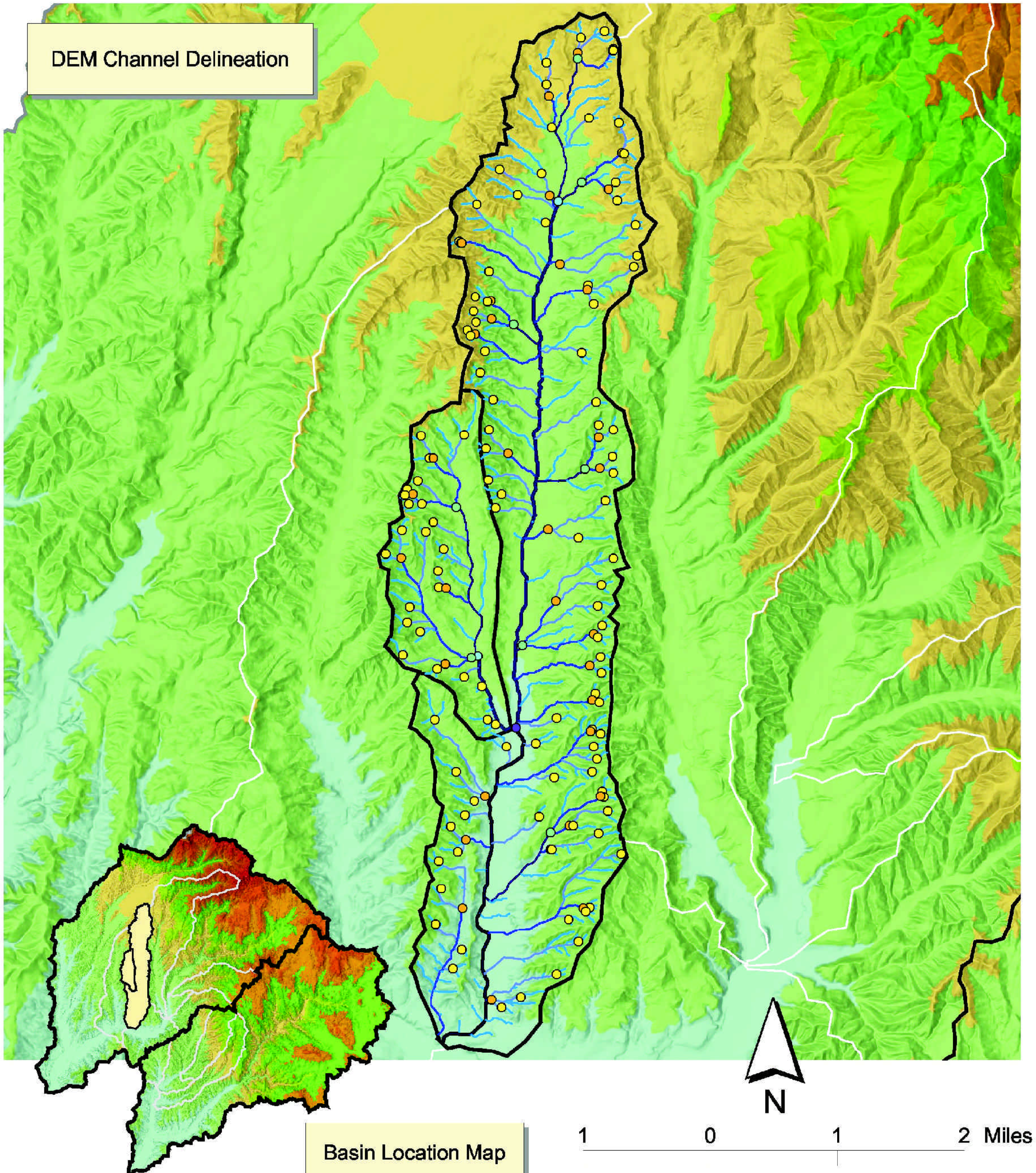


figure 3-21

Channel Network

Canada Gobernadora and Wagon Wheel Basin

Channel Network Statistics

Basin Area = 7,086 acres
Drainage Density = 9 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	500	444	222149	4
2	123	1125	138327	3.47
3	36	2005	72192	4.5
4	8	2888	23107	2.67
5	2	13556	27113	3
6	1	15774	15774	

Total Stream Length: 94.4 mi

Stream Order

1
2
3
4
5
6
7

Order Increment Points

2
3
4
5
6
7

PWA

3.2.4.2 Infiltration

The soil type distribution within the Cañada Gobernadora sub-watershed is shown in Figure 2-2. GIS analysis (Table 3-1) indicates that the majority of the sub-watershed is underlain by soils of hydrologic groups B (27.8%) and C (52.7%). Only 15.2% of the Cañada Gobernadora sub-basin has class-D low infiltrating soils. This is the lowest areal percentage for class-D soils of any of the San Juan sub-basins analyzed in this study. The land-use and vegetation distributions for Cañada Gobernadora are shown in Figure 2-3. As indicated in Table 3-1, of the six sub-watersheds described in this report, Cañada Gobernadora has the second lowest proportion of undeveloped land (57.4%). Developed areas cover approximately 17.6% of the sub-basin and are concentrated in the northern portion of the sub-basin. Agricultural lands, covering approximately 19.0% of the watershed, occur primarily in the broad valley floor of the central and southern basin and include general pastures and grazing lands. Approximately 11.6% of the basin is impervious to infiltration. The predominant vegetation types in the non-developed or non-agricultural portions of the sub-basin are sage and woodland riparian (Figure 2-3). In terms of hydrologic parameters, Canada Gobernadora is interesting and complex in that it contains both the largest developed area and some of the best infiltrating soils in the studied sub-basins.

Assigned runoff curve numbers range from 31 to 97 in Cañada Gobernadora (Figure 2-5). The majority of the basin (71.3%) was characterized by higher curve numbers between 70 and 89. The area-averaged curve number for the sub-basin is 77.9. This is less than for Bell Canyon (78.2) and about the same as Lucas Canyon (78.6). Based on these curve numbers, loss rates were calculated for the sub-basin and incorporated into the HEC-1 model. The area-averaged maximum loss rate for Cañada Gobernadora was calculated to be 0.23 inches/hour for permeable areas for the 10- and 100-year storms, and 0.53 inches/hour for the 2-year event. Total precipitation losses for the 2-, 10-, and 100-year storm events are also reported in Table 3-2.

Relative to the other San Juan watershed areas described in this report, area-averaged loss rates for the Cañada Gobernadora sub-basin are intermediate, with loss rates varying quite a bit within the sub-basin. Precipitation losses in Cañada Gobernadora, considered as a percentage of total storm event rainfall, were also intermediate compared to the other six sub-basins detailed in this report. Loss rates calculated for Cañada Gobernadora suggest that infiltration rates are also likely intermediate for this sub-watershed. Because of the relatively high proportion of better-draining soils (27.8%, type-B), the Cañada Gobernadora sub-basin would likely have relatively high infiltration conditions under natural conditions. However, due to the comparatively high proportion of developed impervious areas (11.6%) in the northern portion of the Cañada Gobernadora watershed, overall infiltration rates for the basin are only intermediate compared to the other six San Juan sub-basins.

High infiltration conditions in the undeveloped portions of the Canada Gobernadora watershed are found in the Wagon Wheel Canyon tributary. Wagon Wheel has a high percentage of type-B soils (30.6%), a very small percentage of type-D soils (5.8%), is relatively undeveloped (84.1%), and has some of the highest loss rates (and hence infiltration rates) of all the sub-basins analyzed. Field evidence from past runoff events, observed by Balance Hydrologics (2001), support this claim that the Wagon Wheel sub-basin is a high infiltrating region.

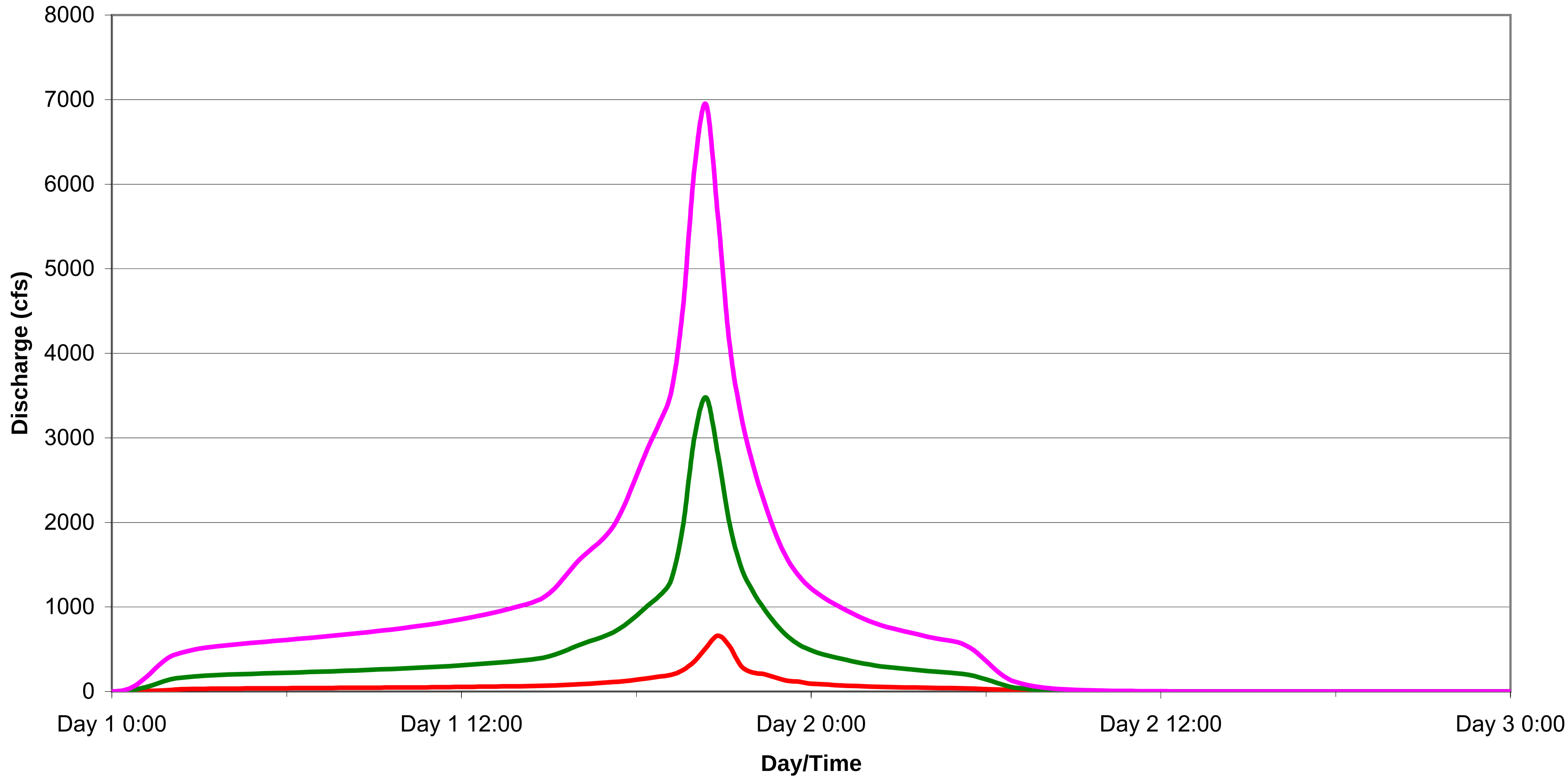


Figure 3-22

South Orange County SAMP
Event Hydrograph for
Canada Gobernadora at Confluence
with San Juan Creek

PWA PWA#: 1393

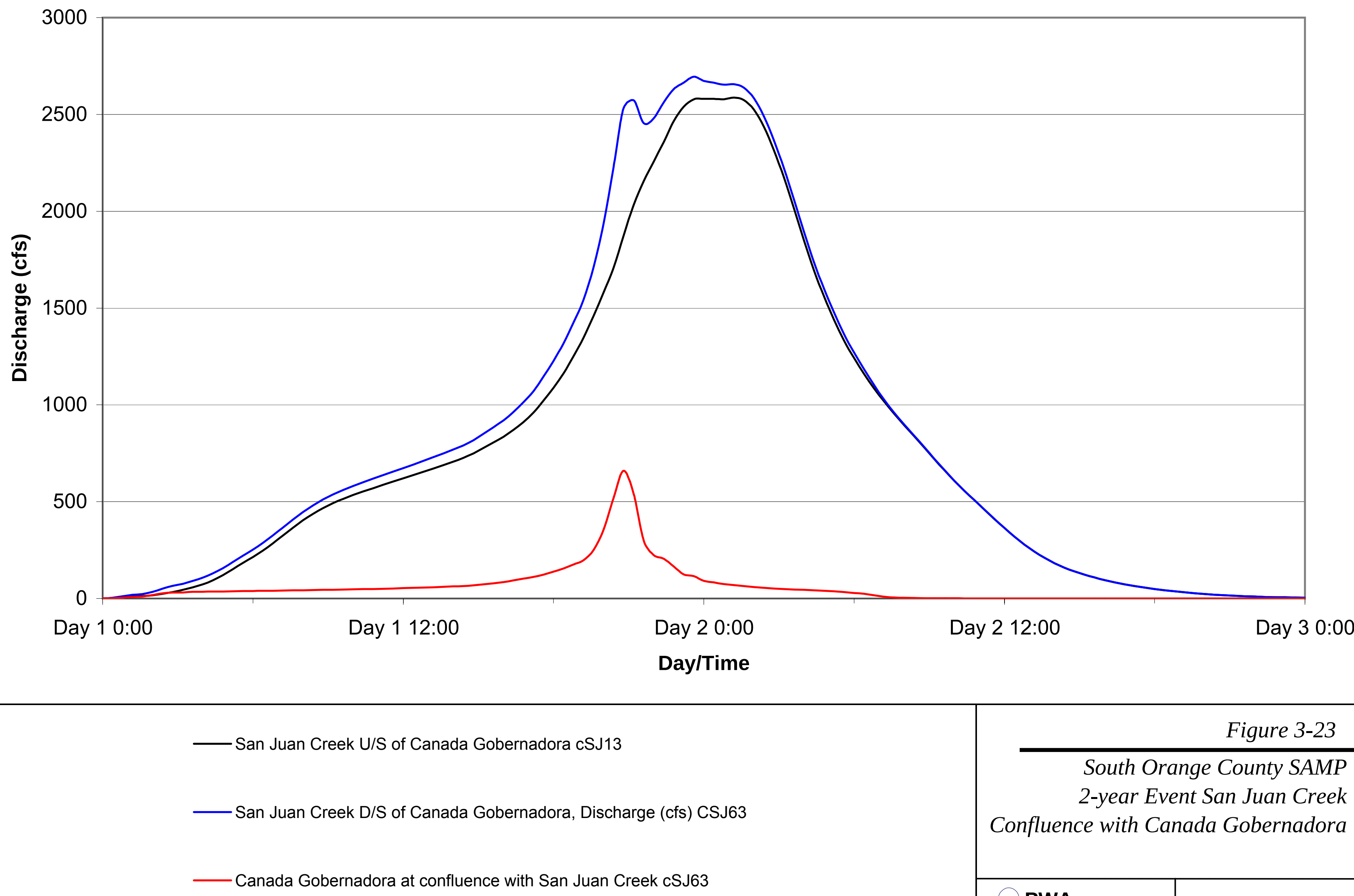


Figure 3-23

South Orange County SAMP
2-year Event San Juan Creek
Confluence with Canada Gobernadora

PWA PWA#: 1393

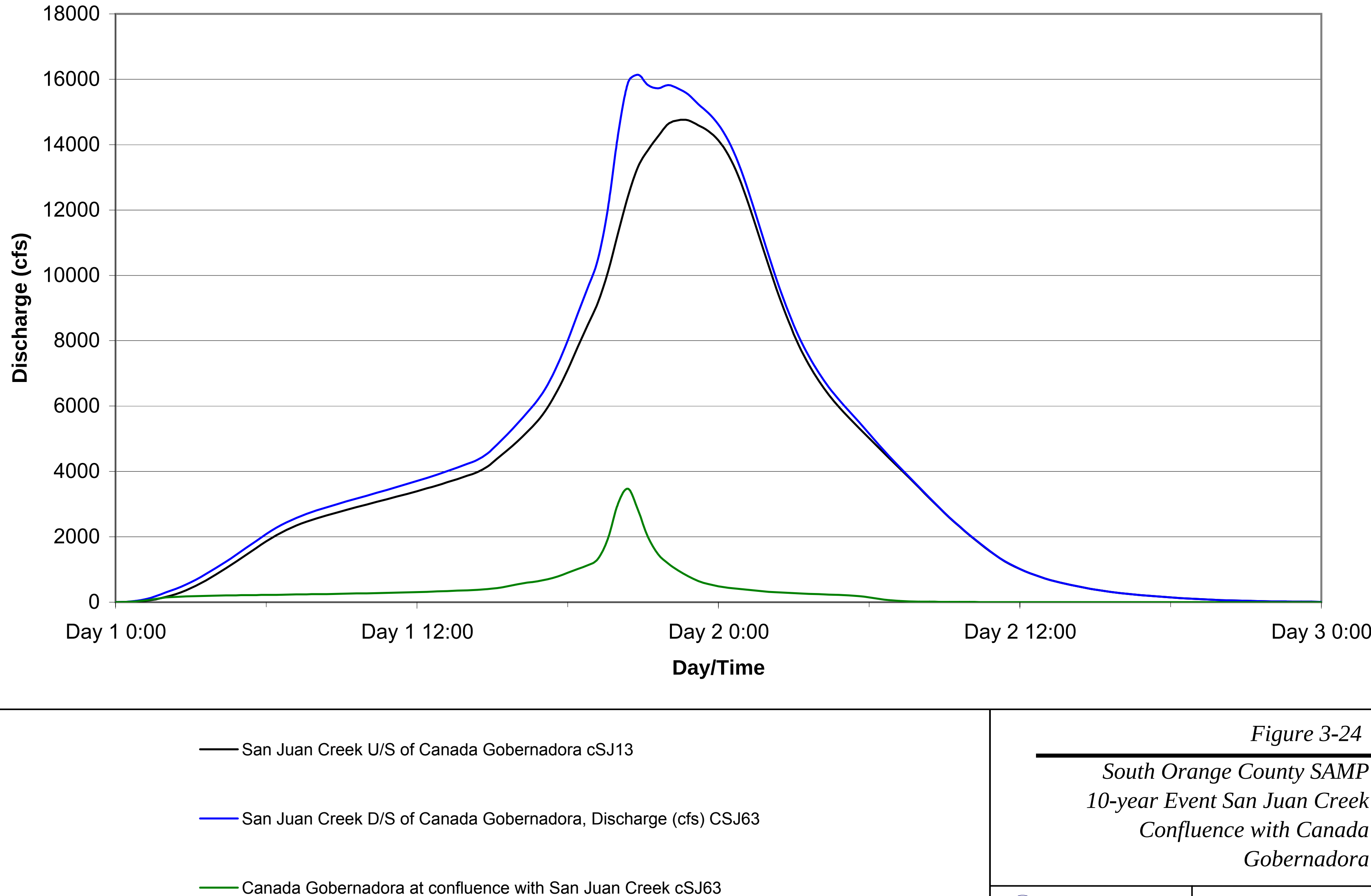


Figure 3-24

South Orange County SAMP
10-year Event San Juan Creek
Confluence with Canada
Gobernadora

PWA | PWA#: 1393

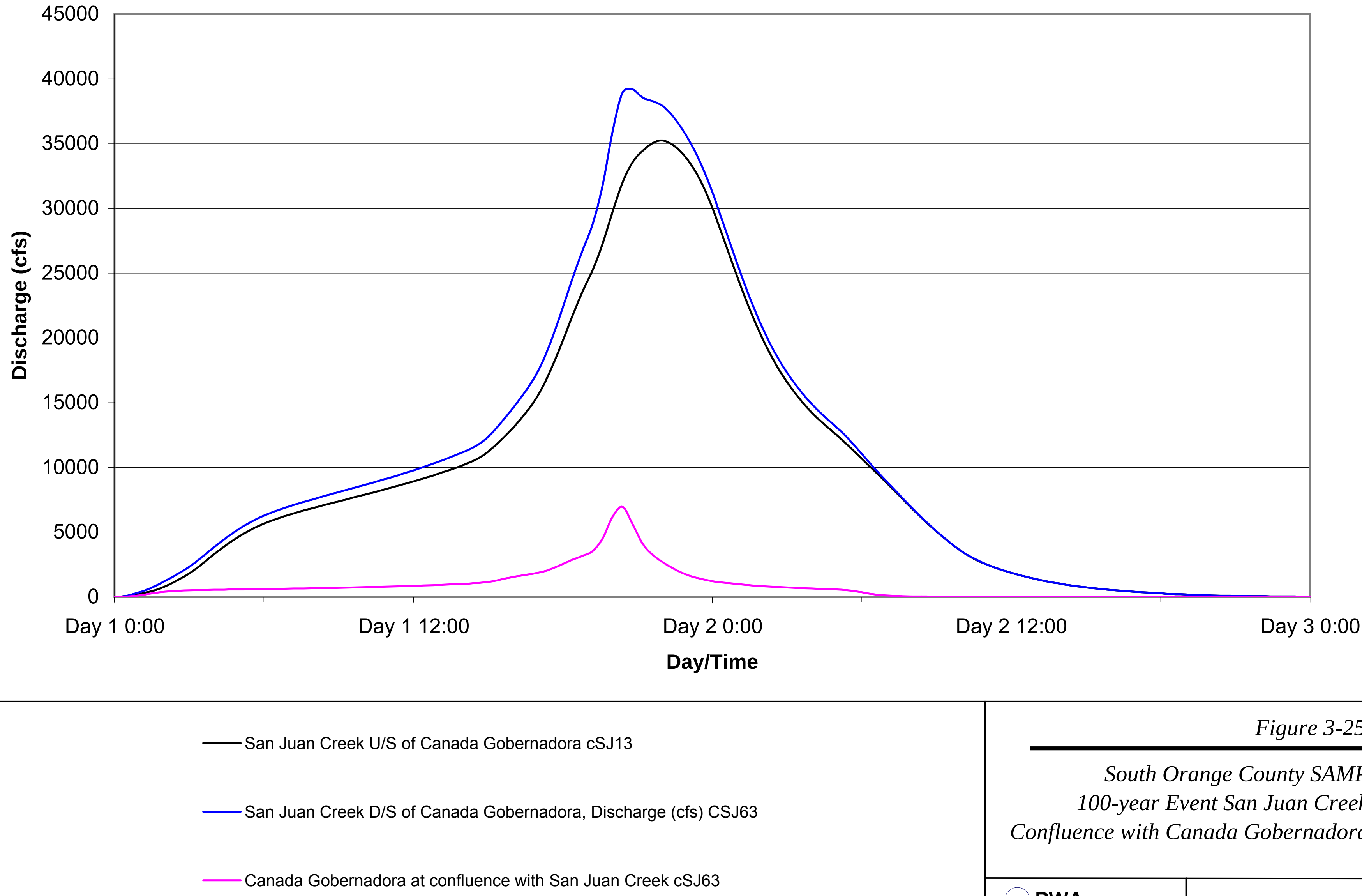


Figure 3-25

South Orange County SAMP
100-year Event San Juan Creek
Confluence with Canada Gobernadora

PWA

PWA#: 1393

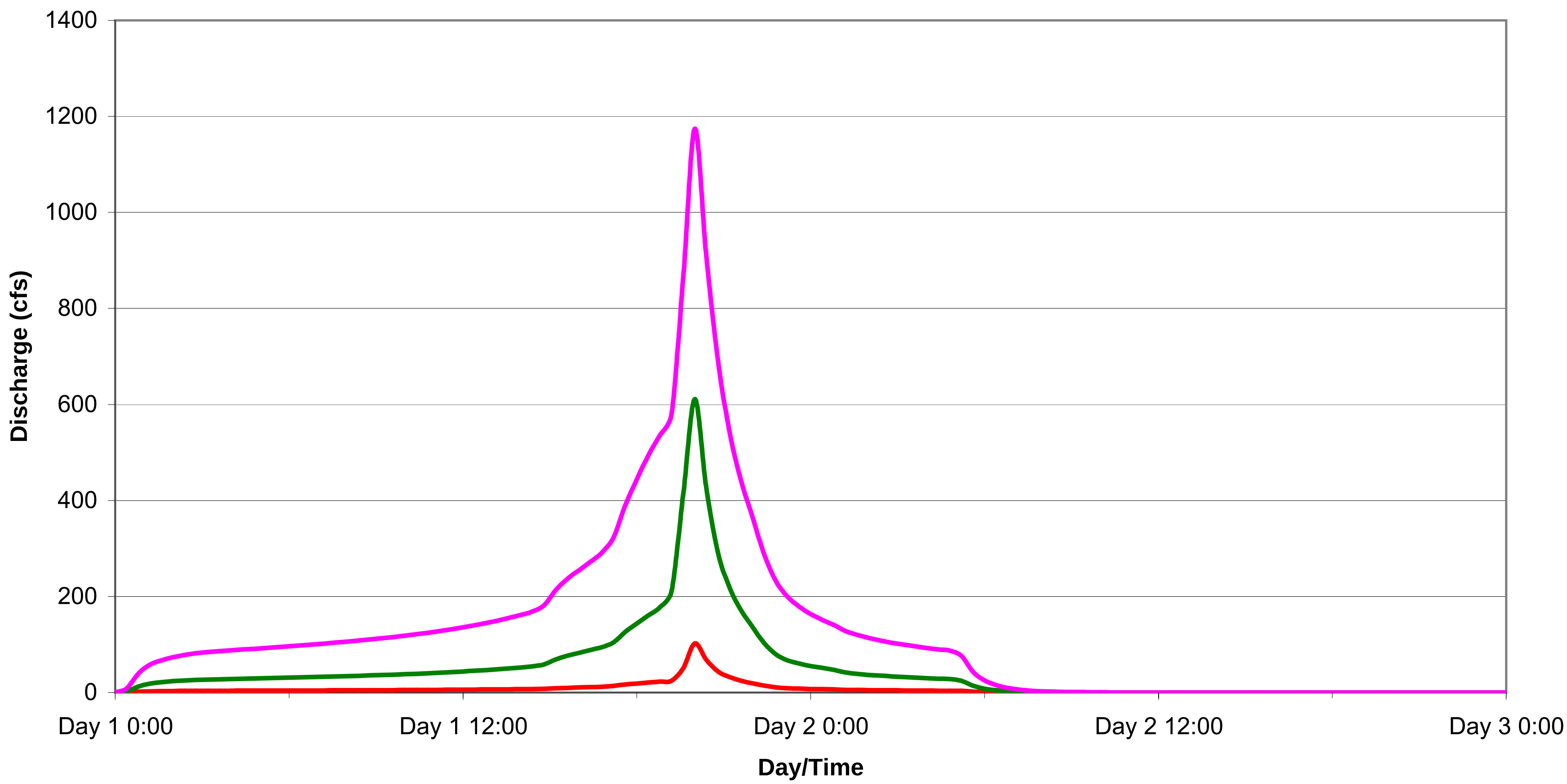


Figure 3-26

South Orange County SAMP
Event Hydrograph for Wagon Wheel Canyon
at Confluence with Canada Gobernadora

PWA PWA#: 1393

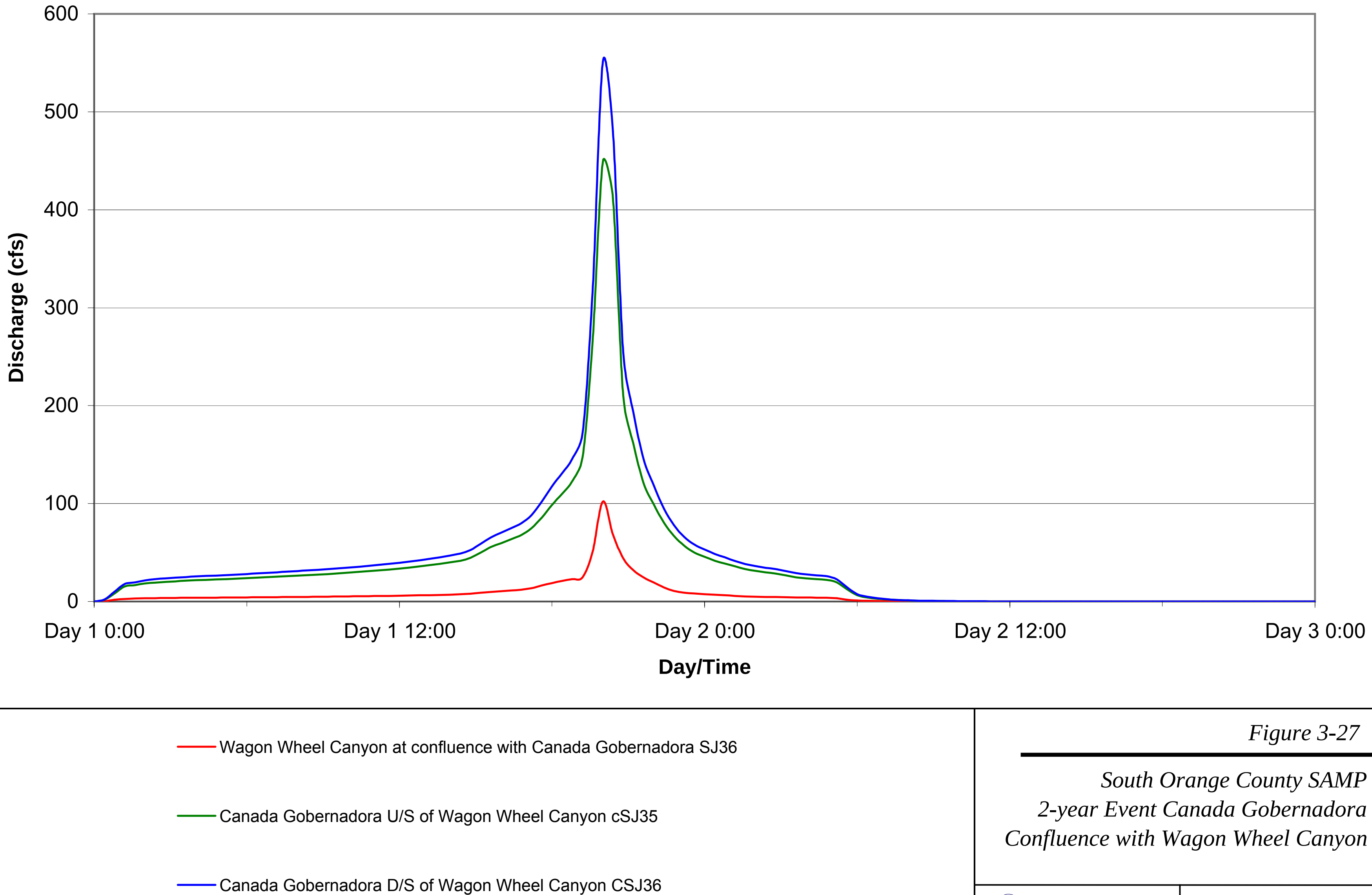
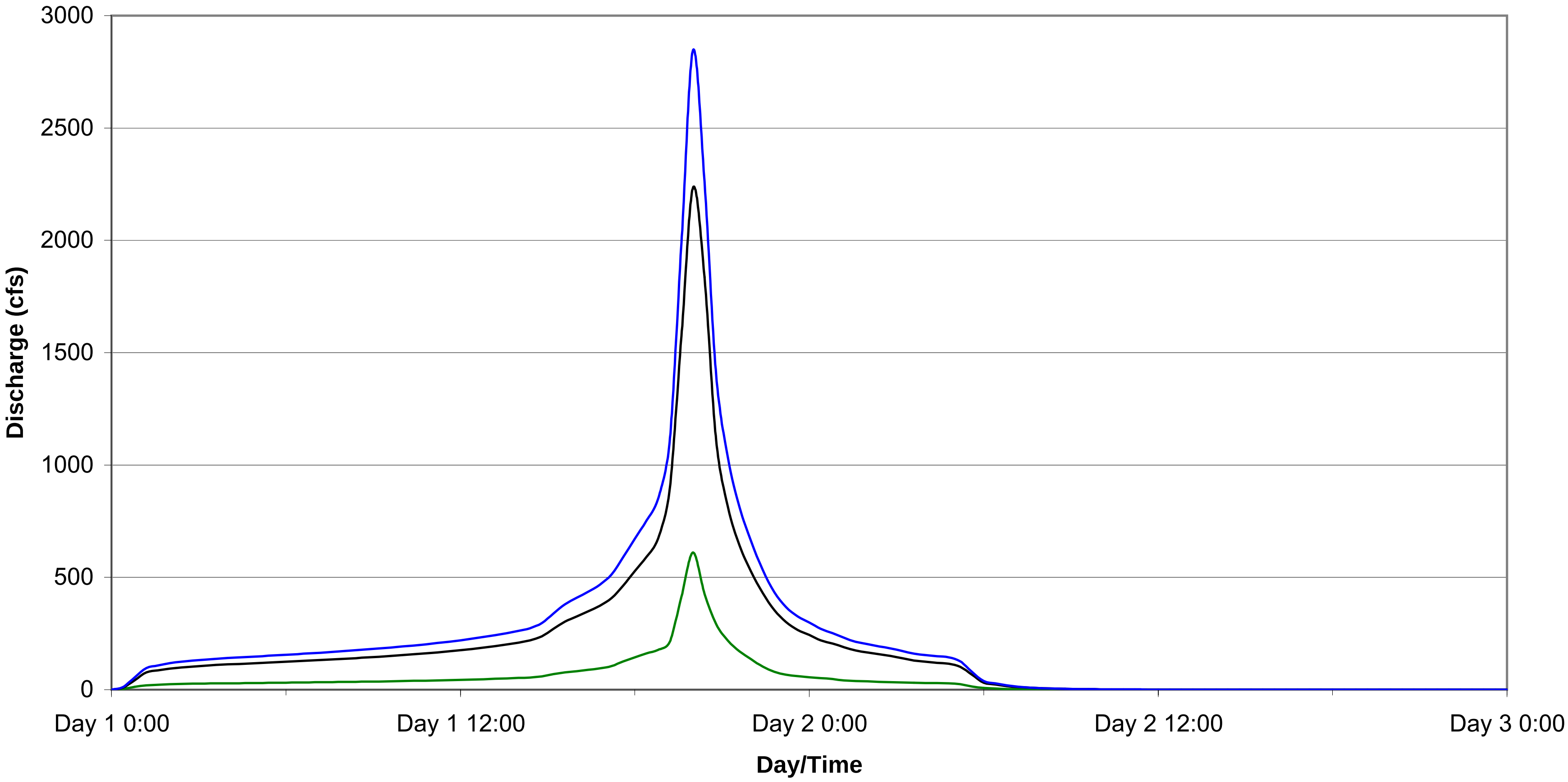


Figure 3-27

South Orange County SAMP
2-year Event Canada Gobernadora
Confluence with Wagon Wheel Canyon

PWA PWA#: 1393



Wagon Wheel Canyon at confluence with Canada Gobernadora SJ36

Canada Gobernadora U/S of Wagon Wheel Canyon cSJ35

Canada Gobernadora D/S of Wagon Wheel Canyon CSJ36

Figure 3-28

South Orange County SAMP
10-year Event Canada Gobernadora
Confluence with Wagon Wheel Canyon

PWA

PWA#: 1393

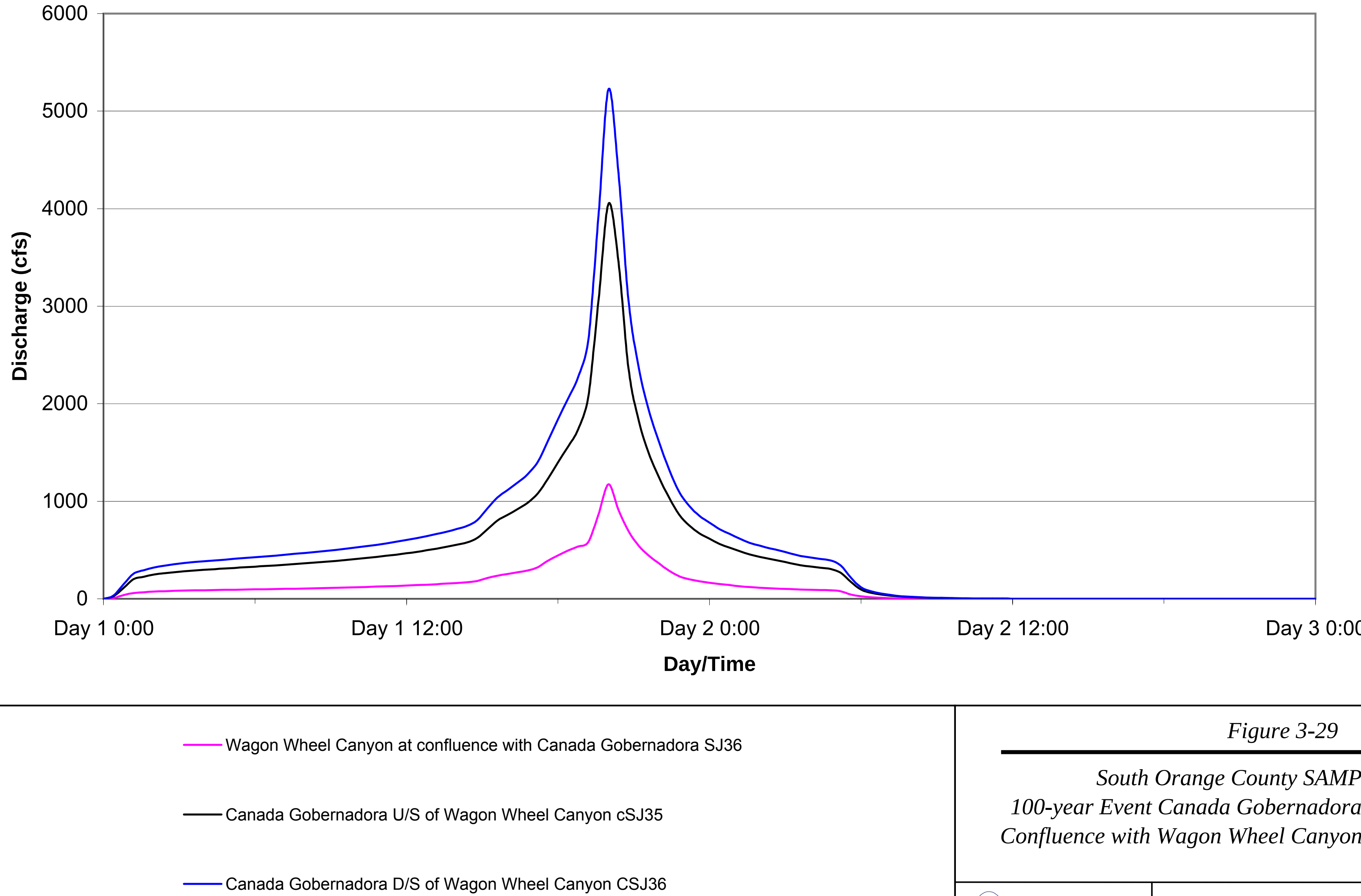


Figure 3-29

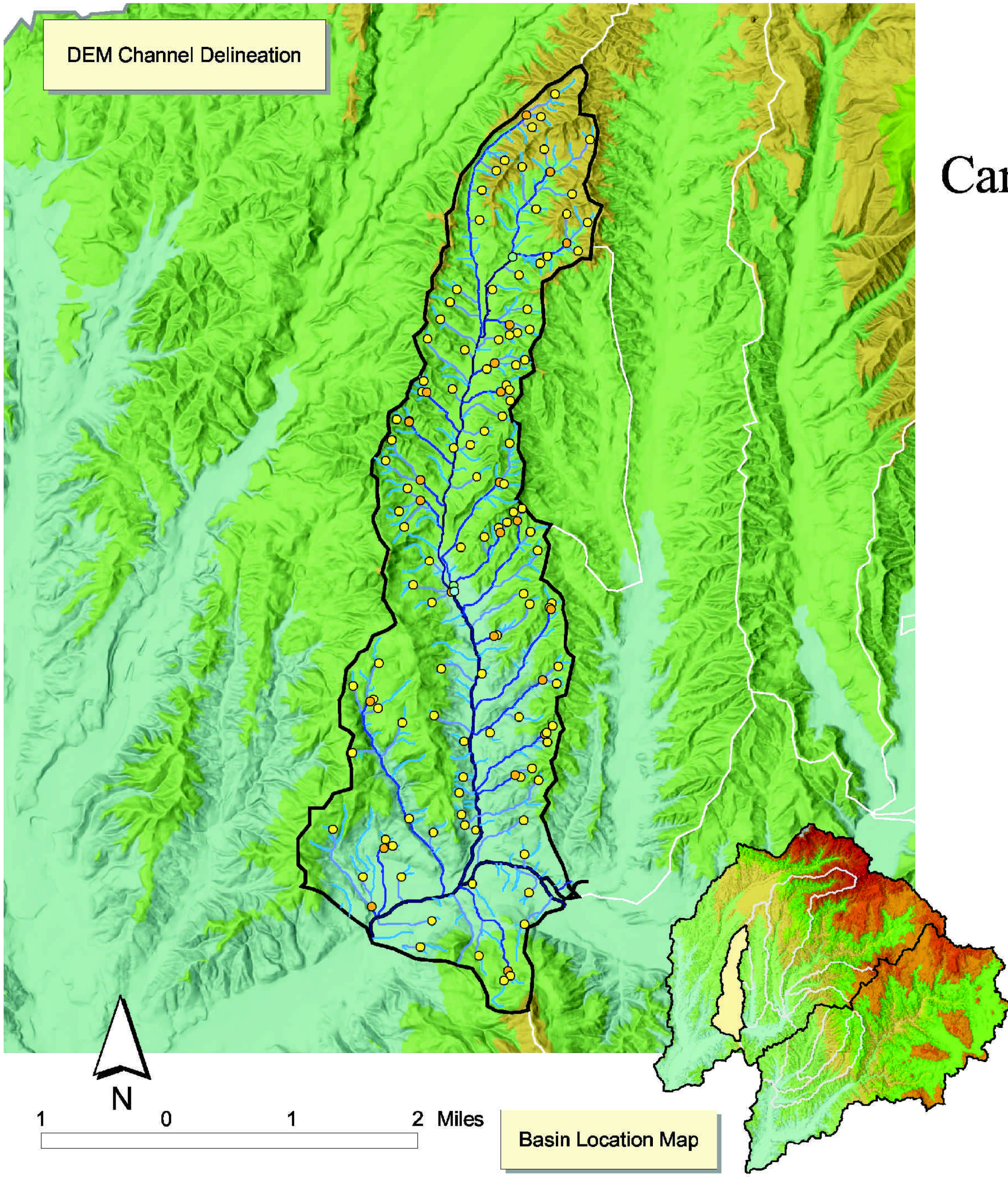
South Orange County SAMP
100-year Event Canada Gobernadora
Confluence with Wagon Wheel Canyon

PWA

PWA#: 1393

figure 3-30

Channel Network
Canada Chiquita and Narrow Canyon

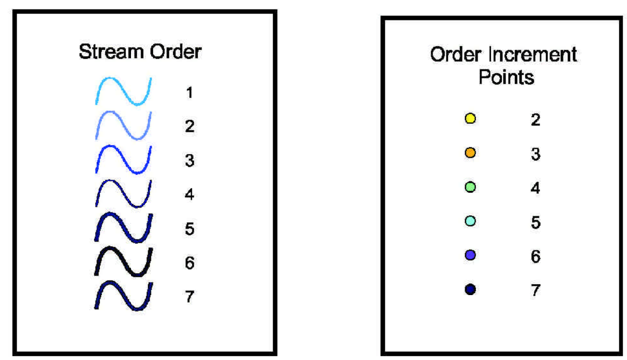


Channel Network Statistics

Basin Area = 5,907 acres
Drainage Density = 9 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	470	419	197135	4.02
2	117	973	113837	4.88
3	24	3336	80061	12
4	2	8071	16142	2
5	1	13575	13575	

Total Stream Length: 79.7 mi



PWA

3.2.4.3 Storm Event Runoff

Three storm hydrographs were calculated for the outlet of Cañada Gobernadora using the HEC-1 hydrologic model (Figure 3-22). For each of the three-modeled events, the Canada Gobernadora hydrographs display rapid singular peaks with similarly shaped rising limbs and falling limbs. This shape is characteristic of the hydrographs in the central portion of the San Juan Creek watershed. It indicates that the characteristics of the sub-basin cause a rapid runoff response. This may be due to the greater proportion of developed areas in this sub-basin (particularly in the northern basin) compared to the other sub-basins investigated.

Another notable feature of the Cañada Gobernadora hydrographs is that peak flows occur at 20:48 (2-yr) and 20:24 (10- and 100-yr) hours following the onset of precipitation (Table 3-7). This peak time is approximately 4.4, 2.4, and 1.6 hours prior to the passing of peak flows along San Juan for the 2-, 10-, and 100-year events respectively (Figure 3-5). Although this represents a substantial time separation, peak flows from Cañada Gobernadora do have a recognizable impact on peak flows in San Juan Creek at the confluence and downstream due to the relatively large size of the peak flow from the canyon. This is illustrated in Table 3-3 and the hydrographs of Figures 3-23, 3-24, and 3-25, which show peak increases of up to 10% in San Juan Creek (for the 10- and 100-year events) due to contributing flows from Cañada Gobernadora. The earlier arriving flows from Cañada Gobernadora steepen the rising limb of the hydrographs for the main San Juan Creek. Hydrographs for the Wagon Wheel tributary of Cañada Gobernadora are shown in Figures 3-26 through 3-29.

Peak runoff rates from Cañada Gobernadora are relatively high in comparison to the other San Juan sub-basins presented (Figure 3-1). Figure 3-2 illustrates that peak discharge per unit area is higher for Cañada Gobernadora than the other studied sub-basins. This is likely due to the presence of existing urban areas in the upper Cañada Gobernadora sub-basin. Cañada Gobernadora has the highest proportion of development of the studied San Juan sub-basins. Peak flows contributed from Cañada Gobernadora are between 17% and 27% of peak flows in San Juan Creek at the confluence. The 10-year peak flow from Cañada Gobernadora was calculated at 3474 cfs. With the existing development in the upper sub-basin, even higher peak runoff rates might be expected from Cañada Gobernadora. However, the sub-basin has a relatively high proportion of permeable soils in its central valley that may help off-set impacts of existing development in the upper watershed. It should be noted that runoff from different parts of Cañada Gobernadora is not uniform due to the varied characteristics of the sub-basin.

In terms of runoff volume, Cañada Gobernadora contributes about 8% of the runoff volume to San Juan Creek at their confluence while it occupies approximately 11.6% of the watershed area at that point (Table 3-3). For the three events modeled, Cañada Gobernadora produced approximately 59-75% as much runoff volume on a per-acre basis as the average for the San Juan Creek watershed as a whole (Table 3-3) and is comparable to the other studied sub-basins (Figure 3-4).

3.2.5 Cañada Chiquita

3.2.5.1 Drainage Network

Cañada Chiquita is an elongated north-south oriented basin, similar to Cañada Gobernadora, which joins the main San Juan channel as a fifth-order stream (Figure 3-30). Narrow Canyon is found just to the west of the lower Cañada Chiquita valley and is included in this analysis. Both stream systems join the seventh-order main San Juan stream at their southern ends. About 60% of the entire San Juan watershed (105 mi^2) drains upstream of the Cañada Chiquita and San Juan Creek confluence. There are 470 first order channels within this system that are distributed on the hillslopes to the east and west of the main valley and represent about 47% of the total stream length. Second and third order confluence points are also distributed fairly evenly throughout the basin. Because of the linear configuration of the main valley, most of the entering tributaries from the side valley hillslopes are third order streams or smaller. Drainage density of this canyon is estimated to be 9 mi/mi^2, which is just slightly higher than the neighboring Cañada Gobernadora basin.

The hydrology of Cañada Chiquita was analyzed as part of the San Juan watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2. Cañada Chiquita is represented by sub-basins 8 and 31 in the HEC-1 model, which also includes the Narrow Canyon area Figure 2-1. The combined drainage area of sub-basins 31 and 8 is 9.24 mi^2. The following paragraphs describe important hydrologic characteristics and processes of the Cañada Chiquita area. Estimated runoff values based upon the HEC-1 analysis are offered and illustrated.

3.2.5.2 Infiltration

The soil type distribution within the Cañada Chiquita sub-watershed is shown in Figure 2-2. As reported in Table 3-1, GIS analysis indicates that this sub-watershed is primarily underlain by soils from three hydrologic groups: B (25.7%), C (36.7%), and D (36.0%). This is the broadest distribution of soils observed for the sub-watersheds described in this report. The land-use and vegetation distributions for Cañada Chiquita are shown in Figure 2-3. Of the six San Juan sub-watersheds described in this report, Cañada Chiquita has the lowest proportion of land in an undeveloped or non-agricultural condition (57.1%). Agricultural lands cover approximately 40.8% of the sub-basin, while developed lands account for only a small proportion (2.0%). Approximately 1.0% of the basin is impervious to infiltration.

Assigned curve numbers range from 31 to 97 in Cañada Chiquita (Figure 2-5, Table 3-2), with an area-averaged curve number of 78.5. The majority of the basin (72.5%) was characterized by curve numbers between 70 and 89. Based on these curve numbers, loss rates were calculated for the sub-basin and incorporated into the HEC-1 model. The area-averaged maximum loss rate calculated for Cañada Chiquita was 0.24 inches/hour for the 10- and 100-year events and 0.59 inches/hour for the 2-year event. These 10- and 100-year rates are similar to rates in Verdugo Canyon and the Central San Juan catchments. Total precipitation losses for the 2-, 10-, and 100-year storm events are also reported in Table 3-2.

Loss rates within the Cañada Chiquita sub-basin were difficult to isolate due to the configuration of the HEC-1 sub-basins (Figure 2-1). However, in general, area-averaged loss rates in Cañada Chiquita were intermediate compared to the other San Juan watershed areas described in this report. When considered as a percentage of total storm event rainfall, losses in Cañada Chiquita were also intermediate compared to the other six San Juan sub-basins. Overall, loss rates calculated for Cañada Chiquita indicate that infiltration rates are likely also in the middle of the range for this sub-watershed.

3.2.5.3 Storm Event Runoff

Three storm hydrographs were calculated for the outlet of Cañada Chiquita using the HEC-1 hydrologic model (Figure 3-31). Each of the three event hydrographs indicate a very steep, or flashy, rise to stormflow peaks that is followed by rapid flow recessions. These results are consistent with the other hydrographs from the central San Juan Creek watershed (Bell Canyon, and Cañada Gobernadora) and may be partially attributable to the shape of the precipitation hyetograph modeled for this portion of the watershed. However, it also may indicate that the particular characteristics of the Cañada Chiquita sub-basin may cause a rapid runoff response. Peak flows exiting Cañada Chiquita occur at 22:24 hours following the onset of precipitation for all three modeled events. For the 10- and 100-year events, peak flow times occur 0.4 hours prior to peaks along San Juan Creek, but for the 2-year event peak flows occur 3.2 hours before the main San Juan channel (Table 3-7, Figure 3-5). The impact of Cañada Chiquita flows on the main San Juan Creek are observed in Figures 3-32, 3-33, 3-34. The rapid 2-year flow exiting Cañada Chiquita directly raises the overall peak of San Juan Creek by about 6%. For the 10- and 100-year events, contributing flows from Cañada Chiquita raise the main channel peaks by about 8% and 10% respectively.

In absolute terms, runoff volumes and peak flows from Cañada Chiquita are relatively intermediate in comparison to the other San Juan sub-basins presented (Figures 3-1, 3-3). However, peak flows per unit area are relatively higher for Cañada Chiquita than the other studied San Juan sub-basins except for Cañada Gobernadora (Figure 3-2). Peak flows from Cañada Chiquita are approximately 11% to 13% of peak flows in San Juan Creek at the confluence, a bit higher than the proportional area (8.8%) of the watershed that the sub-basin occupies at the confluence (Table 3-3). The 10-year peak flow from Cañada Chiquita was calculated at approximately 2204 cfs. In terms of runoff volumes, Cañada Chiquita contributes between 4% and 6% of the runoff volume on San Juan Creek at their confluence, a bit lower than the 8.8% relative area. Cañada Chiquita produced between 42% and 74% as much runoff on a per-acre basis as the average for the San Juan Creek watershed as a whole (Table 3-3). It is important to restate that the runoff per-area values for the entire San Juan Watershed shown in Table 3-3 are skewed because they include the more urbanized portions of the western San Juan watershed. These urbanized western watershed areas experience higher runoff rates in response to precipitation.

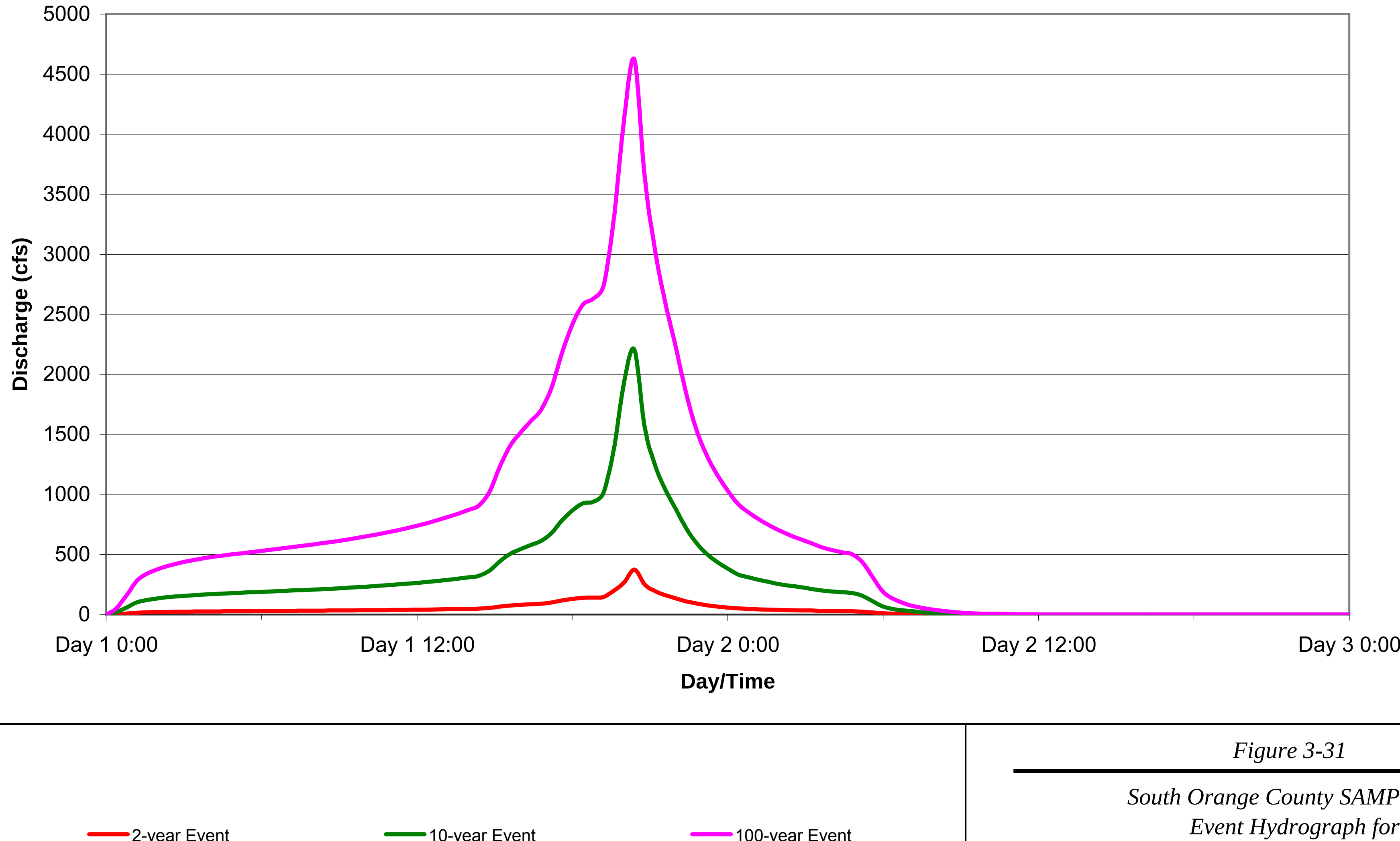
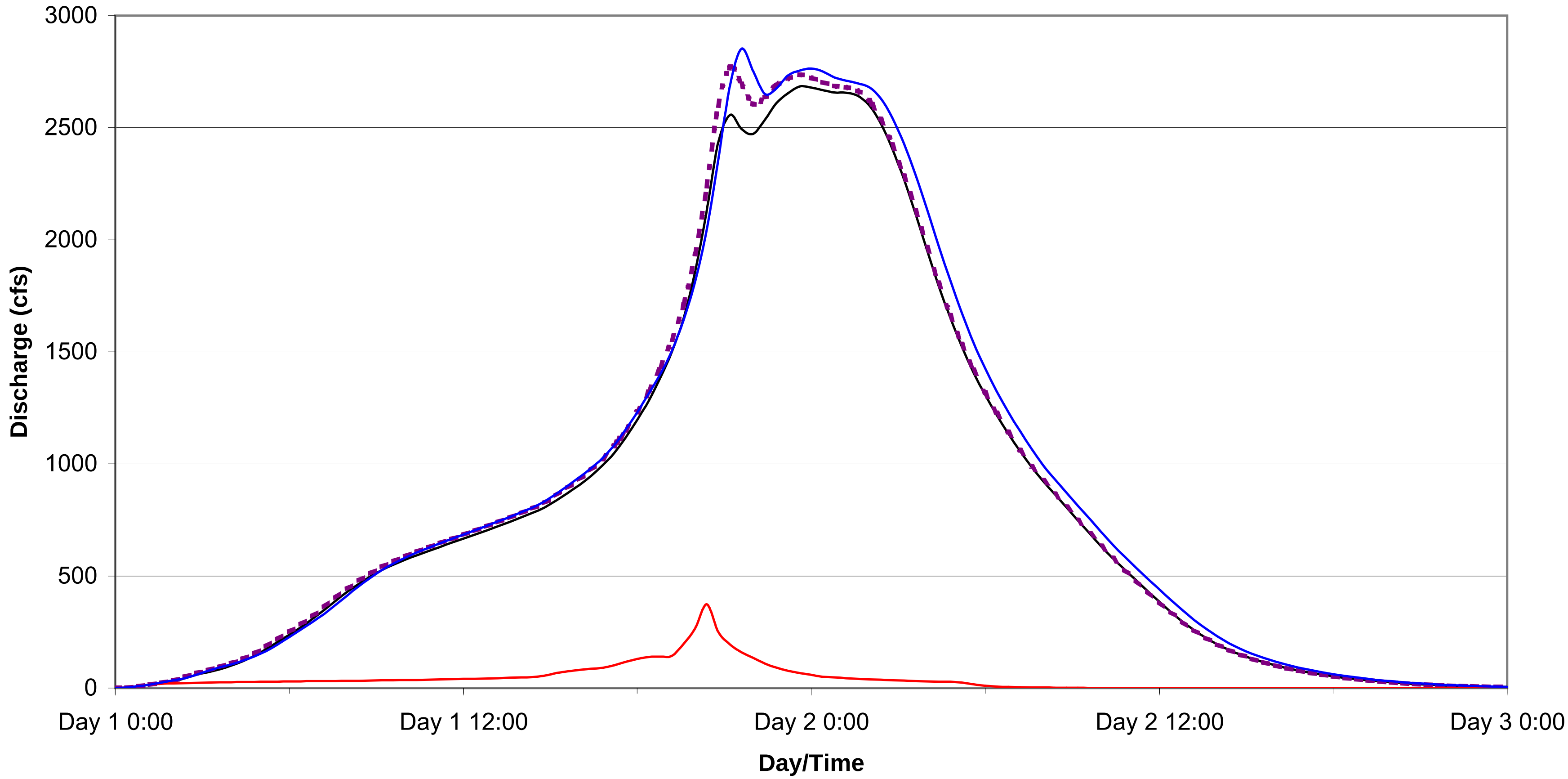


Figure 3-31

South Orange County SAMP
Event Hydrograph for
Canada Chiquita

PWA PWA#: 1393



San Juan Creek U/S of Canada Chiquita ERSJ8

San Juan Creek D/S of Canada Chiquita, U/S of Lowlands UCSJ8

Canada Chiquita and Lowlands Combined, Discharge (cfs)* SJ31 + SJ8

San Juan Creek D/S of Canada Chiquita and Lowlands cSJ8

Figure 3-32

South Orange County SAMP
2-year Event San Juan Creek
Confluence with Canada Chiquita

PWA | PWA#: 1393

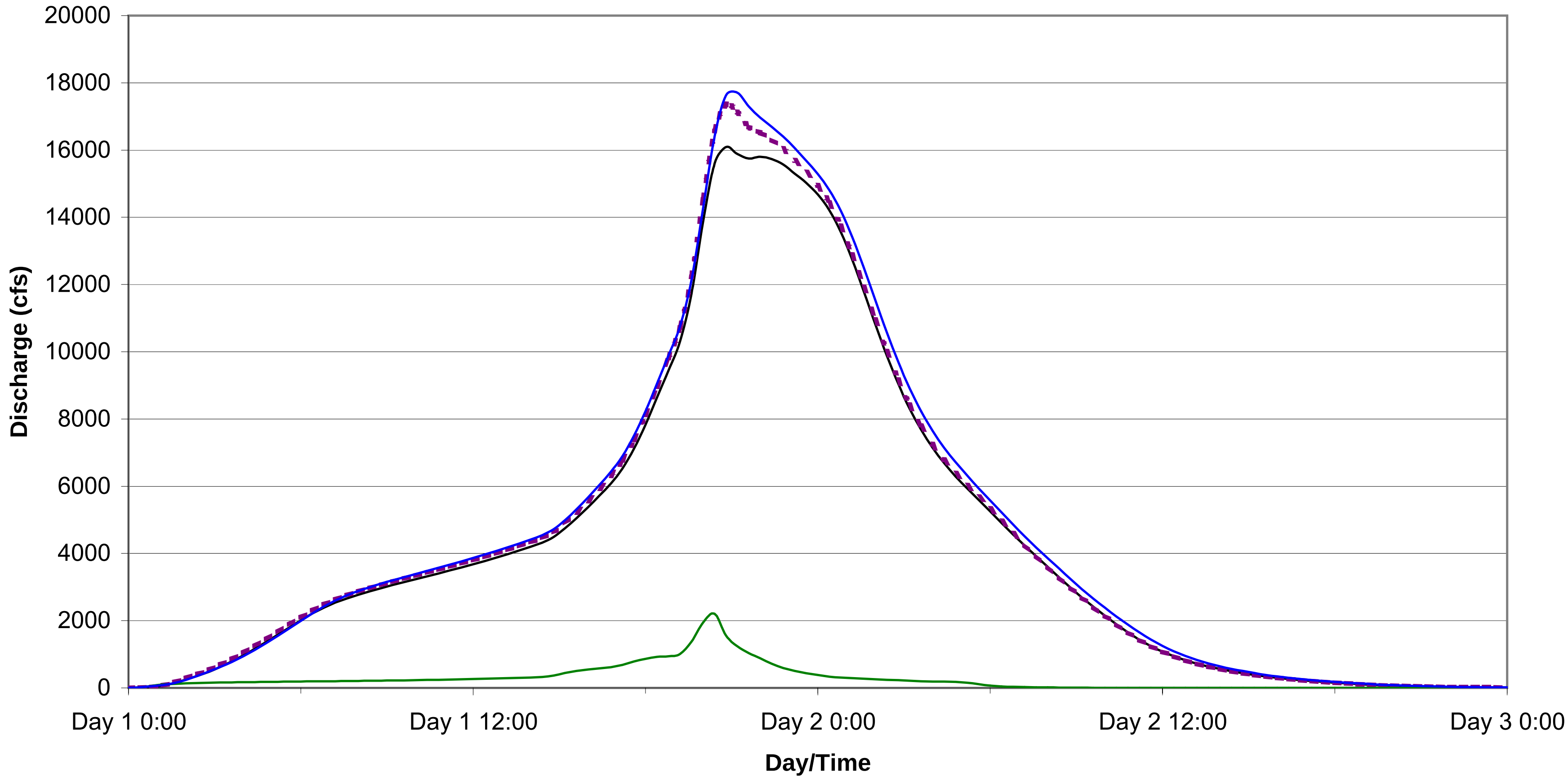


Figure 3-33

South Orange County SAMP
10-year Event San Juan Creek
Confluence with Canada Chiquita

PWA PWA#: 1393

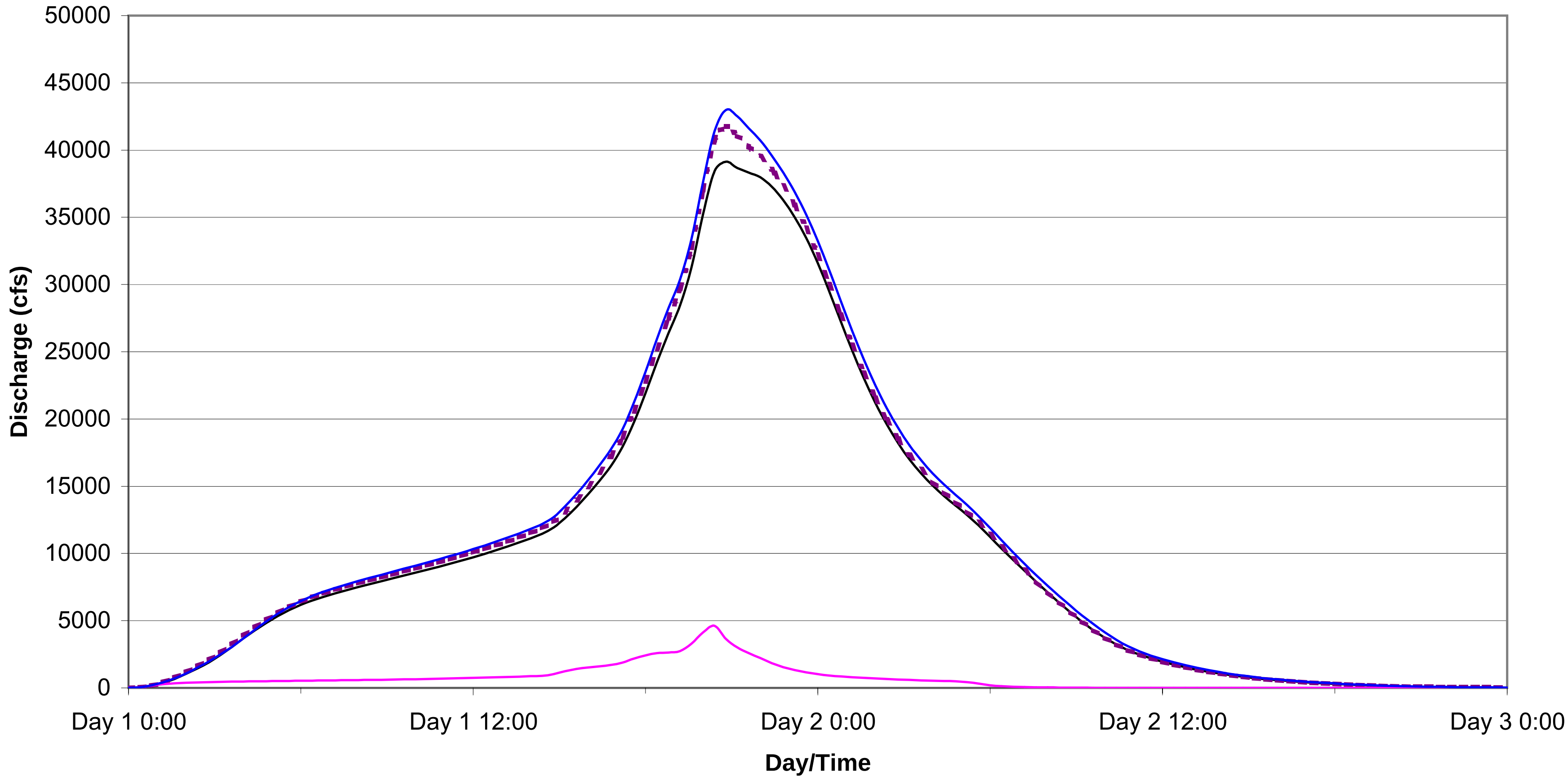


Figure 3-34

South Orange County SAMP
100-year Event San Juan Creek
Confluence with Canada Chiquita

PWA PWA#: 1393

Overall, for the three flood events modeled, runoff from Cañada Chiquita had relatively minor impact on the San Juan Creek hydrograph downstream of the confluence of the two streams. Cañada Chiquita has a relatively high proportion of permeable soils and a low percentage of developed area. The results for Cañada Chiquita are somewhat complex in that runoff volumes (per unit area) are moderate to low, while for peak flow rates (per unit area) are relatively high compared to the other studied San Juan sub-basins.

3.2.6 Central San Juan Catchments

3.2.6.1 Drainage Network

In the central portion of the San Juan watershed, about 10-12 mi upstream from the coast, there is a 7.4 mi^2 area (between the mouths of Cañada Gobernadora and Bell Canyon upstream), which contains several small tributary drainages, which feed directly into the main San Juan channel (Figure 3-35). This sub-basin represents about 7.4% of the upstream San Juan watershed (85 mi^2). The longest watercourse in this area is San Juan Creek itself (4.5 mi). North of the San Juan stream exists a triangular wedge of land, which is neither a source area for the Cañada Gobernadora or Bell Canyon streams, but drains directly southward into the main San Juan system. This triangular area is drained by two third-order creeks and one fourth-order stream. Note, this area includes the existing nurseries and the hillslopes north of the nurseries. On the south side of the San Juan stream, Trampas Canyon is a fifth order system, which drains some steep headwater terrain to the south. In the eastern portion of this central San Juan area there are two fourth order systems, which have a notably higher density of first and second-order channels. This is similar to the pockets of higher drainage density observed in Verdugo and Lucas canyons (to the north) and likely reflects geologic conditions along the east side of the San Juan creek. In this central reach of San Juan Creek downstream of Bell, Lucas, and Verdugo canyons, the stream valley widens to include several floodplain terraces.

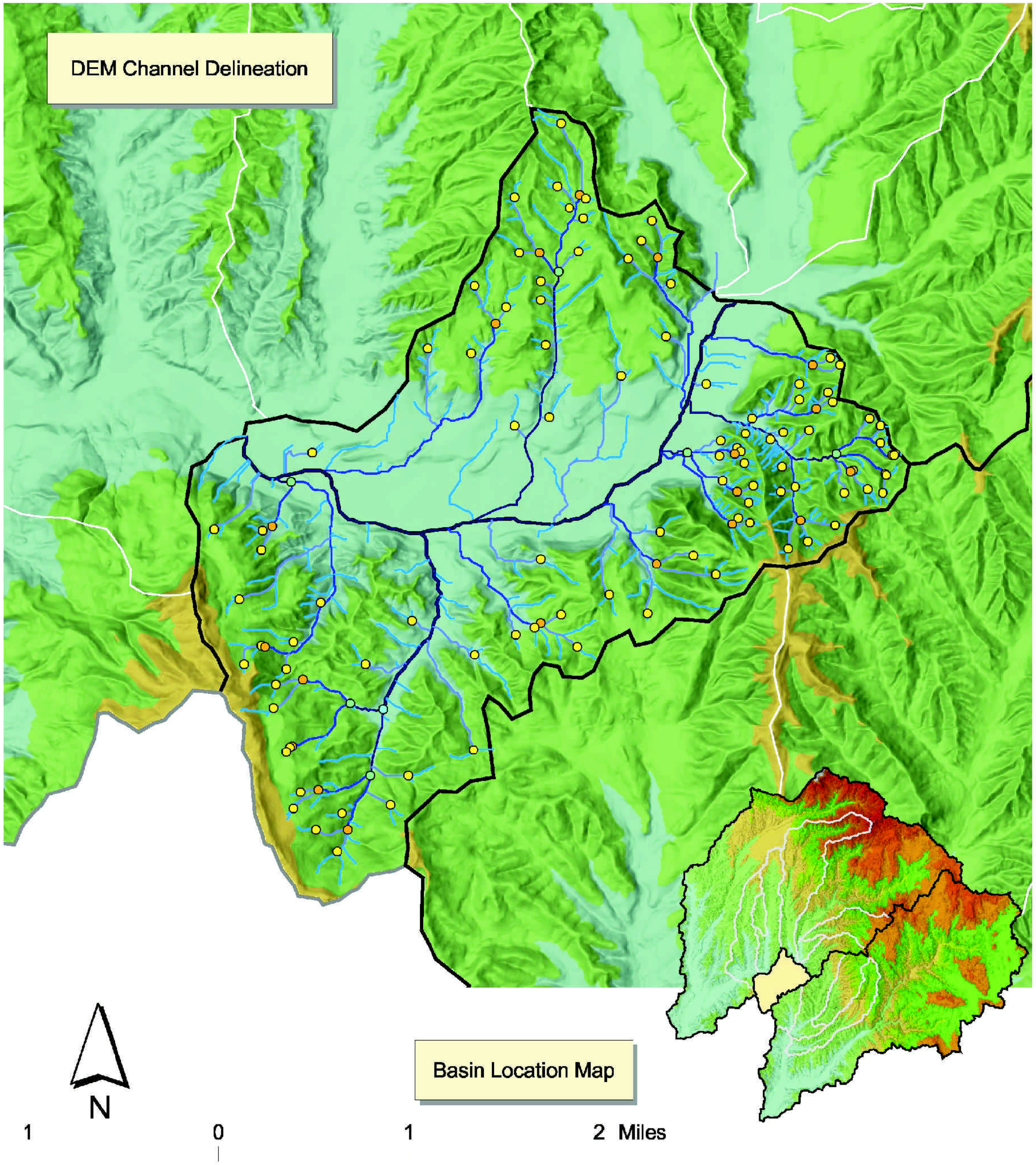
The hydrology of the Central San Juan Catchments was analyzed as part of the San Juan watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2. These catchments are collectively represented by sub-basin 13 in Figure 2-1 and node SJ13 in the HEC-1 network in Figure 2-6. The following paragraphs describe important hydrologic characteristics and processes of the Central San Juan Catchments. Estimated runoff values based upon the HEC-1 analysis are offered and illustrated.

3.2.6.2 Infiltration

The soil type distribution within the Central San Juan Catchments is shown in Figure 2-2. GIS analysis (Table 3-1) indicates that the majority of the sub-basin is underlain by soils of hydrologic groups C (52.6%) and D (29.2%). Soils in these classes are poorer infiltrators than soils in classes A or B. The land-use and vegetation distributions for the Central San Juan Catchments are shown in Figure 2-3. As indicated in Table 3-1, the Central San Juan Catchments are primarily undeveloped (84.8%). Agricultural and developed lands cover approximately 12% of the land in this sub-basin, with the nurseries being a key component of the land-use. Approximately 3.1% of the sub-basin is impervious to infiltration. The predominant vegetation types in the non-developed and non-agricultural lands sub-basin are sage, chaparral, and woodland.

figure 3-35

Channel Network Central San Juan and Trampas Canyons

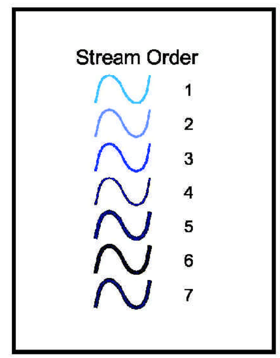


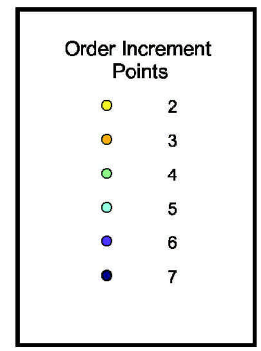
Channel Network Statistics

Basin Area = 4,744 acres
Drainage Density = 9 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	448	397	177710	4.23
2	106	769	81483	4.61
3	23	2428	55840	3.83
4	6	2936	17615	6
5	1	5671	5671	1
7	1	19378	19378	

Total Stream Length: 67.7 mi





PWA

Assigned curve numbers range from 31 to 97 in the Central San Juan Catchments (Table 3-2, Figure 2-5), with an area-averaged curve number of 75.9. A large majority of the basin (81%) was characterized by curve numbers between 70 and 89. Based on these curve numbers, loss rates were calculated for the sub-basin and incorporated into the HEC-1 model. The maximum loss rate for the Central San Juan Catchments was calculated to be 0.24 inches/hour for the 10- and 100-year events and 0.58 inches/hour for the 2-year event. Total precipitation losses for the 2-, 10-, and 100-year storm events are also reported in Table 3-2.

Of the six sub-watersheds described, the Central San Juan Catchments had nearly the highest maximum loss rate, second only to Lucas Canyon. When considered as a percentage of total storm event rainfall, losses in the Central San Juan Catchments were higher than losses in all six reported San Juan sub-watersheds, for all three modeled storm events. Overall, the high loss rates calculated for the Central San Juan Catchments likely indicate that infiltration rates are also relatively high in this sub-basin. This may be a result of the relatively high proportion of undeveloped land in the sub-basin and the relatively high proportion of type-C and type-B soils. Lower slopes in the lowlands adjacent to San Juan Creek may also contribute to the higher losses rates calculated for this sub-basin. However, in the tributaries like Trampas Canyon, the slopes are quite high.

3.2.6.3 Storm Event Runoff

As described above, the tributaries of the Central San Juan catchments enter San Juan Creek at various locations along the 19,617 ft reach through this sub-basin. However, the HEC-1 hydrology model approximates this by assuming that the tributaries all meet San Juan Creek at the downstream end of this sub-basin. This type of spatial averaging, or “bulk” runoff generation method of HEC-1 was used for all of the sub-basins analyzed in this study. In the case of the Central San Juan sub-basin, this approach is even a more dramatic approximation for this sub-basin’s hydrology because the physical reality of the drainage network is irrelevant. The other studied sub-basins considered in this report typically consist of a single canyon whose discharge joins San Juan Creek at a single confluence. The effects of these discharges on San Juan Creek occur primarily at the confluence point. By contrast, within the Central San Juan Catchments, the effects of surface runoff will be distributed along the reach of the main San Juan Creek channel. For this reason the following results that characterize the runoff from this sub-basin and the effect of this runoff upon the flows in San Juan Creek should be interpreted cautiously.

Three storm hydrographs were calculated for the outlet of the Central San Juan Catchments using the HEC-1 hydrologic model (Figure 3-36). Probably due to similar input precipitation hyetographs, hydrographs for the central San Juan sub-basin are similar to results from Lucas and Verdugo canyons. In the Central San Juan Catchments, peak flows occur at 20:00 hours following the beginning of precipitation for all three modeled events. This peak time occurs approximately 4.4, 2.4, and 2.0 hours before peak flows along the San Juan Creek peaks at its confluence with this central sub-basin for the 2-, 10- and 100-year events respectively (Table 3-7, Figure 3-5). Partially due to these differences in peak timing, and also due to the moderate rates and volumes of runoff from this sub-basin, peak flows from the Central San Juan Catchments do not have a significant impact on peak flows in San Juan Creek at the confluence and downstream (Figures 3-37, 3-38, 3-39).

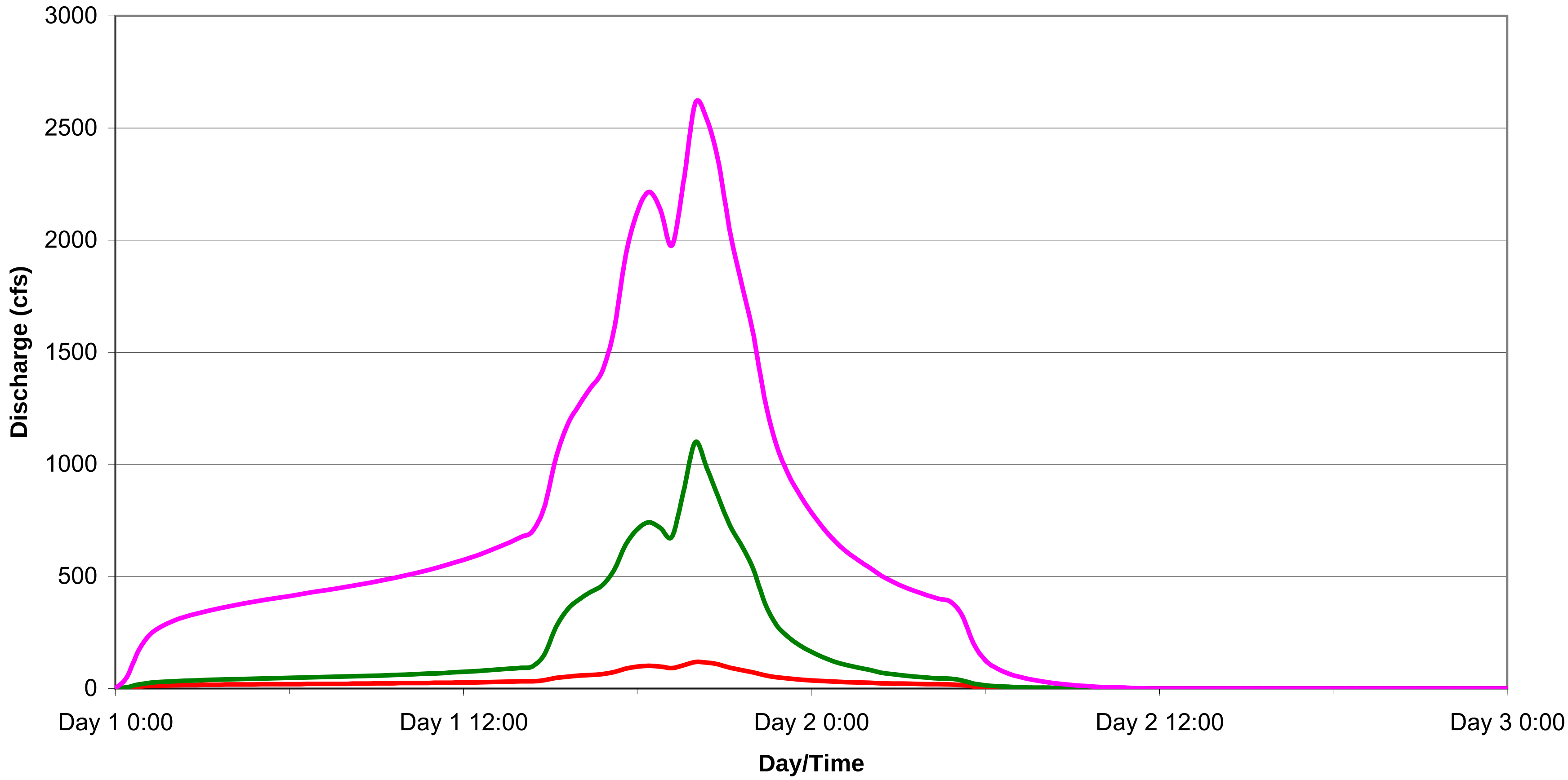


Figure 3-36

South Orange County SAMP
Event Hydrograph for the
Central San Juan Catchments

PWA

PWA#: 1393

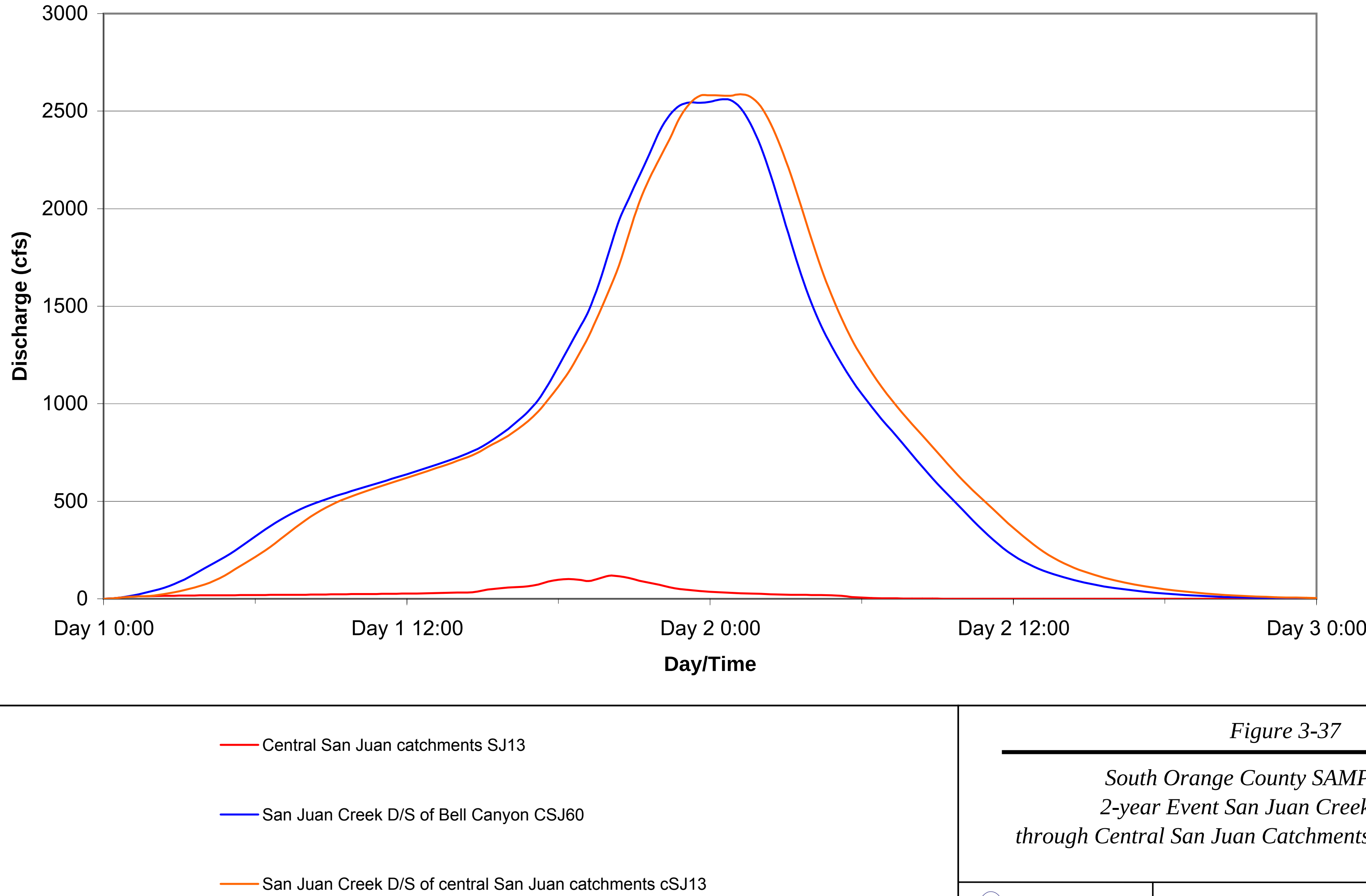


Figure 3-37

South Orange County SAMP
2-year Event San Juan Creek
through Central San Juan Catchments

PWA

PWA#: 1393

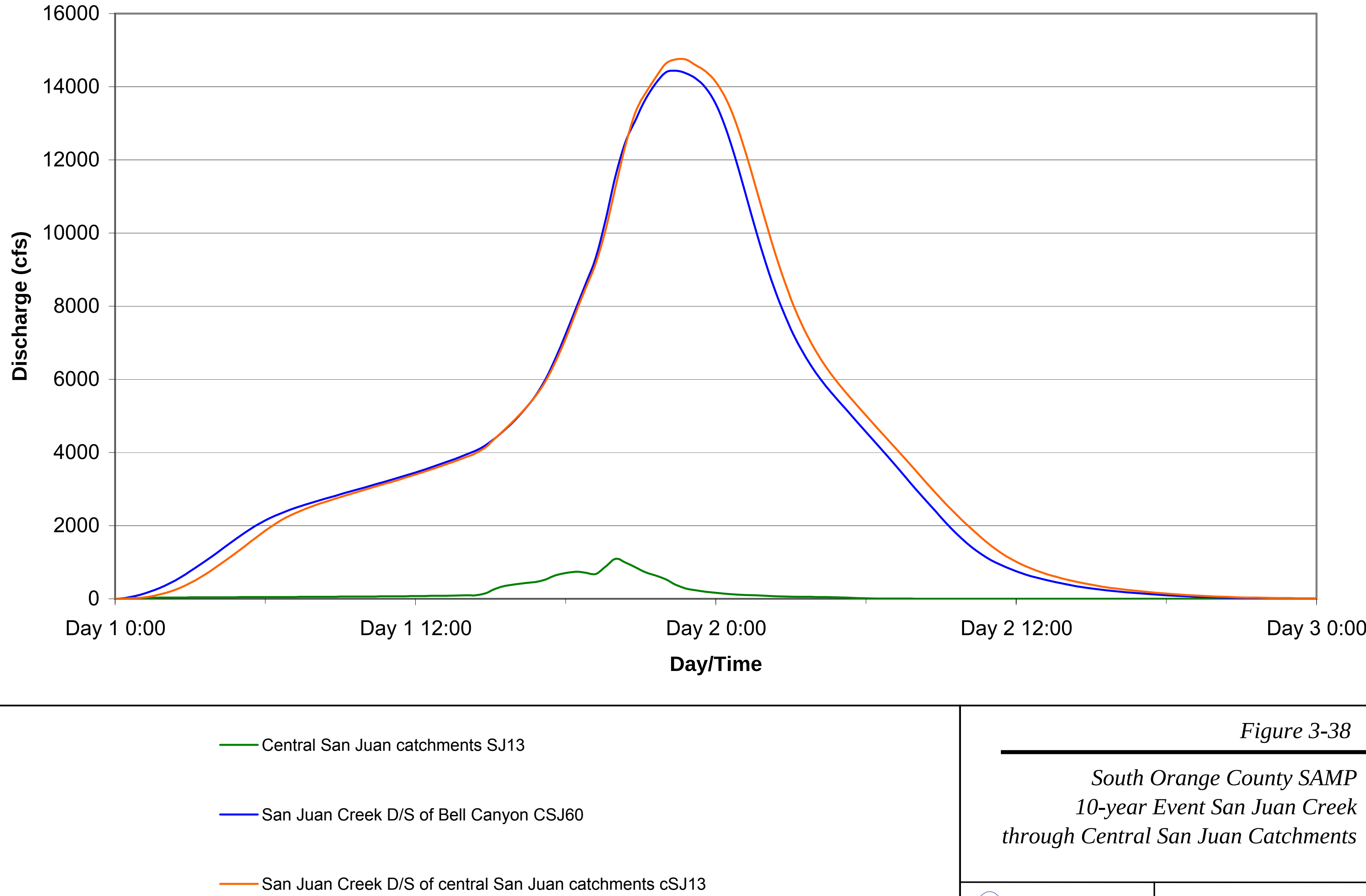


Figure 3-38

South Orange County SAMP
10-year Event San Juan Creek
through Central San Juan Catchments

PWA PWA#: 1393

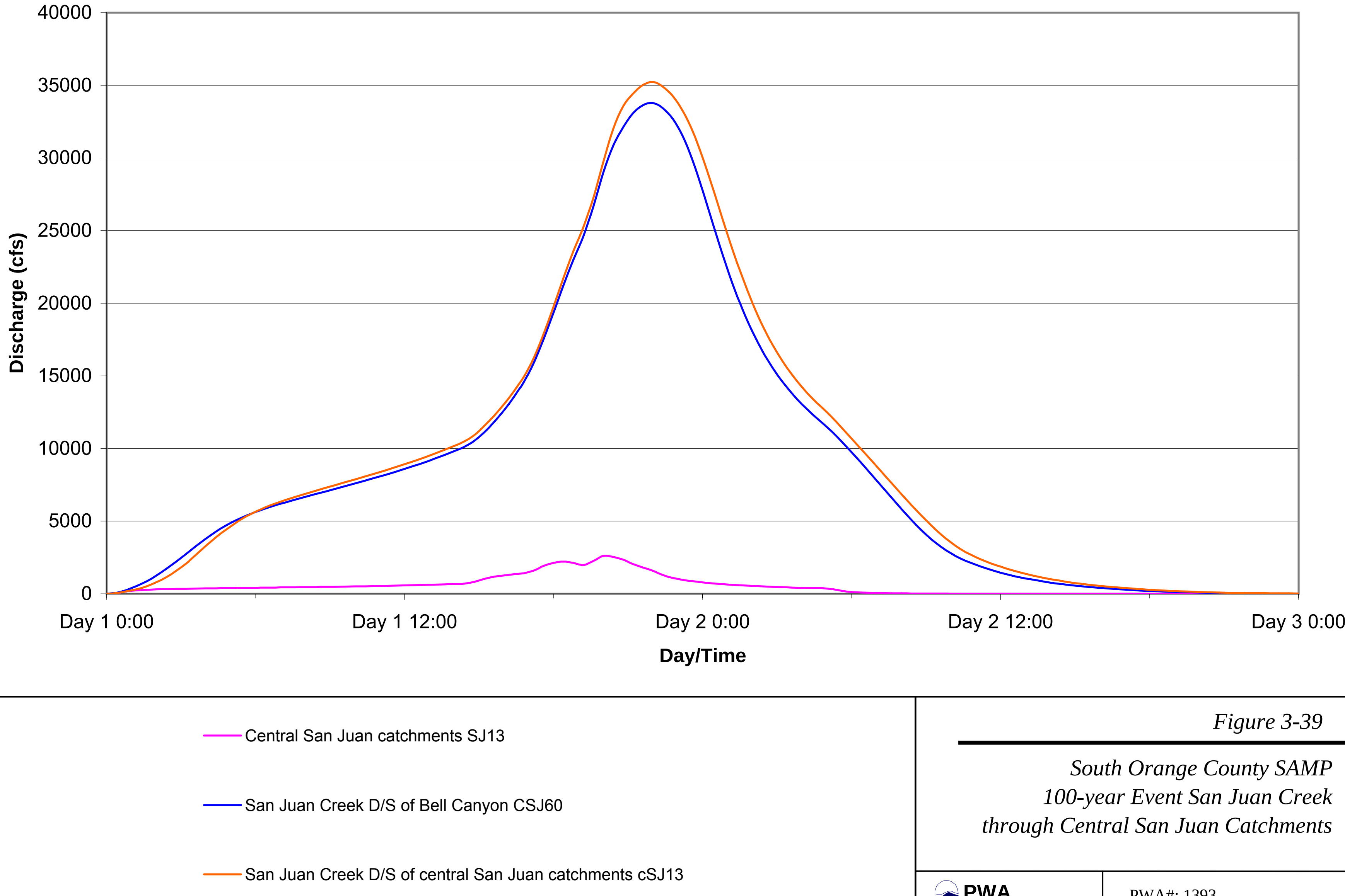


Figure 3-39

South Orange County SAMP
100-year Event San Juan Creek
through Central San Juan Catchments

PWA | PWA#: 1393

In absolute terms, runoff volumes and peak flows from the Central San Juan Catchments are the lowest of the studied San Juan sub-basins, except for Verdugo Canyon (Figures 3-1, 3-3). For all three events, the Central San Juan Catchments contribute between 2% and 5.5% of the runoff volume to San Juan Creek at their confluence while they occupy approximately 8.8% of the watershed area at that point (Table 3-3). Peak flows from the Central San Juan Catchments are approximately between 5% and 7.5% of peak flows in San Juan Creek at the confluence. The 10-year peak flow from the Central San Juan Catchments was calculated at 1099 cfs. For the three events modeled, the Central San Juan Catchments produced between 24% and 69% as much runoff on a per-acre basis as the average for the San Juan Creek watershed as a whole (Table 3-3). These low runoff values are likely due to the large proportion of undeveloped areas in the sub-basin, particularly along the central San Juan Creek floodplain, and the small size of the sub-basin in comparison to the other reported sub-basins. Low sub-basin slopes along the main San Juan Creek corridor and a broader sub-basin shape may also reduce runoff by increasing infiltration. The headwater tributaries of this sub-basin are quite steep and this influenced sediment transport results discussed below in Section 4. Overall, for the three flood events modeled, runoff from the Central San Juan Catchments had a relatively minor impact on the San Juan Creek hydrograph downstream of the confluence of the two streams.

3.3 SAN MATEO CREEK WATERSHED

3.3.1 La Paz Canyon

3.3.1.1 Drainage Network

The La Paz Canyon sub-basin is located in the upper western portion of the San Mateo watershed (Figure 3-40). La Paz Canyon is a tributary to the larger Gabino Canyon, which it joins downstream at its southern outlet (discussed below). The tributary streams of La Paz Canyon were only partially mapped by the WES team. The slope-area threshold method described above, utilizing the 10-m DEM and available mapped WES channels, was utilized to predict channels throughout the entire canyon. The resulting stream network is anchored around a lengthy fifth order trunk channel, which has several fourth-order parallel drainages joining it from the eastern hillslopes. The 7.3-mi2 sub-basin includes 575 first order and 110 second order channels and has a drainage density of 10 mi/mi^2. The longest watercourse is approximately 6.8 miles. First order streams comprise 54% of the total stream length in the basin. Order-increment confluence points are evenly distributed across the sub-basin. The fourth order confluence points in the eastern tributaries may represent zones of enhanced geomorphic and habitat function. The narrow western strip of La Paz Canyon is characterized by short second order streams, which drain from the dividing ridge with Upper Gabbino Canyon and feed into the main La Paz channel.

The hydrology of La Paz Canyon was analyzed as part of the San Mateo watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2 above. This canyon is represented by sub-basin 51 in Figure 3-1 and node CC51 in the HEC-1 network in Figure 2-7. The following paragraphs describe important hydrologic characteristics and processes of the La Paz Canyon sub-basin. Estimated runoff values based upon the HEC-1 analysis are provided.

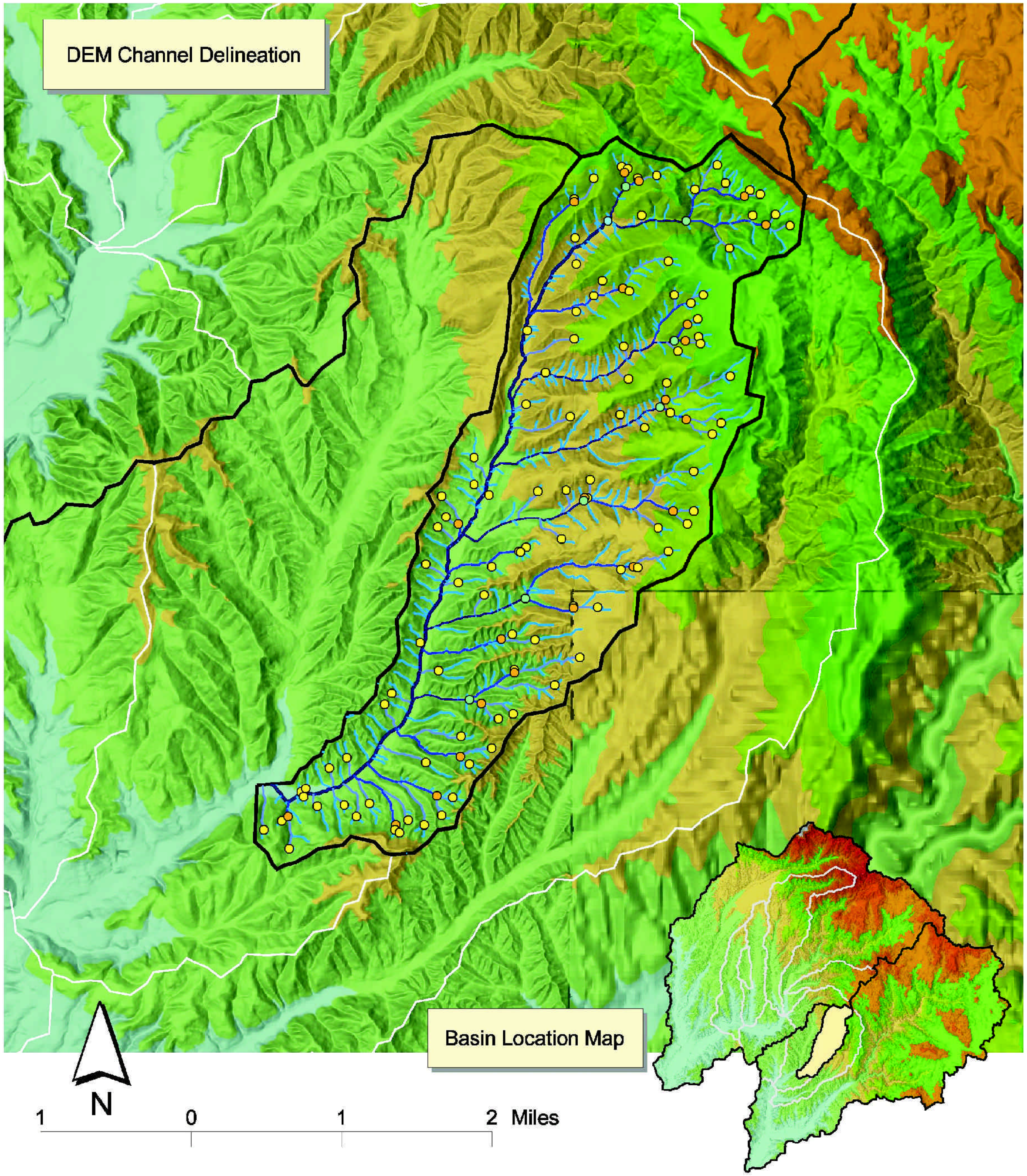


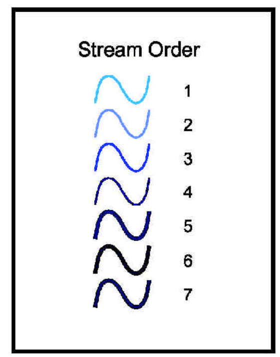
figure 3-40

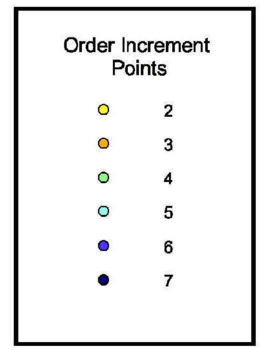
Channel Network
La Paz Canyon

Channel Network Statistics

Basin Area = 4,640 acres
Drainage Density = 10 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	575	366	210515	5.23
2	110	707	77769	4.58
3	24	1954	46896	3.43
4	7	4040	28278	7
5	1	26532	26532	
		Total Stream Length:	73.9 mi	





PWA

3.3.1.2 *Infiltration*

According to HEC-1, the rate of infiltration within a watershed area is generally related to the soil types, vegetation types, and land-use distribution in the watershed. The soil type distribution within La Paz Canyon is shown in Figure 2-2. As reported in Table 3-4, GIS analysis indicates that the majority of the sub-basin is underlain by soils of hydrologic groups C (43.8%) and D (47.8%). Soils in these classes are poorer infiltrators than soils in classes A or B. The land-use and vegetation distributions for La Paz Canyon are shown in Figure 2-3. La Paz Canyon is nearly entirely undeveloped (99.6%). Agricultural and developed lands (mostly roads) cover approximately 0.4% of the sub-basin. Therefore, only a very tiny fraction of the basin is impervious to infiltration. The predominant vegetation types in the sub-basin are sage, chaparral, and grassland.

According to OCHM methods, SCS runoff curve numbers were used in hydrologic modeling of the sub-basin to integrate the effect of soil type, land-use, and vegetation on overall "loss" processes in the sub-basin, which include infiltration. Assigned curve numbers range from 31 to 89 in La Paz Canyon, with an area-averaged curve number of 77.0 (Table 3-5). The vast majority of the basin (91.6%) was characterized by curve numbers between 70 and 89 (Figure 2-5). Based on these curve numbers, loss rates were calculated for the sub-basin and incorporated into the HEC-1 model. The maximum loss rate for La Paz Canyon was calculated to be 0.24 inches/hour for the 10- and 100-year events, and 0.60 inches/hour for the 2-year event. Total precipitation losses for the 2-, 10-, and 100-year storm events are also reported in Table 3-5.

Compared to the other San Mateo Creek sub-basins described below, loss rates for La Paz Canyon are intermediate in value. Of the four sub-watersheds analyzed, upper Gabino Canyon had the highest maximum loss rate. Precipitation losses in La Paz Canyon were second lowest (behind Talega Canyon) when considered as a percentage of total storm event rainfall. Overall, the mid-range loss rates calculated for La Paz Canyon indicate that infiltration rates likely also fall in the middle of the calculated range for the reported San Mateo watershed sub-basins. La Paz Canyon's infiltration rates reflect a balance between poor infiltrating soils in an undeveloped watershed.

3.3.1.3 *Storm Event Runoff*

Three storm hydrographs were calculated for the outlet of La Paz Canyon using the HEC-1 hydrologic model (Figure 3-41). Similar to many of the modeled hydrographs in the central San Juan basin, the La Paz Canyon hydrographs display a single distinct peak that rises and falls relatively rapidly. The rising limb of the hydrograph is steeper (convex) than the falling limb (concave). This shape is indicative of a somewhat flashy responsive watershed and may be attributable to the relatively high proportion of low-permeability soils in the watershed.

An additional feature of the La Paz Canyon hydrographs is that peak flows occur at 20:00 hours following the onset of precipitation (Table 3-7). This peak time is identical to the peak time for upper Gabino Canyon at its confluence with La Paz Canyon. This is not surprising considering that the Upper Gabino Canyon and La Paz Canyon drainages are very similar in size and shape. As a result, peak streamflow from La Paz Canyon directly contributes to increasing peak discharge at Gabino Canyon and further downstream (Figures 3-42, 3-43, 3-44).

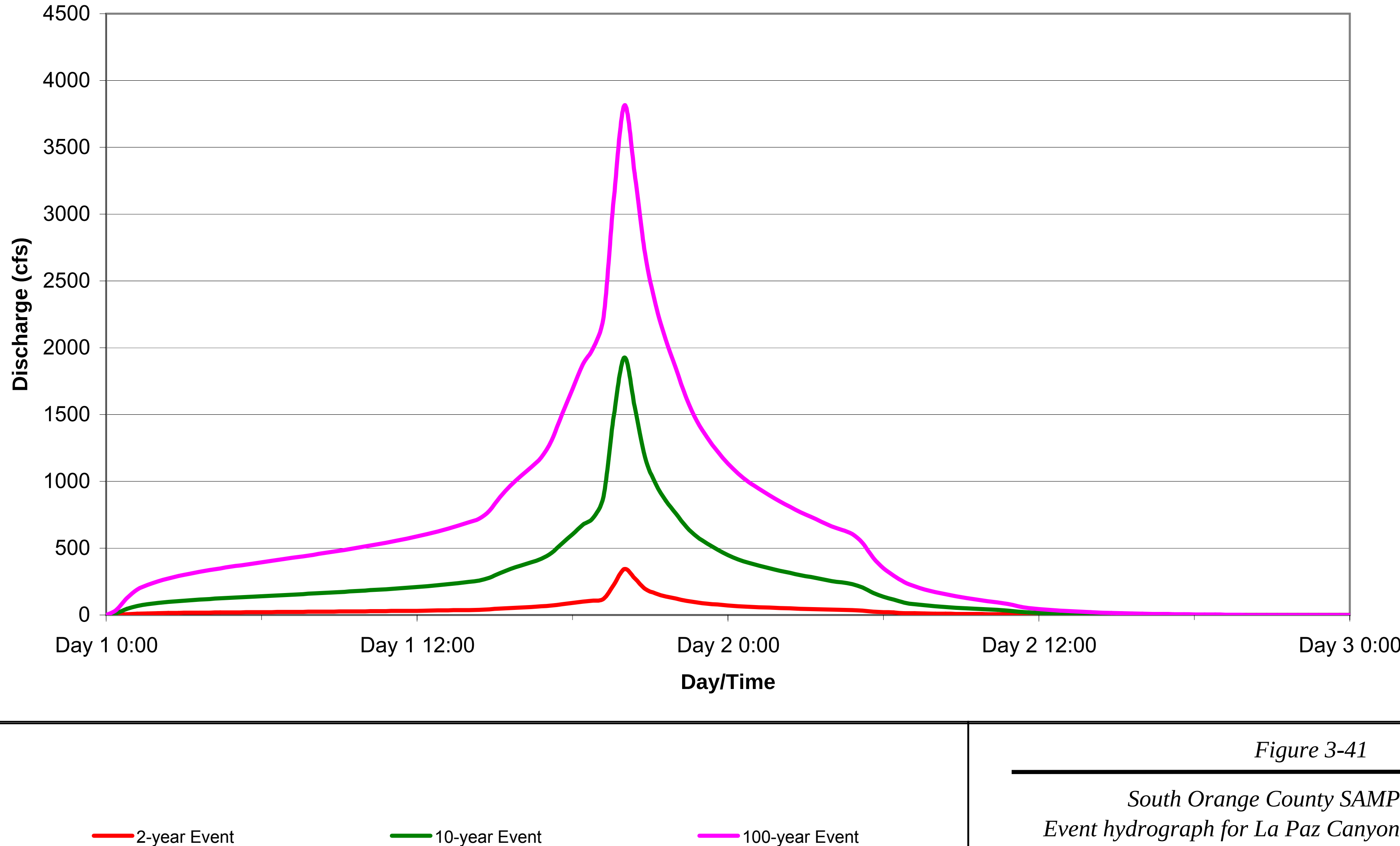


Figure 3-41

South Orange County SAMP
Event hydrograph for La Paz Canyon above Confluence with Gabino Canyon

PWA | PWA#: 1393

In absolute terms, runoff volumes and peak flows from La Paz Canyon are greater than flow values from upper Gabino and upper Cristianitos canyons (Table 3-6). In terms of runoff per unit area, La Paz Canyon runoff is between 59% and 73% of the average for the entire San Mateo watershed for the 2, 10, and 100-year events (Table 3-6). Compared to the other studied sub-basins, peak discharge per unit area is relatively high for La Paz Canyon (Figure 3-2). Runoff volume per unit area at La Paz canyon is slightly greater than for Gabino or upper Cristianitos canyons, but lower than Talega Canyon (Figures 3-2, 3-4).

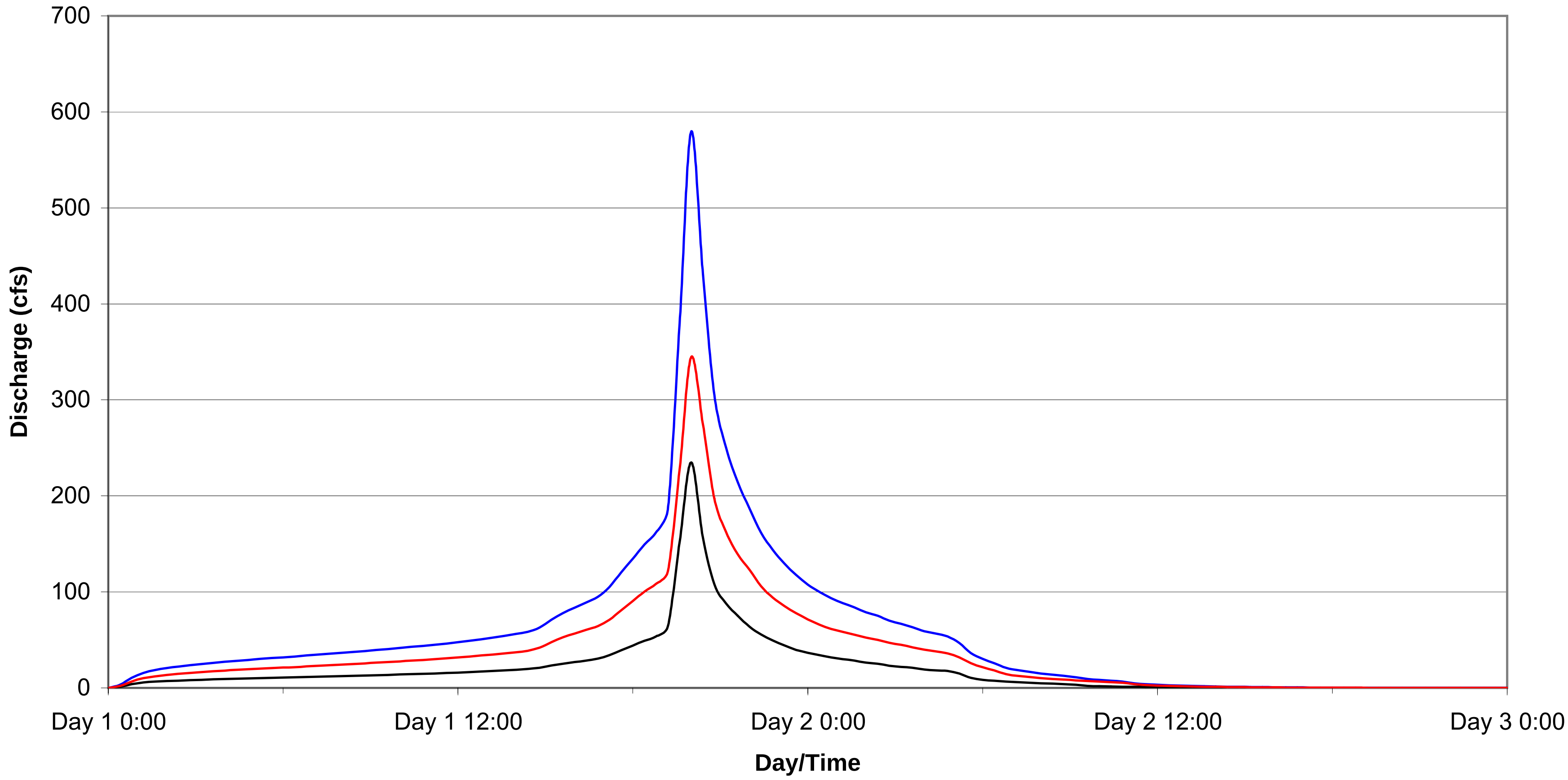
As described above, for the San Juan Creek watershed, a large portion of the western watershed is fully developed. These developed areas raised average values of runoff volumes and peaks for the entire watershed. As a result, runoff volumes and peaks, as a proportion of the total San Juan watershed, appeared low for the relatively undeveloped central San Juan sub-basins studied in this report (Section 3.2 above). A different situation exists in the San Mateo Creek watershed, which is relatively undeveloped throughout its area. For the San Mateo watershed, comparisons between sub-basins and the whole watershed are more meaningful than for the partially developed San Juan watershed. Therefore, results from La Paz and the other studied San Mateo sub-basins, which indicate lower runoff volume per unit area than values for the entire San Mateo Creek watershed, are noteworthy.

3.3.2 Upper Gabino Canyon

3.3.2.1 Drainage Network

The Gabino Canyon sub-basin, including upper Gabino, Blind and La Paz canyons, has an area of 15.6 mi^2 (Figure 3-45). This composite sub-basin has a calculated drainage density of 10 mi/mi^2. The La Paz/Gabino confluence forms a sixth order channel which joins Cristianitos Canyon further downstream. Upper Gabino basin (upstream of the La Paz confluence) is comparable to a reversed image of La Paz Canyon. Rather than tributaries entering from the east (as in the case of La Paz), third and fourth order tributaries enter the main trunk of upper Gabino Canyon from the western side of the sub-basin. Similar to La Paz Canyon, it is believed that these third and fourth order confluence points have enhanced geomorphic and habitat function. The 1274 first order channels within Gabino, Blind, and La Paz canyons account for 51% of the 157 miles of channel mapped for composite sub-basin.

The hydrology of Gabino Canyon was analyzed as part of the San Mateo watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2 above. Upper Gabino and Blind canyons are represented by hydrologic sub-basins 49 and 48 in Figure 3-1 and nodes CC49 and CC48 in the HEC-1 network in Figure 2-7. For the hydrologic analysis, the lower Gabino Canyon sub-basin included Blind Canyon and La Paz Canyon was treated as an independent upstream sub-basin (see above). The upper Gabino, lower Gabino, and Blind canyon hydrologic sub-basins together (excluding La Paz Canyon) have an area of 8.3 mi^2 with a longest watercourse of about 10 miles. Upstream of the Gabino Canyon/Cristianitos Canyon confluence, the upper Cristianitos Canyon watershed has only a small drainage area of 3.7 mi^2. The following paragraphs describe important hydrologic characteristics and processes of the upper and lower Gabino Canyon sub-basins. Estimated runoff values based upon the HEC-1 analysis are offered and illustrated.



Upper Gabino Canyon, U/S of La Paz Canyon CC49

Gabino Canyon D/S of La Paz Canyon CCC49

La Paz Canyon at confluence with Gabino Canyon CC51

Figure 3-42

South Orange County SAMP
2-year Event Gabino Canyon
Confluence with La Paz Canyon

PWA

PWA#: 1393

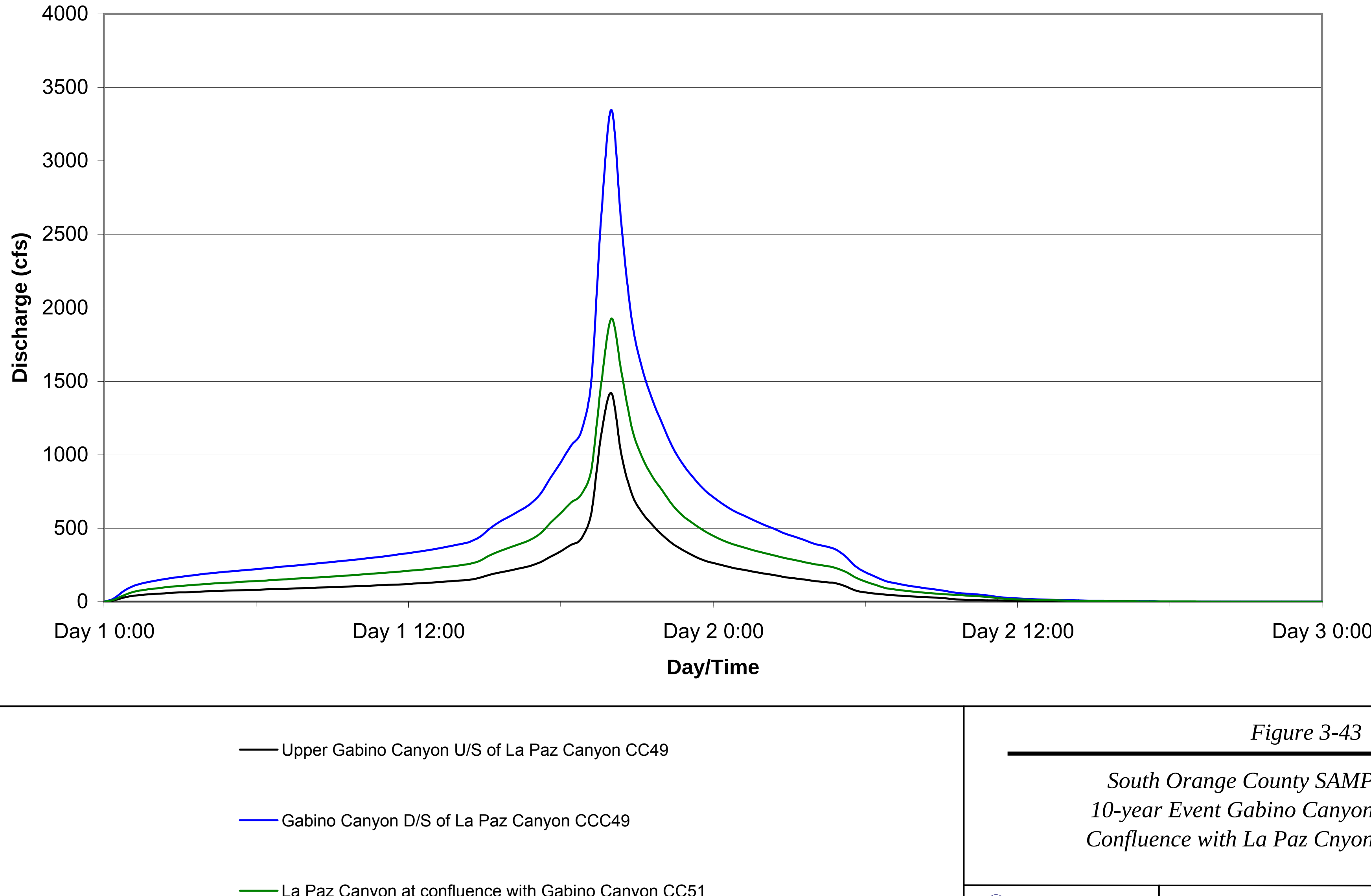


Figure 3-43

South Orange County SAMP
10-year Event Gabino Canyon
Confluence with La Paz Cnyon

PWA | PWA#: 1393

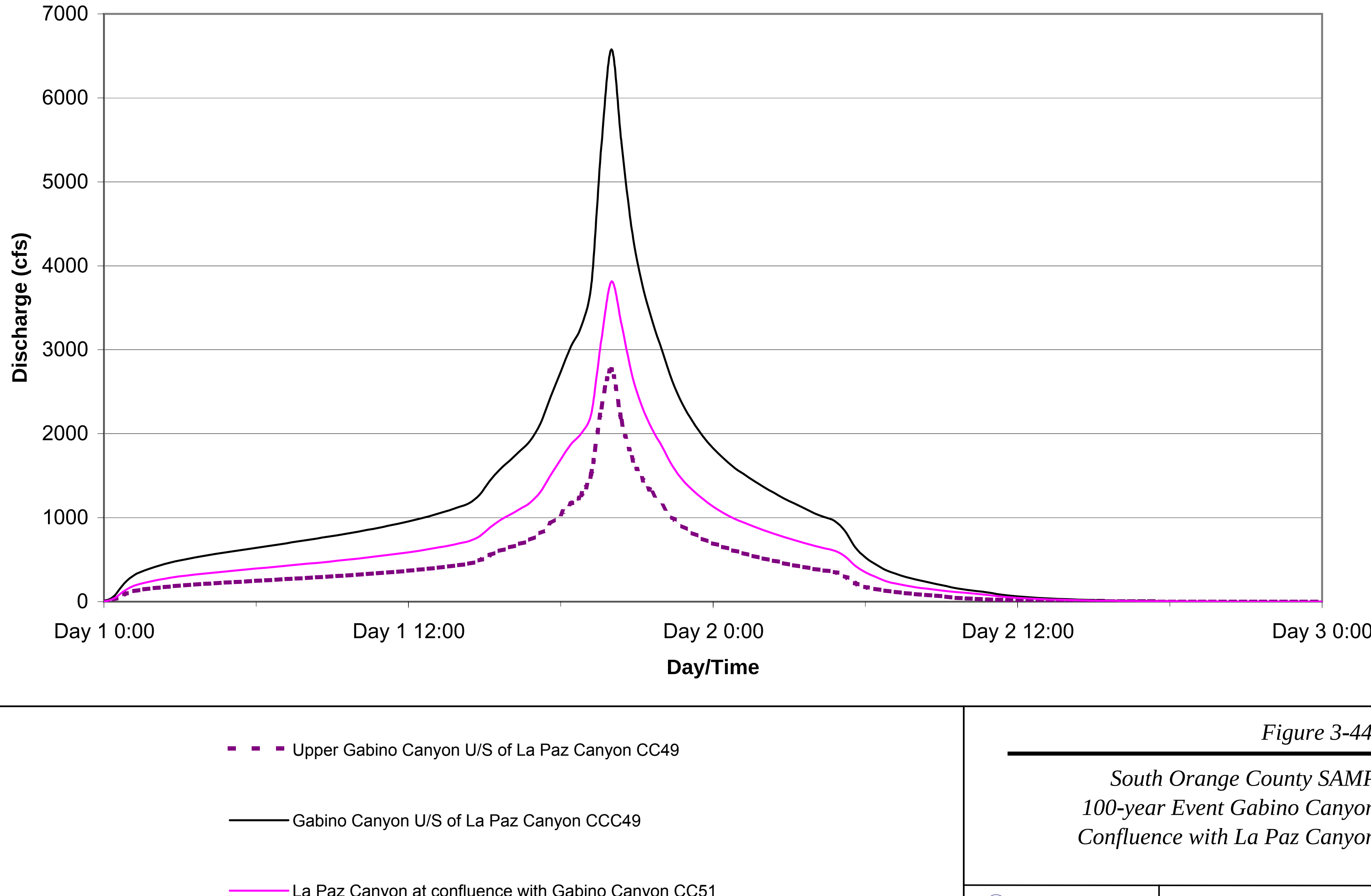


Figure 3-44

South Orange County SAMP
100-year Event Gabino Canyon
Confluence with La Paz Canyon

PWA

PWA#: 1393

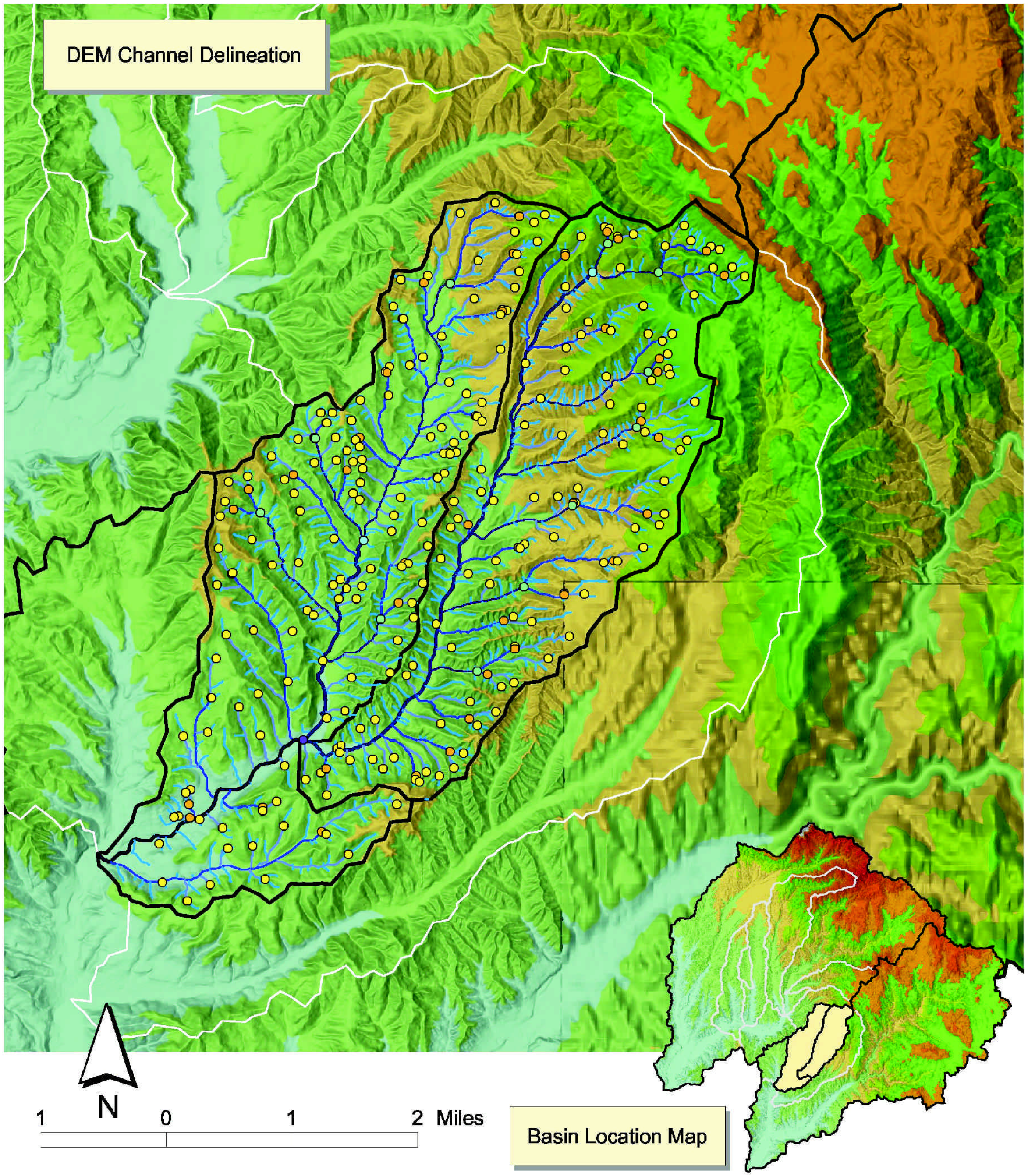


figure 3-45

Channel Network
Gabino, Blind and La Paz Canyons

Channel Network Statistics

Basin Area = 9,959 acres
Drainage Density = 10 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (ft)	Bifurcation Ratio
1	1274	331	421558	5.26
2	242	782	189226	4.94
3	49	2386	116893	4.45
4	11	5046	55509	5.5
5	2	18356	36713	2
6	1	11371	11371	

Total Stream Length: 157.4 mi

Stream Order

1
2
3
4
5
6
7

Order Increment Points

2
3
4
5
6
7

PWA

3.3.2.2 Infiltration

Soil type distributions within Gabino Canyon are shown in Figure 2-2. As reported in Table 3-4, GIS analysis indicates that 56% of the upper sub-basin (node 49) is underlain by soils of hydrologic group C with 31% of the upper basin having the least permeable D-type soils. In the lower Gabino sub-basin and Blind Canyon (node 48), D-type soils are dominant (60%) and C-type soils are less common (34%). Upper Gabino Canyon has better infiltrating soils than La Paz Canyon and lower Gabino Canyon has poorer infiltrating soils than both La Paz and upper Gabbino canyons. The land-use and vegetation distributions for Gabino Canyon are shown in Figure 2-3. As indicated in Table 3-4, upper and lower Gabino Canyon are mostly undeveloped. Developed lands cover approximately 1.3% of the two sub-basins. Therefore, only a small fraction of the basins are impervious to infiltration. The predominant vegetation types in the sub-basins are grassland and sage.

Assigned curve numbers range from 31 to 97 in Gabino Canyon, with an area-averaged curve number of 76.3. The majority of the two sub-basins (88.5%) were characterized by curve numbers between 70 and 89 (Figure 2-5, Table 3-5). Based on these curve numbers, loss rates were calculated for the sub-basins and incorporated into the HEC-1 model. The maximum loss rates for the upper and lower Gabino sub-basins were calculated to be 0.25 and 0.22 inches/hour respectively for the 10- and 100-year events and 0.60 inches/hour for the 2-year event. Total precipitation losses for the 2-, 10-, and 100-year storm events are also reported in Table 3-5.

By a slight amount, upper Gabino Canyon had the highest maximum loss rate of the San Mateo sub-basins analyzed. When considered as a percentage of total storm event rainfall, losses in upper Gabino Canyon were higher than losses in two of the other three reported San Mateo sub-basins for the 2-year and 10-year events and higher than all reported sub-watersheds for the 100-year event. Overall, the slightly higher loss rates calculated for upper Gabino Canyon suggest that infiltration rates may also be relatively higher for this sub-basin compared to the other analyzed San Mateo drainages.

3.3.2.3 Storm Event Runoff

Storm hydrographs were calculated for upper Gabino Canyon, upstream of La Paz Canyon (Figure 3-46), and for the outlet of Gabino Canyon at Cristianitos Canyon (Figure 3-47) using the HEC-1 hydrologic model. Gabino Canyon hydrographs have a similar shape to the La Paz Canyon hydrographs, with a single distinct peak that rises and falls relatively rapidly. The rising limb of the hydrograph is steeper than the falling limb. This shape is indicative of a somewhat flashy runoff response and may be attributable to the relatively high proportion of low-permeability soils in the watershed. Peak flows at the mouth of Gabino Canyon (at the confluence with Cristianitos Creek) occur at 21:12, 20:48, and 20:24 hours following the onset of precipitation for the 2-, 10- and 100-year events respectively (Table 3-7). Flows exiting Gabino Canyon peak about 1.2, 0.8, and 0.4 hours after peak flows have exited the upper Cristianitos sub-basin (upstream of the Gabino confluence) for the 2-, 10-, and 100-year events respectively. Interestingly, for the 2- and 10-year events, storm peaks are somewhat attenuated between the Upper Gabino/La Paz confluence upstream and the Gabino/Cristianitos confluence downstream (Figures 3-48, 3-49). This is not the case for the 100-year event, whereby the downstream location has higher peak flows (Figure 3-50). The influence of runoff from Gabino Canyon on Cristianitos Creek downstream of their confluence can be seen in Figures 3-53, 3-54, and 3-55.

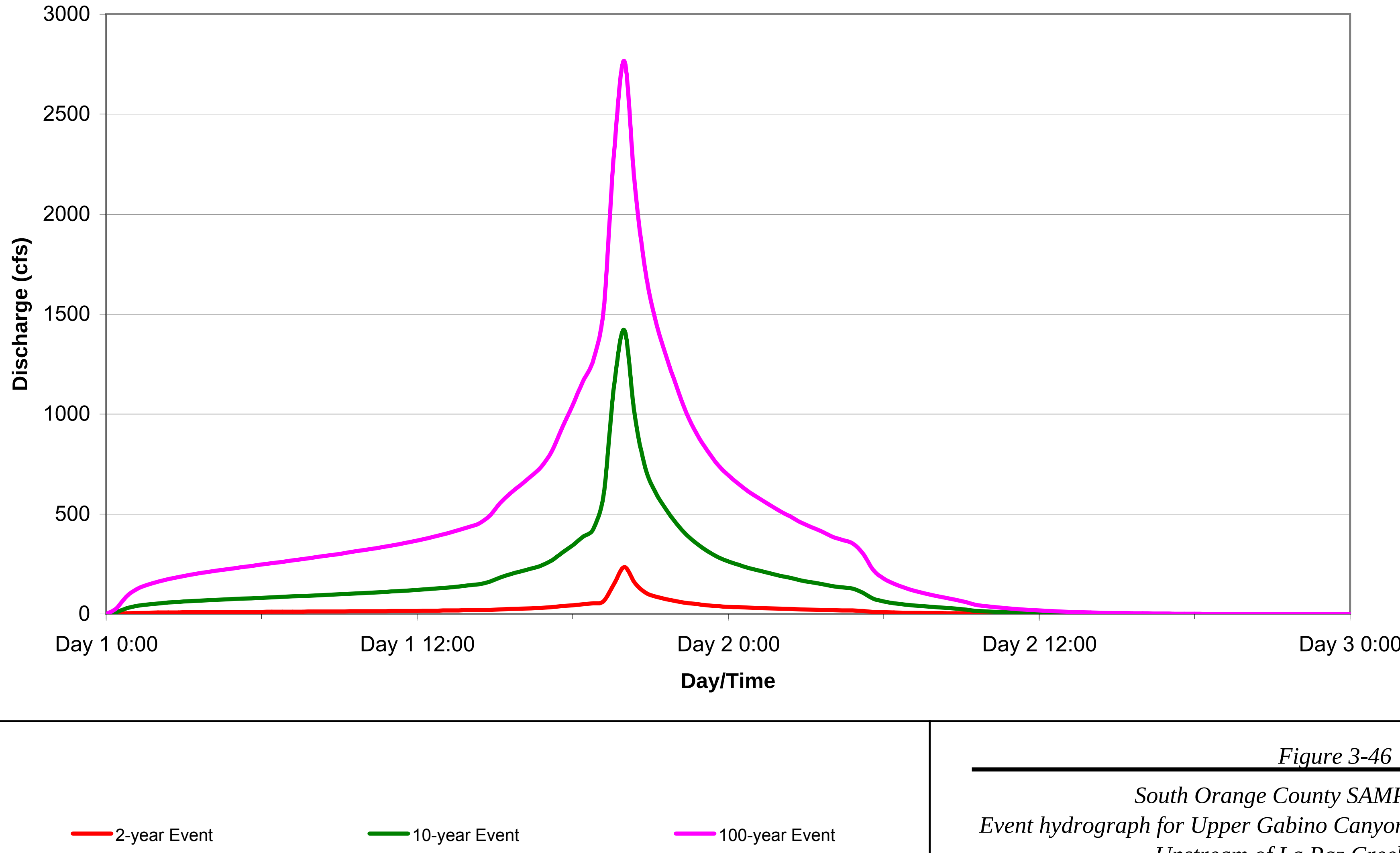


Figure 3-46

South Orange County SAMP
Event hydrograph for Upper Gabino Canyon
Upstream of La Paz Creek

PWA

PWA#: 1393

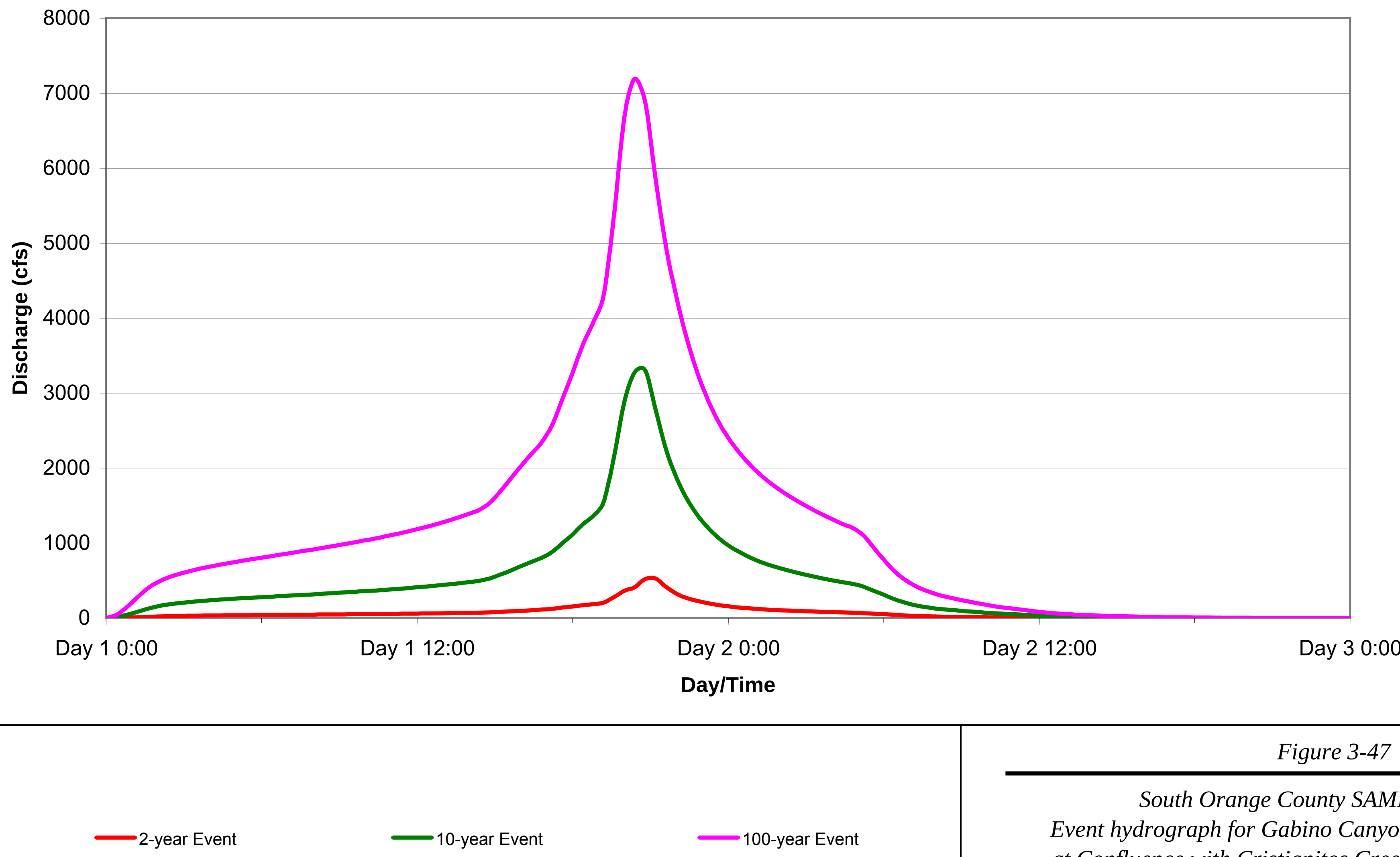


Figure 3-47

South Orange County SAMP
Event hydrograph for Gabino Canyon
at Confluence with Cristianitos Creek

PWA | PWA#: 1393

Peak flow rates and volumes for both upper and lower Gabino Canyon are shown in Table 3-6. In absolute terms, peak flow rates and volumes at the mouth of Gabino Canyon are on the order of four-times greater than flows entering from the neighboring upper Cristianitos sub-basin which is a considerably smaller watershed area. The 10-year peak flow from Gabino Canyon was calculated at 3301 cfs. Gabino Canyon has lower peak discharge per unit area than Cristianitos or La Paz canyons, but not less than Talega Canyon (Figure 3-2). In terms of runoff volume per unit area, Gabino Canyon is similar to Cristianitos Canyon, and a bit less than La Paz and Talega canyons (Figure 3-4).

3.3.3 Upper Cristianitos Canyon

3.3.3.1 Drainage Network

The upper Cristianitos Canyon sub-basin (Figure 3-51), upstream of the Gabino Canyon confluence, has an area of 3.7 mi^2 with a longest watercourse of approximately 3.7 miles. This drainage represents the westernmost headwaters of the San Mateo watershed. Upper Christianitos Canyon is a fifth order network with a calculated drainage density of 8 mi/mi^2. Compared with other sub-basins of this study, the upper Christianitos watershed has a more rounded, or pear-shaped configuration. Additionally, the headwater areas are not as steep as many of the other sub-basins. These conditions reflect the physiographic and geologic setting of the upper Cristianitos basin just south of the dividing ridge with the San Juan watershed. As a result of this setting, third and fourth-order tributary arms are distributed fairly evenly and have similar lengths. There are 187 first-order channels, which accounts for nearly half of the basin’s total stream length.

The hydrology of Cristianitos Canyon was analyzed as part of the San Mateo watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2 above. This canyon is represented by sub-basin 45 in Figure 3-1 and node CC45 in the HEC-1 network in Figure 2-7. The following paragraphs describe important hydrologic characteristics and processes of the Cristianitos Canyon sub-basin. Estimated runoff values based upon the HEC-1 analysis are shown.

3.3.3.2 Infiltration

The soil type distribution within the Cristianitos Canyon sub-basin is shown in Figure 2-2. As reported in Table 3-4, GIS analysis indicates that the majority of the sub-basin is underlain by soils of hydrologic groups C (43.9%) and D (42.7%). Soils in these classes are poor infiltrators. Upper Cristianitos Canyon also contains a relatively larger portion of the better infiltrating soil group B (12.9%) than the other San Mateo sub-basins in this report. The land-use and vegetation distributions for Cristianitos Canyon are shown in Figure 2-3. As indicated in Table 3-4, the vast majority of Cristianitos Canyon is undeveloped (97.2%). It is estimated that there are no significant areas that are impervious to infiltration. The predominant vegetation types in the sub-basin are grassland and sage.

Assigned curve numbers range from 40 to 97 in Cristianitos Canyon (Table 3-5, Figure 2-5), with an area-averaged curve number of 77.2. Most of the basin (85.8%) was characterized by curve numbers between 70 and 89. Based on these curve numbers, loss rates were calculated for the sub-basin and incorporated into the HEC-1 model. The area-averaged maximum loss rate for Cristianitos Canyon was calculated to be 0.24 inches/hour for the 10- and 100-year events, and 0.60 inches/hour for the 2-year event. Total precipitation losses for the 2-, 10-, and 100-year storm events are also reported in Table 3-5.

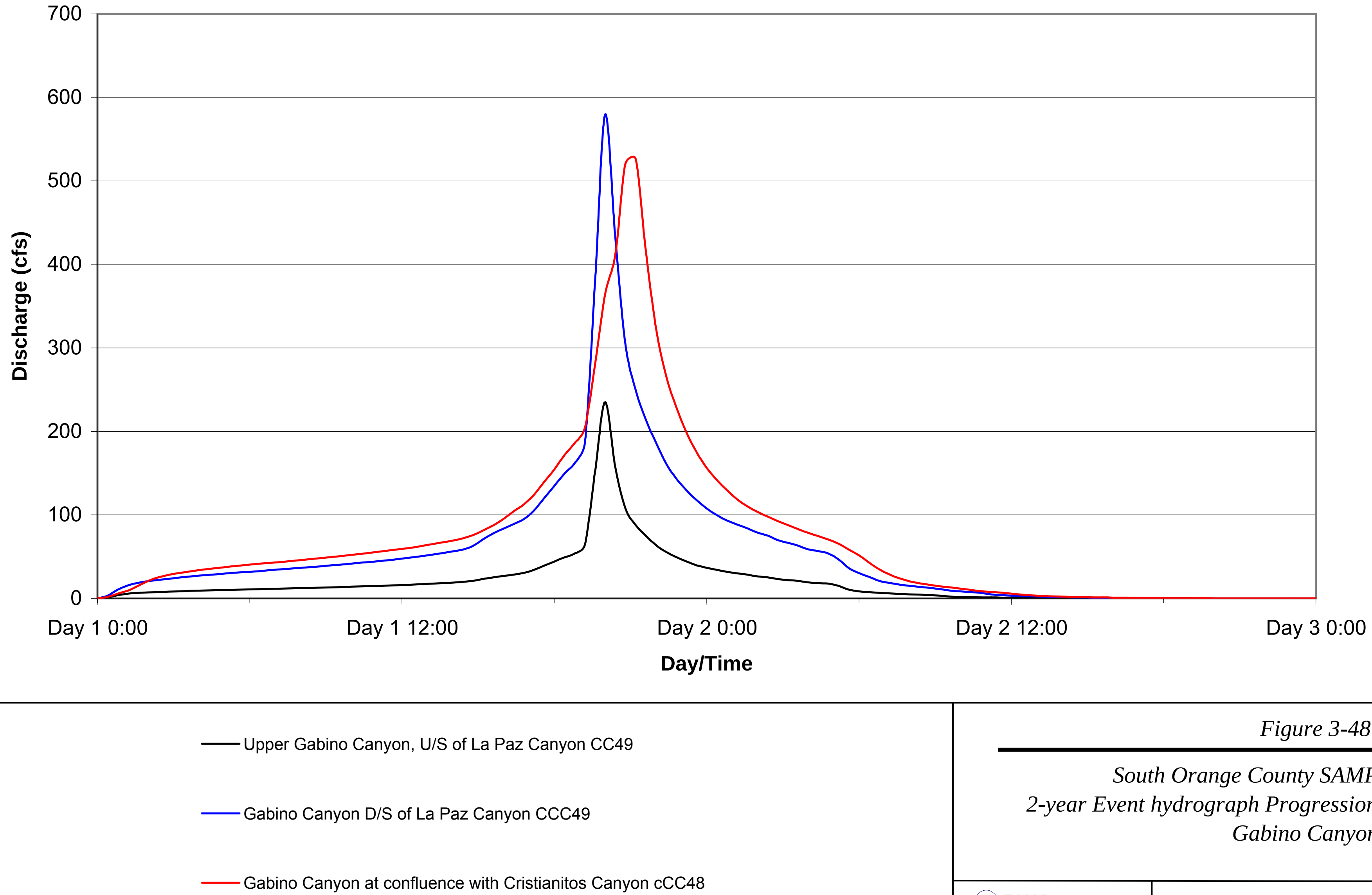


Figure 3-48

South Orange County SAMP
2-year Event hydrograph Progression
Gabino Canyon

PWA

PWA#: 1393

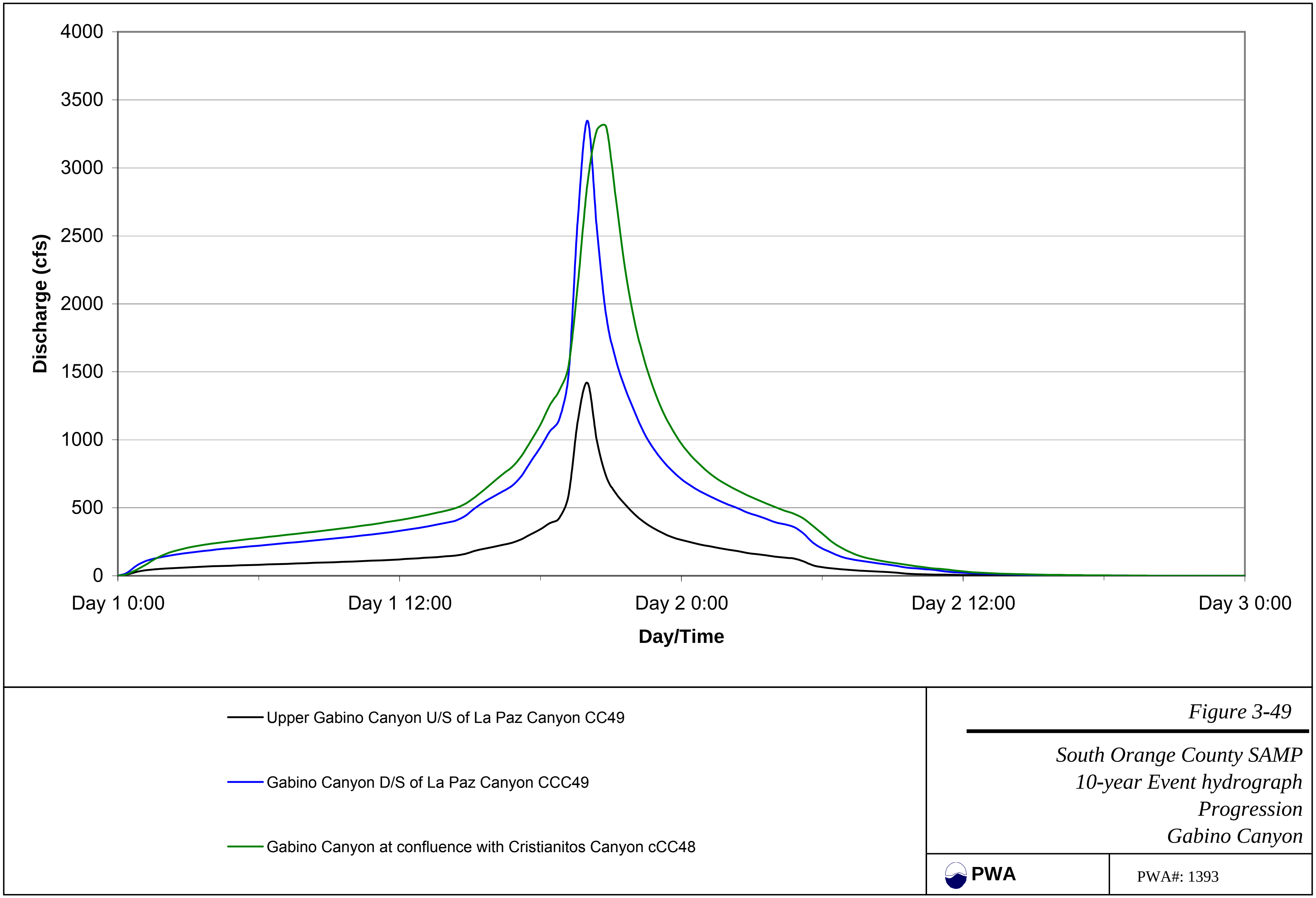


Figure 3-49

South Orange County SAMP
10-year Event hydrograph
Progression
Gabino Canyon

PWA

PWA#: 1393

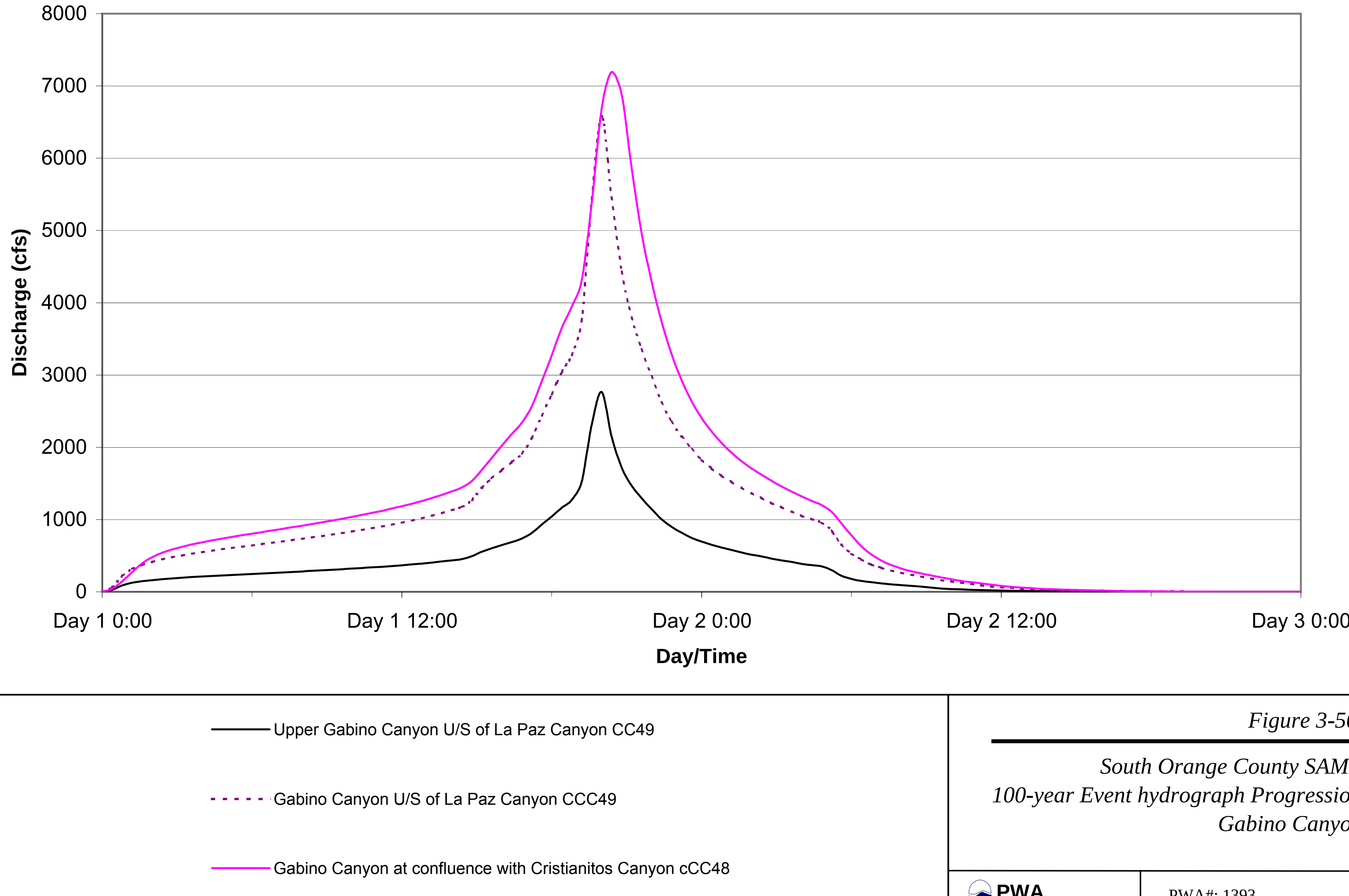
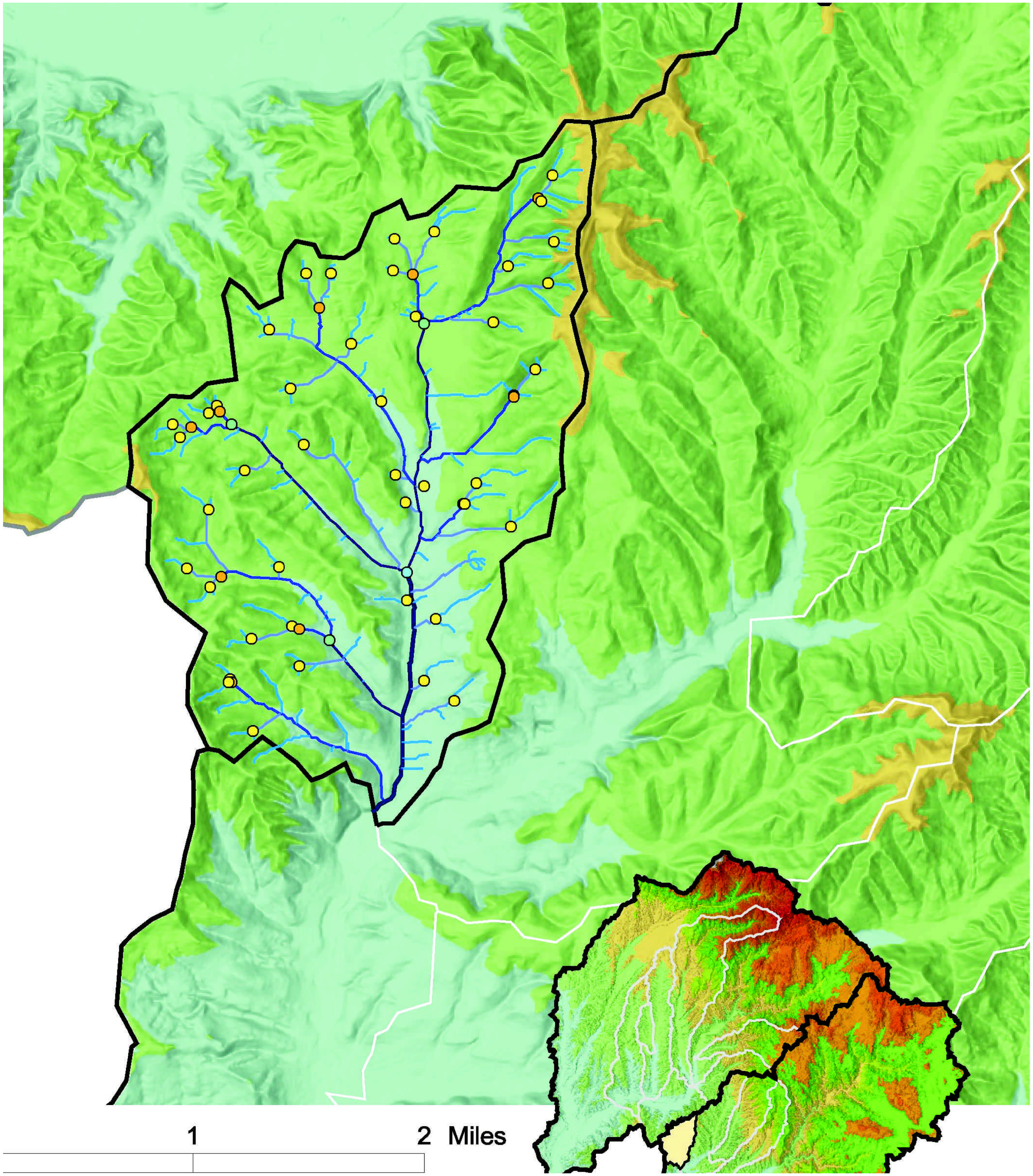


Figure 3-50

South Orange County SAMP
100-year Event hydrograph Progression
Gabino Canyon

PWA | PWA#: 1393



Cristianitos C
upstream of Gabir

Channel Network Statistics

Basi
Drair

Strahler Order	Number of Channels	Average Length (ft)
1	179	407
2	44	754
3	10	2553
4	3	4610
5	1	5862

Total Stream Leng

Stream Order

1
2
3
4
5
6
7

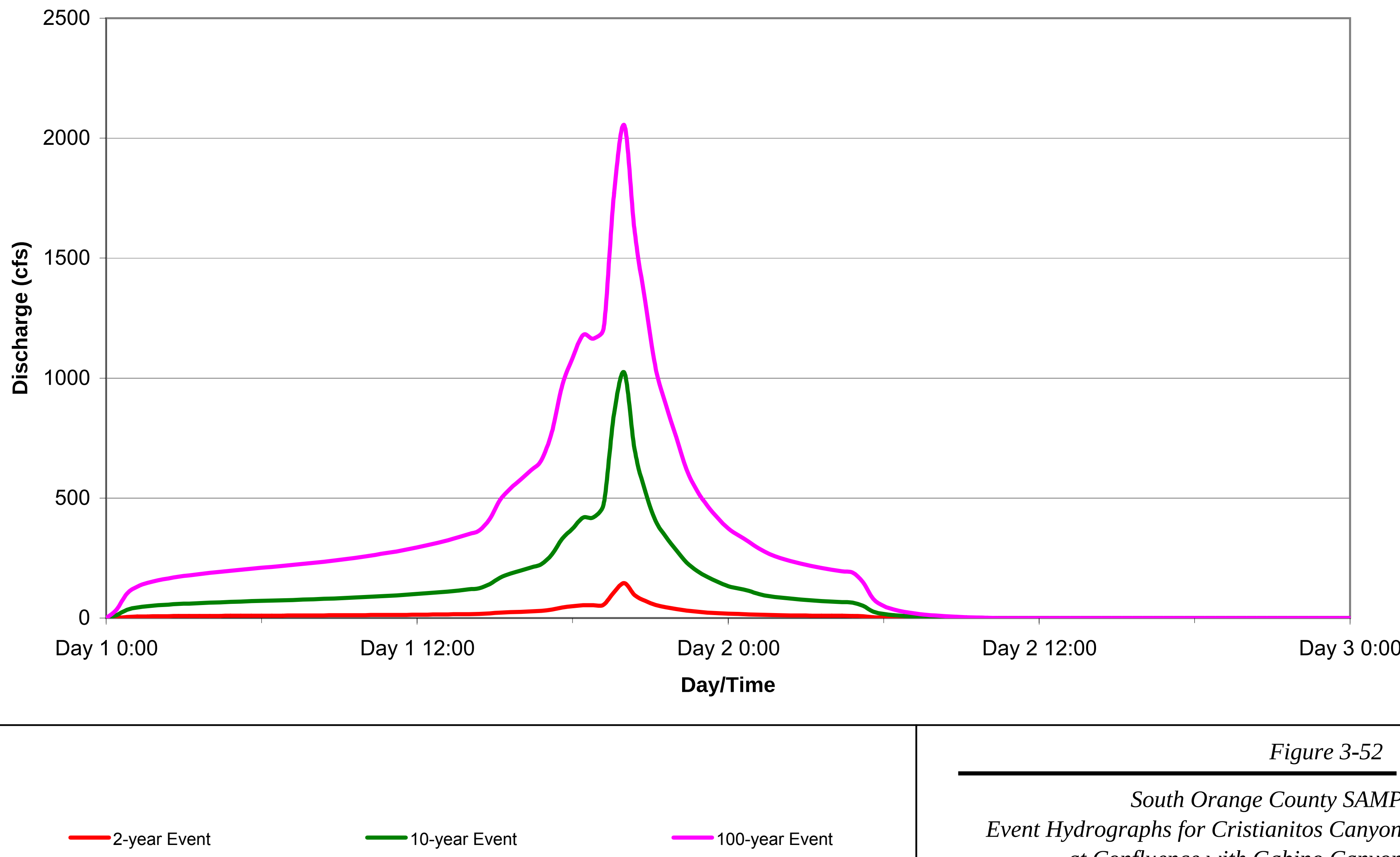


Figure 3-52

South Orange County SAMP
Event Hydrographs for Cristianitos Canyon
at Confluence with Gabino Canyon

PWA PWA#: 1393

As a percentage of precipitation, calculated loss rates for Cristianitos Canyon are comparable to the other studied San Mateo sub-basins and higher than the overall San Mateo watershed totals (Table 3-5). Loss rates calculated for Cristianitos Canyon suggest that infiltration rates within the sub-basin may be a higher relative to the other reported sub-basins. This seems reasonable given the comparatively higher percentage of type-B soils and the minimal development in the sub-basin.

3.3.3.3 Storm Event Runoff

Three storm hydrographs were calculated for the outlet of upper Cristianitos Canyon, upstream of the Gabino Canyon confluence (Figure 3-52). These hydrographs have a pronounced peak similar to the other studied sub-basins. Peak flows at upper Cristianitos Canyon occur at 20:00 hours following the onset of precipitation. As noted above, this peak time occurs prior to peak times for Gabino Canyon at the Cristianitos Canyon confluence. The combined effect of joined runoff from Gabino Canyon and Cristianitos Creek downstream of their confluence is seen in Figures 3-53, 3-54, and 3-55.

In absolute terms, runoff volumes and peak flows from Cristianitos Canyon are the lowest of the studied San Mateo sub-basins (Figures 3-1, 3-3). This is attributable to the smaller size of this sub-basin. In terms of peak discharge per unit area, upper Cristianitos had the highest rates for the 10- and 100-year events of the studied San Mateo sub-basins (Figure 3-2). This higher result for peak discharge per unit area may be somewhat surprising considering that Cristianitos Canyon had more favorable soil and infiltration conditions than the other studied San Mateo sub-basins. It is believed that routing conditions in the Cristianitos Canyon sub-basin, which is the least elongated of the San Mateo sub-basins, enhance flow concentration and generate larger peak flows per unit area. The case of Cristianitos Canyon is a very interesting contrast to peak runoff conditions at the elongated Talega Canyon discussed below. For runoff volume per unit area, values from Cristianitos Canyon are comparable, and a bit lower, than the other studied sub-basins (Figure 3-4) and are only between 43% and 67% of the average for the entire San Mateo watershed (Table 3-6). Lower runoff volumes from Cristianitos Canyon seems reasonable considering the higher proportion of better infiltrating soils in this sub-basin. The 10-year peak flow from Cristianitos Canyon was calculated at 1,022 cfs.

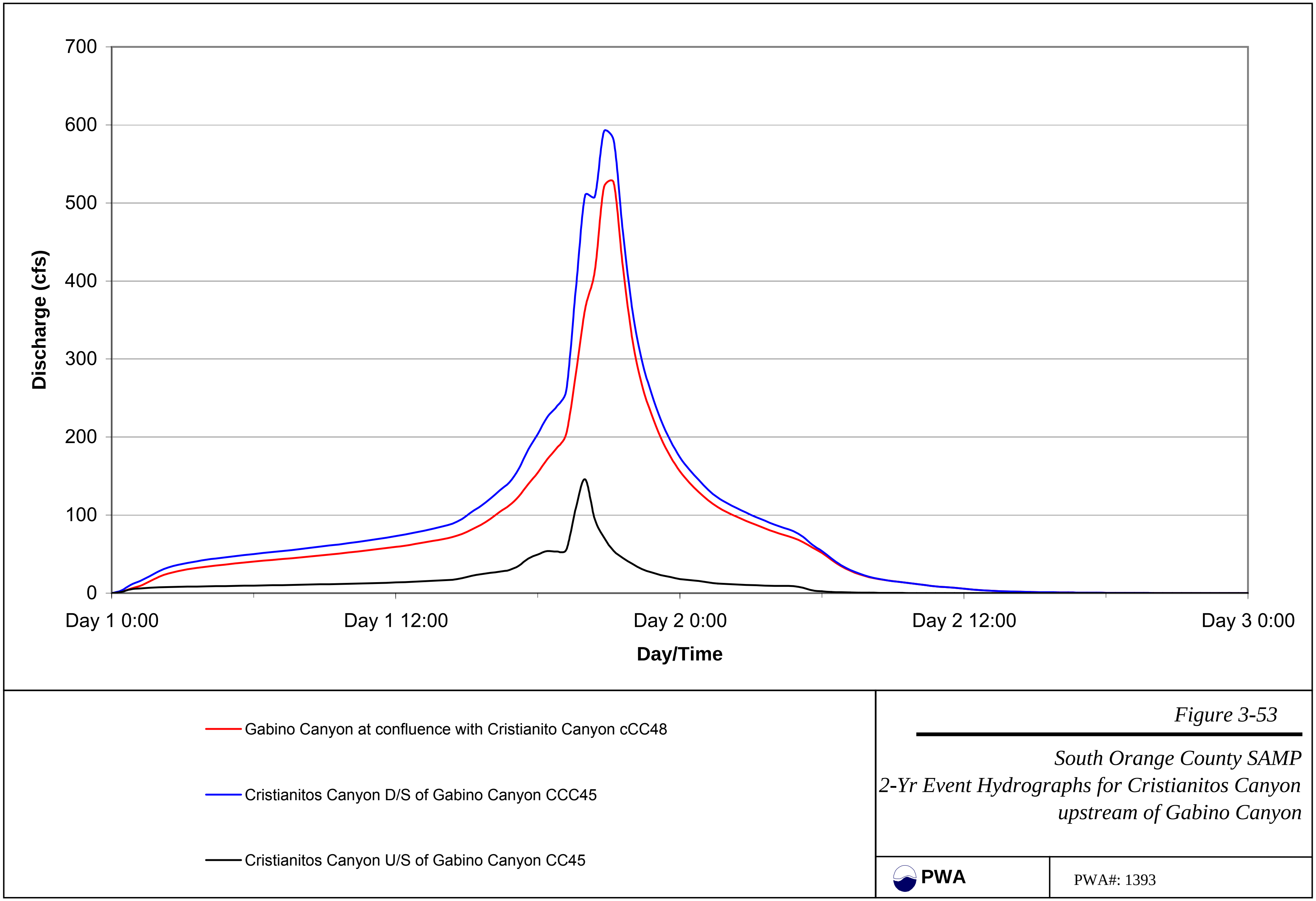


Figure 3-53

South Orange County SAMP
2-Yr Event Hydrographs for Cristianitos Canyon upstream of Gabino Canyon

PWA PWA#: 1393

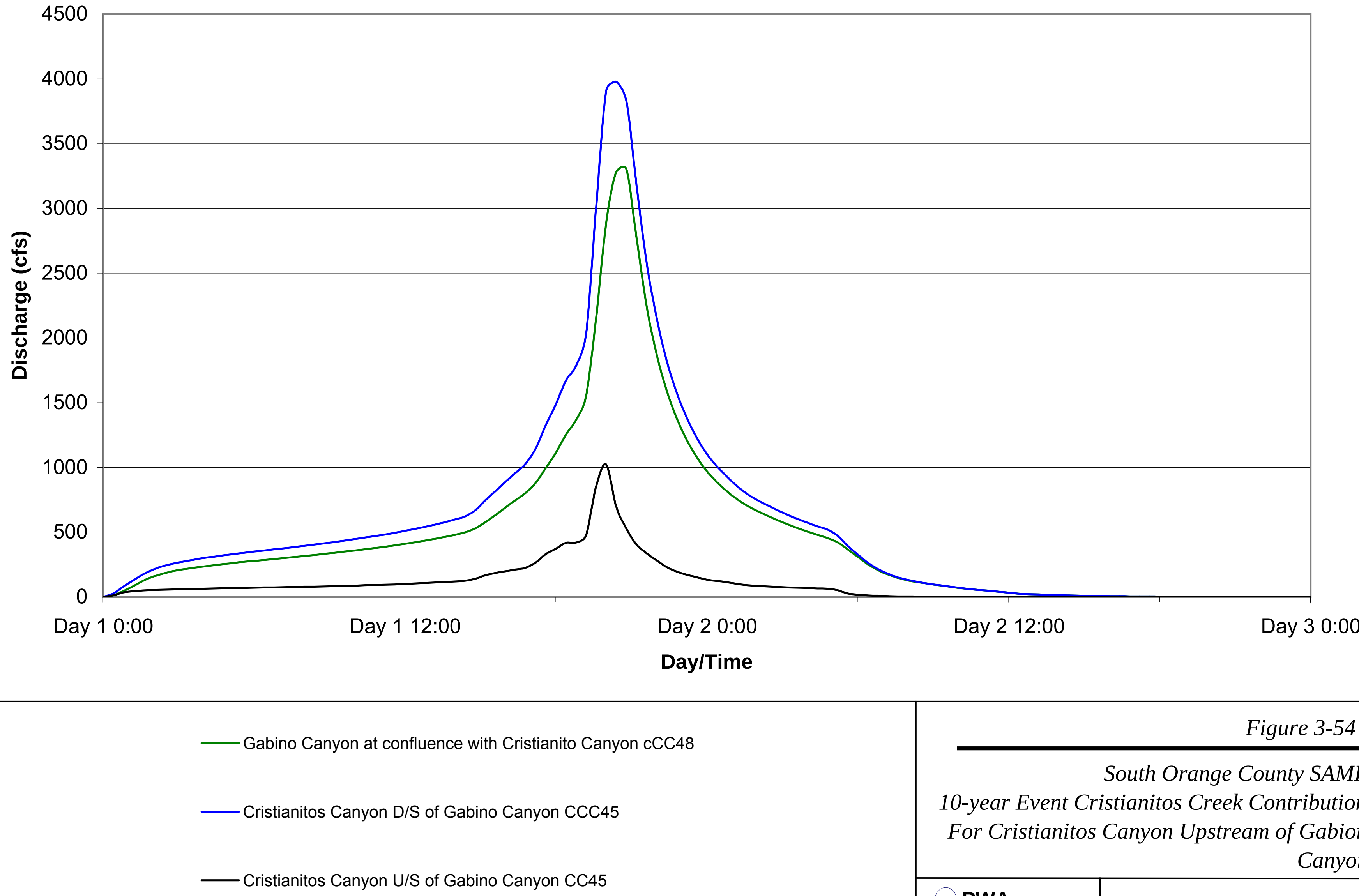


Figure 3-54

South Orange County SAMP
10-year Event Cristianitos Creek Contribution
For Cristianitos Canyon Upstream of Gabion Canyon

PWA PWA#: 1393

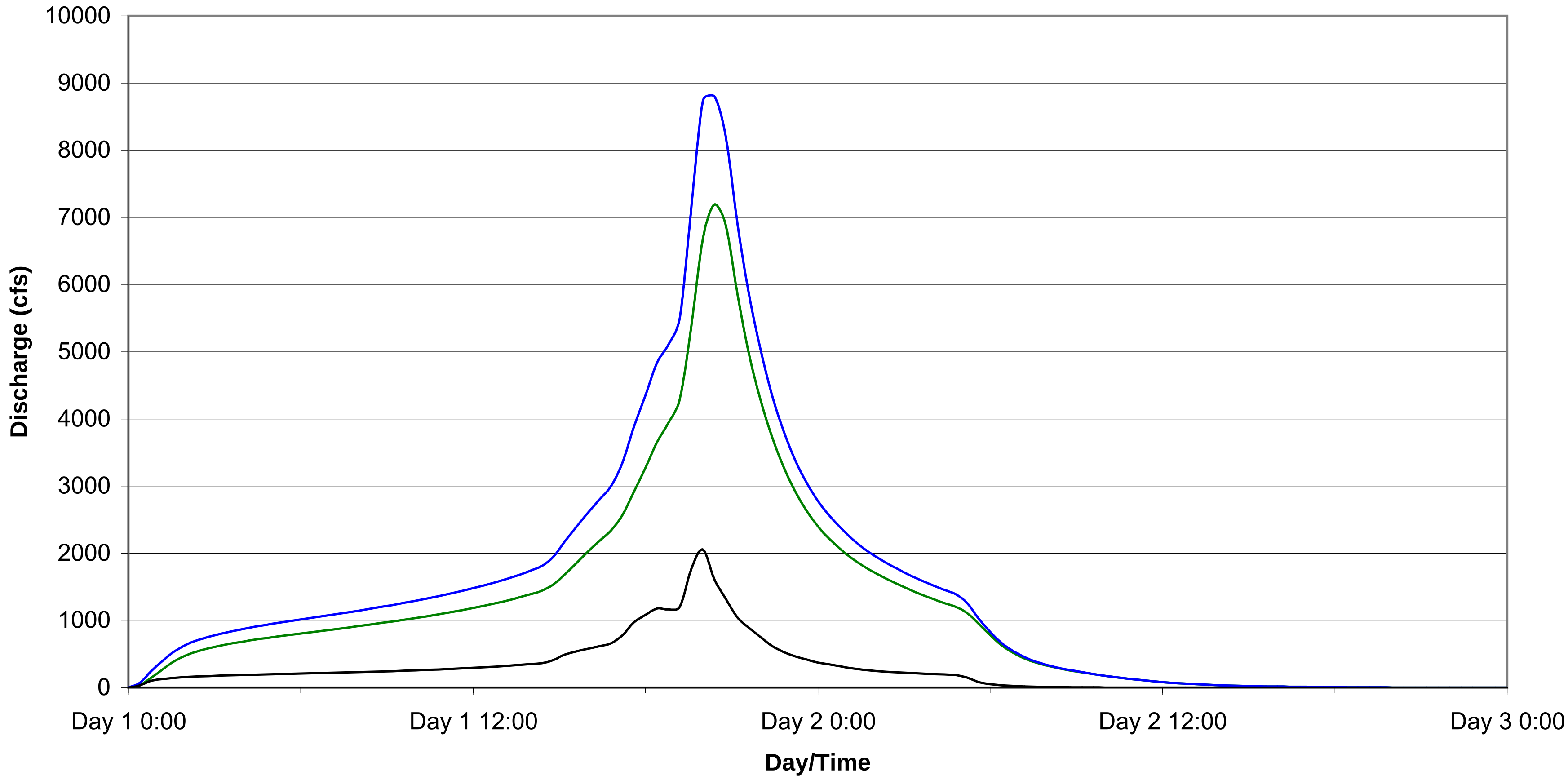


Figure 3-55

South Orange County SAMP
100-year Event Cristianitos Creek Contribution For Cristianitos Canyon Upstream of Gabion Canyon

PWA PWA#: 1393

3.3.4 Talega Canyon

3.3.4.1 Drainage Network

Because WES mapping was not available for Talega Canyon, this sub-basin was mapped using the channel prediction parameters to approximate the density expected of the channel system (Figure 3-56). The resulting fifth order system has a drainage density of 9 mi/mi^2, with 501 first order channels in this 8.3 mi^2 basin. The Talega Canyon sub-basin is extremely elongated, with the longest watercourse over 10.1 miles. Although there are several first and second order channels which join directly to the trunk stream, there is only one fourth order side valley tributary that joins the main stream segment. At its western terminus, Talega Canyon meets Cristianitos Canyon, downstream of the Gabino Confluence. Upstream of the Talega Canyon/Cristianitos Canyon confluence, the Cristianitos Canyon watershed has an area of 28.76 mi^2.

The hydrology of Talega Canyon was analyzed as part of the San Mateo watershed HEC-1 model. Modeling methods and procedures are summarized in Section 2.2 above. This area is represented by sub-basin 47 in Figure 2-1 and node CC47 in the HEC-1 network in Figure 2-7. The following paragraphs describe important hydrologic characteristics and processes of the Talega Canyon sub-basin. Estimated runoff values based upon the HEC-1 analysis are offered and illustrated.

3.3.4.2 Infiltration

The soil type distribution within the Talega Canyon sub-basin is shown in Figure 2-2. As reported in Table 3-4, GIS analysis indicates that the majority of the sub-watershed is underlain by soils of hydrologic groups C (18.8%) and D (75.6%). Talega Canyon has the highest proportion of poorer infiltrating type-D soils than any of the other analyzed San Mateo sub-basins. The land-use and vegetation distributions for Talega Canyon are shown in Figure 2-3. As indicated in Table 3-4, almost the entire Talega Canyon sub-basin is undeveloped (98.9%). Developed lands cover approximately 1.1% of the sub-basin. Approximately 0.6% of the sub-basin is impervious to infiltration. The predominant vegetation types in the sub-basin are sage, chaparral, and grassland.

Assigned curve numbers range from 31 to 89 in Talega Canyon, with an area-averaged curve number of 79.2 (Figure 2-5). The majority of the basin (94.5%) was characterized by curve numbers between 70 and 89. Based on these curve numbers, loss rates were calculated for the sub-basin and incorporated into the HEC-1 model. The area-averaged maximum loss rate for Talega Canyon was calculated to be 0.22 inches/hour for the 10- and 100-year events, and 0.60 inches/hour for the 2-year event. Total precipitation losses for the 2-, 10-, and 100-year storm events are reported in Table 3-5.

Relative to the other San Mateo watershed areas described in this report calculated loss rates for Talega Canyon are low. Of the sub-watersheds described, Talega Canyon had the lowest maximum loss rate. When considered as a percentage of total storm event rainfall, losses in Talega Canyon were the lowest of the studied San Mateo sub-basins. The 10- and 100-year maximum loss rates calculated for Talega Canyon were lower than all of the other studied San Juan or San Mateo sub-basins. This result is likely attributable to the large proportion of type-D soils in the sub-basin (75.6%), which are poor infiltrators.

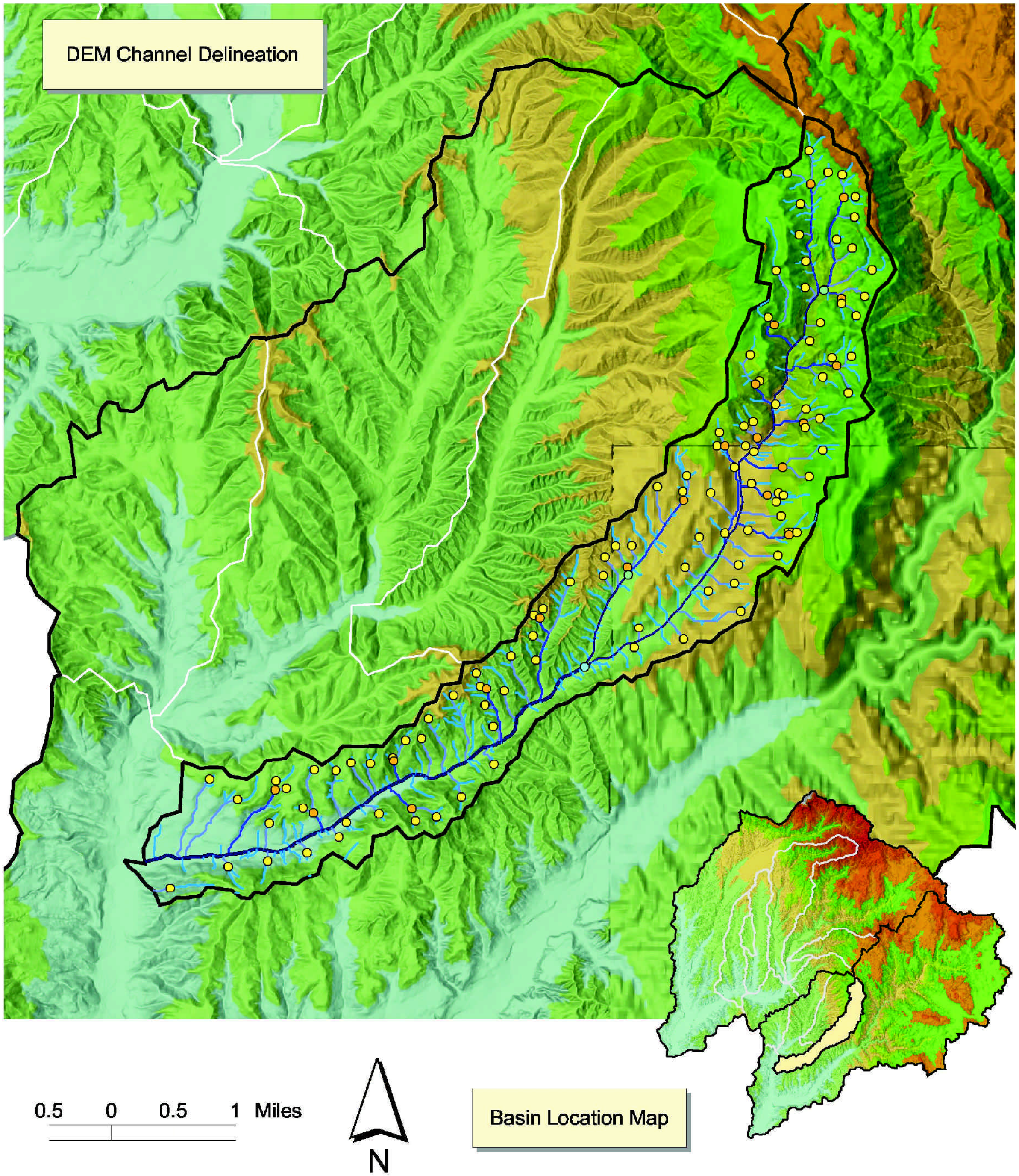


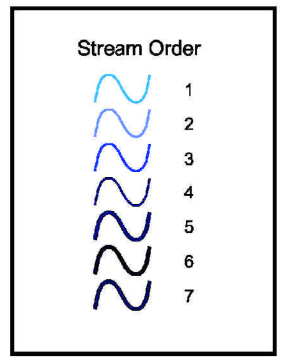
figure 3-56

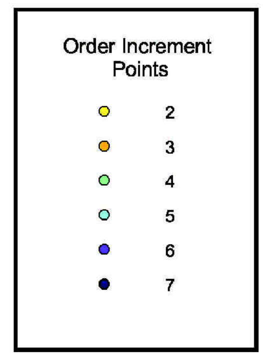
Channel Network Talega Canyon

Channel Network Statistics

Basin Area = 5,360 acres
Drainage Density = 9 mi/mi2

Strahler Order	Number of Channels	Average Length (ft)	Total Length (m)	Bifurcation Ratio
1	501	391	195892	4.36
2	115	905	104121	5.75
3	20	2244	44882	10
4	2	12692	25384	2
5	1	22054	22054	
		Total Stream Length:	74.3	





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3.3.4.3 Storm Event Runoff

Three storm hydrographs were calculated for the outlet of Talega Canyon using the HEC-1 hydrologic model (Figure 3-57). Although there are pronounced peaks, these hydrographs are somewhat broader than the hydrographs for the other studied San Mateo sub-basins. This shape may be attributable to the elongated geometry of the Talega Canyon sub-basin, which tends to attenuate the flood wave as it travels through the sub-basin. While upper tributaries contribute runoff to the main trunk stream, lower tributaries have already conveyed their runoff out of the sub-basin. As a result, elongated basins like Talega Canyon with lengthy routing reaches can have dampened hydrographs.

At Talega Canyon peak flows occur at 20:24 hours following the beginning of precipitation (Table 3-7). This peak time is the same as the peak time for Cristianitos Canyon upstream of its confluence with Talega Canyon. Therefore, peak flows from Talega Canyon contribute strongly to peak flows in Cristianitos Canyon at the confluence. The arrival of these coincidental peaks significantly increases the downstream hydrograph (Figures 3-58, 3-59, 3-60).

In absolute terms, runoff volumes and peak flows from Talega Canyon are intermediate in range compared to other reported San Mateo sub-basins. The 10-year peak flow from Talega Canyon was calculated at 1621 cfs. Peak discharge per unit area is lower for Talega Canyon than the other studied San Mateo sub basins (Figure 3-2). This occurs despite Talega Canyon's lower loss and infiltration conditions. In terms of runoff volume per unit area, Talega Canyon is somewhat higher than the other studied San Mateo sub-basins (Figure 3-4). Talega Canyon produced between 65% and 78% as much runoff on a per-acre basis as the average for the San Mateo Creek watershed as a whole (Table 3-6). These percentages for volume per unit area are higher than the other studied San Mateo sub-basins. Therefore, at Talega Canyon there is an interesting contrast between runoff peaks, which are relatively low, and runoff volumes, which are relatively high. Higher runoff volumes are generated due to the high proportion of poorly draining soils. The abundance of D-type soils increases runoff generation. However, the elongated shape of the sub-basin and long routing distance reduces the magnitude of peak flow rates. Peak discharge rates are attenuated as they travel downstream through the sub-basin. This combination of poorly draining soils in an elongated sub-basin produces a complex result.

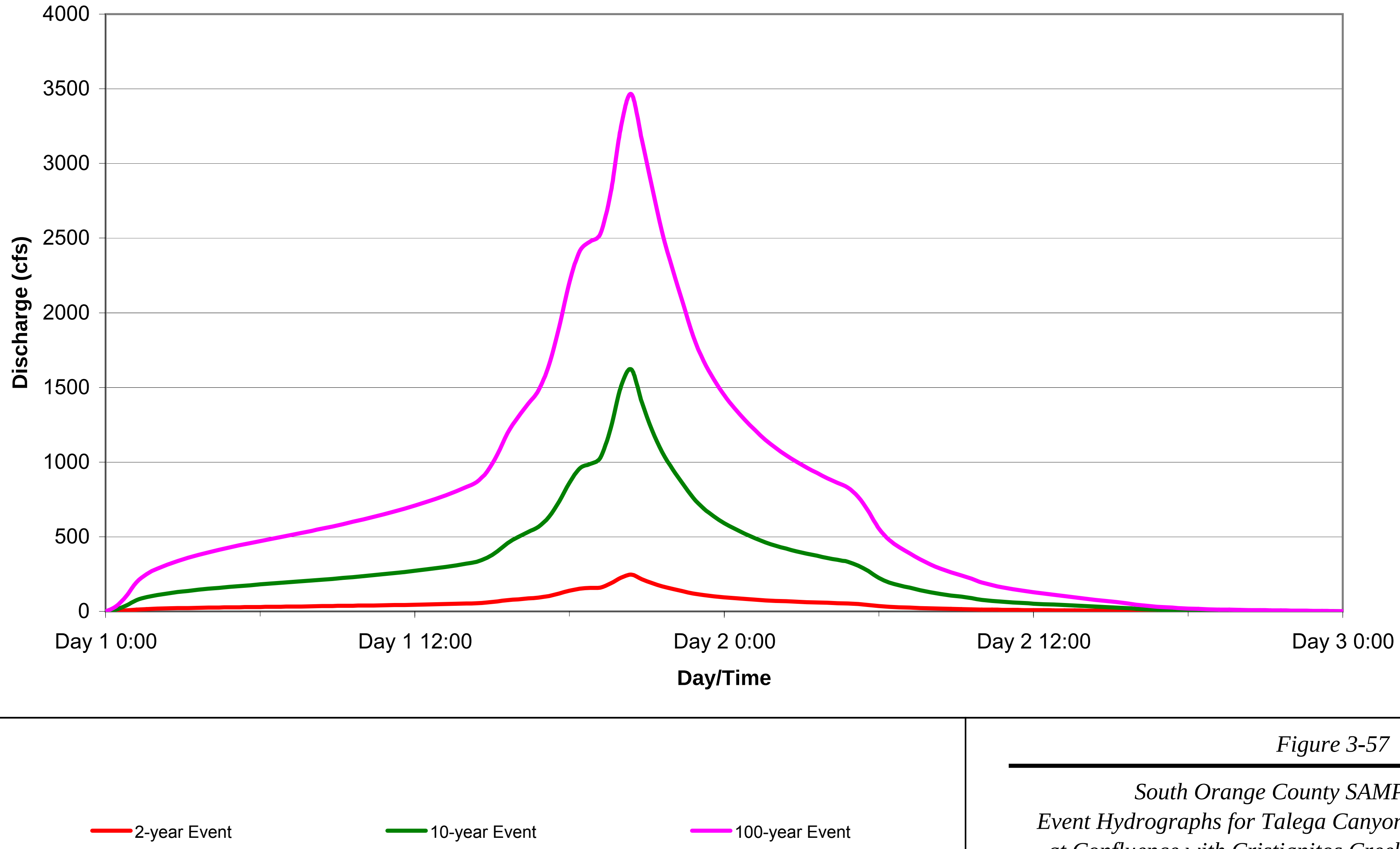
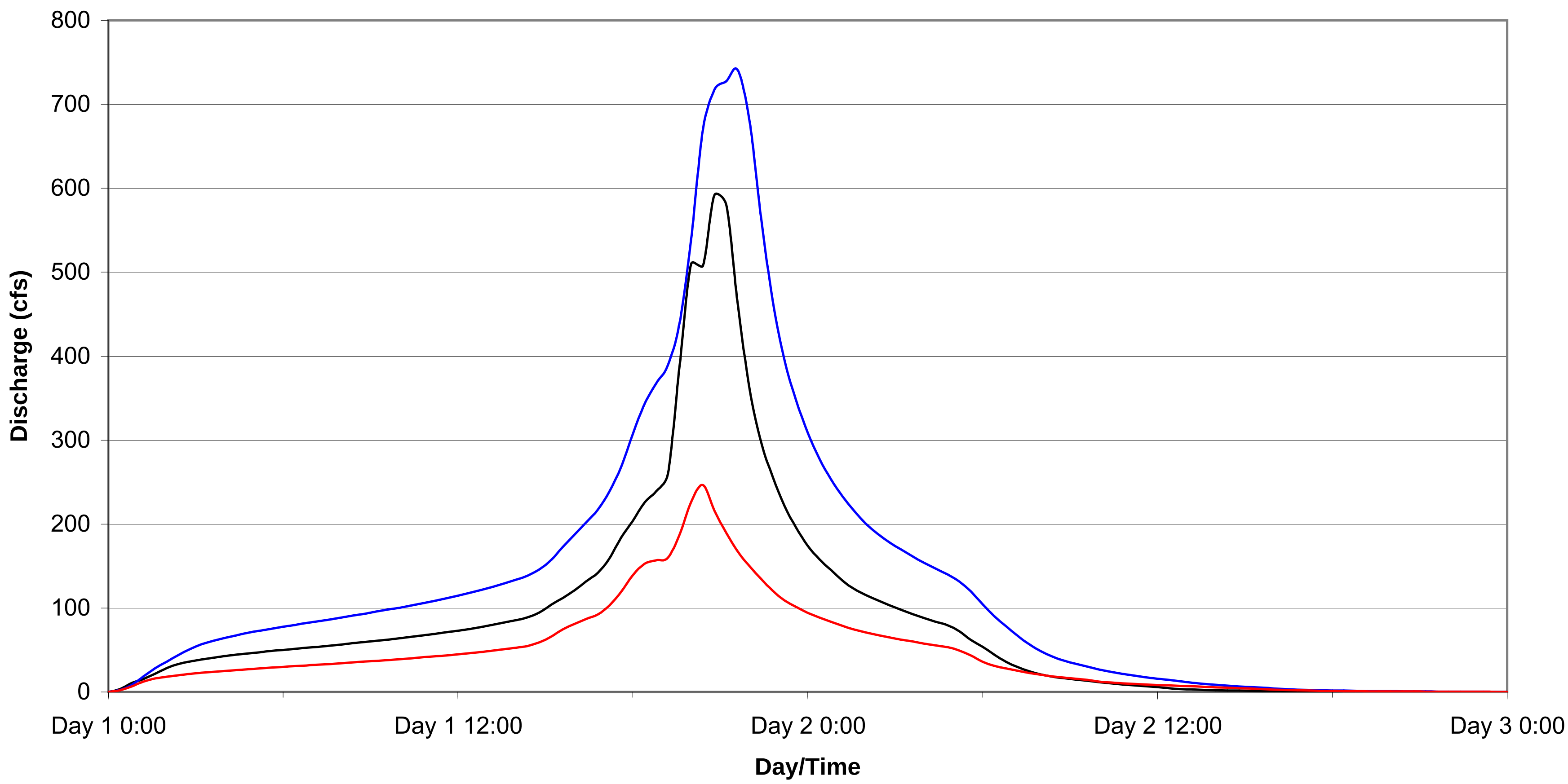


Figure 3-57

South Orange County SAMP
Event Hydrographs for Talega Canyon
at Confluence with Cristianitos Creek

PWA PWA#: 1393



Cristianitos Creek U/S of Talega Canyon CCC45

Cristianitos Creek D/S of Talega Canyon cCC47

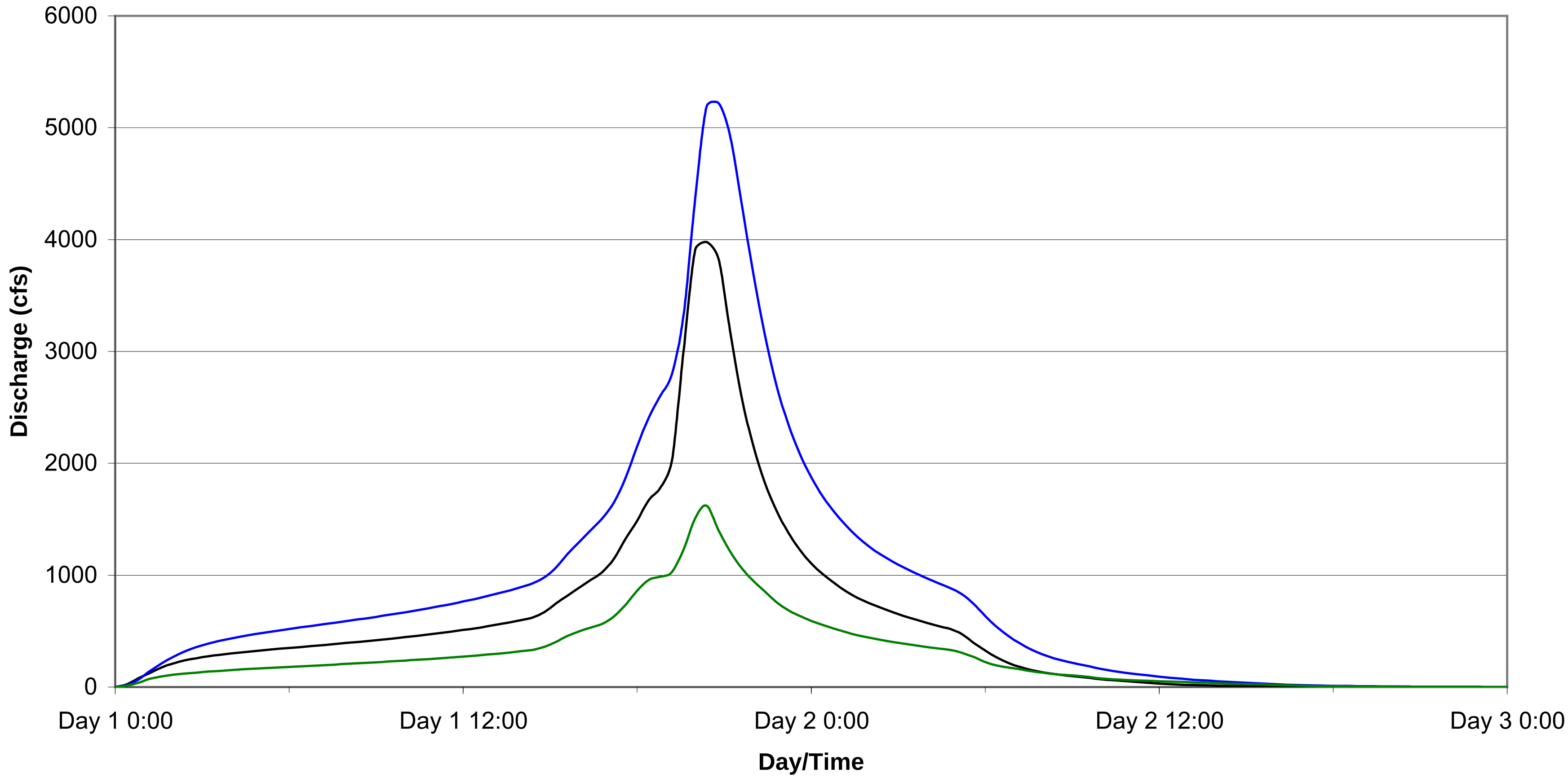
Talega Canyon at confluence with Cristianitos Creek CC47

Figure 3-58

South Orange County SAMP
2-year Event Cristianitos Creek
Confluence with Talega Canyon

PWA

PWA#: 1393



Cristianitos Creek U/S of Talega Canyon CCC45

Cristianitos Creek D/S of Talega Canyon cCC47

Talega Canyon at confluence with Cristianitos Creek CC47

Figure 3-59

South Orange County SAMP
10-year Event Cristianitos Creek
Confluence with Talega Canyon

PWA

PWA#: 1393

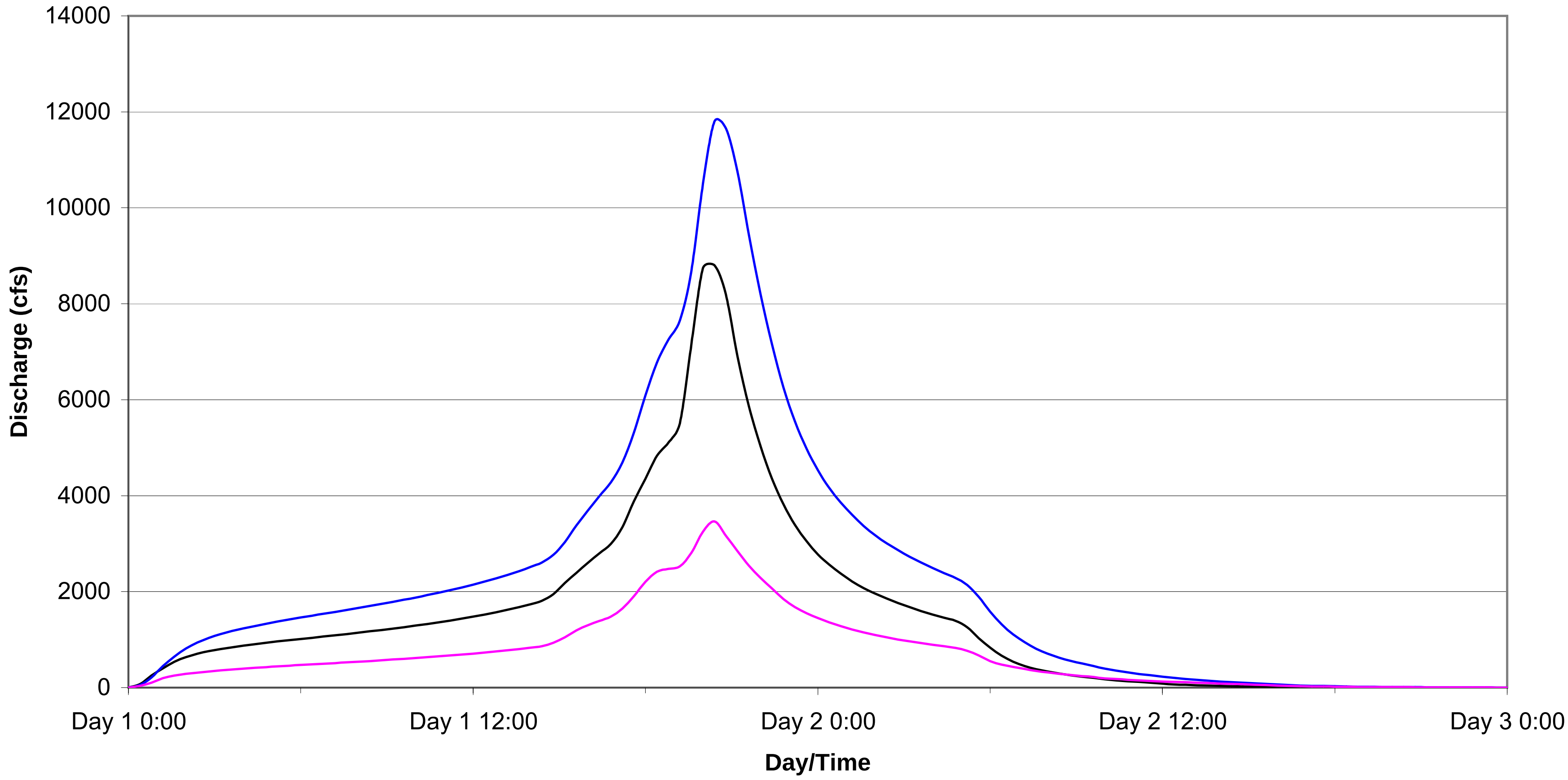


Figure 3-60

South Orange County SAMP
100-year Event Cristianitos Creek
Confluence with Talega Canyon

PWA PWA#: 1393

4. IN-CHANNEL SEDIMENT TRANSPORT

4.1 INTRODUCTION

The entrainment, transport, and deposition of sediment in watersheds of coastal southern California occurs according to a cascading system involving upland hillslopes, alluvial stream channels, estuaries, and the coast. These different geomorphic zones within the cascading system variably shed, move, or store sediment. As the principal conduit of sediment transport, the stream channel system dynamically responds to changes in hydrologic conditions across the watershed. Increases or decreases in runoff and sediment delivery to specific reaches can result in shifts in erosional and depositional patterns throughout the drainage network. Additionally, changes in sediment storage functions within the channel create feedbacks, which further alter stream geometry and slope and are likely to further destabilize stream behavior.

PWA evaluated in-channel sediment transport processes for nine of the ten studied sub-basins in the San Mateo and San Juan Creek watersheds. Sediment transport at Talega Canyon, in the San Mateo watershed, was not evaluated due to lacking sediment and channel data. PWA selected a USACOE computer model, the Hydraulic Design Package for Channels (SAM), to evaluate in-channel sediment processes. SAM allows the computation of both sediment transport capacity and sediment yield for a given flood event. Due to limited data availability and other constraints, SAM was an appropriate choice for this study to establish baseline conditions on which the impacts of future land-use scenarios can be evaluated. Baseline results for in-channel sediment transport rates and yields will be used in a subsequent phase to evaluate the impact of various land-use alternatives.

This chapter includes a description of the methods and assumptions used in the SAM modeling approach (Section 4.2); a presentation of results for the San Juan and San Mateo creek sub-basins (Sections 4.3, 4.4); a sensitivity analysis of the SAM modeling results (Section 4.5); and a comparison of results with other studies (Section 4.6)

4.2 APPROACH AND KEY ASSUMPTIONS

4.2.1 Overview of SAM Modeling Procedure

SAM, a USACE channel design package, was used to calculate sediment transport rates and sediment yields for several channel reaches in the San Juan and San Mateo watersheds (Figure 4-1). Channels were divided into sub-reaches according to topographic and hydraulic conditions and then analyzed using SAM. The SAM model requires streamflow data, channel geometry information, channel hydraulic parameters (including roughness and energy slope), sediment particle-size distributions by reach, and the selection of an appropriate sediment transport function.

Figure 4-1 Sediment Transport Analysis in Hydrologic Sub-basins

The SAM program consists of six modules, two of which are organizational and four of which are computational. The two organizational modules, PSAM and SAMaid facilitate input preparation and transport function selection. The first two computational modules, SAMhyd and SAMavg, are used to combine flows and geometry data to yield average (or effective) hydraulic parameters (flow width, flow depth, and velocity) for a given flow and energy slope. Selecting which initial module to use depends on the type of input data available. SAMhyd uses channel input data (discharge, cross section geometry, roughness, and energy slope) from a single representative location to calculate hydraulic parameters for the entire reach. In contrast, SAMavg uses HEC-2 output to calculate reach-averaged values. The resulting hydraulic parameters, along with sediment gradation data, are input into SAMsed to calculate transport rates for given discharge values. In SAMyld, the transport rate is combined with a storm event hydrograph to produce a sediment yield for that event. Sediment yields can then be used to calculate an average sediment concentration for the event.

4.2.2 Data Sources for Sediment Transport Modeling

Preliminary results from PWA's HEC-1 runoff analysis for the 2, 10, and 100-year discharge events were used as flow input for the sediment transport analysis. Channel geometry and sediment parameters were estimated from several sources. An existing HEC-2 model developed by Simons, Li & Associates (SLA, 1999) provided channel and sediment data for the following reaches:

- San Juan Creek from the river mouth upstream to the upper extent of the Conrock Mining lease, just downstream of Caspers Regional Park.
- Canada Gobernadora from the San Juan Creek confluence upstream to the Coto de Caza golf course.
- Arroyo Trabuco from the San Juan creek confluence upstream to Plano Trabuco.
- Oso Creek from the Arroyo Trabuco confluence upstream to near the I-5 crossing

Of these reaches, only data from the San Juan Creek and Canada Gobernadora HEC-2 reaches was utilized in the current sediment transport study. In addition to the available HEC-2 data, field information from WES (2000) provided measures of bankfull width and depth, channel bed slope, and sediment bed material distributions. The WES study included all of the ten studied sub-basins of the San Juan and San Mateo watersheds except Talega Canyon. The 10-meter digital elevation model (DEM) provided stream valley cross sections which were then used in combination with the WES channel measurements to create composite stream channel and valley cross sections. Field observations conducted by Balance Hydrologics (BH) provided channel roughness values for the majority of the study reaches.

4.2.3 SAM Input Parameters and Selection of Transport Function

Input files for the hydraulic, sediment transport rate, and sediment yield SAM modules were created for each of the studied sub-basins. For each sub-basin the stream channel was divided into reaches of roughly similar geometry and sediment characteristics. Sub-basins were typically organized into 3 to 6 reaches, with reach lengths ranging from approximately 1000 to 3000 feet. As described below, a set of representative hydraulic and sediment parameters were determined for each reach.

For the reaches within the tributary sub-basins, channel geometry was determined using a combination of WES and USGS/DEM data. The WES (2000) study provided a measure of bankfull mean width and depth for each WES reach. The WES width and depth values describe channel form independent of the valley-floor floodplain on either side of the channel. The cross section for each PWA reach includes a WES channel cross-section. Where a PWA reach spanned more than one WES reach, channel widths and depths were averaged to create a representative channel form for the whole reach.

Geomorphologists have used the concept of bankfull width and depth to link streamflow conditions to channel shape. Dominant discharge is considered to be the flow rate (or frequency), which determines channel form and cross-sectional capacity (Wolman and Leopold, 1957). In other words, dominant discharge is the flow which performs the most work, where work is defined in terms of sediment transport (Wolman and Miller, 1960). The frequency of the dominant discharge flow is largely related to regional climatic conditions. Studies from watersheds in the eastern U.S., as well as northern California, suggest that a flow with a return frequency of about 1.5 years is the dominant channel-forming event (Dunne and Leopold, 1978). In more arid and semi-arid climates, such as southern Orange County, with greater annual flow variability and episodicity, the notion of a dominant discharge may be less appropriate. If a dominant discharge does exist in such regions, it more likely has a higher return frequency (perhaps in the 5 to 10 year range) than the annual 1.5-year event (Wolman and Gerson, 1978).

Flows modeled for this study include the frequent 2-year event, the moderate 10-year event, and the extreme 100-year event. For the sediment transport modeling, channel cross sections must have the capacity to contain the largest input flows. Therefore, the WES bankfull width and depth data were supplemented with geometric data for the valley floor provided by the DEM (Figure 4-2). For any given reach, several representative valley cross-sections were available from the DEM that extended across the floodplain up to the adjacent hillslopes. These valley cross-sections were examined to determine an average width at a flow stage of 2 meters (roughly the maximum stage for highest flows along most reaches). The cross section that most closely matched reach average dimensions was used to represent the valley for the particular reach. As illustrated in Figure 4-2, WES bankfull channels were nested within the broader valley profile supplied by the DEM to create a composite cross section.

For the main San Juan channel, HEC-2 cross sections were available at 150-meter intervals for the entire valley width. For these reaches, the composite WES/DEM method was not needed. Since HEC-2 data was also available for Lower Canada Gobernadora, this area was used to compare and refine the composite WES/DEM method (Section 4.5).

In terms of other input parameters, channel bed slopes from WES (2000) were used as energy slopes and channel roughness values were based on field observations by Balance Hydrologics (2000). Sediment distributions, required by the SAMsed module, were provided by WES (2000) and SLA. For the central San Juan channel and portions of Canada Gobernadora, energy slopes, sediment distributions, and channel roughness values were provided by SLA (1999). Tables 4-1 and 4-2 summarize SAM input parameters for the modeled reaches of the San Juan and San Mateo watersheds.

Figure 4-2 Sample cross section used for Tributaries to San Juan and San Mateo Creeks

Table 4-1 San Juan Creek Sediment Transport Analysis Input Data Summary

Table 4-2 San Mateo Creek Sediment Transport Analysis Input Data Summary

Computer based sediment transport models often use recognized sediment transport functions (mathematical formulae that can be used to estimate the movement of sediment based on hydraulic and sediment characteristics) in their calculations. SAM has 19 sediment transport functions available for calculating transport rates. Selecting the appropriate sediment transport function is a critical decision in the modeling process. For this study, the Laursen (Madden) (LM) sediment transport function was selected based upon guidelines in the SAM reference manual and comparisons to previous results by SLA (1999), Vanoni et al (1980), and Kroll and Porterfield (1969) (see Section 4.5 below). This function is suitable for modeling sand and gravel bed streams such as those found in the San Juan and San Mateo Creek Watersheds.

4.3 RESULTS FOR SAN JUAN WATERSHED SUB-BASINS

4.3.1 San Juan Overview

Using the SAM model, peak sediment transport rates were calculated for the studied sub-basins of the San Juan watershed for the 2-year, 10-year, and 100-year discharge events. The Laursen (Madden) sediment transport function was used within the SAM application. Peak transport rates per unit area were also calculated for each of the sub-basins. It should be noted that these rates represent the capacity for the system to transport sediment and may not describe actual sediment transport rates. Actual sediment transport is determined by both transport capacity and sediment supply (Terrains Analysis Technical Appendix by Balance Hydrologics, 2001).

Figure 4-3 compares peak sediment transport capacities for the 100-year flow event for the studied sub-basins in the San Juan and San Mateo watershed. Transport rates are given at the most downstream end of each sub-basin. For the Laursen (Madden) transport function, Cañada Gobernadora and Bell Canyon had the highest absolute sediment transport rates in the San Juan watershed. This result is likely explained by the relatively large size of these two canyons (11.08 miles^2 and 20.57 miles^2, respectively). However, Cañada Gobernadora also has a relatively high transport capacity as calculated per unit area (Figure 4-4). The main stem of the Central San Juan Creek sub-basin also had a relatively high sediment transport rate in absolute terms. Peak transport rates from Lucas Canyon were the lowest of the San Juan Creek watershed sub-basins.

In Figure 4-4, transport rates are shown per unit area at the most downstream reach of each sub-basin. Since these rates are independent of sub-basin size, they reflect other sediment shedding properties, integrating factors of channel geometry, runoff rates, and geology. For the Laursen (Madden) transport function, Trampas Canyon had the highest transport rates per unit area of any of the studied sub-basins entering San Juan Creek. Cañada Gobernadora, Verdugo Canyon, and Lucas Canyon had the next highest transport capacities per unit area. Transport rates per unit area are likely highest for Trampas Canyon due to steep channel slopes at the basin mouth, transportable sediment sizes, and a small drainage area. In many ways, Trampas Canyon is different from the other studied sub-basins, which are larger canyon systems that occupy broader valleys. Trampas Canyon is more representative of the steeper headwater systems of the San Juan watershed where sediment yields are much higher. Conversely, sediment yields per unit area for the main San Juan channel are the lowest. More detailed sediment transport results for each sub-basin are presented below.

Figure 4-3 Peak 100-year Sediment Transport Rate Exiting Sub-basin

Figure 4-4 Peak 100-year Sediment Transport Rate, per Unit Area

Figure 4-5 summarizes calculated sediment yields for the modeled storm events at the mouth of each of the sub-basins. These results represent the potential volume of sediment delivered to the main stem of San Juan Creek from each of the tributary sub-basins during large storm events. Bell Canyon exhibited the highest yield to San Juan Creek. This is not surprising since Bell is the largest of the sub-basins and produced relatively high transport rates. The main stem of the Central San Juan sub-basin, Gobernadora, Trampas, and Lucas Canyons also produced relatively high yields. Cañada Chiquita produced the lowest yields of the San Juan Watershed sub-basins. Figure 4-6 shows sediment yields per unit area. Trampas Canyon has the highest yields per area. This is consistent with the results for transport rates described above for this steep, small tributary catchment. Of the principal canyon sub-basins, Verdugo Canyon had the highest yield per unit area.

Based on the yield results, sediment mass balances were calculated for the four modeled reaches of the main stem of San Juan Creek (Figure 4-7). Upstream sediment input to San Juan Creek, from the upper watershed above Lucas Canyon, was estimated using results from Balance Hydrologics (2001). It was assumed that this sediment enters reach SJ4 of the main San Juan channel along with sediment from Lucas, Verdugo, and Bell Canyons (Figure 4-1). Sediment from Cañada Gobernadora was modeled to enter reach SJ2 and sediment from Cañada Chiquita was modeled to enter reach SJ1. Mass balances exhibit a general pattern of deposition in three of the four modeled reaches during large flood events. The most downstream reach was slightly erosional during flood events according to the mass balances. The delivery of sediment from the canyon sub-basins to the main San Juan Creek channel likely plays a significant role in the depositional pattern observed in the three upstream reaches.

4.3.2 Lucas Canyon

Lucas Canyon was divided into three reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-3. Within Lucas Canyon, Reach 2 has the highest transport capacity for all three modeled flood events. This may be due to a greater percentage of smaller, more transportable sediment in Reach 2 (Table 4-1). Reach 3 upstream tends to have the lowest transport capacity while the capacity of Reach 1 is intermediate between 2 and 3.

Relative to other modeled sub-basins in the San Juan Creek watershed, Lucas Canyon sediment transport rates are in the middle to low end of the range. On a per unit area, the capacity of Lucas Canyon to transport sediment to San Juan Creek was calculated to be higher than the Central San Juan (Main Channel), Chiquita, and Bell Canyon sub-basins, but lower than Trampas, Gobernadora, and Verdugo Canyon sub-basins (Figure 4-4). In absolute terms, the 100-year capacity of Lucas Canyon to transport sediment to San Juan Creek ranked lowest of the modeled sub-basins (Figure 4-3). Overall, Lucas Canyon has the capacity to deliver a significant but relatively small quantity of sediment to San Juan Creek. This is likely due to the basin's small size as well as inherent geological, hydrologic, and geomorphic conditions, including a high percentage of larger less transportable sediment at its mouth.

Within Lucas Canyon, sediment yields follow a pattern similar to sediment transport rates (Table 4-3). Reach 2 has the highest sediment yield for all three modeled storm events, Reach 1 the second highest, and Reach 3 the lowest yield. As discussed above, Reach 2 may be highest due to a larger proportion of mobile sediment sizes than the other two reaches.

Figure 4-5 Sediment Yield at Canyon Mouth

Figure 4-6 Sediment Yield per Unit Area at Canyon Mouth

Figure 4-7 Main Channel Reach Central San Juan Sub-basin Sediment Mass Balance

Table 4-3 Lucas Canyon Sub-basin Sediment Results Summary

Relative to other sub-basins in the San Juan Creek watershed, Lucas Canyon produced mid-range sediment yields on a per unit area basis for all three events (Figure 4-6). As noted above, Lucas Canyon does not appear to have a large capacity for sediment delivery to San Juan Creek.

As part of the sediment analysis, average sediment concentrations were calculated for each reach and storm event. Concentrations were calculated as the sediment yield (in units of mass) divided by the total runoff volume for the storm event, to give a concentration in grams/liter. Results from these calculations are not a measure of actual sediment concentration at any point in time during the event, but are event-based averages and offer a useful comparative basis between sub-basins. Additional discussion of sediment concentrations is presented in Section 4-5.

PWA calculated sub-basin input-output mass balances based on computed sediment yields for each reach of the modeled sub-basin. Mass balances were calculated as the difference between the incoming yield delivered by the upstream reach and the outgoing yield from the given reach. In this way mass balances indicate whether a particular reach is erosional or depositional for a given event. Mass balances were calculated for all three modeled storm events. A sediment mass balance was not calculated for the most upstream reach of each sub-basin since sediment delivery to this reach was not computed.

The sediment mass balances for Lucas Canyon show the potential for erosion in Reach 2 and deposition in Reach 1 for all three storm events (Figure 4-8). In Reach 2 the rate of sediment delivery from upstream is lower than the capacity of the reach to transport sediment downstream. Reach 1 may be subject to deposition during large flood events since Reach 2 appears to be able to deliver sediment from upstream at a higher rate than Reach 1 can transport it to the main stem of San Juan Creek.

4.3.3 Verdugo Canyon

Verdugo Canyon was divided into four reaches for the sediment transport analysis (Figure 4-1). Reach 2 produced the highest peak sediment transport rates, followed closely by Reach 1. Results for reaches 3 and 4 were significantly lower than for reaches 1 and 2. In absolute terms, Verdugo Canyon sediment transport rates are lower than all other sub-basins for all three events, except for Lucas Canyon under 100-year conditions (Figure 4-3). On a per unit area basis the capacity of Verdugo Canyon to transport sediment to San Juan Creek was calculated to be higher than all other sub-basins except Trampas Canyon and Cañada Gobernadora (Figure 4-4).

Table 4-4 shows sediment yield results for Verdugo Canyon. Within Verdugo Canyon, sediment yields follow a pattern similar to sediment transport rates. Relative to other principal sub-basins in the San Juan Creek watershed, Verdugo Canyon produced the highest sediment yields on a per unit area basis for the 10-year and 100-year events (Figure 4-6). In absolute terms, Verdugo Canyon seems to have a mid-to-low range capacity for sediment delivery to San Juan Creek (Figure 4-5). Although it has high sediment yield on a per unit area basis, it is a relatively small basin and thus cannot deliver as much sediment as the larger sub-basins.

Figure 4-8 Lucas Canyon Sub-basin Sediment Mass Balance

Table 4-4 Verdugo Canyon Sub-basin Sediment Transport Results Summary

PWA calculated a mass balance for each reach and storm event for the Verdugo Canyon sub-basin. Results are shown in Table 4-4 and Figure 4-9. Results show the potential for slight erosion in Reach 3, significant erosion in Reach 2, and moderate deposition in Reach 1 under the influence of large storm events.

4.3.4 Bell Canyon

Bell Canyon was divided into six reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-5. Within Bell Canyon, Reach 6, the most upstream reach, has the highest transport capacity for all three modeled flood events. This may be because Reach 6 has steeper channel slopes than any of the other reaches (Table 4-1). Transport rates for Reach 5 are approximately 50% of those for Reach 6. Reaches 1 through 4 exhibit sediment transport rates that are in the range of 25% of those for Reach 6. Relative to other modeled sub-basins in the San Juan Creek watershed, Bell Canyon sediment transport rates per unit area are low, being similar to Cañada Chiquita, and higher than only the Central San Juan (Main Channel) sub-basin (Figure 4-4). In absolute terms, only Cañada Gobernadora has a higher capacity to transport sediment to San Juan Creek than Bell Canyon (Figure 4-3). This is likely due to the basin's large size, higher flows, and other inherent geologic, hydrologic, and geomorphic conditions.

Table 4-5 also shows sediment yield results for Bell Canyon. Within Bell Canyon, sediment yields follow a pattern similar to sediment transport rates. Reach 6 has the highest sediment yield for all three modeled storm events, followed by Reach 5. Yields for Reaches 1 through 4 are similar in magnitude, lower than Reaches 5 and 6. As mentioned above, Reach 6 yields may be highest due to high channel slopes. Relative to other sub-basins in the San Juan Creek watershed, Bell Canyon produced mid-range sediment yields on a per unit area basis for all three events (Figures 4-6). Bell's yields per unit area were generally higher than for Cañada Chiquita and the Central San Juan, and lower than for Cañada Gobernadora, Lucas, and Verdugo Canyons. As noted above, Bell Canyon appears to have the largest capacity (in absolute terms) for sediment delivery to San Juan Creek of any of the other modeled sub-basins. This is likely due to the sub-basin's large size.

The sediment mass balances for Bell Canyon show the potential for significant deposition in Reaches 4 and 5 during large storm events (Figure 4-10). Each of these reaches is downstream of a reach with high sediment transport capacity and yield potential. Relative to the high potential for deposition in Reaches 4 and 5, mass balance results for the lower reaches of Bell Canyon suggest that the channel may tend toward a more stable geomorphic equilibrium position under the influence of large storm events. Results suggest the potential for some erosion in Reach 3 and some deposition in Reach 1. However, the quantity of potential deposition or erosion in these reaches is much lower than for Reaches 4 and 5.

Figure 4-9 Verdugo Canyon Sub-basin Sediment Mass Balance

Table 4-5 Bell Canyon Sub-basin Sediment Transport Results Summary

Figure 4-10 Bell Canyon Sub-basin Sediment Mass Balance

4.3.5 Cañada Gobernadora

Cañada Gobernadora was divided into nine reaches for the sediment transport analysis, the first six of which are aligned with the SLA (1999) reach designations (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-6. Within Cañada Gobernadora, Reach 9, the most upstream reach, has the highest transport capacity for all cases except the 100-year event. This may be because Reach 9 has steeper channel slopes than any of the other reaches (Table 4-1). Runoff rates in Reach 9 are the lowest of the Gobernadora reaches, further suggesting the importance of high slopes in generating the high sediment transport rates. In general, Reaches 1 and 2 also exhibited relatively high sediment transport rates. In absolute terms, Cañada Gobernadora sediment transport rates are higher than rates for all other modeled sub-basins in the San Juan Creek watershed. On a per unit area basis, the sediment transport rate at the mouth of Cañada Gobernadora was also higher than the rates for all other principal San Juan sub-basins (Figure 4-4). High transport rates are likely due to the basin's large size, a high proportion of smaller more transportable sediment, and other inherent geologic, hydrologic, and geomorphic conditions.

Table 4-6 also shows sediment yield results for Cañada Gobernadora. Within Cañada Gobernadora, sediment yields follow a somewhat different pattern than sediment transport rates. Yields are lower in the upper reaches (Reaches 3-9), and then increase toward the mouth of the canyon. Reaches 1 and 2 exhibit the highest yields. This pattern may reflect the importance of flow rate, which increases significantly downstream in Cañada Gobernadora. Relative to other sub-basins in the San Juan Creek watershed, results indicate that Cañada Gobernadora produced relatively high sediment yields on a per unit area basis for all three events (Figure 4-6). Only Verdugo Canyon has higher yields on a per unit area basis for the 10-year and 100-year events. In absolute terms, Cañada Gobernadora appears to have an upper mid-range capacity for sediment delivery to San Juan Creek compared to the other modeled sub-basins. Yields exiting the sub-basin were lower than for Bell Canyon and the Central San Juan sub-basin, but higher than for the Chiquita, Verdugo, and Lucas Canyon sub-basins.

The sediment mass balances for Cañada Gobernadora show the potential for significant deposition in Reaches 8, 7, 4 and 3 during large storm events (Figure 4-11). Calculations show the potential for erosion in Reaches 6, 5, 2 and 1.

4.3.6 Cañada Chiquita

Cañada Chiquita was divided into six reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-7. Generally, the sediment transport trends within Cañada Chiquita are the same for all three events. Results indicate that sediment transport capacity is highest in Reach 5 under all three storm events. Relative to other modeled sub-basins in the San Juan Creek watershed, Cañada Chiquita sediment transport rates are intermediate. Cañada Chiquita was calculated to have a higher transport capacity in absolute terms than Lucas and Verdugo Canyons. On a per unit area basis, Cañada Chiquita sediment transport rates were calculated to be lower than all but Bell Canyon and the Central San Juan sub-basins.

Table 4-6 Canada Gobernadora Sub-basin Sediment Transport Results Summary

Figure 4-11 Canada Gobernadora Sub-basin Sediment Mass Balance

Table 4-7 Canada Chiquita Sub-basin Sediment Transport Results Summary

Table 4-7 also shows sediment yield results for Cañada Chiquita. Within Cañada Chiquita, sediment yields follow a pattern very similar to the pattern of sediment transport rates. Yields tend to alternate between high and low values from reach to reach for all three modeled events. The highest yields were calculated in Reach 5. Relative to other sub-basins in the San Juan Creek watershed, sediment yields from Cañada Chiquita are low. In absolute terms sediment yields from Cañada Chiquita were calculated to be the lowest of all modeled sub-basins. On a per unit area basis only the Central San Juan sub-basin had a lower yield.

The sediment mass balances for Cañada Chiquita show the potential for deposition in Reaches 4 and 2 during large storm events (Figure 4-12). Calculations show the potential for erosion in Reaches 5, 3 and 1.

4.3.7 Central San Juan Catchments

The Central San Juan Creek sub-basin was divided into 11 reaches from four small catchment tributaries that directly enter San Juan Creek (Figure 4-1). Catchments include the Southwest, Trampas Canyon, Northwest, and Northeast tributaries. Results of the sediment transport analysis are shown in Table 4-8. Within the Central San Juan Sub-basin, reaches 1 and 2 of the Main Channel and reaches 1 and 3 of Trampas Canyon have the highest sediment transport rates. Trampas Canyon is a very steep headwater tributary and had higher flow rates than the other tributaries. Transport rates for the main San Juan channel are higher than the tributaries due to larger flows and channel size.

Relative to other modeled sub-basins in the San Juan Creek watershed, Trampas Canyon (Figure 4-3) sediment transport rates are low (only Verdugo and Chiquita were lower). However, Trampas Canyon transport rates per unit area were higher than all other sub-basins (Figure 4-4). This is due to steep channel slopes at the basin mouth, transportable sediment sizes, and a small drainage area. In contrast, the main channel of the Central San Juan sub-basin actually had the lowest per unit area transport capacity of all modeled sub-basins. In absolute terms, transport capacities for the main channel of the Central San Juan sub-basin are in the mid-to-high range compared to other San Juan sub-basins (Figure 4-3).

Table 4-8 also lists sediment yield results for the Central San Juan sub-basin. Values for the main channel and Trampas Canyon are plotted in Figures 4-5 and 4-6. Absolute sediment yields are relatively high for the main channel and lower for the Trampas tributary. Sediment yields per unit area are extremely high for the Trampas Canyon tributary for the same reasons as described above for transport rates. In fact, yields per unit area are higher from Trampas Canyon than any other studied catchment. In many ways, Trampas Canyon is different from the other studied sub-basins, which are larger canyon systems that occupy broader valleys. Trampas Canyon is more representative of the steeper headwater systems of the San Juan watershed where sediment yields are much higher. Conversely, sediment yields per unit area for the main San Juan channel are the lowest of the study due to the large size of the contributing catchment and low channel slopes (Figure 4-6).

Figure 4-12 Canada Chiquita Sub-basin Sediment Mass Balance

Table 4-8 Central San Juan Creek Sub-basin Sediment Transport Results Summary

Sediment mass balances were computed for the main channel of San Juan Creek from the confluence with Bell and Verdugo Canyons to the Ortega Highway crossing downstream of the mouth of Chiquita Canyon (Figure 4-7). Along the main channel, mass balances indicate the potential for deposition in all four reaches during large storm events, except reach 1. This seems reasonable since high sediment loads from the steeper canyon sub-basins discharge directly to these central reaches of San Juan Creek. For Trampas Canyon, mass balance results show the potential for deposition in Reach 2 and erosion in Reach 1 for all three events (Figure 4-13). This is likely a reflection of the high slopes and transport capacities in Reach 3 (which passes sediment to Reach 2) and Reach 1 which transports sediment out of Trampas Canyon.

4.4 RESULTS FOR SAN MATEO WATERSHED SUB-BASINS

4.4.1 San Mateo Overview

Similar to the San Juan watershed, the SAM model was used to calculate peak sediment transport rates for the studied sub-basins of the San Mateo watershed (excluding Talega Canyon) for the 2-year, 10-year, and 100-year discharge events. As described above, these rates represent the capacity for the system to transport sediment but may not describe actual sediment transport rates. Actual sediment transport is determined by both transport capacity and sediment supply.

In the San Mateo Creek watershed, Gabino Canyon (upstream of the Cristianitos Creek confluence) was calculated to have the highest sediment transport capacity (Figure 4-3). This absolute rate is actually the highest of all modeled sub-basins in the San Juan and San Mateo Watersheds and is similar in magnitude to rates calculated for Gobernadora and Bell Canyons in the San Juan watershed. Transport rates calculated for La Paz and Cristianitos Canyons are similar to values calculated for Lucas and Verdugo canyons.

The Upper Cristianitos sub-basin (3.67 mi^2) had the highest transport capacity per unit area of the three modeled San Mateo sub-basins (Figure 4-4). The basin's per unit area transport rate surpasses rates calculated for all other sub-basins except Trampas Canyon. This implies that the hydrology, geology, and geomorphology of Upper Cristianitos Creek are conducive to transporting sediment. The transport capacity per unit area of Gabino Canyon is intermediate between estimated rates for La Paz and Cristianitos canyons. La Paz Canyon exhibited transport rates per unit area that were slightly higher than those for Lucas Canyon.

Figure 4-5 summarizes calculated sediment yields at the mouth of the three San Mateo sub-basins. These figures illustrate that the Gabino Canyon sub-basin exhibits the highest sediment yield of the three San Mateo sub-basins. This is most likely due to the somewhat larger size of Gabino Canyon relative to the Upper Cristianitos and La Paz sub-basins. Although the Upper Cristianitos sub-basin is half the size of the La Paz sub-basin, its relatively high rate of sediment transport per unit area (Figure 4-6) resulted in total sediment yields that were slightly higher than those from the La Paz sub-basin for the 10-year and 100-year events.

Figure 4-13 Trampas Canyon Reach

4.4.2 La Paz Canyon

La Paz Canyon was divided into three reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis for La Paz Canyon are shown in Table 4-9. Within La Paz Canyon, Reach 3, the most upstream reach, has the highest transport capacity for all three storm events. Sediment transport capacity is lower in Reach 2 and lower still in Reach 1. This decrease in transport capacity from upstream to downstream is likely a reflection of decreasing channel slopes. Relative to other modeled sub-basins in the San Mateo Creek watershed, sediment transport rates from the mouth of La Paz Canyon are low. On a per unit area basis, the capacity of La Paz Canyon to transport sediment downstream was calculated to be lower than both the Gabino and Cristianitos sub-basins (Figure 4-4). In absolute terms, La Paz Canyon transport rates are also lower than the other San Mateo sub-basins. La Paz Canyon's comparatively low transport rates may be due to relatively coarse bed material along its less steep downstream reach.

Table 4-9 also shows sediment yield results for the La Paz Canyon sub-basin. Within La Paz Canyon, sediment yields follow a pattern identical to sediment transport rates, decreasing from upstream to downstream. Yields are highest in Reach 3 and lowest in Reach 1 for all three storm events. As previously discussed, this may be a reflection of decreasing channel slopes. In absolute terms, La Paz Canyon appears to have the lowest capacity for sediment delivery downstream, compared to the two other modeled San Mateo sub-basins (Figures 4-5 and 4-6). Yields exiting the sub-basin were lower than those for Gabino Canyon and were in the same range as those for the Cristianitos Creek sub-basin. As mentioned in the sediment transport section, low yields may be due to coarse bed-material in the more gently sloped downstream reach. Relative to other sub-basins in the San Mateo Creek watershed, La Paz Canyon also produced the lowest sediment yields on a per unit area basis. This is likely a reflection of low absolute yields in a medium-sized sub-basin.

The sediment mass balances for La Paz Canyon show the potential for significant deposition in reaches 1 and 2 during large storm events (Figure 4-14). The depositional pattern is a reflection of decreasing yields from upstream to downstream. More sediment flows into Reaches 1 and 2 than can be transported downstream, causing deposition.

4.4.3 Gabino Canyon

Gabino Canyon was divided into five reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-10. Within Gabino Canyon, Reach 5, the most upstream reach, has the highest transport capacity for all three storm events. High transport capacities in Reach 5 are likely due to high channel slopes in this reach. Sediment transport capacity is also comparatively high in Reaches 4 and 1, with significantly lower transport capacities in Reaches 2 and 3. The larger size of the channel, and the greater proportion of small sediment sizes may explain the relatively high transport rate in Reach 1.

Table 4-9 La Paz Canyon Sub-basin Sediment Transport Results Summary

Figure 4-14 La PazCanyon Sub-basin Sediment Mass Balance

Table 4-10 Gabino Canyon Sub-basin Sediment Transport Results Summary

Relative to the two other modeled sub-basins in the San Mateo Creek watershed, Gabino Canyon sediment transport rates are high. In absolute terms, Gabino Canyon has the highest capacity to transport sediment downstream of any of the San Mateo sub-basins (Figure 4-3). This is likely due to its large sub-basin area and relatively high runoff rate, which includes tributary flow from La Paz Canyon. On a per unit area basis, the capacity of Gabino Canyon to transport sediment downstream was calculated to be lower than the Cristianitos Creek sub-basin but higher than La Paz Canyon (Figure 4-4). The small size of the Cristianitos Creek sub-basin tends to boost its transport capacity on a per unit area basis.

Table 4-10 also shows sediment yield results for the Gabino Canyon sub-basin. Within Gabino Canyon, sediment yields follow a pattern somewhat different from sediment transport rates. For the 2-year and 10-year events Reach 1 was calculated to have the highest sediment yield. For the 100-year event Reach 5 had the highest sediment yield, although Reach 1 was a close second. Yields in Reaches 5 and 1 are generally quite close in magnitude. Reach 1 has lower channel slopes than Reach 5. However, it conveys a significantly higher volume of runoff than Reach 5 since it includes flow from La Paz Canyon. These two effects seem to offset each other to produce similar sediment yields.

In absolute terms, Gabino Canyon was calculated to have the highest capacity for sediment delivery downstream, compared to the other modeled San Mateo sub-basins (Figures 4-5 and 4-6). These high yields are likely attributable to the relatively large size of the Gabino Canyon sub-basin and the relatively high runoff volume it produces for the three modeled storm events. Relative to other sub-basins in the San Mateo Creek watershed, Gabino Canyon also produced the mid-range sediment yields on a per unit area basis. Cristianitos Creek had higher yields while La Paz Canyon had lower yields on a per unit area basis. This order is likely a reflection of the small area of the Cristianitos Creek sub-basin.

The sediment mass balances for Gabino Canyon generally show the potential for deposition in Reaches 4 and 3, and the potential for erosion in Reaches 2 and 1 during large storm events (Figure 4-15).

4.4.4 Upper Cristianitos Canyon

Upper Cristianitos Creek was divided into three reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-11. Reach 1 exhibited the highest sediment transport capacities. This result may reflect the larger (yet still transportable) bed-material size exhibited by Reach 1. The bed-material distribution for Reach 1 has a larger proportion of sand and gravel than the other two reaches. Also, channel width in Reach 1 is larger than in Reach 2. This may also contribute to the larger transport capacity in Reach 1 relative to Reach 2, even though their slopes are similar.

Relative to the two other modeled sub-basins in the San Mateo Creek watershed, Upper Cristianitos Creek sediment transport rates are low on an absolute basis. Sediment transport capacities are only slightly higher than for La Paz Canyon during the 10-year and 100-year events, and are significantly lower than for Gabino Canyon in all three modeled events (Figure 4-3). However, on a per unit area basis, the capacity of Upper Cristianitos Creek to transport sediment downstream was calculated to be the highest of the three modeled San Mateo sub-basins (Figure 4-4). The relatively small size of the Upper Cristianitos sub-basin is an important factor in its large per unit area sediment transport capacity.

Figure 4-15 Gabino Canyon Sub-basin Sediment Mass Balance

Table 4-11 Upper Cristianitos Creek Sub-basin Sediment Transport Results Summary

Table 4-11 also shows sediment yield results for the Upper Cristianitos Creek sub-basin. Within the sub-basin, sediment yields follow a pattern identical to sediment transport rates. Yields are highest in Reach 1, the most downstream reach. As previously discussed, high yields in Reach 1 may be explained by the relatively large proportion of sand and gravel bed material and the relatively wide channel. In absolute terms, the capacity of Upper Cristianitos Creek to deliver sediment downstream is in the same range as the yield of La Paz Canyon, and much lower than the yield of Gabino Canyon (Figures 4-5 and 4-6). The moderate size of these absolute yields is likely related to the small size of the Upper Cristianitos sub-basin. Relative to other sub-basins in the San Mateo Creek watershed, Upper Cristianitos Creek produced the highest sediment yields on a per unit area basis. This is likely also a reflection of the relatively small size of the sub-basin.

The sediment mass balance for Upper Cristianitos Creek shows the potential for moderate deposition in Reach 2 and significant erosion in Reach 1 (Figure 4-16). Erosion in Reach 1 is a reflection of the high transport rates and yields calculated for this reach, and the low rates and yields calculated for the upstream Reach 2.

4.5 SENSITIVITY ANALYSIS OF SAM MODELING

To evaluate the performance of the SAM model for this project, a sensitivity analysis was conducted. As described above (Section 4.2), several data sources were used to supply input parameters for the SAM modeling process. Hydraulic parameters and sediment distributions were available for Canada Gobernadora and the main San Juan channel from SLA (1999), but not for the other tributary sub-basin systems. The following sections assess the suitability of using composite channel geometry data from WES and the DEM, sediment texture data from Balance (2000), the Laursen (Madden) transport function for modeling in the sub-basins. This sensitivity analysis is based on a series of comparative SAM model runs where channel geometry, sediment distribution, and transport function input parameters were altered with resulting changes in sediment transport results.

4.5.1 Channel Geometry

PWA compared sediment transport rates based on hydraulic geometry input from the WES/DEM composite method and the available HEC-2 data at several locations including: five reaches of lower Canada Gobernadora, San Juan Creek at the Conrock gravel mining pit, and San Juan Creek at the Ortega Highway (USGS stream gage 11046500) (Figure 4-1). In order to compare the influence of hydraulic geometry (channel shape and energy slope), other variables (discharge input, sediment distributions, and transport function) were held constant for all runs. Table 4-12 lists channel geometry parameters and the resulting sediment transport rates for the compared reaches.

Table 4-12 Channel Geometry Sensitivity Analysis

Sub-basin	Reach	Data Source	Channel Hydraulic Parameters Width (feet)	Depth (feet)	Slope (feet/feet)	Transport Rate (tons/day)
Canada Gobernadora	GO1	WES-DEM	150	5.8	0.018	684,823
		HEC-2	528	2.4	0.003	134,219
		variation(1)	*0.3*	*2.4*	*6.0*	*5.1*
	GO2	WES-DEM	167	5.4	0.018	668,461
		HEC-2	164	4.5	0.004	287,202
		variation(1)	*1.0*	*1.2*	*4.5*	*2.3*
	GO3	WES-DEM	179	5.0	0.008	380,567
		HEC-2	644	3.2	0.0009	25,125
		variation(1)	*0.3*	*1.6*	*8.9*	*15.1*
	GO4	WES-DEM	140	5.8	0.008	406,279
		HEC-2	694	1.6	0.007	357,924
		variation(1)	*0.2*	*3.6*	*1.1*	*1.1*
	GO5	WES-DEM	163	5.1	0.009	448,654
		HEC-2	615	1.7	0.007	370,595
		variation(1)	*0.3*	*2.9*	*1.3*	*1.2*
Central San Juan	GRAV	WES-DEM	378	9.1	0.005	622,433
		HEC-2	583	11.0	0.0007	53,877
		variation(1)	*0.6*	*0.8*	*7.6*	*11.6*
	GAGE	WES-DEM	307	10.1	0.007	1,062,658
		HEC-2	228	11.1	0.005	923,649
		variation(1)	*1.3*	*0.9*	*1.4*	*1.2*

Notes: (1) WES-DEM / HEC-2

Information presented corresponds to:

SLA (1999) 100-year peak discharges

SLA (1999) sediment distributions

Laursen (Madden) transport function

Results indicate that the energy slope parameter has greater impact on transport rates than channel cross section dimensions. For example, at reaches GO4 and GO5, the WES/DEM and HEC-2 data sources supply very different widths and depths. However, because the energy slopes are similar, the resulting transport rates are also fairly close. In contrast, at Reach GO2 WES/DEM and HEC-2 offer similar widths and depths, but energy slopes vary by a factor of 4.5. As a result, transport rates differ by more than a factor of 2. In some cases, both channel dimensions and slope inputs differ significantly which results in transport rates that vary by an order of magnitude. Results from Canada Gobernadora suggest that using bed slope in place of energy slope is reasonable upstream in the canyon but becomes less appropriate downstream towards the canyon mouth where possible backwater effects from the confluence with the main San Juan channel result in flatter energy slopes.

Figure 4-16 Upper Cristianitos Sub-basin Sediment Mass Balance

4.5.2 Sediment Distribution

The effect of using different sediment texture distributions was examined by comparing model results using different sediment data for reaches in lower Canada Gobernadora and along the main San Juan channel at the Conrock gravel mining pit and the Ortega Highway stream gage downstream. In addition, the effect of altering small grain size distinctions was evaluated using sediment data from Vanoni et al. (1980) from the Conrock gravel pit. 100-year flows from SLA (1999), WES/DEM-based channel geometry, and the Laursen (Madden) transport function were held constant for these sediment distribution comparisons.

Different sediment distributions for Canada Gobernadora and San Juan Creek (at the Conrock mine and at the Ortega Highway stream gage downstream) were compared resulting in transport rates that varied within a factor of two (Table 4-13). Figures 4-17, 4-18, and 4-19 show cumulative sediment distributions from WES (2000), SLA (1999), Vanoni et al (1980), and Kroll and Porterfield (1969).

Table 4-13 Sediment Distribution Sensitivity Analysis

Sub-basin	Reach	Data Source	Transport Rate (tons/day)
Canada Gobernadora	GO1	WES	1,287,074
		SLA	684,823
		variation[1]	*1.9*
	GO2	WES	1,278,896
		SLA	668,461
		variation[1]	*1.9*
	GO3	WES	948,368
		SLA	380,567
		variation[1]	*2.5*
	GO4	WES	964,859
		SLA	406,279
		variation[1]	*2.4*
	GO5	WES	1,070,095
		SLA	448,654
		variation[1]	*2.4*
San Juan	GRAV	Vanoni	283,656
		SLA	622,433
		variation[1]	*0.5*
	GAGE	Kroll	1,394,309
		SLA	1,062,658
		variation[1]	*1.3*

Notes: (1) WES, Vanoni, or Kroll / SLA

Information presented corresponds to:

SLA (1999) 100-year peak discharges

WES-DEM channel geometry

Laursen (Madden) transport function

Figure 4-17 Sediment Distribution for San Juan Creek

**Figure 4-18	Sediment Distribution for San Juan Creek**

Figure 4-19 Sediment Distribution for Canada Gobernadora

The sediment distribution reported in Vanoni et al. (1980) for San Juan Creek at the Conrock gravel pit did not include a low-end data point on the sediment curve to define the final 0% finer class. The SAM Users Manual, as well as experience from other sediment transport studies (PWA, 1996), suggests that SAM transport results are particularly sensitive to finer sediment characteristics at the lower end of the distribution curve. To examine the importance of the 0%-finer designation, PWA performed a series of modeling runs while varying this parameter within a reasonable range of values. Table 4-14 shows how subtle changes in defining the 0%-finer grain size class cause transport rates to vary by as much as a factor of 3.

Table 4-14 0% Finer Sensitivity Analysis

Sub-basin	Reach	Sediment Distribution	Grain size for 0% finer (mm)	Transport Rate (tons/day)	Transport Rate Variation[1]
San Juan	GR	Vanoni	--	283,656	
		Vanoni 0	0.1	724,647	2.6
		Vanoni 1	0.075	809,855	2.9
		Vanoni 2	0.01	477,548	1.7
		Vanoni 3	0.001	396,697	1.4

Notes: [1] Vanoni X / Vanoni

Information presented corresponds to:

SLA (1999) 100-year peak discharges

WES-DEM channel geometry

Laursen (Madden) transport function

4.5.3 Transport Function

4.5.3.1 Comparative analysis

The influence of transport function selection for SAM modeling was evaluated by comparing transport rates calculated by all transport functions available to SAM for lower Canada Gobernadora, San Juan Creek at the Conrock gravel pit, and San Juan Creek at the Ortega Highway stream gage. Sediment sizes in these three reaches range from coarse (mostly gravels and cobbles in San Juan Creek) to medium-sized (mostly sand in Canada Gobernadora). Using multiple reaches with varied sediment qualities helps illustrate the combined effect of testing different transport functions with different sediment size classes. Channel geometry (WES/DEM), 100-year streamflow (SLA, 1999) and sediment distributions (SLA, 1999) were held constant for all comparisons.

Results shown in Table 4-15 and graphed in Figure 4-20 indicate that selecting different transport functions results in transport rates that vary by as much as 3 orders of magnitude. After examining the output files, it appears that two of the transport functions do not function properly for the input grain size distributions for the studied areas. The Colby transport function is for grain sizes ranging from 0.125 to 1.0 mm, while the Parker function is suited for grain sizes larger than 2.0 mm in its calculations. Because the sediment distributions from all three of the study sites included large fractions of sediment beyond these ranges, results from these functions were not considered.

Figure 4-20 Transport Function Sensitivity Analysis

Table 4-15 Transport Function Sensitivity Analysis

Transport Function	Transport Rate (tons/day) Canada Gobernadora Reach 1	San Juan Creek at Conrock Gravel Mining Pit	San Juan Creek at Ortega Highway Stream Gage
Ackers-White, D50	99,	53,513	196,081
Ackers-White	16,886,958	5,977,328	15,616,489
Brownlie, D50	529,214	411,297	* 1,455,551
Colby	*25,9(	39,962	63,518
Einstein (Bed-load)	11,752	34,272	41,906
Engelund (Hansen)	5,535,538	2,482,112	6,790,045
Einstein (Total-load)	469,716	261,821	441,208
Laursen (Copeland)	* 787,955	* 9,563,344	* 30,422,008
Laursen (Madden)	* 684,823	622,433	1,062,658
MPM, D50	20,902	241,220	483,193
MPM	* 20,229	175,398	* 347,085
Parker	95,862	255	11
Profitt (Sutherland)	5,086,815	263,705	1,727,769
Schoklitsch	453,379	162,812	330,250
Toffaletti-MPM	64,099	305,471	667,487
Toffaleti	64,099	305,472	667,735
Toffaleti-Schoklitsch	453,379	349,017	712,162
Yang	931,377	622,065	1,225,746
Yang, D50	* 516,588	* 519,994	* 1,084,052

Notes: ** indicates SAMaid "best match" recommendation.*
Gray background indicates that function does include full range of sediment sizes in transport rate calculations

Information presented corresponds to:
SLA (1999) 100-year peak discharges
WES-DEM channel geometry
SLA (1999) sediment distribution

PWA used the SAMaid module to help select the most appropriate sediment transport functions to conduct the sediment analysis. SAMaid was used to compare input parameters (median sediment size, slope, velocity, width and depth) from the current PWA study with test data used to originally develop the functions and coordinate their use in SAM. The output from SAMaid is a list of functions whose input parameters most closely match the original test data. The SAMaid "best match" transport functions are indicated by asterisks in Table 4-15 and Figure 4-20.

For Canada Gobernadora Reach 1 (Figure 4-20), SAMaid recommended six transport functions: Brownlie D50; Colby; Laursen (Copeland); Laursen (Madden); MPM; and Yang D50. Transport rates produced by four of the six recommended functions (Brownlie D50, Laursen (Copeland), Laursen (Madden), Yang D50) were on the order of 10e5 tons/day. The other two functions (Colby, MPM) produced rates that were an order of magnitude smaller. The smaller transport rate calculated by the Colby function is likely caused by the limited range of sediment sizes included in the Colby transport calculations (described above) which make this function an inappropriate choice for the San Juan and San Mateo watersheds.

In the case of San Juan Creek at the Conrock gravel pit (Figure 4-20), SAMaid recommended two functions: Laursen (Copeland), and Yang D50. These functions generated transport rates that varied by an order of magnitude (10e6 vs. 10e7). At the Ortega Highway stream gage, SAMaid recommended five transport functions (Brownlie D50, Laursen-Copeland, Laursen-Madden, MPM, Yang D50) whose transport rates varied by two orders of magnitude (10e5 to 10e7).

4.5.3.2 Selection of transport functions

To choose which transport functions would be used in the main study, PWA evaluated functions based on the following criteria: (1) suitability according to the SAM user manual transport function descriptions; (2) SAMaid results and recommendations; and (3) comparisons with other San Juan Creek sediment studies. Transport function descriptions from the SAM user's manual included target river size and sediment type. These guidelines provided and initial assessment of function suitability for the San Juan and San Mateo streams. The SAMaid input data matching procedure provided another means of narrowing the field of possible functions. Results from other sediment studies in the San Juan watershed (described below) were used to compare the magnitude of PWA results with other measured data. The referenced studies included: SLA (1999) for transport rates from Canada Gobernadora; Vanoni (1980) for sediment concentration at the Conrock gravel mine; and Kroll and Porterfiled (1969) for transport rates at the Ortega Highway stream gage.

These criteria led to initially selecting three functions: Laursen (Madden), Laursen (Copeland), and Engelund (Hansen). After transport rates and sediment yields were calculated for the study areas using these functions, yield results were converted to event-averaged sediment concentrations. As an additional check, these concentrations were compared with results from other sediment transport studies. The Laursen (Copeland) results were removed from consideration in the main study because of their excessively high concentrations.

The Laursen (Madden) transport function was selected for use in the main study because it met the four criteria more favorably than the other functions. As a transport function, Laursen (Madden) is characterized for use in channels with sand and gravel loads. This function was recommended by SAMaid as a "best match" at the mouth of Canada Gobernadora and at the USGS stream gage on San Juan Creek. Laursen (Madden) produced transport rates which compared well with the Kroll and SLA studies, although sediment concentrations at the gravel mine did not compare as well with the Vanoni study. The Laursen (Madden) function produced sediment concentrations in the tributary canyon sub-basins that were considered reasonable.

The Engelund (Hansen) function was initially selected because it produced concentrations that best matched those of the Vanoni study at the Conrock gravel mine. As a function, Engelund (Hansen) is recommended for use in sandy bed streams such as Canada Gobernadora. However, Engelund (Hansen) was not recommended as a SAMaid "best match" for any of the three stream zones during the sensitivity analysis. Sediment concentrations produced by Engelund (Hansen) were considered acceptable for most of the study area, but were not considered as reasonable as results based on the Laursen (Madden) function.

Similar to Laursen (Madden), the Laursen (Copeland) function met the first three selection criteria in that it was based on the original Laursen formula, modified to extend its range to larger gravel sizes. This function was a SAMaid "best match" for all three areas; and its concentrations at the Conrock gravel mine compared well with the Vanoni study. However, for the canyon study areas with larger sediment sizes (gravels and cobbles) and steeper slopes, Laursen (Copeland) produced extremely high yields that converted to concentrations that seem unacceptably too high. As such, this function was not considered appropriate for the main study.

Based on the transport functions in the SAM user's manual, functions which were not described as applicable to both sand and gravel sediment conditions were generally not selected. In terms of comparison with other studies, about half of the 19 available functions produced transport rates or sediment concentrations that were significantly lower than published results. Of the transport functions recommended by SAMaid, Browlie D50 and Colby are described as sand functions and MPM is described as a gravel-only function that is invalid for conditions with appreciable suspended load. In addition, results from the sensitivity analysis indicated that the Laursen (Madden) represented results from the Brownlie D50 and Yang D50 functions.

4.5.3.3 Conclusions about transport functions and SAM

Results from the sensitivity analysis and other conducted SAM model runs suggest that certain transport functions are very sensitive to either hydraulic conditions (slope, channel geometry) or sediment size distributions, or both issues. For example, in sandy channels, Laursen (Copeland) transport rates are similar to results from the other functions, but in gravel-cobble streams Laursen (Copeland) rates are several orders of magnitude higher than the other functions. The Laursen (Copeland) results, when converted to concentrations, seem to be within a realistic range for the larger main San Juan Creek, but become impossibly high in the smaller, steeper canyons.

Of the compared sediment transport functions, the Laursen (Madden) results seem to provide the best general results across the varied sediment and channel conditions of the studied reaches. Therefore, the Laursen (Madden) function was chosen as the transport function to hold constant in the channel geometry and sediment distribution sensitivity analyses described above. The Laursen (Madden) transport function will be emphasized during a subsequent phase of work where alternative land use scenarios in the central San Juan and western San Mateo watersheds are evaluated for their hydrologic and geomorphic impacts.

4.6 COMPARISON OF RESULTS WITH OTHER SEDIMENT STUDIES

Results from three previous sediment transport studies in the San Juan Creek were compared with the current SAM model results. Results were compared with SLA (1999), who also used SAM to model sediment transport; Vanoni et al (1980) who used measurements of bedload deposition at the Conrock site; and Kroll and Porterfield (1969) who presented suspended load data from the Ortega Highway stream gage.

4.6.1 Comparison with SLA (1999)

Table 4-16 and Figure 4-21 compare transport rates for the 2, 25, 50, and 100-year peak flows[2] for reaches in Canada Gobernadora[3].

Table 4-16 Transport Rate Comparison at Canada Gobernadora Reaches 1-5

		2-year		25-year		50-year		100-year	
Reach		Q = 318 cfs$^{(1)}$		Q = 3,319 cfs$^{(2)}$		Q = 5,190 cfs$^{(3)}$		Q = 6,920 cfs$^{(4)}$	
PWA	**SLA**	**PWA**	**SLA**	**PWA**	**SLA**	**PWA**	**SLA**	**PWA**	**SLA**
GO1	6	47,491	2,996	596,801	64,812	959,944	323,881	1,287,074	481,527
GO2	5	45,946	61,316	587,316	1,111,884	949,961	756,469	1,278,896	953,314
GO3	4	30,861	319	426,587	28,331	691,174	64,639	948,368	108,730
GO4	3	35,313	66	440,941	382,008	711,947	752,941	964,859	1,120,738
GO5	2	38,607	1,080	491,568	96,388	790,138	901,810	1,070,095	1,302,452

Notes: (1) 2-year peak flow from SLA (1999)
(2) 25-year peak flow from SLA (1999)
(3) 50-year peak flow from SLA (1999)
(4) 100-year peak flow from SLA (1999)

For Reach GO1 at the mouth of Canada Gobernadora, PWA transport rates are approximately 1 order of magnitude higher than SLA rates. This difference is likely caused by the combination of different energy slope and sediment distribution data between the two models. As discussed in Section A-4, it is suspected that energy slope differs more significantly from bed slope at the mouth of the canyon than higher up in the watershed. At Reach GO2, SLA rates are approximately the same order of magnitude as PWA rates. For reach GO3, both PWA and SLA rates decrease relative to reach GO2, although the decrease in the SLA runs is much more dramatic, particularly for the lower flows. SLA rates for Reaches GO4 and GO5 show a similar trend: they remain extremely for low flows and increase significantly for higher flows, even higher than PWA rates. PWA rates increase slightly for these reaches, compared to rates in GO3. A comparison of input parameters in provided in Table 4-17.

Table 4-17 Comparison of Input Parameters for Canada Gobernadora Reaches 1-5

Parameter	PWA	SLA (1999)
Bankfull geometry	WES	HEC-2
Valley geometry	DEM	HEC-2
Energy slope	WES bed slope	HEC-2
Sediment curve	WES	SLA
Transport function	Laursen (Madden)	Yang, D50
Method	SAM modeling	SAM modeling

In summary, the PWA and SLA studies exhibit similar trends in transport rates by reach for a given flow. However, the SLA rates are more variable by reach for the same flow, while PWA rates for all reaches are generally more consistent for a given flow (Figure 4-21).

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[2] *As estimated in SLA (1999). Sections 2,3,4 above present peak flows estimated by the current PWA analysis.*

[3] *Note that the naming scheme differs between the two studies: PWA reach numbers begin at the mouth of the canyon while SLA reach numbers begin at the upstream extent.*

Figure 4-21 Canada Gobernadora Sub-basin Sediment Transport Rates

4.6.2 Comparison with Vanoni ET AL (1980)

Event-averaged sediment concentrations from the current study and Vanoni et al (1980) for San Juan Creek at the Conrock gravel mining pit are presented in Table 4-18. SLA (1999) results for this location have also been included for comparison. Both PWA and SLA (1999) results shown in Table 4-18 are based on channel geometry and sediment data from SLA Reach 1 of San Juan Creek.

Table 4-18 Sediment Yield and Concentration on San Juan Creek at the Conrock Gravel Mine

Study	Event	Runoff Volume (ac-ft)	Sediment Yield (tons)(1)			Sediment Concentration (g/liter)(2)		
			LM	EH	LC	LM	EH	LC
PWA	PWA Q2	3,238	9,636	13,039	148,558	2	3	32
PWA	PWA Q10	15,562	30,217	42,376	396,580	1	2	18
PWA	PWA Q100	36,048	45,829	63,704	522,281	1	1	10
Study	**Event**	**Runoff Volume (ac-ft)**	**Sediment Yield (CY)(3) measured**			**Sediment Concentration (g/liter)(4)**		
Vanoni et al	2/1/69	37,000	775,000			24		
Vanoni et al	1/15-19/78(5)	580	55,000			110		
Vanoni et al	3/4/78(5)	8,070	282,000			23		
Study	**Event**	**Runoff Volume (ac-ft)(6)**	**Sediment Yield (tons)(7)** Yang, D50			**Sediment Concentration (g/liter)** Yang, D50		
SLA	SLA Q2	401	1,583			3		
SLA	SLA Q25	11,498	21,162			1		
SLA	SLA Q50	18,242	30,498			1		
SLA	SLA Q100	27,106	40,196			1		

Notes: (1) Using SLA (1999) HEC-2 geometry and SLA (1999) sediment distribution for SLA Reach 1 of San Juan Creek.

(2) Event-averaged sediment concentration (total yield/total runoff volume)

(3) Sediment yields in Vanoni et al (1980) reported as cubic yards.

(4) Values in table represent reported concentrations from Vanoni et al (1980). No specific weight information for the sediment was provided in the Vanoni et al report; therefore, a specific weight of 1.26 tons/CY was assumed for verification of sediment concentrations. Attempts to reproduce reported sediment concentrations produced values of 19, 84, and 31 g/liter, respectively. Discrepancy may be partially caused by specific weight assumption.

(5) Difference between the volume of sediment deposited in the pit and that eroded from degraded reach of channel immediately upstream (Vanoni et al, 1980). (Local upstream erosion caused by the gravel mine subtracted out of yield measurement.)

(6) Runoff volume for SJ2t from Table 37, SLA (1999) Hydrology Appendix. May be slightly different than hydrograph used to calculate yield (see Note 7).

(7) SLA (1999) Reach 1 results. Yields calculated from "batch hydrographs" scaled to match peak flow for each event.

Comparing values in Table 4-18 indicates that concentrations from Vanoni et al (1980) are an order of magnitude higher than those produced from the current study using the Laursen (Madden) and the Engelund (Hansen) transport functions. Concentrations given by the Laursen (Copeland) function are the same order of magnitude as the Vanoni results. Concentrations calculated from the Yang, D50 function are also an order of magnitude smaller than the Vanoni concentrations.

Although the Laursen (Copeland) model results were the best match with the Vanoni data, this transport function was not selected for use in the main study for two reasons. First, as discussed in Section 5.5.3.2, this transport function resulted in unrealistically high concentrations in the steeper canyon study sub-basins that are the focus of the main study. Second, concentrations from Vanoni et al (1980), which were based on surveys of the gravel pit before and after storm events, may be somewhat elevated. The authors note that the 1969 and 1978 floods both followed several relatively dry years when sediment accumulated in tributary channels as storage. This stored sediment was readily available for transport during the large events of 1969 and 1978. In addition, it has been suggested (B. Hecht, pers. comm.) that the sediment quantities cited in Vanoni et al (1980) for the Conrock gravel mine may be high relative to other reaches due to the disturbed nature of the gravel mine site. This suggests that the Laursen (Copeland) function may produce inappropriately high transport rates for other areas in the watershed since it matched most closely with data in the vicinity of the gravel mine.

As described above, the Engelund (Hansen) function was initially selected because it produced sediment concentrations that agreed most closely with the Vanoni et al (1980) results. These initial results were based on model runs that used WES-DEM channel geometry data and the Vanoni et al (1980) sediment distribution. Subsequent refinement of the model indicated that the use of the incomplete Vanoni sediment distribution (no zero percent finer grain size) made it difficult to compare the results of the Engelund (Hansen) transport function, which is particularly sensitive to the lower grain sizes, with the results of the Laursen (Madden) and Laursen (Copeland) functions.

4.6.3 Comparison with Kroll and Porterfield (1969)

Sediment transport rates from the current study are compared to results from Kroll and Porterfield (1969) in Table 4-19 and Figure 4-22. SLA (1999) results for this location are included for comparison. Both PWA and SLA (1999) results are based on channel geometry and sediment data from SLA Reach 11 of San Juan Creek. The Ortega Highway stream gage is located at SLA river station 189+00, the upstream end of Reach 11.

Data for the Kroll and Porterfield study were collected during the 1967 and 1968 water years, during a relatively low rainfall period prior to the 1969 floods. Their results do not include transport rates for discharge events comparable to the higher flows modeled in the current study. For the 2-year peak flow both PWA and SLA (1999) transport rates are smaller than the Kroll and Porterfield measured rates by approximately a factor of 2. Where flows are comparable, the current results show general agreement with the Kroll and Porterfield data.

**Figure 4-22	San Juan Creek at Ortega Highway Stream Gage Sediment Transport Rates**

Table 4-19 Transport Rate Comparison for San Juan Creek at Ortega Highway Stream Gage

Flow (cfs)	Transport Rate (tons/day)		
	Kroll and Porterfield (1969)	PWA[1]	SLA (1999)[1]
0	0		
38	98		
170	3,900		
330	7,700		
440	10,500		
494[2]		4,869	6,334
560	13,500		
660	16,500		
1,500	44,000		
3,200	120,000		
4,100	170,000		
15,113[3]		360,346	439,062
24,400[4]		659,040	749,948
36,123[5]		1,053,503	1,144,508
51,342[6]		1,293,625	1,368,684
75,847[7]		1,645,285	1,755,536

Notes: [1] PWA and SLA results based on SLA (1999) HEC-2 geometry and SLA (1999) sediment distribution.
PWA study uses Laursen (Madden) transport function; SLA (1999) uses Yang, D50.
[2] 2-year peak flow from SLA (1999)
[3] 25-year peak flow from SLA (1999)
[4] 50-year peak flow from SLA (1999)
[5] 100-year peak flow from SLA (1999)
[6] 200-year peak flow from SLA (1999)
[7] 500-year peak flow from SLA (1999)

4.6.4 Conclusions of Sediment Transport Analysis

In conclusion, the description of the methods, sensitivity analysis, and comparison of results presented in Section 5 indicate that sediment transport and yield results may vary by several orders of magnitude depending upon input parameters. This is especially true with the selection of transport function. Relative to the other transport functions available in SAM, the Laursen (Madden) transport function compared favorably with the SAM guidelines, other studies, and storm event data. The Laursen (Copeland) function seemed to achieve the closest fit on the main San Juan channel at the gravel mine but was not appropriate for the steeper tributary sub-basins entering the main channel due to different hydraulic conditions. Despite uncertainties surrounding absolute values according to particular sediment transport functions, the current results provide relatively consistent trends for individual sub-basins. This information will be used as a baseline to evaluate impacts of potential development scenarios and to make planning level recommendations.

5. LIST OF PREPARERS

This report was prepared by the following PWA staff:

Kenneth Schwarz, Ph.D.	Director
Aaron Mead, P.E.	Hydrology, Hydraulics and Sediment Transport
Katie Pilat	Hydraulics and Sediment Transport
Nicola Mawer	Hydrology
Steve Blake	Stream Network Analysis, GIS Operations
Gwyn Barton	Report Production
Jeffrey Haltiner, Ph.D., P.E.	Principal in Charge

Eric Stein, D.Env. of PCR Services supplied valuable comments and suggestions following a review of this work.

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4. IN-CHANNEL SEDIMENT TRANSPORT

4.1 INTRODUCTION

The entrainment, transport, and deposition of sediment in watersheds of coastal southern California occurs according to a cascading system involving upland hillslopes, alluvial stream channels, estuaries, and the coast. These different geomorphic zones within the cascading system variably shed, move, or store sediment. As the principal conduit of sediment transport, the stream channel system dynamically responds to changes in hydrologic conditions across the watershed. Increases or decreases in runoff and sediment delivery to specific reaches can result in shifts in erosional and depositional patterns throughout the drainage network. Additionally, changes in sediment storage functions within the channel create feedbacks, which further alter stream geometry and slope and are likely to further destabilize stream behavior.

PWA evaluated in-channel sediment transport processes for nine of the ten studied sub-basins in the San Mateo and San Juan Creek watersheds. Sediment transport at Talega Canyon, in the San Mateo watershed, was not evaluated due to lacking sediment and channel data. PWA selected a USACOE computer model, the Hydraulic Design Package for Channels (SAM), to evaluate in-channel sediment processes. SAM allows the computation of both sediment transport capacity and sediment yield for a given flood event. Due to limited data availability and other constraints, SAM was an appropriate choice for this study to establish baseline conditions on which the impacts of future land-use scenarios can be evaluated. Baseline results for in-channel sediment transport rates and yields will be used in a subsequent phase to evaluate the impact of various land-use alternatives.

This chapter includes a description of the methods and assumptions used in the SAM modeling approach (Section 4.2); a presentation of results for the San Juan and San Mateo creek sub-basins (Sections 4.3, 4.4); a sensitivity analysis of the SAM modeling results (Section 4.5); and a comparison of results with other studies (Section 4.6)

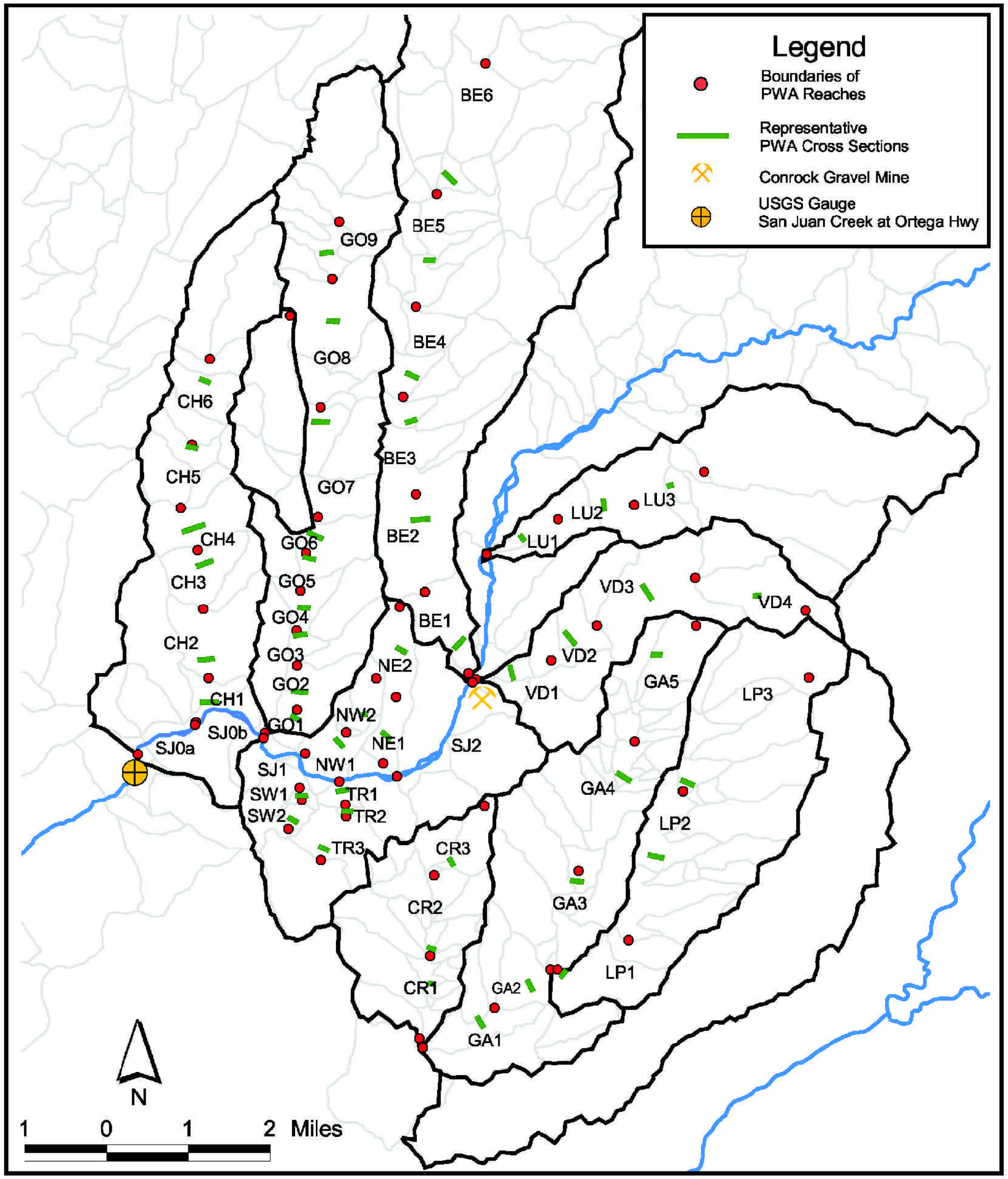
4.2 APPROACH AND KEY ASSUMPTIONS

4.2.1 Overview of SAM Modeling Procedure

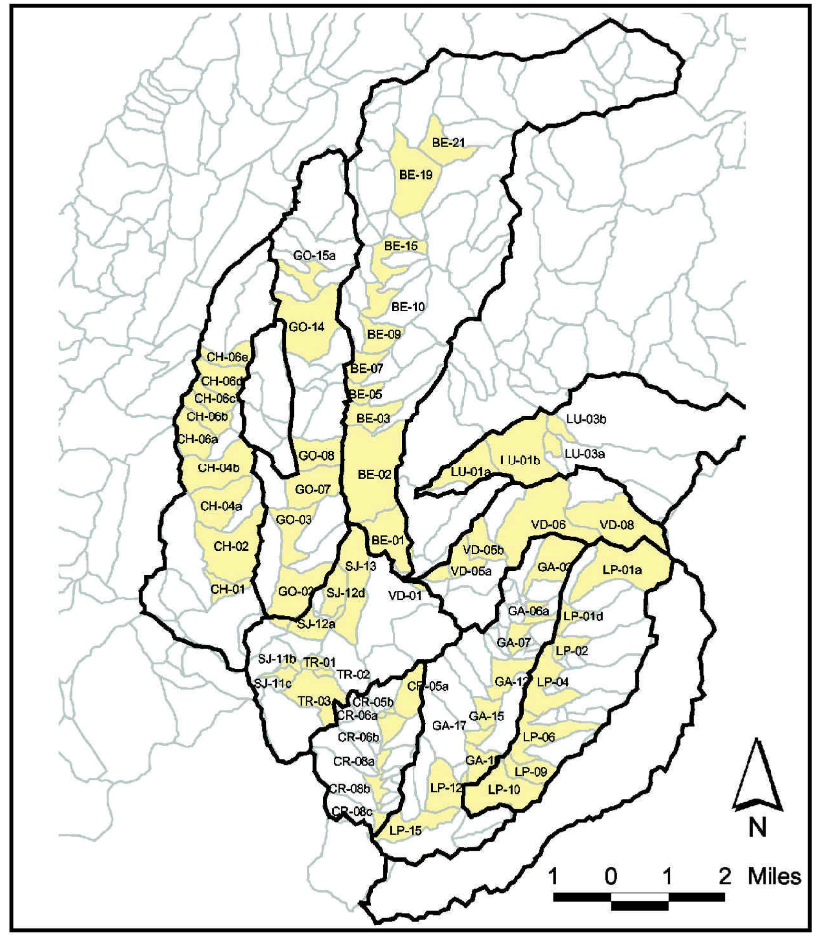
SAM, a USACE channel design package, was used to calculate sediment transport rates and sediment yields for several channel reaches in the San Juan and San Mateo watersheds (Figure 4-1). Channels were divided into sub-reaches according to topographic and hydraulic conditions and then analyzed using SAM. The SAM model requires streamflow data, channel geometry information, channel hydraulic parameters (including roughness and energy slope), sediment particle-size distributions by reach, and the selection of an appropriate sediment transport function.

figure 4-1

Sediment Transport Analysis in Hydrologic Sub-basins



A. PWA Sediment Transport Reaches



B. USACE WES Reaches

Channel geometry and sediment parameters from shaded reaches were used in PWA analysis

PWA

The SAM program consists of six modules, two of which are organizational and four of which are computational. The two organizational modules, PSAM and SAMaid facilitate input preparation and transport function selection. The first two computational modules, SAMhyd and SAMavg, are used to combine flows and geometry data to yield average (or effective) hydraulic parameters (flow width, flow depth, and velocity) for a given flow and energy slope. Selecting which initial module to use depends on the type of input data available. SAMhyd uses channel input data (discharge, cross section geometry, roughness, and energy slope) from a single representative location to calculate hydraulic parameters for the entire reach. In contrast, SAMavg uses HEC-2 output to calculate reach-averaged values. The resulting hydraulic parameters, along with sediment gradation data, are input into SAMsed to calculate transport rates for given discharge values. In SAMyld, the transport rate is combined with a storm event hydrograph to produce a sediment yield for that event. Sediment yields can then be used to calculate an average sediment concentration for the event.

4.2.2 Data Sources for Sediment Transport Modeling

Preliminary results from PWA's HEC-1 runoff analysis for the 2, 10, and 100-year discharge events were used as flow input for the sediment transport analysis. Channel geometry and sediment parameters were estimated from several sources. An existing HEC-2 model developed by Simons, Li & Associates (SLA, 1999) provided channel and sediment data for the following reaches:

- San Juan Creek from the river mouth upstream to the upper extent of the Conrock Mining lease, just downstream of Caspers Regional Park.
- Canada Gobernadora from the San Juan Creek confluence upstream to the Coto de Caza golf course.
- Arroyo Trabuco from the San Juan creek confluence upstream to Plano Trabuco.
- Oso Creek from the Arroyo Trabuco confluence upstream to near the I-5 crossing

Of these reaches, only data from the San Juan Creek and Canada Gobernadora HEC-2 reaches was utilized in the current sediment transport study. In addition to the available HEC-2 data, field information from WES (2000) provided measures of bankfull width and depth, channel bed slope, and sediment bed material distributions. The WES study included all of the ten studied sub-basins of the San Juan and San Mateo watersheds except Talega Canyon. The 10-meter digital elevation model (DEM) provided stream valley cross sections which were then used in combination with the WES channel measurements to create composite stream channel and valley cross sections. Field observations conducted by Balance Hydrologics (BH) provided channel roughness values for the majority of the study reaches.

4.2.3 SAM Input Parameters and Selection of Transport Function

Input files for the hydraulic, sediment transport rate, and sediment yield SAM modules were created for each of the studied sub-basins. For each sub-basin the stream channel was divided into reaches of roughly similar geometry and sediment characteristics. Sub-basins were typically organized into 3 to 6 reaches, with reach lengths ranging from approximately 1000 to 3000 feet. As described below, a set of representative hydraulic and sediment parameters were determined for each reach.

For the reaches within the tributary sub-basins, channel geometry was determined using a combination of WES and USGS/DEM data. The WES (2000) study provided a measure of bankfull mean width and depth for each WES reach. The WES width and depth values describe channel form independent of the valley-floor floodplain on either side of the channel. The cross section for each PWA reach includes a WES channel cross-section. Where a PWA reach spanned more than one WES reach, channel widths and depths were averaged to create a representative channel form for the whole reach.

Geomorphologists have used the concept of bankfull width and depth to link streamflow conditions to channel shape. Dominant discharge is considered to be the flow rate (or frequency), which determines channel form and cross-sectional capacity (Wolman and Leopold, 1957). In other words, dominant discharge is the flow which performs the most work, where work is defined in terms of sediment transport (Wolman and Miller, 1960). The frequency of the dominant discharge flow is largely related to regional climatic conditions. Studies from watersheds in the eastern U.S., as well as northern California, suggest that a flow with a return frequency of about 1.5 years is the dominant channel-forming event (Dunne and Leopold, 1978). In more arid and semi-arid climates, such as southern Orange County, with greater annual flow variability and episodicity, the notion of a dominant discharge may be less appropriate. If a dominant discharge does exist in such regions, it more likely has a higher return frequency (perhaps in the 5 to 10 year range) than the annual 1.5-year event (Wolman and Gerson, 1978).

Flows modeled for this study include the frequent 2-year event, the moderate 10-year event, and the extreme 100-year event. For the sediment transport modeling, channel cross sections must have the capacity to contain the largest input flows. Therefore, the WES bankfull width and depth data were supplemented with geometric data for the valley floor provided by the DEM (Figure 4-2). For any given reach, several representative valley cross-sections were available from the DEM that extended across the floodplain up to the adjacent hillslopes. These valley cross-sections were examined to determine an average width at a flow stage of 2 meters (roughly the maximum stage for highest flows along most reaches). The cross section that most closely matched reach average dimensions was used to represent the valley for the particular reach. As illustrated in Figure 4-2, WES bankfull channels were nested within the broader valley profile supplied by the DEM to create a composite cross section.

For the main San Juan channel, HEC-2 cross sections were available at 150-meter intervals for the entire valley width. For these reaches, the composite WES/DEM method was not needed. Since HEC-2 data was also available for Lower Canada Gobernadora, this area was used to compare and refine the composite WES/DEM method (Section 4.5).

In terms of other input parameters, channel bed slopes from WES (2000) were used as energy slopes and channel roughness values were based on field observations by Balance Hydrologics (2000). Sediment distributions, required by the SAMsed module, were provided by WES (2000) and SLA. For the central San Juan channel and portions of Canada Gobernadora, energy slopes, sediment distributions, and channel roughness values were provided by SLA (1999). Tables 4-1 and 4-2 summarize SAM input parameters for the modeled reaches of the San Juan and San Mateo watersheds.

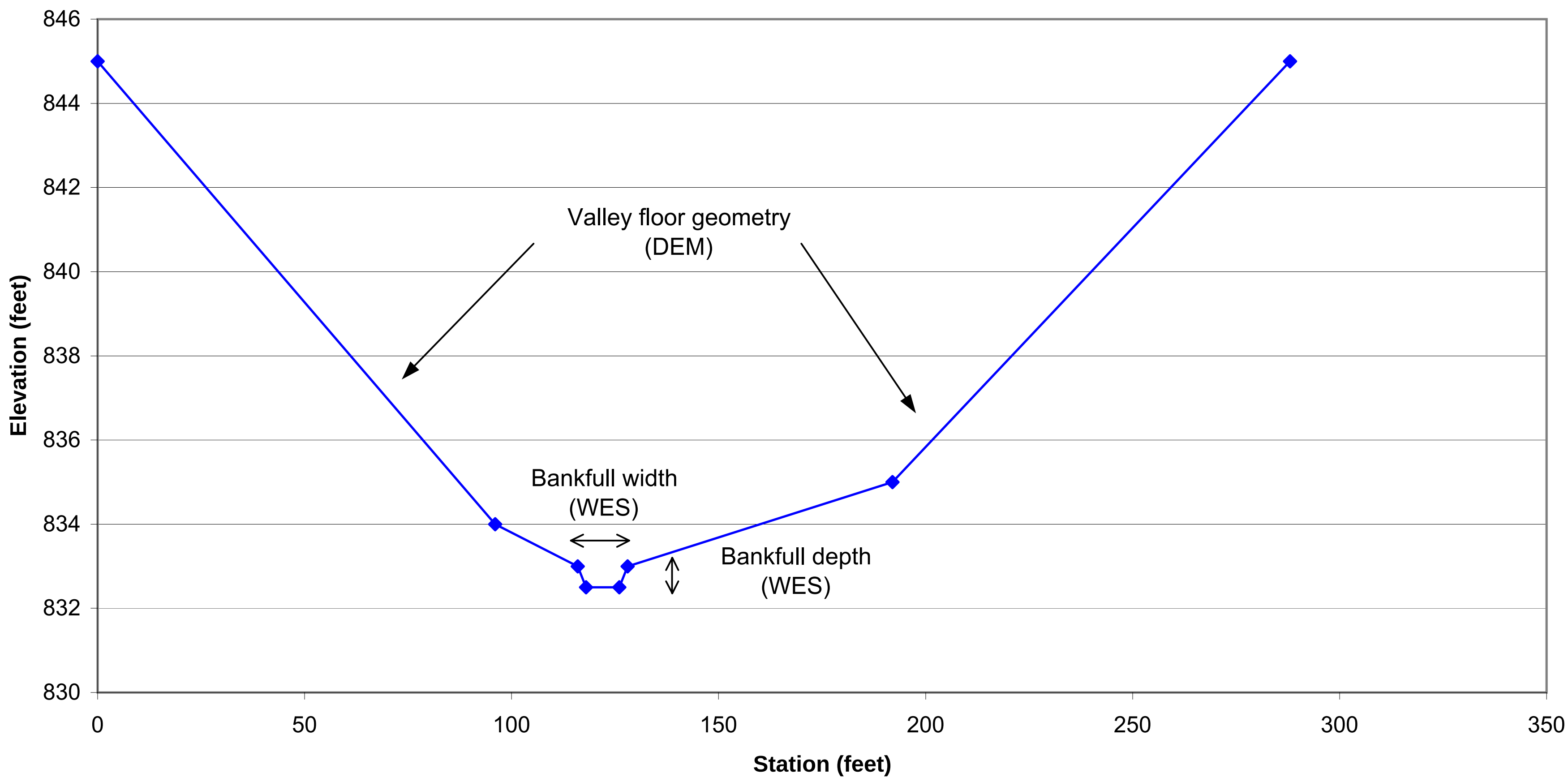


Figure 4-2

Sample cross section used for Tributaries to San Juan and San Mateo Creeks

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Table 4-1 SAN JUAN CREEK SEDIMENT TRANSPORT ANALYSIS - INPUT DATA SUMMARY

Sub-basin	Catchment	Reach	Flow Rates (cfs)[1]			Channel Hydraulic Parameters				Sediment Data[4]				
			Q_2	Q_{10}	Q_{100}	Width (feet)[2]	Depth (feet)[2]	Slope (feet/feet)[2]	Manning's n[3]	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt/Clay (%)
Lucas Canyon	-	1	255	1,627	3,449	72	4.4	0.019	0.050	10	70	15	5	0
Lucas Canyon	-	2	255	1,627	3,449	45	5.3	0.026	0.050	10	50	30	10	0
Lucas Canyon	-	3	255	1,627	3,449	26	5.7	0.065	0.050	59	31	11	0	0
Verdugo Canyon	-	1	87	815	1,880	90	2.5	0.020	0.047	0	64	26	10	0
Verdugo Canyon	-	2	87	815	1,880	41	3.7	0.029	0.047	7	66	17	10	0
Verdugo Canyon	-	3	87	815	1,880	44	3.3	0.037	0.047	0	0	0	20	80
Verdugo Canyon	-	4	87	815	1,880	16	4.0	0.155	0.047	60	30	10	0	0
Bell Canyon	-	1	733	3,920	8,517	171	6.6	0.006	0.053	10	25	30	35	0
Bell Canyon	-	2	733	3,920	8,517	187	5.2	0.011	0.053	30	35	25	10	0
Bell Canyon	-	3	733	3,920	8,517	157	5.6	0.012	0.053	26	43	23	9	0
Bell Canyon	-	4	749	3,745	7,590	99	6.5	0.015	0.053	10	40	40	10	0
Bell Canyon	-	5	749	3,745	7,590	101	6.4	0.015	0.053	15	45	25	15	0
Bell Canyon	-	6	749	3,745	7,590	57	6.5	0.046	0.053	34	30	28	9	0
Canada Gobernadora	-	1	601	3,092	5,722	143	5.3	0.018	0.080	0	0	0	100	0
Canada Gobernadora	-	2	601	3,092	5,722	159	5.0	0.018	0.080	0	0	0	100	0
Canada Gobernadora	-	3	601	3,092	5,722	175	4.5	0.008	0.050	0	0	10	90	0
Canada Gobernadora	-	4	601	3,092	5,722	131	5.4	0.008	0.050	0	0	10	90	0
Canada Gobernadora	-	5	601	3,092	5,722	151	4.8	0.009	0.050	0	0	0	100	0
Canada Gobernadora	-	6	601	3,092	5,722	167	4.1	0.012	0.050	0	0	0	80	20
Canada Gobernadora	-	7	385	1,803	3,427	94	4.3	0.012	0.050	0	0	0	80	20
Canada Gobernadora	-	8	385	1,803	3,427	109	3.6	0.016	0.050	0	0	10	70	20
Canada Gobernadora	-	9	304	1,413	2,424	58	2.9	0.056	0.050	0	0	10	60	30
Canada Chiquita	-	1	179	1,031	2,121	107	2.8	0.024	0.065	0	0	0	80	20
Canada Chiquita	-	2	179	1,031	2,121	82	4.8	0.007	0.065	0	0	0	80	20
Canada Chiquita	-	3	179	1,031	2,121	60	5.1	0.026	0.100	0	0	0	80	20
Canada Chiquita	-	4	179	1,031	2,121	89	4.5	0.017	0.100	0	0	0	60	40
Canada Chiquita	-	5	179	1,031	2,121	63	3.7	0.028	0.065	0	42	21	37	0
Canada Chiquita	-	6	179	1,031	2,121	96	3.0	0.023	0.065	0	0	12	59	28
Central San Juan Creek	SW	1	5	45	106	16	1.0	0.036	0.040	0	0	0	40	60
Central San Juan Creek	SW	2	5	45	106	7	1.8	0.021	0.040	0	0	0	80	20
Central San Juan Creek	Trampas	1	27	248	589	64	1.1	0.043	0.040	0	0	0	100	0
Central San Juan Creek	Trampas	2	27	248	589	89	1.9	0.004	0.040	0	0	0	60	40
Central San Juan Creek	Trampas	3	27	248	589	33	1.4	0.083	0.040	0	0	0	60	40
Central San Juan Creek	NW	1	11	103	245	33	1.2	0.024	0.040	0	0	25	75	0
Central San Juan Creek	NW	2	11	103	245	8	2.7	0.029	0.040	0	0	0	100	0
Central San Juan Creek	NE	1	13	120	284	14	2.0	0.034	0.040	10	10	10	70	0
Central San Juan Creek	NE	2	13	120	284	35	1.1	0.034	0.040	10	10	10	70	0
Central San Juan Creek	Main[5], [6]	1	3,302	18,044	41,192	616	6.7	0.005	0.036	18	8	19	55	0
Central San Juan Creek	Main[5], [6]	2	3,142	17,322	38,927	452	8.8	0.003	0.039	18	8	19	55	0
Central San Juan Creek	Main[5], [6]	3	2,922	15,452	34,955	388	12.2	0.001	0.039	14	9	24	53	0
Central San Juan Creek	Main[5], [6]	4	2,874	15,068	33,591	433	10.9	0.002	0.039	14	9	24	53	0

Notes: [1] Flow rates from PWA's preliminary HEC-1 hydrology analysis.

[2] Except where indicated, channel width, depth, and slope were calculated based on the USGS 10-meter digital elevation model (DEM) for the watershed and field data collected by WES (1999
Channel widths and depths vary for different flow rates. Values shown in this table correspond to the 100-year flow rate. Slopes represent bed slope for all reaches except where indicated.

[3] Representative Manning's n-values are based on field estimates by Balance Hydrologics (2000) and SLA (1999)

[4] Except where indicated, sediment size data is based on field data collected by WES (1999)

[5] Effective channel parameters (width, depth, slope) for the the main channel catchment of the Central San Juan Creek sub-basin were computed directly in the SAM model based on the SL
(1999) HEC-2 model. Slopes represent the average energy slope as calculated in HEC-2 and SAM. Parameters shown are for the 100-year flow rate.

[6] Sediment size data for the main channel catchment of the Central San Juan Creek sub-basin is based on field data collected by SLA (1999)

Table 4-2 SAN MATEO CREEK SEDIMENT TRANSPORT ANALYSIS

INPUT DATA SUMMARY														
Sub-basin	Reach	Flow Rates (cfs)[1]			Channel Hydraulic Parameters				Sediment Data[4]					
		Q_2	Q_{10}	Q_{100}	Width (feet)[2]	Depth (feet)[2]	Slope (feet/feet)[2]	Manning's n[3]	Boulder (%)	Cobble (%)	Gravel (%)	Sand (%)	Silt/Clay (%)
La Paz Canyon	1	404	2,160	4,235	83	4.7	0.016	0.048	9	75	11	5	0
	2	404	2,160	4,235	60	5.3	0.021	0.048	30	35	22	13	0
	3	404	2,160	4,235	46	4.3	0.073	0.048	36	44	10	10	0
Gabino Canyon	1	594	3,661	7,565	114	7.0	0.007	0.048	5	30	30	35	0
	2	594	3,661	7,565	113	5.5	0.016	0.048	5	85	5	5	0
	3	256	1,499	2,923	99	3.5	0.014	0.048	1	38	31	24	6
	4	256	1,499	2,923	63	4.6	0.014	0.048	6	52	16	26	0
	5	256	1,499	2,923	41	3.9	0.058	0.048	25	52	16	7	0
Upper Cristianitos Creek	1	147	1,028	2,066	47	4.7	0.012	0.048	5	35	30	30	0
	2	147	1,028	2,066	38	4.7	0.018	0.048	2	13	4	18	63
	3	147	1,028	2,066	70	2.4	0.051	0.048	7	30	1	12	49
Talega Canyon	SEDIMENT TRANSPORT ANALYSIS NOT CONDUCTED FOR TALEGA CANYON DUE TO LACK OF DATA.												

Notes: [1] Flow rates from PWA's preliminary HEC-1 hydrology analysis.

[2] Channel width, depth, and slope were calculated based on the USGS 10-meter digital elevation model (DEM) for the watershed and field data collected by WES (1999). Channel widths and depths correspond to the 100-year flow rate. Slopes represent bed slope for all reaches except where indicated.

[3] Representative Manning's n-values are based on field estimates by Balance Hydrologics (2000) and SLA (1999).

[4] Sediment size data is based on field data collected by WES (1999).

Computer based sediment transport models often use recognized sediment transport functions (mathematical formulae that can be used to estimate the movement of sediment based on hydraulic and sediment characteristics) in their calculations. SAM has 19 sediment transport functions available for calculating transport rates. Selecting the appropriate sediment transport function is a critical decision in the modeling process. For this study, the Laursen (Madden) (LM) sediment transport function was selected based upon guidelines in the SAM reference manual and comparisons to previous results by SLA (1999), Vanoni et al (1980), and Kroll and Porterfield (1969) (see Section 4.5 below). This function is suitable for modeling sand and gravel bed streams such as those found in the San Juan and San Mateo Creek Watersheds.

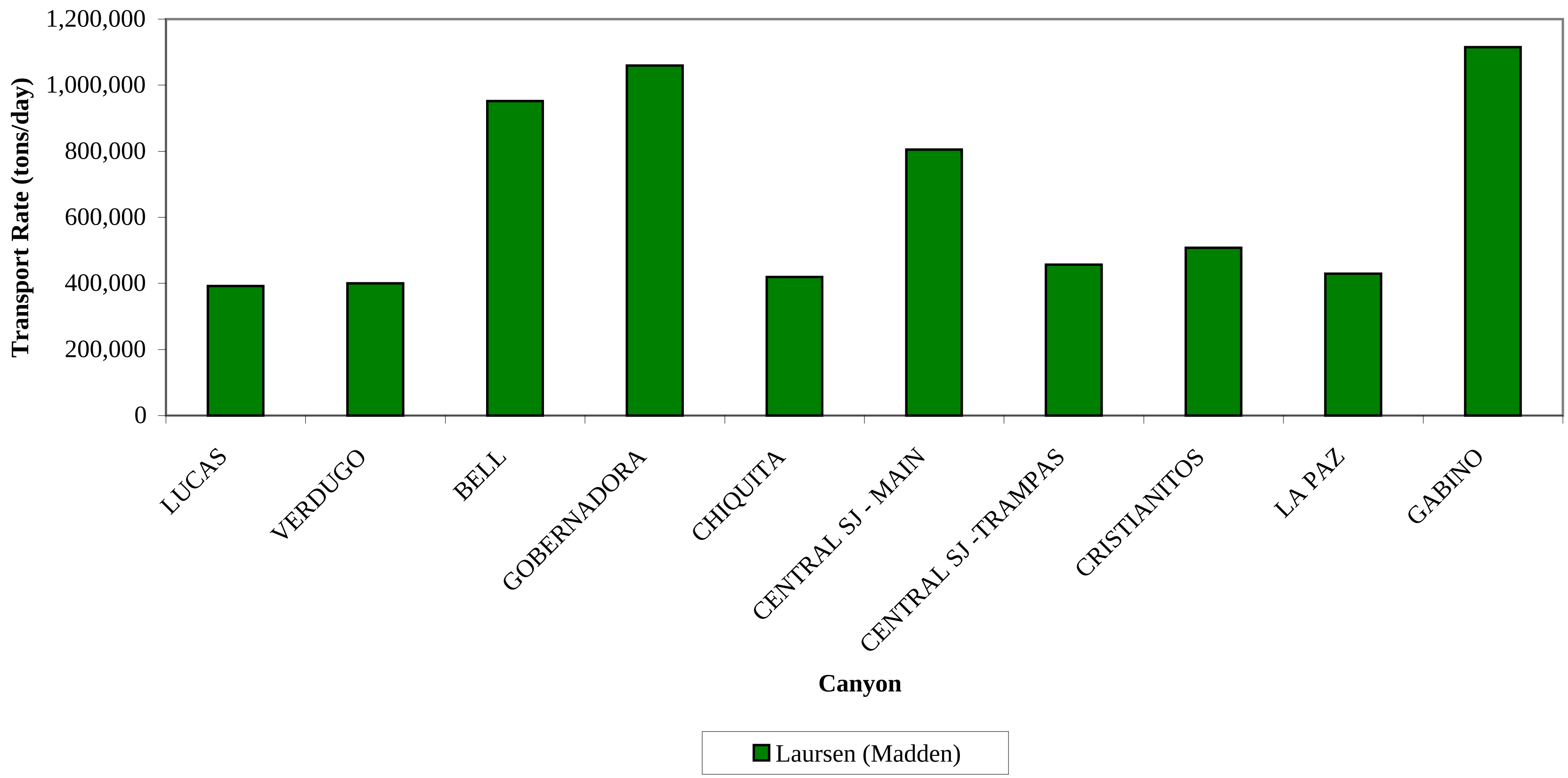
4.3 RESULTS FOR SAN JUAN WATERSHED SUB-BASINS

4.3.1 San Juan Overview

Using the SAM model, peak sediment transport rates were calculated for the studied sub-basins of the San Juan watershed for the 2-year, 10-year, and 100-year discharge events. The Laursen (Madden) sediment transport function was used within the SAM application. Peak transport rates per unit area were also calculated for each of the sub-basins. It should be noted that these rates represent the capacity for the system to transport sediment and may not describe actual sediment transport rates. Actual sediment transport is determined by both transport capacity and sediment supply (Terrains Analysis Technical Appendix by Balance Hydrologics, 2001).

Figure 4-3 compares peak sediment transport capacities for the 100-year flow event for the studied sub-basins in the San Juan and San Mateo watershed. Transport rates are given at the most downstream end of each sub-basin. For the Laursen (Madden) transport function, Cañada Gobernadora and Bell Canyon had the highest absolute sediment transport rates in the San Juan watershed. This result is likely explained by the relatively large size of these two canyons (11.08 miles^2 and 20.57 miles^2, respectively). However, Cañada Gobernadora also has a relatively high transport capacity as calculated per unit area (Figure 4-4). The main stem of the Central San Juan Creek sub-basin also had a relatively high sediment transport rate in absolute terms. Peak transport rates from Lucas Canyon were the lowest of the San Juan Creek watershed sub-basins.

In Figure 4-4, transport rates are shown per unit area at the most downstream reach of each sub-basin. Since these rates are independent of sub-basin size, they reflect other sediment shedding properties, integrating factors of channel geometry, runoff rates, and geology. For the Laursen (Madden) transport function, Trampas Canyon had the highest transport rates per unit area of any of the studied sub-basins entering San Juan Creek. Cañada Gobernadora, Verdugo Canyon, and Lucas Canyon had the next highest transport capacities per unit area. Transport rates per unit area are likely highest for Trampas Canyon due to steep channel slopes at the basin mouth, transportable sediment sizes, and a small drainage area. In many ways, Trampas Canyon is different from the other studied sub-basins, which are larger canyon systems that occupy broader valleys. Trampas Canyon is more representative of the steeper headwater systems of the San Juan watershed where sediment yields are much higher. Conversely, sediment yields per unit area for the main San Juan channel are the lowest. More detailed sediment transport results for each sub-basin are presented below.



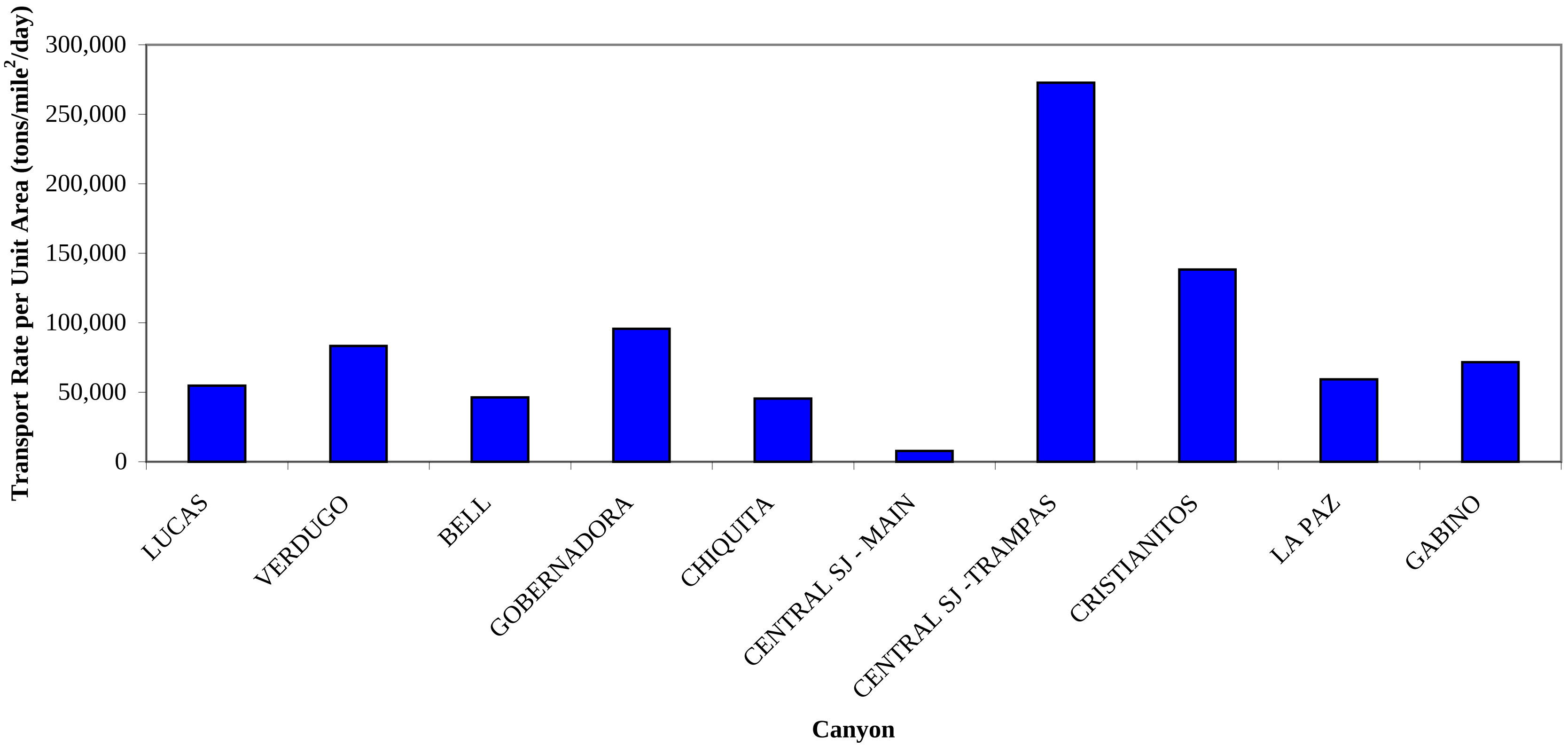
Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-3

Peak 100-year Sediment Transport Rate Exiting Sub-basin, San Juan & San Mateo Creek Watersheds

PWA

PWA #:1393



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-4

Peak 100-year Sediment Transport Rate, per Unit Area,
San Juan & San Mateo Creek Watersheds
Laursen (Madden) Transport Function

PWA

PWA #:1393

Figure 4-5 summarizes calculated sediment yields for the modeled storm events at the mouth of each of the sub-basins. These results represent the potential volume of sediment delivered to the main stem of San Juan Creek from each of the tributary sub-basins during large storm events. Bell Canyon exhibited the highest yield to San Juan Creek. This is not surprising since Bell is the largest of the sub-basins and produced relatively high transport rates. The main stem of the Central San Juan sub-basin, Gobernadora, Trampas, and Lucas Canyons also produced relatively high yields. Cañada Chiquita produced the lowest yields of the San Juan Watershed sub-basins. Figure 4-6 shows sediment yields per unit area. Trampas Canyon has the highest yields per area. This is consistent with the results for transport rates described above for this steep, small tributary catchment. Of the principal canyon sub-basins, Verdugo Canyon had the highest yield per unit area.

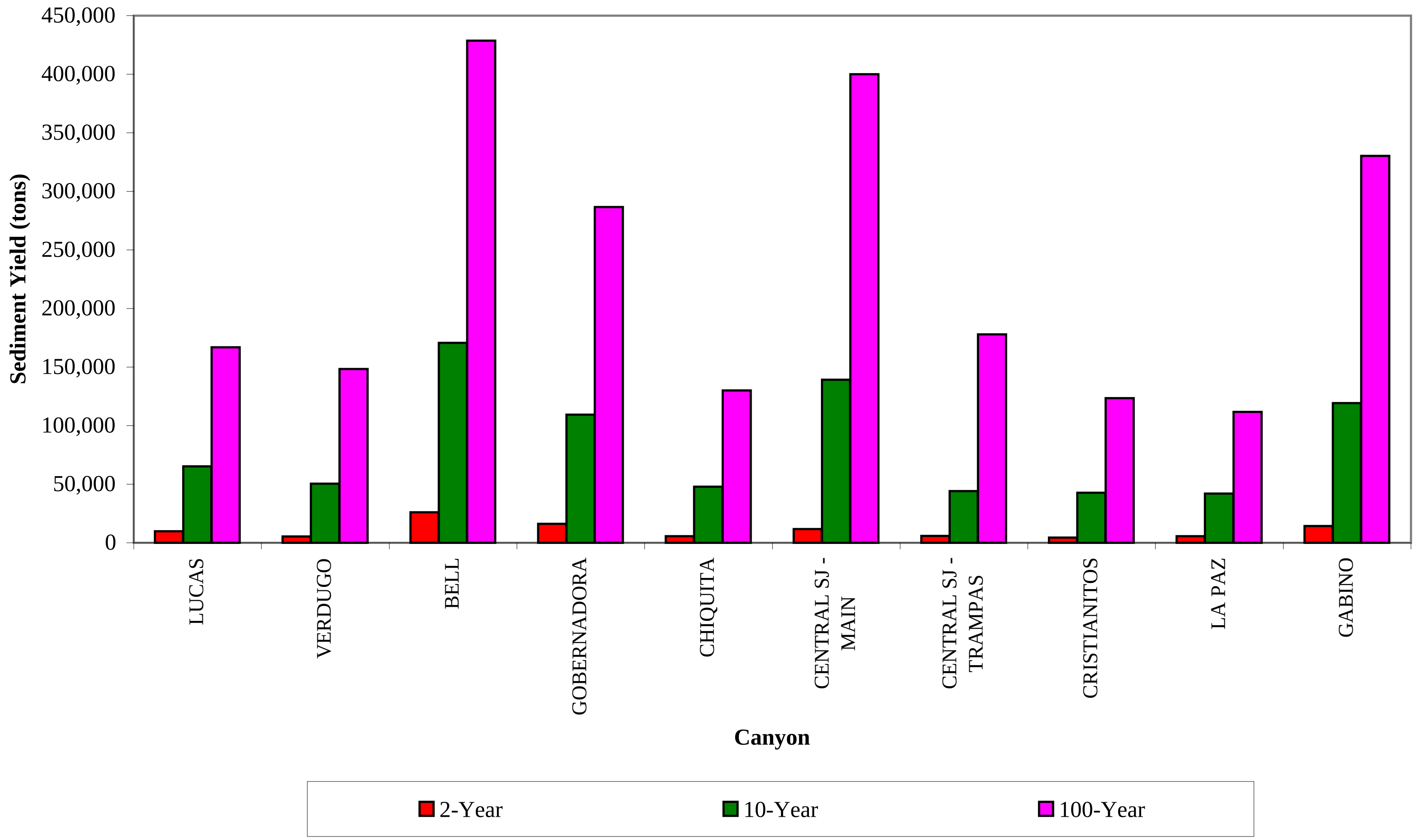
Based on the yield results, sediment mass balances were calculated for the four modeled reaches of the main stem of San Juan Creek (Figure 4-7). Upstream sediment input to San Juan Creek, from the upper watershed above Lucas Canyon, was estimated using results from Balance Hydrologics (2001). It was assumed that this sediment enters reach SJ4 of the main San Juan channel along with sediment from Lucas, Verdugo, and Bell Canyons (Figure 4-1). Sediment from Cañada Gobernadora was modeled to enter reach SJ2 and sediment from Cañada Chiquita was modeled to enter reach SJ1. Mass balances exhibit a general pattern of deposition in three of the four modeled reaches during large flood events. The most downstream reach was slightly erosional during flood events according to the mass balances. The delivery of sediment from the canyon sub-basins to the main San Juan Creek channel likely plays a significant role in the depositional pattern observed in the three upstream reaches.

4.3.2 Lucas Canyon

Lucas Canyon was divided into three reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-3. Within Lucas Canyon, Reach 2 has the highest transport capacity for all three modeled flood events. This may be due to a greater percentage of smaller, more transportable sediment in Reach 2 (Table 4-1). Reach 3 upstream tends to have the lowest transport capacity while the capacity of Reach 1 is intermediate between 2 and 3.

Relative to other modeled sub-basins in the San Juan Creek watershed, Lucas Canyon sediment transport rates are in the middle to low end of the range. On a per unit area, the capacity of Lucas Canyon to transport sediment to San Juan Creek was calculated to be higher than the Central San Juan (Main Channel), Chiquita, and Bell Canyon sub-basins, but lower than Trampas, Gobernadora, and Verdugo Canyon sub-basins (Figure 4-4). In absolute terms, the 100-year capacity of Lucas Canyon to transport sediment to San Juan Creek ranked lowest of the modeled sub-basins (Figure 4-3). Overall, Lucas Canyon has the capacity to deliver a significant but relatively small quantity of sediment to San Juan Creek. This is likely due to the basin's small size as well as inherent geological, hydrologic, and geomorphic conditions, including a high percentage of larger less transportable sediment at its mouth.

Within Lucas Canyon, sediment yields follow a pattern similar to sediment transport rates (Table 4-3). Reach 2 has the highest sediment yield for all three modeled storm events, Reach 1 the second highest, and Reach 3 the lowest yield. As discussed above, Reach 2 may be highest due to a larger proportion of mobile sediment sizes than the other two reaches.



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-5

Sediment Yield at Canyon Mouth
Laursen (Madden)

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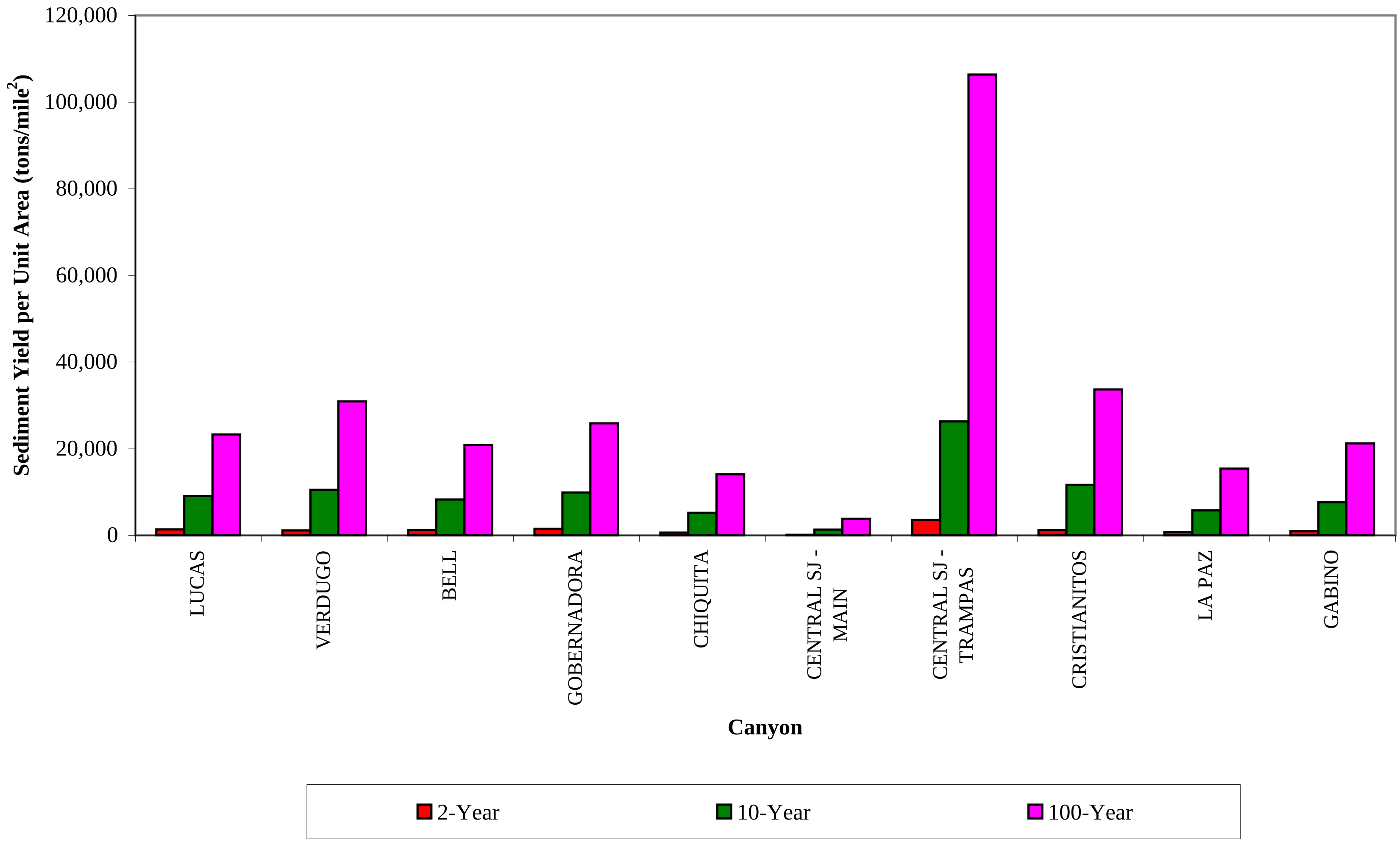

Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-6

Sediment Yield per Unit Area at Canyon Mouth
Laursen (Madden)

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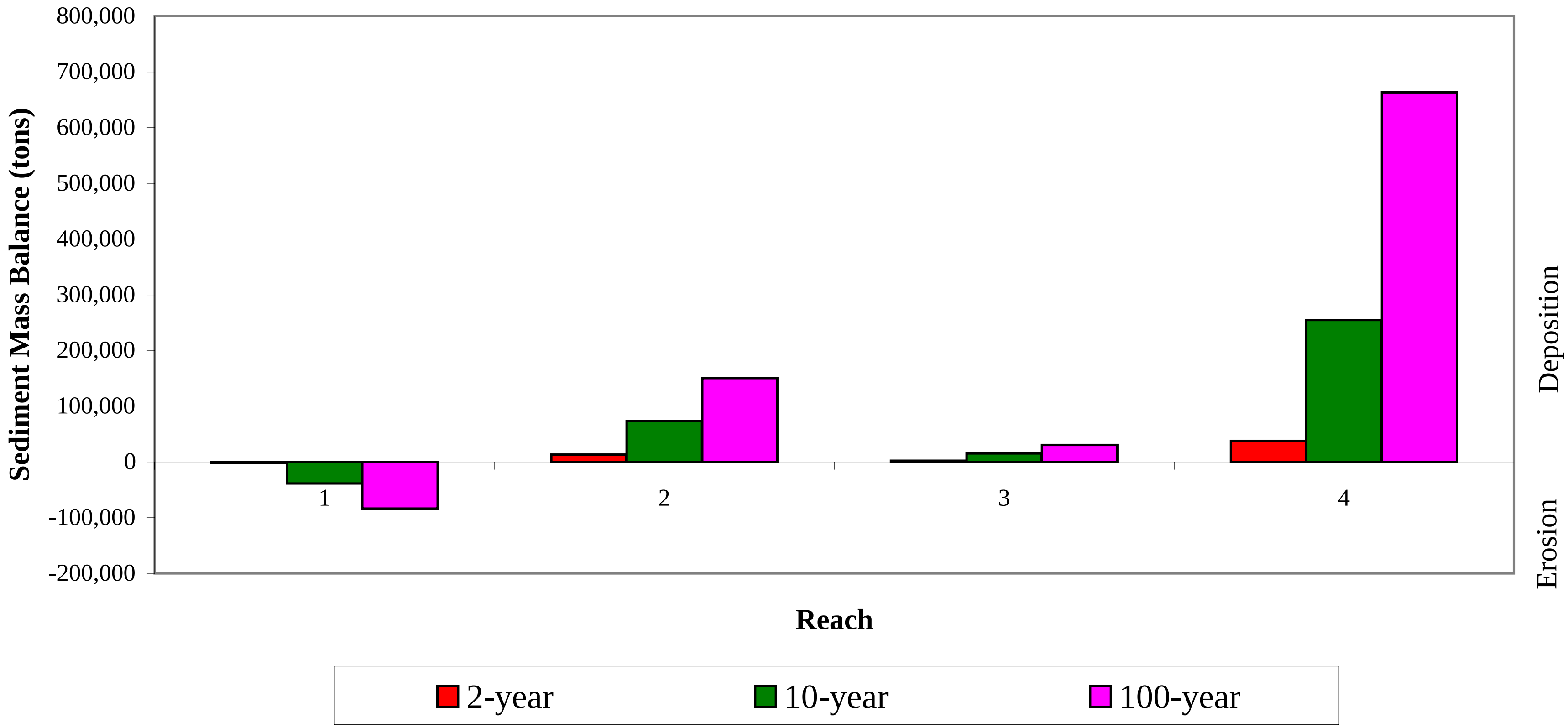
Laursen (Madden) Transport Function



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis. These results only incorporate sediment inflow from analyzed sub-basins, not areas upstream of Lucas Canyon.

figure 4-7

Main Channel Reach
Central San Juan Sub-basin
Sediment Mass Balance

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Table 4-3 LUCAS CANYON SUB-BASIN SEDIMENT RESULTS SUMMARY

Reach Number	Peak Transport Rate (tons/day) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	24,400	175,300	392,200
2	60,200	438,400	945,800
3	1,800	26,300	75,200

Sub-basin Area (miles^2)	Peak Transport Rate Exiting Sub-basin per Unit Area (tons/mile^2/day) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
7.17	3,400	24,400	54,700

Reach Number	Sediment Yield (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	9,900	65,300	166,800
2	24,500	162,400	412,100
3	600	7,100	24,800

Sub-basin Area (miles^2)	Sub-basin Sediment Yield, per Unit Area (tons/mile^2) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
7.17	1,400	9,100	23,300

Reach Number	Average Sediment Concentration (g/L) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	31	36	38
2	75	89	94
3	2	4	6

Reach Number	Sediment Mass Balance (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	14,600	97,200	245,300
2	-23,900	-155,300	-387,200
3	0	0	0

orca/pwa/projects/1393SAMP/t/Baseline Report/Tables/ Table 4.3 Lucas Canyon.xls 6/23/2004

Relative to other sub-basins in the San Juan Creek watershed, Lucas Canyon produced mid-range sediment yields on a per unit area basis for all three events (Figure 4-6). As noted above, Lucas Canyon does not appear to have a large capacity for sediment delivery to San Juan Creek.

As part of the sediment analysis, average sediment concentrations were calculated for each reach and storm event. Concentrations were calculated as the sediment yield (in units of mass) divided by the total runoff volume for the storm event, to give a concentration in grams/liter. Results from these calculations are not a measure of actual sediment concentration at any point in time during the event, but are event-based averages and offer a useful comparative basis between sub-basins. Additional discussion of sediment concentrations is presented in Section 4-5.

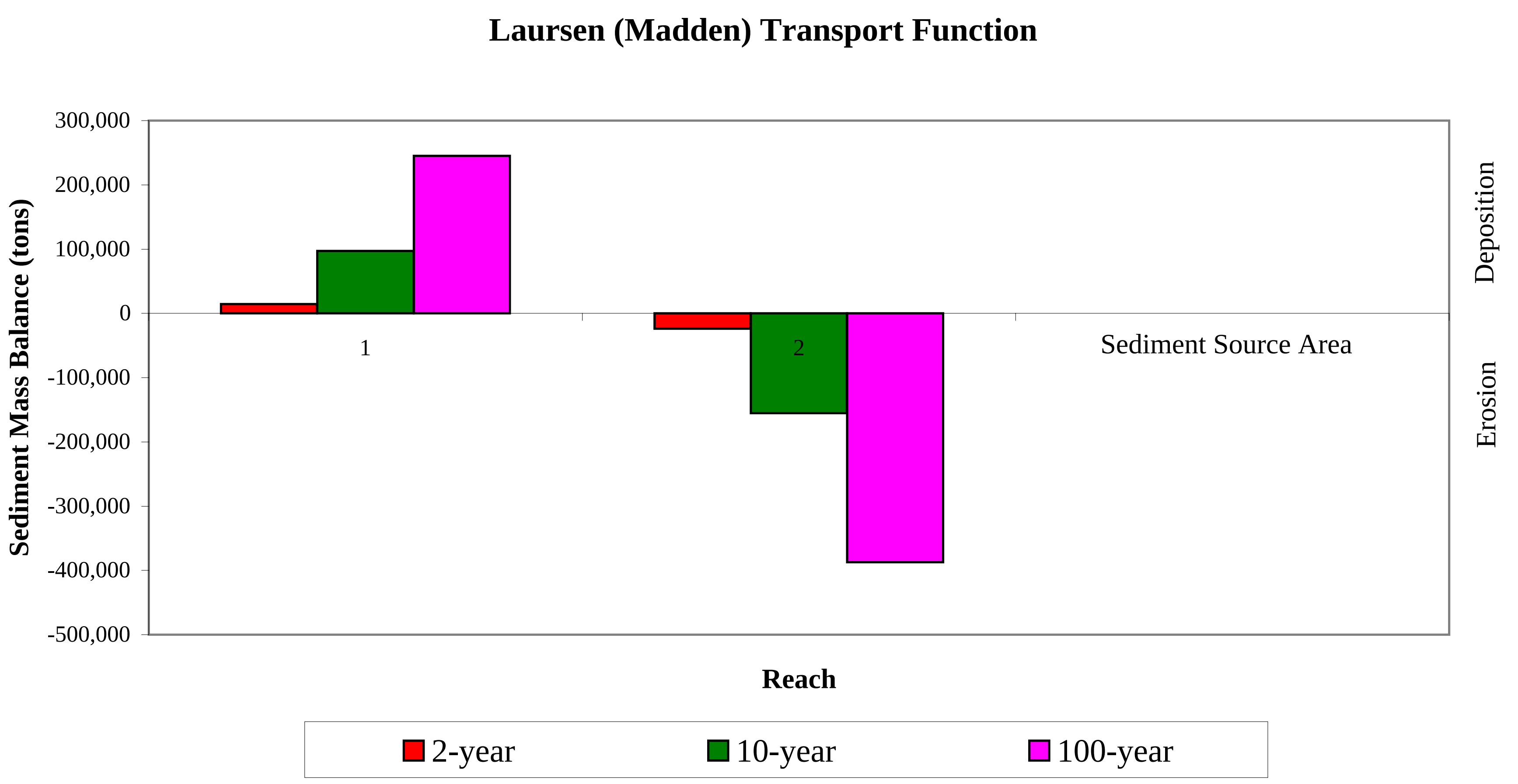
PWA calculated sub-basin input-output mass balances based on computed sediment yields for each reach of the modeled sub-basin. Mass balances were calculated as the difference between the incoming yield delivered by the upstream reach and the outgoing yield from the given reach. In this way mass balances indicate whether a particular reach is erosional or depositional for a given event. Mass balances were calculated for all three modeled storm events. A sediment mass balance was not calculated for the most upstream reach of each sub-basin since sediment delivery to this reach was not computed.

The sediment mass balances for Lucas Canyon show the potential for erosion in Reach 2 and deposition in Reach 1 for all three storm events (Figure 4-8). In Reach 2 the rate of sediment delivery from upstream is lower than the capacity of the reach to transport sediment downstream. Reach 1 may be subject to deposition during large flood events since Reach 2 appears to be able to deliver sediment from upstream at a higher rate than Reach 1 can transport it to the main stem of San Juan Creek.

4.3.3 Verdugo Canyon

Verdugo Canyon was divided into four reaches for the sediment transport analysis (Figure 4-1). Reach 2 produced the highest peak sediment transport rates, followed closely by Reach 1. Results for reaches 3 and 4 were significantly lower than for reaches 1 and 2. In absolute terms, Verdugo Canyon sediment transport rates are lower than all other sub-basins for all three events, except for Lucas Canyon under 100-year conditions (Figure 4-3). On a per unit area basis the capacity of Verdugo Canyon to transport sediment to San Juan Creek was calculated to be higher than all other sub-basins except Trampas Canyon and Cañada Gobernadora (Figure 4-4).

Table 4-4 shows sediment yield results for Verdugo Canyon. Within Verdugo Canyon, sediment yields follow a pattern similar to sediment transport rates. Relative to other principal sub-basins in the San Juan Creek watershed, Verdugo Canyon produced the highest sediment yields on a per unit area basis for the 10-year and 100-year events (Figure 4-6). In absolute terms, Verdugo Canyon seems to have a mid-to-low range capacity for sediment delivery to San Juan Creek (Figure 4-5). Although it has high sediment yield on a per unit area basis, it is a relatively small basin and thus cannot deliver as much sediment as the larger sub-basins.



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-8

Lucas Canyon Sub-basin
Sediment Mass Balance

PWA

PWA #:1393

TABLE 4-4 VERDUGO CANYON SUB-BASIN SEDIMENT TRANSPORT RESULTS SUMMARY

Reach Number	Peak Transport Rate (tons/day) Laursen (Madden) Q_2	Q_{10}	Q_{100}
1	15,600	164,400	400,000
2	25,000	269,700	639,000
3	5,900	63,600	150,800
4	1,600	44,400	133,100

Sub-basin Area ($miles^2$)	Peak Transport Rate Exiting Sub-basin per Unit Area ($tons/mile^2/day$) Laursen (Madden) Q_2	Q_{10}	Q_{100}
4.8	3,300	34,300	83,300

Reach Number	Sediment Yield (tons) Laursen (Madden) Q_2	Q_{10}	Q_{100}
1	5,500	50,500	148,500
2	8,800	82,200	241,400
3	2,200	19,400	56,800
4	400	9,500	38,600

Sub-basin Area ($miles^2$)	Sub-basin Sediment Yield, per Unit Area ($tons/mile^2$) Laursen (Madden) Q_2	Q_{10}	Q_{100}
4.8	1,100	10,500	30,900

Reach Number	Average Sediment Concentration (g/L) Laursen (Madden) Q_2	Q_{10}	Q_{100}
1	56	67	71
2	90	110	116
3	23	26	27
4	4	13	19

Reach Number	Sediment Mass Balance (tons) Laursen (Madden) Q_2	Q_{10}	Q_{100}
1	3,300	31,700	92,900
2	-6,600	-62,800	-184,600
3	-1,800	-9,900	-18,200
4	0	0	0

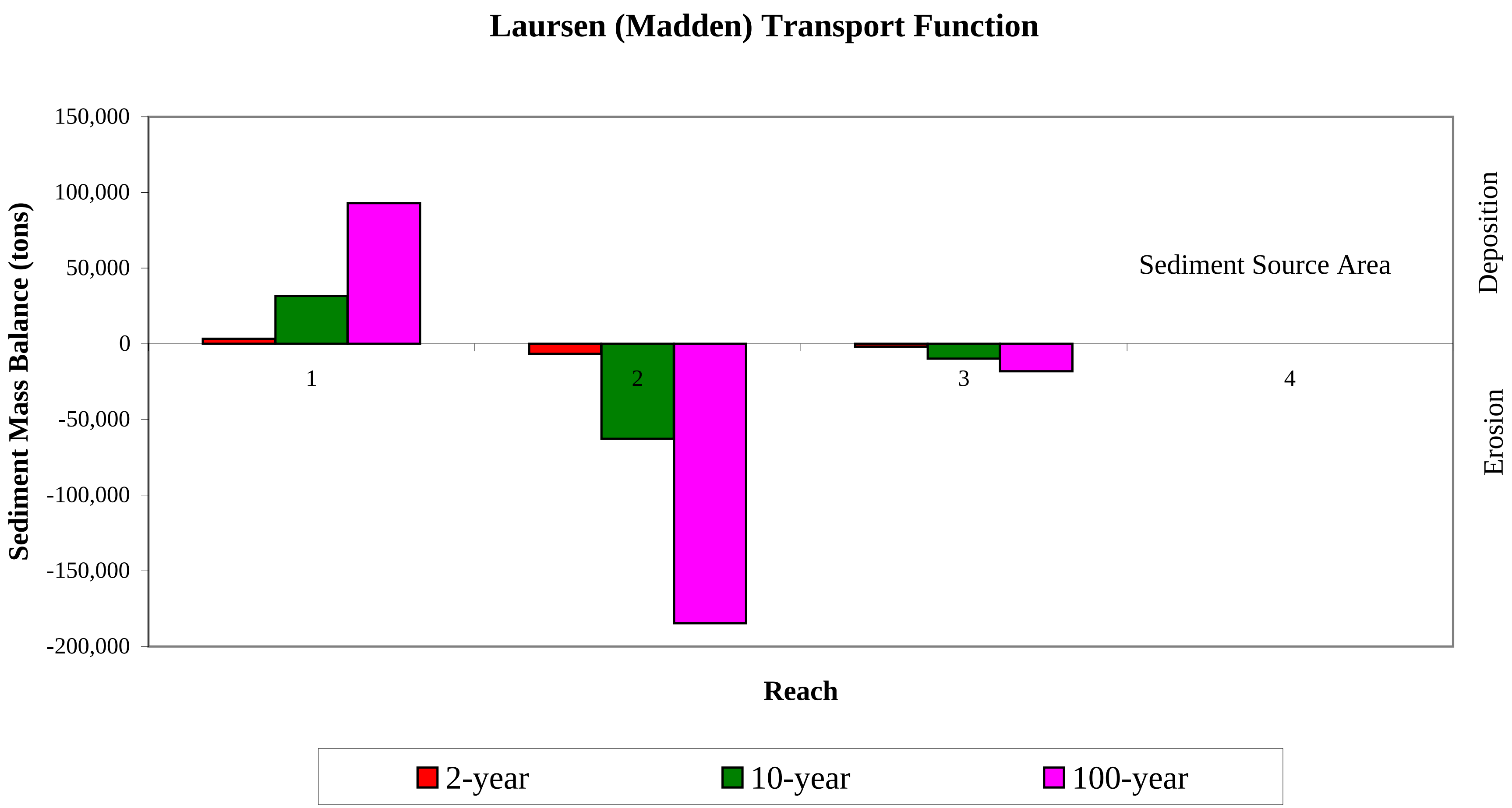
PWA calculated a mass balance for each reach and storm event for the Verdugo Canyon sub-basin. Results are shown in Table 4-4 and Figure 4-9. Results show the potential for slight erosion in Reach 3, significant erosion in Reach 2, and moderate deposition in Reach 1 under the influence of large storm events.

4.3.4 Bell Canyon

Bell Canyon was divided into six reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-5. Within Bell Canyon, Reach 6, the most upstream reach, has the highest transport capacity for all three modeled flood events. This may be because Reach 6 has steeper channel slopes than any of the other reaches (Table 4-1). Transport rates for Reach 5 are approximately 50% of those for Reach 6. Reaches 1 through 4 exhibit sediment transport rates that are in the range of 25% of those for Reach 6. Relative to other modeled sub-basins in the San Juan Creek watershed, Bell Canyon sediment transport rates per unit area are low, being similar to Cañada Chiquita, and higher than only the Central San Juan (Main Channel) sub-basin (Figure 4-4). In absolute terms, only Cañada Gobernadora has a higher capacity to transport sediment to San Juan Creek than Bell Canyon (Figure 4-3). This is likely due to the basin's large size, higher flows, and other inherent geologic, hydrologic, and geomorphic conditions.

Table 4-5 also shows sediment yield results for Bell Canyon. Within Bell Canyon, sediment yields follow a pattern similar to sediment transport rates. Reach 6 has the highest sediment yield for all three modeled storm events, followed by Reach 5. Yields for Reaches 1 through 4 are similar in magnitude, lower than Reaches 5 and 6. As mentioned above, Reach 6 yields may be highest due to high channel slopes. Relative to other sub-basins in the San Juan Creek watershed, Bell Canyon produced mid-range sediment yields on a per unit area basis for all three events (Figures 4-6). Bell's yields per unit area were generally higher than for Cañada Chiquita and the Central San Juan, and lower than for Cañada Gobernadora, Lucas, and Verdugo Canyons. As noted above, Bell Canyon appears to have the largest capacity (in absolute terms) for sediment delivery to San Juan Creek of any of the other modeled sub-basins. This is likely due to the sub-basin's large size.

The sediment mass balances for Bell Canyon show the potential for significant deposition in Reaches 4 and 5 during large storm events (Figure 4-10). Each of these reaches is downstream of a reach with high sediment transport capacity and yield potential. Relative to the high potential for deposition in Reaches 4 and 5, mass balance results for the lower reaches of Bell Canyon suggest that the channel may tend toward a more stable geomorphic equilibrium position under the influence of large storm events. Results suggest the potential for some erosion in Reach 3 and some deposition in Reach 1. However, the quantity of potential deposition or erosion in these reaches is much lower than for Reaches 4 and 5.



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-9

Verdugo Canyon Sub-basin
Sediment Mass Balance

PWA

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Table 4-5 BELL CANYON SUB-BASIN SEDIMENT TRANSPORT RESULTS SUMMARY

Reach Number	Peak Transport Rate (tons/day) Laursen (Madden) Q_2	Q_{10}	Q_{100}
1	66,200	413,700	951,800
2	77,300	462,700	1,061,900
3	77,100	462,300	1,062,400
4	91,700	520,800	1,101,400
5	153,500	855,700	1,810,700
6	317,800	1,660,300	3,412,900

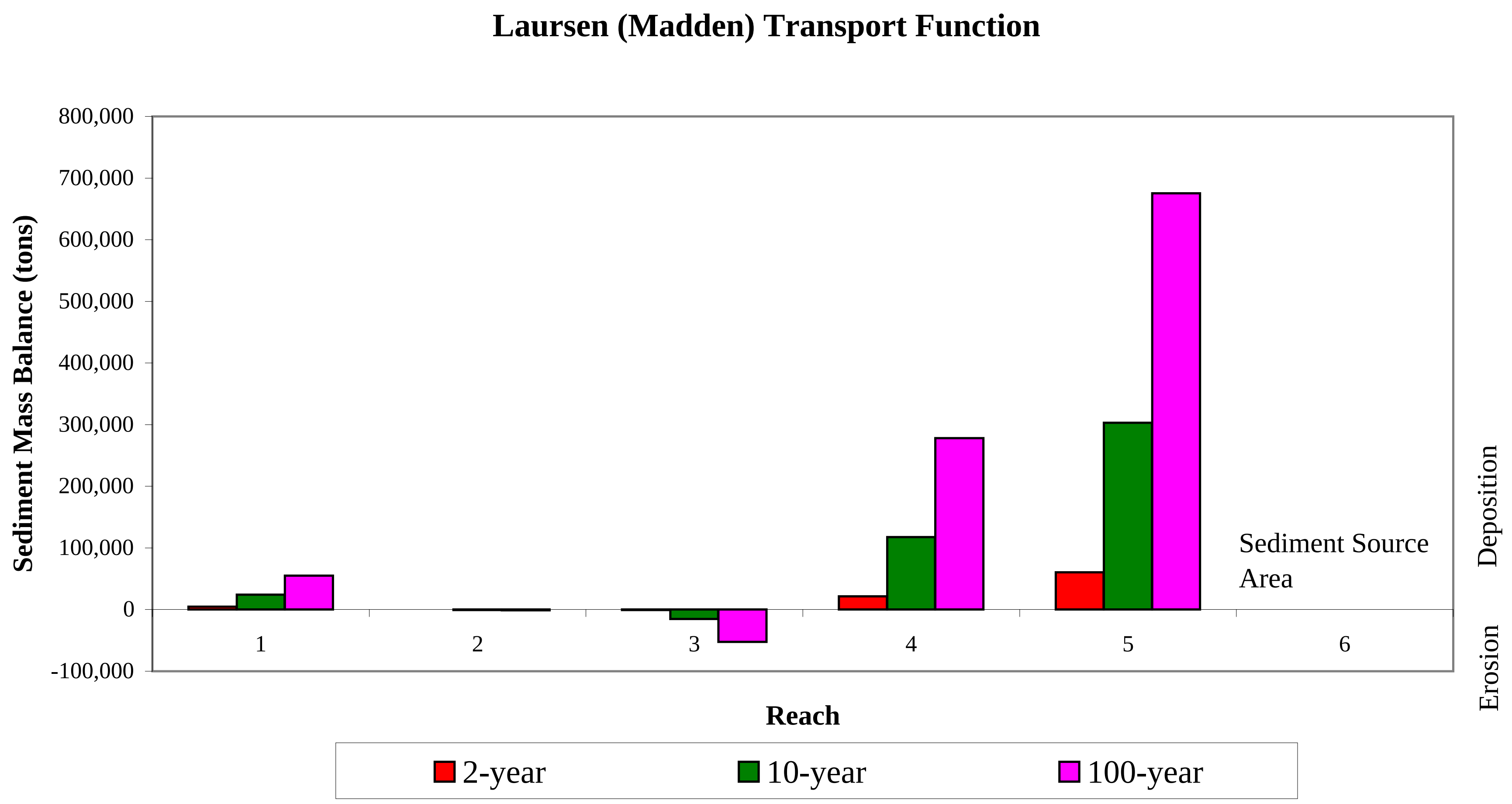
Sub-basin Area (miles^2)	Peak Transport Rate Exiting Sub-basin per Unit Area (tons/mile^2/day) Laursen (Madden) Q_2	Q_{10}	Q_{100}
20.57	3,200	20,100	46,300

Reach Number	Sediment Yield (tons) Laursen (Madden) Q_2	Q_{10}	Q_{100}
1	26,100	170,600	428,500
2	30,700	194,700	483,500
3	30,900	194,200	482,200
4	29,900	178,900	430,000
5	51,300	296,800	708,100
6	111,900	599,900	1,383,400

Sub-basin Area (miles^2)	Sub-basin Sediment Yield, per Unit Area (tons/mile^2) Laursen (Madden) Q_2	Q_{10}	Q_{100}
20.57	1,300	8,300	20,800

Reach Number	Average Sediment Concentration (g/L Laursen (Madden) Q_2	Q_{10}	Q_{100}
1	28	35	37
2	33	40	42
3	33	39	42
4	37	46	49
5	64	75	80
6	140	153	156

Reach Number	Sediment Mass Balance (tons) Laursen (Madden) Q_2	Q_{10}	Q_{100}
1	4,600	24,100	54,900
2	100	-500	-1,300
3	-900	-15,300	-52,200
4	21,400	117,800	278,100
5	60,600	303,100	675,300
6	0	0	0



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-10

Bell Canyon Sub-basin
Sediment Mass Balance

PWA

PWA #:1393

4.3.5 Cañada Gobernadora

Cañada Gobernadora was divided into nine reaches for the sediment transport analysis, the first six of which are aligned with the SLA (1999) reach designations (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-6. Within Cañada Gobernadora, Reach 9, the most upstream reach, has the highest transport capacity for all cases except the 100-year event. This may be because Reach 9 has steeper channel slopes than any of the other reaches (Table 4-1). Runoff rates in Reach 9 are the lowest of the Gobernadora reaches, further suggesting the importance of high slopes in generating the high sediment transport rates. In general, Reaches 1 and 2 also exhibited relatively high sediment transport rates. In absolute terms, Cañada Gobernadora sediment transport rates are higher than rates for all other modeled sub-basins in the San Juan Creek watershed. On a per unit area basis, the sediment transport rate at the mouth of Cañada Gobernadora was also higher than the rates for all other principal San Juan sub-basins (Figure 4-4). High transport rates are likely due to the basin's large size, a high proportion of smaller more transportable sediment, and other inherent geologic, hydrologic, and geomorphic conditions.

Table 4-6 also shows sediment yield results for Cañada Gobernadora. Within Cañada Gobernadora, sediment yields follow a somewhat different pattern than sediment transport rates. Yields are lower in the upper reaches (Reaches 3-9), and then increase toward the mouth of the canyon. Reaches 1 and 2 exhibit the highest yields. This pattern may reflect the importance of flow rate, which increases significantly downstream in Cañada Gobernadora. Relative to other sub-basins in the San Juan Creek watershed, results indicate that Cañada Gobernadora produced relatively high sediment yields on a per unit area basis for all three events (Figure 4-6). Only Verdugo Canyon has higher yields on a per unit area basis for the 10-year and 100-year events. In absolute terms, Cañada Gobernadora appears to have an upper mid-range capacity for sediment delivery to San Juan Creek compared to the other modeled sub-basins. Yields exiting the sub-basin were lower than for Bell Canyon and the Central San Juan sub-basin, but higher than for the Chiquita, Verdugo, and Lucas Canyon sub-basins.

The sediment mass balances for Cañada Gobernadora show the potential for significant deposition in Reaches 8, 7, 4 and 3 during large storm events (Figure 4-11). Calculations show the potential for erosion in Reaches 6, 5, 2 and 1.

4.3.6 Cañada Chiquita

Cañada Chiquita was divided into six reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-7. Generally, the sediment transport trends within Cañada Chiquita are the same for all three events. Results indicate that sediment transport capacity is highest in Reach 5 under all three storm events. Relative to other modeled sub-basins in the San Juan Creek watershed, Cañada Chiquita sediment transport rates are intermediate. Cañada Chiquita was calculated to have a higher transport capacity in absolute terms than Lucas and Verdugo Canyons. On a per unit area basis, Cañada Chiquita sediment transport rates were calculated to be lower than all but Bell Canyon and the Central San Juan sub-basins.

Table 4-6 CANADA GOBERNADORA SUB-BASIN SEDIMENT TRANSPORT RESULTS SUMMARY

Reach Number	Peak Transport Rate (tons/day) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	93,900	552,400	1,059,500
2	91,600	545,400	1,055,400
3	61,600	380,700	740,300
4	67,600	392,800	756,900
5	77,100	455,200	
6	72,100	411,900	796,000
7	45,600	241,200	478,600
8	53,200	290,800	580,000
9	118,500	593,400	1,027,400

Sub-basin Area (miles^2)	Peak Transport Rate Exiting Sub-basin per Unit Area (tons/mile^2/day) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
11.08	8,500	49,900	95,600

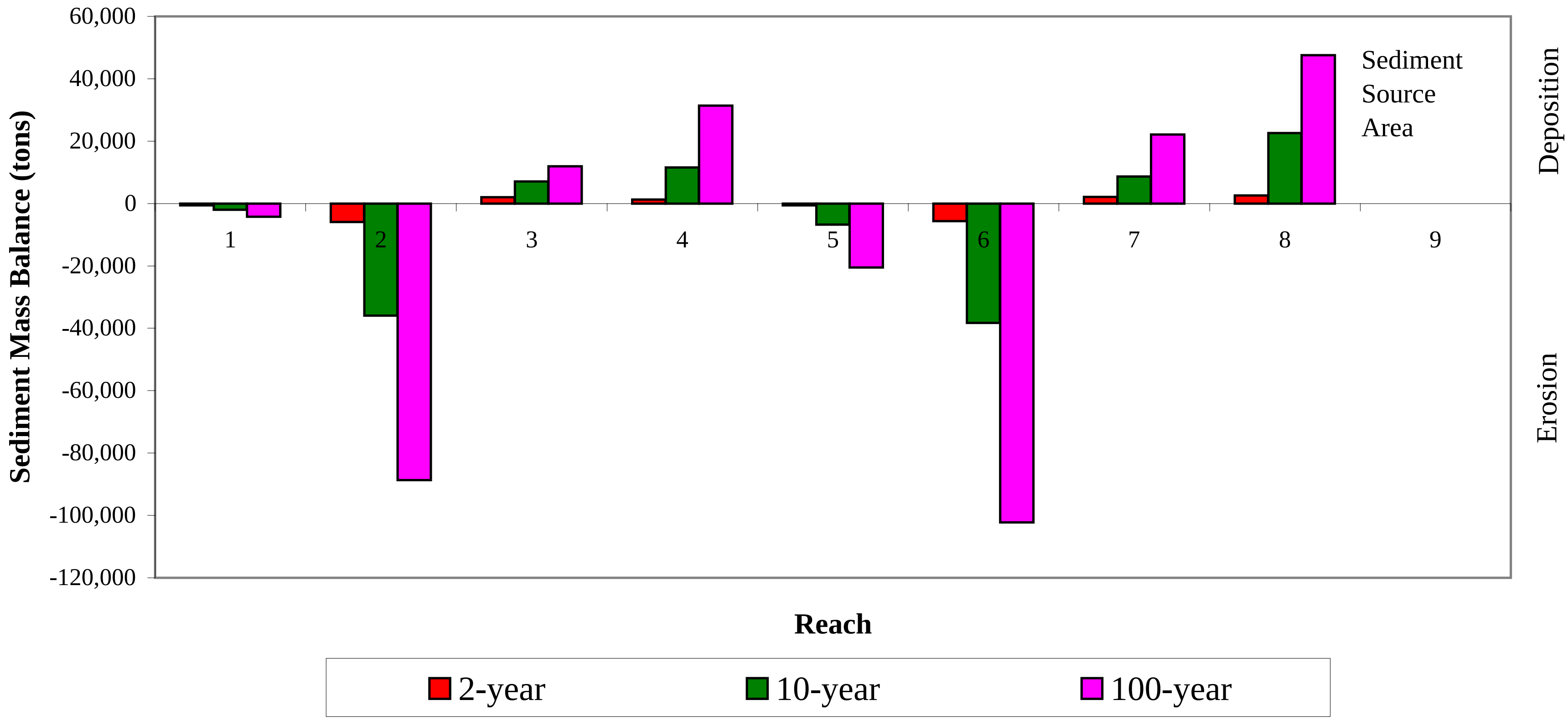
Reach Number	Sediment Yield (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	16,300	109,500	286,700
2	15,800	107,500	282,500
3	9,800	71,500	193,800
4	11,800	78,700	205,700
5	13,000	90,300	237,200
6	12,500	83,400	216,600
7	6,900	45,100	114,400
8	9,000	53,800	136,600
9	11,600	76,300	184,200

Sub-basin Area (miles^2)	Sub-basin Sediment Yield, per Unit Area (tons/mile^2) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
11.08	1,500	9,900	25,900

Reach Number	Average Sediment Concentration (g/L) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	48	57	61
2	47	56	60
3	29	37	41
4	35	41	43
5	39	47	50
6	37	43	46
7	34	42	45
8	44	50	54
9	97	133	142

Reach Number	Sediment Mass Balance (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	-600	-2,000	-4,200
2	-5,900	-35,900	-88,700
3	2,000	7,100	11,900
4	1,300	11,600	31,400
5	-600	-6,800	-20,500
6	-5,600	-38,300	-102,200
7	2,100	8,700	22,100
8	2,600	22,600	47,600
9	0	0	0

Laursen (Madden) Transport Function



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-11

Canada Gobernadora Sub-basin
Sediment Mass Balance

PWA

PWA #:1393

Table 4-7 CANADA CHIQUITA SUB-BASIN SEDIMENT TRANSPORT RESULTS SUMMARY

Reach Number	Peak Transport Rate (tons/day) Laursen (Madden) Q$_2$	Q$_{10}$	Q$_{100}$
1	31,000	194,300	419,400
2	8,300	58,400	128,200
3	21,000	139,500	292,800
4	7,600	51,400	113,400
5	73,500	466,600	986,000
6	21,000	138,900	303,600

Sub-basin Area (miles^2)	Peak Transport Rate Exiting Sub-basin per Unit Area (tons/mile^2/day) Laursen (Madden) Q$_2$	Q$_{10}$	Q$_{100}$
9.24	3,400	21,000	45,400

Reach Number	Sediment Yield (tons) Laursen (Madden) Q$_2$	Q$_{10}$	Q$_{100}$
1	5,700	47,800	130,100
2	1,200	13,100	38,000
3	3,600	33,100	91,800
4	1,300	12,000	34,000
5	14,500	114,400	310,600
6	3,900	33,100	92,200

Sub-basin Area (miles^2)	Sub-basin Sediment Yield, per Unit Area (tons/mile^2) Laursen (Madden) Q$_2$	Q$_{10}$	Q$_{100}$
9.24	600	5,200	14,100

Reach Number	Average Sediment Concentration (g/L) Laursen (Madden) Q$_2$	Q$_{10}$	Q$_{100}$
1	49	62	66
2	11	17	19
3	31	43	46
4	12	16	17
5	127	149	156
6	34	43	46

Reach Number	Sediment Mass Balance (tons) Laursen (Madden) Q$_2$	Q$_{10}$	Q$_{100}$
1	-4,400	-34,700	-92,100
2	2,400	20,000	53,800
3	-2,300	-21,000	-57,800
4	13,200	102,400	276,600
5	-10,600	-81,300	-218,400
6	0	0	0

Table 4-7 also shows sediment yield results for Cañada Chiquita. Within Cañada Chiquita, sediment yields follow a pattern very similar to the pattern of sediment transport rates. Yields tend to alternate between high and low values from reach to reach for all three modeled events. The highest yields were calculated in Reach 5. Relative to other sub-basins in the San Juan Creek watershed, sediment yields from Cañada Chiquita are low. In absolute terms sediment yields from Cañada Chiquita were calculated to be the lowest of all modeled sub-basins. On a per unit area basis only the Central San Juan sub-basin had a lower yield.

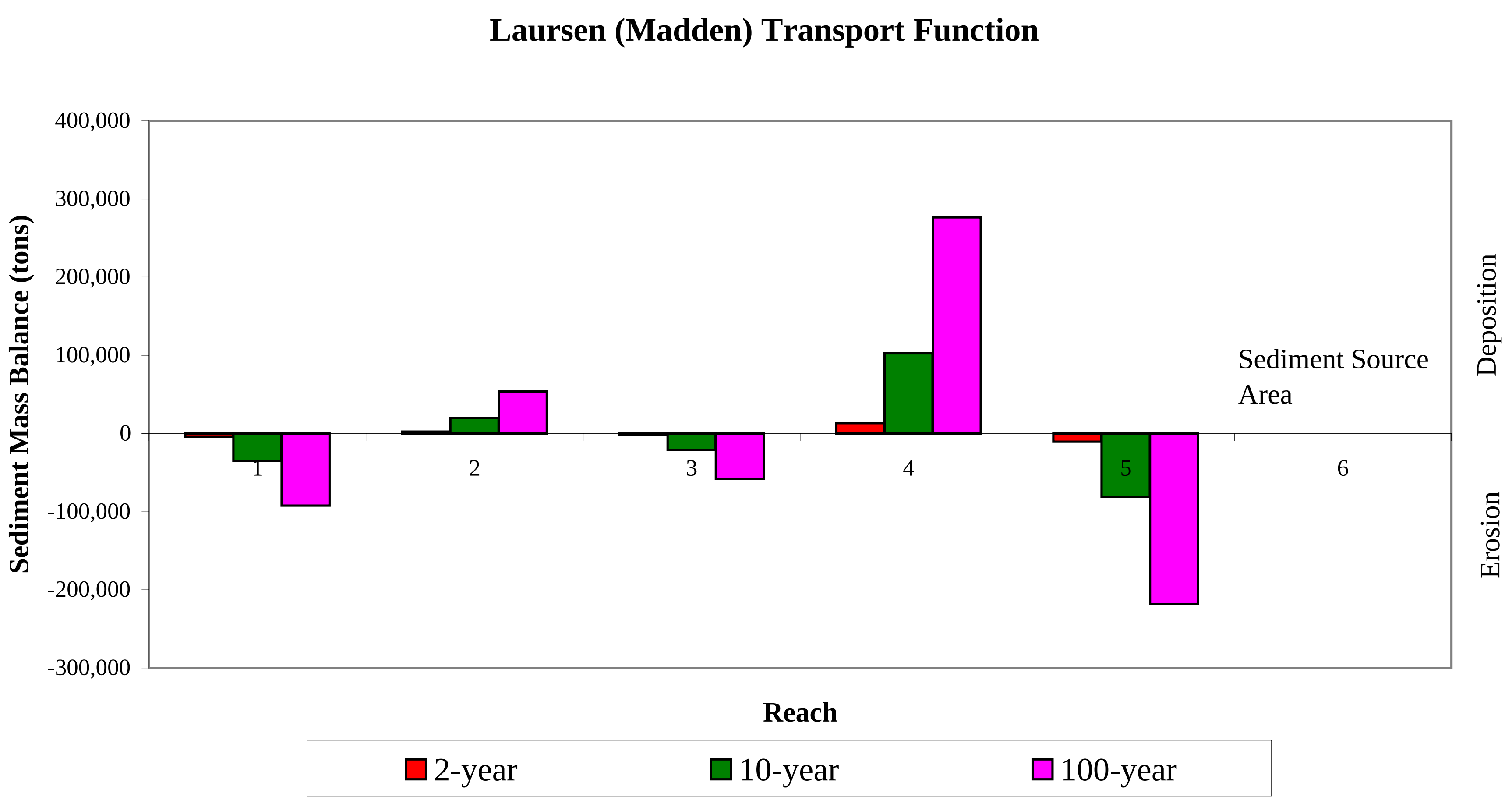
The sediment mass balances for Cañada Chiquita show the potential for deposition in Reaches 4 and 2 during large storm events (Figure 4-12). Calculations show the potential for erosion in Reaches 5, 3 and 1.

4.3.7 Central San Juan Catchments

The Central San Juan Creek sub-basin was divided into 11 reaches from four small catchment tributaries that directly enter San Juan Creek (Figure 4-1). Catchments include the Southwest, Trampas Canyon, Northwest, and Northeast tributaries. Results of the sediment transport analysis are shown in Table 4-8. Within the Central San Juan Sub-basin, reaches 1 and 2 of the Main Channel and reaches 1 and 3 of Trampas Canyon have the highest sediment transport rates. Trampas Canyon is a very steep headwater tributary and had higher flow rates than the other tributaries. Transport rates for the main San Juan channel are higher than the tributaries due to larger flows and channel size.

Relative to other modeled sub-basins in the San Juan Creek watershed, Trampas Canyon (Figure 4-3) sediment transport rates are low (only Verdugo and Chiquita were lower). However, Trampas Canyon transport rates per unit area were higher than all other sub-basins (Figure 4-4). This is due to steep channel slopes at the basin mouth, transportable sediment sizes, and a small drainage area. In contrast, the main channel of the Central San Juan sub-basin actually had the lowest per unit area transport capacity of all modeled sub-basins. In absolute terms, transport capacities for the main channel of the Central San Juan sub-basin are in the mid-to-high range compared to other San Juan sub-basins (Figure 4-3).

Table 4-8 also lists sediment yield results for the Central San Juan sub-basin. Values for the main channel and Trampas Canyon are plotted in Figures 4-5 and 4-6. Absolute sediment yields are relatively high for the main channel and lower for the Trampas tributary. Sediment yields per unit area are extremely high for the Trampas Canyon tributary for the same reasons as described above for transport rates. In fact, yields per unit area are higher from Trampas Canyon than any other studied catchment. In many ways, Trampas Canyon is different from the other studied sub-basins, which are larger canyon systems that occupy broader valleys. Trampas Canyon is more representative of the steeper headwater systems of the San Juan watershed where sediment yields are much higher. Conversely, sediment yields per unit area for the main San Juan channel are the lowest of the study due to the large size of the contributing catchment and low channel slopes (Figure 4-6).



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-12

Canada Chiquita Sub-basin
Sediment Mass Balance

PWA

PWA #:1393

Table 4-8 CENTRAL SAN JUAN CREEK SUB-BASIN SEDIMENT TRANSPORT RESULTS SUMMARY

Catchment	Reach Number	Peak Transport Rate (tons/day) Laursen (Madden) Q_2	Q_{10}	Q_{100}
Southwest (SW)	1	600	6,700	16,600
	2	1,100	11,500	28,300
Trampas (TR)	1	19,100	189,400	456,700
	2	300	5,600	16,100
	3	14,900	153,400	367,400
Northwest (NW)	1	3,600	38,200	95,500
	2	5,200	54,800	135,300
Northeast (NE)	1	6,400	66,300	164,400
	2	5,800	61,200	155,200
Main Channel (SJ)	1	29,400	362,200	805,500
	2	11,700	142,000	484,300
	3	3,500	42,700	104,300
	4	8,700	77,600	154,700

Catchment	Sub-basin Area (miles^2)	Peak Transport Rate Exiting Sub-basin per Unit Area (tons/mile^2/day) Laursen (Madden) Q_2	Q_{10}	Q_{100}
Trampas (TR)	1.7	11,200	111,400	268,600
Main Channel (SJ)	104.4	300	3,500	7,700

Catchment	Reach Number	Sediment Yield (tons) Laursen (Madden) Q_2	Q_{10}	Q_{100}
Southwest (SW)	1	200	1,500	6,200
	2	400	2,500	10,600
Trampas (TR)	1	5,900	44,000	178,000
	2	100	1,000	5,200
	3	4,600	35,600	144,100
Northwest (NW)	1	800	8,200	36,000
	2	1,200	11,900	51,500
Northeast (NE)	1	1,900	14,800	62,400
	2	1,500	13,100	57,100
Main Channel (SJ)	1	11,700	139,100	399,900
	2	4,500	52,500	186,200
	3	1,400	16,500	49,800
	4	3,700	31,800	80,300

Catchment	Sub-basin Area (miles^2)	Sub-basin Sediment Yield, per Unit Area (tons/mile^2) Laursen (Madden) Q_2	Q_{10}	Q_{100}
Trampas (TR)	1.7	3,500	25,900	104,700
Main Channel (SJ)	104.4	100	1,300	3,800

Catchment	Reach Number	Average Sediment Concentration (g/L) Laursen (Madden) Q_2	Q_{10}	Q_{100}
Southwest (SW)	1	42	48	52
	2	68	81	89
Trampas (TR)	1	199	261	270
	2	2	6	8
	3	156	211	219
Northwest (NW)	1	62	116	132
	2	98	169	188
Northeast (NE)	1	132	180	197
	2	104	160	180
Main Channel (SJ)	1	2	5	6
	2	1	2	3
	3	0	1	1
	4	1	1	2

Catchment	Reach Number	Sediment Mass Balance (tons) Laursen (Madden) Q_2	Q_{10}	Q_{100}
Southwest (SW)	1	100	1,000	4,400
	2	0	0	0
Trampas (TR)	1	-5,900	-43,000	-172,800
	2	4,600	34,500	138,900
	3	0	0	0
Northwest (NW)	1	500	3,700	15,400
	2	0	0	0
Northeast (NE)	1	-400	-1,700	-5,300
	2	0	0	0
Main Channel (SJ)	1	-1,600	-38,900	-83,600
	2	13,200	73,500	150,300

Sediment mass balances were computed for the main channel of San Juan Creek from the confluence with Bell and Verdugo Canyons to the Ortega Highway crossing downstream of the mouth of Chiquita Canyon (Figure 4-7). Along the main channel, mass balances indicate the potential for deposition in all four reaches during large storm events, except reach 1. This seems reasonable since high sediment loads from the steeper canyon sub-basins discharge directly to these central reaches of San Juan Creek. For Trampas Canyon, mass balance results show the potential for deposition in Reach 2 and erosion in Reach 1 for all three events (Figure 4-13). This is likely a reflection of the high slopes and transport capacities in Reach 3 (which passes sediment to Reach 2) and Reach 1 which transports sediment out of Trampas Canyon.

4.4 RESULTS FOR SAN MATEO WATERSHED SUB-BASINS

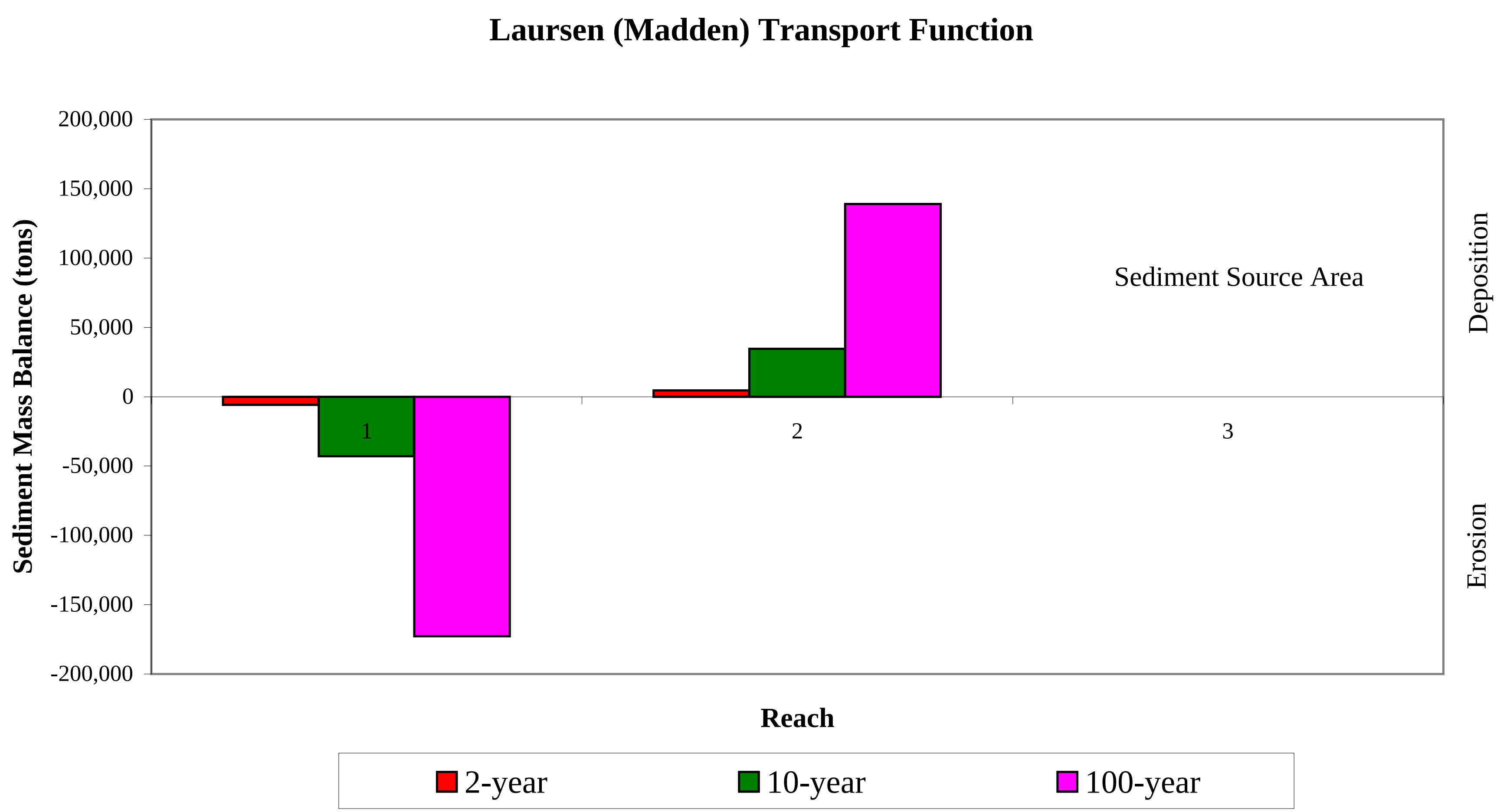
4.4.1 San Mateo Overview

Similar to the San Juan watershed, the SAM model was used to calculate peak sediment transport rates for the studied sub-basins of the San Mateo watershed (excluding Talega Canyon) for the 2-year, 10-year, and 100-year discharge events. As described above, these rates represent the capacity for the system to transport sediment but may not describe actual sediment transport rates. Actual sediment transport is determined by both transport capacity and sediment supply.

In the San Mateo Creek watershed, Gabino Canyon (upstream of the Cristianitos Creek confluence) was calculated to have the highest sediment transport capacity (Figure 4-3). This absolute rate is actually the highest of all modeled sub-basins in the San Juan and San Mateo Watersheds and is similar in magnitude to rates calculated for Gobernadora and Bell Canyons in the San Juan watershed. Transport rates calculated for La Paz and Cristianitos Canyons are similar to values calculated for Lucas and Verdugo canyons.

The Upper Cristianitos sub-basin (3.67 mi^2) had the highest transport capacity per unit area of the three modeled San Mateo sub-basins (Figure 4-4). The basin's per unit area transport rate surpasses rates calculated for all other sub-basins except Trampas Canyon. This implies that the hydrology, geology, and geomorphology of Upper Cristianitos Creek are conducive to transporting sediment. The transport capacity per unit area of Gabino Canyon is intermediate between estimated rates for La Paz and Cristianitos canyons. La Paz Canyon exhibited transport rates per unit area that were slightly higher than those for Lucas Canyon.

Figure 4-5 summarizes calculated sediment yields at the mouth of the three San Mateo sub-basins. These figures illustrate that the Gabino Canyon sub-basin exhibits the highest sediment yield of the three San Mateo sub-basins. This is most likely due to the somewhat larger size of Gabino Canyon relative to the Upper Cristianitos and La Paz sub-basins. Although the Upper Cristianitos sub-basin is half the size of the La Paz sub-basin, its relatively high rate of sediment transport per unit area (Figure 4-6) resulted in total sediment yields that were slightly higher than those from the La Paz sub-basin for the 10-year and 100-year events.



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-13

Trampas Canyon Reach
Central San Juan Sub-basin
Sediment Mass Balance

PWA

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4.4.2 La Paz Canyon

La Paz Canyon was divided into three reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis for La Paz Canyon are shown in Table 4-9. Within La Paz Canyon, Reach 3, the most upstream reach, has the highest transport capacity for all three storm events. Sediment transport capacity is lower in Reach 2 and lower still in Reach 1. This decrease in transport capacity from upstream to downstream is likely a reflection of decreasing channel slopes. Relative to other modeled sub-basins in the San Mateo Creek watershed, sediment transport rates from the mouth of La Paz Canyon are low. On a per unit area basis, the capacity of La Paz Canyon to transport sediment downstream was calculated to be lower than both the Gabino and Cristianitos sub-basins (Figure 4-4). In absolute terms, La Paz Canyon transport rates are also lower than the other San Mateo sub-basins. La Paz Canyon's comparatively low transport rates may be due to relatively coarse bed material along its less steep downstream reach.

Table 4-9 also shows sediment yield results for the La Paz Canyon sub-basin. Within La Paz Canyon, sediment yields follow a pattern identical to sediment transport rates, decreasing from upstream to downstream. Yields are highest in Reach 3 and lowest in Reach 1 for all three storm events. As previously discussed, this may be a reflection of decreasing channel slopes. In absolute terms, La Paz Canyon appears to have the lowest capacity for sediment delivery downstream, compared to the two other modeled San Mateo sub-basins (Figures 4-5 and 4-6). Yields exiting the sub-basin were lower than those for Gabino Canyon and were in the same range as those for the Cristianitos Creek sub-basin. As mentioned in the sediment transport section, low yields may be due to coarse bed-material in the more gently sloped downstream reach. Relative to other sub-basins in the San Mateo Creek watershed, La Paz Canyon also produced the lowest sediment yields on a per unit area basis. This is likely a reflection of low absolute yields in a medium-sized sub-basin.

The sediment mass balances for La Paz Canyon show the potential for significant deposition in reaches 1 and 2 during large storm events (Figure 4-14). The depositional pattern is a reflection of decreasing yields from upstream to downstream. More sediment flows into Reaches 1 and 2 than can be transported downstream, causing deposition.

4.4.3 Gabino Canyon

Gabino Canyon was divided into five reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-10. Within Gabino Canyon, Reach 5, the most upstream reach, has the highest transport capacity for all three storm events. High transport capacities in Reach 5 are likely due to high channel slopes in this reach. Sediment transport capacity is also comparatively high in Reaches 4 and 1, with significantly lower transport capacities in Reaches 2 and 3. The larger size of the channel, and the greater proportion of small sediment sizes may explain the relatively high transport rate in Reach 1.

Table 4-9 LA PAZ CANYON SUB-BASIN SEDIMENT TRANSPORT RESULTS SUMMARY

Reach Number	Peak Transport Rate (tons/day) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	36,000	209,800	429,300
2	121,700	719,300	1,435,500
3	351,300	1,926,900	3,803,000

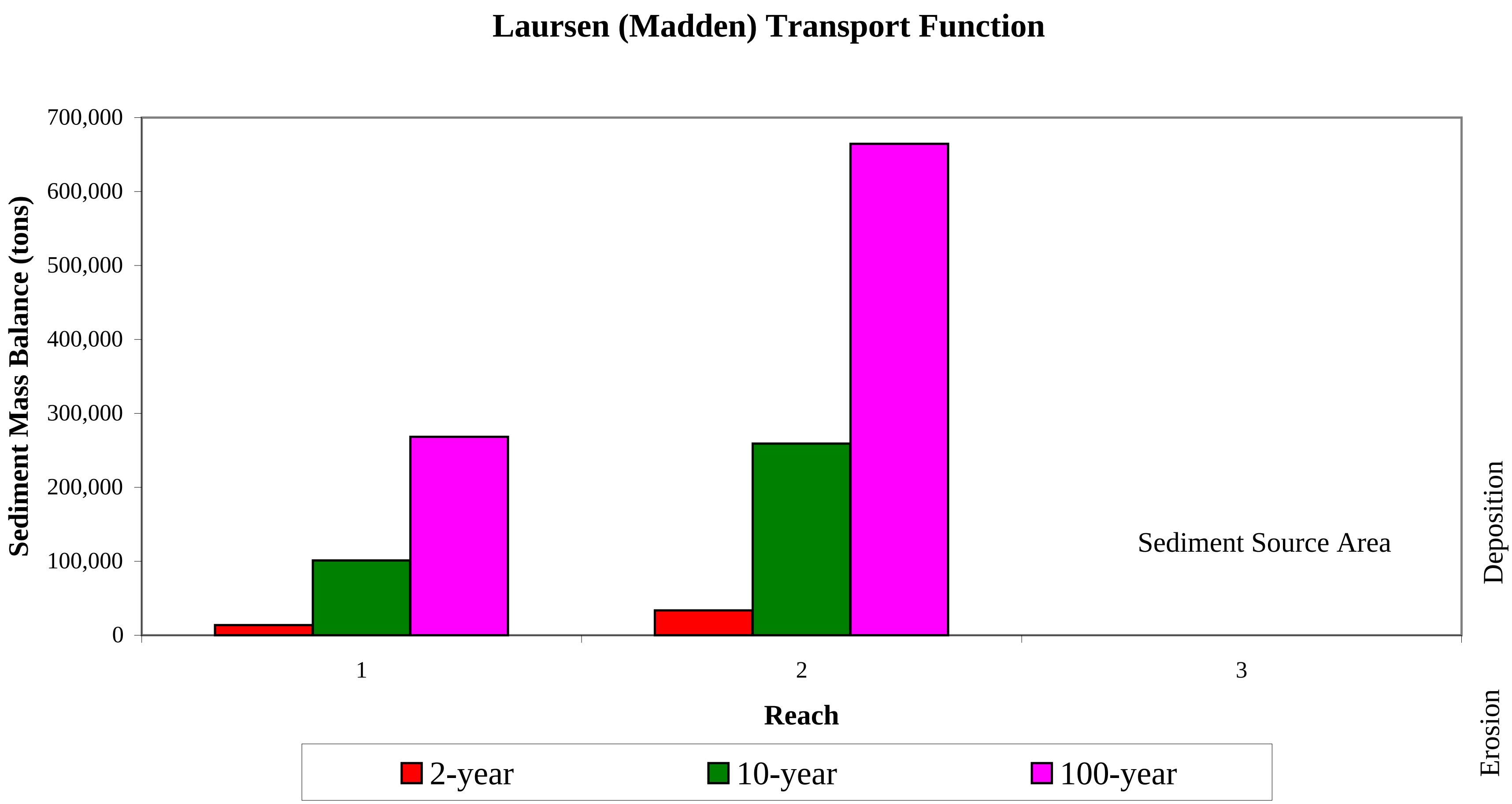
Sub-basin Area (miles^2)	Peak Transport Rate Exiting Sub-basin per Unit Area (tons/mile^2/day) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
7.25	5,000	28,900	59,200

Reach Number	Sediment Yield (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	5,600	42,000	111,800
2	19,300	143,100	380,300
3	52,700	402,400	1,044,700

Sub-basin Area (miles^2)	Sub-basin Sediment Yield, per Unit Area (tons/mile^2) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
7.25	772	5,793	15,421

Reach Number	Average Sediment Concentration (g/L) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	27	32	33
2	93	108	114
3	253	305	313

Reach Number	Sediment Mass Balance (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	13,800	101,100	268,500
2	33,400	259,300	664,400
3	0	0	0



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-14

La Paz Canyon Sub-basin
Sediment Mass Balance

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PWA #:1393

Table 4-10 GABINO CANYON SUB-BASIN SEDIMENT TRANSPORT RESULTS SUMMARY

Reach Number	Peak Transport Rate (tons/day) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	71,000	513,800	1,115,100
2	52,000	360,900	790,500
3	45,200	311,000	638,300
4	84,400	568,100	1,157,000
5	116,100	702,000	1,391,200

Sub-basin Area (miles^2)	Peak Transport Rate Exiting Sub-basin per Unit Area (tons/mile^2/day) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
15.57	4,560	32,999	71,618

Reach Number	Sediment Yield (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	14,300	119,200	330,300
2	11,300	86,100	234,500
3	5,400	50,600	146,200
4	10,200	93,900	268,500
5	6,900	110,300	338,600

Sub-basin Area (miles^2)	Sub-basin Sediment Yield, per Unit Area (tons/mile^2) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
15.57	918	7,656	21,214

Reach Number	Average Sediment Concentration (g/L) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	35	45	48
2	28	32	34
3	49	63	70
4	92	118	128
5	62	138	161

Reach Number	Sediment Mass Balance (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	-3,000	-33,100	-95,700
2	-5,900	-35,500	-88,300
3	4,800	43,300	122,300
4	-3,300	16,400	70,100
5	0	0	0

Relative to the two other modeled sub-basins in the San Mateo Creek watershed, Gabino Canyon sediment transport rates are high. In absolute terms, Gabino Canyon has the highest capacity to transport sediment downstream of any of the San Mateo sub-basins (Figure 4-3). This is likely due to its large sub-basin area and relatively high runoff rate, which includes tributary flow from La Paz Canyon. On a per unit area basis, the capacity of Gabino Canyon to transport sediment downstream was calculated to be lower than the Cristianitos Creek sub-basin but higher than La Paz Canyon (Figure 4-4). The small size of the Cristianitos Creek sub-basin tends to boost its transport capacity on a per unit area basis.

Table 4-10 also shows sediment yield results for the Gabino Canyon sub-basin. Within Gabino Canyon, sediment yields follow a pattern somewhat different from sediment transport rates. For the 2-year and 10-year events Reach 1 was calculated to have the highest sediment yield. For the 100-year event Reach 5 had the highest sediment yield, although Reach 1 was a close second. Yields in Reaches 5 and 1 are generally quite close in magnitude. Reach 1 has lower channel slopes than Reach 5. However, it conveys a significantly higher volume of runoff than Reach 5 since it includes flow from La Paz Canyon. These two effects seem to offset each other to produce similar sediment yields.

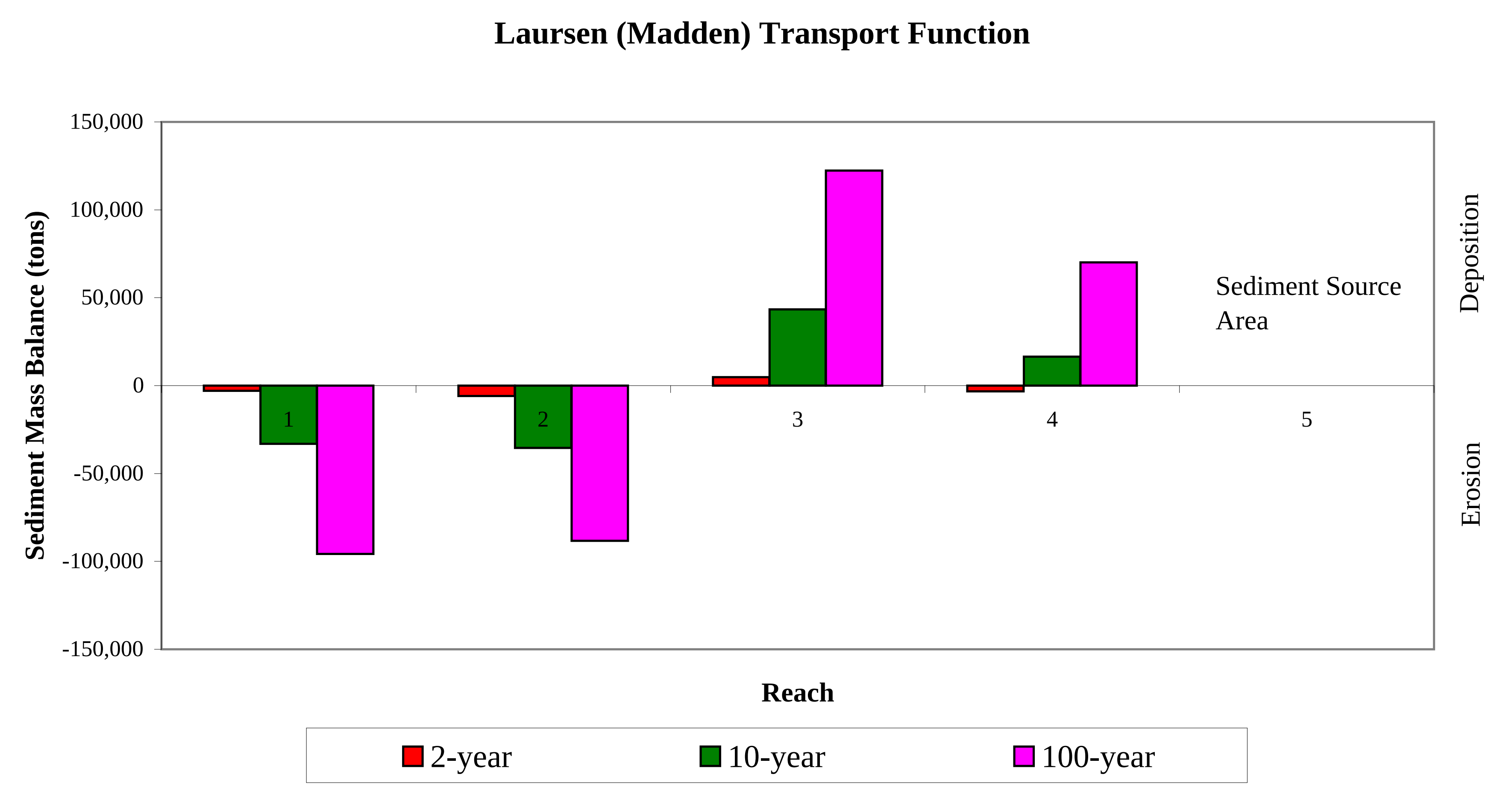
In absolute terms, Gabino Canyon was calculated to have the highest capacity for sediment delivery downstream, compared to the other modeled San Mateo sub-basins (Figures 4-5 and 4-6). These high yields are likely attributable to the relatively large size of the Gabino Canyon sub-basin and the relatively high runoff volume it produces for the three modeled storm events. Relative to other sub-basins in the San Mateo Creek watershed, Gabino Canyon also produced the mid-range sediment yields on a per unit area basis. Cristianitos Creek had higher yields while La Paz Canyon had lower yields on a per unit area basis. This order is likely a reflection of the small area of the Cristianitos Creek sub-basin.

The sediment mass balances for Gabino Canyon generally show the potential for deposition in Reaches 4 and 3, and the potential for erosion in Reaches 2 and 1 during large storm events (Figure 4-15).

4.4.4 Upper Cristianitos Canyon

Upper Cristianitos Creek was divided into three reaches for the sediment transport analysis (Figure 4-1). Results of the sediment transport analysis are shown in Table 4-11. Reach 1 exhibited the highest sediment transport capacities. This result may reflect the larger (yet still transportable) bed-material size exhibited by Reach 1. The bed-material distribution for Reach 1 has a larger proportion of sand and gravel than the other two reaches. Also, channel width in Reach 1 is larger than in Reach 2. This may also contribute to the larger transport capacity in Reach 1 relative to Reach 2, even though their slopes are similar.

Relative to the two other modeled sub-basins in the San Mateo Creek watershed, Upper Cristianitos Creek sediment transport rates are low on an absolute basis. Sediment transport capacities are only slightly higher than for La Paz Canyon during the 10-year and 100-year events, and are significantly lower than for Gabino Canyon in all three modeled events (Figure 4-3). However, on a per unit area basis, the capacity of Upper Cristianitos Creek to transport sediment downstream was calculated to be the highest of the three modeled San Mateo sub-basins (Figure 4-4). The relatively small size of the Upper Cristianitos sub-basin is an important factor in its large per unit area sediment transport capacity.



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-15

Gabino Canyon Sub-basin
Sediment Mass Balance

PWA

PWA #:1393

Table 4-11
UPPER CRISTIANITOS CREEK SUB-BASIN SEDIMENT TRANSPORT RESULTS SUMMARY

Reach Number	Peak Transport Rate (tons/day) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	29,300	241,300	507,700
2	4,300	34,000	71,900
3	8,400	68,400	140,400

Sub-basin Area ($miles^2$)	Peak Transport Rate Exiting Sub-basin per Unit Area ($tons/mile^2/day$) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
3.67	7,984	65,749	138,338

Reach Number	Sediment Yield (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	4,400	42,600	123,500
2	700	6,100	17,600
3	1,400	12,200	34,900

Sub-basin Area ($miles^2$)	Sub-basin Sediment Yield, per Unit Area ($tons/mile^2$) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
3.67	1,199	11,608	33,651

Reach Number	Average Sediment Concentration (g/L) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	57	74	80
2	9	11	11
3	18	21	23

Reach Number	Sediment Mass Balance (tons) Laursen (Madden)		
	Q_2	Q_{10}	Q_{100}
1	-3,700	-36,500	-105,900
2	700	6,100	17,300
3	0	0	0

Table 4-11 also shows sediment yield results for the Upper Cristianitos Creek sub-basin. Within the sub-basin, sediment yields follow a pattern identical to sediment transport rates. Yields are highest in Reach 1, the most downstream reach. As previously discussed, high yields in Reach 1 may be explained by the relatively large proportion of sand and gravel bed material and the relatively wide channel. In absolute terms, the capacity of Upper Cristianitos Creek to deliver sediment downstream is in the same range as the yield of La Paz Canyon, and much lower than the yield of Gabino Canyon (Figures 4-5 and 4-6). The moderate size of these absolute yields is likely related to the small size of the Upper Cristianitos sub-basin. Relative to other sub-basins in the San Mateo Creek watershed, Upper Cristianitos Creek produced the highest sediment yields on a per unit area basis. This is likely also a reflection of the relatively small size of the sub-basin.

The sediment mass balance for Upper Cristianitos Creek shows the potential for moderate deposition in Reach 2 and significant erosion in Reach 1 (Figure 4-16). Erosion in Reach 1 is a reflection of the high transport rates and yields calculated for this reach, and the low rates and yields calculated for the upstream Reach 2.

4.5 SENSITIVITY ANALYSIS OF SAM MODELING

To evaluate the performance of the SAM model for this project, a sensitivity analysis was conducted. As described above (Section 4.2), several data sources were used to supply input parameters for the SAM modeling process. Hydraulic parameters and sediment distributions were available for Canada Gobernadora and the main San Juan channel from SLA (1999), but not for the other tributary sub-basin systems. The following sections assess the suitability of using composite channel geometry data from WES and the DEM, sediment texture data from Balance (2000), the Laursen (Madden) transport function for modeling in the sub-basins. This sensitivity analysis is based on a series of comparative SAM model runs where channel geometry, sediment distribution, and transport function input parameters were altered with resulting changes in sediment transport results.

4.5.1 Channel Geometry

PWA compared sediment transport rates based on hydraulic geometry input from the WES/DEM composite method and the available HEC-2 data at several locations including: five reaches of lower Canada Gobernadora, San Juan Creek at the Conrock gravel mining pit, and San Juan Creek at the Ortega Highway (USGS stream gage 11046500) (Figure 4-1). In order to compare the influence of hydraulic geometry (channel shape and energy slope), other variables (discharge input, sediment distributions, and transport function) were held constant for all runs. Table 4-12 lists channel geometry parameters and the resulting sediment transport rates for the compared reaches.

Table 4-12 Channel Geometry Sensitivity Analysis

Sub-basin	Reach	Data Source	Channel Hydraulic Parameters: Width (feet)	Depth (feet)	Slope (feet/feet)	Transport Rate (tons/day)
Canada Gobernadora	GO1	WES-DEM	150	5.8	0.018	684,823
		HEC-2	528	2.4	0.003	134,219
		variation(1)	*0.3*	*2.4*	*6.0*	*5.1*
	GO2	WES-DEM	167	5.4	0.018	668,461
		HEC-2	164	4.5	0.004	287,202
		variation(1)	*1.0*	*1.2*	*4.5*	*2.3*
	GO3	WES-DEM	179	5.0	0.008	380,567
		HEC-2	644	3.2	0.0009	25,125
		variation(1)	*0.3*	*1.6*	*8.9*	*15.1*
	GO4	WES-DEM	140	5.8	0.008	406,279
		HEC-2	694	1.6	0.007	357,924
		variation(1)	*0.2*	*3.6*	*1.1*	*1.1*
	GO5	WES-DEM	163	5.1	0.009	448,654
		HEC-2	615	1.7	0.007	370,595
		variation(1)	*0.3*	*2.9*	*1.3*	*1.2*
Central San Juan	GRAV	WES-DEM	378	9.1	0.005	622,433
		HEC-2	583	11.0	0.0007	53,877
		variation(1)	*0.6*	*0.8*	*7.6*	*11.6*
	GAGE	WES-DEM	307	10.1	0.007	1,062,658
		HEC-2	228	11.1	0.005	923,649
		variation(1)	*1.3*	*0.9*	*1.4*	*1.2*

Notes: (1) WES-DEM / HEC-2

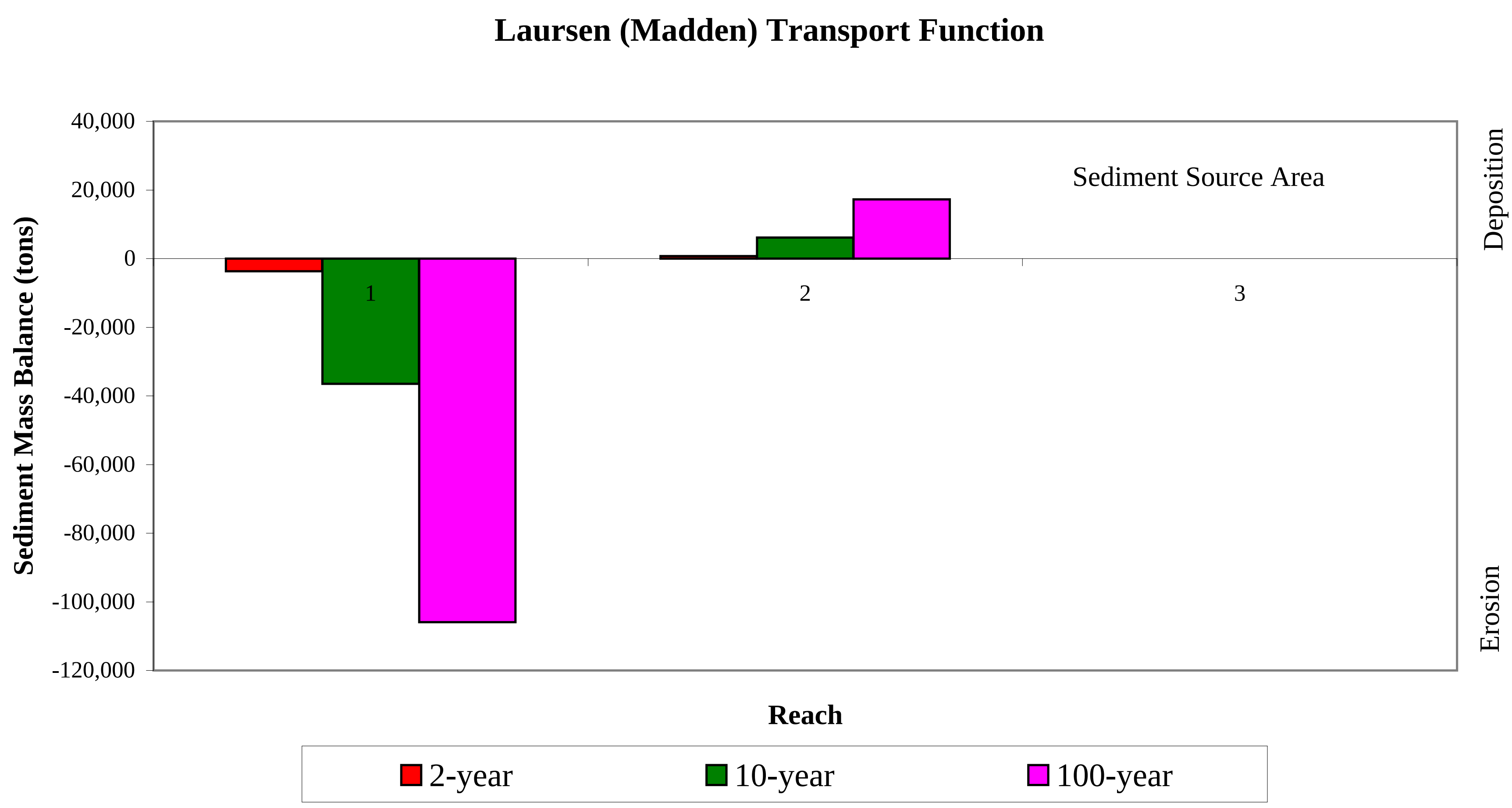
Information presented corresponds to:

SLA (1999) 100-year peak discharges

SLA (1999) sediment distributions

Laursen (Madden) transport function

Results indicate that the energy slope parameter has greater impact on transport rates than channel cross section dimensions. For example, at reaches GO4 and GO5, the WES/DEM and HEC-2 data sources supply very different widths and depths. However, because the energy slopes are similar, the resulting transport rates are also fairly close. In contrast, at Reach GO2 WES/DEM and HEC-2 offer similar widths and depths, but energy slopes vary by a factor of 4.5. As a result, transport rates differ by more than a factor of 2. In some cases, both channel dimensions and slope inputs differ significantly which results in transport rates that vary by an order of magnitude. Results from Canada Gobernadora suggest that using bed slope in place of energy slope is reasonable upstream in the canyon but becomes less appropriate downstream towards the canyon mouth where possible backwater effects from the confluence with the main San Juan channel result in flatter energy slopes.



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-16

Upper Cristianitos Sub-basin
Sediment Mass Balance

PWA

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4.5.2 Sediment Distribution

The effect of using different sediment texture distributions was examined by comparing model results using different sediment data for reaches in lower Canada Gobernadora and along the main San Juan channel at the Conrock gravel mining pit and the Ortega Highway stream gage downstream. In addition, the effect of altering small grain size distinctions was evaluated using sediment data from Vanoni et al. (1980) from the Conrock gravel pit. 100-year flows from SLA (1999), WES/DEM-based channel geometry, and the Laursen (Madden) transport function were held constant for these sediment distribution comparisons.

Different sediment distributions for Canada Gobernadora and San Juan Creek (at the Conrock mine and at the Ortega Highway stream gage downstream) were compared resulting in transport rates that varied within a factor of two (Table 4-13). Figures 4-17, 4-18, and 4-19 show cumulative sediment distributions from WES (2000), SLA (1999), Vanoni et al (1980), and Kroll and Porterfield (1969).

Table 4-13 Sediment Distribution Sensitivity Analysis

Sub-basin	Reach	Data Source	Transport Rate (tons/day)
Canada Gobernadora	GO1	WES	1,287,074
		SLA	684,823
		variation[1]	*1.9*
	GO2	WES	1,278,896
		SLA	668,461
		variation[1]	*1.9*
	GO3	WES	948,368
		SLA	380,567
		variation[1]	*2.5*
	GO4	WES	964,859
		SLA	406,279
		variation[1]	*2.4*
	GO5	WES	1,070,095
		SLA	448,654
		variation[1]	*2.4*
San Juan	GRAV	Vanoni	283,656
		SLA	622,433
		variation[1]	*0.5*
	GAGE	Kroll	1,394,309
		SLA	1,062,658
		variation[1]	*1.3*

Notes: [1] WES, Vanoni, or Kroll / SLA

Information presented corresponds to:

SLA (1999) 100-year peak discharges

WES-DEM channel geometry

Laursen (Madden) transport function

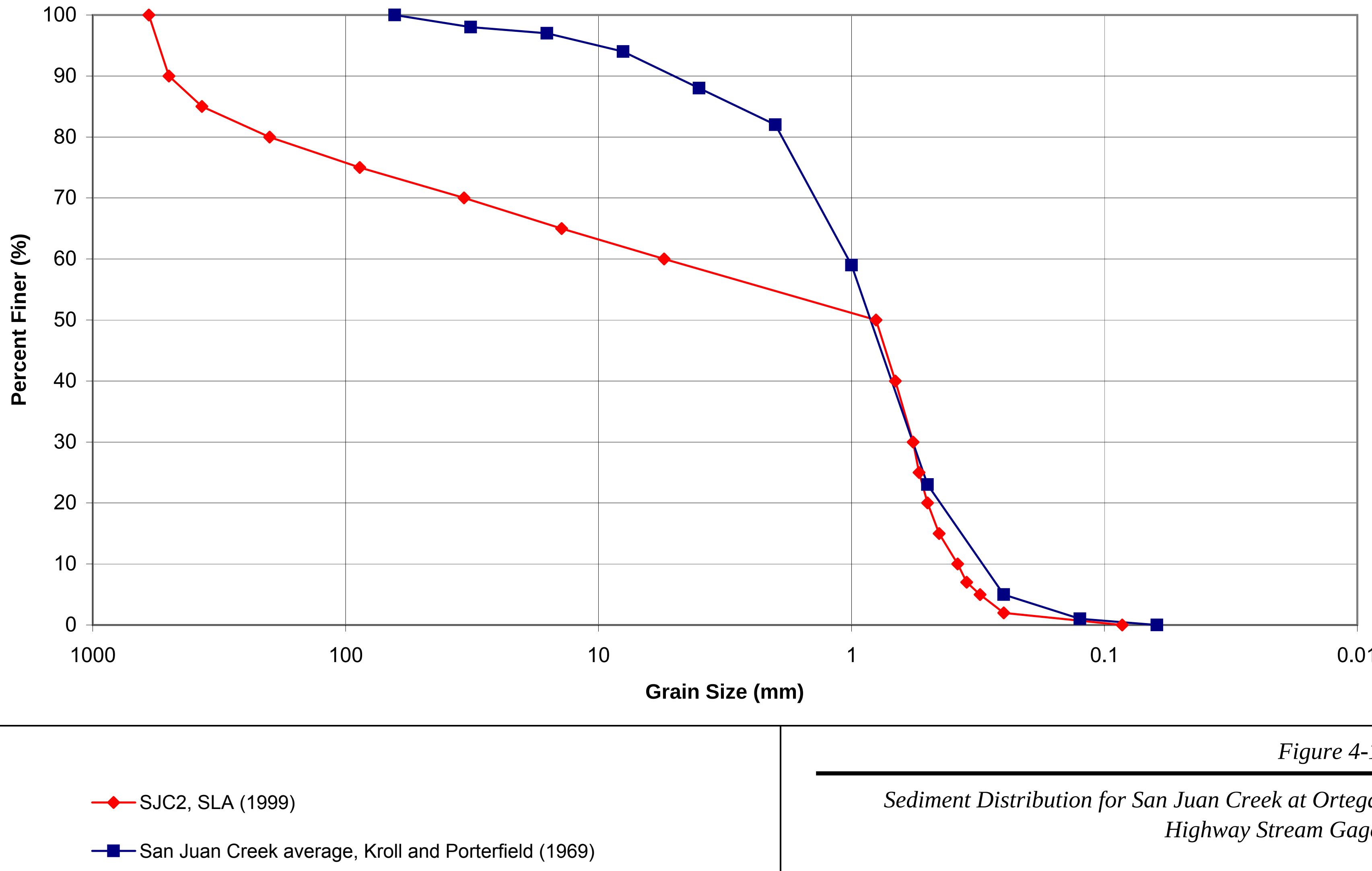


Figure 4-17

Sediment Distribution for San Juan Creek at Ortega Highway Stream Gage

PWA PWA#: 1393

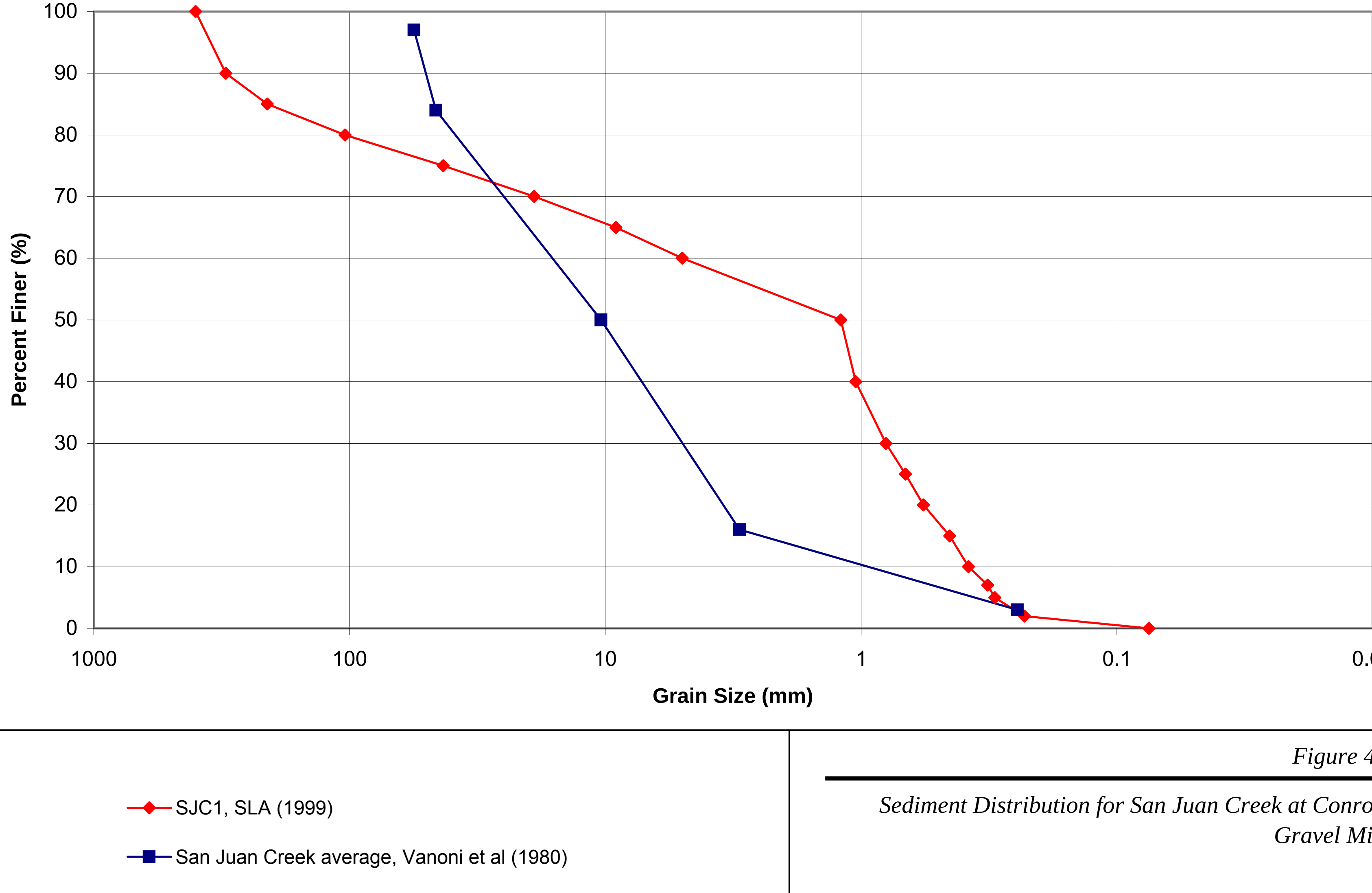


Figure 4-18

Sediment Distribution for San Juan Creek at Conrock Gravel Mine

PWA PWA#: 1393

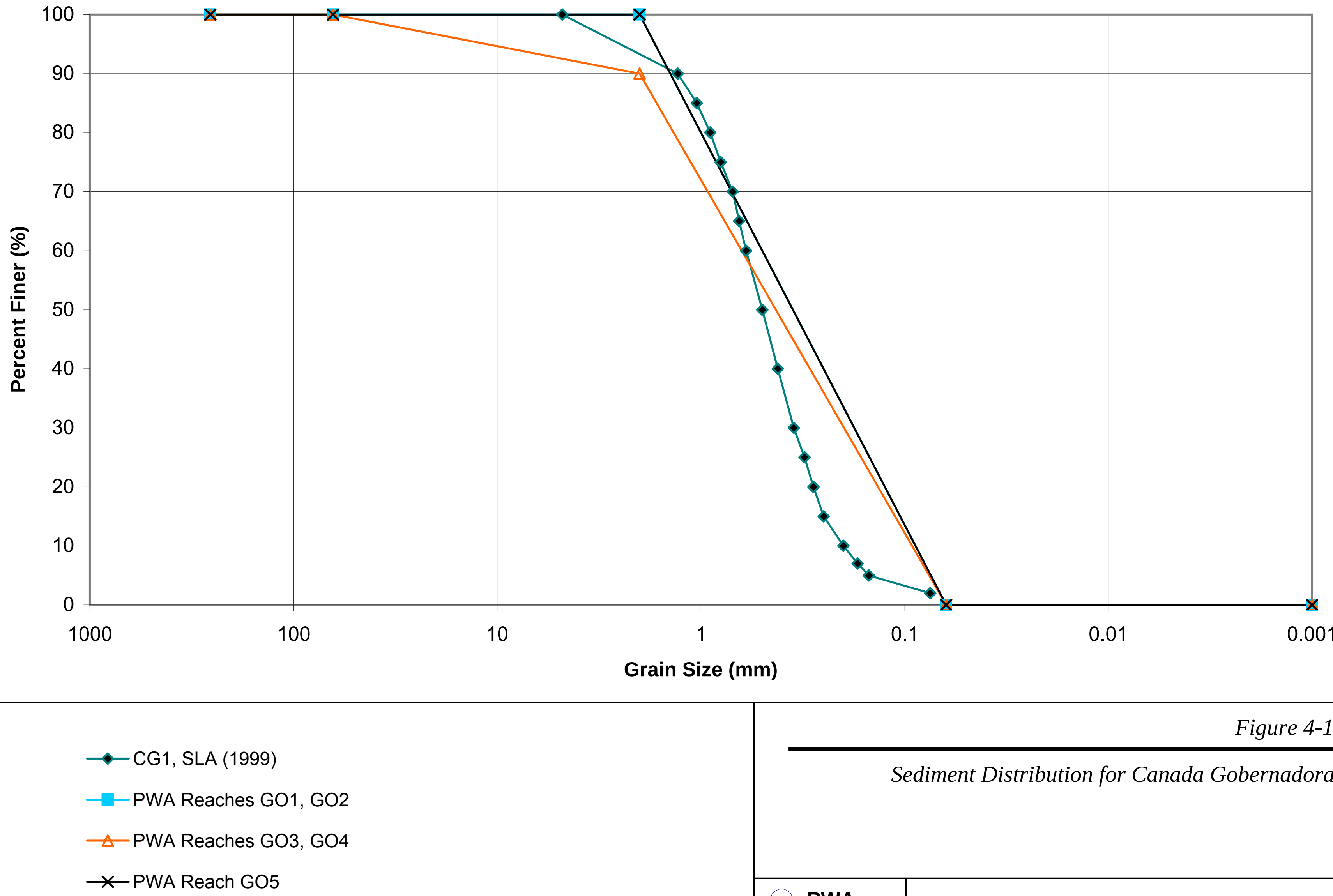


Figure 4-19

Sediment Distribution for Canada Gobernadora

PWA

PWA#: 1393

The sediment distribution reported in Vanoni et al. (1980) for San Juan Creek at the Conrock gravel pit did not include a low-end data point on the sediment curve to define the final 0% finer class. The SAM Users Manual, as well as experience from other sediment transport studies (PWA, 1996), suggests that SAM transport results are particularly sensitive to finer sediment characteristics at the lower end of the distribution curve. To examine the importance of the 0%-finer designation, PWA performed a series of modeling runs while varying this parameter within a reasonable range of values. Table 4-14 shows how subtle changes in defining the 0%-finer grain size class cause transport rates to vary by as much as a factor of 3.

Table 4-14 0% Finer Sensitivity Analysis

Sub-basin	Reach	Sediment Distribution	Grain size for 0% finer (mm)	Transport Rate (tons/day)	Transport Rate Variation[(1)]
San Juan	GR	Vanoni	--	283,656	
		Vanoni 0	0.1	724,647	2.6
		Vanoni 1	0.075	809,855	2.9
		Vanoni 2	0.01	477,548	1.7
		Vanoni 3	0.001	396,697	1.4

Notes: [(1)] Vanoni X / Vanoni

Information presented corresponds to:

SLA (1999) 100-year peak discharges

WES-DEM channel geometry

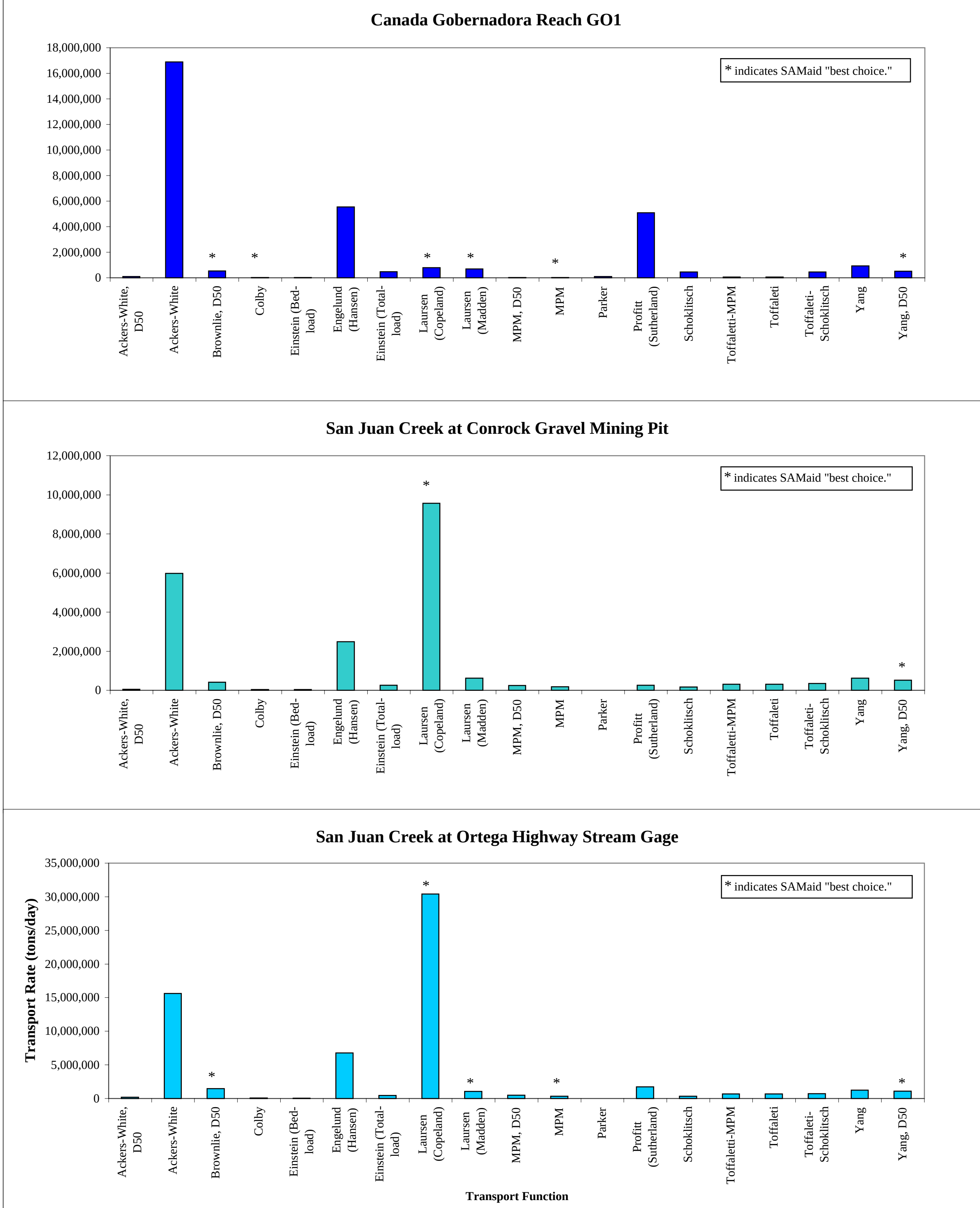
Laursen (Madden) transport function

4.5.3 Transport Function

4.5.3.1 Comparative analysis

The influence of transport function selection for SAM modeling was evaluated by comparing transport rates calculated by all transport functions available to SAM for lower Canada Gobernadora, San Juan Creek at the Conrock gravel pit, and San Juan Creek at the Ortega Highway stream gage. Sediment sizes in these three reaches range from coarse (mostly gravels and cobbles in San Juan Creek) to medium-sized (mostly sand in Canada Gobernadora). Using multiple reaches with varied sediment qualities helps illustrate the combined effect of testing different transport functions with different sediment size classes. Channel geometry (WES/DEM), 100-year streamflow (SLA, 1999) and sediment distributions (SLA, 1999) were held constant for all comparisons.

Results shown in Table 4-15 and graphed in Figure 4-20 indicate that selecting different transport functions results in transport rates that vary by as much as 3 orders of magnitude. After examining the output files, it appears that two of the transport functions do not function properly for the input grain size distributions for the studied areas. The Colby transport function is for grain sizes ranging from 0.125 to 1.0 mm, while the Parker function is suited for grain sizes larger than 2.0 mm in its calculations. Because the sediment distributions from all three of the study sites included large fractions of sediment beyond these ranges, results from these functions were not considered.



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis

figure 4-20

Transport Function Sensitivity Analysis

PWA

PWA #:1393

Table 4-15 Transport Function Sensitivity Analysis

Transport Function	Transport Rate (tons/day) Canada Gobernadora Reach 1	San Juan Creek at Conrock Gravel Mining Pit	San Juan Creek at Ortega Highway Stream Gage
Ackers-White, D50	99,	53,513	196,081
Ackers-White	16,886,958	5,977,328	15,616,489
Brownlie, D50	529,214	411,297	* 1,455,551
Colby	*25,9(	39,962	63,518
Einstein (Bed-load)	11,752	34,272	41,906
Engelund (Hansen)	5,535,538	2,482,112	6,790,045
Einstein (Total-load)	469,716	261,821	441,208
Laursen (Copeland)	* 787,955	* 9,563,344	* 30,422,008
Laursen (Madden)	* 684,823	622,433	1,062,658
MPM, D50	20,902	241,220	483,193
MPM	* 20,229	175,398	* 347,085
Parker	95,862	255	11
Profitt (Sutherland)	5,086,815	263,705	1,727,769
Schoklitsch	453,379	162,812	330,250
Toffaletti-MPM	64,099	305,471	667,487
Toffaleti	64,099	305,472	667,735
Toffaleti-Schoklitsch	453,379	349,017	712,162
Yang	931,377	622,065	1,225,746
Yang, D50	* 516,588	* 519,994	* 1,084,052

Notes: ** indicates SAMaid "best match" recommendation.*
Gray background indicates that function does include full range of sediment sizes in transport rate calculations

Information presented corresponds to:
SLA (1999) 100-year peak discharges
WES-DEM channel geometry
SLA (1999) sediment distribution

PWA used the SAMaid module to help select the most appropriate sediment transport functions to conduct the sediment analysis. SAMaid was used to compare input parameters (median sediment size, slope, velocity, width and depth) from the current PWA study with test data used to originally develop the functions and coordinate their use in SAM. The output from SAMaid is a list of functions whose input parameters most closely match the original test data. The SAMaid "best match" transport functions are indicated by asterisks in Table 4-15 and Figure 4-20.

For Canada Gobernadora Reach 1 (Figure 4-20), SAMaid recommended six transport functions: Brownlie D50; Colby; Laursen (Copeland); Laursen (Madden); MPM; and Yang D50. Transport rates produced by four of the six recommended functions (Brownlie D50, Laursen (Copeland), Laursen (Madden), Yang D50) were on the order of 10e5 tons/day. The other two functions (Colby, MPM) produced rates that were an order of magnitude smaller. The smaller transport rate calculated by the Colby function is likely caused by the limited range of sediment sizes included in the Colby transport calculations (described above) which make this function an inappropriate choice for the San Juan and San Mateo watersheds.

In the case of San Juan Creek at the Conrock gravel pit (Figure 4-20), SAMaid recommended two functions: Laursen (Copeland), and Yang D50. These functions generated transport rates that varied by an order of magnitude (10e6 vs. 10e7). At the Ortega Highway stream gage, SAMaid recommended five transport functions (Brownlie D50, Laursen-Copeland, Laursen-Madden, MPM, Yang D50) whose transport rates varied by two orders of magnitude (10e5 to 10e7).

4.5.3.2 Selection of transport functions

To choose which transport functions would be used in the main study, PWA evaluated functions based on the following criteria: (1) suitability according to the SAM user manual transport function descriptions; (2) SAMaid results and recommendations; and (3) comparisons with other San Juan Creek sediment studies. Transport function descriptions from the SAM user's manual included target river size and sediment type. These guidelines provided and initial assessment of function suitability for the San Juan and San Mateo streams. The SAMaid input data matching procedure provided another means of narrowing the field of possible functions. Results from other sediment studies in the San Juan watershed (described below) were used to compare the magnitude of PWA results with other measured data. The referenced studies included: SLA (1999) for transport rates from Canada Gobernadora; Vanoni (1980) for sediment concentration at the Conrock gravel mine; and Kroll and Porterfiled (1969) for transport rates at the Ortega Highway stream gage.

These criteria led to initially selecting three functions: Laursen (Madden), Laursen (Copeland), and Engelund (Hansen). After transport rates and sediment yields were calculated for the study areas using these functions, yield results were converted to event-averaged sediment concentrations. As an additional check, these concentrations were compared with results from other sediment transport studies. The Laursen (Copeland) results were removed from consideration in the main study because of their excessively high concentrations.

The Laursen (Madden) transport function was selected for use in the main study because it met the four criteria more favorably than the other functions. As a transport function, Laursen (Madden) is characterized for use in channels with sand and gravel loads. This function was recommended by SAMaid as a "best match" at the mouth of Canada Gobernadora and at the USGS stream gage on San Juan Creek. Laursen (Madden) produced transport rates which compared well with the Kroll and SLA studies, although sediment concentrations at the gravel mine did not compare as well with the Vanoni study. The Laursen (Madden) function produced sediment concentrations in the tributary canyon sub-basins that were considered reasonable.

The Engelund (Hansen) function was initially selected because it produced concentrations that best matched those of the Vanoni study at the Conrock gravel mine. As a function, Engelund (Hansen) is recommended for use in sandy bed streams such as Canada Gobernadora. However, Engelund (Hansen) was not recommended as a SAMaid "best match" for any of the three stream zones during the sensitivity analysis. Sediment concentrations produced by Engelund (Hansen) were considered acceptable for most of the study area, but were not considered as reasonable as results based on the Laursen (Madden) function.

Similar to Laursen (Madden), the Laursen (Copeland) function met the first three selection criteria in that it was based on the original Laursen formula, modified to extend its range to larger gravel sizes. This function was a SAMaid "best match" for all three areas; and its concentrations at the Conrock gravel mine compared well with the Vanoni study. However, for the canyon study areas with larger sediment sizes (gravels and cobbles) and steeper slopes, Laursen (Copeland) produced extremely high yields that converted to concentrations that seem unacceptably too high. As such, this function was not considered appropriate for the main study.

Based on the transport functions in the SAM user's manual, functions which were not described as applicable to both sand and gravel sediment conditions were generally not selected. In terms of comparison with other studies, about half of the 19 available functions produced transport rates or sediment concentrations that were significantly lower than published results. Of the transport functions recommended by SAMaid, Browlie D50 and Colby are described as sand functions and MPM is described as a gravel-only function that is invalid for conditions with appreciable suspended load. In addition, results from the sensitivity analysis indicated that the Laursen (Madden) represented results from the Brownlie D50 and Yang D50 functions.

4.5.3.3 Conclusions about transport functions and SAM

Results from the sensitivity analysis and other conducted SAM model runs suggest that certain transport functions are very sensitive to either hydraulic conditions (slope, channel geometry) or sediment size distributions, or both issues. For example, in sandy channels, Laursen (Copeland) transport rates are similar to results from the other functions, but in gravel-cobble streams Laursen (Copeland) rates are several orders of magnitude higher than the other functions. The Laursen (Copeland) results, when converted to concentrations, seem to be within a realistic range for the larger main San Juan Creek, but become impossibly high in the smaller, steeper canyons.

Of the compared sediment transport functions, the Laursen (Madden) results seem to provide the best general results across the varied sediment and channel conditions of the studied reaches. Therefore, the Laursen (Madden) function was chosen as the transport function to hold constant in the channel geometry and sediment distribution sensitivity analyses described above. The Laursen (Madden) transport function will be emphasized during a subsequent phase of work where alternative land use scenarios in the central San Juan and western San Mateo watersheds are evaluated for their hydrologic and geomorphic impacts.

4.6 COMPARISON OF RESULTS WITH OTHER SEDIMENT STUDIES

Results from three previous sediment transport studies in the San Juan Creek were compared with the current SAM model results. Results were compared with SLA (1999), who also used SAM to model sediment transport; Vanoni et al (1980) who used measurements of bedload deposition at the Conrock site; and Kroll and Porterfield (1969) who presented suspended load data from the Ortega Highway stream gage.

4.6.1 Comparison with SLA (1999)

Table 4-16 and Figure 4-21 compare transport rates for the 2, 25, 50, and 100-year peak flows[2] for reaches in Canada Gobernadora[3].

Table 4-16 Transport Rate Comparison at Canada Gobernadora Reaches 1-5

		2-year		25-year		50-year		100-year	
Reach		Q = 318 cfs[(1)]		Q = 3,319 cfs[(2)]		Q = 5,190 cfs[(3)]		Q = 6,920 cfs[(4)]	
PWA	SLA	PWA	SLA	PWA	SLA	PWA	SLA	PWA	SLA
GO1	6	47,491	2,996	596,801	64,812	959,944	323,881	1,287,074	481,527
GO2	5	45,946	61,316	587,316	1,111,884	949,961	756,469	1,278,896	953,314
GO3	4	30,861	319	426,587	28,331	691,174	64,639	948,368	108,730
GO4	3	35,313	66	440,941	382,008	711,947	752,941	964,859	1,120,738
GO5	2	38,607	1,080	491,568	96,388	790,138	901,810	1,070,095	1,302,452

Notes: (1) 2-year peak flow from SLA (1999)
(2) 25-year peak flow from SLA (1999)
(3) 50-year peak flow from SLA (1999)
(4) 100-year peak flow from SLA (1999)

For Reach GO1 at the mouth of Canada Gobernadora, PWA transport rates are approximately 1 order of magnitude higher than SLA rates. This difference is likely caused by the combination of different energy slope and sediment distribution data between the two models. As discussed in Section A-4, it is suspected that energy slope differs more significantly from bed slope at the mouth of the canyon than higher up in the watershed. At Reach GO2, SLA rates are approximately the same order of magnitude as PWA rates. For reach GO3, both PWA and SLA rates decrease relative to reach GO2, although the decrease in the SLA runs is much more dramatic, particularly for the lower flows. SLA rates for Reaches GO4 and GO5 show a similar trend: they remain extremely for low flows and increase significantly for higher flows, even higher than PWA rates. PWA rates increase slightly for these reaches, compared to rates in GO3. A comparison of input parameters in provided in Table 4-17.

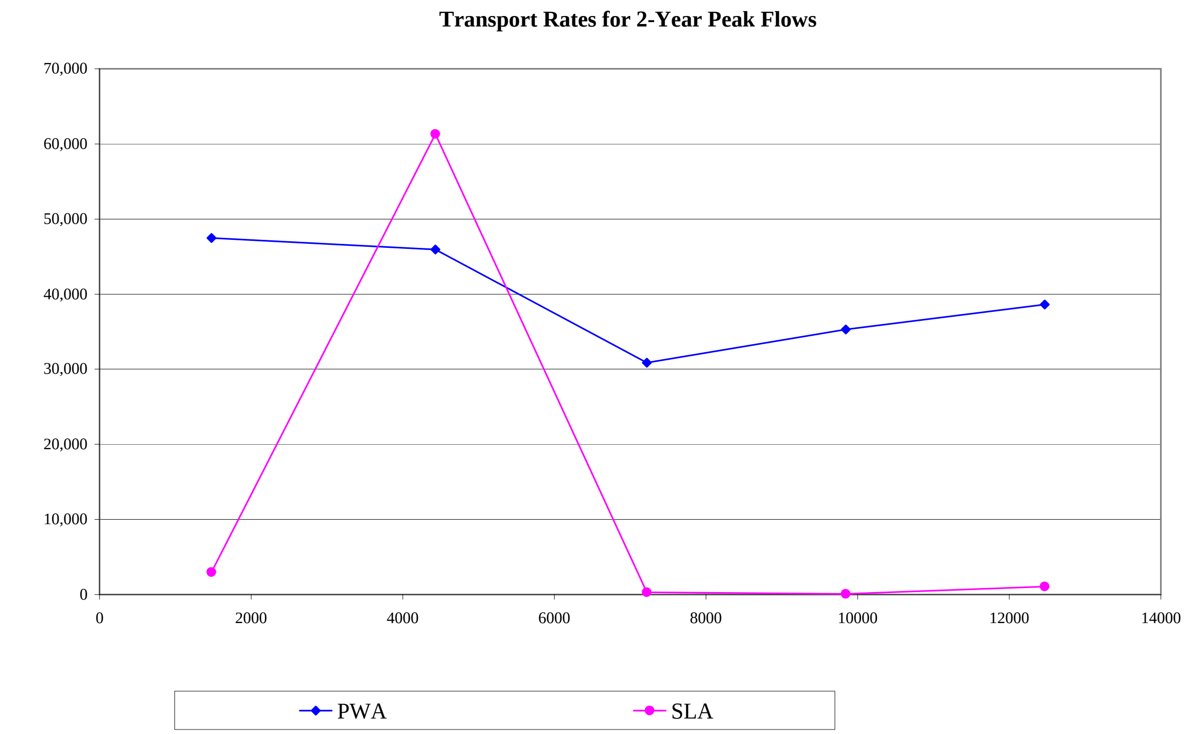
Table 4-17 Comparison of Input Parameters for Canada Gobernadora Reaches 1-5

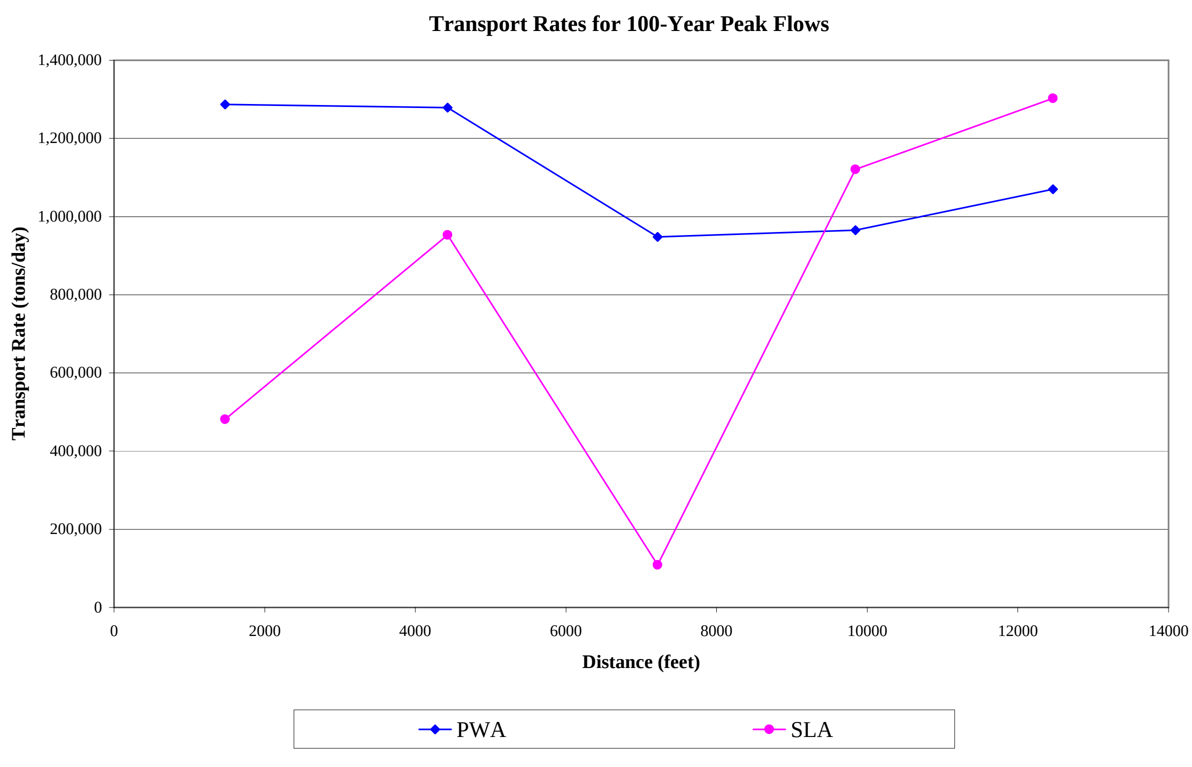
Parameter	PWA	SLA (1999)
Bankfull geometry	WES	HEC-2
Valley geometry	DEM	HEC-2
Energy slope	WES bed slope	HEC-2
Sediment curve	WES	SLA
Transport function	Laursen (Madden)	Yang, D50
Method	SAM modeling	SAM modeling

In summary, the PWA and SLA studies exhibit similar trends in transport rates by reach for a given flow. However, the SLA rates are more variable by reach for the same flow, while PWA rates for all reaches are generally more consistent for a given flow (Figure 4-21).

[2] *As estimated in SLA (1999). Sections 2,3,4 above present peak flows estimated by the current PWA analysis.*

[3] *Note that the naming scheme differs between the two studies: PWA reach numbers begin at the mouth of the canyon while SLA reach numbers begin at the upstream extent.*





Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis.

figure 4-21

Canada Gobernadora Sub-basin
Sediment Transport Rates

PWA

PWA #:1393

4.6.2 Comparison with Vanoni ET AL (1980)

Event-averaged sediment concentrations from the current study and Vanoni et al (1980) for San Juan Creek at the Conrock gravel mining pit are presented in Table 4-18. SLA (1999) results for this location have also been included for comparison. Both PWA and SLA (1999) results shown in Table 4-18 are based on channel geometry and sediment data from SLA Reach 1 of San Juan Creek.

Table 4-18 Sediment Yield and Concentration on San Juan Creek at the Conrock Gravel Mine

Study	Event	Runoff Volume (ac-ft)	Sediment Yield (tons)(1) LM	EH	LC	Sediment Concentration (g/liter)(2) LM	EH	LC
PWA	PWA Q2	3,238	9,636	13,039	148,558	2	3	32
	PWA Q10	15,562	30,217	42,376	396,580	1	2	18
	PWA Q100	36,048	45,829	63,704	522,281	1	1	10
Study	**Event**	**Runoff Volume (ac-ft)**	**Sediment Yield (CY)(3) measured**			**Sediment Concentration (g/liter)(4)**		
Vanoni et al	2/1/69	37,000	775,000			24		
	1/15-19/78(5)	580	55,000			110		
	3/4/78(5)	8,070	282,000			23		
Study	**Event**	**Runoff Volume (ac-ft)(6)**	**Sediment Yield (tons)(7)** Yang, D50			**Sediment Concentration (g/liter)** Yang, D50		
SLA	SLA Q2	401	1,583			3		
	SLA Q25	11,498	21,162			1		
	SLA Q50	18,242	30,498			1		
	SLA Q100	27,106	40,196			1		

Notes: (1) Using SLA (1999) HEC-2 geometry and SLA (1999) sediment distribution for SLA Reach 1 of San Juan Creek.

(2) Event-averaged sediment concentration (total yield/total runoff volume)

(3) Sediment yields in Vanoni et al (1980) reported as cubic yards.

(4) Values in table represent reported concentrations from Vanoni et al (1980). No specific weight information for the sediment was provided in the Vanoni et al report; therefore, a specific weight of 1.26 tons/CY was assumed for verification of sediment concentrations. Attempts to reproduce reported sediment concentrations produced values of 19, 84, and 31 g/liter, respectively. Discrepancy may be partially caused by specific weight assumption.

(5) Difference between the volume of sediment deposited in the pit and that eroded from degraded reach of channel immediately upstream (Vanoni et al, 1980). (Local upstream erosion caused by the gravel mine subtracted out of yield measurement.)

(6) Runoff volume for SJ2t from Table 37, SLA (1999) Hydrology Appendix. May be slightly different than hydrograph used to calculate yield (see Note 7).

(7) SLA (1999) Reach 1 results. Yields calculated from "batch hydrographs" scaled to match peak flow for each event.

Comparing values in Table 4-18 indicates that concentrations from Vanoni et al (1980) are an order of magnitude higher than those produced from the current study using the Laursen (Madden) and the Engelund (Hansen) transport functions. Concentrations given by the Laursen (Copeland) function are the same order of magnitude as the Vanoni results. Concentrations calculated from the Yang, D50 function are also an order of magnitude smaller than the Vanoni concentrations.

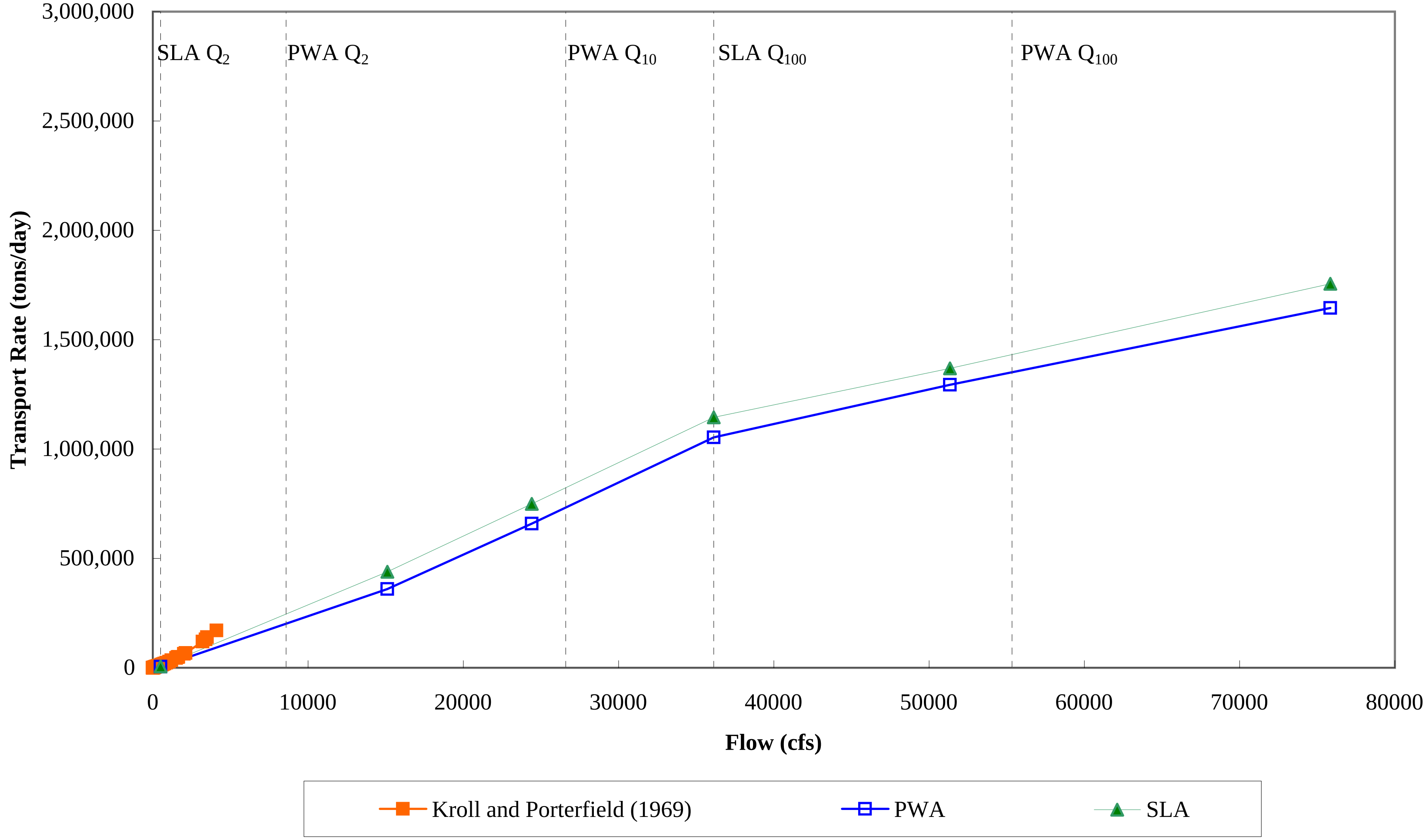
Although the Laursen (Copeland) model results were the best match with the Vanoni data, this transport function was not selected for use in the main study for two reasons. First, as discussed in Section 5.5.3.2, this transport function resulted in unrealistically high concentrations in the steeper canyon study sub-basins that are the focus of the main study. Second, concentrations from Vanoni et al (1980), which were based on surveys of the gravel pit before and after storm events, may be somewhat elevated. The authors note that the 1969 and 1978 floods both followed several relatively dry years when sediment accumulated in tributary channels as storage. This stored sediment was readily available for transport during the large events of 1969 and 1978. In addition, it has been suggested (B. Hecht, pers. comm.) that the sediment quantities cited in Vanoni et al (1980) for the Conrock gravel mine may be high relative to other reaches due to the disturbed nature of the gravel mine site. This suggests that the Laursen (Copeland) function may produce inappropriately high transport rates for other areas in the watershed since it matched most closely with data in the vicinity of the gravel mine.

As described above, the Engelund (Hansen) function was initially selected because it produced sediment concentrations that agreed most closely with the Vanoni et al (1980) results. These initial results were based on model runs that used WES-DEM channel geometry data and the Vanoni et al (1980) sediment distribution. Subsequent refinement of the model indicated that the use of the incomplete Vanoni sediment distribution (no zero percent finer grain size) made it difficult to compare the results of the Engelund (Hansen) transport function, which is particularly sensitive to the lower grain sizes, with the results of the Laursen (Madden) and Laursen (Copeland) functions.

4.6.3 Comparison with Kroll and Porterfield (1969)

Sediment transport rates from the current study are compared to results from Kroll and Porterfield (1969) in Table 4-19 and Figure 4-22. SLA (1999) results for this location are included for comparison. Both PWA and SLA (1999) results are based on channel geometry and sediment data from SLA Reach 11 of San Juan Creek. The Ortega Highway stream gage is located at SLA river station 189+00, the upstream end of Reach 11.

Data for the Kroll and Porterfield study were collected during the 1967 and 1968 water years, during a relatively low rainfall period prior to the 1969 floods. Their results do not include transport rates for discharge events comparable to the higher flows modeled in the current study. For the 2-year peak flow both PWA and SLA (1999) transport rates are smaller than the Kroll and Porterfield measured rates by approximately a factor of 2. Where flows are comparable, the current results show general agreement with the Kroll and Porterfield data.



Source: PWA (2000) Analysis.
Notes: USACOE SAM model was used in analysis. PWA analysis used Laursen (Madden) sediment transport function; SLA (1999) analysis used Yang, D50 transport function.

figure 4-22

San Juan Creek at Ortega Highway Stream Gage
Sediment Transport Rates

PWA

PWA #:1393

Table 4-19 Transport Rate Comparison for San Juan Creek at Ortega Highway Stream Gage

Flow (cfs)	Transport Rate (tons/day)		
	Kroll and Porterfield (1969)	PWA[1]	SLA (1999)[1]
0	0		
38	98		
170	3,900		
330	7,700		
440	10,500		
494[2]		4,869	6,334
560	13,500		
660	16,500		
1,500	44,000		
3,200	120,000		
4,100	170,000		
15,113[3]		360,346	439,062
24,400[4]		659,040	749,948
36,123[5]		1,053,503	1,144,508
51,342[6]		1,293,625	1,368,684
75,847[7]		1,645,285	1,755,536

Notes: [1] PWA and SLA results based on SLA (1999) HEC-2 geometry and SLA (1999) sediment distribution.
PWA study uses Laursen (Madden) transport function; SLA (1999) uses Yang, D50.
[2] 2-year peak flow from SLA (1999)
[3] 25-year peak flow from SLA (1999)
[4] 50-year peak flow from SLA (1999)
[5] 100-year peak flow from SLA (1999)
[6] 200-year peak flow from SLA (1999)
[7] 500-year peak flow from SLA (1999)

4.6.4 Conclusions of Sediment Transport Analysis

In conclusion, the description of the methods, sensitivity analysis, and comparison of results presented in Section 5 indicate that sediment transport and yield results may vary by several orders of magnitude depending upon input parameters. This is especially true with the selection of transport function. Relative to the other transport functions available in SAM, the Laursen (Madden) transport function compared favorably with the SAM guidelines, other studies, and storm event data. The Laursen (Copeland) function seemed to achieve the closest fit on the main San Juan channel at the gravel mine but was not appropriate for the steeper tributary sub-basins entering the main channel due to different hydraulic conditions. Despite uncertainties surrounding absolute values according to particular sediment transport functions, the current results provide relatively consistent trends for individual sub-basins. This information will be used as a baseline to evaluate impacts of potential development scenarios and to make planning level recommendations.

5. LIST OF PREPARERS

This report was prepared by the following PWA staff:

Kenneth Schwarz, Ph.D.	Director
Aaron Mead, P.E.	Hydrology, Hydraulics and Sediment Transport
Katie Pilat	Hydraulics and Sediment Transport
Nicola Mawer	Hydrology
Steve Blake	Stream Network Analysis, GIS Operations
Gwyn Barton	Report Production
Jeffrey Haltiner, Ph.D., P.E.	Principal in Charge

Eric Stein, D.Env. of PCR Services supplied valuable comments and suggestions following a review of this work.

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Appendix B

Baseline Water Quality Conditions, San Juan/San Mateo Creeks Special Area Management Plan (SAMP), Southern Orange County, California

Letter report prepared for:

Rancho Mission Viejo

Prepared by:

Edward Ballman

Barry Hecht

Bonnie Mallory

Balance Hydrologics, Inc.

September 2001

A report prepared for:

Rancho Mission Viejo
28811 Ortega Highway
San Juan Capistrano, California 92692

Appendix B

Baseline Water Quality Conditions, San Juan/San Mateo Creeks Special Area Management Plan (SAMP), Southern Orange County, California

Balance Project Assignment 99058

by

Leslie Mack For Ed Ballman
Ed Ballman
Civil Engineer/Hydrologist

Barry Hecht
Barry Hecht, CEG,CHg
Hydrologist, Hydrogeologist

REGISTERED CERTIFIED ENGINEERING GEOLOGIST
BARRY HECHT
NO. 1245
Exp. 10/03
STATE OF CALIFORNIA

REGISTERED GEOLOGIST
BARRY HECHT
NO. 50
CERTIFIED
HYDROGEOLOGIST
STATE OF CALIFORNIA

Bonnie Mallory
Bonnie Mallory
Hydrologist/Water Quality Specialist

Balance Hydrologics, Inc.
900 Modoc Street
Berkeley, CA 94707-2208
(510) 527-0727
office@balancehydro.com

September 18, 2001

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APPENDICES

1. INTRODUCTION

1.1 Purpose

This report provides an overview of baseline water quality conditions and issues within the boundaries of the San Juan and San Mateo Creek Special Area Management Plan (SAMP) study area. This area encompasses the majority of the San Juan Creek watershed and a small portion of the San Mateo Creek watershed in the southern portion of Orange County, California.

Water quality considerations are clearly an integral element related to many of the resource management goals being addressed by the SAMP effort. This is especially true given the diversity of geology, terrains, land cover and land use within the study area. Water quality directly impacts the health of aquatic habitats, and it is the associated concerns related to mitigating potential degradations in water quality that underlie the regulatory and permitting activities of a number of resource agencies.

1.2 Goals and Objectives of the Study

Experience indicates that presenting a concise and coherent assessment of water quality, especially at the spatial scale of the SAMP, can be difficult. This reality stems from a number of factors not the least of which is the fact that the term "water quality" is applied to a wide range of metrics and indicators. These measurements represent an interplay of compounds that may, or may not, function independently within aquatic ecosystems resulting in cause and effect relationships which are often difficult to discern. Additionally, constituents of concern cycle through these aquatic habitats in pathways which are almost always spatially and temporally transient, leading to ecosystems that are rarely, if ever, at steady state.

The primary goal of this study is to present an overview of baseline water quality conditions in the respective watersheds, mindful of the constraints discussed above. There are several specific objectives that underlie this goal and these include:

- Outlining the pertinent framework under which local and regional policies and regulations are developed and implemented.

- Summarizing and analyzing the most important water quality data sets that have been collected within the SAMP study area.

- Building on the data analyses and an understanding of terrains to infer how key constituents of concern are mobilized, transported and assimilated within sub-watersheds.

- Comparing specific sub-watershed characteristics to identify the opportunities and constraints that will most directly influence land use planning, permitting processes and the selection and design of features intended to maintain or enhance water quality.

1.3 Work Conducted

For this study, we conducted a thorough search for reports pertaining to both the San Juan and San Mateo watersheds that include any water quality data. We reviewed the following available reports:

- KEA Environmental, Inc., 1998, Final San Juan Creek Watershed Baseline Conditions Report;

- Lang, J.S., Oppenheim, B.F., and Knight, R.N., 1998, Southern Steelhead *Oncorhynchus mykiss* Habitat Suitability Survey of the Santa Margarita River, San Mateo and San Onofre Creeks on Marine Corps Base Camp Pendleton, California;

- California Department of Water Resources, 1972, Planned Utilization of Water Resources in the San Juan Creek Basin Area;

- Toups Engineering, Inc., 1966, Report on Local Water Supply, Rancho Mission Viejo, Orange County, California;

- California Department of Water Resources, 1964, San Juan Creek Ground Water Study.

Additionally, our review of water quality considerations was greatly assisted by the water quality data collected by the Orange County Public Facilities and Resources Department (Orange County PFRD). The department was kind enough to provide their data sets in digital form, streamlining the analyses of pollutant source and transport trends.

This water quality data collected by others was augmented by a series of field surveys in the sub-basins within the SAMP study area in order to assess the roles that various geomorphic and biological features may be playing in controlling the mobilization and cycling of key nutrients and constituents of concern. Historical aerial photography was used to put this present-day view of the sub-basins in a context more appropriate to the temporal scale that shapes both acute and chronic water quality in these highly episodic watersheds.

2. REGULATORY SETTING AND BACKGROUND ISSUES

2.1 Regulatory Framework

Water quality is of particular importance in the SAMP study area both from a regulatory and environmental perspective. The California State Water Resources Control Board (SWRCB or "State Board") and the nine Regional Water Quality Control Boards (RWQCB or "Regional Board") have the authority in California to protect and enhance water quality. This authority is derived through the state's primary water-pollution control legislation, the Porter-Cologne Act as well as through the Boards' designation as the lead agencies in implementing the Section 319 non-point source program of the federal Clean Water Act. The RWQCB Region 9 office guides and regulates water quality in San Diego, Riverside, and portions of Orange Counties in accordance with the Water Quality Control Plan or "Basin Plan" (RWQCB, 1994). This plan establishes designated beneficial uses and water-quality objectives and criteria that must be met to protect these uses (see Table 1).

The State of California's strategy for addressing nonpoint source pollution is laid out in the most recent Nonpoint Source (NPS) Program Plan approved by the U.S. Environmental Protection Agency in July 2000. The NPS Program Plan recognizes the importance of watershed-scale approaches to water quality management. For example, the overall goal of the Program is:

> "...to manage NPS pollution, where feasible, at the watershed level, including pristine areas and watersheds that contain water bodies on the CWA [Clean Water Act] section 303(d) list and where local stewardship and site-specific management practices can be implemented through comprehensive watershed protection or restoration plans."

The California Toxics Rule (CTR) establishes numeric water quality criteria for priority toxic pollutants listed under Section 307(a) of the Clean Water Act, as required by Section 303(c)(2)(B). Promulgated in April 2000, the CTR supplements the narrative water quality criterion contained the 1994 Basin Plan with ambient aquatic life criteria for 23 priority toxics and ambient human health criteria for 57 priority toxics (see Table

2). These numeric criteria must not be exceeded in inland surface waters, enclosed bays or estuaries of the State.

The San Diego RWQCB also administers the National Pollution Discharge Elimination System (NPDES) permit program for municipal storm water and construction site runoff within the SAMP study area. The intent of the NPDES permits is to avoid degradation of water quality through appropriate design (including source control) and implementation of best management practices and other treatment control measures. The RWQCB requires NPDES permits for storm water discharges from construction activities that disturb more than five acres, from municipalities and also from selected commercial/industrial sources. These programs are intended to protect and maintain the uses of water necessary for the survival and well being of man, plants and wildlife.

Recent actions by the RWQCB have moved to stricter controls on discharges to and from municipal separate storm sewer systems (MS4s) as a means of achieving the goals of the NPS Program Plan and are summarized in Tentative Order 2001-193. Specific requirements will include Urban Runoff Management Plans (URMPs) for each municipality and county agency owning or operating an MS4 and the development of Standard Urban Storm Water Mitigation Plans (SUSMPs) to reduce pollutants and runoff flows from all new development and significant redevelopment meeting certain criteria. In general, the SUSMP requirements will apply to most development or redevelopment creating 5,000 or more square feet of impervious area (2,500 square feet in environmentally sensitive areas).

2.2 Beneficial Uses

State policy for water quality control in California is directed toward achieving the highest water quality consistent with maximum benefit to the people of the state. In an effort to develop water quality standards which are consistent with the uses of a given water body, the Regional Board has classified historical, present and future beneficial uses. This classification is included in the Basin Plan published by the Regional Board (Water Quality Control Plan, San Diego Basin, 1975, and as updated in 1991 and 1994). The Basin Plan presents the beneficial uses that the Regional Board has designated for local aquifers, streams, marshes, rivers and coastal waters. Numerous existing and potential beneficial uses have been designated for the San Juan and San Mateo

Watersheds (Table 1). It is important to note that Regional Board policy is to protect uses that might reasonably apply to the tributaries of the listed waters as well. This list is a good indication of the types of human uses that are at risk from water pollution and hydrologic disturbance.

2.3 Water Quality Objectives in the Basin Plan

The San Diego Regional Board has adopted a number of objectives for inland surface waters (including enclosed bays and estuaries) that pertain to nutrients, pesticides and other potential constituents of runoff or percolate. Furthermore, the State Board also adheres to an "Anti-Degradation Policy". This policy states that, "whenever the existing quality of water is better than the quality of water established [in the Basin Plan] as objectives, such existing quality shall be maintained unless otherwise provided by SWRCB Resolution No. 68-16." Thus, there are specific water quality objectives, and even where water quality is better than these standards the Regional Board is directed to prevent significant degradation.

The objectives most relevant to water-quality protection within the SAMP study area may be summarized as follows:

- The pH shall not be depressed below 6.5, nor raised above 8.5.

- Waters shall not contain biostimulatory substances (e.g. nutrients) in concentrations that promote aquatic growth to the extent that such growth causes nuisance or adversely affects beneficial uses.

- Discharges shall not increase the total dissolved solids or salinity of waters of the State so as to adversely affect beneficial uses, particularly fish migration and estuarine habitat.

- Waters shall not contain oil, greases or waxes in concentrations that result in a visible film or coating on the surface of the water, or on objects in the water or which might impact beneficial uses.

- There shall be no acute toxicity in ambient waters, including mixing zones, and there shall be no chronic toxicity (generally, exposures to pollutants exceeding 96 hours) in ambient waters outside mixing zones.

- Discharges shall not result in detrimental increases in the concentrations of toxic substances found in bottom sediment or aquatic life.

- Ambient numeric aquatic and human life criteria for priority toxic pollutants promulgated in the CTR are not to be exceeded in inland surface waters, enclosed bays or estuaries. Selected freshwater aquatic life criteria are listed in Table 2.

- Discharges shall not cause receiving waters to contain concentrations of un-ionized ammonia in excess of specific pH and temperature dependent values. For example, four-day average concentrations of un-ionized ammonia should not exceed 0.0058 mg/liter (as N) at a pH of 7.0 and a temperature of 20° C.

- Numerical objectives for some inorganic chemicals have been established in the Basin Plan which are not to be exceeded in inland surface waters. Table 2 summarizes these objectives for the San Juan Hydrologic Unit.

- No controllable water-quality factor shall degrade the quality of any groundwater resource or adversely affect long-term soil productivity.

2.4 Section 303(d) of the Federal Clean Water Act

The State of California is required by Section 303(d) of the federal Clean Water Act to provide to the United States Environmental Protection Agency (EPA) a list of waterbodies considered by the State to be impaired (i.e., not meeting water quality standards and not supporting their beneficial uses). The list also identifies the pollutant or stressor causing impairment, and establishes a schedule for developing a control plan (typically a TMDL) to address the impairment. Recommendations are made to the SWRCB by each of the nine RWQCBs using available information and data. The resulting list is employed by the EPA to prepare the biennial federal Clean Water Act Section 305(b) Report on Water Quality.

While no lakes, wetlands or groundwater units within the SAMP study area have been included in the 303(d) list, the San Diego Regional Board has identified 1 mile of the lower San Juan Creek and 0.02 miles of coastal shoreline at the lower San Juan HSA as not meeting water quality standards or supporting their beneficial uses. High coliform counts from point and nonpoint sources were identified as the pollutant or stressor for both areas, and both were placed on the TMDL development schedule.

2.5 Constituents of Concern in Southern California Watersheds

2.5.1 Temperature

Water temperature in most southern California aquatic habitats can fluctuate markedly both diurnally and seasonally, and a number of factors can directly impact the prevailing water temperature. These factors include turbulence and cascading that can increase evaporative cooling, runoff from warm surfaces such as roadways and parking lots, groundwater infiltration and the amount of shading of the water surface that reduces insulation. Therefore, measurements of water temperature can be site-specific and strongly vary with time of day.

Changes in water temperature can have a large number of collateral impacts. Changes in the metabolic rates of aquatic organisms, algal growth, shifting of chemical and partitioning equilibria and, perhaps most importantly, changes in the solubility of key gases such as oxygen can all be linked to changes in water temperature. Therefore, fluctuations can have a deleterious effect on sensitive species such as the federally-listed steelhead rainbow trout *(Oncorhynchus mykiss)*.

2.5.2 Turbidity

Turbidity refers to the cloudiness of the water, usually measured in Nephelometric Turbidity Units (NTU). It is caused by suspended particulate matter (e.g., clay, silt, colloids, plankton, etc.) that scatters light passing through water. Turbidity typically increases with suspended sediment concentration, however, the relationship depends on the river system or water body. For example, rivers with muddy bottoms can have natural levels of 1000 NTU or more while the open ocean has naturally low levels of <1 NTU. Most systems have a range of turbidity from <1 NTU to maximum levels of 10 to 100 NTU. Under the Safe Water Drinking Act, the National Primary Drinking Water Standard is 0.5 NTU.

Turbidity affects the aquatic environment in many ways. It alters the rate of photosynthesis in a system by blocking out sunlight that is needed by submerged aquatic vegetation. It can damage or clog the gills of fish and invertebrates, bury eggs and benthic organisms, and interfere with the ability of organisms to find food. Wildlife activities based on visual cues (such as courtship behavior patterns) may be disturbed by turbidity. The suspended particles also absorb additional heat from the sun, thus raising water temperature. In contrast, the particles that contribute to turbidity can adsorb phosphates, ammonium ions, metals and pesticides, decreasing their bioavailability (Dunne and Leopold, 1978).

2.5.3 Nutrients

Typically, the two nutrients of highest concern within rivers and streams are nitrogen and phosphorus. Nutrients can be, and in fact have been, significant constituents of concern in several watersheds near the SAMP study area. For example, there are ongoing processes to establish Total Maximum Daily Load (TMDL) guidelines for both nitrogen and phosphorus in the San Diego Creek watershed in Orange County (RWQCB Region 8) due to impacts in Upper Newport Bay. The primary concern related to nutrients is the biostimulatory effect that they can have on aquatic ecosystems. Many, but not all, aquatic ecosystems function in an equilibrium determined by the scarcest necessary nutrients utilized at the lower levels of the food chain, particularly by plants. The scarcest nutrient is referred to as the "limiting nutrient". When increases in the limiting nutrient occur, there generally is an associated increase in biological activity that often shifts the dominant bio-geochemical equilibria. A common manifestation of this eutrophication process is an algal bloom. The shift in other equilibria associated with eutrophication can be very significant. For example, the increased consumption of carbon dioxide by the algal bloom can markedly increase pH values initiating a subsequent cascade of disequilibria as ionization levels adjust (e.g. ammonium ions converting to the much more toxic undissociated ammonium hydroxide) and partitioning coefficients adjust (e.g. a reduction in dissolved metal concentrations). On the other hand, the decomposition of the increased algal biomass can significantly reduce dissolved oxygen levels with potentially detrimental effects on aquatic animals.

Nitrogen sources include septic system leachate, wastewater treatment plant discharges, nurseries, livestock and animal manure, fertilizers, and yard waste (SQFT, 1993). The most readily accessible forms of nitrogen in stream systems are typically the nitrate (NO_3^-) and ammonium (NH_4^+) ions, although relatively large amounts of nitrogen can be stored in both living and dead biomass. Ammonium is the form produced during decomposition of organic matter and is common in fertilizers. Due to its positive charge, it is readily adsorbed by soils, but is also relatively quickly converted to nitrate when exposed to oxygen. Nitrate, by contrast, persists much longer in the environment and is more mobile in soil. Excessive amounts of nitrogen can contribute to eutrophication and groundwater contamination (Laws, 1993).

Phosphorus sources include animal wastes, fertilizers, some detergents and household products, and mineral weathering of natural phosphate deposits. It is almost always the limiting nutrient in freshwater systems in the northern and eastern portions of the country and is directly tied to eutrophication of streams and lakes (Laws, 1993). However, it is important to note that the situation is often quite different in semi-arid regions characterized by high erosion rates such as the SAMP study area. Here, abundant natural sources of phosphorus from Monterey shale bedrock deposits may shift nutrient limitation to nitrogen (Dailey et al., 1993).

Orthophosphate (PO4) is typically the most common form of phosphate and is most readily available for uptake by plants and animals. However, unlike nitrate, orthophosphate reacts quickly with soils particles and is overall quite immobile. Therefore, phosphorus loads in natural systems generally depend on the high erosion and transport rates that accompany flood events.

2.5.4 Metals

Metal sources include automobiles, household toxics, some herbicides, and natural weathering of bedrock and soils (SQTF, 1993). Most metals are carried to the stream system with storm water. The concentration of metals in stormwater is a function of factors such as the time that stormwater is in contact with paved surfaces, the flow rate per unit area of impervious surface, and the pH of the rain. Metals can occur in both particulate and dissolved forms. It is the dissolved form that is most bioavailable and can be highly toxic to plants and animals (Laws, 1993). Metal toxicity has been a serious concern in watersheds near the SAMP study area. For example, the RWQCB for Region 9 has promulgated TMDL guidelines for copper, lead and zinc in the Chollas Creek watershed in San Diego County (RWQCB Region 9, 2000). An analogous TMDL is pending for selenium in the San Diego Creek / Newport Bay system under guidance of the RWQCB Region 8 office (RWQCB Region 8, 2000).

Speciation is the term used to describe how much of the total load of a particular metal is found in dissolved or particulate forms. Metals in the dissolved form are considered more readily available to organisms and therefore potentially more deleterious. Metal speciation depends on water pH, chemical properties of the specific metal, and the nature of the suspended solids that are present in the water (Sansalone and Buchberger, 1997a and 1997b). At typical pH levels of 7 to 8, metals are generally more likely to adsorb onto particles, while depressed pH levels favor the dissolved form (Paulson and Amy, 1993). Higher suspended sediment or turbidity concentrations will increase the particulate metal fraction due to a greater number of sites that are available for adsorption. Ambient water quality criteria for several dissolved metals are set forth in both the Basin Plan and the CTR (Table 2).

The amount of metal in the particulate phase also depends on the metal itself. When there is a high concentration of many metals in the system, the more competitive metals are more likely to be found in their particulate form. Lead and copper are highly competitive and are therefore more commonly found in their particulate form, whereas zinc and cadmium are less competitive and are often found in their dissolved phase (Characklis and Wiesner, 1997, Flores-Rodriguez et al, 1994).

It is important to note that many metals have been shown to be associated with the smallest of the suspended particles (Dempsey et al, 1993, Sansalone and Buchberger, 1997a). This is significant because small colloidal particles and their associated metals are suspended in the water for longer time periods and transported greater distances than the large particles. This can have important implications in the selection and design of Best Management Practices (BMPs) intended to control metal loads to aquatic systems.

2.5.5 Pesticides and other organics

Pesticides (i.e., insecticides, herbicides, and fungicides) are designed to kills plants and animals. Non-target organisms exposed to the constituents or active ingredients in pesticides may suffer acute or chronic effects. For example, recent studies carried out the

RWQCB Region 8 have identified detrimental effects from the pesticides diazanon and chlorpyrofos within the San Diego Creek / Newport Bay system. Work is currently underway to establish TMDLs for these and other toxics in that watershed (RWQCB Region 8, 2000). In addition, the CTR of April 2000 sets forth numeric aquatic and human life criteria for several pesticide constituents listed by the EPA as priority toxic pollutants.

The chemical and physical properties of most available pesticides can be found in the Farm Chemicals Handbook (Meister Publishing, 2000). Important characteristics that determine their environmental fate include 1) solubility in water, 2) persistence in soil, and 3) ability to adsorb to soils. Soluble constituents are likely to leach into the groundwater or be transported in runoff. Depending on toxicity effects, those that resist degradation are more prone to impact water quality.

2.5.6 Pathogens

The term pathogen is used to refer to any pollutant capable of causing disease or illness. The most commonly examined of these agents include the coliform, cryptosporidium and giardia bacteria, with the primary interest being the prevention of contamination of drinking water supplies. However, there has been growing attention to the fate and transport of pathogens in the natural environment, both as indicators of other potential pollution problems (e.g. sanitary sewer leaks, overflows or cross-connections) and for the potential health problems associated with contact water sports.

The South East Regional Reclamation Authority (SERRA) is responsible for regional wastewater treatment facilities and has carried out sampling for fecal coliform near the mouth of San Juan Creek (KEA, 1998). This monitoring program has shown numerous exceedances of the Orange County Health Care Agency threshold of 200 organisms/100 ml. On this basis, California RWQCB Region 9 has determined that the lower 1.5 miles of San Juan Creek are impaired due to coliform levels.

2.5.7 Oil and grease

This group consists mainly of hydrocarbons from petroleum origin and has a highly complex chemical composition. The primary source of oil and grease is vehicles, however, some sediments also release hydrocarbons. Because of their diverse nature, their behavior in the environment varies widely. Most will eventually break down through natural bioremediation, and a majority float on water.

3. WATERSHED-SCALE PERSPECTIVE

3.1 Factors Affecting Water Quality and Pollutant Mobility

Pollutant pathways and cycles within settings as diverse as the San Juan and San Mateo Creek watersheds can be complex. The previous section cited some of the more important constituents of concern with reference to typical sources in both natural and altered stream systems. Many pollutants are assimilated within the watershed through processes such as biological uptake, chemical transformation and loss to sinks such as deep sediments or even the atmosphere.

Although the biogeochemical relationships that govern the fate of different constituents can be complicated, it is important to note that a number of generalizations are possible regarding the effect of the environmental setting on water quality. These important generalizations, if applied in the proper context, can provide a framework within which to understand monitoring data, develop strategies for water quality management and assess the success (or lack thereof) of facilities, programs and policies.

A key point of departure in generalizations regarding pollutants in these watersheds is the concept of terrains. From a water-quality perspective, one can identify four general terrain types: silty, sandy, clayey and crystalline.

- Sandy terrains. Sandy terrains generally heavily favor infiltration of rainfall and therefore have the potential to direct pollutants mobilized in low to moderate rainfall events into subterranean pathways, with little or no actual biogeochemical cycling taking place in surface waters. Sequestered in sands, pollutants have the opportunity to degrade and attenuate via contact with soils and plants in the root /vadose zones before passage to groundwater or mobilization and transport to surface waters during larger storm events. There may be a higher risk to groundwater quality in sandy terrains; however, the process of movement through the sands is often sufficient to degrade most pollutants.

- Silty terrains. Silty terrains are characterized by higher runoff rates and tend to favor surface water pathways more than sandy terrains (but less than clayey terrains). This can be especially important when one considers the high erosion potential of many of the silty substrates in the SAMP area. During all types of rainfall events, silty substrates can be a significant source of turbidity and supply many of the fine sediments that have documented deleterious impacts on specific watershed functions (e.g. spawning gravels). On the other hand, the finer sediments derived from the silty substrates promote the transport of metals and certain pesticides in particulate form. This makes them less-readily available in first and second-order stream reaches, but potentially allows transport and subsequent deposition over long distances.

- Clayey terrains. In contrast, clayey terrains should be characterized by very high rates of surface runoff during low and moderate events, with only a minor role for groundwater processes. Although clay soils are generally quite resistant to erosion, they can be very significant sources of turbidity during extreme rainfall events when erosion occurs and/or headcutting or incision within the streambed begins.

- Crystalline terrains. Crystalline terrains are common only in the uppermost reaches of the San Juan and San Mateo Creek systems where development is absent. Similar to clayey terrains and in contrast to sandy terrains, it is reasonable to expect that, during low to moderate rainfall events, primary pollutant pathways will be in surface water flow, leading to the potential for rapid mobilization and transport of constituents. Unlike clayey terrains, however, the crystalline substrates may be relatively poor in the finer particles that cause turbidity. Like all terrain types, extreme events will likely result in the mobilization and transport of all sizes of sediments from these areas.

Another important water quality consideration is the geology of specific sub-watersheds. Geology naturally plays a critical role in setting the geomorphic context of each stream system, but can also have a direct impact on specific constituent concentrations. A potentially significant example of this is the occurrence of Monterey shale bedrock in several of the San Juan Creek sub-basins. Elsewhere in the state this formation is a known source of high levels of phosphate (Dickert, 1966) and certain metals such as cadmium (Majmundar, 1980).

3.2 Water Quality in the San Juan Creek Watershed

Relative to specific sub-basins in the area, there is actually a considerable amount of reliable water quality monitoring data for the San Juan watershed and especially for the main stem of San Juan Creek. The project team has located a number of records reaching back to the 1950's. Additionally, the Stormwater Section of the Orange County PFRD has carried out a comprehensive monitoring program with data readily available for the entire decade of the 1990's. The following sub-sections discuss the most important aspects of these data sets with regard to two of the most closely watched constituents of concern: nutrients and metals. Issues related to sediment sources will be covered in a future technical report.

3.2.1 Recent monitoring data from San Juan Creek watershed

Appendix A includes tabular summaries of the water quality monitoring that has been carried out by the Orange County PFRD in the 1990's on San Juan Creek. The most extensive data set is that for the main stem of the creek at the La Novia Street bridge in San Juan Capistrano. A smaller data set, but very important for comparison purposes, has been collected at Caspers Regional Park, approximately 10 miles upstream from the La Novia site. In contrast to the mixed land use (grazing, urban, nurseries and mining) that drains to the La Novia Street bridge sampling station, the drainage to the Caspers Park station is characterized predominately by protected open space. The water quality data collected at these two monitoring points includes a good cross-section of important parameters with an emphasis on nutrients and metals.

Monitoring activities at the La Novia site have been generally consistent since early 1992, with the notable exceptions of the winters of 1995 and 1998 when no data was collected. This record is particularly interesting for the relatively large number of dry weather samples that were taken. Reliable measurements from dry weather periods typically allow for increased insight into the sources and transport of constituents of concern. As mentioned, the Caspers data set is less extensive, covering the period from mid-1993 to the present. Similar to the La Novia sampling, more measurements were taken during WY 1994 and there is a relatively large number of dry weather samples. A significant limitation is that concurrent discharge measurements were not taken at the time of sampling for either the La Novia or Caspers data sets. This is not quite as serious a limitation for the La Novia data, since the USGS operates a gage that is representative of flow at the sampling location. Interpretation of the Caspers data is made particularly difficult by the lack of any representative discharge information covering the times of sampling.

Appendix C tabulates recent monitoring data from Oso Creek and Arroyo Trabuco, both right bank tributaries of the San Juan Creek system that enter below the La Novia sampling site. This data was collected by the Orange County PFRD and measures the same constituents of concern that were sampled in the La Novia and Caspers data sets.

Of these two data sets, that for Oso Creek is the more extensive, with consistent coverage back to WY 1992. On the other hand, sampling on Arroyo Trabuco was concentrated in WY 1994, with only a few additional samples being collected in 1996 and 1999. Our review of the monitoring data focuses on the Oso Creek data due to the more extensive coverage and the fact that, as an urbanized sub-watershed, it provides a suitable contrast in land use to the existing conditions on the main stem of San Juan Creek.

Appendix D summarizes historical data collected on Oso Creek and Arroyo Trabuco, with similar data sources to those used in Appendix B. Again, the primary focus of historical studies was on the suitability of the streams for domestic water supply purposes.

Appendix E summarizes historical monitoring data for bacterial contaminants near the mouth of San Juan Creek. This data was collected by the South East Regional Reclamation Authority for the period from 1982 to the present.

3.2.2 Historical monitoring data from San Juan Creek

Appendix B summarizes monitoring data collected on the main stem of San Juan Creek dating back to the early 1950's. This data was assembled from a number of studies carried out by agencies other than the Orange County PFRD.

These data have been included for general comparison purposes, and because they appear in studies that are out of print or may otherwise be lost. The data from the 1950's was collected for studies that were analyzing the domestic water supply potential of San Juan Creek. Therefore, there was a concentration on the ions of most concern from a drinking water perspective with a notable lack of data for phosphate and heavy metals.

3.2.3 Discussion of the San Juan Creek monitoring data

3.2.3.1 Nutrients in the San Juan Creek main stem

The data for the key nutrients (nitrate, ammonia and phosphate) monitored by the Orange County PFRD are summarized in Tables 3 through 5. These tables include statistical summaries for the measured concentrations of these nutrients as a function of the 3-day antecedent rainfall measured at the Tustin rain gage.[1] It is important to note that the measured nutrient concentrations, especially during dry periods, was at or below the detection limit for one of more of these constituents. In the interest of conserving the already small sample size, these data points were not removed from the set. Instead, the detection limit values were used in the statistical summaries. This method of dealing with below detection limit values was chosen with the intent that conservative estimates of low level concentrations will be made. However, any conclusions about absolute nutrient concentrations at low levels should be considered tentative. The disaggregation of the data was carried out in an effort to identify patterns of nutrient mobility as a function of rainfall, which is generally considered the primary mobilizing event within any watershed.

Several observations can be made on the basis of this data, as well as the historical data included in Appendix B:

- Nitrogen loading between Caspers and La Novia. Chronological representations of the nitrate monitoring data at these two monitoring stations are illustrated in Figures 1 and 2. The data indicate that there are one or more significant sources of nitrogen loading between the Caspers and La Novia monitoring stations. This is particularly evident for samples collected with measurable 3-day antecedent rainfall. It is impossible to ascertain the sources of the additional loading, but it may include factors such as the location of several nursery operations downstream of the Caspers site, development on San Juan tributaries (e.g. Coto de Caza on Cañada Gobernadora) and the large amount of grassland in the sub-basins below Caspers.[2] Again, the lack of discharge measurements concurrent with the

[1] Rainfall data from the Tustin gage was chosen due to the completeness of the data and the relative proximity of the gage to the watershed. The gage is operated by the Orange County PFRD and is located approximately 15 miles to the northwest of the water quality stations on San Juan and Oso Creeks. Additionally, the gage is located at an elevation (and thus mean annual rainfall) similar to the monitored watersheds. It is reasonable to assume that storm patterns and relative intensities observed at Tustin will be generally representative of conditions within the San Juan, Arroyo Trabuco, and Oso Creek sub-watersheds. Additional insight could be gained with precipitation data, and especially stream discharge data, collected within these basins.

[2] Grasslands have been shown to contribute relatively high loadings of nitrogen in studies carried out in several locations. One obvious potential contributing factor is the fact that grasslands are ideal for livestock grazing with the

Caspers sampling makes it very difficult to estimate the actual loading (in pounds/acre or pounds/year). Nonetheless, median nitrate concentrations are several times higher at La Novia for a wide range of antecedent rainfall conditions. This trend is not seen in ammonia concentrations, but this could simply be due to the rapid assimilation of ammonia in these waters. There is insufficient reliable data to determine whether a similar situation exists with regard to phosphate loadings between the two sites.

- Nitrate mobility with rainfall. Figure 3 illustrates the relationship between measured nitrate concentrations at La Novia and 3-day antecedent rainfall. There are indications that nitrate is introduced into the lower San Juan Creek system by a mechanism that generally increases proportionally with precipitation up to 1.50 inches of 3-day rainfall. Statistical analysis of nitrate data collected on days with less than 1.50 inches of 3-day rainfall has an r-squared value of 0.42. For the La Novia data this relationship can be further examined by plotting the sampled nitrate concentrations as a function of mean daily discharge as measured at the USGS gage (see Figure 4). The latter figure gives a better indication of the relative saturation of the watershed at the time of sampling. The data are consistent with N mobilization either through direct transport by surface storm water runoff or by the displacement of nitrate rich groundwater into the stream system. The close grouping of measured nitrate values (roughly 0.4 mg/L NO_3 as N) found at higher discharge values partially reflect the fact that most of these samples were taken in a single month (February 1993). Nonetheless, it is reasonable to assume that this cluster of points represents the baseline nitrate loading associated with rainfall, since most rainfall would be running off under these saturated watershed conditions and nitrate assimilation by the biota would be relatively insignificant.[3]

- Phosphate mobility. Figures 5 and 6 display a chronological record of the monitoring results for phosphate at Caspers and La Novia respectively. The monitoring results for phosphate at La Novia indicate that there is a modest tendency to higher phosphate levels with increases in both 3-day antecedent rainfall and discharge. This trend has an r-squared value of 0.28 for data collected at 0 to 1.50 inches of 3-day antecedent rainfall at Tustin. These relationships are presented graphically in Figure 7 and 8. This possible relationship between phosphate and rainfall/discharge is consistent with erosion being the primary contributor of phosphorus loading. Unfortunately, not enough samples were collected at Caspers to ascertain whether this observation applies to the watershed as a whole or only to that portion below Bell Canyon.

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associated potential for N mobilization from animal wastes. Additionally, grassland soils are typically roughly four to five percent nitrogen by weight, and this N is available to rainfall passing over or through these soils.

[3] A background nitrate concentration of 0.4 mg/L in rainfall would be consistent with studies in other locations in the nation. For example, Betson (1978) measured a nitrate plus nitrite concentration of 0.47 mg/L in rainfall at Knoxville, Tennessee.

- One note is in order with regard to the phosphate data collected. It appears that the detection limits for phosphate have only recently been reduced to 0.06 mg/L as PO_4. This is a very important improvement in the resolution of the phosphate monitoring since target TMDL concentrations in nearby watersheds have often been set at 0.1 mg/L of phosphorus as P. Therefore, sampling data from before WY 1998 will be of little use in ascertaining what an appropriate background loading is within the San Juan Creek watershed.

- The role of channel incision. It is possible that channel incision can be a contributing factor to both nitrogen and phosphorus loading in the San Juan system. The link between channel incision and phosphorus loading is relatively straightforward, erosion of channel and floodplain terrace material can release significant quantities of stored phosphates. The link to nitrogen loading may be less readily apparent and centers around the potential for changes to groundwater inflows to stream reaches as the channel bed degrades. Deeper groundwater, and especially that flowing along the bedrock interface at the bottom of an alluvial deposit, is often enriched in nitrate. As a stream cuts downward, it dewaters adjacent aquifers from a progressively greater depth. This can lead to relatively large increases in the nitrogen loading in the surface stream waters under baseflow conditions, loading that previously may have completely bypassed long channel reaches in a subterranean pathway.

3.2.3.2 Nutrients in the Oso Creek sub-watershed

As mentioned previously, discussion will focus on the more extensive data set collected by the Orange County PRFD in Oso Creek during the 1990's. These monitoring results present a markedly different picture of nutrient levels and transport than that on the main stem of San Juan Creek. Although the data for the two stream systems have somewhat different biases (e.g. the San Juan sampling includes many more dry weather samples), there are several preliminary conclusions that can be put forth.

- Nitrate concentrations in Oso Creek. Figure 9 illustrates the chronological trend in nitrate sampling. The data in this figure and in Table 3 indicate that overall nitrate concentrations in Oso Creek are higher than those in San Juan at either Caspers or La Novia. This is particularly true for those samples taken with very little or no 3-day antecedent rainfall. Again, it is unfortunate that more samples were not collected under dry conditions to allow an assessment of how persistent the higher nitrate levels actually are.

- Ammonia concentrations in Oso Creek. Perhaps the most apparent difference in the monitoring results for the two stream systems is that for ammonia. Ammonia concentrations were markedly higher, sometimes by an order of magnitude, in Oso

Creek under all antecedent rainfall conditions (see Table 4). However, as was previously discussed, ammonia is rapidly assimilated or converted in most stream systems. Therefore, much of the observed differences between the Oso and San Juan Creek numbers could be explained by a storm water outfall particularly close to the Oso sampling site.

- Nitrogen transport. Regardless of the other mechanisms at work, it is reasonable to surmise that there is a fundamentally different mobilization mechanism for nitrogen in the Oso Creek watershed, at least at the sampling locations used by the Orange County PFRD. Nitrate concentrations as a function of 3-day antecedent rainfall are illustrated in Figure 10. In contrast to the situation on San Juan Creek, there is no apparent relationship between rainfall and nitrate concentrations. This is consistent with nitrate sources that are either more persistent at low flows or are more easily mobilized. Examples of such circumstances would include so-called "nuisance flows" entering the stream system or wash-off of nitrates from impervious surfaces. The former would be consistent with the observed establishment of perennial flow in the Oso Creek system (KEA, 1998), which would logically be due in large part to nuisance flows. Another possible explanation is the much higher average clay content of the soils in the Oso watershed that likely lead to more rapid, and larger, runoff rates. Table 7 shows that 82 percent of the watershed is underlain by clay soils (or was so prior to urbanization).

- Phosphate concentrations. Another marked difference between the Oso and San Juan data is the tendency to higher phosphate concentrations in the former (see Table 5 and Figure 11). The behavior in this regard is very similar to the inter-stream comparison of nitrate levels. Phosphate levels in Oso Creek are much higher with little or no antecedent rain, with the difference between the levels in the two streams decreasing with increasing rainfall. Again, conclusions in this regard must remain tentative given the emphasis on storm sampling for the Oso monitoring program. However, it does appear that phosphate is more abundant at lower flow conditions and/or is more easily mobilized in the Oso Creek watershed. This may be due, at least in part, to the presence of significant amounts of Monterey Shale within the Oso Creek system. For example, Table 8 indicates that roughly 12 percent of the watershed is underlain by Monterey Shale, far higher than any other sub-watershed in the SAMP study area. Phosphorus loading could also be increased due to wildlife use of the ponds within the Oso sub-watershed, especially by birds. Conversely, phosphorus loading at higher rainfall levels may be reduced due to reductions in erosion that potentially could accompany the widespread urbanization in the sub-watershed.

- Landscape-scale considerations. The data collected to date by the Orange County PFRD is very consistent with the type of landscape-scale assessment presented in Smith (2000). That methodology correctly identifies the Oso Creek sub-watershed as being the most likely area to currently exhibit degraded water quality. This follows naturally from the fact that the Oso Creek system has seen roughly 82 percent of its land area converted to urban uses (see Table 9) and that Smith's methodology directly correlates land use to water quality. However, it is reasonable to assume that very little application of best management practices (BMPs) was made during the urbanization of the Oso sub-watershed. Urban development occurred here in the early 1970s before implementation of the Basin Plan in 1994. In this sense, it is not at all clear whether the Oso Creek data are representative of the magnitude of impacts from nutrients that can be expected to accompany future development that does incorporate state-of-the-art BMPs.

3.2.3.3 *Metals in the San Juan Creek main stem*

Monitoring carried out by the Orange County PFRD in the 1990's in San Juan Creek included analysis of several metals: cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), silver (Ag) and zinc (Zn). The results are reported in Appendix A. It is important to note that the analyses were primarily conducted on unfiltered samples, meaning that the reported values represent the total metal concentration that includes both the dissolved and particulate fractions. As discussed above in Section 2.4.4., in waters with typical pH levels of 7 to 8, as found in San Juan Creek, metals are most likely to be found in their particulate phase. Therefore one can assume that the more bioavailable dissolved fraction will have a much lower concentration. Another limitation to this data set, in contrast to the nutrient monitoring, is that very few water samples collected during dry weather periods or summer months were analyzed for metal concentrations. However, because metals are typically found in their particulate form and are therefore transported in the same manner as sediments, it is unlikely that significant metal transport will occur during the dry season, as the majority of sediment transport occurs during storm events.

An initial examination of the San Juan Creek monitoring data shows that, with the notable exception of zinc, most metals are found in concentrations below the detection limit. Where measured concentrations of other metals do occur, it is typically during storm events and they appear to be loosely correlated with zinc concentrations. Therefore, this discussion will focus on zinc. It should be noted that zinc is the most soluble metal in the suite of metals analyzed. The other less soluble metals may behave differently in the specific climate, geologic and environmental conditions of the various San Juan sub-basins.

The zinc data is summarized in Table 6. Similar to the nutrients tables, Table 6 represents statistical summaries of zinc concentrations as a function of the 3-day antecedent rainfall measured at the Tustin rain gage. Detection limit values were also included in the statistical summaries.

Several observations can be made on the basis of this data:

- Zinc loading between Caspers and La Novia. The data do not indicate a significant difference in zinc concentrations between the Caspers and La Novia monitoring stations. This suggests that equivalent zinc sources are found both upstream and downstream of the Caspers site. Such sources likely include galvanized metal products (e.g., steel culverts), automobile tire wear, roof drainage, and natural mineral weathering. As with the nutrient analysis, comparison of actual zinc loadings estimates are difficult to make due to the lack of discharge measurements collected at Caspers.

- Zinc mobility with rainfall. Table 6 and Figures 14 and 15 illustrate the relationship between measured zinc concentrations and 3-day antecedent rainfall at both the Caspers and La Novia monitoring stations respectively. These figures suggest that zinc concentrations increase with increasing rainfall until approximately one inch of 3-day cumulative antecedent rainfall is reached, at which point zinc concentrations begin to decrease. This response is further illustrated in Figure 16, which shows the relationship between measured zinc concentrations and daily flow measured at La Novia. The highest levels of zinc occur at flows between 10 and 100 cfs. This pattern can be explained by a background loading of zinc, as seen at low flows. As discharge increases, sediments are mobilized and transported downstream with the associated particulate metals. At the highest flows, zinc concentrations decrease as a result of dilution from rainwater and removal of contaminated sediments from the system.

- Zinc concentrations. Total zinc concentrations in water samples collected from San Juan Creek range from below the detection limit to 420 μg/L (measured at Caspers Regional Park on 11/15/93). The latter value may be indicative of high background zinc levels within this watershed. While no specific standards have been established in the San Diego Region (RWQCB, 1994), the CTR criteria for zinc is 120 μg/L (both maximum and continuous). As stated previously, we would expect dissolved zinc concentrations to be much lower than the total concentrations reported in the data set.

3.2.3.4 *Metals in the Oso Creek sub-watershed*

The Orange County PRFD has an extensive data set of monitoring activities conducted in Oso Creek in the 1990's (Appendix C). In contrast to the San Juan Creek data, water samples collected from Oso Creek in the winter of 1999 were analyzed both before and after filtration. The filtered samples represent the dissolved fraction of zinc in the water, the most bioavailable form. As expected, the filtered fraction of the metal concentration is almost always lower than that found in the unfiltered sample, which contains the particulate phase. This implies that stormwater treatment methods designed to remove sediments will have a significant impact on metal concentrations in the stream.

The data indicate that, while transport and mobility processes appear to be similar to those in San Juan Creek (Figure 17), overall zinc concentrations are much higher in Oso Creek (Table 6). This would suggest that similar types of zinc sources (galvanized metal products, tire wear and roof runoff as well as natural mineral weathering) are found in the Oso Creek watershed. Once again, assuming that few BMPs have been applied in the Oso Creek watershed, it is not clear whether the Oso Creek data are representative of the impacts that can be expected to accompany future development in the San Juan Creek watershed.

3.2.3.5 *Total dissolved solids as an indicator of water quality*

Total dissolved solids (TDS) is a measurement of all constituents dissolved in water. The main constituents are: calcium, magnesium, potassium, sodium, sulfate, bicarbonate, chloride, and silica. Sources of these constituents include natural weathering of bedrock and soils as well as anthropogenic contributions such as fossil fuel emissions, landfill leachate and sewage treatment discharge. While not necessarily indicative of "healthier" watershed systems, low TDS concentrations are associated with higher quality water. Therefore, we can use TDS as a general indicator of water quality and as a means of comparison between sub-basins in the San Juan Creek watershed. Because TDS concentrations decrease at higher flows, some information on flow conditions is necessary for interpreting TDS values.

Total dissolved solids data collected in the 1960s was used in a 1972 report that assessed various tributaries of San Juan Creek for their potential for domestic use (Livermore et al, 1972). The following TDS values were reported in this publication. It is important to note that these data were collected before most of urbanization in the watershed occurred. Reported values likely reflect the natural mineral composition of the watersheds influenced by irrigation return flows and other agricultural impacts.

- Upper San Juan Creek below the confluence of Lion, Hot Spring and Lucas canyons: 228 mg/L TDS at winter flows.
- Thermal and cold springs: 500 mg/L.
- San Juan Creek below Bell Canyon, Canada Gobernadora and Canada Chiquita: 500 mg/L during storm runoff.
- Bell Canyon: 500 mg/L (flow information not reported).
- Canada Gobernadora: 452 to 1807 mg/L for winter flows.
- Canada Chiquita: 598 to 1152 mg/L for winter flows.
- San Juan Creek at Ortega Highway: 121 mg/L for high flows to 611 mg/L for low flows.
- Horno Creek: 1327 mg/L (flow information not reported).
- Lower San Juan Creek below the confluence of Arroyo Trabuco at Camino Capistrano: 440 mg/L (flow information not reported).
- Lower San Juan Creek one half mile inland from the Pacific Ocean: 1241 mg/L (flow information not reported).
- Remmer tile drains that discharge water to lower San Juan Creek: 2699 mg/L (flow information not reported).
- Arroyo Trabuco above confluence with Oso and San Juan Creeks: 398 mg/L (flow information not reported).

- Arroyo Trabuco above Holy Jim Creek: 200 mg/L (flow information not reported).

- Arroyo Trabuco below confluence with Oso Creek: 294 to 3940 mg/L winter and spring flows.

- Oso Creek influenced by its bedrock materials and irrigation drainage: 334 mg/L for high flows to 12,880 mg/L for very low flows.

The data set suggests that TDS concentrations in San Juan Creek increase from 200 mg/L at its upper reaches to over 1,000 mg/L in the lower reach. This 500 percent increase in TDS is likely primarily the result of: 1) inputs from tributaries and their under flow, especially basins (such as Cañada Chiquita and Oso Creek) that drain sedimentary substrates such as Monterey shale, 2) irrigation return flows in Oso Creek, Canada Chiquita and Canada Gobernadora, and 3) evaporative processes that occur throughout the length of San Juan Creek.

3.2.3.6 *Suspended sediment as an indicator of water quality*

The erosion, transport and deposition of sediments in the San Juan Creek watershed are natural processes that are influenced by both land use and terrain type. The quantity and size of sediment that passes through or is deposited in a system has important impacts on water quality and aquatic habitat concerns. It might be noted that no local data have been collected for bedload sediment, an important influence on channel stability and habitat quality.

3.2.3.7 *Bacteria monitoring results for San Juan Creek*

Appendix E summarizes the results of bacteria monitoring in the waters near the mouth of San Juan Creek carried out by the South East Regional Reclamation Agency (SERRA). These data point to persistently high counts of total and fecal coliform, as well as enterococcus. Additionally, the data indicate that high bacterial concentrations are frequently detected upstream of the treatment plant and that measured values shift widely even during extended dry periods.

Overall, there are numerous periods over the last several years of the monitoring data where the RWQCB water quality objective for contact recreation of 200/ml (log mean over 30-day period) is not met. The objective of less than 10 percent of samples testing above 400/ml in a 30-day period is even more rarely attained. However, the water quality objective for non-contact recreation of 2000/ml is generally attained at the upstream monitoring site. For calendar year 2000 the log mean fecal coliform concentration at Del Obispo Park in San Juan Capistrano was roughly 300/ml. The U.S. EPA guidelines for enterococci that are cited in the Basin Plan (151/ml for infrequently used freshwater areas) was met on only roughly one-third of the samples taken over recent years at the upstream Del Obispo Park monitoring site. The log mean enterococci concentration for calendar year 2000 was approximately 540/ml.

As mentioned previously, both the lower reaches and mouth of San Juan Creek are on the 303(d) list of impaired water bodies due to high coliform counts. The State NPS Program Plan anticipates completion of TMDLs for coliform contamination in these two areas by July 2010.

It is important to note that both of the SERRA monitoring sites are located at essentially the most downstream reaches of San Juan Creek, within and below extensive urbanized areas. Unfortunately, the ultimate sources and fates of these bacterial contaminants cannot be ascertained with existing data. The impacts of bacterial contamination on important resources (such as aquatic and beach recreation) is leading to expanded monitoring throughout southern California and much additional information will likely come forth in upcoming years.

3.3 Water Quality in the San Mateo Creek Watershed

A portion of the SAMP study area lies within the San Mateo watershed. Four northern tributaries to San Mateo Creek are included in this area: Cristianitos Canyon, Gabino and Blind Canyons, La Paz Canyon, and Talega Canyon. These sub-watersheds are characterized in Section 4.2. We were able to compile a limited data set from various studies available (Lang and others, 1998), however, no samples were analyzed for metals, and the few (five) samples analyzed for nutrients were all collected on the same day (March 17, 1997) and there is no corresponding discharge measurement (Appendix D). Our analysis of baseline water quality conditions would be furthered if the study team can gain access to the monitoring data collected on the Marine Base Camp

Pendleton and any data collected by the TCA for the Foothill South planning and CEQA/NEPA review.

Additional and ongoing water quality monitoring is currently being conducted by Rivertech Inc. for Rancho Mission Viejo. The sampling plan, begun in early 2001, calls for a comprehensive analysis of both storm event and dry weather samples collected from nine locations within the SAMP study area, including two sites within the San Mateo Creek watershed (Cristianitos and Gabino Creeks). This data is supplemented by continuous monitoring of temperature, conductivity, dissolved oxygen, pH and flow at four stations (including Cristianitos Creek). Data already collected is not yet available for analysis. However, it will be an important resource for future updates to this report.

4. San Juan Creek Sub-Basins

4.1 San Juan Creek Sub-Basins

4.1.1 Lucas Canyon

Table 8 indicates that the Lucas Canyon sub-basin is characterized by a very high proportion of sandy soils. Roughly 49 percent of the soils classified as sandy or alluvial, this is the by far the sandiest of the sub-watersheds examined in detail. The underlying bedrock is a contrast, with most of the watershed underlain by the highly-indurated Trabuco formation and Santiago Peak volcanics, both amongst the crystalline substrates with the lowest permeabilities. Another important characteristic of this sub-basin is the limited extent of riparian vegetation, comprising roughly five percent. Land cover is predominately chaparral and sage scrub, which together comprise approximately 88 percent of the area. The Wheeler Ranch subdivision, with perhaps 50 rural residential units served by septic systems, is largely in the headwaters of San Lucas Creek, with perhaps half of the units draining to its Aliso Creek tributary. Quarrying occurs both in bedrock north of the stream and in its alluvium.

Based on these considerations, overall rates of runoff would be expected to be relatively low, with the watershed capable of infiltrating much, if not all, of typical small to moderate sized rainfall events. Pollutant mobility can be expected to be relatively high into groundwater, with less of annual constituent loading leaving the sub-basin in surface flows. The background phosphorus loading can be expected to be quite high during events that generate significant runoff. On the other hand, background nitrate values are likely quite low given the restricted amount of agricultural uses and grasslands (only five percent of the land area). Heavy metal partitioning can be expected to favor the more readily available dissolved forms. Low levels of domestic and possibly industrial contaminants related to the ongoing land uses may also affect this watershed, on occasion.

4.1.2 Verdugo Canyon

The Verdugo Canyon sub-basin is another left bank tributary to San Juan Creek located to the southeast of Lucas Canyon. Several of the characteristics of this sub-basin contrast with Lucas Canyon. One of the primary differences lies in the soils, 50 percent of which are classified as silty and 49 percent of which are classified as highly erodible silty substrates. This clearly places the Verdugo sub-basin within the band of silty terrains that sweep through the center of the SAMP study area. Sage scrub and chaparral dominate the land cover (roughly 88 percent of the area is in these two types), but there is markedly more sage scrub in the Verdugo sub-basin than in Lucas Canyon. Another distinguishing feature of the Verdugo sub-basin is a more intact riparian corridor than that found in Lucas Canyon. Portions of the Wheeler Ranch subdivision drain into the northern fork of Verdugo Canyon.

Verdugo Canyon is probably characterized by a definite tendency to infiltration rather than surface water runoff. Our field observations of peak flows in 1998 and 2000 suggest that the watershed produces flood peaks that are lower than the mean for the San Juan watershed for all but the largest storms. However, nutrient and pollutant pathways to surface waters are likely quite direct due to the terrains and steep topography. The existence of an intact riparian corridor implies that there is potential for sequestration of constituents of concern within floodplain terraces, with increased amounts of organic carbon available to augment nitrogen cycling. Unfortunately, there are no monitoring data to ascertain whether the riparian corridor is large enough to play a major role as a sink for constituents released/mobilized in upland areas. Nonetheless, the Verdugo sub-basin can be expected to be a relatively significant source of phosphorus loading to the San Juan, especially given the large quantities of highly erodible soils. Nitrogen loading from the sub-basin is expected to be low given that only six percent of the watershed is covered with grasslands. Speciation is expected to favor the transport of metals and pesticides (were any to be present) in an adsorbed form.

4.1.3 Bell Canyon

Bell Canyon has several distinguishing features that make it somewhat difficult to predict the fate and transport of potential pollutants. On one hand, this sub-basin is characterized by a very high percentage of sandy soils, covering 41 percent of the total area. In this regard, Bell Canyon is more similar to Lucas Canyon than to the sub-basins lying in the silty band just to the southwest. However, large areas of these sandy substrates are relatively old, badlands-type soils that favor relatively rapid runoff of stormwater. This would imply ready mobilization of constituents in surface water pathways. Nonetheless, any tendency toward high pollutant mobility in this regard is balanced by the fact that Bell Canyon has a riparian corridor that covers fully 14 percent of the sub-basin area. This corridor has active floodplains with adequate sources of organic carbon to facilitate the cycling of nutrients and ample space for depositional processes. Additionally, the riparian corridor implies an accessible alluvial aquifer system that would encourage both aerobic and anaerobic cycling processes.

Existing water quality may be impacted by the Dove Canyon development near the head of the watershed. The sub-basin likely is a moderate source of both nitrogen and phosphorus, with the tendency to produce high loadings mitigated by natural assimilation processes on and under the floodplains. It is reasonable to expect a balanced partitioning of metals and pesticides between the dissolved and adsorbed forms.

4.1.4 Trampas Canyon

Trampas Canyon lies within the band of sub-basins underlain by large areas of highly erodible silty soils. In fact, roughly 44 percent of the area is covered by silty soils with the remainder equally divided between sands and clays. Most of the watershed is underlain by the relatively pervious lower Santiago sandstone, which lends the sub-basin a sandier hydrologic response than the soils would imply. The sands are notable since they support an active glass sand mining operation. The land cover includes a rather large percentage of grasslands (21 percent) that can serve as a significant source of nitrogen loading. There is a relatively small amount of riparian corridor in Trampas Canyon itself and the channel network has been actively incising for at least 60 years.

With adequate antecedent rainfall, the nature of the soils favors the relatively rapid mobilization of constituents into surface water flows. This, coupled with incision reducing access to floodplain surfaces, tends to favor the ready transport of pollutants out of this sub-basin and into the main stem of the San Juan. This sub-basin can be expected to generate relatively large nitrogen and phosphorus loadings for its size and may be a contributor to the increases in nutrient concentrations between Caspers Regional Park and La Novia that is evident in the Orange County PFRD monitoring program. High loads of fine sediment and particulates should favor the adsorbed phases of heavy metals and pesticides.

4.1.5 Cañada Gobernadora

This north bank tributary is very similar to Trampas Canyon in the nature and erosion potential of the underlying soils, with roughly 45 percent of the sub-basin underlain by silty substrates. Cañada Gobernadora is currently the uppermost sub-basin with large areas of development (e.g. Coto de Caza) that cover roughly one-quarter of the land area. There are also relatively large expanses of grasslands. Wagon Wheel Canyon, for example, is approximately 38 percent grassland. Field surveys indicate that the reaches of Cañada Gobernadora immediately below Coto de Caza are experiencing significant aggradation, dominated by active deposition of sands. The lower reaches of the sub-basin are experiencing active downcutting that is severely constraining channel-floodplain connectivity for much of the lowermost mile of channel.

Pollutant transport within the Cañada Gobernadora sub-basin is likely quite complicated with different pathways dominating by location and even season. Much of the watershed lands in the middle and lower reaches are underlain by the permeable Santiago sandstone. Therefore, early in the winter it is reasonable to assume that most rainfall infiltrates, and that groundwater pathways are predominant. The presence of sandy apron deposits at the mouth of side canyons can locally encourage infiltration. Where the channel is aggrading, there is a greater connectivity with the floodplain and more possibilities for the riparian corridor to play a role in assimilating constituents of concern. Large area of valley flats within a two or three feet of the channel bed, including some that have been deliberately converted to mitigation wetlands in recent years, abet cycling and connectivity. However, surface water pathways likely predominate in the lower reaches due to incision that has led to a loss of channel-floodplain connectivity and the presence of heavy clays that bring groundwater to the surface. This sub-basin is probably a very significant source of both nitrogen and phosphorus loadings, from grasslands/agriculture, urbanization in the upper reaches with minimal use of BMPs and the presence of large nursery operations. Conditions favor the transport of metals and pesticides in particulate form.

The upstream half of the basin is the setting of the large Coto de Caza residential project, which has been gradually expanding since the early 1980's. Coto and related projects in this watershed may well be contributing to the increases in nutrients and zinc observed between the Caspers and La Novia water-quality stations. Occasional elevated readings of specific conductance (or salinity) appear to originate in the headwaters of Gobernadora Canyon, and may be related to the older sedimentary rocks which outcrop in that portion of the basin, although other sources cannot be ruled out (see Appendix A of the concurrent groundwater report).

4.1.6 Cañada Chiquita

Cañada Chiquita differs from the above sub-basins in that it has a much higher portion of the clay terrain that runs across the southwest portion of the SAMP study area, particularly along in the western tributary canyons. Large portions of the sub-basin are in grassland/agriculture, with a relatively wide flood plain and a narrow riparian corridor covering only three percent of the land area. Additionally, field surveys indicate moderate and discontinuous channel incision. Additionally, roughly eight percent of this sub-basin is underlain by Monterey shale bedrock. This formation has been shown to produce high amounts of both phosphates and cadmium (Majmundar, 1980), and can add salinity to both surface and groundwaters.

Infiltration likely plays a significant role in the sandier substrates and, analogous to Cañada Gobernadora , wherever tributary canyons cross coarser apron deposits along the edges of the floodplain. As with Trampas and Gobernadora Canyons, much of the watershed is underlain by pervious sandstones and has a sandier hydrologic response than might be expected from its soils. Nitrogen and phosphorus loadings from this sub-basin are likely quite high with limited capacity for assimilation within the watershed itself. This may be especially true for phosphorus loadings given the presence of the Monterey formation and evidence of channel incision. Both metals and any pesticides would tend to move in particulate forms.

4.1.7 Southern San Juan Catchments

The Southern San Juan Catchments lie within the belt of silty substrate sub-basins and therefore are similar to Trampas Canyon in many regards. The only significant floodplain areas lie along San Juan Creek itself. Significant land area is in grassland/agriculture, and there are large nursery operations that may already have an impact on water quality. Portions of these watersheds are underlain by Monterey formation, which may contribute moderately-elevated levels of phosphorus, sulfate, and dissolved solids.

Overall, these catchments are likely characterized by relatively rapid rainfall runoff that favors surface water pathways for pollutant mobility. The exception is in the main stem of San Juan Creek where constituents may be sequestered, at least seasonally, in the alluvial aquifer. Land use considerations indicate that large quantities of nitrogen may be mobilized. Phosphorus loadings are also likely to be moderate when compared to other sub-basins where more active channel incision is taking place.

4.1.8 Narrow Canyon

In most respects, the Narrow Canyon sub-basin is the archetypical watershed with clay-rich soils and the presence of the Monterey formation. Additionally, this sub-basin may have already been affected by recent development activities that would make it difficult to separate the true baseline conditions. This canyon receives much of the runoff from the Antonio Parkway, and from a small portion of the Ladera community. Because contributions from roadways and parks are not dissimilar from the naturally-occurring constituents entering from the Monterey formation, care should be exercised in inferring origins of any elevated concentrations that may be observed in the future, especially for phosphorus, sulfate, cadmium and selected other trace metals (c.f., Majmundar, 1980).

Therefore, pollutant mobility in Narrow Canyon is likely to be dominated by surface water transport processes. Nitrogen, and particularly phosphorus, loadings are expected to be significant. Metal partitioning will favor particulate forms.

4.2 San Mateo Creek Sub-basins

4.2.1 La Paz Canyon

La Paz Canyon clearly lies within the band of silty substrate dominated sub-basins at the center of the SAMP study area. Fully 52 percent of the soils in the La Paz sub-basin are classified as silty and all of these are found on relatively high slopes that are prone to erosion. The land cover is almost entirely sage scrub and chaparral with only four percent of the area in grassland and an equal amount in riparian vegetation.

The steep topography and less permeable soils favor rapid runoff, and it is reasonable to assume that potential impacts to groundwater are minor. Existing nitrogen loadings should be relatively low. The lack of well-developed floodplain structure likely limits the ability of the sub-basin to store phosphates and fairly significant quantities are probably mobilized and transported to the main stem of the San Mateo. Background metal loadings are likely to be relatively low, with metal speciation favoring particulate forms.

4.2.2 Gabino Canyon

From a water-quality perspective Gabino Canyon both resembles and differs from La Paz Canyon in significant ways. The overall percentage of each sub-basin in silty substrates is quite similar, although Gabino Canyon has markedly more clay, much of which is found on steep slopes. Bedrock beneath Gabino Creek is mainly old tightly-consolidated sediments, which yield saltier baseflow than the crystalline bedrock underlying La Paz. Another notable difference is the much more wide-spread grassland cover, roughly 27 percent of total sub-basin area. Additionally, there is approximately twice the percentage of riparian vegetation in Gabino, indicative of a more extensive floodplain/riparian corridor. Much of the floodplain area lies in the upper reaches of the canyon, which is a lower gradient system than the middle reaches. The stream in this area is dominated by gravels and cobbles, but still has a wider floodplain than the lower reaches. In earlier times the stream probably migrated through this floodplain, but now is confined by headcutting and incision processes. In some reaches this incision is in excess of ten feet and appears to have intercepted subsurface flow.

In contrast the middle reaches of Gabino Canyon exhibit a steeper gradient and are dominated by oak or sycamore riparian communities. These riparian zones are narrower than in the upper reaches due to the physiography of the canyon. Incision is evident in several locations in the middle reaches.

Overall runoff rates are expected to be relatively high in this sub-basin with little potential for groundwater quality impairment from infiltration. The high proportion of grasslands is indicative of potentially high nitrogen loadings, but there is insufficient information to assess whether the existing riparian corridor is playing a role in assimilation of nitrates. Similarly, phosphate loadings should be generally moderate with the floodplain potentially playing a role in mitigating the transport of phosphate downstream to the San Mateo main stem. Baseline metal loadings should be relatively low under existing conditions with most metals transported in particulate form. The windmill at the mouth of Gabino yields water with specific conductance values of slightly over 2000 umhos/cm at 25 deg. C, equivalent to a TDS concentration of about 1200 to 1500 mg/L. This approaches the upper end of use by livestock, and is above the recommended upper limit of 1000 mg/L for public water supply. It is well below the concentrations of 3000 to 4000 mg/L typical of baseflows and seeps supporting halophytic ('salt-loving') endemic species.

4.2.3 Cristianitos Canyon

Cristianitos Canyon is located primarily within the belt of high-clay soils that trend across the southwest portion of the SAMP study area. In fact, with only nine percent of the sub-basin in sandy substrates, this is the least sandy of any of the sub-basins. The remaining soils are roughly equally divided between clays and silts, with high proportions in the most inherently erodible of these substrates. Another important distinguishing factor is that fully 41 percent of the sub-basin is covered in grasslands. Riparian cover is moderate in extent, covering roughly nine percent of the area.

These characteristics indicate that runoff is relatively high in Cristianitos Canyon. Pollutant transport and cycling likely occurs predominately within surface waters, but, much like Bell Canyon in the San Juan Creek watershed, there is not enough reliable monitoring data to ascertain to what degree the riparian corridor serves to sequester and process key constituents. The extent of grasslands in the sub-basin strongly suggests that nitrogen loading is currently high, while the high erosion potential indicates that the mobilization of phosphorus sources may be equally high. Metal loadings to the sub-basin are likely low at present and most metal transport can be expected in the particulate form.

Portions of the Cristianitos watershed west of the creek (and the Mission Viejo fault) are underlain by the Santiago sandstone and related formations. These rock units have permeable properties beneath the generally silty soils. Infiltration is higher in these western areas, and at least one large wetland is sustained by shallow ground water. Runoff from the western segment of the basin will have water-quality attributes similar to those of the Trampas basin, as described above.

4.2.4 Talega Canyon

Talega Canyon lies within the silt-rich set of sub-basins and from a substrate perspective is similar to La Paz Canyon in that silty soils constitute roughly half of the soils with remainder being divided equally between sands and clays. From a land cover perspective, the sub-basin is quite similar to Verdugo Canyon in the San Juan Creek watershed. The dominant communities are essentially equally divided between sage scrub and chaparral with riparian cover making up roughly nine percent of the area and limited by the steep topographic. Very little of the sub-basin is covered in grasslands.

We know of no water-quality data from Talega Canyon. Overall, there should be a moderate tendency to runoff generation within the sub-basin and pollutant interactions with groundwater may be locally significant where sandy substrates are found. Nitrogen loading should be relatively low given the existing land use and cover. On the other hand, the potential for generating large amounts of fine sediments indicates that Talega can be a significant source of phosphates. Historical aerial photography shows that a well-vegetated floodplain has often been absent, suggesting that the riparian corridor may play a relatively minor role in cycling of pollutants. Metal partitioning should heavily favor transport in the less biologically available particulate forms.

5. OVERALL CONCLUSIONS

1. The California State Water Resources Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCB) are given authority to protect and enhance water quality in California through the state Porter-Cologne Act and Section 319 of the federal Clean Water Act. In San Diego, Riverside and southern Orange Counties, the Region 9 RWQCB regulates water quality in accordance with the Basin Plan by establishing designated beneficial uses and water quality objectives and criteria that must be met to protect these uses.

2. Non-point constituents of concern in Southern California watersheds are those that have the potential to degrade water quality and aquatic habitats. They include temperature, salinity, turbidity, nutrients, metals, pesticides and other organics, pathogens, and oil and grease.

3. Pollutant pathways and cycles within the San Juan and San Mateo Creek watersheds can be generalized based upon critical characteristics of sub-basin terrain types. *Sandy* terrains typically favor infiltration, mobilizing pollutants in subterranean pathways with little or no biogeochemical cycling taking place in surface waters. *Silty* terrains have higher runoff rates and often contribute fine sediments (that have the ability to adsorb metals and pesticides) to downstream waterways. *Clayey* terrains are characterized by very high surface runoff rates and therefore play only a minor role in groundwater processes. Although typically resistant to erosion, clay soils can be a significant source of turbidity where incision occurs. *Crystalline* terrains have high runoff rates during larger storms and, in a natural state, produce much of the sediment and eroded soil that moves down the creeks.

4. The bulk of recent water quality monitoring data in the San Juan Creek watershed was collected by the Orange County PFRD in the 1990's at three sampling points that allow for a great deal of comparison among land use and terrain types. 1) The main stem San Juan Creek sampled at La Novia bridge in San Juan Capistrano has a large drainage area with diverse land use and a representation of all terrain types. 2) The main stem San Juan Creek sampled at the Caspers Regional Park entry road (approximately 10 miles upstream of San Juan Capistrano) represents runoff from primarily open space coastal scrub and chaparral on crystalline terrains. 3) The Oso Creek sample location is largely influenced by urban land uses and clayey terrains.

5. The available water quality data sets are limited and therefore restrict the degree to which detailed quantitative conclusions can be made about baseline water quality conditions in the SAMP study area. For example, limited data for metals above detection limits and an absence in some locations of dissolved metals analyses (the most bioavailable form) hinder the assessment of metals persistence and toxicity that

can be made. Additionally, there is very little data for the four Orange County tributaries to San Mateo Creek.

6. Nitrate concentrations are markedly higher in Oso Creek and San Juan Creek at La Novia when compared to concentrations in San Juan Creek at Caspers. While these two stations have a similar range of nitrate-N concentrations (0 to 2.7 mg/L N at La Novia and 0 to 3.4 mg/L at Oso), there appears to be a different primary mobilization mechanism for nitrogen in the two watersheds. Nitrate concentrations in San Juan Creek at La Novia generally increase with discharge, whereas the Oso Creek data does not display a similar trend. The difference may be due in part from increased urbanization in the Oso Creek watershed with its associated dry season "nuisance flows" entering the stream system or wash-off of nitrates from impervious surfaces.

7. When inter-stream comparisons are made, phosphate concentrations follow a similar trend as nitrate – phosphate levels are higher in Oso Creek than San Juan Creek. In this case, increased phosphate concentrations in Oso Creek may be due in part to the presence of highly erodible, phosphate rich Monterey Shale in its watershed.

8. Zinc concentrations were examined at the three sample points. While there appears to be very little difference between the two sample points on San Juan Creek, zinc concentrations were higher in Oso Creek. Increased urbanization may be one explanation for this difference. At all sample locations, zinc concentrations increase with increasing rainfall until approximately one inch of 3-day cumulative antecedent rainfall in reached, at which point zinc concentrations begin to decrease.

9. During the 1960's, extensive efforts were made to locate municipal water sources in the San Juan Creek watershed. As part of this effort, surface water samples were analyzed for total dissolved solids (TDS), a summary parameter that measures dissolved salts in water. Sources of salts include natural weathering of bedrock and soils as well as anthropogenic sources from agriculture and urbanization. The data set suggests that TDS concentrations in San Juan Creek increase from 200 mg/L at its upper reaches to over 1,000 mg/L in the lower reach. This 500 percent increase in TDS is likely the result of: 1) inputs from systems (Canada Chiquita and Oso Creek) that drain sedimentary rock units that naturally contribute higher salinity ground water than the crystalline rocks underlying the headwaters, 2) irrigation return flows in Oso Creek, Canada Chiquita and Canada Gobernadora, and 3) evaporative processes that occur throughout the length of San Juan Creek.

10. Frequent, but spatially limited bacteria monitoring data is available in the waters near the mouth of San Juan Creek under a program carried out by the South East Regional Reclamation Agency (SERRA). These data point to persistently high counts of total and fecal coliform, as well as enterococcus. Additionally, the data indicate that high bacterial concentrations are frequently detected upstream of the treatment

plant and that measured values shift widely even during extended dry periods. It is important to note that both of the SERRA monitoring sites are located at essentially the most downstream reaches of San Juan Creek, within and below extensive urbanized areas. The State NPS Program Plan anticipates completion of coliform TMDLs for the lower reaches and mouth of San Juan Creek by July 2010.

11. During the 1960's, extensive efforts were made to locate municipal water sources in the San Juan Creek watershed. As part of this effort, surface water samples were analyzed for total dissolved solids (TDS), a summary parameter that measures dissolved salts in water. Sources of salts include natural weathering of bedrock and soils as well as anthropogenic sources from agriculture and urbanization. The data set suggests that TDS concentrations in San Juan Creek increase from 200 mg/L at its upper reaches to over 1,000 mg/L in the lower reach. This 500 percent increase in TDS is likely the result of: 1) inputs from systems (Canada Chiquita and Oso Creek) that drain sedimentary rock units that naturally contribute higher salinity ground water than the crystalline rocks underlying the headwaters, 2) irrigation return flows in Oso Creek, Canada Chiquita and Canada Gobernadora, and 3) evaporative processes that occur throughout the length of San Juan Creek.

12. Frequent, but spatially limited bacteria monitoring data is available in the waters near the mouth of San Juan Creek under a program carried out by the South East Regional Reclamation Agency (SERRA). These data point to persistently high counts of total and fecal coliform, as well as enterococcus. Additionally, the data indicate that high bacterial concentrations are frequently detected upstream of the treatment plant and that measured values shift widely even during extended dry periods. It is important to note that both of the SERRA monitoring sites are located at essentially the most downstream reaches of San Juan Creek, within and below extensive urbanized areas.

13. A total of twelve sub-basins are included in the SAMP study area. Lucas Canyon, Verdugo Canyon, Bell Canyon, Trampas Canyon, Cañada Gobernadora, Cañada Chiquita, Southern San Juan Catchments and Narrow Canyon are found in the San Juan Creek watershed and La Paz Canyon, Gabino Canyon, Cristianitos Canyon and Talega Canyon are found in the San Mateo watershed. Current terrains information allows an understanding of basic infiltration and surface water transport characteristics that are relevant to future sub-watershed water quality analyses.

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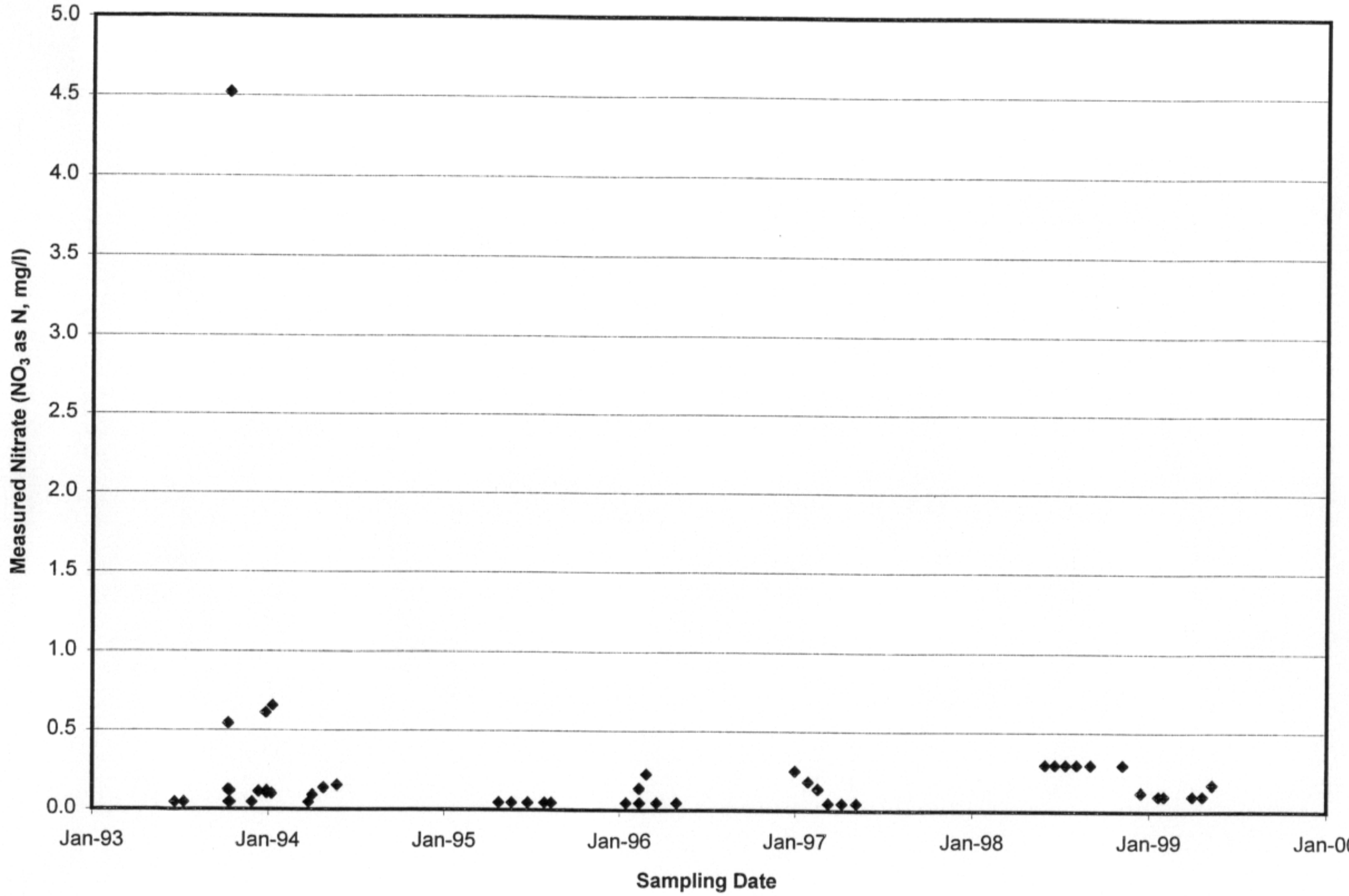
FIGURES



Balance Hydrologics, Inc.

Figure 1. **Measured nitrate concentrations in San Juan Creek at Caspers Regional Park, WY 1994 to WY 1999.**

Note the one outlier in the 1994 sampling and the fact that no winter sampling was carried out in WY 1995 or WY 1998. Source data: Orange County Public Facilities and Resources Department.

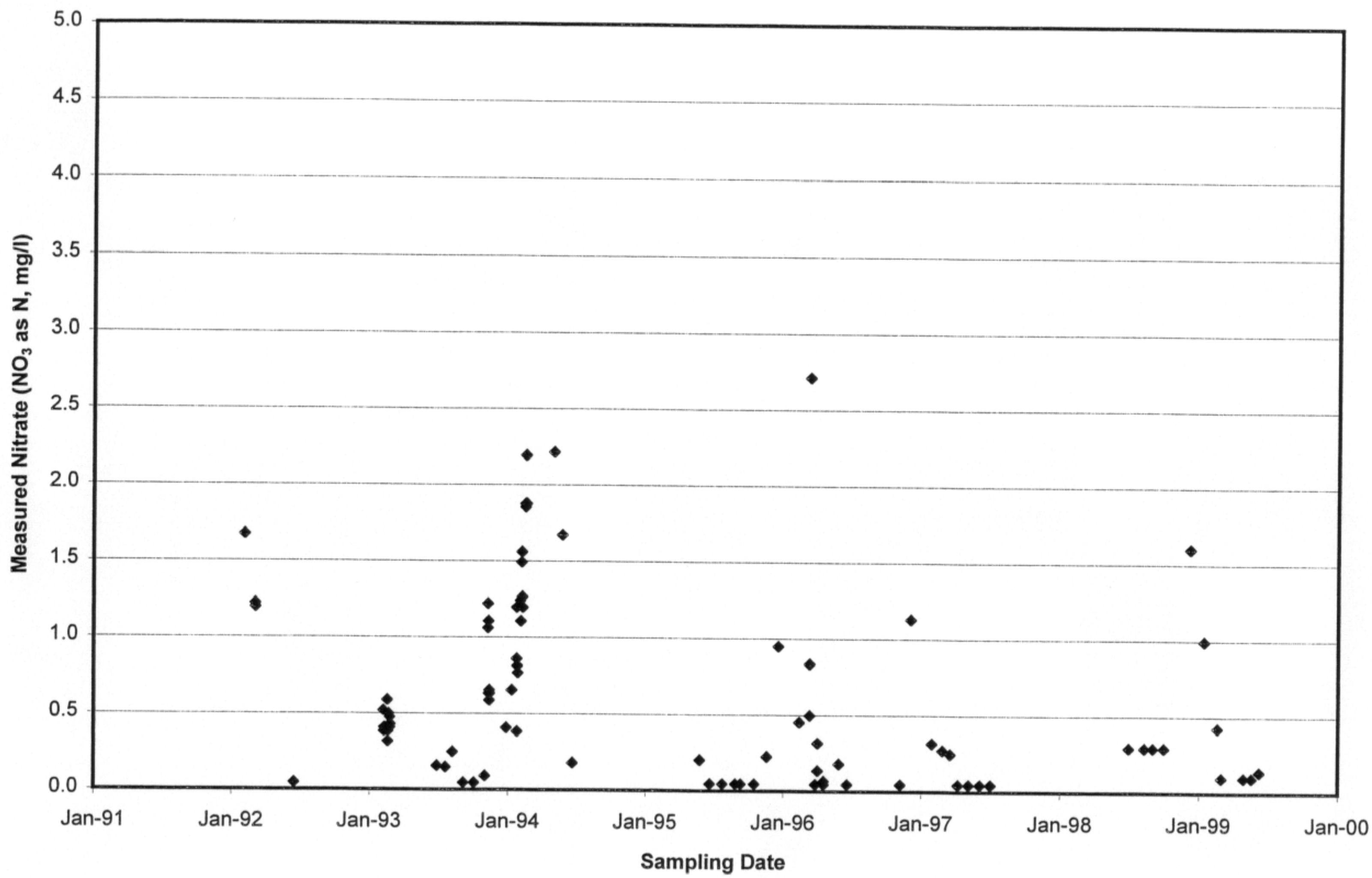


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Figure 2. Measured nitrate concentrations in San Juan Creek at La Novia, WY 1992 to WY1999

Note the relatively high winter season levels and the fact that no winter sampling was carried out in WY 1995 or WY 1998. There is no definite trend over a period of years. Source data: Orange County Public Facilities and Resources Department.

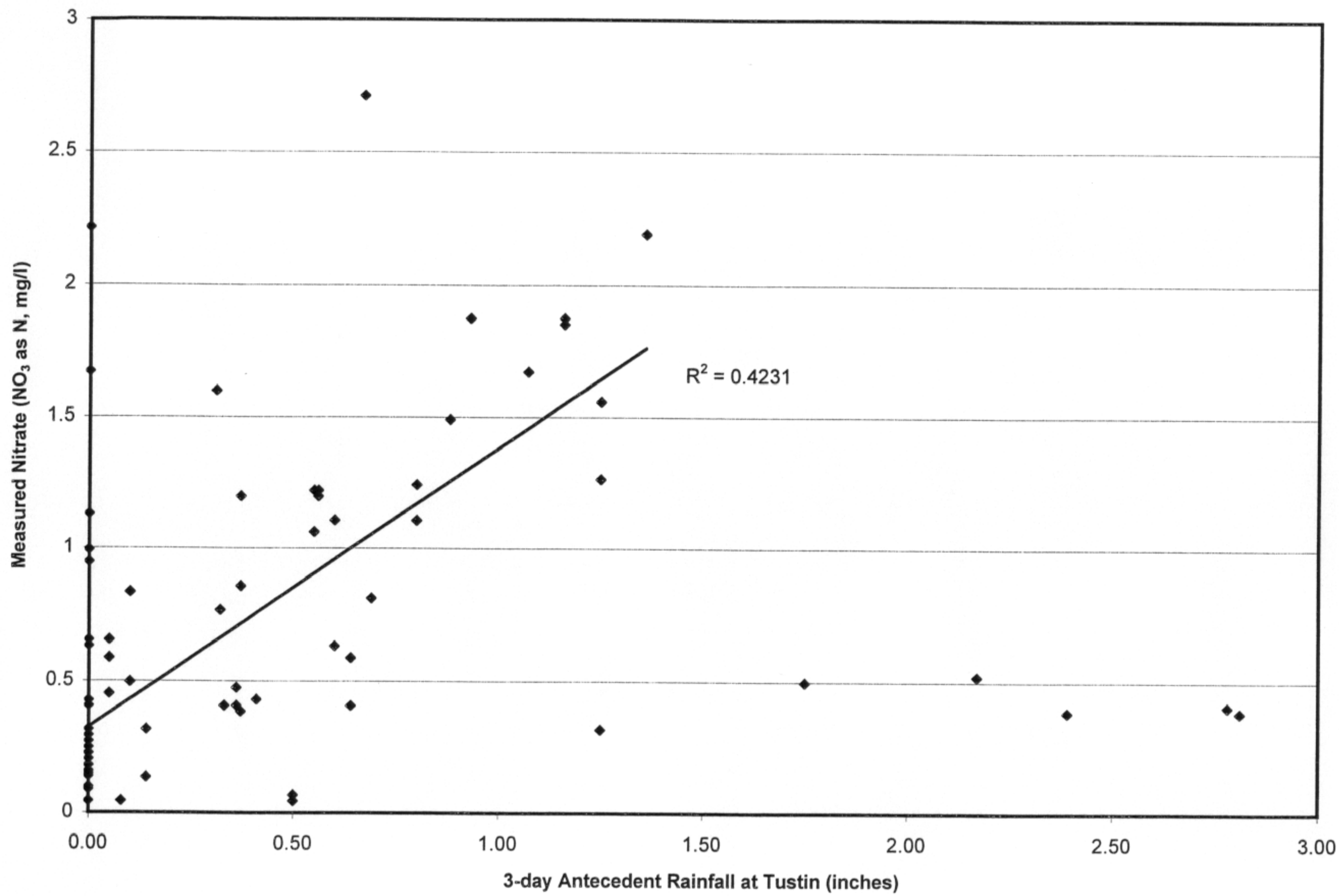

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Figure 3. **Measured nitrate concentrations in San Juan Creek at La Novia as a function of antecedent rainfall.**
Note that there is a marked trend to higher nitrate concentrations up to approximately 1.5 inches of antecedent rainfall. Source data: Orange County Public Facilities and Resources Department.

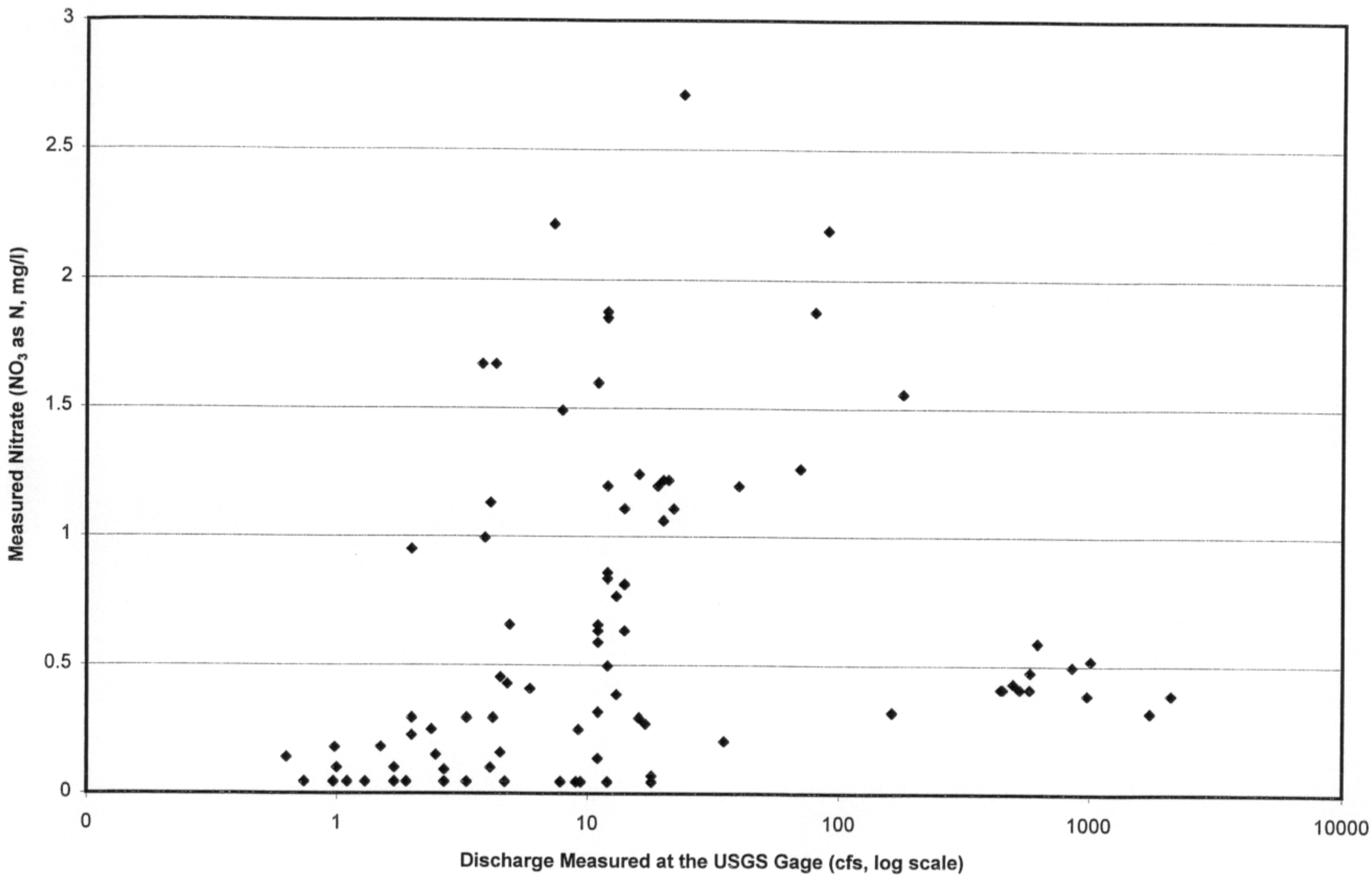

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Figure 4. **Measured nitrate concentrations in San Juan Creek at La Novia as a function of discharge.**
Note that there is a marked trend to higher nitrate concentrations with increasing discharge to approximately 100 cfs. Also note the clustering of values at higher flows. Source data: Orange County Public Facilities and Resources Department.

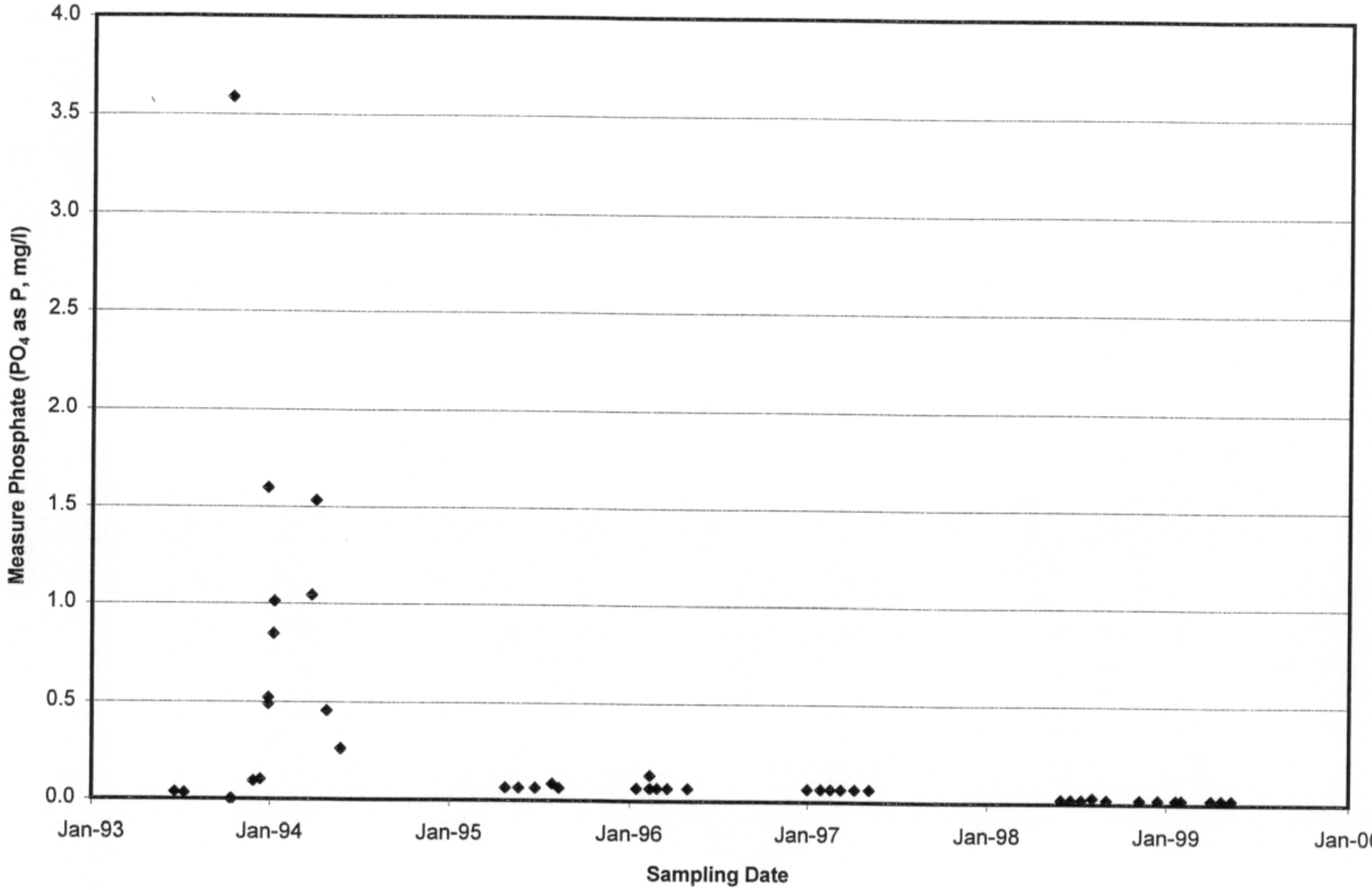

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Figure 5. **Measured phosphate concentrations in San Juan Creek at Caspers Regional Park,WY 1994 to WY 1999.**

Note that two high values recorded on 11/11/93 (10.8 and 6.8 mg/l) were not included to maintain a similar vertical scale to the other monitoring stations. Also note the consistently low values recorded in recent years. Source data: Orange County Public Facilities and Resources Department.

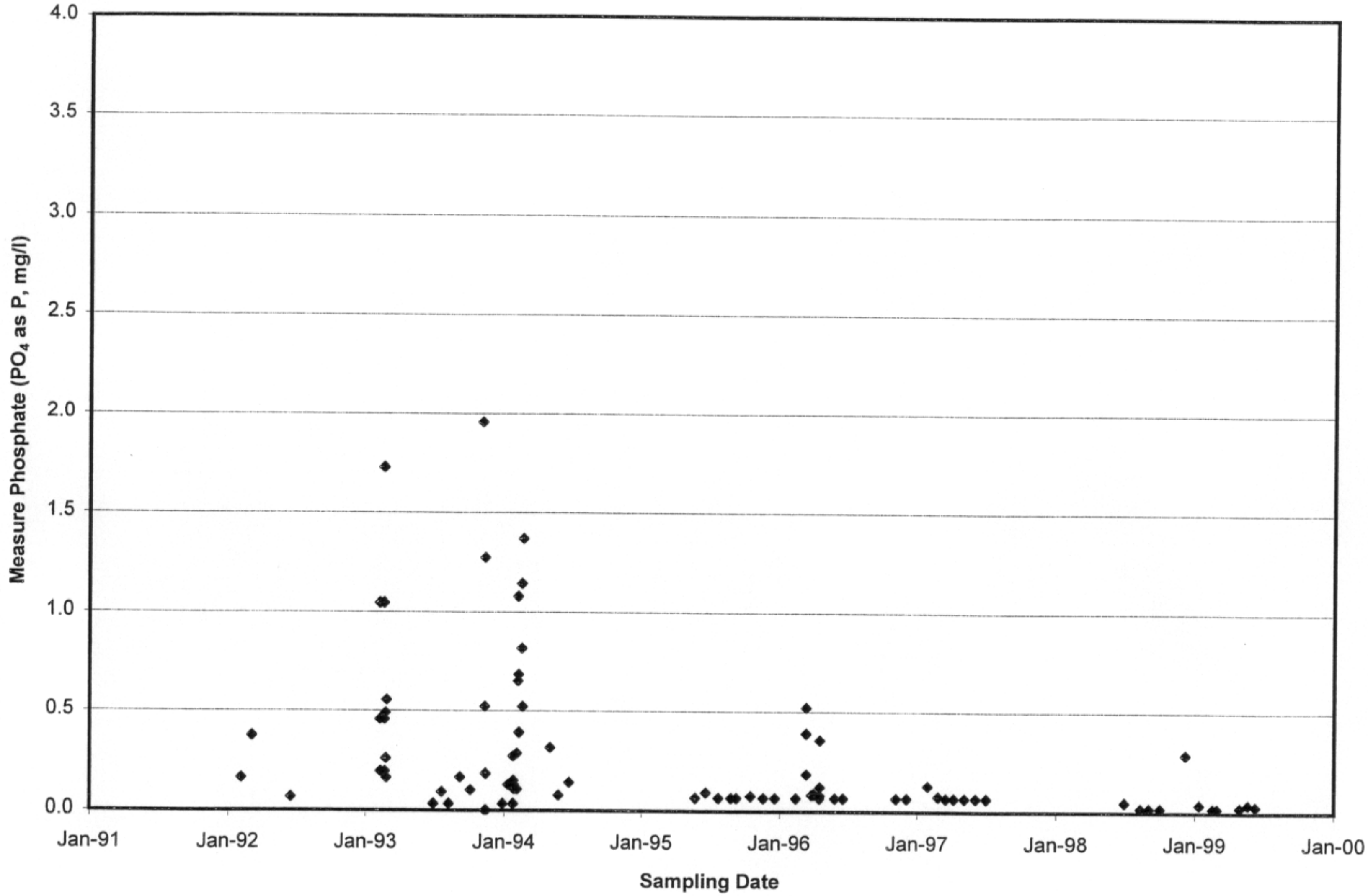

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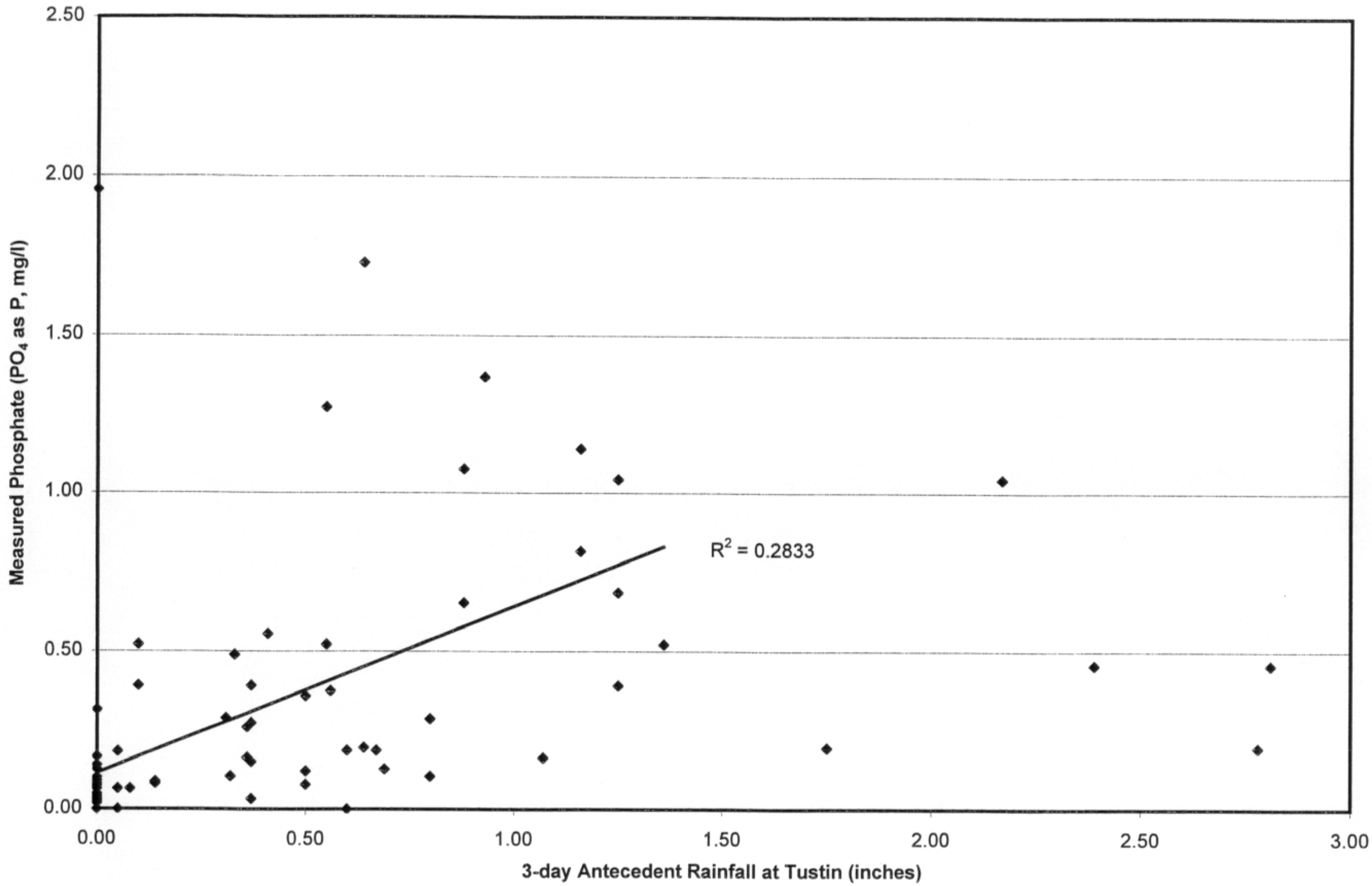
Figure 6. **Measured phosphate concentrations in San Juan Creek at La Novia, WY 1992 to WY1999**

Note that summer baseline values are relatively low and that no winter sampling was carried out in WY 1995 or WY 1998. There may be a slight downward trend over a period of years. Source data: Orange County Public Facilities and Resources Department.



Balance Hydrologics, Inc.

Figure 7. Measured phosphate concentrations in San Juan Creek at La Novia as a function of antecedent rainfall.

Note that there may be a slight trend to higher phosphate concentrations up to approximately 1.5 inches of antecedent rainfall. Source data: Orange County Public Facilities and Resources Department.

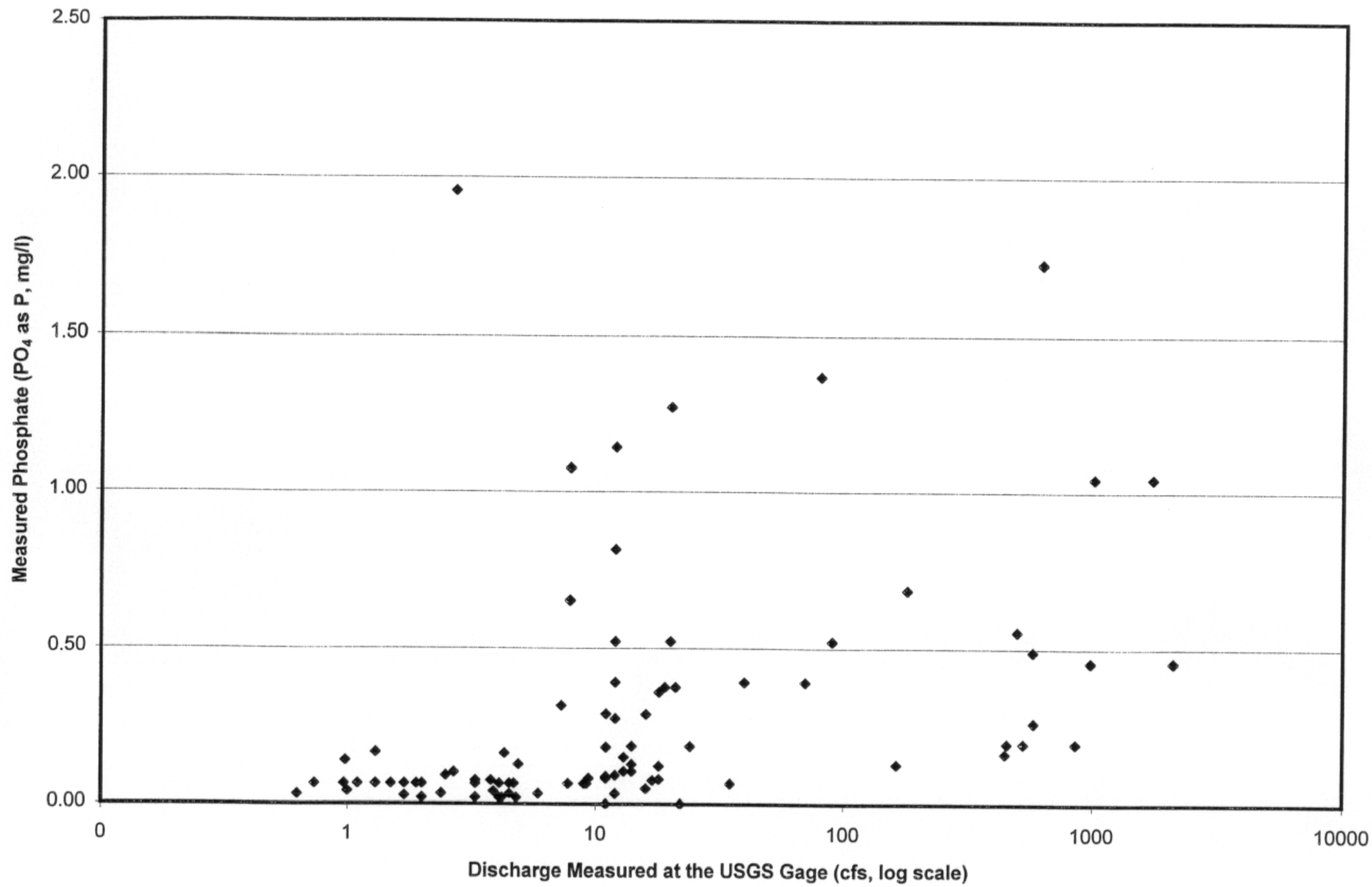


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Figure 8. **Measured phosphate concentrations in San Juan Creek at La Novia as a function of discharge.**
Note that the marked trend to higher phosphate concentrations with increasing discharge. This is consistent with erosion, and especially channel incision, as a significant source of P. Source data: Orange County Public Facilities and Resources Department.

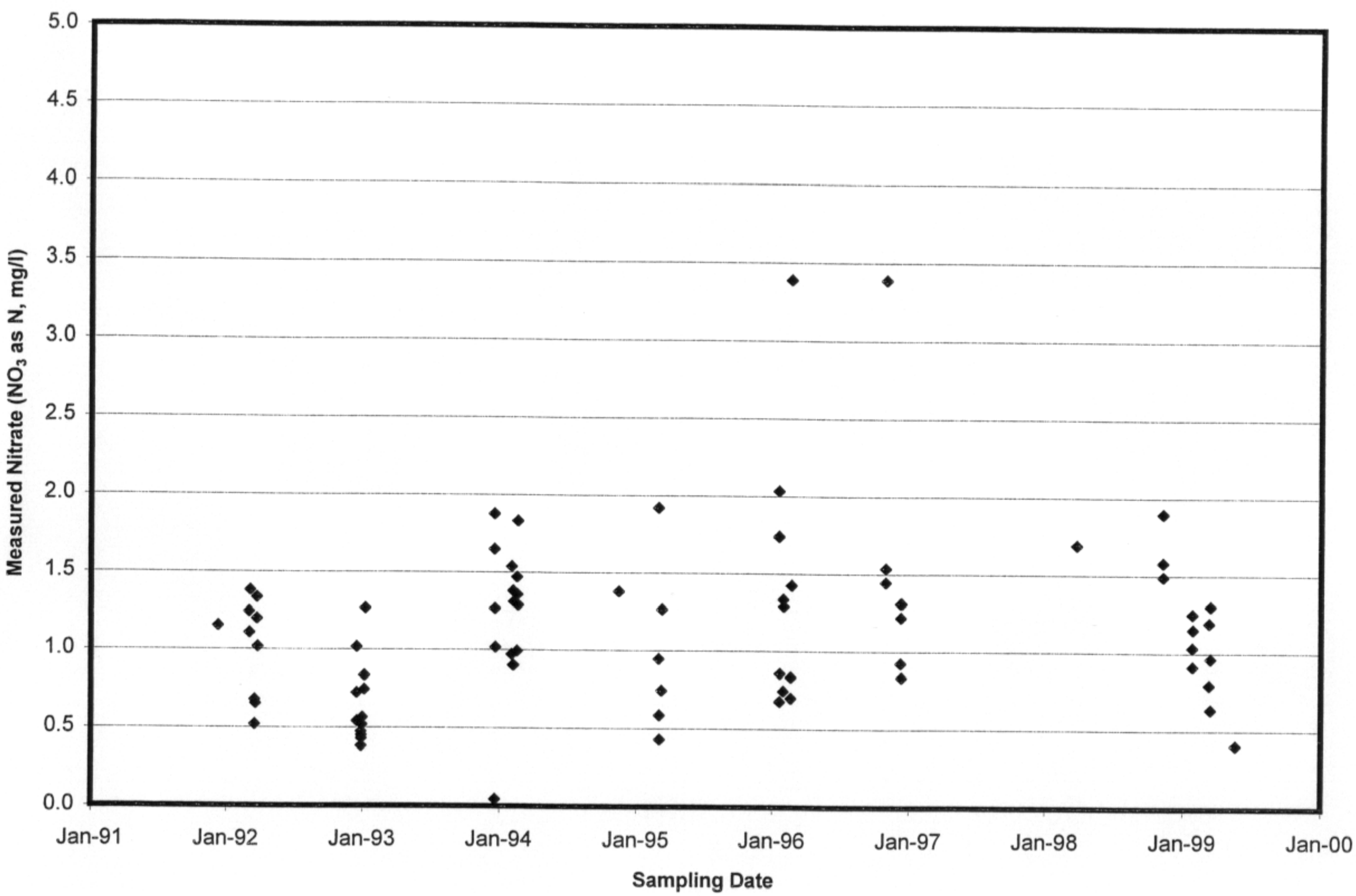

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Figure 9. **Measured nitrate concentrations in Oso Creek, WY 1992 to WY1999**

Note that the majority of sampling was carried out in the winter. Also note the relatively high values overall and possible slight upward trend over a period of years. Source data: Orange County Public Facilities and Resources Department.

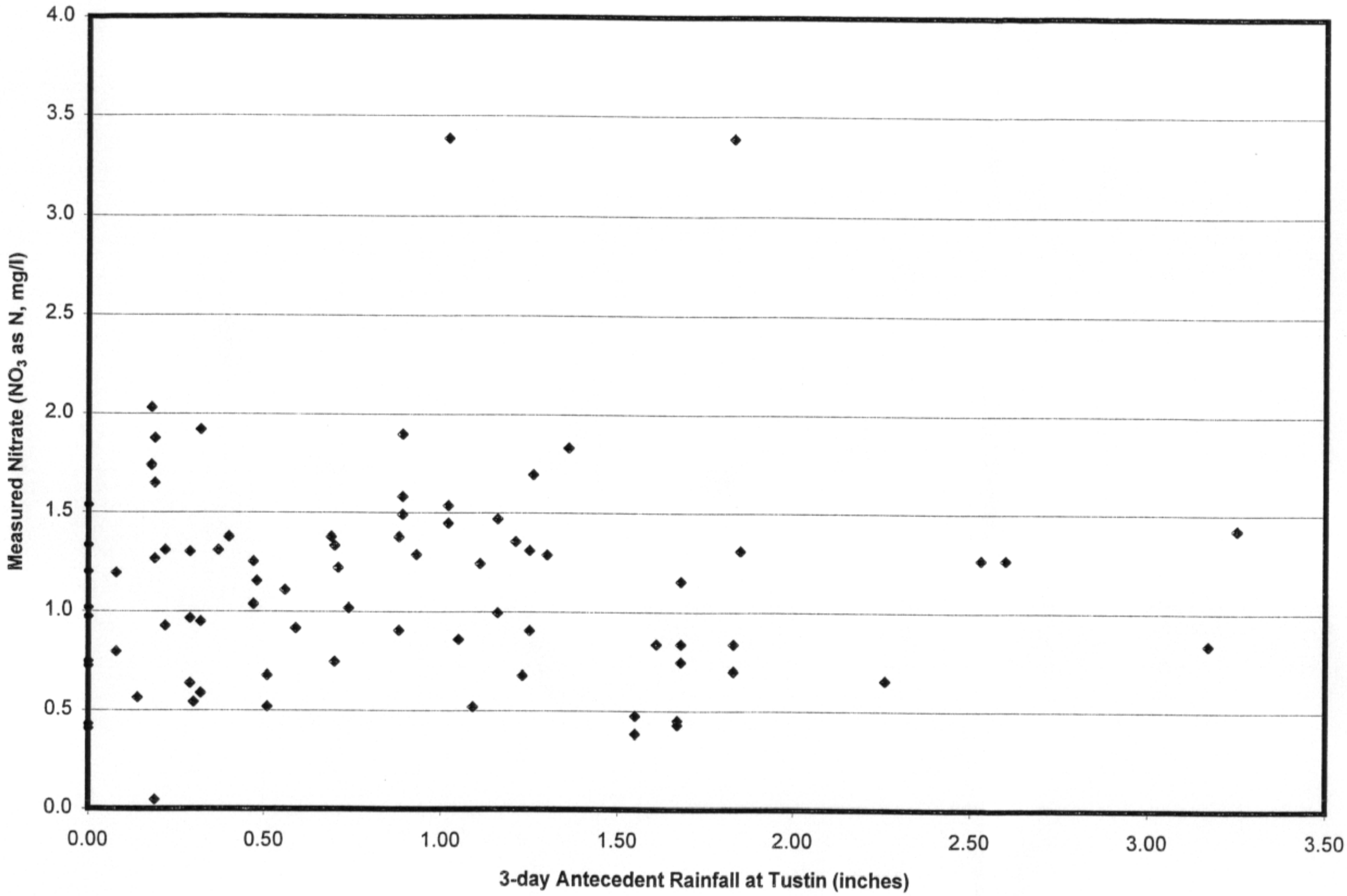

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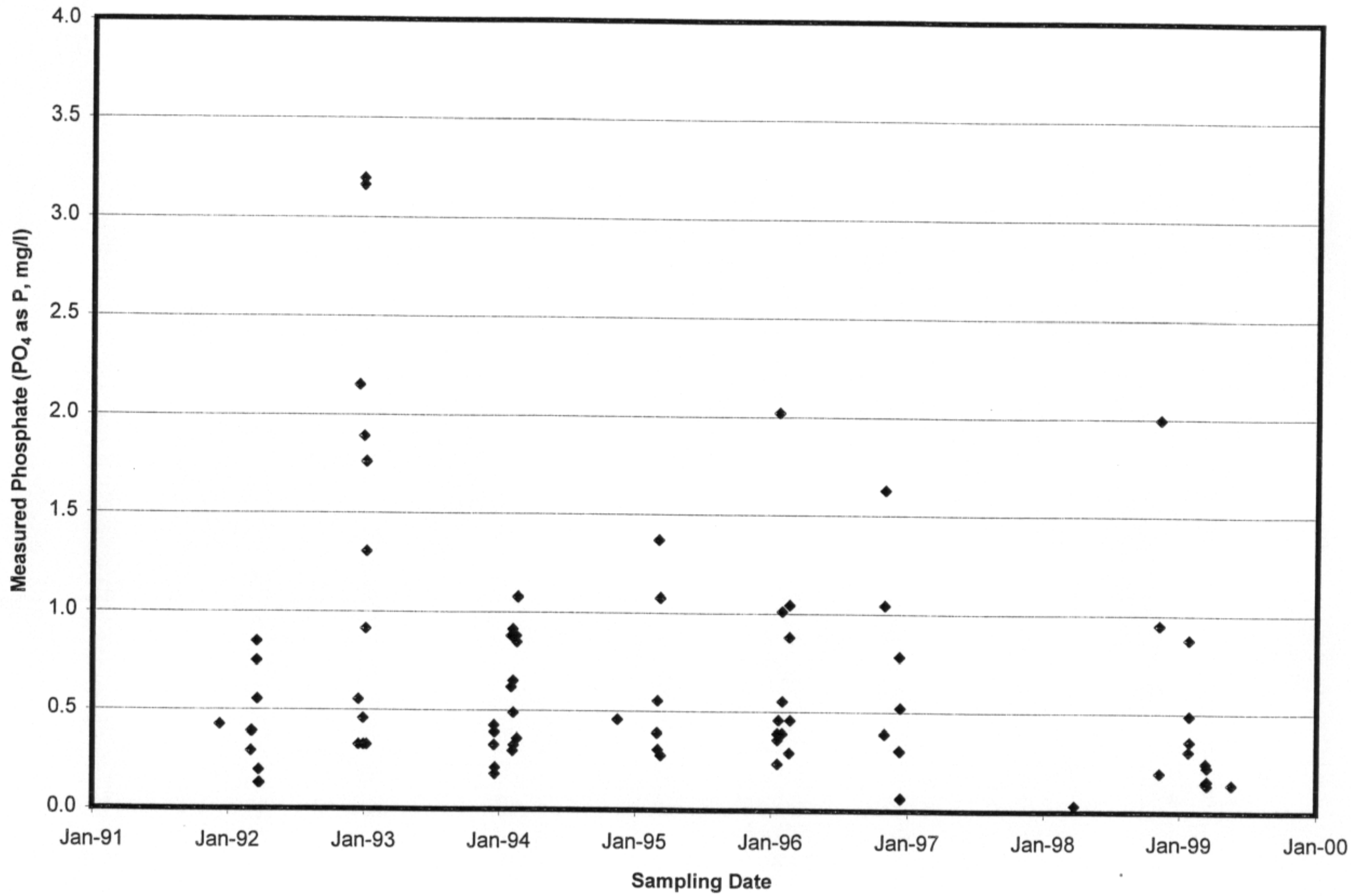
Figure 10. **Measured nitrate concentrations in Oso Creek at Mission Viejo as a function of antecedent rainfall.**
Note the lack of any clear trend in the measured nitrate concentrations, suggesting that nitrate mobilization is controlled by different processes than those operating in San Juan Creek. Source data: Orange County Public Facilities and Resources Department.



Balance Hydrologics, Inc.

Figure 11. **Measured phosphate concentrations in Oso Creek, WY 1992 to WY1999.**

Note that the majority of sampling was carried out in the winter. Also note the relatively high values overall and lack of any clear trend over a period of years. Source data: Orange County Public Facilities and Resources Department.

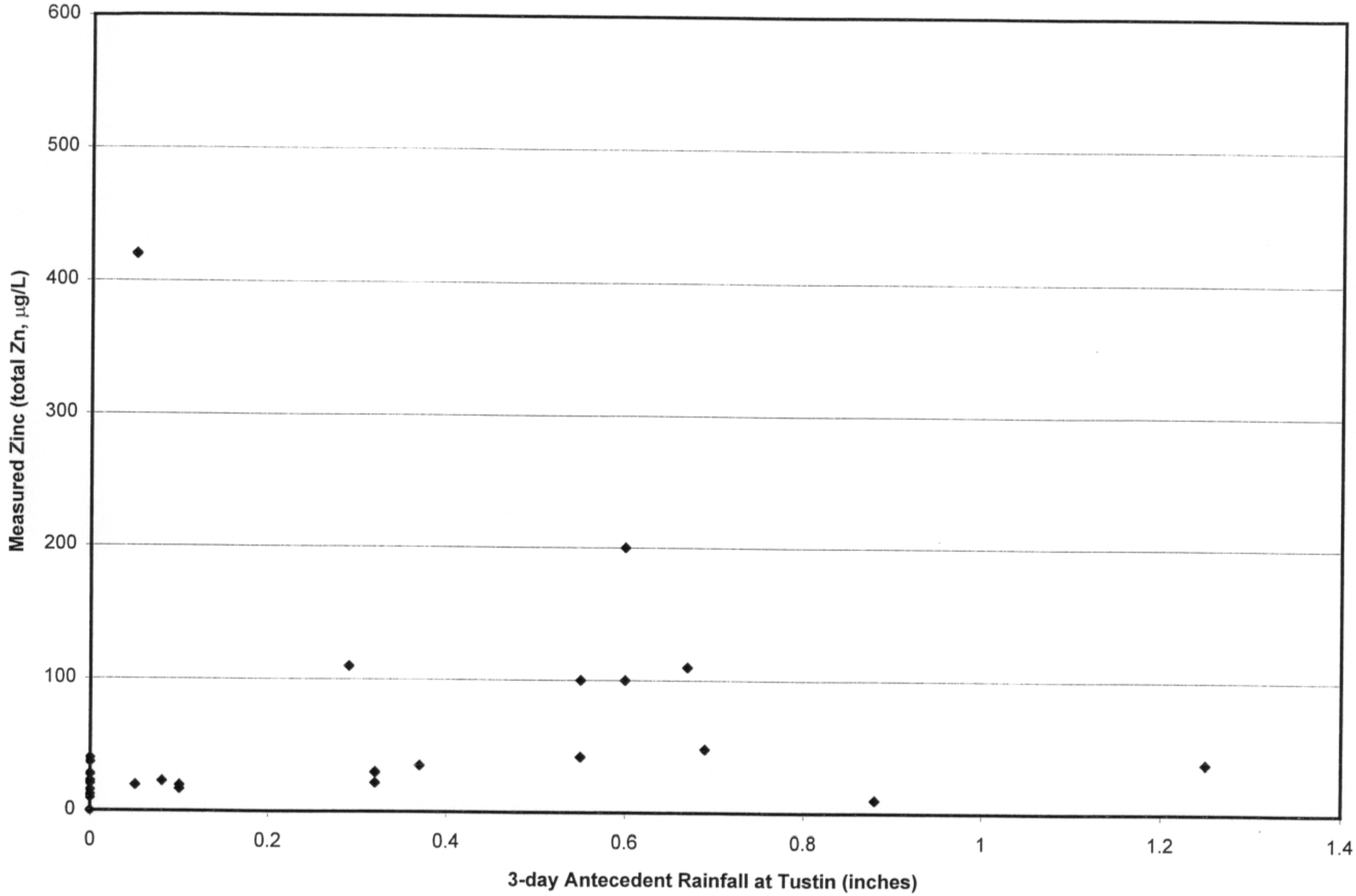


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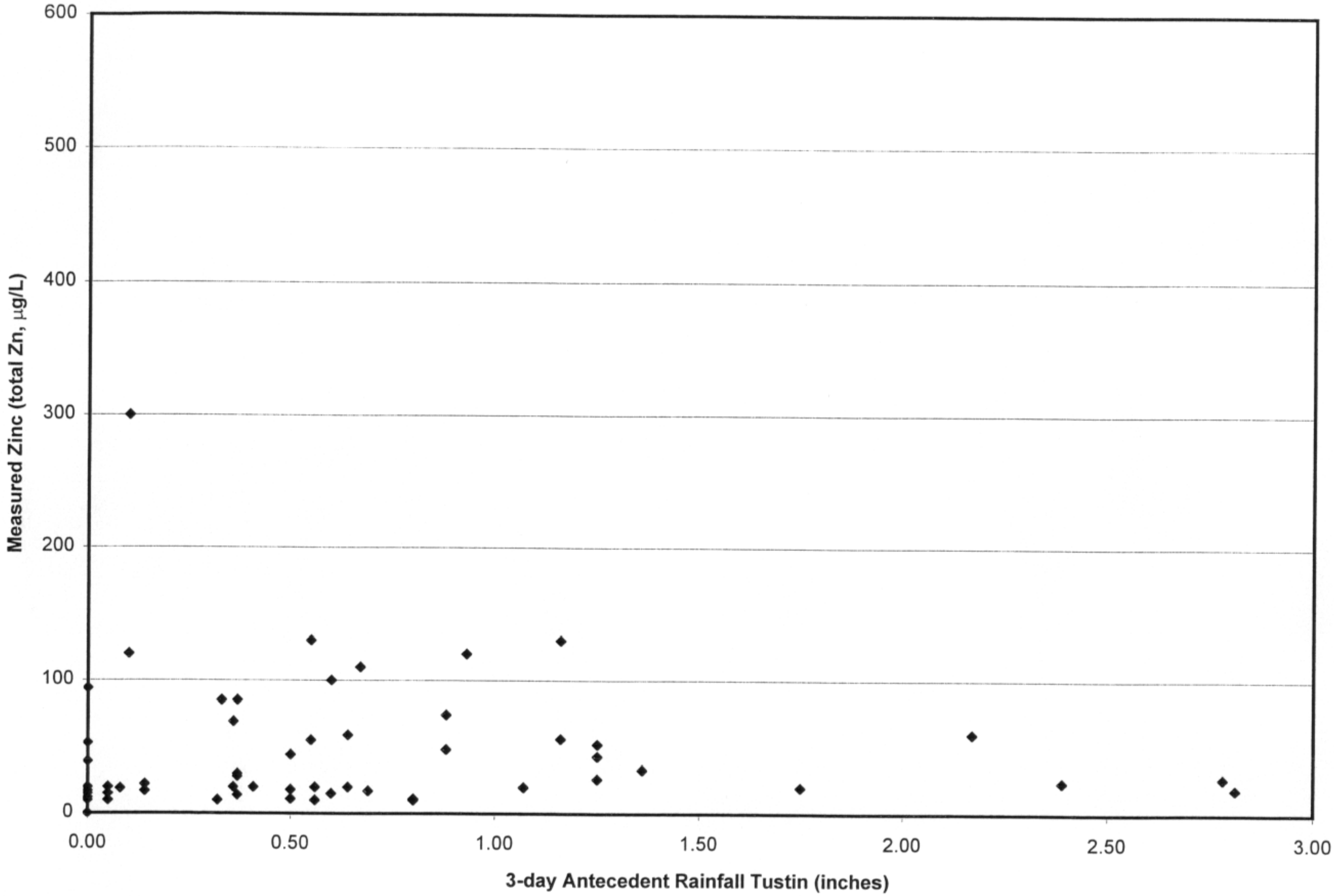
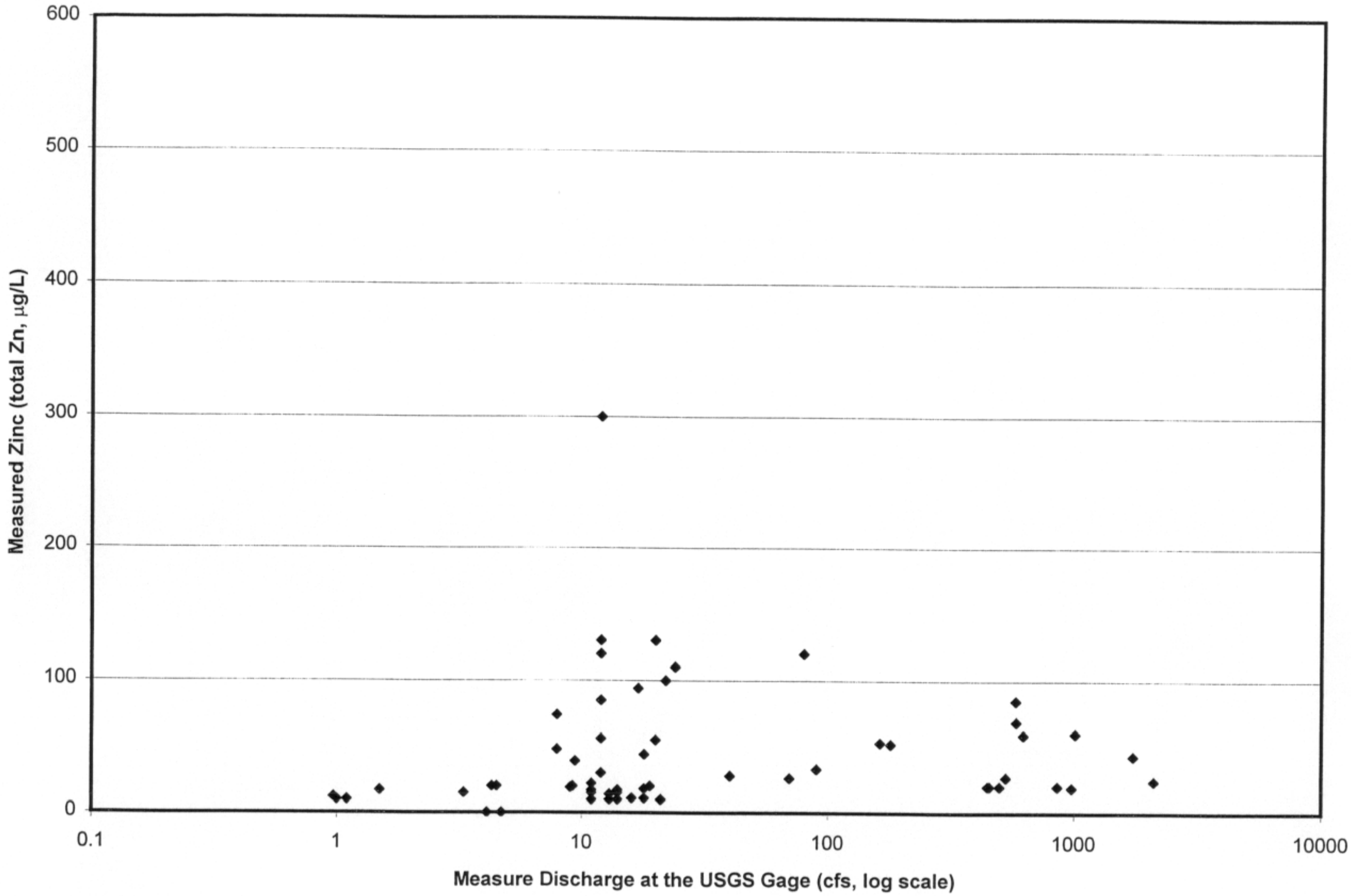
Figure 12. **Measured zinc concentrations in San Juan Creek at Caspers Regional Park as a function of antecedent rainfall.**
Note that the highest values occur when 3-day antecedent rainfall is close to one inch. Source data: Orange County Public Facilities and Resources Department.



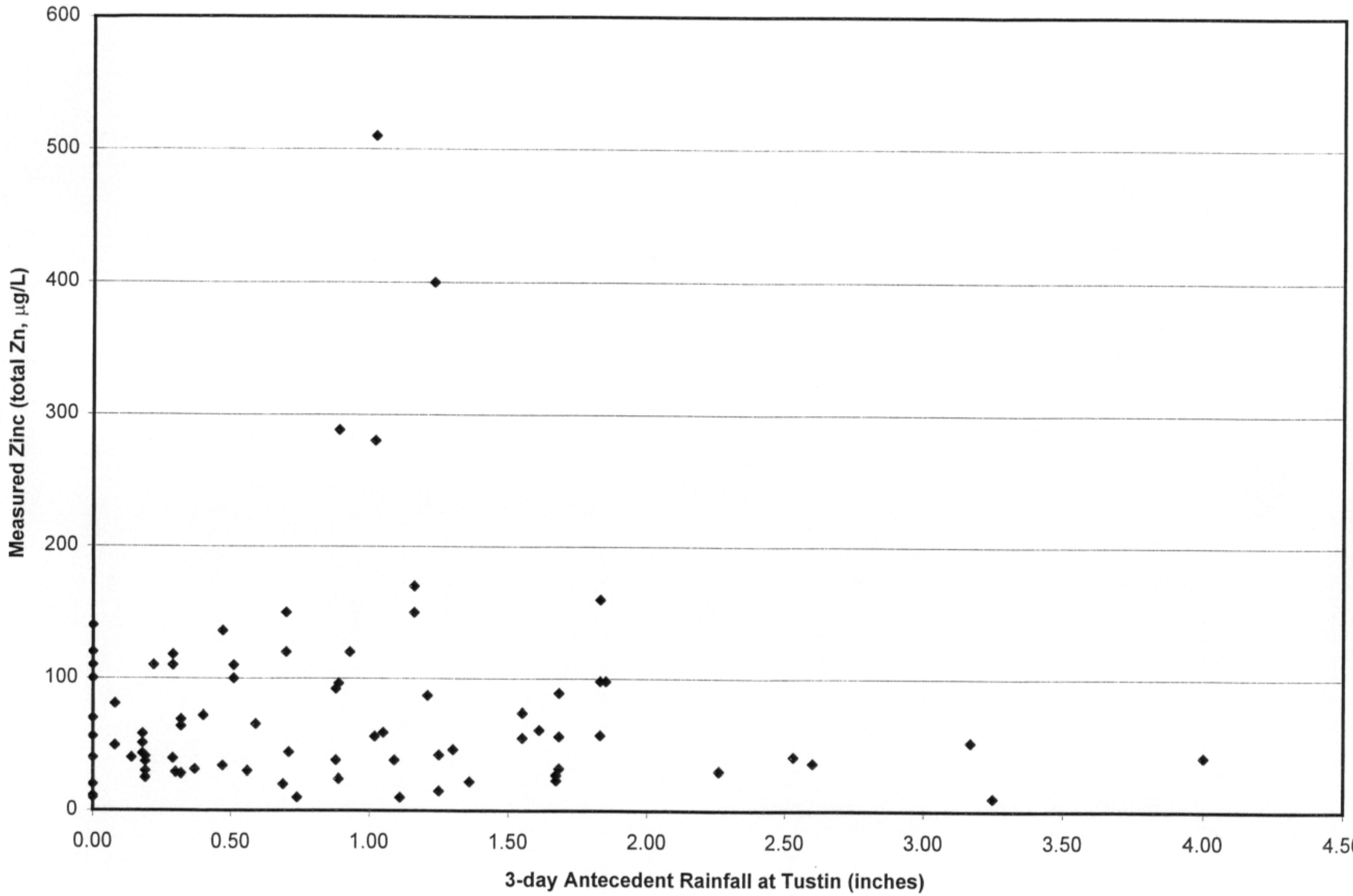
Balance Hydrologics, Inc.

Figure 13. **Measured zinc concentrations in San Juan Creek at La Novia as a function of antecedent rainfall.**
Note the lack of any definite trend with antecedent rainfall. Source data: Orange County Public Facilities and Resources Department.



Balance Hydrologics, Inc.

Figure 14. **Measured zinc concentrations in San Juan Creek at La Novia as a function of discharge.**
Note that the majority of sampling was conducted at flow rates above 1.0 cfs. Also note that the highest values occur at flow rates between 10 and 100 cfs. Source data: Orange County Public Facilities and Resources Department and USGS.



Balance Hydrologics, Inc.

Figure 15. **Measured zinc concentrations in Oso Creek as a function of antecedent rainfall.**

Note that the highest zinc concentrations occur when 3-day antecedent rainfall is close to one inch. Source data: Orange County Public Facilities and Resources Department.

TABLES

Table 1. Existing (X) and potential (O) beneficial uses of waters in the San Juan and San Mateo Watersheds.

	Municipal and Domestic Supply (MUN)	Agricultural Supply (AGR)	Industrial Service Supply (IND)	Contact Water Recreation (REC-1)	Non-contact Water Recreation (REC-2)	Warm Freshwater Habitat (WARM)	Cold Freshwater Habitat (COLD)	Marine Habitat (MAR)	Wildlife Habitat (WILD)	Rare, Threatened, or Endangered Species (RARE)	Migration of Aquatic Organisms (MIGR)	Preservation of Biological Habitats of Special Significance (BIOL)	Shellfish Harvesting (SHELL)
San Juan Creek Watershed													
San Juan Creek	+	X	X	X	X	X	X		X				
Morrell Canyon	+	X	X	X	X	X	X		X				
Decker Canyon	+	X	X	X	X	X	X		X				
Long Canyon	+	X	X	X	X	X	X		X				
Lion Canyon	+	X	X	X	X	X	X		X				
Hot Spring Canyon	+	X	X	X	X	X	X		X				
Cold Spring Canyon	+	X	X	X	X	X	X		X				
Lucas Canyon	+	X	X	X	X	X	X		X				
Aliso Canyon	+	X	X	X	X	X	X		X				
Verdugo Canyon	+	X	X	X	X	X	X		X				
Bell Canyon	+	X	X	X	X	X	X		X				
Fox Canyon	+	X	X	X	X	X	X		X				
Dove Canyon	+	X	X	X	X	X	X		X				
Crow Canyon	+	X	X	X	X	X	X		X				
Trampas Canyon	+	X	X	X	X	X	X		X				
Canada Gobernadora	+	X	X	X	X	X	X		X				
Canada Chiquita	+	X	X	X	X	X	X		X				
Horno Creek	+	X	X	X	X	X	X		X				
Arroyo Trabuco Creek	+	X	X	X	X	X	X		X				
Holy Jim Canyon	+	X	X	X	X	X	X		X				
Falls Canyon	+	X	X	X	X	X	X		X				
Rose Canyon	+	X	X	X	X	X	X		X				
Hickey Canyon	+	X	X	X	X	X	X		X				
Live Oat Canyon	+	X	X	X	X	X	X		X				
Tijeras Canyon	+	X	X	X	X	X	X		X				
Oso Creek	+	X	X	X	X	X	X		X				
La Paz Creek	+	X	X	X	X	X	X		X				
San Juan Creek Mouth				X	X			X	X	X	X		X

Table 1. Existing (X) and potential (O) beneficial uses of waters in the San Juan and San Mateo Watersheds.

	Municipal and Domestic Supply (MUN)	Agricultural Supply (AGR)	Industrial Service Supply (IND)	Contact Water Recreation (REC-1)	Non-contact Water Recreation (REC-2)	Warm Freshwater Habitat (WARM)	Cold Freshwater Habitat (COLD)	Marine Habitat (MAR)	Wildlife Habitat (WILD)	Rare, Threatened, or Endangered Species (RARE)	Migration of Aquatic Organisms (MIGR)	Preservation of Biological Habitats of Special Significance (BIOL)	Shellfish Harvesting (SHELL)
San Mateo Creek Watershed													
San Mateo Creek	+			O	X	X			X	X			
Devil Canyon	+			O	X	X			X				
Cold Spring Canyon	+			O	X	X			X				
San Mateo Canyon	+			O	X	X			X	X			
Los Almos Canyon	+			O	X	X			X				
Wildhorse Canyon	+			O	X	X			X				
Tenaja Canyon	+			O	X	X			X				
Bluewater Canyon	+			O	X	X			X				
Nickel Canyon	+			O	X	X			X				
Christianitos Creek	+			O	X	X			X				
Gabino Canyon	+			O	X	X			X				
La Paz Canyon	+			O	X	X			X				
Blind Canyon	+			O	X	X			X				
Talega Canyon	+			O	X	X			X				
San Mateo Creek Mouth				X	X			X	X	X	X	X	
Ground Water													
Mission Viejo													
Oso	X	X	X										
Upper Trabuco	X	X	X										
Middle Trabuco	X	X	X										
Gobernadora	X	X	X										
Upper San Juan	X	X	X										
Middle San Juan	X	X	X										
Lower San Juan	X	X	X										
Ortega	X	X	X										
San Mateo Canyon	X	X	X										

Notes:

A '+' indicates that the water body has been exempted by the Regional Board from the municipal use designation under the terms and conditions of State Board Resolution No. 88-63, Sources of Drinking Water Policy.

Table 2. California RWQCB Region 9 and CTR standards and objectives applicable to the quality of water in the SAMP study area.

Constituent	Units	California Drinking Water Standards[1] (MCL)	Basin Plan Objectives [2]	California Toxics Rule[6] (CMC)[7]	California Toxics Rule[6] (CCC)[8]
INORGANIC CHEMICALS					
Aluminum	mg/L	1	--	--	--
Antimony	mg/L	0.006	--	--	--
Arsenic	mg/L	0.05	--	0.34	0.15
Asbestos	MFL	7	--	--	--
Barium	mg/L	1	--	--	--
Beryllium	mg/L	0.004	--	--	--
Boron	mg/L	--[3]	0.75	--	--
Cadmium	mg/L	0.005	--	0.0043	0.0022
Chromium	mg/L	0.05	--	0.016	0.011
Chloride	mg/L	none	250	--	--
Copper	mg/L	1.3	--	0.013	0.009
Cyanide	mg/L	0.2	--	--	--
Fluoride	mg/L	2	1	--	--
Iron	mg/L	0.3	0.3	--	--
Lead	mg/L	0.015	--	0.065	0.0025
Manganese	mg/L	0.05	0.05	--	--
Mercury	mg/L	0.002	--	--	--
Nickel	mg/L	0.1	--	0.47	0.52
Nitrate+Nitrite (as N)	mg/L	10	--[5]	--	--
Nitrite (as N)	mg/L	1	--	--	--
Selenium	mg/L	0.01	--	--	0.005
Silver	mg/L	0.05	--	0.0034	--
Sodium	%	--[3]	60	--	--
Sulfate	mg/L	250, 500	250	--	--
Thallium	mg/L	0.002	--	--	--
Zinc	mg/L	5	--	0.12	0.12
OTHERS					
pH	pH Units	6.5-8.5	6.5-8.5	--	--
Specific Conductance	(µs)	900, 1600	--	--	--
Total dissolved solids	mg/L	500	500	--	--
Ammonia (as N)	mg/L	30	--[4]	--	--
Fecal coliform bacteria	MPN/100m	log mean <20	--	--	--

Notes:

1) Maximum contaminant levels established by the DHS, from Title 22 of the California Code of Regulations, April 2000.
Where two values are shown, they represent the "recommended" and "mandatory" values.
2) Concentrations not to be exceeded more than 10% of the time during any one year period.
3) No primary drinking water standards have been established for boron or sodium. At elevated concentrations, these constituents may constrain plant or crop growth.
4) Un-ionized ammonia concentrations exceeding 0.0025 mg/l can be toxic
5) Biostimulating constituents
6) California Toxics Rule (CTR) freshwater aquatic life criteria.
7) Criteria Maximum Concentration (CMC) equals the highest concentration to which aquatic life can be exposed for a short period of time.
8) Criteria Continuous Concentration (CMC) equals the highest concentration to which aquatic life can be exposed for an extended (4-days) period of time.

Table 3. Nitrate concentrations (mg/l NO_3 as N) measured by the Orange County Public Facilities and Resources Department as function of antecedent rainfall, WY 1991 to WY 1999.

3-Day Rainfall[1]	San Juan Creek: Caspers Regional Park # of Samples	Mean	Median	San Juan Creek: La Novia # of Samples	Mean	Median	Oso Creek: Mission Viejo # of Samples	Mean	Median
0.00	32	0.1	0.1	43	0.3	0.2	10	0.9	1.0
0.01-0.50	10	0.2	0.1	21	0.5	0.5	23	1.2	1.3
0.51-1.00	6	0.9	0.1	15	1.2	1.2	15	1.2	1.2
1.01-1.50	1	0.7	0.7	7	1.5	1.7	15	1.4	1.3
>1.50	0	n.d.	n.d.	5	0.4	0.4	18	1.0	0.8

1 Sum of three-day rainfall in inches as measured at the Orange County PFRD gage in Tustin.
n.d. = "no data".
The data suggests that significant nitrogen loads are introduced to the San Juan system between the Caspers and La Novia monitoring stations.
Note the markedly higher nitrate concentrations found in Oso Creek during drier conditions.
Also note the higher proportion of wet weather samples from Oso Creek when compared to the San Juan Creek stations.

Table 4. Ammonia concentrations (mg/l NH_3 as N) measured by the Orange County Public Facilities and Resources Department as function of antecedent rainfall, WY 1991 to WY 1999.

	San Juan Creek						Oso Creek		
	Caspers Regional Park			La Novia			Mission Viejo		
3-Day Rainfall[1]	# of Samples	Mean	Median	# of Samples	Mean	Median	# of Samples	Mean	Median
0.00	31	0.1	0.1	42	0.1	0.1	10	0.9	1.0
0.01-0.50	9	0.4	0.1	20	0.1	0.1	23	1.2	1.3
0.51-1.00	5	2.5	0.5	14	0.1	0.1	15	1.2	1.2
1.01-1.50	1	0.5	0.5	7	0.3	0.3	15	1.4	1.3
>1.50	0	n.d.	n.d.	5	0.1	0.1	18	1.0	0.8

1 Sum of three-day rainfall in inches as measured at the Orange County PFRD gage in Tustin.
n.d. = "no data".
The data suggests that there is no significant increase in ammonia concentrations between the Caspers and La Novia monitoring stations on San Juan Creek, or that any additional ammonia loading is quickly converted or assimilated.
Note the markedly higher ammonia concentrations found in Oso Creek during all conditions.
Also note the higher proportion of wet weather samples from Oso Creek as compared to the San Juan Creek stations.

Table 5. Phosphate concentrations (mg/l PO_4 as P) measured by the Orange County Public Facilities and Resources Department as function of antecedent rainfall, WY 1991 to WY 1999.

3-Day Rainfall[1]	San Juan Creek						Oso Creek		
	Caspers Regional Park			La Novia			Mission Viejo		
	# of Samples	Mean	Median	# of Samples	Mean	Median	# of Samples	Mean	Median
0.00	31	0.1	0.1	43	0.1	0.1	10	0.7	0.6
0.01-0.50	9	0.4	0.1	21	0.2	0.2	23	0.4	0.3
0.51-1.00	5	4.4	3.6	15	0.6	0.4	15	0.7	0.5
1.01-1.50	1	1.0	1.0	7	0.7	0.7	15	0.7	0.6
>1.50	0	n.d.	n.d.	5	0.5	0.5	18	1.0	0.5

1 Sum of three-day rainfall in inches as measured at the Orange County PFRD gage in Tustin.
n.d. = "no data".
The data suggests that there is no significant change, and perhaps a slight decrease, in phosphate concentrations between the Caspers and La Novia monitoring stations on San Juan Creek.
There is a generalized trend toward higher phosphate levels with increased antecedent rainfall for the San Juan stations, a trend that is missing from the Oso Creek data.
Also note the generally higher levels found in Oso Creek, especially during dry conditions.

Table 6. Zinc concentrations (total Zn, μg/L) measured by the Orange County Public Facilities and Resources Department as function of antecedent rainfall, WY 1991 to WY 1999.

3-Day Rainfall[1]	San Juan Creek						Oso Creek		
	Caspers Regional Park			La Novia			Mission Viejo		
	# of Samples	Mean	Median	# of Samples	Mean	Median	# of Samples	Mean	Median
0.00	11	23	22	12	28	16	10	68	63
0.01-0.50	9	77	23	17	52	20	23	61	49
0.51-1.00	7	87	100	18	48	32	15	87	92
1.01-1.50	1	38	38	7	51	43	14	135	58
>1.50	0	n.d.	n.d.	5	30	24	18	58	54

1 Sum of three-day rainfall in inches as measured at the Orange County PFRD gage in Tustin.
n.d. = "no data".
The data suggests that there is no significant change in zinc concentrations between the Caspers and La Novia monitoring stations on San Juan Creek.
There is a generalized trend toward higher zinc concentrations with increased antecedent rainfall for all stations. However, this trend reverses at the highest levels of antecedent rainfall.
Note the generally higher levels found in Oso Creek.

Table 7. Inherent shallow substrate erodability proportion and occurrence of Monterey shale by sub-basin for the SAMP study area.

Description	Bell Canyon	Canada Chiquita and Narrow Canyon	Canada Gobernadora	Central San Juan and Trampas Canyon	Cristianitos Canyon	Gabino and Blind Canyons	La Paz Canyon	Lucas Canyon	Talega Canyon	Verdugo Canyon	Wagon Wheel Canyon	*Oso Creek*[1]	*Arroyo Trabuco*[1]
Unclassified	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	*0.00*	*0.00*
Erodable Sand	0.11	0.00	0.00	0.03	0.00	0.01	0.17	0.24	0.26	0.16	0.00	*0.00*	*0.17*
Alluvial	0.07	0.19	0.26	0.19	0.08	0.09	0.09	0.05	0.03	0.09	0.27	*0.07*	*0.08*
Less Erodable Upland Sand	0.23	0.00	0.00	0.01	0.00	0.00	0.00	0.20	0.00	0.00	0.01	*0.00*	*0.23*
Erodable Clay	0.03	0.12	0.09	0.15	0.14	0.10	0.01	0.04	0.15	0.02	0.06	*0.05*	*0.06*
Less Erodable Clay, Mid to Low Slope	0.02	0.17	0.08	0.05	0.12	0.11	0.02	0.15	0.04	0.05	0.04	*0.39*	*0.08*
Less Erodable Clay, High Slope	0.27	0.23	0.07	0.03	0.21	0.22	0.20	0.15	0.08	0.16	0.02	*0.38*	*0.23*
Erodable Silt, Low Slope	0.01	0.00	0.06	0.03	0.02	0.01	0.00	0.00	0.00	0.01	0.01	*0.01*	*0.00*
Erodable Silt, High Slope	0.25	0.28	0.38	0.41	0.42	0.46	0.52	0.17	0.42	0.49	0.60	*0.09*	*0.13*
Rock Outcrop	0.02	0.01	0.04	0.09	0.00	0.00	0.00	0.00	0.01	0.01	0.00	*0.00*	*0.02*
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	*1.00*	*1.00*
Aggregate groupings													
Sands	0.41	0.19	0.27	0.23	0.09	0.10	0.26	0.49	0.29	0.26	0.27	*0.08*	*0.47*
Silts	0.26	0.28	0.45	0.44	0.44	0.47	0.52	0.17	0.42	0.50	0.60	*0.10*	*0.14*
Clays	0.32	0.52	0.25	0.23	0.48	0.43	0.23	0.34	0.27	0.23	0.12	*0.82*	*0.37*
Occurrence of Monterey Shale													
Monterey Shale	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.12	*0.04*
Other Bedrock Type	0.00	0.92	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	*0.96*
Total Area (acres)	**13165**	**5910**	**5958**	**4747**	**2347**	**5323**	**4643**	**4586**	**5363**	**3069**	**1133**	***10422***	***23555***

Data source: Balance Hydrologics, Inc., 2000

Notes:

1. Oso Creek and Arroyo Trabuco are not in the SAMP study area, however they are trubutary to San Juan Creek.

Table 8. Land use and cover proportion by sub-basin for the SAMP study area.

Description	Bell Canyon	Canada Chiquita and Narrow Canyon	Canada Gobernadora	Central San Juan and Trampas Canyon	Cristianitos Canyon	Gabino and Blind Canyons	La Paz Canyon	Lucas Canyon	Talega Canyon	Verdugo Canyon	Wagon Wheel Canyon	*Oso Creek* [1]	*Arroyo Trabuco* [1]
Dunes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*0.000*	*0.000*
Sage Scrub	0.348	0.295	0.239	0.291	0.272	0.361	0.445	0.229	0.411	0.456	0.335	*0.041*	*0.168*
Chaparral	0.356	0.031	0.058	0.187	0.143	0.236	0.470	0.655	0.400	0.420	0.010	*0.004*	*0.331*
Grassland	0.086	0.188	0.136	0.212	0.413	0.268	0.039	0.050	0.084	0.050	0.377	*0.084*	*0.093*
Riparian	0.135	0.032	0.079	0.087	0.094	0.083	0.036	0.045	0.088	0.060	0.104	*0.014*	*0.090*
Woodland	0.018	0.024	0.010	0.067	0.051	0.022	0.007	0.006	0.007	0.013	0.015	*0.005*	*0.048*
Wetlands	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*0.001*	*0.000*
Streams	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	*0.004*	*0.001*
Rock Outcrops	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*0.000*	*0.001*
Agriculture	0.000	0.371	0.204	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.086	*0.000*	*0.027*
Irrigated Crops	0.000	0.017	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*0.000*	*0.000*
Vineyards	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*0.011*	*0.004*
Nurseries	0.000	0.014	0.006	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*0.006*	*0.000*
Developed	0.035	0.010	0.170	0.042	0.000	0.013	0.003	0.004	0.011	0.001	0.019	*0.703*	*0.135*
Parks	0.012	0.010	0.036	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	*0.103*	*0.018*
Disturbed Areas	0.009	0.001	0.061	0.034	0.028	0.014	0.000	0.011	0.000	0.000	0.054	*0.025*	*0.084*
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	*1.000*	*1.000*
Total Area (acres)	**13165**	**5910**	**5958**	**4747**	**2347**	**5323**	**4643**	**4586**	**5363**	**3069**	**1133**	***10422***	***23555***

Data source: PWA, 2000 (for use by WES/CRRL team)
Notes:
1. Oso Creek and Arroyo Trabuco are not in the SAMP study area, however they are trubutary to San Juan Creek.

APPENDIX A

Orange County PFRD monitoring data from San Juan Creek (Caspers Regional Park and La Novia)

Appendix A. Orange County PFRD monitoring data from San Juan Creek at La Novia, San Juan Capistrano

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
La Novia	2/7/92	14:15	ST		1400	7.9	8	7.4	0.06	<0.5	0.5		<5	<5	<20	<30	<20	<2	<40	<10	20	
La Novia	3/6/92	13:45	ST	12	940	24	8	5.4	<0.1	1.2	1.15		27	9	3	<10	6	<2	<10	<2	<10	322
La Novia	3/7/92	11:45																				
La Novia	3/7/92	13:45	ST	11	900	90	7.9	5.3	<0.1	1.4	1.15		100	18	<2	<10	6	3	<10	<2	20	190
La Novia	3/8/92	11:45																				
La Novia	6/17/92	13:40	DT	24	1400	7.1	8.1	<0.2	<0.1	0.4	0.2		18	6	<20	<30	<20	3	<40	<10	10	
La Novia	6/18/92	12:40																				
La Novia	2/8/93	12:18	ST	12	370	700	8.1	2.3	0.2	1.2	3.2		1100	110	<20	<30	<20	24	<40	<10	60	124
La Novia	2/9/93	10:18																				
La Novia	2/9/93	12:18	ST	12	340	250	8.2	1.7	0.2	0.6	1.4		280	27	<20	<30	20	3	<40	<10	19	108
La Novia	2/10/93	10:18																				
La Novia	2/10/93	12:10	ST	12	390	100	8	1.8	0.1	0.6	0.6		130	14	<7	10	60	3	8	<4	27	125
La Novia	2/11/93	10:10																				
La Novia	2/11/93	12:10	ST	11	420	66	8.1	1.8	0.1	0.5	0.6		110	12	<7	<10	40	<2	4	<4	<20	145
La Novia	2/12/93	8:10																				
La Novia	2/18/93	12:50	ST	7	440	830	8.1	2.6	0.1	2.2	5.3		1200	120	<7	32	40	10	20	<4	59	164
La Novia	2/19/93	0:50																				
La Novia	2/19/93	2:50	ST	15	250	640	8.1	1.4	<0.1	1.2	3.2		1500	130	<7	10	<30	9	8	<4	43	104
La Novia	2/20/93	7:10																				
La Novia	2/20/93	8:48	ST	12	260	320	8	1.7	0.1	1.1	1.4		620	65	<7	<10	30	2	<5	<4	24	100
La Novia	2/21/93	6:48																				
La Novia	2/21/93	8:48	ST	12	320	140	8.1	2.2	0.1	0.4	0.6		230	23	<7	<10	<30	<2	<3	<4	<20	110
La Novia	2/22/93	6:48																				
La Novia	2/23/93	9:00	ST	12	400	200	8	1.8	0.2	0.6	1.5		390	41	<7	<10	<30	3	7	<4	85	116
La Novia	2/24/93	7:00																		<4		
La Novia	2/24/93	9:00	ST	12	400	120	8	2.1	0.1	0.5	0.8		200	22	<7	<10	<30	<2	3	<4	69	120
La Novia	2/25/93	7:00																				
La Novia	2/25/93	13:54	ST	11	480	58	8	1.8	0.1	0.3	0.5		110	19	<7	<10	<30	<2	3	<4	<20	172
La Novia	2/26/93	9:54																				
La Novia	2/26/93	11:54	ST	11	430	260	8	1.9	0.1	0.8	1.7		620	70	<7	<10	30	6	<3	<4	20	136
La Novia	2/27/93	7:36																				
La Novia	6/29/93	13:05	DT	24	900	1.2	8.2	0.7	<0.1	0.3	<0.1		<5	<5								
La Novia	6/30/93	12:05																				
La Novia	7/21/93	14:10	DT	1	990	0.89	8.2	0.66	<0.1	0.41	0.28		<5	<5								
La Novia	8/9/93	14:11	DT	24	1000	2	8	1.1	0.1	0.1	0.1		5	5								
La Novia	8/10/93	13:11																				
La Novia	9/7/93	10:44	DT	24	1100	3.8	8.4	<0.2	<0.1	0.28	0.51		15	7								
La Novia	9/8/93	9:44																				
La Novia	10/5/93	13:00	DT	24	1100	0.75	8.5	<0.2	<0.1	0.32	0.31		9	9								

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
La Novia	10/6/93	12:00																				
La Novia	11/3/93	9:48	DT	24	1100	0.5	8.2	<0.4	<0.1	0.41	6		<5	<5								
La Novia	11/4/93	8:48																				
La Novia	11/11/93	3:55	ST	9	1100	360	7.8	5.4	<0.1	4.7	3.9		670	120	8.1	<10	25	3.6	<40	<10	130	340
La Novia	11/11/93	19:55																				
La Novia	11/11/93	21:55	ST	9	970	110	8	4.7	0.11	2.1	1.6		260	40	<5	<10	20	2	<40	<10	55	290
La Novia	11/12/93	13:50																				
La Novia	11/12/93	14:00	ST	1	990	11	8.1	4.9							<5	<10	70	<50	<40	<10	100	370
La Novia	11/13/93	15:55	ST	11	1000	10	8.2	2.8	<0.1	1.1	0.57		82	15	<5	<10	<20	<2	<40	<10	15	324
La Novia	11/14/93	11:55																				
La Novia	11/14/93	11:50	ST	1	1000	2	8.2	2.9							<5	<10	20	50	<40	<100	10	660
La Novia	11/14/93	13:55	ST	6	1000	2.5	8.2	2.6	<0.1	0.59	0.56		63	6	<5	<10	<20	<2	<40	<10	15	390
La Novia	11/15/93	23:55																				
La Novia	11/15/93		ST	1	1000	1.1	8.1	2.8					100	<5	<5	<10	<20	<50	<40	<100	<10	440
La Novia	12/29/93	13:30	DT	1	1100	0.72	8.6	1.8	<0.1	0.21	<0.1		5	<5								
La Novia	1/12/94	11:09	DT	24	1100	12	8.4	2.9	0.1	0.61	0.39		31	9								
La Novia	1/13/94	10:09																				
La Novia	1/25/94	2:56	ST	4	920	95	8	3.8	<0.1	0.77	0.84		240	33	<5	<10	<20	7.3	<40	<10	85	304
La Novia	1/25/94	8:56																				
La Novia	1/25/94	10:56	ST	12	1100	24	8.1	5.3	<0.1	0.4	<0.1		65	8	<5	<10	<20	<2	<40	<10	30	362
La Novia	1/26/94	8:56	SF												<5	<10	20	2	<40	<10	10	
La Novia	1/26/94	10:56	ST	6	1000	5.6	8.2	1.7	<0.1	0.97	0.46		24	8	<5	<10	<20	<2	<40	<10	14	328
La Novia	1/26/94	20:56																				
La Novia	1/27/94	10:56	ST	6	990	12	8.3	3.6	<0.1	0.8	0.39		48	16	<5	<10	<20	<2	<40	<10	17	330
La Novia	1/28/94	4:15																				
La Novia	1/28/94	6:15	ST	11	1000	6	8.3	3.4	0.1	0.6	0.32		22	5	<5	<10	20	2	<40	<10	10	354
La Novia	1/29/94	2:15																				
La Novia	2/4/94	16:46	ST	12	900	74	8.1	5.5	<0.1	1.5	0.88		<5	<5	<5	<10	<20	<2	<40	<10	11	290
La Novia	2/5/94	14:46																				
La Novia	2/5/94	16:46	ST	12	960	10	8.1	4.9	<0.1	0.7	0.32		130	26	<5	<10	<20	<2	<40	<10	<10	344
La Novia	2/6/94	14:46																				
La Novia	2/7/94	11:10	ST	4	760	120	8	6.6	0.16	2.6	2		220	7	<5	<10	<20	3.5	<40	<10	48	242
La Novia	2/7/94	17:10																				
La Novia	2/7/94	19:10	ST	8	710	490	8	6.6	0.26	3.7	3.3		910	33	<5	<10	<20	8	<40	<10	74	260
La Novia	2/8/94	9:10																				
La Novia	2/8/94	11:10	ST	12	690	260	8	6.9	0.44	3	2.1		330	10	<5	<10	20	2.9	<40	<10	52	226
La Novia	2/9/94	9:10																				
La Novia	2/9/94	11:10	ST	12	790	18	8.3	5.6	0.36	0.93	1.2		81	<5	<5	<10	<20	<2	<40	<10	26	330
La Novia	2/10/94	9:10																				
La Novia	2/10/94	11:10	ST	12	850	21	8.2	5.3	0.23	0.95	1.2		110	9	<5	<10	<20	<2	<40	<10	28	320
La Novia	2/11/94	9:10																				
La Novia	2/17/94	9:42	ST	5	670	690	7.5	8.2	0.23	1.9	3.5		1000	62	<5	32	45	20	<40	<10	130	254

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
La Novia	2/17/94	17:42																				
La Novia	2/17/94	19:42	ST	19	710	310	7.5	8.3	0.42	2.6	2.5		460	27	<5	14	20	11	<40	<10	56	275
La Novia	2/19/94	7:42																				
La Novia	2/19/94	9:42	ST	12	800	160	8.1	9.7	0.34	1.8	1.6		270	27	<5	<14	20	7.7	<40	<10	33	254
La Novia	2/20/94	7:42																				
La Novia	2/20/94	9:42	ST	10	590	560	8	8.3	0.27	2.9	4.2		1100	100	<5	30	35	21	<40	<10	120	190
La Novia	2/21/94	7:42																				
La Novia	5/4/94	12:00	DT	1	960	4	8.3	9.8	<0.1	0.79	0.97		8	<5								
La Novia	5/26/94	10:15	DT	1	1100	1	8.5	7.4	0.1	0.27	0.23		5	5								
La Novia	6/23/94	11:20	DT	1	1800	0.71	8.8	0.79	0.11	<0.2	0.43		9	<5								
La Novia	5/25/95	11:45	DT	1	720	1.2	8.3	0.9	<0.1	<0.2	<0.2		<6	<6								
La Novia	6/21/95	11:06	DT	24	720	1.3	8.3	<0.2	<0.1	0.23	0.28		<6	<6								
La Novia	6/22/95	10:06																				
La Novia	7/25/95	12:30	DT	24	940	24	8.4	0.2	0.21	1	0.2		45	18								
La Novia	7/26/95	11:30																				
La Novia	8/28/95	9:50	DT	24	1100	13.0	8.3	<0.2	0.18	0.48	<0.20		39	8								
La Novia	8/29/95	8:50																				
La Novia	9/11/95	12:40	DT	24	1100	1.0	8.5	<0.2	0.19	0.54	<0.20		<6	<6								
La Novia	9/12/95	11:40																				
La Novia	10/18/95	10:45	DT	24	1200	9.9	8.4	<0.2	<0.10	0.52	0.23		18	8								
La Novia	10/19/95	9:45																				
La Novia	11/20/95	10:57	DT	24	1100	0.4	8.3	1.0	<0.10	<0.50	<0.20		<6	<6								
La Novia	11/21/95	9:57																				
La Novia	12/20/95	9:00	DT	1	1200	1	8	4.2	0.1	0.62	0.2		6	6								
La Novia	2/14/96	12:30	DT	1	1100	2.5	8.5	2.0	0.14	0.56	<0.20		<6	<6	3	27	3	<2	<2	2	20	340
La Novia	3/12/96	14:22	ST	5	530	260.0	7.6	2.2	0.34	1.70	1.20		360	46	<1	19	43	31	15	<1	300	180
La Novia	3/12/96	15:22																				
La Novia	3/12/96	15:22	ST	13	630	230.0	7.9	3.7	0.20	1.10	1.60		430	60	<1	<10	32	18	8	<1	120	226
La Novia	3/13/96	19:22																				
La Novia	3/13/96	21:22	ST	33	6100	31.0	8.3	12.0	0.14	1.10	0.57		78	25	24	<10	26	<2	180	<1	110	2200
La Novia	3/16/96	13:22																				
La Novia	3/27/96	14:10	DT	1	940	5.2	8.0	<0.2	0.10	0.72	0.25		20	9	<1	<10	4	<2	4	<1	39	350
La Novia	4/2/96	3:13	ST	5	1000	5.8	7.6	0.6	0.14	<0.50	0.27		13	<6	<1	<10	40	11	7	<1	22	340
La Novia	4/2/96	4:13																				
La Novia	4/2/96	6:13	ST	47	870	14.0	8.0	1.4	0.17	<0.50	0.25		32	11	<1	<10	15	<2	5	<1	17	314
La Novia	4/6/96	2:13																				
La Novia	4/17/96	11:30			910	5.6	8.3	<0.2	0.10	<0.50	<0.20		25	9	<1	<10	15	<2	6	<1	19	290
La Novia	4/18/96	1:02	ST	5	810	9.1	8.0	0.3	0.18	0.78	0.37		37	9	<1	<10	16	<2	7	<1	18	280
La Novia	4/18/96	2:02																				
La Novia	4/18/96	4:02	ST	5	830	160.0	8.1	<0.2	<0.10	1.70	1.10		270	46	<1	<10	19	7	4	<1	44	260
La Novia	4/18/96	12:02																				
La Novia	4/18/96	14:02	ST	41	900	7.2	8.4	<0.2	0.10	0.58	0.24		20	8	<1	<10	11	3	<2	<1	11	290

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
La Novia	4/22/96	0:02																				
La Novia	5/28/96	15:15	DT	1	1100	1	8.4	0.8	0.1	0.5	0.2		6	6	<1	<10	2	2	<6	<1	17	
La Novia	6/19/96	12:00	DT	1	1000	2.8	8.2	<0.2	0.11	<0.50	<0.20		21	12	<1	<10	<2	<2	5	<1	12	230
La Novia	11/6/96	15:35	DT	1	1400	0.9	8.1	<0.2	0.23	0.85	<0.2		<6	<6								
La Novia	12/4/96	14:20	DT	1	1200	1.6	8.7	5.0	0.23	<0.5	<0.2		<6	<6	<1	<10	<4	<2	<4	<1	<10	395
La Novia	1/29/97	12:00	DT	1	480	25.0	7.9	1.4	<0.1	<0.5	0.39		69	10	<1	<10	4	<2	<4	2	53	160
La Novia	2/26/97	13:20	DT	1	760	3	8.4	1.2	0.11	0.54	0.23		<6	<6	<1	<10	<4	<2	<4	<1	94	240
La Novia	3/18/97	13:45	DT	1	780	0.9	9.0	1.1	<0.5	<0.5	<0.2		<6	<6	<1	<10	<4	<2	<4	<1	20	225
La Novia	4/8/97	9:50	DT	1	940	<0.5	8.3	<0.2	<0.5	<0.5	<0.2		<6	<6	<1	<10	<4	<2	<4	<1	<10	300
La Novia	5/6/97	9:45	DT	1	1100	0.7	8.0	<0.2	<0.1	<0.5	<0.2		<6	<6	<1	<10	12	<2	23	<1	15	370
La Novia	6/5/97	9:15	DT	1	1200	0.5	8.2	0.2	0.10	0.50	0.20		6	6								
La Novia	7/2/97	9:35	DT	1	1400	1	8.2	0.2	0.1	0.5	0.2		6	7								
La Novia	6/30/98	13:00	DT	1	605	1.4	9.1	<1.3	<0.05	<1.0	0		7	5								
La Novia	7/20/98	13:40	D	1																		
La Novia	8/11/98	11:51	D	1	830	3.3	8.7	<1.3	<0.05	1.0	<0.061		37	14								
La Novia	9/2/98	9:10	D	1	1140	0.2	8.4	<1.3	<0.05	1.0	<0.061		27	9								
La Novia	10/1/98	9:15	D	1	1050	0	8	1.3	0.05	0.39	0.061		4	1								
La Novia	12/7/98	12:00	D	1	930	14.0	8.4	7.1	<0.05	0.5	1		20	7								
La Novia	1/13/99	9:35	D	1	1170	4.4	8.3	4.4	<0.05	0.5	0		17	8								
La Novia	2/18/99	13:00	D	1	975	1.3	8.7	1.9	<0.05	0.4	<0.061		9	6								
La Novia	3/1/99	13:25	D	1	930	0.4	8.9	<0.44	<0.05	0.5	<0.061		<4	<1								
La Novia	4/29/99	10:00	D	1	1070	1	8.3	0.44	0.05	0.28	0.08		4	1								
La Novia	5/20/99	13:13	DT	1	1280	0.3	8.3	<0.44	<0.05	0.4	0.1		4	<1	<1	8	<2	<2	<4	<2	<10	
La Novia	5/20/99	13:13	DF												<1	11	<2	<2	<4	<2	<10	
La Novia	6/9/99	11:15	D	1	1150	0.5	8.4	1	<0.05	0.4	0.1		6	4								

Appendix A. Orange County PFRD monitoring data from San Juan Creek at Caspers Regional Park

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
Caspers	7/21/93	15:00	DT	1	480	0.66	8.2	<0.2	0.15	0.14	0.11		<5	<5								
Caspers	8/9/93	14:41	DT	24	500	0.6	7.9	<0.2	<0.1	<0.1	<0.1		<5	<5								
Caspers	8/10/93	13:41																				
Caspers	11/11/93	11:00	ST	1	1300	8200	7.6	2.4	8.7	45	21		11000	4000	<5	<10	37	<2	<40	<10	42	
Caspers	11/11/93	18:00	ST	3	830	1200	7.5	0.54	2.9	36	33		4200	1200	<5	<10	<20	8.5	<40	<10	100	310
Caspers	11/12/93	14:30																				
Caspers	11/12/93	14:30	ST	1	780	400	7.8	<0.2							<5	<10	70	<50	<40	<10	200	350
Caspers	11/12/93	20:00	ST	9	760	600	7.7	20	0.52	14	11		1100	150	<5	<10	<20	17	<40	<10	100	300
Caspers	11/15/93	7:30																				
Caspers	11/14/93	12:30	ST	1	850	870	8.2	0.52							<5	<10	<20	50	<40	<10	420	410
Caspers	11/15/93		ST	1	720	99	8	<0.2					150	37	<5	<10	<20	<50	<40	<10	40	310
Caspers	12/29/93	14:00	DT	1	640	5.3	8.7	<0.2	<0.1	0.23	0.29		16	<5								
Caspers	1/12/94	11:46	DT	24	630	2.6	8.5	0.49	<0.1	0.18	0.32		<5	<5								
Caspers	1/13/94	10:46																				
Caspers	1/26/94	12:20	ST	11	620	410	8.2	2.7	0.46	5.4	4.9		590	82	<5	<10	<20	5.9	<40	<10	35	200
Caspers	1/27/94	9:20																				
Caspers	1/27/94	12:00	ST	1											<5	<10	<20	21	<40	<10	48	147
Caspers	1/28/94	11:37	ST	7	630	170	8.4	0.45	0.35	2.2	1.6		300	96	<5	<10	<20	9.6	<40	<10	30	226
Caspers	1/28/94	23:37																				
Caspers	1/28/94	12:00	ST	1	620	120	7.3	0.51	0.28	1.5	1.5		220	49	<5	<10	<20	2	<40	<10	22	220
Caspers	2/7/94	10:30	ST	1	540	120	8.1	0.44	0.2	2.8	2.6		310	120	<5	<10	<20	3.2	<40	<10	<10	210
Caspers	2/9/94	11:00	ST	1	530	440	8	2.9	0.47	5.2	3.1		730	24	<5	<10	<20	14	<40	<10	38	176
Caspers	4/25/94	13:00	DT	2				<0.2	<0.1	4.7	3.2				<5	29	34	33	<40	<10	110	160
Caspers	4/25/94	15:00																				
Caspers	5/3/94	12:32	DT	4	570	380	8.2	0.41	0.1	4	4.7		1300	140								
Caspers	5/4/94	11:32																				
Caspers	5/26/94	10:45	DT	1	610	190	8.1	0.6	<0.1	0.84	1.4		49	41								
Caspers	6/23/94	10:55	DT	1	1100	0.96	7.9	0.67	0.15	<0.2	0.8		22	8								
Caspers	5/25/95	13:30			400	0.7	8.1	<0.2	<0.1	<0.2	<0.2		<6	<6								
Caspers	6/21/95	11:42	DT	24	490	1	8.1	0.2	0.1	0.2	0.2		6	6								
Caspers	6/22/95	10:42																				
Caspers	7/25/95	11:30	DT	24	470	20.0	8.2	<0.2	0.21	0.88	<0.20		42	24								
Caspers	7/26/95	10:30																				
Caspers	8/28/95	10:30	DT	24	530	32.0	8.3	<0.2	0.21	0.29	0.27		65	24								
Caspers	8/29/95	9:30																				
Caspers	9/11/95	14:03	DT	24	980	3.4	8.4	<0.2	<0.10	0.76	<0.20		<6	<6								
Caspers	9/12/95	13:03																				
Caspers	2/14/96	13:00	ST	1	490	1.4	8.3	<0.2	0.32	<0.50	<0.20		15	10	<1	13	3	<2	<2	<1	20	135
Caspers	3/12/96	15:18	ST	5	440	1.1	7.9	0.6	<0.10	<0.50	<0.20		<6	<6	<1	<10	12	<2	5	<1	17	142

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
Caspers	3/12/96	16:18																				
Caspers	3/12/96	18:18	ST	11	370	32.0	7.9	0.2	<0.10	<0.50	0.41		40	12	<1	<10	15	3	3	<1	20	198
Caspers	3/13/96	14:18																				
Caspers	3/13/96	16:18	ST	36	360	3.6	8.0	0.2	<0.10	<0.50	<0.20		<6	<6	<1	<10	16	<2	<4	<1	110	128
Caspers	3/16/96	14:18																				
Caspers	3/27/96	14:35	DT	1	440	1	7.8	1	0.1	0.5	0.2		6	6	<1	<10	<3	2	<2	<1	37	320
Caspers	4/17/96	13:00	DT	1	450	0.3	7.6	<0.2	0.10	<0.50	<0.20		<6	<6	<1	<10	<2	<2	<4	<1	23	115
Caspers	5/28/96	15:45	DT	1	450	0.6	7.6	<0.2	<0.10	<0.50	<0.20		<6	<6	<1	<10	<2	<2	7	<1	23	
Caspers	1/29/97	14:15	DT	1	260	4.0	7.8	1.1	<0.1	<0.5	<0.2		<6	<6	<1	<10	<4	<2	<4	<1	28	70
Caspers	2/26/97	12:50	DT	1	390	0.9	7.7	0.8	<0.1	<0.5	<0.2		<6	<6	<1	<10	<4	<2	<4	<1	<10	140
Caspers	3/18/97	14:20	DT	1	410	<0.5	7.7	0.6	<0.5	<0.5	<0.2		<6	47	<1	<10	<4	<2	<4	<1	16	135
Caspers	4/8/97	10:20	DT	1	400	<0.5	7.5	<0.2	<0.5	<0.5	<0.2		<6	<6	<1	<10	<4	<2	<4	<1	<10	140
Caspers	5/6/97	10:15	DT	1	430	<0.5	7.6	<0.2	<0.1	<0.5	<0.2		<6	<6	<1	<10	4	<2	5	<1	21	134
Caspers	6/5/97	9:55	DT	1	450	0.5	7.2	0.2	0.10	0.50	0.20		6	6								
Caspers	6/30/98	13:30	DT	1	390	0.40	7.8	<1.3	<0.05	<1.0	0.06		4	2								
Caspers	7/20/98	14:00	D	1	400	0	7.8	1.3	0.05	1.4	0.061		4	1								
Caspers	8/11/98	12:14	D	1	430	0.9	7.6	<1.3	<0.05	<1	<0.061		10	6								
Caspers	9/2/98	9:37	D	1	410	0.2	7.7	<1.3	<0.05	<1	0.09		<4	<1								
Caspers	10/1/98	9:45	D	1	435	0.3	7.5	<1.3	<0.05	<0.2	<0.061		<4	<1								
Caspers	12/7/98	12:40	D	1	425	0.2	7.9	<1.3	<0.05	0.3	0.061		<4	<1								
Caspers	1/13/99	9:15	D	1	460	0	7.6	0.53	0.05	0.2	0.061		4	5								
Caspers	2/18/99	12:20	D	1	460	0.2	7.8	<0.44	<0.05	0	0.06		<4	<1								
Caspers	3/1/99	13:15	D	1	445	0.2	7.7	<0.44	<0.05	<0.2	<0.061		<4	<1								
Caspers	4/29/99	9:30	D	1	430	0.2	7.6	<0.44	<0.05	<0.2	<0.061		<4	<1								
Caspers	5/20/99	12:35	DT	1	455	0.2	7.7	<0.44	<0.05	0.4	<0.061		<4	<1	<1	<8	<2	4	<4	<2	<10	
Caspers	5/20/99	12:35	DF												<4	<8	<3	2	<4	<2	12.6	
Caspers	6/9/99	10:45	D	1	405	0.2	7.7	0.8	<0.05	1.5	0.1		<4	<1								

APPENDIX B
Historical monitoring data from San Juan Creek

Appendix B. Compilation of historical water quality data for the mainstem of San Juan Creek, Orange County, California

STATION	DATE	Flow cfs	Ave Depth m	EC umhos	DO mg/L	pH	Temp C	F mg/L	Cl mg/L	NO3 mg/L	SO4 mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	SiO2 mg/L	B mg/L	Hardness mg/L	CO3 mg/L	HCO3 mg/L	TDS mg/L	Salinity ppt
SJ at mile 0.4	3/26/54	5		527		7.9			30	2.5	103	55	13	40	1.9		0.04	190	0	156	350	
SJ at mile 0.4	5/4/54	12		1001		7.7		0.3	70	0.6	264	111	264	67	2.1		0.2	386	0	200	510	
SJ at mile 0.4	1/19/55			1099		7.8	13.3	0.7	92	3.9	285	125	28	81	3.7		0.23	428		217	788	
SJ at mile 2.6	3/26/54	2.5		721		7.2			33	0	199	77	21	44	2		0.1	279	0	144	509	
SJ at mile 2.6	3/26/54	50		424		8.0	13.9		28	0	72	46	9	34	1.3		0.04	152	0	144	288	
SJ at mile 2.6	1/26/56	125		845		7.1			77	38	190	63	24	45	9.9		0.18	256	0	74	572	
SJ at mile 2.6	2/4/58	150		1376		7.5		0.5	186	8	286	101	34	128	10.2	10	0.08	391	0	129	881	
SJ at mile 2.6	4/3/58	3000		373		7.5		0.5	22	0	61	39	8	22	3.9	28	0	131	0	111	257	
SJ at mile 2.6	1/6/59	40		975		7.9	20	0.5	86	1	222	82	24	92	3	10	0.32	306	0	181	640	
SJ at mile 2.6	2/17/59			534		7.1	15	0.1	28	9.3	91	60	12	28	4.9	18	0.02	198	0	159	365	
SJ at mile 2.6	2/9/60	75		435		7.4	12.2	0.3	25	6.2	67	52	14	17	3.1	22	0.14	188	0	146	295	
SJ at mile 5.7 USGS g	3/1/51	1.75		757		8.1			61	1.6	137	69	16	70	1.5	25	0.24	238	0	198	490	
SJ at mile 5.7 USGS g	4/8/52	67		397		7.7			34	0.5	61	44	10	33	1.3		0.07	151	0	139	298	
SJ at mile 5.7 USGS g	12/20/52	5		775	8.1				71										0	195		
SJ at mile 5.7 USGS g	8/10/53			878		7.7			71	1.2	172	78	19	78	2.6		0.1	274	0	290	528	
SJ at mile 5.7 USGS g	3/26/54	85.4		405		7.9			26	2	60	41	11	30	1		0.12	147	0	142	264	
SJ at mile 5.7 USGS g	1/10/55	6.73		495		7.0		0.4	57	10.7	125	42	16	36	12.1		0.1	171		67	353	
SJ at mile 5.7 USGS g	2/17/55			751		8.1			66	1	131	54	25	69	1.6		0.16	238	7	178	435	
SJ at mile 5.7 USGS g	1/6/59	30		712		7.6		0.6	62	1	114	56	17	71	2.4	10	0.3	209	0	188	445	
SJ at Highway 74	May-98		13	890			23.3															
SJ at Highway 74	Sep-98		13	890			23.3															
SJ at Highway 74	Nov-98		15.8	700	9.25	7.2	14.4															
SJ at Highway 74	May-99		19.3	1012	6.32	8.2	16.2															0.5

Source data from:
RWQCB9, 1999 Biological Assessment Annual Report
Toups Engineering, 1966, Report on Local Water Supply, Rancho Mission Viejo
California Department of Water Resources, 1964, San Juan Creek Ground Water Study

Appendix B. Historical monitoring data from San Juan Creek

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
Station X11005.10 San Juan Creek at Pacific Coast Highway					
5/14/64	---	4149	8.4	---	---
4/7/65	---	3910	8.0	---	---
Station X11010.10 San Juan Creek above Capistrano Beach S.T.P.					
3/26/54	5	527	7.9	2.5	350
5/4/54	12	1001	7.7	0.6	510
1/19/55	---	1099	7.8	3.9	740
5/14/64	---	3696	8.3	---	---
7/19/66	1.0	2750	---	---	1760
7/25/66	---	2546	7.8	28.0	---
11/19/68	1.3	2540	7.9	35.0	1912
2/10/70	22	1132	7.4	7.0	755
Station X11020.10 Remmer Drainage System at mouth above San Juan Creek					
7/16/64	---	4149	7.3	116.0	---
Station X11030.10 San Juan Creek below confluence of Trabuco Creek					
1/22/62	---	884	8.1	---	---
8/16/62	---	1723	7.8	---	1200
7/6/67	---	1390	7.9	3.0	1000
2/10/70	21	1064	7.4	6.0	694
Station X11040.00 San Juan Creek at Camino Capistrano					
3/26/54	3	721	7.2	0.0	509
3/26/54	50	424	8.0	0.0	250
1/26/56	125	845	7.1	38.0	572
2/3/58	150	1376	7.5	0.5	881
4/3/58	3000	373	7.5	0.0	257
1/6/59	40	975	7.9	1.0	640
2/17/59	---	534	7.1	9.3	365
2/9/60	75	435	7.4	6.2	295
2/9/62	30	460	7.6	9.5	352
1/27/69	650	363	7.6	4.0	---
2/10/70	13	1074	7.6	1.0	711
Station X11045.10 Horno Creek at mouth above San Juan Creek					
7/19/66	2.0	2010	---	---	1286
7/25/66	---	2160	8.1	17.0	---
Station X11100.00 San Juan Creek at Ortega Highway					
3/1/51	1.8	757	8.1	1.6	490
4/8/52	6.7	397	7.7	0.5	298
12/20/52	5.0	775	8.1	---	---
8/10/53	---	878	7.7	1.2	528
3/26/54	85.4	405	7.9	2.0	264
1/10/55	6.7	495	7.0	10.7	353

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
2/17/55	---	751	8.1	1.0	435
1/6/59	30.0	712	7.6	1.0	445
1/22/62	---	753	7.8	0.0	509
2/9/62	---	813	8.1	6.0	548
4/5/62	---	691	8.0	---	441
4/5/62	---	---	8.0	0.0	441
4/3/65	0.5	941	7.8	0.0	611
4/8/65	1.0	916	7.7	---	---
11/23/65	449.0	296	7.6	---	---
7/19/66	1.5	862	8.0	0.0	---
1/10/67	13.3	616	8.1	2.0	---
1/23/67	86.3	484	7.7	4.0	---
1/22/69	---	452	7.6	5.0	---
2/10/69	7	782	8.0	0.0	483
2/14/69	300.0	442	7.9	4.0	312
2/24/69	2500.0	221	7.7	3.9	---

Station X11100.10 San Juan Creek near San Juan Capistrano

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
1/22/62	---	742	8.0	---	507
2/9/62	---	794	8.1	---	515

Station X11110.10 San Juan Creek at proposed damsite below mouth Canada Chiquita

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
7/19/66	1.5	850	---	---	550

Station X11115.10 Canada Chiquita Creek at Farm Road above San Juan Creek

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
1/22/62	---	1196	8.3	---	880
2/9/62	---	598	8.3	---	590
7/11/62	---	---	8.3	---	942
7/19/66	---	1800	---	---	1152
7/10/67	---	1700	8.7	2.0	---

Station X11125.10 Canada Gobernadora 0.5 miles above San Juan Creek

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
2/9/62	---	660	7.9	---	452
7/19/66	1.0	890	---	---	570
1/10/67	---	2870	8.0	3.0	---

Station X11140.10 San Juan Creek above California Aggregate Products

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
7/19/66	0.5	590	---	---	378

Station X11150.10 Verdugo Canyon Creek at Ortega Highway

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
1/10/67	---	521	8.2	9.0	---

Station X11155.10 Bell Canyon above San Juan Creek

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
1/22/62	---	620	8.3	---	554
2/9/62	---	3	7.2	---	8
1/10/67	---	635	8.1	4.0	---

Station X11160.10 San Juan Creek above Bell Canyon

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
1/22/62	---	721	8.1	---	481
2/9/62	---	435	7.9	---	267

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
Station X11175.10 Lucas Canyon Creek 0.5 miles east of San Juan Creek					
7/19/66	---	800	---	---	512
1/10/67	---	521	8.7	2.0	---

Notes:

All data have been transcribed from moderately legible tables included in DWR Bulletin No. 104-7. Some errors in transcription to electronic spreadsheet form are likely and these data should only be used for general comparitive purposes without consulting an original version of the bulletin.
Discharge values shown to the nearest whole number were cited as estimated values in the source document.

APPENDIX C

Orange County PFRD monitoring data from San Juan Creek tributaries (Oso Creek and Arroyo Trabuco)

Appendix C. Orange County PFRD monitoring data from Arroyo Trabuco at Camino Capistrano.

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
Arroyo Trabuco	3/19/94	1:21	ST	3	390	110	7.8	4.1	0.57	3.1	1.8		240	54	<5	18	39	55	<40	<10	220	120
Arroyo Trabuco	3/19/94	5:21																				
Arroyo Trabuco	3/19/94	7:21	ST	7	520	220	7.7	2.4	0.15	1.6	1.6		270	44	<5	16	<20	6.9	<40	<10	44	170
Arroyo Trabuco	3/19/94	19:21																				
Arroyo Trabuco	3/19/94	21:21	ST	6	530	120	7.7	3.5	0.18	1	0.94		75	28	<5	<10	<20	8.8	<40	<10	15	180
Arroyo Trabuco	3/20/94	7:21																				
Arroyo Trabuco	3/20/94	9:21	ST	12	600	27	8.3	3	<0.1	0.77	0.57		13	<5	<5	<10	<20	<2	<40	<10	14	196
Arroyo Trabuco	3/21/94	7:21																				
Arroyo Trabuco	3/21/94	9:21	ST	12	660	16	8.3	2.8	<0.1	0.91	0.57		7	<5	<5	<10	<20	<2	<40	<10	10	204
Arroyo Trabuco	3/22/94	7:21																				
Arroyo Trabuco	3/22/94	9:21	ST	8	700	8.1	8.1	3.1	<0.1	0.2	0.35		<5	<5	<5	<10	<20	<2	<40	<10	21	254
Arroyo Trabuco	3/22/94	23:21																				
Arroyo Trabuco	3/24/94	18:25	ST	3	420	76	8.1	2.6	0.1	1.7	5.8		150	6	<5	<10	23	37	<40	<10	84	108
Arroyo Trabuco	3/24/94	22:25																				
Arroyo Trabuco	3/25/94	0:25	ST	7	500	320	8	2.3	0.1	0.9	1.9		350	36	<5	<19	<24	8.5	<40	<10	55	172
Arroyo Trabuco	3/25/94	12:25																				
Arroyo Trabuco	3/25/94	14:25	ST	10	530	120	8	2.6	<0.1	1.3	4.6		92	14	<5	<10	<20	4.1	<40	<10	20	178
Arroyo Trabuco	3/26/94	8:25																				
Arroyo Trabuco	3/26/94	10:25	ST	12	610	28	8.2	2.6	<0.1	0.66	0.64		11	6	<5	<10	<20	2.6	<40	<10	<10	200
Arroyo Trabuco	3/27/94	8:25																				
Arroyo Trabuco	3/27/94	10:25	ST	12	680	15	8.2	2.6	<0.1	0.73	0.38		9	<5	<5	<10	<20	<2	<40	<10	<10	222
Arroyo Trabuco	3/28/94	8:25																				
Arroyo Trabuco	3/28/94	10:25	ST	5	730	12	8.6	2.8	<0.1	0.28	0.85		<5	<5	<5	<10	<20	<2	<40	<10	<10	256
Arroyo Trabuco	3/28/94	18:25																				
Arroyo Trabuco	4/25/94	14:25	ST	4	670	15	8.2	1.2	0.1	0.78	0.75		12	6	<5	<10	<20	7.8	<40	<10	35	210
Arroyo Trabuco	4/25/94	20:25																				
Arroyo Trabuco	4/25/94	22:25	ST	19	710	34	8.3	1.6	<0.1	0.47	0.88		35	7	<5	<10	<20	<2	<40	<10	19	212
Arroyo Trabuco	4/27/94	10:25																				
Arroyo Trabuco	4/27/94	12:25	ST	10	710	16	8.2	2.3	0.1	0.68	0.52		5	<5	<5	11	<20	<2	<40	<10	14	234
Arroyo Trabuco	4/28/94	6:25																				
Arroyo Trabuco	4/28/94	8:25	ST	10	750	8.2	8.2	2	<0.2	0.27	0.42		<5	<5	<5	<10	<20	<2	<40	<10	12	236
Arroyo Trabuco	4/29/94	2:25																				
Arroyo Trabuco	1/21/96	18:56	ST	33	490	1200.0	7.9	2.6	0.15	5.10	4.60		2000	210	3	72	84	39	76	<1	380	330
Arroyo Trabuco	1/21/96	23:56																				
Arroyo Trabuco	2/20/96	13:22	ST	15	370	700	7.9	3.3	0.1	2.2	3.1		1400	100	<1	<50	<54	2	<2	<1	180	120
Arroyo Trabuco	2/21/96	17:22																				
Arroyo Trabuco	11/21/96	14:30	ST	1	500	240.0	8.9	3.0	0.56	2.50	1.80		430	68	1	28	55	57	18	<1	380	160
Arroyo Trabuco	11/21/96	16:30	ST	3	480	770.0	8.3	4.0	0.16	3.20	3.50		1200	110	11	47	72	24	24	<1	240	208
Arroyo Trabuco	11/21/96	20:30																				
Arroyo Trabuco	5/20/99	11:00	DT	1	1040	0.7	8.3	<0.44	<0.05	0.6	0.1		7	3	<1	8	2	<2	<4	<2	<10	
Arroyo Trabuco	5/20/99	11:00	DF												<1	8	2	<2	<4	<2	<10	

Appendix C. Orange County PFRD monitoring data from Oso Creek at Mission Viejo

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
Mission Viejo	8/27/91	11:15		26	3400	3	8.1	<0.2	<0.1	0.7	1.2		11	<5								
Mission Viejo	8/28/91	12:15																				
Mission Viejo	12/12/91	13:45			9800	8	8.1	5.1	0.4	1.7	1.3		<5	<5								
Mission Viejo	3/5/92	17:00	ST	5	2600	3.3	8.2	5.5	<0.1	0.9	0.9		<5	<5	<2	<10	37	<2	20	<2	<10	1004
Mission Viejo	3/6/92	5:00																				
Mission Viejo	3/6/92	8:00	ST	9	1400	75	7.8	4.9	<0.1	0.8	1.2		120	18	18	<10	10	3	20	<2	30	502
Mission Viejo	3/6/92	11:00																				
Mission Viejo	3/8/92	17:00	ST	5	1800	20	7.9	6.1	<0.1	1.1	1.2		26	8	2	<10	7	<2	10	<2	20	660
Mission Viejo	3/9/92	17:00																				
Mission Viejo	3/20/92	15:04	ST	4	1600	430	7.5	2.3	<0.3	1.1	2.6		900	120	20	30	30	13	40	<10	100	560
Mission Viejo	3/20/92	17:04																				
Mission Viejo	3/20/92	18:04	ST	9	630	340	7.5	3	<0.1	0.7	2.3		500	72	<20	<30	<20	3	<40	<10	110	240
Mission Viejo	3/21/92	21:04																				
Mission Viejo	3/22/92	3:04	ST	11	1100	48	7.6	2.9	<0.1	0.9	1.7		120	14	<20	<30	<20	2	<40	<10	30	414
Mission Viejo	3/24/92	13:46																				
Mission Viejo	3/26/92	18:04	ST	4	1800	8.3	7.9	5.3	0.1	0.7	0.6		15	7	<7	<10	14	5	10	<2	70	676
Mission Viejo	3/26/92	20:04																				
Mission Viejo	3/26/92	21:04	ST	8	1700	7.9	7.9	5.9	<0.1	0.5	0.4		9	6	<7	<10	11	4	<10	<2	<10	622
Mission Viejo	3/27/92	18:04																				
Mission Viejo	3/28/92	0:04	ST	12	2500	10	8	4.5	<0.1	0.5	0.4		20	7	7	10	5	5	10	<2	10	945
Mission Viejo	3/29/92	18:04																				
Mission Viejo	12/17/92	11:15	ST	5	2000	200	8	4.5	0.2	2.8	6.6		480	60	<20	<30	24	11	45	<10	100	
Mission Viejo	12/17/92	15:15																				
Mission Viejo	12/17/92	16:15	ST	7	960	67	7.8	3.2	0.2	1.6	1.7		120	24	<20	<30	<20	<2	<40	<10	40	
Mission Viejo	12/18/92	10:15																				
Mission Viejo	12/18/92	16:15	ST	12	2100	10	8.1	2.4	<0.1	0.7	1		14	6	<20	<30	<20	<2	<40	<10	29	
Mission Viejo	12/20/92	10:15																				
Mission Viejo	12/29/92	7:50	ST	6	650	470	7.9	1.7	0.3	1.8	9.8		1100	120	<20	<30	<20	6	<40	<10	74	
Mission Viejo	12/29/92	17:50																				
Mission Viejo	12/29/92	19:50	ST	5	730	440	7.9	2.1	<0.3	1.6	9.7		1000	110	20	30	20	6	40	<10	55	
Mission Viejo	12/30/92	3:50																				
Mission Viejo	12/30/92	5:50	ST	5	750	79	7.8	1.9	0.3	0.6	5.8		140	23	<20	<30	<20	2	<40	<10	27	
Mission Viejo	12/30/92	13:50																				
Mission Viejo	12/30/92	15:50	ST	8	1300	41	8.1	2	0.3	0.5	1.4		58	10	<20	<30	<20	4	<40	<10	23	
Mission Viejo	12/31/92	5:50																				
Mission Viejo	12/31/92	7:50	ST	12	2000	4	8.1	2.3	0.2	1	1		21	6	<20	<30	<20	<2	<40	<10	38	
Mission Viejo	1/1/93	5:50																				
Mission Viejo	1/1/93	7:50	ST	12	2400	2.2	8.2	2.5	0.2	1.8	1		24	6	<20	<30	<20	<2	<40	<10	40	
Mission Viejo	1/2/93	5:50																				

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
Mission Viejo	1/6/93	1:50	ST	5	1000	1100	7.8	3.7	<0.1	1.3	2.8		950	75	20	30	20	8	40	<10	56	340
Mission Viejo	1/6/93	5:50																				
Mission Viejo	1/6/93	6:50	ST	8	510	470	7.9	3.3	0.1	1.4	5.4		1300	91	<20	<30	<20	3	46	<10	89	180
Mission Viejo	1/7/93	6:50																				
Mission Viejo	1/7/93	12:50	ST	11	970	1400	7.9	3.7	0.1	1.4	4		840	63	<20	<30	<20	7	<40	31	52	330
Mission Viejo	1/8/93	12:50																				
Mission Viejo	1/8/93	12:35	ST	9	1200	100	8.1	4.2	<0.1	1.2	1.5		200	26	<20	<30	<20	3	<40	<10	41	416
Mission Viejo	1/9/93	4:35																				
Mission Viejo	1/9/93	6:35	ST	15	2000	25	8.3	5.6	0.1	1.2	1		58	12	<20	<30	<20	<2	<40	<10	36	748
Mission Viejo	1/10/93	20:35																				
Mission Viejo	12/19/93	3:00	ST	6	2000	54	8.1	7.3	<0.1	0.92	1.3		89	6	5	10	23	4.3	40	<10	41	684
Mission Viejo	12/19/93	13:00																				
Mission Viejo	12/19/93	15:00	ST	11	2100	50	8.1	8.3	<0.1	0.82	1		71	<5	<5	<10	<20	2.1	<40	<10	37	705
Mission Viejo	12/20/93	11:00																				
Mission Viejo	12/20/93	13:00	ST	12	2100	18	8.1	5.6	<0.1	1.1	1.2		30	30	<5	10	<20	<2	<40	<10	25	772
Mission Viejo	12/21/93	11:00																				
Mission Viejo	12/21/93	13:00	ST	12	2500	8.8	8.1	0.2	<0.1	1.1	0.55		21	21	5.1	<10	<20	<2	<40	10	30	780
Mission Viejo	12/22/93	9:00																				
Mission Viejo	12/22/93	11:00	ST	8	2800	5.5	8.2	4.5	<0.1	0.91	0.65		24	<5	<5	<10	20	<2	<40	<10	20	1032
Mission Viejo	12/23/93	1:00																				
Mission Viejo	2/3/94	18:30	ST	2	2400	110	8	6.8	<0.5	3.1	1.9		290	41	5	10	20	5.6	40	<10	56	1010
Mission Viejo	2/3/94	20:30																				
Mission Viejo	2/3/94	22:30	ST	3	790	180	6.9	4.3	0.44	2.7	2.7		420	51	6.5	19	50	16	58	<10	140	250
Mission Viejo	2/4/94	2:30																				
Mission Viejo	2/7/94	2:00	ST	4	1400	36	8	6.1	0.56	1.4	0.91		190	22	<5	<10	24	3	<40	<10	38	464
Mission Viejo	2/7/94	8:00																				
Mission Viejo	2/7/94	10:00	ST	13	510	180	8.2	4	0.6	1.2	2.8		560	58	<5	<10	22	7.3	<40	<10	92	156
Mission Viejo	2/8/94	10:00																				
Mission Viejo	2/8/94	12:00	ST	12	980	52	8.1	4	0.14	0.69	2		150	15	<5	<10	25	<2	<40	<10	42	320
Mission Viejo	2/9/94	10:00																				
Mission Viejo	2/9/94	12:00	ST	12	1900	11	8.1	5.8	<0.1	0.83	1.5		80	10	5	10	20	2	40	<10	15	694
Mission Viejo	2/10/94	10:00																				
Mission Viejo	2/10/94	12:00	ST	7	2500	7.6	8.2	5.8	0.27	0.35	1		27	7	<5	<10	<20	<2	<40	<10	31	990
Mission Viejo	2/11/94	0:00																				
Mission Viejo	2/17/94	7:29	ST	3	1200	240	7.9	4.4	0.31	3.1	2.7		690	44	<5	48	50	16	<40	<10	150	410
Mission Viejo	2/17/94	11:29																				
Mission Viejo	2/17/94	13:29	ST	11	910	240	8	6.5	0.76	2.6	2.7		530	47	6.3	39	38	7.4	41	<10	170	296
Mission Viejo	2/18/94	9:29																				
Mission Viejo	2/18/94	11:29	ST	11	1000	170	7.6	6	0.45	1.8	2.6		360	20	<5	22	23	12	<40	<10	87	360
Mission Viejo	2/19/94	7:29																				
Mission Viejo	2/19/94	9:27	ST	11	1300	29	7.8	8.1	<0.1	0.24	1.1		45	6	5	14	20	2	40	<10	22	472
Mission Viejo	2/20/94	5:27																				
Mission Viejo	2/20/94	7:27	ST	13	940	330	7.9	5.7	0.2	2.1	3.3		700	52	10	45	28	10	<40	<10	120	268

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
Mission Viejo	2/21/94	7:27																				
Mission Viejo	11/16/94	6:00	ST	3	2400	56	7.8	6.1	0.2	2.9	1.4		120	26	2.7	<10	28	7.3	<40	<0.3	72	975
Mission Viejo	11/16/94	10:00																				
Mission Viejo	3/2/95	19:30	ST	3	2900	54	8.0	8.5	<0.1	3.2	1.2		130	30	5	<10	6	6.5	<40	1.5	64	1008
Mission Viejo	3/2/95	23:30																				
Mission Viejo	3/3/95	1:30	ST	16	1300	130	7.8	4.2	0.24	2.1	1.7		210	32	4.8	<10	25	8.5	<40	3.6	69	378
Mission Viejo	3/4/95	7:30																				
Mission Viejo	3/4/95	9:30	ST	8	1300	42	7.6	2.6	<0.1	1.1	0.94		65	14	1	10	26	3.5	40	<1	28	346
Mission Viejo	3/4/95	23:30																				
Mission Viejo	3/5/95	1:30	ST	16	690	240	7.6	1.9	0.23	2.3	4.2		880	82	4.5	30	31	11	<40	<1	110	214
Mission Viejo	3/6/95	7:30																				
Mission Viejo	3/10/95	22:54	ST	18	1300	230	7.9	3.3	0.25	3.0	3.3		680	79	3.7	27	41	11	63	<1	120	402
Mission Viejo	3/12/95	8:54																				
Mission Viejo	3/12/95	10:54	ST	9	2500	16	8.0	5.6	<0.1	0.74	0.85		28	<5	7.4	<10	29	<2	59	<1	41	875
Mission Viejo	3/13/95	2:54																				
Mission Viejo	1/19/96	9:08	ST	5	1900	65.0	8.1	9.0	0.49	3.10	1.10		100	22	3	<10	22	4	19	<1	58	712
Mission Viejo	1/19/96	10:08																				
Mission Viejo	1/19/96	12:08	ST	4	2300	48	8.3	9	<0.3	2.6	1.2		76	18	2	16	19	5	18	<1	51	872
Mission Viejo	1/19/96	18:08																				
Mission Viejo	1/19/96	20:08	ST	23	2500	30.0	8.1	7.7	<0.10	1.20	0.73		49	7	2	<10	29	2	24	<1	43	988
Mission Viejo	1/21/96	20:08																				
Mission Viejo	1/21/96	22:08	ST	3	680	630.0	7.7	3.0	0.67	4.80	6.20		1500	190	26	59	140	35	82	<1	400	210
Mission Viejo	1/22/96	2:08																				
Mission Viejo	1/22/96	10:08	ST	12	1200	46.0	7.7	3.8	0.43	1.50	1.40		57	15	4	<10	19	3	17	<1	59	364
Mission Viejo	1/23/96	8:08																				
Mission Viejo	1/31/96	2:58	ST	5	2100	64.0	8.1	3.3	<0.10	4.20	1.20		92	16	3	<10	30	8	23	1	120	736
Mission Viejo	1/31/96	3:58																				
Mission Viejo	1/31/96	5:58	ST	12	560	230	7.8	5.9	<0.4	5.2	3.1		470	58	7	28	46	16	27	<2	150	162
Mission Viejo	2/1/96	3:58																				
Mission Viejo	2/1/96	5:58	ST	18	1100	50.0	8.0	5.7	0.30	1.70	1.70		67	18	2	<10	26	3	13	6	46	458
Mission Viejo	2/2/96	11:58																				
Mission Viejo	2/20/96	2:12	ST	5	2400	29.0	7.7	3.1	<0.10	2.80	0.90		84	<20	2	<10	21	3	13	<1	57	846
Mission Viejo	2/20/96	3:12																				
Mission Viejo	2/20/96	5:12	ST	7	510	310.0	7.7	3.7	0.17	2.80	3.20		710	78	6	31	41	<2	<2	<1	160	160
Mission Viejo	2/20/96	17:12																				
Mission Viejo	2/20/96	19:12	ST	20	710	140.0	7.8	15.0	0.27	1.90	2.70		380	38	4	19	29	<2	<2	<1	98	208
Mission Viejo	2/22/96	9:21																				
Mission Viejo	2/22/96	11:21	ST	21	2300	21	8.1	6.3	<0.2	1.6	1.4		27	9	1	10	21	2	24	<1	10	732
Mission Viejo	2/24/96	3:21																				
Mission Viejo	10/30/96	6:46	ST	5	1700	170.0	7.3	15.0	1.60	6.70	3.20		290	68	6	15	62	7	30	<1	510	604
Mission Viejo	10/30/96	7:46	F												<1	<10	14	<2	18	<1	190	
Mission Viejo	10/30/96	10:01	ST	5	760	380.0	7.4	6.8	1.00	6.60	5.00		910	140	15	36	43	21	37	1	280	244

STATION	DATE	TIME	SAMPLES Type	#	EC umhos	Turb NTU	pH	NO3 mg/L	NH3 mg/L	TKN mg/L	PO4 mg/L	o-PO4 mg/L	TSS mg/L	VSS mg/L	Cd ug/L	Cr ug/L	Cu ug/L	Pb ug/L	Ni ug/L	Ag ug/L	Zn ug/L	Hardness mg/L
Mission Viejo	10/30/96	18:01																				
Mission Viejo	10/30/96	20:01	ST	43	2100	29.0	8.2	6.4	0.54	1.10	1.20		48	11	2	<10	17	6	13	<1	56	814
Mission Viejo	11/3/96	8:01																				
Mission Viejo	12/9/96	13:21	ST	5	1800	51.0	8.0	5.8	0.18	1.80	0.94		72	19	2	<10	22	6	13	<1	110	700
Mission Viejo	12/9/96	14:21																				
Mission Viejo	12/9/96	16:21	ST	7	590	210	7.6	4.1	<0.2	2.1	2.4		380	44	3	17	32	11	17	<1	110	158
Mission Viejo	12/10/96	4:21																				
Mission Viejo	12/10/96	6:21	ST	9	1000	120.0	7.9	5.4	0.21	1.60	0.93		105	18	1	<10	15	<2	11	<1	44	335
Mission Viejo	12/10/96	22:21																				
Mission Viejo	12/11/96	0:21	ST	13	670	150.0	7.8	3.7	0.19	1.70	1.60		240	28	2	<10	21	4	15	<1	61	230
Mission Viejo	12/12/96	0:21																				
Mission Viejo	12/12/96	2:21	ST	17	1800	23.0	8.1	5.8	0.23	1.90	<0.2		37	7	3	<10	15	<2	21	<1	98	700
Mission Viejo	12/13/96	10:21																				
Mission Viejo	3/25/98	6:00	ST	5	2760	20	7.65	8	0	1.8	<0.1		33	19								1080
Mission Viejo	3/25/98	7:00	SF												2	3	14	2	26	<1.00	54	
Mission Viejo	11/8/98	5:45	ST	5	2250	200	7.6	8.4	<0.4	6.81	6.12		960	180	9.88	40.2	59.2	46.7	33	<2	288	755
Mission Viejo	11/8/98	6:45	SF												<1	<8	9	<2	10	<2	21	
Mission Viejo	11/8/98	8:45	ST	8	745	44	7.6	7.0	0.3	2.2	2.9		200	120	9	14	25	6	21	<2	96	240
Mission Viejo	11/8/98	22:45	SF												4	9	16	3	14	<2	55	
Mission Viejo	11/9/98	0:45	ST	39	1960	9	8.0	6.6	0.2	1.2	0.6		38	14	1	<8	13	<2	8	<2	24	685
Mission Viejo	11/12/98	4:45	SF												1.1	8	10.7	2	7.68	<2	19.8	
Mission Viejo	1/25/99	4:30	ST	5	1680	130	7.7	5.5	0.2	4.0	2.7		730	150	8	19	35	20	28	<2	136	620
Mission Viejo	1/25/99	5:30	SF												<1	<8	8	<2	12	<2	11	
Mission Viejo	1/25/99	7:30	ST	11	785	26	7.7	4.6	0.1	1.3	0.9		100	30	3	<8	17	3	10	<2	34	280
Mission Viejo	1/26/99	3:30	SF												1	<8	10	<2	9	<2	13	
Mission Viejo	1/26/99	5:30	ST	15	700	60	7.7	4.05	<0.2	1.312	1.5		200	60	3.64	9.1	26.4	6.08	28.8	<2	65.6	210
Mission Viejo	1/27/99	9:30	SF												<1	<8	12	<2	6	<2	14	
Mission Viejo	1/27/99	11:30	ST	21	1300	26	7.8	5.1	0.1	1.0	1.1		58	34	2	<8	19	3	12	<2	32	404
Mission Viejo	1/29/99	3:30	SF												1	<8	12	<2	6	<2	14	
Mission Viejo	3/11/99	11:56	ST	5	2710	28	8.4	3.5	<0.05	1.0	0.5		98	20	3	<8	23	4	16	<2	49	1048
Mission Viejo	3/11/99	12:56	SF												1.51	8	16.8	2	12.8	<2	17	
Mission Viejo	3/11/99	14:56	ST	5	2430	68	8.3	5.3	<0.05	1.7	0.8		270	38	6	12	29	8	21	<2	81	974
Mission Viejo	3/11/99	22:56	SF												1	<8	13	<2	12	<2	13	
Mission Viejo	3/15/99	9:07	ST	5	2240	80	8.1	2.8	0.1	2.1	0.5		300	40	6	12	29	8	15	<2	110	1300
Mission Viejo	3/15/99	10:07	SF												1	<8	14	<2	7	<2	18	
Mission Viejo	3/15/99	12:07	ST	3	920	76	7.8	5.76	<0.1	2.32	0.704		260	44	7	13.2	38.1	8.75	21.6	<2	118	436
Mission Viejo	3/15/99	16:07	SF												1	<8	18	<2	12	<2	13	
Mission Viejo	3/15/99	18:07	ST	44	2020	12	8.2	4.3	<0.05	0.9	0.4		40	11	3	<8	22	2	15	<2	39	750
Mission Viejo	3/19/99	10:45	SF												2	<8	25	<2	15	<2	29	
Mission Viejo	5/20/99	14:00	DT	1	3020	5	8.4	1.8	0.1	0.9	0.4		39	9	1	9	10	<2	9	<2	12	
Mission Viejo	5/20/99	14:00	DF												<1	9	9	<2	8	<2	16	

APPENDIX D
Historical monitoring from San Juan Creek and San Mateo Creek tributaries

Appendix D. Compilation of historical water quality data for Arroyo Trabuco and Oso Creeks, Orange County, California

STATION	DATE	TIME	Flow cfs	Ave Depth m	EC umhos	DO mg/L	pH	Temp C	F mg/L	Cl mg/L	NO3 mg/L	SO4 mg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	SiO2 mg/L	B mg/L	Hardness mg/L	CO3 mg/L	HCO3 mg/L	TDS mg/L
Arroyo Trabuco																						
AT at mile 2.9	3/17/52				437		8.0			17	3.7	77	47	15	18			0.1	180	0	143	238
AT at mile 2.9	4/8/52		21.34		508		8.2			24	4.5	99	75	16	27	1.5		0.04	253	5	195	395
AT at mile 2.9	12/28/52		0.1		328		6.9			32										0	49	
AT at mile 2.9	3/26/54	10:15	2.5		497		8.0			14	1	97	51	22	24	1.1		0.02	218	0	183	334
AT at mile 2.9	3/26/54	14:10	23.2		498		8.2			15	3	92	66	13	21	1.2		0.08	218	5	176	330
AT at mile 2.9	3/26/54	15:15	40		497		8.2			14	0	93	68	12	22	1.2		0	219	0	181	316
AT at mile 2.9	1/10/55		0.28		621		8.2		0.6	55	3.8	155	62	13	66	1.6		0.35	208		174	415
AT at mile 2.9	2/4/58		5		479		6.9		0.2	36	20.4	132	34	17	31	9.9	10	0.05	155	0	43	351
AT at mile 2.9	4/3/58		1250		220		7.1		0.2	13.5	0	32	23	6	12	3.9	29	0.1	83	0	73	148
AT at USGS gaging	6/29/65				815		7.8			35	5	183	111	17	35	3		0		0	245	
AT at Avery Parkwa	May-98			23.7	970			22.8														
AT at Avery Parkwa	Sep-98			23.7	970			22.8														
AT at Avery Parkwa	Nov-98			11.7	810	9.8	7.3	14.4														
AT at Avery Parkwa	May-99			9.3	894	9.32	8.8	23.9														
Oso																						
Oso at mile 1.4	3/17/52	2	3140		8.2		371	7.4	1060	270	114	356			0.55	1144	5.1	296	2613			
Oso at mile 1.4	2/4/58	3	72	2500	6.6	0	8	2.2	6.7	4.3	0.5	9	2.3	20	0.08	13	0	18	111			

Source data from:
RWQCB9, 1999 Biological Assessment Annual Report
Toups Engineering, 1966, Report on Local Water Supply, Rancho Mission Viejo
California Department of Water Resources, 1964, San Juan Creek Ground Water Study

Appendix D. Historical monitoring data from San Juan Creek tributaries

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
Station X12010.00 Trabuco Creek at Del Obispo Street Bridge					
1/22/62	---	1653	8.0	---	1155
2/9/62	---	1142	7.7	---	784
1/22/64	1	1100	7.7	31.0	838
4/8/65	---	521	7.2	---	---
1/27/69	---	452	7.8	5.0	---
2/10/70	8	1189	7.3	9.0	814
Staton X12050.10 Trabuco Creek at Oso Road below confluence of Oso Creek					
3/11/66	---	6160	8.3	---	---
Station X12055.10 Oso Creek at Bathgate Ranch Road bridge					
3/17/52	2	3140	8.2	7.4	2613
2/4/58	3	72	6.6	2.2	111
2/9/62	5	1751	7.1	8.0	1215
4/2/65	1	3040	7.4	9.0	2311
4/3/65	---	605	7.2	6.0	334
4/7/65	---	1495	7.2	---	---
4/8/65	---	908	7.4	---	---
Station X12060.00 Oso Creek at OCFCD Gage on Crown Valley Parkway					
3/11/60	---	7820	8.2	0.0	---
6/7/66	---	13000	7.7	0.0	12000
8/1/66	---	7950	7.9	0.0	---
2/10/70	3	2632	7.5	8.0	2078
Station X12100.00 Trabuco Creed at Camino Capistrano Bridge					
3/17/52	175	---	---	3.7	---
4/8/52	21.3	---	---	4.5	395
12/28/52	0.1	328	6.9	---	---
3/26/54	3	497	8.0	1.0	334
3/26/54	23.2	498	8.2	3.0	330
3/26/54	40	497	8.2	0.0	316
1/10/55	0.3	621	8.2	3.8	415
2/4/58	5	479	6.9	20.4	351
4/3/58	1250.0	220	7.1	0.0	148
1/22/62	---	977	7.4	---	709
2/9/62	---	345	7.6	---	201
2/9/62	0.1	959	7.5	22.0	667
4/2/65	0.1	692	7.4	35.0	462
4/3/65	---	508	7.6	35.0	404
4/8/65	---	516	7.3	---	---
11/23/65	---	333	7.7	---	---
1/23/67	---	496	7.3	6.0	---
4/21/67	---	616	8.2	0.0	---
1/22/69	---	415	7.8	7.0	---
2/6/69	---	328	7.4	2.8	---
2/14/69	---	573	8.2	6.0	375
2/24/69	---	363	7.5	2.7	---

Date	Discharge (cfs)	EC umhos	pH	NO3 mg/L	TDS mg/L
Station X12110.10 Trabuco Creek north of San Diego Freeway					
3/11/66	10	707	8.3	---	---
1/10/67	---	645	8.2	3.0	---
3/30/67	---	701	8.1	0.0	---
4/11/67	---	598	8.0	3.0	---
2/11/70	2.1	736	8.0	0.0	398
Station X12150.10 Trabuco Creek above Gravel Plant					
7/19/66	---	707	8.0	2.0	---
7/19/66	1.0	700	---	---	---

Notes:

All data have been transcribed from moderately legible tables included in DWR Bulletin No. 104 7. Some errors in transcription to electronic spreadsheet form are likely and these data should only be used for general comparitive purposes without consulting an original version of the bulletin.
Discharge values shown to the nearest whole number were cited as estimated values in the source document.

Appendix D. Compilation of historical water quality data for San Mateo Creek

STATION	DATE	TIME	Ave Depth m	EC umhos	DO mg/L	pH	Temp C	NO3 mg/L	NH4 mg/L	TDS mg/L	Salinity ppt
SM across from State park campground	3/17/97 to 3/26/9	9:45	0.15	610	9	7.7	18	2.1	>.01	24	0
SM at Firing range 314	3/17/97 to 3/26/9	14:50	0.27	570	12	7.5	17	2.2	<.1	29	<.01
SM at Firing range 314	4/22/96 to 4/24/9	9:45			10.4		22				
SM at Telega road (on Base)	3/17/97 to 3/26/9	17:05	0.18	360	8.4	6.8	18	1.6	<.1	18	0.5
SM at upper USGS gage	3/17/97 to 3/26/9	12:00	0.45	600	9.6	7.5	18	2.1	negligible	31	0.2
SM at USGS gage pool	4/22/96 to 4/24/9	16:41			9.8		26				
SM at USGS gage riffle	4/22/96 to 4/24/9	16:49			9.8		25				
SM below Bluewater Canyon, Cleveland Natl Forest	3/17/97 to 3/26/9	13:00	0.46			7.5	17-18			26	0
SM at Tenaja road, Cleveland Natl Forest	3/17/97 to 3/26/9	11:53	0.91	590	8.5	7.0	17	2.1	0.2	30	0
SM at trap site	4/22/96 to 4/24/9	10:05			9.2		21.5				
SM Estuary(top)	4/22/96 to 4/24/9	12:00			14.2		20.5				0
SM Estuary(top)	4/22/96 to 4/24/9	12:00			13.6		20.5				10
SM Estuary(top)	4/22/96 to 4/24/9	12:00			12.8		20.5				20
SM Estuary(top)	4/22/96 to 4/24/9	12:00			12		20.5				30
SM Estuary(top)	4/22/96 to 4/24/9	12:00			11.4		20.5				40
SM Estuary (bottom)	4/22/96 to 4/24/9	12:00			14.4		20				0
SM Estuary (bottom)	4/22/96 to 4/24/9	12:00			13.8		20				10
SM Estuary (bottom)	4/22/96 to 4/24/9	12:00			12.8		20				20
SM Estuary (bottom)	4/22/96 to 4/24/9	12:00			12		20				30
SM Estuary (bottom)	4/22/96 to 4/24/9	12:00			11.4		20				40

Source:
Lang, Oppenheim and Knight, 1998, Southern Steelhead report, USFWS

APPENDIX E
Monitoring data for bacterial contamination near the mouth of San Juan Creek

Appendix E. Monitoring data for bacterial contamination near the mouth of San Juan Creek.

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
12/11/00	7,300	2,200	4,800	5,700	2,900	2,800	
12/04/00	9,300	3,800	2,700	140	20	30	
11/27/00	15,000	11,000	8,800	60	10	20	
11/20/00	11,000	4,600	4,300	1,000	330	230	
11/13/00	11,000	4,100	7,000	5,100	730	900	
11/06/00	21,000	10,000	8,600	3,600	1,200	700	
11/01/00	42,000	17,000	20,000	6,600	820	1,000	
10/30/00	70,000	26,000	27,000	50,000	25,000	30,000	
10/25/00	36,000	9,400	6,500	550	120	150	
10/23/00	7,700	1,600	1,300	500	45	200	
10/18/00	>200000	190,000	140,000	1,700	640	1,100	
10/16/00	61,000	22,000	20,000	1,400	550	190	
10/11/00	42,000	4,000	2,400	66,000	24,000	54,000	
10/09/00	6,600	3,700	1,800	4,100	900	64	
10/04/00	6,300	3,400	3,500	610	300	80	
10/02/00	4,500	1,200	700	810	340	110	
09/27/00	6,700	1,700	1,000	930	300	200	
09/25/00	56,000	6,000	1,200	4,600	770	590	
09/20/00	32,000	13,000	15,000	350	100	90	
09/18/00	2,100	1,600	3,600	510	55	150	
09/13/00	2,500	2,100	700	160	40	54	
09/12/00	7,400	1,600	360	220	82	72	
09/06/00	2,300	1,300	1,400	240	10	120	
09/05/00	4,300	3,300	5,200	130	18	110	
08/29/00	9,500	2,100	640	380	300	240	
08/28/00	24,000	2,500	640	400	60	270	
08/23/00	6,500	4,600	100	400	130	210	
08/22/00	17,000	5,400	1,400	6,700	900	1,800	
08/15/00	32,000	4,200	1,400	12,000	860	1,700	
08/14/00	56,000	10,000	3,100	>30,000	9,800	11,000	
08/08/00	11,400	2,100	800	500	310	50	
08/07/00	4,800	730	1,200	2,500	140	320	
07/31/00	2,300	450	400	880	590	4,500	
07/27/00	5,700	4,200	1,400	22,000	1,800	660	
07/25/00	37,000	4,700	540	2,800	330	930	
07/18/00	5,400	1,400	450	82	130	420	
07/17/00	37,000	2,900	730	3,800	2,400	4,500	
07/12/00	4,600	500	200	2,600	270	3,200	
07/10/00	6,900	600	100	140	70	3,700	
07/05/00	300	300	<100	290	110	3,000	
07/03/00	400	360	200	64	64	1,700	
06/27/00	25,000	820	<100	290	130	3,600	
06/26/00	400	200	200	500	73	1,100	
06/21/00	3,100	1,300	400	280	64	3,700	
06/19/00	3,200	200	200	260	140	2,000	
06/14/00	7,200	640	540	140	100	1,500	
06/12/00	>200,000	53,000	2,600	91	50	1,200	
06/07/00	60,000	51,000	13,000	210	110	680	
06/05/00	1,500	1,400	2,300	210	40	1,100	
05/31/00	4,500	1,200	500	310	70	200	
05/30/00	58,000	58,000	16,000	290	150	310	
05/25/00	5,500	1,600	3,600	690	290	520	
05/22/00	2,900	3,300	2,200	360	230	450	
05/18/00	100,000	11,000	3,900	150	88	91	
05/16/00	27,000	1,300	500	3,000	2,200	2,400	
05/10/00	>20,000	>20,000	20,000	80	45	90	
05/08/00	30,000	4,900	5,000	340	220	110	
05/02/00	1,200	640	300	>30,000	17,000	13,000	
05/01/00	>20,000	>20,000	>20,000	500	120	91	
04/24/00	>20,000	>20,000	>20,000	760	280	90	
04/17/00	8,700	2,500	980	80	45	90	
04/10/00	4,100	1,500	2,000	710	310	50	
04/03/00	24,000	5,800	7,300	4,200	420	91	
03/28/00	16,000	10,000	9,700	700	170	90	
03/20/00	>30,000	20,000	>20,000	1,700	610	350	
03/13/00	2,100	1,400	400	3,500	450	540	
03/07/00	9,500	3,500	2,400	7,000	1,400	2,500	
02/29/00	7,900	4,300	4,700	10,000	1,000	100	
02/23/00	23,000	4,200	5,800	12,000	3,300	3,800	
02/15/00	26,000	12,000	8,300	4,200	800	1,000	
02/08/00	9,600	2,900	3,100	5,500	270	470	
02/01/00	64,000	37,000	34,000	44,000	2,200	3,400	

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
01/26/00	>200,000	28,000	29,000	>200,000	31,000	26,000	
01/19/00	16,000	7,400	17,000	2,500	490	640	
01/11/00	7,800	7,000	5,800	940	270	380	
01/04/00	20,000	7,000	7,300	7,700	750	1,300	
12/27/99	550	240	180	1,000	320	220	
12/20/99	10,000	5,400	5,400	1,400	290	630	
12/13/99	9,700	2,000	4,200	4,100	4,500	810	
12/08/99	9,600	2,200	2,300	3,100	1,000	490	
11/29/99	3,600	400	510	4,000	840	1,000	
11/23/99	6,800	4,300	2,200	3,400	340	270	
11/16/99	>20000	15,000	>20000	4,100	430	630	
11/08/99	7,300	960	4,500	4,400	690	940	
11/01/99	6,300	1,400	2,400	3,400	120	470	
10/27/99	5,700	1,000	3,100	4,000	430	770	
10/25/99	1,100	530	420	4,100	420	970	
10/20/99	>20000	>20000	>20000	2,400	330	750	
10/18/99	4,000	1,000	2,300	2,000	240	460	
10/13/99	4,400	850	1,700	4,500	280	790	
10/11/99	2,700	500	850	3,300	130	1,100	
10/06/99	7,900	1,300	3,100	3,800	220	1,200	
10/04/99	2,300	250	530	5,200	310	720	
09/29/99	8,300	500	1,300	10,000	8,000	790	
09/28/99	Cw/C	14,000	>20000	2,500	2,500	3,700	
09/22/99	1,400	170	350	6,300	640	850	
09/20/99	1,000	130	250	3,300	100	400	
09/14/99	910	210	260	6,700	370	290	
09/13/99	1,600	250	290	4,100	230	240	
09/08/99	320	120	170	730	500	440	
09/07/99	910	780	270	6,800	310	460	
09/01/99	3,800	1,000	3,200	7,300	480	240	
08/30/99	>6000	1,800	6,100	8,600	320	250	
08/25/99	5,200	860	4,800	220	150	140	
08/23/99	3,100	430	1,900	2,100	310	300	
08/18/99	4,100	1,500	1,200	9,700	7,200	390	
08/16/99	2,900	120	2,800	4,700	230	210	
08/11/99	1,800	1,400	660	3,500	3,500	190	
08/09/99	2,900	140	810	300	370	340	
08/04/99	3,300	1,300	2,200	3,100	440	180	
08/02/99	520	91	480	1,700	210	430	
07/28/99	700	270	<100	2,000	370	530	
07/26/99	900	100		2,700	590	N/S	
07/21/99	5,600	1,600	450	1,600	230	130	
07/19/99	2,300	500	300	2,000	380	310	
07/14/99	5,000	3,300	1,400	5,000	1,000	390	
07/12/99	2,500	1,300	2,300	2,500	160	300	
07/07/99	18,000	7,000	3,000	2,600	2,100	730	
07/05/99	300	<100	1,300	2,100	280	40	
06/30/99	2,200	620	190	2,200	360	450	
06/28/99	2,700	100	200	2,400	260	280	
06/23/99	4,600	200	<100	7,800	700	810	
06/21/99	7,000	3,500	2,000	2,600	510	330	
06/16/99	78,000	6,900	5,900	1,800	1,600	530	
06/14/99	9,800	1,600	1,000	800	330	200	
06/09/99	23,000	5,800	650	1,100	390	100	
06/07/99	100,000	63,000	20,000	1,000	390	220	
06/02/99	49,000	7,700	3,700	23,000	12,000	6,000	
06/01/99	9,300	3,900	2,000	220	64	36	
05/26/99	32,000	12,000	6,300	380	140	150	
05/24/99	11,000	2,100	820	540	300	120	
05/19/99	68,000	32,000	8,900	810	270	100	
05/17/99	41,000	7,100	2,600	350	210	140	
05/12/99	21,000	8,800	4,400	690	210	170	
05/10/99	34,000	1,400	820	540	99	99	
05/04/99	14,000	4,300	2,800	320	110	100	
05/03/99	4,300	1,600	900	520	240	130	
04/26/99	65,000	48,000	11,000	610	290	170	
04/20/99	120,000	27,000	2,200	1,700	400	100	
04/14/99	2,100	500	100	800	320	130	
04/06/99	260,000	37,000	3,700	1,600	140	90	
03/30/99	180,000	72,000	29,000	790	450	130	
03/22/99	56,000	16,000	7,400	840	450	240	
03/16/99	22,000	3,700	4,800	8,200	1,400	1,000	
03/08/99	60,000	23,000	7,900	1,700	380	190	
03/01/99	9,900	5,300	3,300	440	210	110	
02/22/99	16,000	4,800	3,300	3,800	900	290	
02/17/99	21,000	28,000	7,500	1,000	350	290	
02/08/99	18,000	5,100	5,100	2,000	200	1,000	

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
02/01/99	19,000	1,700	2,800	6,700	1,200	1,300	
01/25/99	48,000	3,500	5,800	58,000	5,200	4,500	
01/18/99	16,000	12,000	7,200	850	250	170	
01/11/99	19,000	12,000	5,300	2,500	300	280	
01/04/99	16,000	6,400	7,000	1,000	110	80	
12/28/98	10,000	5,600	7,100	2,000	360	270	
12/21/98	5,400	15,000	22,000	4,900	800	900	
12/14/98	35,000	7,500	4,800	1,600	220	170	
12/07/98	10,000	3,400	6,200	5,400	990	310	
11/30/98	31,000	7,200	360	4,100	2,000	2,100	
11/23/98	16,000	5,000	3,500	3,600	210	140	
11/16/98	66,000	47,000	34,000	2,700	340	180	
11/09/98	40,000	20,000	8,400	47,000	18,000	4,300	
11/02/98	160,000	130,000	43,000	2,100	510	360	
10/28/98	8,400	6,000	3,000	1,600	370	180	
10/26/98	7,900	3,700	2,400	470	340	210	
10/21/98	220,000	140,000	87,000	800	460	700	
10/19/98	180,000	110,000	59,000	100	160	230	
10/14/98	32,000	23,000	5,500	16,000	670	600	
10/12/98	9,400	4,900	2,900	1,700	300	470	
10/07/98	10,000	6,100	3,700	1,100	520	520	
10/05/98	6,800	5,000	5,400	2,400	360	280	
09/30/98	43,000	24,000	5,100	700	300	50	
09/28/98	11,000	10,000	5,300	3,400	1,600	380	
09/23/98	50,000	24,000	15,000	1,600	640	420	
09/21/98	28,000	28,000	3,800	2,400	360	180	
09/16/98	16,000	13,000	4,300	4,400	950	640	
09/14/98	12,000	8,500	2,700	1,700	450	410	
09/09/98	7,500	5,500	2,000	3,500	2,100	680	
09/08/98	18,000	9,000	3,000	7,400	900	550	
09/02/98	130,000	37,000	7,200	2,800	800	580	
08/31/98	18,000	18,000	1,300	4,200	1,100	270	
08/26/98	25,000	>2000	5,400	1,700	600	200	
08/24/98	600	360	130	2,500	1,400	320	
08/19/98	20,000	7,100	3,400	700	350	100	
08/17/98	24,000	9,800	3,800	520	230	150	
08/12/98	14,000	12,000	2,900	410	410	60	
08/10/98	8,200	3,900	1,700	2,000	440	280	
08/05/98	7,200	7,000	7,100	2,300	680	430	
08/03/98	3,500	3,300	630	1,700	210	150	
07/29/98	3,800	850	3,000	1,200	440	170	
07/27/98	14,000	6,300	9,500	1,000	250	170	
07/22/98	Cw/C	2,300	200	340	340	160	
07/20/98	13,000	2,400	530	270	170		
07/15/98	11,000	8,200	4,300	230	150	50	
07/13/98	23,000	7,600	360	160	110	70	
07/08/98	2,500	2,500	1,600	Cw/C	140	120	
07/06/98	Cw/C	680	150	50	50	100	
07/01/98	1,500	610	590	130	130	110	
06/29/98	400	400	210	73	54	160	
06/24/98	2,300	1,400	680	290	280	70	
06/22/98	620	600	410	140	90	20	
06/17/98	14,000	1,700	560	180	110	50	
06/15/98	3,000	930	300	590	180	140	
06/10/98	1,800	590	440	200	190	100	
06/09/98	4,700	1,300	1,100	630	230	60	
06/03/98	920	520	220	190	110	30	
06/01/98	960	290	160	340	130	60	
05/28/98	1,100	250	160	190	130	10	
05/27/98	4,100	510	230	780	230	110	
05/20/98	3,700	1,700	1,200	460	160	160	
05/18/98	1,400	870	650	270	110	80	
05/13/98	Cw/C	Cw/C	80,000	Cw/C	120,000	120,000	
05/11/98	4,100	890	540	790	310	180	
05/06/98	99,000	36,000	50,000	>20,000	>20,000	>20,000	
05/04/98	17,000	3,400	690	>20,000	2,000	350	
04/27/98	560	320	70	160	80	20	
04/20/98	1,600	120	130	610	370	40	
04/13/98	2,100	490	160	900	530	160	
04/06/98	7,300	640		600	300		
04/01/98	32,000	3,900	4,900	27,000	3,400	6,000	
03/23/98	7,800	3,900	830	200	70	20	
03/16/98	3,300	510	740	2,700	430	770	
03/09/98	5,300	1,100	970	460	60	150	
03/02/98	6,600	160	220	1,500	160	180	
02/25/98	98,000	72,000	9,300	5,700	2,600	400	
02/17/98	49,000	14,000	13,000	40,000	10,000	16,000	

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
02/09/98	8,400	4,100	4,800	7,400	3,500	4,800	
02/02/98	>20,000	3,800	5,400	3,700	1,200	2,100	
01/26/98	24,000	11,000	4,600	2,300	280	120	
01/19/98	>20,000	24,000	8,000	17,000	11,000	4,800	
01/12/98	10,000	3,400	2,500	3,500	530	520	
01/05/98	22,000	8,000	5,700	17,000	10,000	2,000	
12/29/97	12,000	2,500	3,800	4,200	600	1,300	
12/22/97	12,000	1,900	2,300	3,600	350	230	
12/15/97	140,000	25,000	41,000	14,000	6,100	3,000	
12/08/97	44,000	14,000	3,300	30,000	16,000	2,500	
12/01/97	>50,000	>50,000	29,000	25,000	5,600	>2,000	
11/24/97	>20,000	16,000	9,000	1,000	430	330	
11/17/97	16,000	4,200	6,500	630	180	200	
11/12/97	28,000	13,000	6,100	3,800	1,900	820	
11/05/97	25,000	17,000	7,400	560	380	150	
10/29/97	30,000	26,000	1,100	560	240	50	
10/27/97	9,100	6,500	4,000	320	200	60	
10/22/97	8,300	5,900	2,600	710	410	70	
10/20/97	810	570	270	660	460	91	
10/15/97	>20,000	>20,000	3,700	1,200	210	80	
10/13/97	6,600	5,200	500	2,000	290	130	
10/08/97	12,000	6,800	2,600	2,100	380	170	
10/06/97	28,000	20,000	16,000	1,200	400	230	
10/01/97	25,000	24,000	5,500	6,000	820	150	
09/29/97	32,000	20,000	3,100	2,600	900	<100	
09/25/97	250,000	60,000	59,000	>200,000	110,000	75,000	
09/23/97	5,700	700	90	11,000	800	450	
09/18/97	10,000	7,400	2,600	8,300	400	70	
09/16/97	20,000	3,100	560	20,000	2,700	690	
09/11/97	9,100	2,000	110	10,000	1,300	40	
09/09/97	6,700	800	91	10,000	400	30	
09/04/97	4,700	2,400	330	18,000	690	90	
09/02/97	16,000	9,200	370	16,000	1,600	54	
08/28/97	2,300	980	260	9,300	550	54	
08/26/97	4,800	4,200	240	6,400	6,000	640	
08/21/97	7,100	2,400	130	7,200	1,100	80	
08/19/97	5,700	2,100	120	4,700	600	120	
08/14/97	4,700	900	240	4,900	290	60	
08/12/97	570	370	120	6,400	580	260	
08/07/97	4,500	2,600	650	1,100	270	980	
08/05/97				3,600	1,400	340	
07/31/97	>2,000	7,100	420	2,300	360	40	
07/29/97	5,600	5,000	810	3,200	1,000	290	
07/24/97	12,000	7,100	2,500	530	180	54	
07/22/97	4,800	1,200	520	3,200	390	140	
07/17/97	9,300	6,400	3,500	1,300	210	100	
07/15/97	1,100	700	140	260	140	30	
07/10/97	3,000	730	390	1,500	260	170	
07/08/97	2,900	1,200	370	700	91	20	
07/01/97	680	730	10	140	130	60	
06/30/97	7,600	2,900	120	800	100	70	
06/26/97	3,000	730	390	1,500	260	170	
06/24/97	16,000	420	700	730	160	91	
06/19/97	2,100	900		670	370		
06/18/97	13,000	6,000		3,100	810		
06/12/97	12,000	3,900	<10	680	260	<10	
06/10/97	14,000	3,400	8,000	2,000	650	130	
06/05/97	1,400	3,000	400	700	260	54	
06/02/97	7,900	11,000	1,400	900	520	220	
05/29/97	19,000	7,200	5,200	200	200	240	
05/27/97	2,100	1,000	450	500	160	70	
05/22/97	15,000	13,000	6,400	750	160	200	
05/20/97	11,000	3,500	1,500	2,000	1,100	2,600	
05/15/97	24,000	12,000	300	300	200	<100	
05/14/97	>20,000	>20,000	13,000	360	170	150	
05/08/97	18,000	12,000	6,700	82	64	90	
05/06/97	12,000	9,500	2,600	310	82	100	
05/01/97	18,000	800	2,500	200	100	70	
04/22/97	5,600	3,600	890	360	100	82	
04/15/97	7,000	4,100	1,700	160	50	50	
04/08/97	3,700	1,400	550	210	20	50	
04/01/97	2,500	2,100	200	250	40	30	
03/26/97	12,000	4,100	370	850	100	30	
03/19/97	11,000	8,800	2,400	530	160	70	
03/11/97	6,900	5,400	1,700	370	220	40	
03/04/97	2,000	1,700	300	200	100	60	
02/25/97	2,100	1,300	2,100	400	40	70	

Date	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			Notes
	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	
02/18/97	770	190	120	410	100	140	
02/12/97	4,600	580	490	2,300	290	180	
02/04/97	1,800	430	430	290	140	170	
01/30/97	2,200	370	230	900	310	300	
01/21/97	600	<100	<100	300	<100	100	
01/14/97	13,000	3,200	3,800	15,000	3,500	7,800	
01/07/97	1,400	200	700	900	400	100	
01/02/97	13,000	3,200	4,200	24,000	3,900	3,700	
12/22/96	5,700	4,500	1,300	690	190	530	
12/18/96	7,200	1,100	1,000	1,900	300	500	
12/10/96	29,000	6,800	20,000	33,000	11,000	68,000	
12/03/96	5,100	240	380	5,500	440	400	
11/25/96	2,100	100	10	3,600	300	17,000	
11/19/96	6,300	2,600		2,100	720		
11/13/96	35,000	9,000	20,000	650	150	40	
11/05/96	68,000	36,000	17,000	1,700	200	<10	
10/31/96	50,000	30,000	12,000	40,000	10,000	10,000	
10/30/96	28,000	15,000	28,000	86,000	58,000	66,000	
10/23/96	5,400	2,100	1,200	1,500	220	100	
10/21/96	27,000	30,000	19,000	300	150	120	
10/17/96	76,000	82,000	13,000	220	180	400	
10/15/96	5,700	3,000	2,200	700	140	480	
10/10/96	40,000	39,000	2,900	1,300	100	160	
10/08/96	1,900	200	300	2,200	750	220	
10/03/96	82,000	5,100	6,500	160	190	100	
09/26/96	>16,000	42,000	4,900	230	110	220	
09/24/96	2,900	1,800	400	1,400	180	170	
09/19/96	30,000	22,000	46,000	600	120	90	
09/17/96	5,200	3,300	2,600	700	140	170	
09/12/96	19,000	8,300	3,700	Cw/C	500	530	
09/10/96	6,600	4,300	4,000	700	400	400	
09/05/96	Cw/C	11,000	2,600	1,000	300	100	
09/04/96	6,000	4,400	500	Cw/C	2,400	500	
08/29/96	16,000	8,600	3,400	Cw/C	7,600	1,000	
08/27/96	400	400	100	Cw/C	660	230	
08/22/96	11,000	7,600	11,000	600	500	50	
08/20/96	1,700	1,500	900	400	340	140	
08/15/96	<1000	<1000	400	200	100	500	
08/13/96	10,000	7,300	3,600	1,100	200	200	
08/08/96	Cw/C	11,000	9,900	600	800	1,100	
08/07/96	1,400	600	<100	5,200	4,100	<100	
08/01/96	Cw/C	2,800	500	600	200	500	
07/30/96	19,000	2,900	1,000	700	400	100	
07/24/96	Cw/C	14,000	2,000	70	50	50	
07/23/96	Cw/C	11,000	400	20	60	60	
07/17/96	19,000	5,300	300	60	90	49	
07/15/96	38,000	9,000	1,800	200	130	300	
07/11/96	2,500	900	100	80	10	30	
07/09/96	6,000	2,000	200	100	200	200	
07/02/96	6,000	2,000	1,000	300	200	200	
07/01/96	6,500	3,700	1,600	500	700	100	
06/27/96	900	300	100	180	280	170	
06/25/96	6,900	6,700	1,200	200	190	110	
06/19/96	8,900	8,800	2,300	300	100	<100	
06/17/96	4,000	3,000	400	100	300	<100	
06/16/96	9,000	4,000	2,000	500	300	900	
06/15/98	7,300	5,900	1,800	100	<100	200	
06/14/96	2,600	2,700	2,000	600	200	100	
06/11/96	8,500	9,300	3,000	200	200	<100	
06/06/96	1,000	1,100	400	190	200	100	
06/02/96	6,000	3,900	200	300	250	60	
05/30/96	3,600	2,000	2,000	1,300	<100	400	
05/29/96	24,000	4,000	3,700	300	240	110	
05/23/96	1,800	1,400	700	200	200	100	
05/21/96	1,200	200	400	<100	300	400	
05/16/96	3,600	6,800	3,500	100	200	<100	
05/14/96	2,500	1,800	300	400	100	100	
05/09/96	4,300	2,900	200	200	<100	<100	
05/07/96	2,600	1,100	200	<100	200	100	
05/01/96	44,000	24,000	23,000	300	100	<100	
04/30/96	7,600	6,700	2,200	500	<100	200	
04/23/96	1,800	500	100	1,500	100	<100	
04/16/96	2,800	2,700	700		400	<100	
04/09/96	5,500	3,600	2,200	200	100	,100	
04/02/96	6,500	2,300	200	1,900	100	200	
03/26/96	900	500	200	<100	<100	<100	
03/20/96	140,000	9,000	48,000	<100	<100	<100	

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
03/12/96	9,200	5,500	1,500	900	<100	100	
03/05/96	87,000	25,000	42,000	88,000	10,000	44,000	
02/27/96	6,900	1,600	4,200	5,000	<1000	7,000	
02/20/96	140,000	44,000	71,000	95,000	49,000	78,000	
02/13/96	9,900	4,700	2,100	4,300	400	200	
02/06/96	63,000	29,000	5,000	1,700	200	100	
01/30/96	89,000	42,000	5,600	900	500	200	
01/23/96	8,500	1,900	2,200	3,700	800	300	
01/16/96	57,000	33,000	9,000	150	30	10	
01/09/96	41,000	12,000	5,000	5,800	2,900	800	
01/04/96	53,000	35,000	42,000	700	200	100	
12/27/95	6,600	2,900	1,700	2,200	600	100	
12/19/95	21,000	5,400	260	3,200	100	200	
12/12/95	14,000	5,500	1,700	2,600	400	<100	
12/06/95	140,000	83,000	18,000				
12/04/95	50,000	22,000	12,000	12,000	1,000	1,000	
11/28/95	3,500	1,500	700	100	<100	<100	
11/21/95	45,000	38,000	14,000	2,200	100	200	
11/14/95	75,000	47,000	21,000	1,000	400	100	
11/07/95	22,000	9,800	3,700	26,000	4,700	1,700	
10/30/95	60,000	18,000	4,200	500	<100	<100	
10/26/95	7,900	5,600	5,600	100	100	<100	
10/24/95	45,000	24,000	5,400	900	100	<100	
10/19/95	22,000	7,900	4,000	1,300	200	300	
10/17/95	13,000	8,200	2,300	9,000	<100	<100	
10/12/95	33,000	12,000	3,100	5,000	4,400	3,400	
10/10/95	3,400	2,300	300	700	200	200	
10/05/95	4,400	600	400	600	300	<100	
10/03/95	800	600	<100	700	700	100	
09/28/95	2,300	1,600	1,200	2,000	100	300	
09/26/95	10,000	3,400	1,700	100	<100	200	
09/20/95	27,000	27,000	2,500	700	200	100	
09/18/95	1,800	1,300	500	200	<100	300	
09/14/95	1,600	1,600	600	400	400	100	
09/12/95	1,000	500	400	1,300	200	<100	
09/07/95	37,000	25,000	450	2,000	500	360	
09/05/95	1,200	1,200	300	1,400	800	100	
08/31/95	1,000	1,000	200	<100	100	<100	
08/29/95	8,000	5,700	700	12,000	4,900	<100	
08/24/95	9,200	8,600	400	3,400	3,300	700	
08/22/95	6,400	5,900	1,500	4,800	500	300	
08/17/95	6,000	6,000	1,700	1,300	400	300	
08/14/95	3,800	3,100	1,300	2,400	1,500	300	
08/09/95	22,000	8,900	5,100	700	200	100	
08/07/95	1,400	1,300	200	3,100	1,700	400	
08/02/95	2,800	1,100	300	2,000	300	700	
07/31/95	5,000	2,000	700	2,000	700	<100	
07/26/95	3,000	2,600	1,300	200	100	100	
07/24/95	5,400	5,300	4,300	2,100	730	500	
07/19/95	8,500	8,600	3,500	600	500	<100	
07/17/95	6,300	6,300	3,900	4,200	2,500	300	
07/12/95	8,000	8,300	2,800	1,300	200	200	
07/10/95	6,200	5,800	2,600	800	80	180	
07/07/95	6,800	5,000	1,900	500	100	100	
07/05/95	6,000	4,500	1,600	1,800	290	400	
06/28/95	3,600	1,600		150	130		
06/26/95	5,100	3,500		610	540		
06/21/95	1,300	450		370	120		
06/19/95	1,000	670		900	190		
06/14/95	1,600	1,400		100	60		
06/12/95	2,200	2,600		200	200		
06/07/95	4,100	3,300		1,000	<100		
06/05/95	3,500	3,000		900	300		
06/01/95	2,900	1,000		5,100	300		
05/30/95	2,000	200		500	<100		
05/24/95	5,200	2,200		3,300	350		
05/22/95	470	440		420	390		
05/17/95	730	240		580	510		
05/16/95	1,200	100		1,600	100		
05/11/95	3,000	310		410	240		
05/08/95	4,400	1,200		1,100	200		
05/03/95	1,400	200		<100	<100		
05/01/95	2,900	1,300		1,200	<100		
04/25/95	1,700	1,400		640	500		
04/19/95	42,000	6,300		45,000	490		
04/12/95	1,100	300		600	100		
04/05/95	1,500	100		9,000	300		

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
03/29/95	3,000	<20		5,000	<20		
03/22/95	15,000	5,000		7,200	2,100		
03/15/95	3,800	100		4,200	300		
03/08/95	11,000	1,800					
03/01/95	1,400	200		2,200	200		
02/22/95	13,000	1,600		2,300	500		
02/15/95	8,400	4,900					
02/08/95	36,000	6,100		40,000	2,300		
02/01/95	7,000	2,200		2,900	1,400		
01/25/95	84,000	32,000					
01/17/95	2,900	450		3,700	730		
01/09/95	4,200	1,200		3,800	900		
01/05/95	42,000	10,000					
12/29/94	7,100	2,100		8,000	640		
12/21/94	7,300	4,100		1,200	500		
12/13/94	14,000	4,400		23,000	2,300		
12/07/94	3,300	1,600		1,200	100		
11/30/94	11,000	4,600		3,500	100		
11/21/94	2,800	2,400		1,100	200		
11/15/94	11,000	4,600		2,400	270		
11/09/94	15,000	6,700		4,000	200		
11/01/94	6,000	2,000		300	<100		
10/27/94	8,400	5,100		1,300	<100		
10/25/94	8,400	3,500		3,200	200		
10/21/94	9,100	3,000		3,400	300		
10/19/94	4,200	2,000		8,300	3,300		
10/12/94	27,000	6,400		4,900	2,000		
10/11/94	35,000	8,000		500	800		
10/07/94	52,000	11,000		42,000	4,800		
10/05/94	Cw/C	170,000		Cw/C	86,000		
09/30/94	31,000	10,000		14,000	400		
09/28/94	180,000	50,000		19,000	800		
09/23/94	20,000	8,800		21,000	1,900		
09/21/94	3,900	4,500		11,000	200		
09/16/94	24,000	22,000		16,000	640		
09/14/94	8,500	5,400		14,000	<100		
09/09/94	5,000	5,000		12,000	170		
09/07/94	2,900	1,700		13,000	500		
09/02/94	7,000	4,200		9,200	540		
08/31/94	110,000	11,000		10,200	270		
08/24/94	1,300	1,100		420	420		
08/22/94	4,000	3,200		250	190		
08/17/94	21,000	13,000		1,100	940		
08/15/94	41,000	6,100		1,000	250		
08/11/94	6,800	6,000		1,000	900		
08/09/94	2,000	1,900		300	340		
08/03/94	2,500	3,100		1,100	1,100		
08/01/94	33,000	27,000		800	110		
07/27/94	3,400	3,400		200	120		
07/25/94	3,000	1,400		300	190		
07/20/94	35,000	33,000		180	290		
07/18/94	3,600	2,900		360	350		
07/13/94	800	700		800	310		
07/11/94	430	430		170	190		
07/07/94	1,200	100		2,300	250		
07/05/94	1,000	300		150	140		
06/29/94	3,700	3,600		82	130		
06/27/94	7,000	9,100		200	100		
06/22/94	200	180		64	64		
06/20/94	2,000	2,000		200	90		
06/15/94	2,900	2,000		1,100	900		
06/13/94	8,000	8,000		280	160		
06/08/94	730	590		64	73		
06/06/94	1,600	450		100	100		
06/02/94	1,200	910		1,000	550		
05/31/94	3,000	4,800		150	80		
05/25/94	3,900	3,400		5,200	100		
05/23/94	2,700	1,200		600	60		
05/18/94	13,000	2,700		1,800	500		
05/16/94	2,800	300		280	120		
05/11/94	11,000	3,100		2,600	200		
05/09/94	2,600	600		500	460		
05/04/94	5,800	900		1,100	100		
05/02/94	1,900	640		450	270		
04/27/94	31,000	5,300		4,400	500		
04/20/94	8,100	5,900		730	180		
04/13/94	11,000	3,600		540	<20		

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
04/06/94	3,500	2,200		700	<20		
03/30/94	5,200	1,900		500	<20		
03/22/94	18,000	5,200		1,500	360		
03/16/94	2,400	1,000		1,500	640		
03/09/94	6,100	1,900		2,700	700		
03/01/94	2,100	400		450	450		
02/23/94	5,400	400		1,500	91		
02/16/94	5,700	450		1,500	200		
02/09/94	14,000	1,800		16,000	1,800		
02/02/94	7,000	1,200		1,100	100		
01/26/94	43,000	3,700		8,800	910		
01/19/94	4,200	2,000		<200	<200		
01/12/94	4,500	2,500		1,800	180		
01/05/94	5,100	2,000		3,300	200		
12/27/93	25,000	2,300		2,200	180		
12/21/93	4,200	1,000		3,200	3,200		
12/15/93	22,000	5,000		10,000	900		
12/08/93	38,000	6,300		700	<20		
12/01/93	34,000	20,000		6,100	6,100		
11/22/93	43,000	30,000		3,200	100		
11/17/93	22,000	9,200		3,500	300		
11/09/93	15,000	8,300		1,600	180		
11/03/93	4,500	2,800		2,000	300		
10/28/93	49,000	15,000		3,300	100		
10/26/93	50,000	21,000		3,900	1,000		
10/21/93	23,000	5,800		3,400	400		
10/19/93	7,900	3,600		5,200	450		
10/13/93	25,000	7,500		5,200	820		
10/11/93	50,000	2,300		3,800	1		
10/06/93	3,500	2,000		4,700	2,000		
10/04/93	2,100	1,600		290	170		
09/29/93	5,700	2,800		800	100		
09/27/93	7,400	3,900		1,400	<20		
09/23/93	10,000	6,000		2,300	500		
09/21/93	12,000	3,200		2,100	270		
09/16/93	10,000	6,000		7,000	1,100		
09/14/93	1,200	800		8,000	200		
09/09/93	1,600	1,300		7,800	500		
09/07/93	7,800	2,100		1,400	<20		
09/02/93	8,300	670		3,000	400		
08/31/93	7,500	5,000		3,000	1,000		
08/26/93	33,000	1,700		4,000	200		
08/24/93	8,000	3,500		6,000	730		
08/19/93	22,000	7,800		2,500	300		
08/17/93	3,800	1,700		2,700	270		
08/12/93	3,000	500		1,000	700		
08/10/93	1,000	550		1,000	500		
08/05/93	7,000	2,500		1,800	180		
08/03/93	5,000	1,400		5,000	180		
07/29/93	3,000	450		8,000	450		
07/27/93	1,000	1,000		1,800	640		
07/22/93	3,000	1,200		1,000	180		
07/20/93	4,400	640		820	180		
07/15/93	3,000	820		3,000	270		
07/13/93	2,400	730		1,400	270		
07/08/93	8,500	1,100		450	91		
07/06/93	8,000	1,100		2,200	540		
07/01/93	1,800	820		1,700	540		
06/29/93	9,000	100		4,000	500		
06/24/93	1,100	1,100		5,000	500		
06/22/93	2,400	500		12,000	600		
06/17/93	2,800	1,400		2,400	2,600		
06/15/93	5,000	1,800		5,000	600		
06/10/93	7,000	400		13,000	1,100		
06/08/93	8,000	1,300		>16000	1,100		
06/03/93	1,000	300		700	400		
06/01/93	700	100		400	100		
05/27/93	1,200	200		1,400	400		
05/25/93	800	800		1,600	200		
05/20/93	3,900	210		4,500	90		
05/18/93	1,000	700		1,700	<20		
05/13/93	1,700	400		7,300	300		
05/11/93	2,300	800		>16000	9,300		
05/06/93	1,700	600		>16000	3,800		
05/04/93	9,000	620		2,400	700		
04/27/93	2,300	900		6,000	500		
04/20/93	7,700	2,200		6,100	1,900		

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
04/13/93	7,700	3,200		3,900	760		
04/05/93	4,400	2,200		4,600	1,400		
03/29/93	>16000	4,900		5,200	1,700		
03/22/93	>16000	5,300		1,800	970		
03/16/93	5,400	840		7,600	640		
03/08/93	10,000	2,800		1,600	500		
03/02/93	4,800	1,000		1,400	500		
02/23/93	5,300	2,000					
02/16/93	44,000	4,700		16,000	3,000		
02/09/93	24,000	5,900		16,000	3,000		
02/02/93	40,000	4,300		730	100		
01/26/93	15,000	1,900		1,500	270		
01/19/93	13,000	6,100					
01/12/93	1,800	4,530		1,800	400		
01/04/93	750	100		1,200	150		
12/28/92	6,000	2,200		5,600	1,100		
12/21/92	1,300	290		3,300	140		
12/15/92	2,200	1,200		2,000	380		
12/07/92	>16000	>16000		19,000	15,000		
12/01/92	5,100	2,900		570	<20		
11/23/92	990	510		1,400	210		
11/17/92	9,200	8,200		1,300	120		
11/09/92	1,600	1,100		4,100	320		
11/02/92	7,800	6,800		1,900	610		
10/28/92	>16000	>16000		4,600	490		
10/26/92	2,500	860		4,800	810		
10/21/92	2,000	110		8,100	180		
10/19/92	310	160		6,100	310		
10/14/92	2,500	1,800		15,000	14,000		
10/12/92	3,700	2,900		6,900	190		
10/07/92	>16000	>16000		9,000	150		
10/05/92	2,300	1,100		5,000	150		
09/30/92	13,000	3,800		>16000	3,900		
09/28/92	8,400	9,000		6,600	150		
09/23/92	2,800	1,900		5,000	900		
09/21/92	820	930		3,500	320		
09/16/92	7,400	5,200		5,600	150		
09/14/92	>16000	14,000		4,700	480		
09/10/92	4,700	2,400		7,200	410		
09/08/92	8,700	7,600		4,200	300		
09/02/92	>16000	470		>16000	3,700		
08/31/92	600	270		3,500	480		
08/26/92	3,500	2,200		6,300	1,300		
08/24/92	1,300	660		6,200	1,000		
08/19/92	10,000	12,000		2,900	200		
08/17/92	6,600	4,900		6,700	1,100		
08/12/92	900	590		6,300	5,000		
08/10/92	2,200	2,700		11,000	1,300		
08/06/92	>16000	>16000		6,500	750		
08/04/92	490	310		6,200	190		
07/29/92	60	<20		7,200	470		
07/27/92	15,000	12,000		4,800	500		
07/23/92	4,400	2,800		4,400	1,300		
07/21/92	4,700	1,400		2,400	200		
07/15/92	6,400	5,300		2,600	350		
07/13/92	>16000	>16000		4,400	1,800		
07/08/92	>16000	>16000		>16000	>16000		
07/06/92	4,400	1,300		870	30		
07/01/92	100	70		960	310		
06/29/92	3,500	700		800	210		
06/24/92	>16000	>16000		520	150		
06/22/92	>16000	>16000		690	100		
06/18/92	>16000	>16000		700	130		
06/16/92	5,600	5,600		1,100	330		
06/11/92	14,000	8,700		540	80		
06/09/92	>16000	8,700		1,700	180		
06/04/92	5,900	460		660	170		
06/02/92	>16000	5,600		480	370		
05/28/92	12,000	3,400		280	60		
05/26/92	8,300	4,100		810	60		
05/21/92	>16000	8,000		70	50		
05/19/92	>16000	6,700		300	64		
05/14/92	200	120		200	20		
05/12/92	8,000	2,200		400	40		
05/07/92	>16000	140		1,600	<20		
05/05/92	>16000	>16000		370	60		
04/28/92	450	320		960	40		

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
04/21/92	7,700	3,400		2,800	730		
04/14/92	8,100	450		420	50		
04/08/92	4,200	1,400		570	140		
03/31/92	3,500	700		>16000	7,000		
03/24/92	12,000	3,100		9,300	4,700		
03/18/92	3,800	2,500		610	110		
03/10/92	1,800	800		550	100		
03/03/92	18,000	1,800		18,000	840		
	Analysis Performed by Multiple Tube Fermentation						
	MPN/100 ml	MPN/100 ml		MPN/100 ml	MPN/100 ml		
02/25/92	1,600	860		580	140		MPN/100 ml
02/18/92	6,400	4,400		2,800	1,200		
02/12/92	>16000	16,000		>16000	>16000		
02/04/92	230	230		1,300	230		
01/28/92	9,000	9,000		1,700	700		
01/22/92	170	110		5,000	3,000		
01/14/92	1,300	500		500	130		
01/07/92	>16000	>16000		16,000	9,000		
12/30/91	>16000	16,000		>16000	9,000		
12/23/91	9,000	9,000		700	170		
12/16/91	9,000	9,000		1,100	80		
12/10/91	>16000	500		1,700	230		
12/04/91	2,800	2,200		700	40		
11/25/91	5,000	5,000		1,100	70		
11/20/91	>16000	>16000		40	<20		
11/13/91	>16000	16,000		1,300	500		
11/06/91	5,000	1,300		700	40		
10/31/91	9,000	2,200		3,000	170		
10/29/91	>16000	3,000		5,000	500		
10/24/91	16,000	3,000		>16000	800		
10/22/91	5,000	1,700		500	300		
10/16/91	9,000	1,100		1,700	130		
10/14/91	16,000	3,500		3,000	130		
10/10/91	5,000	3,000		1,100	110		
10/08/91	2,400	1,300		1,700	80		
10/03/91	>16000	>16000		1,700	300		
10/01/91	5,000	3,000		3,000	20		
09/26/91	5,000	5,000		800	<20		
09/24/91	9,000	2,200		1,100	80		
09/19/91	16,000	9,000		1,700	230		
09/17/91	3,000	1,300		1,700	70		
09/11/91	1,300	20		3,000	800		
09/09/91	1,300	500		5,000	230		
09/05/91	5,000	1,100		1,700	20		
09/03/91	3,000	3,000		9,000	20		
08/28/91	800	300		2,200	70		
08/26/91	1,100	210		5,000	90		
08/21/91	1,100	40		2,400	220		
08/19/91	1,300	140		16,000	500		
08/14/91	2,400	1,300		1,300	130		
08/12/91	9,000	2,400		1,300	40		
08/07/91	16,000	3,000		800	130		
08/05/91	1,700	300		230	80		
07/31/91	2,200	700		3,000	1,700		
07/29/91	<20	40		800	800		
07/24/91	1,300	300		1,100	110		
07/22/91	>16000	40		1,100	20		
07/17/91	500	170		500	80		
07/15/91	2,200	500		1,400	20		
07/11/91	230	80		360	40		
07/09/91	3,000	500		1,300	800		
07/03/91	5,000	80		3,000	40		
07/01/91	300	300		500	40		
06/27/91	3,000			300			
06/25/91	600			2,200			
06/20/91	2,200			1,700			
6/18//91	1,300			300			
06/12/91	>16000			1,100			
06/10/91	5,000			1,700			
06/06/91	2,400			16,000			
06/04/91	1,100			3,000			
05/30/91	3,000			900			
05/28/91	16,000			16,000			
05/22/91	3,500			1,700			
05/20/91	800			300			
05/16/91	1,700			5,000			
05/14/91	9,000			3,000			

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
05/08/91	>16000			2,200			
05/06/91	1,700			2,400			
05/02/91	5,000			800			
04/30/91	1,700			50			
04/23/91	9,000			500			
04/17/91	800			500			
04/10/91	1,300			300			
04/03/91	9,000			500			
03/27/91	>16000			>16000			
03/20/91	>16000			>16000			
03/12/91	5,000			3,000			
03/06/91	9,000			5,000			
02/27/91	5,000			>16000			
02/20/91	9,000			16,000			
02/13/91	9,000			1,400			
02/06/91	9,000			2,400			
01/30/91	5,000			5,000			
01/23/91	2,200			2,200			
01/15/91	1,300			5,000			
01/09/91	>16000			>16000			
01/02/91	3,000			9,000			
12/26/90	16,000			800			
12/19/90	9,000			>16000			
12/11/90	2,400			1,100			
12/05/90	1,700			1,300			
11/27/90	>16000			9,000			
11/20/90	>16000			>16000			
11/14/90	5,000			16,000			
11/08/90	3,000			16,000			
10/31/90	>16000			>16000			
10/25/90	>16000			>16000			
10/22/90	9,000			5,000			
10/18/90	5,000			5,000			
10/16/90	9,000			9,000			
10/11/90	9,000			5,000			
10/09/90	9,000			9,000			
10/04/90	5,000			5,000			
10/02/90	>16000			9,000			
09/27/90	16,000			16,000			
09/25/90	800			>16000			
09/20/90	>16000			16,000			
09/18/90	9,000			5,000			
09/13/90	16,000			5,000			
09/10/90	5,000			16,000			
09/06/90	16,000			9,000			
09/04/90	16,000			5,000			
08/30/90	9,000			9,000			
08/28/90	9,000			5,000			
08/23/90	16,000			5,000			
08/21/90	3,000			2,400			
08/15/90	3,000			5,000			
08/13/90	1,300			2,400			
08/09/90	2,400			9,000			
08/07/90	>16000			3,000			
08/02/90	9,000			1,300			
07/31/90	3,000			1,700			
07/25/90	16,000			1,700			
07/23/90	5,000			16,000			
07/18/90	800			9,000			
07/16/90	800			2,400			
07/12/90	16,000			9,000			
07/10/90	2,800			2,400			
07/05/90	800			500			
07/03/90	300			2,200			
06/28/90	500			2,200			
06/26/90	3,000			3,000			
06/21/90	16,000			5,000			
06/19/90	900			500			
06/13/90	>16000			9,000			
06/11/90	>16000			9,000			
06/06/90	3,000			5,000			
06/04/90	9,000			2,400			
05/31/90	9,000			5,000			
05/29/90	>16000			16,000			
05/23/90	5,000			1,100			
05/21/90	2,400			300			
05/17/90	3,000			700			

Date	SERRA Station C1 - San Juan Creek Mouth Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	SERRA Station C2 - Upstream of Latham Facility Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
05/15/90	9,000			1,100			
05/09/90	9,000			3,500			
05/07/90	900			500			
05/02/90	3,000			2,400			
04/30/90	5,000			3,000			
04/24/90	>16000			>16000			
04/17/90	>16000			>16000			
04/11/90	16,000			5,000			
04/04/90	>16000			>16000			
03/27/90	5,000			500			
03/21/90	16,000			2,400			
03/14/90	16,000			5,000			
03/06/90	3,000			5,000			
03/01/90	16,000			24,000			
02/28/90	30,000			50,000			
02/21/90	>16000			>16000			
02/14/90	2,200			700			
02/06/90	9,000			1,100			
01/30/90	>16000			5,000			
01/24/90	1,100			2,200			
01/16/90	16,000			>16000			
01/09/90	9,000			3,000			
01/03/90	>16000			16,000			
12/27/89	2,400			1,700			
12/20/89	2,200			1,000			
12/12/89	5,000			3,000			
12/05/89	5,000			>16000			
11/28/89	>16000			16,000			
11/20/89	16,000			>16000			
11/14/89	16,000			5,000			
11/07/89	16,000			5,000			
11/02/89	1,300			1,700			
10/26/89	16,000			16,000			
10/24/89	>16000			>16000			
10/19/89	16,000			9,000			
10/17/89	170			5,000			
10/12/89	>16000			9,000			
10/10/89	5,000			5,000			
10/05/89	>16000			5,000			
10/03/89	80			5,000			
09/28/89	16,000			3,000			
09/26/89	9,000			2,400			
09/21/89	>16000			9,000			
09/19/89	>16000			>16000			
09/14/89	16,000			5,000			
09/12/89	5,000			3,000			
09/07/89	1,700			9,000			
09/05/89	9,000			9,000			
08/30/89	2,800			1,700			
08/29/89	9,000			16,000			
08/24/89	2,400			2,800			
08/22/89	2,800			9,000			
08/17/89	>16000			9,000			
08/15/89	9,000			2,200			
08/10/89	5,000			16,000			
08/08/89	>16000			5,000			
08/03/89	>16000			16,000			
08/01/89	1,400			3,500			
07/27/89	5,000			16,000			
07/25/89	>16000			9,000			
07/20/89	>16000			16,000			
07/18/89	16,000			16,000			
07/12/89	16,000			16,000			
07/10/89	>16000			3,000			
07/05/89	2,800			16,000			
07/03/89	2,400			5,000			
06/29/89	5,000			16,000			
06/27/89	9,000			16,000			
06/22/89	5,000			800			
06/20/89	>16000			9,000			
06/14/89	16,000			3,000			
06/12/89	9,000			1,700			
06/08/89	5,000			9,000			
06/06/89	3,000			3,000			
06/01/89	5,000			300			
05/30/89	2,800			700			
05/25/89	2,400			1,100			

Date	SERRA Station C1 - San Juan Creek Mouth Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	SERRA Station C2 - Upstream of Latham Facility Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
05/23/89	5,000			800			
05/17/89	16,000			210			
05/15/89	3,000			1,300			
05/11/89	9,000			400			
05/09/89	9,000			2,400			
05/04/89	>16000			2,400			
05/02/89	1,100			900			
04/25/89	9,000			>16000			
04/17/89	16,000			2,200			
04/12/89	16,000			16,000			
04/04/89	5,000			1,400			
03/29/89	9,000			9,000			
03/21/89	16,000			2,200			
03/14/89	16,000			>16000			
03/07/89	2,400			5,000			
02/28/89	>16000			9,000			
02/21/89	3,000			16,000			
02/14/89	16,000			5,000			
02/07/89	>16000			>16000			
01/31/89	9,000			9,000			
01/24/89	16,000			3,000			
01/17/89	1,700			800			
01/09/89	3,000			2,400			
01/04/89	2,800			>16000			
12/27/88	>16000			>16000			
12/19/88	>16000			>16000			
12/13/88	1,300			170			
12/07/88	1,700			500			
11/30/88	5,000			5,000			
11/21/88	9,000			2,200			
11/15/88	>16000			>16000			
11/08/88	16,000			>16000			
11/02/88	9,000			>16000			
10/27/88	300			16,000			
10/25/88	9,000			>16000			
10/19/88	16,000			16,000			
10/17/88	>16000			>16000			
10/13/88	3,000			3,000			
10/11/88	5,000			>16000			
10/06/88	>16000			16,000			
10/04/88	>16000			9,000			
09/29/88	>16000			>16000			
09/27/88	3,000			>16000			
09/22/88	>16000			>16000			
09/20/88	>16000			16,000			
09/15/88	9,000			5,000			
09/13/88	5,000			16,000			
09/08/88	9,000			5,000			
09/06/88	5,000			16,000			
09/01/88	9,000			9,000			
08/30/88	3,000			>16000			
08/25/88	5,000			5,000			
08/23/88	5,000			2,200			
08/18/88	5,000			5,000			
08/16/88	16,000			3,000			
08/11/88	700			5,000			
08/09/88	1,700			16,000			
08/05/88	1,100			5,000			
08/02/88	3,000			3,000			
07/27/88	5,000			16,000			
07/25/88	16,000			2,200			
07/20/88	1,700			3,000			
07/18/88	9,000			16,000			
07/14/88	9,000			>16000			
07/11/88	>16000			9,000			
07/07/88	16,000			>16000			
07/05/88	>16000			3,000			
06/30/88	>16000			3,000			
06/28/88	1,300			800			
06/23/88	9,000			5,000			
06/21/88	9,000			1,300			
06/16/88	2,400			3,000			
06/14/88	9,000			1,700			
06/09/88	5,000			3,000			
06/07/88	700			3,000			
06/02/88	16,000			2,200			
05/31/88	2,400			>16000			

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
05/26/88	1,700			16,000			
05/24/88	2,400			300			
05/19/88	2,400			3,000			
05/17/88	400			16,000			
05/12/88	3,000			3,000			
05/10/88	9,000			9,000			
05/05/88	3,000			2,400			
05/03/88	1,300			1,700			
04/27/88	5,000			1,100			
04/21/88	>16000			2,400			
04/13/88	16,000			3,000			
04/06/88	16,000			16,000			
03/30/88	1,700			1,300			
03/23/88	1,300			1,300			
03/16/88	2,200			3,000			
03/08/88	9,000			3,000			
03/02/88	>16000			>16000			
02/25/88	800			9,000			
02/17/88	1,700			1,300			
02/10/88	16,000			2,400			
02/03/88	>16000			>16000			
01/27/88	3,000			1,300			
01/20/88	3,000			>16000			
01/13/88	1,300			300			
01/06/88	9,000			3,000			
12/28/87	2,800			1,300			
12/21/87	5,000			5,000			
12/15/87	5,000			2,200			
12/08/87	9,000			500			
12/02/87	3,000			5,000			
11/24/87	800			3,000			
11/18/87	>16000			3,000			
11/10/87	2,400			500			
11/04/87	16,000			5,000			
10/29/87	>16000			>16000			
10/27/87	9,000			2,400			
10/21/87	>16000			2,400			
10/19/87	>16000			16,000			
10/15/87	16,000			>16000			
10/13/87	>16000			>16000			
10/08/87	5,000			9,000			
10/06/87	16,000			9,000			
10/01/87	16,000			16,000			
09/29/87	16,000			9,000			
09/24/87	9,000			>16000			
09/22/87	>16000			9,000			
09/17/87	9,000			5,000			
09/15/87	>16000			16,000			
09/10/87	20			5,000			
09/08/87	2,400			16,000			
09/03/87	16,000			3,000			
09/01/87	3,000			5,000			
08/27/87	3,000			5,000			
08/25/87	>16000			16,000			
08/20/87	5,000			2,400			
08/18/87	>16000			>16000			
08/13/87	9,000			16,000			
08/10/87	5,000			>16000			
08/06/87	1,300			2,400			
08/04/87	>16000			16,000			
07/30/87	3,000			>16000			
07/28/87	5,000			9,000			
07/23/87	5,000			2,400			
07/21/87	5,000			3,000			
07/16/87	5,000			16,000			
07/14/87	16,000			5,000			
07/09/87	9,200			16,000			
07/08/87	3,000			1,100			
07/02/87	16,000			2,200			SERRA Lab collects and analyzes
06/30/87	3,000			3,000			Associated Lab collects & analyzes
06/25/87	>24000			16,000			
06/22/87	>24000			>24000			
06/19/87	>16000			>24000			
06/16/87	5,400			>24000			
06/12/87	9,200			16,000			

Date	SERRA Station C1 - San Juan Creek Mouth Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	SERRA Station C2 - Upstream of Latham Facility Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
06/08/87	>24000			>24000			
06/04/87	16,000			>24000			
06/01/87	>24000			>24000			
05/30/87	16,000			>24000			
05/28/87	>24000			>24000			
05/19/87	>24000			9,200			
05/17/87	>24000			>24000			
05/14/87	9,200			>24000			
05/11/87	9,200			>24000			
05/08/87	9,200			9,200			
05/04/87	16,000			>24000			
05/01/87	16,000			5,400			
04/23/87	>24000			9,200			
04/17/87	16,000			>24000			
04/09/87	3,500			9,200			
04/04/87	9,200			>24000			
03/22/87	16,000			>24000			
03/20/87	>24000			>24000			
03/12/87	9,300			5,400			
03/05/87	5,400			3,500			
02/27/87	9,200			16,000			
02/20/87	9,200			5,400			
02/13/87	16,000			2,400			
02/05/87	>24000			5,400			
01/30/87	350			2,400			
01/22/87	460			1,700			
01/16/87	2,400			5,400			
01/09/87	16,000			16,000			
12/21/86	2,400			2,400			
12/19/86	3,500			9,200			
12/12/86	5,400			5,400			
12/05/86	1,100			1,300			
11/25/86	16,000			2,800			
11/17/86	>24000			>24000			
11/11/86	5,400			9,200			
11/04/86	490			2,400			
10/30/86	2,200			490			
10/27/86	3,500			1,100			
10/23/86	2,400			3,500			
10/20/86	5,400			16,000			
10/17/86	1,300			5,400			
10/15/86	5,400			16,000			
10/10/86	>24000			>24000			
10/07/86	>24000			>24000			
10/03/86	>24000			>24000			
09/29/86	>24000			>24000			
09/26/86	>24000			>24000			
09/22/86	>24000			>24000			
09/19/86	>24000			5,000			
09/15/86	>24000			>24000			
09/12/86	>24000			>24000			
09/10/86	>24000			>24000			
09/05/86	>24000			>24000			
09/03/86	>24000			>24000			
08/29/86	>24000			>24000			
08/27/86	>24000			>24000			
08/22/86	16,000			16,000			
08/19/86	>24000			>24000			
08/15/86	5,400			490			
08/11/86	3,500			9,200			
08/08/86	5,400			1,100			
08/06/86	9,200			9,200			
07/31/86	>24000			>24000			
07/29/86	>24000			>24000			
07/25/86	>24000			>24000			
07/21/86	>24000			>24000			
07/18/86	>24000			>24000			
07/14/86	>24000			>24000			
07/11/86	>24000			>24000			
07/07/86	5,400			9,200			
07/02/86	5,400			2,400			
06/30/86	5,400			>24000			
06/27/86	>24000			9,200			
06/23/86	>24000			>24000			
06/20/86	>24000			16,000			
06/18/86	940			3,500			
06/13/86	60			210			

	SERRA Station C1 - San Juan Creek Mouth			SERRA Station C2 - Upstream of Latham Facility			
Date	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
06/11/86	>24000			>24000			
06/06/86	80			490			
06/02/86	2,400			2,400			
05/30/86	>24000			>24000			
05/28/86	3,500			490			
05/23/86	2,400			1,100			
05/21/86	790			940			
05/15/86	490			1,100			
05/12/86	3,500			2,400			
05/09/86	5,400			9,200			
05/05/86	16,000			9,200			
04/30/86	1,700			2,200			
04/21/86	5,400			1,300			
04/18/86	1,400			1,400			
04/07/86	>24000			9,200			
04/04/86	80			70			
03/27/86	490			230			
03/17/86	16,000			9,200			
03/14/86	>24000			>24000			
03/03/86	>24000			1,300			
02/28/86	>24000			1,700			
02/18/86	3,500			3,500			
02/14/86	3,500			5,400			
02/07/86	790			790			
01/27/86	<20			2,200			
01/25/86	<20			9,200			
01/17/86	1,100			1,100			
01/09/86	16,000			9,200			
12/31/85	16,000			>24000			
12/28/85	>24000			>24000			
12/20/85	490			700			
12/13/85	9,200			16,000			
12/05/85	1,300			>24000			
11/27/85	9,200			5,400			
11/22/85	>24000			>24000			
11/15/85	790			2,400			
11/08/85	9,200			9,200			
10/31/85	2,800			16,000			
10/25/85	>24000			>24000			
10/21/85	>24000			>24000			
10/17/85	3,500			2,400			
10/14/85	>24000			16,000			
10/10/85	>24000			>24000			
10/07/85	>24000			>24000			
10/04/85	>24000			>24000			
10/01/85	5,400			>24000			
09/27/85	5,400			5,400			
09/23/85	1,700			2,400			
09/20/85	9,200			16,000			
09/16/85	2,200			1,300			
09/12/85	230			3,500			
09/10/85	2,400			16,000			
09/06/85	2,400			2,400			
09/03/85	3,500			2,400			
08/29/85	9,200			3,500			
08/26/85	>24000			5,400			
08/23/85	<20			2,400			
08/19/85	700			2,800			
08/15/85	130			>24000			
08/12/85	3,500			9,200			
08/07/85	16,000			3,500			
08/05/85	5,400			2,400			
08/01/85	2,400			2,400			
07/29/85	2,400			2,400			
07/24/85	430			9,200			
07/22/85	330			9,200			
07/19/85	>24000			>24000			
07/17/85	>24000			>24000			
07/11/85	3,500			1,700			
07/08/85	9,200			5,400			
07/05/85	3,500			3,500			
07/03/85	3,500			700			
06/27/85	<20			<20			
06/24/85	20			<20			
06/20/85	<20			<20			
06/18/85	<20			50			
06/13/85	490			50			

Date	SERRA Station C1 - San Juan Creek Mouth Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	SERRA Station C2 - Upstream of Latham Facility Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
06/10/85	230			430			
06/08/85	<20			50			
06/03/85	<20			<20			
05/31/85	20			<20			
05/29/85	20			80			
05/22/85	<20			<20			
05/19/85	20			40			
05/17/85	<20			<20			
05/13/85	20			20			
05/09/85	<20			<20			
05/05/85	<20			<20			
05/02/85	<20			50			
04/22/85	330			490			
04/15/85	<20			<20			
04/08/85	<20			<20			
04/01/85	<20			<20			
03/25/85	<20			<20			Samples collected by Assoc. Lab/analyzed by SERRA
03/21/85	79			79			
03/14/85	17			130			
03/07/85	7			4			
02/25/85	23			49			
02/21/85	<2			<2			
02/14/85	13			33			
02/04/85	11			13			
01/28/85	170			540			
01/21/85	>2400			>2400			
01/17/85	46			33			
01/07/85	540			540			
01/02/85	350			220			
12/29/84	240			240			
12/17/84	79			540			
12/12/84	350			350			
12/05/84	350			350			
11/26/84	33			49			
11/19/84	240			44			
11/12/84	23			44			
11/05/84	130			79			
10/29/84	<2			<2			
10/25/84	<2			<2			
10/22/84	<2			<2			
10/18/84	<2			<2			
10/15/84	2			2			
10/10/84	220			350			
10/08/84	5			<2			
10/04/84	<2			<2			
10/01/84	2			8			
09/27/84	240			240			
09/25/84	<2			<2			
09/20/84	2			2			
09/19/84	350			220			
09/12/84	540			23			
09/10/84	<2			5			
09/08/84	49			49			
09/06/84	170			240			
08/27/84	920			920			
08/23/84	79			110			
08/20/84	<2			<2			
08/16/84	4			2			
08/13/84	33			46			
08/08/84	<2			<2			
08/06/84	2			<2			
08/02/84	<2			<2			
07/30/84	<2			2			
07/26/84	<2			<2			
07/25/84	8			8			
07/21/84	79			240			
07/17/84	7			<2			
07/12/84	11			11			
07/10/84	33			110			
07/05/84	23			14			
07/02/84	79			26			
06/28/84	49			33			
06/26/84	13			17			
06/21/84	2			2			
06/19/84	46			110			
06/14/84	33			79			

Date	SERRA Station C1 - San Juan Creek Mouth Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	SERRA Station C2 - Upstream of Latham Facility Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
06/12/84	220			110			
06/07/84	2			11			
06/05/84	4			11			
05/31/84	13			11			
05/28/84	49			13			
05/25/84	130			130			
05/19/84	110			79			
05/17/84	170			49			
05/15/84	23			13			
05/10/84	130			170			
05/07/84	23			8			
05/03/84	33			17			
05/02/84	23			23			
04/23/84	1,600			240			
04/17/84	5			8			
04/10/84	79			70			
04/04/84	27			33			
03/26/84	49			23			
03/19/84	49			79			
03/12/84	1,600			1,600			
03/07/84	49			49			
02/27/84	31			130			
02/21/84	350			350			
02/14/84	2			<2			
02/07/84	>2400			>2400			
02/03/84	>2400			>2400			
01/28/84	920			1,600			
01/21/84	<2			2			
01/14/84	<2			<2			
01/06/84	240			350			
12/31/83	2			5			
12/19/83	2			<2			
12/15/83	2			<2			
12/08/83	>2400			>2400			
11/28/83	>2400			>2400			
11/21/83	9			7			
11/14/83	920			350			
11/11/83	>2400			>2400			
11/01/83	>2400			>2400			
10/28/83	>2400			>2400			
10/27/83	>2400			>2400			
10/20/83	>2400			>2400			
10/17/83	1,600			>2400			
10/14/83	>2400			>2400			
10/12/83	1,600			350			
10/05/83	>2400			>2400			
10/03/83	>2400			>2400			
09/27/83	540			>2400			
09/21/83	>2400			>2400			
09/19/83	920			>2400			
09/15/83	>2400			>2400			
09/13/83	>2400			>2400			
09/08/83	1,600			>2400			
09/06/83	350			920			
09/01/83	79			79			
08/30/83	>2400			>2400			
08/25/83	>2400			>2400			
08/22/83	240			350			
08/20/83	>2400			>2400			
08/17/83	>2400			>2400			
08/11/83	>2400			>2400			
08/09/83	920			>2400			
08/04/83	540			130			
08/01/83	350			170			
07/30/83	920			350			Samples collected and analyzed by Assoc. Lab
07/25/83	920			>2400			
07/21/83	1,600			>2400			
07/19/83	8			23			
07/11/83	>2400			>2400			
07/07/83	920			1,600			
07/05/83	>2400			>2400			
07/02/83	>2400			1,600			
06/25/83	920			540			
06/20/86	1,600			>2400			
06/16/83	920			540			
06/14/83	1,600			1,600			

Date	SERRA Station C1 - San Juan Creek Mouth Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	SERRA Station C2 - Upstream of Latham Facility Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml	Enterococcus CFU/100 ml	Notes
06/10/83	540			>2400			
06/06/83	170			540			
06/03/83	920			920			
06/01/83	>2400			1,600			
05/25/83	1,600			>2400			
05/23/83	>2400			1,600			
05/19/83	1,600			>2400			
05/17/83	>2400			540			
05/14/83	920			920			
05/12/83	920			1,600			
05/05/83	>2400			>2400			
05/04/83	1,600			>2400			
04/27/83	540			540			
04/24/83	1,600			>2400			
04/20/83	>2400			>2400			
04/18/83	>2400			>2400			
04/13/83	>2400			920			
04/11/83	240			170			
04/06/83	>2400			>2400			
04/04/83	1,600			920			
03/30/83	350			350			
03/28/83	>2400			>2400			
03/25/83	>2400			>2400			
03/22/83	920			>2400			
03/19/83	>2400			>2400			
03/14/83	1,600			350			
03/10/83	1,600			1,600			
03/08/83	>2400			>2400			
03/04/83	>2400			>2400			
03/03/83	>2400			>2400			
02/25/83	>2400			>2400			
02/23/83	>2400			920			
02/19/83	220			350			
02/15/83	>2400			1,600			
02/10/83	540			160			
02/09/83	>2400			>2400			
02/03/83	>2400			>2400			
01/27/83	>2400			>2400			
01/25/83	>2400			>2400			
01/20/83	1,600			>2400			
01/18/83	1,600			>2400			
01/14/83	49			49			
01/11/83	1,600			1,600			
01/06/83	170			540			
01/03/83	350			140			
12/30/82	220			170			
12/27/82	>2400			1,600			
12/20/82	920			540			
12/18/82	>2400			540			
12/16/82	540			920			
12/15/82	280			350			
12/10/82	1,600			>2400			
12/09/82	>2400			>2400			
12/03/82	>2400			>2400			
12/02/82	>2400			>2400			

Notes:
Data provided by South East Regional Reclamation Authority.
Site C1 is located at the mouth of San Juan Creek above the surfzone at Doheny State Beach.
Site C2 is located above the J.B. Latham Treatment Plant in Del Obispo Park.

Appendix: C

Groundwater Sustaining Landscape-Scale Wetland Functions, San Juan and San Mateo Watersheds, Southern Orange County, California

Prepared for:

Rancho Mission Viejo

Prepared by:

Barry Hecht

Balance Hydrologics, Inc

September 2001

A report prepared for:

Rancho Mission Viejo
28811 Ortega Highway
San Juan Capistrano, California 92692
Attention: Laura Coley Eisenberg
(949) 240-3363 ext. 297

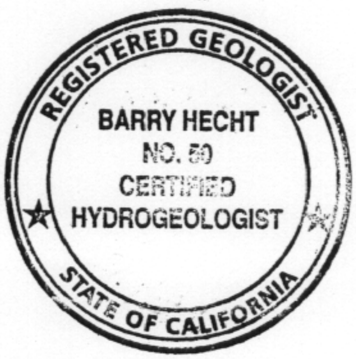
Appendix: C

Groundwater Sustaining Landscape-Scale Wetland Functions, San Juan and San Mateo Creek Watersheds, Southern Orange County, California

Balance Project Assignment 99058

by

Barry Hecht, RG3664, CHg50



Balance Hydrologics, Inc.
900 Modoc Street
Berkeley, CA 94707-2208
(510) 527-0727
bhecht@balancehydro.com

September 20, 2001

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C. East-west hydrogeologic cross section through the central SAMP area

1. INTRODUCTION

1.1 Background of Study

This report is intended to characterize existing groundwater conditions affecting riparian and aquatic habitat functions within the San Juan and portions of the San Mateo Creek basin watershed in southern Orange County. The report considers:

- Groundwater dynamics affecting seeps, springs and summer live streams and the habitat that they support in the two watersheds, and in that light:

  a. The occurrence of groundwater, and the properties of aquifers and aquicludes

  b. A summary of existing and potential groundwater use

  c. Groundwater level fluctuations

  d. Recharge and movement of groundwater

  e. Chemistry of groundwater, where salinity or ionic composition helps in understanding the paths through which groundwater moves, especially in the bedrock-aquifer settings so important in parts of the area.

- Existing groundwater data and future monitoring needs.

This report is part of a series of investigations which are helping to describe and interpret baseline conditions in the Special Area Management Plan portions of the San Juan and San Mateo watersheds in Orange County designated for landscape- or watershed-scale assessment, as part of the Corps of Engineers. Of necessity, groundwater is closely linked to system-wide analysis of soil-geomorphic terrains, of slope wetlands (springs and seeps) and of water quality, among other issues. In many respects, groundwater is also inversely linked to sediment yield, in that (under natural conditions) yields tend to be low where recharge is high, and bank erosion is low where water tables are high enough to sustain vigorous riparian vegetation, and vice versa. Information presented or derived in these and other reports is not necessarily repeated in this document, and they are best read as a set.

Because this report is directed primarily at groundwater-sustained areas of habitat value, its focus is upon factors which affect flows in seeps and springs, and in groundwater-supplied baseflow reaches. Traditional hydrogeologic or yield descriptors are included primarily to the extent that they are needed to understand how and where groundwater is available to sustain wetland or riverine functions. Readers seeking a treatment of hydrogeologic conditions directed at groundwater-resource utilization will find a habitat-oriented overview in Chapter 5, which will also point them to recent comprehensive reports, cited in the references.

At the watershed scale, recharge to groundwater is likely to increase moderately as the watershed is converted to uses that generally may be characterized as suburban[1], absent extensive areas of new and continuous impervious surfaces such as might occur in large industrial parks. The additional recharge is likely to have a chemistry and quality typical of water imported to urban areas in Orange County, which (on average) has lower concentrations of dissolved solids and most other constituents in comparison with local groundwater presently supporting springs, seeps and live streams. Hence, at the *landscape or watershed* scale or for all such wetlands collectively, major changes in inflows to these specific sites would not be expected.[2] However, as reviewed below such changes could be significant, when combined with changes in surface flow at a sub-watershed level.

A useful baseline hydrogeologic analysis of flow to these areas of habitat significance, however, should reasonably recognize that effects of land-use change are likely to be specific to individual wetlands and stream segments. The baseflow analysis can identify areas where similar groundwater processes and functions supporting the habitat areas occur. It can also usefully discuss individual wetlands

[1] For a recent impact analysis of effects of a large nearby residential project on recharge in a broadly similar setting, see Hamilton's recent (2000) simulations of effects in the Muddy Canyon area, which assume drought-tolerant vegetation in common areas, and "lush" plantings in residential areas.

[2] Increases in dry-season stream baseflows excepted; to be meaningful, these must be assessed in the context of a particular plan or alternative.

and groups of wetlands at a level which can guides future changes to minimize changes in yields, duration of flow, and chemistry of water entering the wetland or reach of stream with sustained baseflows. This report attempts to address these issues by collecting and applying the available information such that reasonable inferences and guidances can be introduced into the planning process at an early date and a broad scale.

1.2 Organization of this Report

Prior hydrogeologic work and other available information, as well as how it can used in the present context, is discussed in Chapter 2. Chapter 3 describes the occurrence of ground water in and near the SAMP areas, and the physical and chemical hydrogeologic attributes of individual formations or areas. Chapter 4 focuses on groundwater movement, and where and when recharge occurs. Chapter 5 is a limited discussion of existing and future groundwater development, including only background data essential for interpreting flows to habitat areas; more detailed information previously developed for the SAMP is available in recent watershed-scale reports by the Corps of Engineers (1999) and KEA (2000). Chapter 6 discusses the unique attributes of the lower Chiquita and Gobernadora areas, where most of the existing wetlands occur, and how some of these lessons may be applied elsewhere in the SAMP region. Findings are summarized in Chapter 7. References used in developing this analysis are included in Chapter 8.

The organization of the first four chapters is typical of many conventional hydrogeologic investigations, which fundamentally focus upon the potential or actual development of groundwater. Later chapters are more specific to hydrogeologic support of individual wetlands and live stream segments. A separate chapter considering water quality is not included for reasons discussed in the next section.

1.3 Groundwater Chemistry and Quality

Groundwater chemistry is a focus of this report, because the data help infer where and through what paths water reaches sensitive habitat areas. Since other hydrogeologic information is often sparse and the subsurface geology of the study area is complex, use of water chemistry as a 'tracer' is especially important.

Water quality in the traditional sense – as a set of standards or management objectives and constraints – is probably not an issue in maintaining the functions of groundwater in supporting the wetlands. The salinity, pH, and ionic composition of waters in the seeps, springs and live streams do not appear to constrain their role as habitat. The native vegetation which is supported by the emanating groundwater is – almost by definition -- able to utilize the existing quality of water. Boron, which can inhibit growth of some crops and a few native species, does not appear to be present in concentrations that approach known tolerance thresholds. A few of the seeps near the mouth of Chiquita Canyon are proportionately very high in sodium, which can potentially affect which plant species are supported. Otherwise, water chemistry is significant more as an indicator of process than as a planning consideration, and hence is considered in several portions of the report.

2. PRIOR WORK AND SOURCES USED

Groundwater conditions in the San Juan watershed are known primarily from a series of reports prepared during the 1960s and 1970s, plus more recent investigations sponsored by the San Juan Basin Authority. Information available to the public on groundwater conditions in the San Mateo watershed is extremely limited, particularly for the Cristianitos sub-basin draining the portion in Orange County; however, observations of surface flow and land use allow reasonable inferences to be made.

Balance staff systematically measured groundwater outflow -- seeps, springs, and baseflow in streams -- during late-fall 1999 and intermittently during 2000 throughout the study area, primarily in May and June. Results are presented in Appendix A. PCR Services staff (Lee and Stein, 2000) also measured yields and specific conductances of seeps and springs at slope wetlands at more frequent intervals during both years, and submitted samples of soil and water for analyses of major constituents.

Principal documentary sources used for this analysis include:

1. Primary data and sources of information, including selected well completion reports, geologic investigations, water-level measurements, and water-quality analyses

2. Earlier technical reports describing groundwater conditions in this area, many of which are listed below in Section 8, References Cited

3. Existing summaries of groundwater and hydrogeologic conditions in various documents prepared by or for the Corps of Engineers (KEA, 1998; Smith, 2000; Lichvar and others, 2000), California Department of Fish and Game, 2000, U.S. Fish and Wildlife Service (Wilkinson and Collier, 2000) and other state, federal and local agencies with resource-management responsibilities

4. A number of detailed investigations by the California Department of Water Resources, as well as consultants to DWR and local water districts developed

during the 1960s, when seminal decisions were made to import Feather and Colorado River water

5. Portions of the Basin Plan for the San Diego Regional Water Quality Control Board bearing upon groundwater.

Recent information on groundwater conditions in several areas is not yet publicly available, including (a) results from piezometers emplaced throughout the study area by TCA's consultants, (b) data from the San Mateo Creek Valley within the Marine Corps Base at Camp Pendleton (MCBCP), and in the vicinity of the TRW facility near the confluence of Gabino and Cristianitos Creeks. Once these materials become available to us, conclusions regarding specific areas or the vicinities of individual wetlands may be revised.

Older information regarding the history of groundwater development is essential to understanding when and where pumping began to affect riparian corridors. In southern Orange County, historical groundwater information is limited. We have searched conventional archives at State offices in Sacramento, and at several key repositories at the University of California at Berkeley, among them the Bancroft Library and the state's Water Resources Center Archives. Tom Staley, Director of Engineering at Rancho Mission Viejo, located a number of important sources not available elsewhere in the ranch's files. Gilbert Aguirre and Fred Verhoogen, long-time staff at the ranch, share their memories of spring locations and histories, as well as the effects of the 1969 floods on the ranch's wells and distributions system. Collectively, these documents paint a coherent picture of alluvial systems in the core of the SAMP study area that were largely undisturbed by groundwater pumpage until the mid 1960s or (where slowed by the 1969 storm damage) even later, a truly unusual situation in Southern California.

3. GROUNDWATER OCCURRENCE

The types and distributions of aquifers and non-water-bearing geologic units are discussed in this section of the report. The chapter also discusses their aquifer properties and the magnitude of water-level fluctuations which might be expected both seasonally and during droughts.

3.1 Unconsolidated Aquifers and Aquicludes

For the purposes of assessing linkages to landscape-scale aquatic and riparian habitat functions, it may prove helpful to consider that groundwater occurs in four types of aquifers within the San Juan and Orange County portions of the San Mateo watershed. One of these is the unconsolidated aquifers of recent age.

3.1.1 Alluvial and terrace aquifers

Aquifers composed of alluvial materials are the predominant source of water used for municipal and agricultural uses throughout the San Juan and San Mateo watersheds. They are also of both local and regional significance in sustaining riparian corridors and/or phreatophytic vegetation. These aquifers include:

1. older alluvium which fills the larger valleys to depths increasing coastward and eventually thickening to about 200 feet near the mouth of San Juan (California Department of Water Resources, 1971) and San Mateo Creeks, and which contains distinct cobble/gravel, sandy, and clay-rich lake deposits,

2. recent alluvium of the active channel and floodplains, which is an important source of water for most hydrophytic woody plants in the two watersheds,

3. stream terrace and related colluvial deposits, which can store water seasonally, replenishing alluvium beneath it, or (in some cases) concentrating and directing bedrock outflows into sustained springs and slope wetlands (see Figure 1).

The alluvial aquifers of the San Juan watershed were systematically assessed in the late 1960s and early and 1970s by senior professionals from the Department of Water

Resources (1971, Appendix B) and Division of Mines and Geology (Morton, 1974; Blanc and Cleveland, 1968). They divided the alluvium into approximately 100 reaches, and estimated potential groundwater storage within each. Their findings indicate a total of approximately 90,000 acre feet of alluvial groundwater storage in the main valleys of the San Juan watershed, including:

Table 1. Approximate volume of groundwater in alluvial aquifers of named drainages

MAJOR CHANNEL	LIMITS	SUB-BASIN	VOLUME OF GROUNDWATER, SUB-BASIN	VOLUME OF GROUNDWATER, MAJOR BASIN
			(Acre Feet.)	(Acre Feet)
San Juan Cr.	Main stem, coast to elev. 620			45, 700
		Horno Creek	650	
		Chiquita Canyon	4,850	
		Gobernadora	9,180	
		Bell Canyon	3,490	
		Verdugo Canyon	790	
		Lucas	390	
		Total, tributaries	19,350	19,350
		Total, San Juan	65,065	
Arroyo Trabuco	Main fork, excl. Oso, to elev. 1400			17,740
		Tijeras +Live Oak	610	610
Oso Cr.	Mouth to elev. 1100			6,550
Approximate total				*90,000*

It should be noted that Chiquita and Gobernadora Canyons contain large volumes of groundwater in comparison both to Oso Creek and to tributaries further upstream. Older alluvium beneath these channels increases southward to a maximum depth of about 125 feet, resulting in relatively large volumes of stored groundwater and significant inflows into the San Juan Creek alluvial aquifer.

Since the State estimates of groundwater volume stored in the alluvial aquifers were developed, incision of several streams has likely diminished the available storage volume.

No comparable estimates have been developed for lower San Mateo Creek and its tributaries. Because of similarities in the width and depth of the alluvial aquifers in the lower reaches of the two stream systems, it is possible to estimate that the lower three miles of the San Mateo valley, to the confluence of Cristianitos Creek, may contain on the order of 15,000 to 20,000 acre feet[3]. By analogy to lower Oso Creek, the alluvium of Cristianitos Creek to its confluences with San Mateo Creek may hold on the order of an additional 2000 to 3000 acre feet, assuming porosity in the Cristianitos alluvial valley is slightly higher.

Only a small portion of the storage within any basin is (a) accessible to phreatophytes, (b) available to sustain valley or slope wetlands, and (c.) developable for water supplies. Consequently, the significance of aquifer storage for the purpose of this report might best be seen as directed toward comparing available storage with flows in the adjoining streams, and to place withdrawals from individual wells or well fields into a broader ecological context.

The alluvial aquifers of lower Chiquita and Gobernadora Creeks are partly separated from the alluvium of middle San Juan Creek by fine-grained lake deposits at their mouths (Morton, 1974) which impede movement of water from the aquifers underlying these two tributary canyons into that of San Juan. These quiet-water sediments were naturally formed during one of the Pleistocene rises in sea level, when San Juan Creek was able to aggrade more rapidly than the tributaries draining the sandy terrain, where natural rates of erosion were usually quite low.[4] The manner in which the lake deposits are thought to have been deposited is shown in Figure 5. Water levels are held higher behind these

[3] A slightly greater effective porosity is assumed for lower San Mateo Creek with a watershed yielding much granitic debris, but not for Cristianitos Creek, which is underlain primarily by consolidated sedimentary rocks.

[4] Similar 'Garin Lake' type wetlands of high habitat value occur elsewhere in coastal California, most notably in the eastern Monterey Bay area (Hecht and others, 1984), but also in many alluvial valleys south of San Francisco, and along the Santa Barbara Coast. See section 6.3.

low-permeability sediment wedges than they would otherwise be, allowing perennial trees and forbs to be sustained in the lower one-half mile of these two creeks. These deposits are further discussed in Section 6.3.

3.1.2 Landslides and related slope deposits

Landslides and related slope deposits contain aquifers with generally limited continuity and storage. These units hold sufficient water to locally sustain slope wetlands, but do not in all probability contribute substantially or persistently to longitudinal or lateral continuity of wetlands and riparian zones. The volume stored in landslides or other slope deposits throughout the study area is not known to any precise quantitative degrees, but it is quite small in comparison to the volume held in alluvial aquifers.

The largest landslides are often associated with fault zones; fractured bedrock along the faults, combined with the water held in the landslide lobes, may be sufficient to support wetlands of moderate size (such as wetland 10, see Figure 3). These excepted all but the largest, landslide aquifers have only a limited present role in the integrity and continuity of the stream corridor systems; they are unlikely to have a larger role in any future land - or water-use pattern in the region, given the limited aquifer sizes and the inadvisability of recharging unstable ground except where they support slope wetlands.

3.2 Tertiary Sandstones

The Santiago and Sespe formations are two widespread, relatively uniform and continuous geologic units, which hold substantial volumes of water, usually of low salinity. The two sandstones outcrop extensively in the Chiquita, Gobernadora and Trampas watersheds (see Figure 4). The lower member of the Santiago formation is the most permeable of these units (Morton 1974), based on geophysical logs from several of the exploratory oil wells in the area. Massive sandstones in the lower Santiago formation are continuous over distances of several miles (see also, Appendix C). In 1970, these sandstone beds were explored as a potential water-supply aquifer by the Orange County Flood Control District with a test well drilled in the north-central portion of Section 26, adjacent to the Humble O'Neill exploratory oil well, and just north of the present-day Color Spot nursery. The well produced 48 gallons per minute (equivalent to about 0.1 cubic foot per second) of water, at 257 feet of drawdown (specific capacity of 0.17 gallon/foot drawdown). Salinity was measured at 450 mg/L, a low value in comparison with other sandstone aquifers in Orange County or elsewhere in the watershed (Engineering Science, 1986). Calculated transmissivity was 240 gal/day/foot, within the range considered as a "good aquifer", but at least an order of magnitude less than the values associated with production wells. Approximately 20 to 30 percent of the sandstone was found to be composed of material finer than 0.1 mm (parsons, 1970), the principal reason why its water-bearing characteristics are limited.

The Sespe formation outcrops in middle Chiquita and Gobernadora Canyons. It sustains the wetlands at the new Tesoro High School, as well as several other wetland and riparian areas south of Oso Parkway in the Wagon Wheel, Sulphur, and Gobernadora canyons. The wetlands are often found where faults or fracture zones cut the Sespe sandstones, possibly serving as a conduit for water released from the sandstone, or where clay beds direct flow toward the canyons (see Figure 2).

These Santiago and Sespe formations sandstones occur elsewhere in Orange County, but not in the contiguous or largely-undisturbed blocks present in Chiquita, Gobernadora, and to a lesser but still significant degree in Trampas and Cristianitos Canyons.

3.3 Weathered Crystalline Rocks

Weathered granitic, metavolcanic and other metamorphic rocks yield small to moderate volumes of groundwater to baseflow, seeps, and springs in the northern and eastern portion of the study area. The crystalline rocks typically produce water from fractures draining weathered granitic rocks. Deeper fractures with larger yields convey water from the Santiago Volcanics. The hot springs north of Caspers Park are an example of the larger individual springs, with a summer yield estimated to be 35 gallons per minute (Waring, 1915). Few springs with higher yields occur in the crystalline rocks of these watersheds in Orange County. Reaches of upper San Juan Creek near the ranger station are considered perennial, supported by water emanating from the crystalline rocks

(Hassan, 1970). Water from the weathered crystalline aquifers tends to be of excellent quality, with the lowest salinities of all groundwater sources in the region. Early summer baseflows often have specific conductance values of 200 to 300 micromhos/cm, equivalent to total dissolved solids concentrations of about 130 to 200 mg/L; these values are about half of those in the least mineralized of the sedimentary bedrock aquifers.

3.4 Non-Water-Bearing Units

Several geologic units are generally considered to be non-water-bearing relative to needs of wetlands, or local baseflow within the area of study. These include (a) the late-Tertiary siltstones and mudstones of the Niguel, Capistrano, and Monterey formations, and (b) possibly, most of the Silverado and Trabuco formations. It is unlikely that these units will yield sufficient volume and persistence of flow to appreciably support wetlands or baseflow, or to fundamentally affect the quality of water used by these habitats. Discrete shaley beds, such as the interbeds observed throughout the Sespe and Santiago formations, the 'caprock' of the lower Santiago formation (Williams, 1969), or individual perched hardpan units (Morton, 1970 and 1974) may technically be considered aquicludes, but are best considered at the site scale.

4. GROUNDWATER MOVEMENT AND RECHARGE

4.1 Approach and Data Used

Assessments of groundwater movement and recharge are most frequently based on water-level data and inferred geometries of the water table. Under past land uses, it has not been necessary to collect such data for the study area. They are still not sufficient to develop the conventional analyses based on water levels. As stated in chapter 1, useful understandings of the processes supporting springs, seeps, and live-stream baseflows in this area can be developed from field observations of water quality, supplemented with hydrogeologic mapping and knowledge of the proclivities of these formations in other areas. These understandings can be updated and revised where needed as additional wetland-oriented groundwater level and quality information comes available.

As groundwater passes through the bedrock aquifers, it also acquires chemical characteristics typical of that aquifer, which are usually retained as flows are discharged in the seeps and springs, and/or into the alluvial aquifers beneath the main valleys, leaving traces of the route taken to the alluvial aquifers or the streams with which they are connected. As one example, many waters with substantial travel through the Tertiary-aged sandstones of the area, such as the Sespe and Santiago formations, tend to have specific conductance values of about 500 to 800 micromhos/cm at 25 degrees Celsius. Much higher specific conductance measurements are reported at seeps supported by groundwater originating in the Monterey formation.[5] These salinity properties, as well as distinctive ionic compositions, have been reported for these same formations or their correlates elsewhere in Orange (Hassan, 1970), Ventura and Santa Barbara (Hecht and others, in prep), and Monterey and Santa Cruz Counties (Hecht and others, 1984).

[5] Many of Monterey-influenced seeps in the study area originate from recent landslides where water circulates rapidly and flushes salts typical of groundwater in less-disturbed, insitu Monterey formation; many of the latter waters are encountered near and beyond the boundaries of the study area in the headwaters of the Primera and Segunda Desechas, Horno Creek, and Aliso Creek.

Most of the data used for interpretation are for specific conductance or total dissolved solids, both measures of the amount of total salts in the shallow groundwater system. These are widely-used metrics of groundwater conditions and movement. Their value comes from this widespread use and their familiarity. Neither parameter is intrinsically precise, either at the field or laboratory levels, because they can be measured different ways or with varying instruments, because field conditions cause variations with depth or over the course of a day, because salinity has been concentrated temporarily by evaporation, or due simply to sampling or analytical error. Experienced professionals who use these data usually look beyond the variability or fluctuations for long-term or fundamental patterns. In the following chapter, the data are presented as collected, including these 'noisy' factors, so that readers from many backgrounds and disciplines become familiar with the character of the data and the benefits of using measurements collected over relatively long periods to obtain useful conclusions.

4.2 Inferences Regarding Recharge Dynamics

Analysis of the data to date can offer understandings of groundwater functions and processes which support or sustain the wetlands and baseflow reaches. The data indicate that there are some difference amongst the source aquifer types which should be used to help plan for the future of this area unfolds. In this section of the chapter, differences in the processes are described, and implications for rates of recharge are explored. Implications for relative resilience are considered in Section 4.3.

4.2.1 Processes or recharge and movement

4.2.1.1 Sandy swales[6]

Perhaps the simplest of the groundwater environments in the SAMP study area are the tributary swales within the areas underlain by sandy soils and sandstones. These include large areas in Chiquita, Gobernadora, Trampas and portions of Cristianitos Canyons.

[6] Much of the data used in this section of the report and Figure 9 was kindly provided by Pat Jenks (Goffman, McCormick and Urban)

Figure 6 depicts trends in salinity observed in a piezometer in a tributary to Chiquita Canyon (for locations, see Figure 4). The piezometer was constructed in early December 2000 to a depth of 51 feet through the sandy swale deposits, and includes the uppermost 5 feet of the underlying Santiago sandstone. Groundwater was encountered at a depth of about 10 feet when the piezometer was constructed, and rose slightly more than one foot before receding, based on five depth-to-water measurements made in late February through June. Based on experience in other sandy areas of similar topography, it is likely that this piezometer allows sampling of a water table recharged by (a) rainfall percolating through the sandy soils to groundwater, (b) storm runoff from adjoining uplands infiltrating through the bottom of the broad swale, and (c) late-season winter baseflow from the adjoining uplands (underlain by Santiago sandstone beneath soils that generally are sandy) which occurs only once the upper watershed is saturated, at least in part. The duration of winter baseflow is not known, but it probably occurs only during wetter-than-normal seasons.

Sampling commenced in late February, immediately following the main storms of the season.[7] Infiltration during the late-February and March storms (processes a and b, above) is thought to have recharged the water table in the swale deposits. Because this water reaches the water table quickly and directly, it has little opportunity to dissolve or acquire salts during percolation. The late-season recharge typically is saltier, since it includes water that has passed through more soil and aquifer over a longer period, or because it includes water from the underlying Santiago sediments, where groundwater is slightly saltier (often in the range of 350 to 500 mg/L), and resulted in a small but discernible increase in total dissolved solids. The delayed late-season recharge occurs when infiltration to the water table is rapid, because the unsaturated soils above the water table are already wet and pass the percolating waters efficiently.

4.2.1.2 Large landslides with a Monterey-formation influence

Figure 7 shows seasonal trends in salinity in two wetlands sustained from landslide sources on Radio Tower Hill. The two sources are located approximately 0.5 miles apart, and are likely independent of each other.

[7] Rainfall prior to mid-February was probably insufficient to generate measurable recharge in this and most other piezometers discussed in this section.

Nonetheless, salinity trends were very similar in the two wetlands. Salinities crested early in the season as salts accumulated in the soils and fractures were re-mobilized and entered the aquifer.[8] Over the course of the season, these salts were mixed in the aquifer and others were introduced through recharge. A slight salinity increase was observed during this above-average rainfall year, as is often reported in shale-influenced aquifers. During very wet years, such as 1998, 1993 or 1969, much greater recharge often 'flushes' salts from the aquifer and lowers the salinity of the aquifer.

4.2.1.3 Smaller landslides

Variable concentrations of total dissolved solids ('salinity') are reported from wetlands sustained by landslides directly recharged by rainfall, with only limited inflows from the larger aquifer units in the underlying bedrock. Figure 7 shows reported groundwater salinity values from PCR wetland 5, which emanates from a landslide on the western side of Chiquita Canyon. In addition to very variable salinities, the data show very rapid aquifer response – perhaps within a day -- even to the initial storms of WY2000, together with short seasonal recession curves returning to the high summer salinities characterizing this seep. The elevated dry-season salinities suggest that the Monterey shale and breccia underlying this seep do contribute some flows, which help sustain the seep once the landslide ceases yielding water in May. It might be noted that daily variations in total dissolved solids of 200 to 300 mg/L were reported in July and October 2000, substantially greater than at other wetlands.

4.2.1.4 Bedrock sandstones

Conversely, figure 7 shows the salinity of water in seeps and springs supported by water emerging from sandstone bedrock. As with the bedrock-sustained large landslide seeps, those emanating from the two named sandstone formations exhibit only limited variability in concentrations of total dissolved solids. Here, again, an initial pulse of saltier water was observed in wetland 6; in this case, the salts were probably mobilized from nearby soils, since only minimal rainfall introduced them into the spring. At wetland 14, a late-season

[8] Early-season or post-drought salinity peaks are typical or even diagnostic of recharge through Monterey and related shales. (see Hecht and others, in prep.)

rise in salinity probably reflects arrival of water which has moved along the shaley interbeds within the sandstones, replacing lower-salinity water directly recharged into the sources of the spring (see Figure 2). Concentrations of total dissolved solids seemed to increase very gradually over the two-year sampling period, rising from an inferred low following the heavy rains of WY1998, which likely flushed salts from the aquifers.

4.2.2 Estimating likely timing of recharge

All four hydrogeologic settings reflect the effects of recharge rapidly following large storms, and generally within a month. Rates of recharge appear to increase over the course of winter, probably because more water percolates as the soils reach saturation and the unsaturated zone between the soils and local water table becomes increasingly wetted.

Although some seeps recharged virtually overnight following the first minor or major rainfall events of the year in October 2000, most sustained recharge seem to commence after 3 to 6 inches of rain had fallen. Data are not sufficient for evaluating timing of recharge through the sandy swales.

4.3 Reliability and Resilience

Reliability of seepage is the likelihood that the groundwater system will sustain growth of seasonal vegetation at a spring or seep long enough for the plants to produce viable seed. Virtually all seeps and springs identified by PCR staff in Chiquita and Gobernadora Canyons (Lee and Stein, 2000) are likely to reliably sustain outflow during nearly all years. Although, responses during periods of sustained drought are not known. Conversely, most groundwater sources in Cristianitos watershed are *not* reliable sources in most years, although during very wet years, seepage and baseflow can continue into late June or early July.

Resilience is the property of springs and seeps to maintain reliable flows when disturbed or when flows are partly diverted from the groundwater system that supports the wetland. Resilient systems draw upon larger aquifers which will adjust to changes in contributions from one part of the recharge area. Resilient groundwater units include those where variations in salinity at a given seep or spring were limited, and where salinities were consistent between or among seeps drawing from similar sources. Resilient sources are thought to include:

- Seeps, springs, and baseflow reaches with sources predominantly in the Santiago and/or Sespe formations in areas where continuous aquifers extend some distance (perhaps 500 to 1500 feet) from the wetland or riparian areas they sustain (c.f., Figures 1 and 2).

- Seeps and springs with sources in large landslides also receiving substantial recharge from the underlying bedrock aquifers. Criteria for recognizing underlying recharge include minimal relatively small daily and seasonal variations in salinity, and salinity trends which track with those of sandstone-aquifer seeps (such as PCR 1 and PCR 14), or those of the larger wetlands on Radio Tower Hill (PCR 13 and PCR 15).

- Wetlands sustained by large sandy swales, such as PCR 9 and PCR 16, where large upland drainage areas likely maintain late-season recharge in many or most years.

- Wetlands and baseflow reaches in which clay-rich marsh or lake deposits help bring shallow ground water to the surface (Fig. 5), such as wetlands 18, 19, 21, 23, 24, 25 (Balance Hydrologics numbering system, see Appendix A) and PCR wetlands 3, 4, and 6.

Non-resilient wetlands include those sustained from:

- landslides lacking the stable salinities typical of the large bedrock-supplemented landslides (e.g., Figure 8)

- coarse alluvium, where incision or excessive permeabilities inhibit persistent flows (such as Balance 27, 28 or 37)

- channels sustained primarily by consolidated shales (Balance 14, 29 and 38)

- Seeps and baseflow reaches may be re-evaluated in summer 2002 using these (and other, including vegetation) criteria based on their responses during the WY2002 season.

4.4 Water-Level Fluctuations

While minimal data are presently available describing seasonal or wet-dry cycle groundwater fluctuations, several observations and useful inferences may be developed:

- In the absence of active pumping, seasonal water-level fluctuations in both bedrock and alluvial aquifers tend to be very small, except within localized landslide aquifers or other areas where slopes are very steep. Prior to extensive pumping of the San Juan alluvial aquifer, measurements of two wells in the alluvium of San Juan Creek near the mouth of Chiquita (Well No. 7/7-33B1) and east of the existing ranch headquarter (7/7-33M1), California Department of Water Resources staff (Parsons, 1970) found seasonal fluctuations of usually less than 5 to 10 feet over an 18-year planning period during the 1950's and 1960's. Wells drawing from the same aquifer within the actively pumped area just northeast of downtown San Juan Capistrano fluctuated 15 to 25 feet seasonally, and then rose 40 feet once imported water came available in late 1960s.

- Records for static water-level fluctuations in bedrock wells are sparse, but suggest seasonal fluctuations of 10 feet or (commonly) less, with variable fluctuations over wet and dry cycles. Most springs, slope wetlands or summer live-stream reaches support vegetation which would be consistent with fluctuations of less than 20 feet during the wet-and-dry decadal-scale cycles which typify this part of Southern California (Lynch, 1931; Reichard, 1970; Lang and others, 2000). The distribution of woody vegetation surrounding slope wetlands throughout the Chiquita, Gobernadora and western Cristianitos Creek watersheds is not markedly different in aerial photographs taken in June 1938 – following one of the driest decades or record – than at present; such differences which can be observed are likely attributable to grazing practices rather than groundwater support.[9]

[9] Grazing pressures were likely greater in the late 1930s, based on widespread regional practices, plus visibly fewer oaks in grass/woodland ecotonal areas in the 1938 aerials compared with more recent photos, plus discernible contrasts across fencelines in the earlier photos.

Since slope wetlands typically fluctuate more than reaches and seeps supported by alluvial aquifers, it is likely that baseflow reaches and valley-floor wetlands also do not experience large inter-decadal fluctuations in water levels.

- Groundwater levels in two sets of piezometers installed by Goffman, McCormick and Urban in March 2001 through the soils in swales tributary to Chiquita and Gobernadora Creeks varied about one to five feet during the wetter-than-normal 2001 rainfall year (see Figure 9). Larger fluctuations (and perhaps surfacing of runoff) may occur during wetter years; smaller fluctuations will occur during drier years. These fluctuations are of a range which suggest that it may be physical feasible to create or enhance seasonal wetlands as well as perennial wetlands in these settings, assuming otherwise suitable conditions and confirmation with additional measurements at more sites.

4.5 Directions for Future Groundwater Monitoring

Once ongoing and follow-up geotechnical, wetlands, and habitat investigations are completed, it will prove useful to implement a monitoring program directed at least part toward observing future changes in groundwater supply to the springs, seeps and baseflow reaches. In the interim, Balance Hydrologics habitat-hydrology specialists identified and sampled approximately 40 locations throughout the portions of the San Juan and San Mateo watersheds under study where regular observations of flow (if any), specific conductance and general conditions affecting groundwater can be made periodically. These sites are listed and findings presented in Appendix A. At most sites, spring and fall measurements will prove useful to further elaborate the description of baseline conditions. More frequent and broader monitoring at selected individual slope wetlands, such as those assessed by ecological and soils specialists at PCR (c.f., Lee and Stein, 2000), will provide the detail needed at a number of the more complex sources.

5. GROUNDWATER DEVELOPMENT FOR WATER SUPPLY

Groundwater has been developed for municipal and institutional water supply within the SAMP study area primarily from the main alluvial aquifers of middle and lower San Juan and from lower Cristianitos Creeks. This chapter presents basic information on groundwater development needed to understand management of aquifers sustaining seeps, springs, and baseflow reaches.

5.1 Middle and Lower San Juan Creek Alluvial Aquifer

The alluvial aquifer beneath middle and lower San Juan Creek is the most developed of all groundwater sources in the SAMP area. Development for commercial irrigation began in the late 1800's, and greatly expanded during the first half of the 20th century. Irrigated acreage tripled between 1920 and 1935 (Perkins, 1935; see Appendix B, this report), which likely was due to widespread use of the new submersible pumps.[10] Use of alluvial groundwater continued to expand, although at a reduced pace, through the late-1960s, when vast amounts of imported Feather and Colorado River water became available. Expansion of pumpage gradually moved up the San Juan Valley. It was not until the mid-1960s that significant withdrawals from the alluvium of San Juan Creek within the SAMP study area were regularly made (Parsons, 1970). Pumping was interrupted shortly there after by the damage to wells during the floods of 1969, and resumed some years later.

Use of the San Juan alluvial aquifer gradually increased to about 7800 acre feet per year in 1993, with water levels maintained or slightly lowered in most wells. The most recent studies (c.f., Culbertson, Adams & Associates, 1999) project that pumpage will increase to about 9000 acre feet per year over the next two decades. The additional recharge is expected to be primarily return flows from urban areas, principally from the Chiquita (about 223 acre feet per year), Gobernadora (about 312 acre feet per year) and middle

[10] Gravity or suction pumps are limited to lifts of less than atmospheric pressure, which in reality precludes pumping water deeper than 28 to 30 feet. Allowing for drawdown during pumping, static (no pumping) water levels deeper than about 20 feet require the new submersible pumps. Many riparian plants are able to draw water from such depths. The onset of significant effects on riparian communities or the inter-linked wetlands would logically be when the submersibles came into general use. It should also be noted that alluvial groundwater levels in much of the study area are and were deeper than 30 feet, and these aquifers could not be beneficially used until the 1930s.

and upper San Juan (also about 312 acre feet per year), as well as upper Trabuco (400 acre feet per year) watersheds. These correspond to average annual flows of about 0.31, 0.43, 0.43 and 0.55 cfs, respectively, flow rates that entail discernible increases in dry-season baseflows. Overall, the 9000 acre feet per year is equivalent to a flow of about 12.5 cubic feet per second, sustained 24 hours per day, 365 days per year.[11]

Most of increased water will be utilized by the San Juan Basin Authority, a joint powers agency, including the Capistrano Valley Water District, the Santa Margarita Water District, the Trabuco Canyon Water District, and the Moulton Niguel Water District.[12] Use of treated effluent in the lower San Juan watershed is the responsibility of SERRA. Water quality in the alluvial aquifer is of interest to both authorities. At least two wells within the alluvium yield concentrations of total dissolved solids (2000 to 2200 mg/L) and sulfate (700 to 750 mg/L) which substantially exceed levels suited for municipal water supply (KEA, 2000, Table 3-12). These analyses likely reflect inflow of salts from the Monterey and related formations (Figure 10). Maintaining water quality suited for municipal supply requires that certain portions of the aquifer be avoided or pumped at reduced rates, likely precluding sustained or excessive overpumping of the alluvial aquifer, a practice which has lead to increased salinity or sulfate content in other 'shoestring' alluvial aquifers with similar geologic conditions (such as Carmel Valley in Monterey County or the Santa Ynez riparian aquifer in Santa Barbara County).. There have been several assessments or investigations directed toward enhancing the quality of water within the alluvial aquifer (c.f., Jack G. Raub Company, 1977; Stamp-Alexander and Guymon, 1995).

The alluvial aquifer is managed using assumptions which anticipate return flows from future urban areas within the SAMP study area. The densities anticipated to generate these return flows are not known.

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[11] Mean annual flow reported for the USGS gage on San Juan Capistrano Creek at La Novia Drive is 26.0 cfs. Allowing for inflow from Arroyo Trabuco, the ratio of planned sustained yield to mean annual flow is quite high relative to that reported from other alluvial basins in coastal California.

[12] The Capistrano Beach Water District, not a member of the San Juan Basin Authority, draws water from wells downstream from the Arroyo Trabuco confluence.

5.2 Cristianitos Creek Alluvial Aquifer

Only limited information is available regarding groundwater development in the lower Cristianitos Creek alluvial aquifer. With the exception of a single shallow well and small water-storage system on lower Gabino Creek, there is no development of groundwater north of the Orange/San Diego County line. Substantial additional supplies are drawn from this aquifer for use at facilities on Marine Corps Base, Camp Pendleton (MCBCP). Detailed information on the location, and the current uses, water levels and water chemistry of these wells has not been accessible. MCBCP technical staff, have advised the SAMP study team that their models indicate that approximately 17 percent of the alluvial groundwater in San Mateo Creek at the coastline originates in the Cristianitos/Gabino/La Paz watershed, and that their use of groundwater from this source is consistent with this value.

The absence of springs, seeps, and baseflow in the Orange County portions of the Gabino, La Paz and Talega watersheds is worthy of note. Water sources for game and wildlife during dry seasons and years are very sparse.[13] Hydrogeologic conditions in these watersheds are not favorable for development of any significant aquifer storage, other than relatively small volumes in the thin alluvial aquifers flowing beneath the canyon floors. Minimal amounts of groundwater can be stored in the two main bedrock units which outcrop in these watersheds, the Trabuco formation and the Schulz shale member of the Williams formation. The extreme headwaters of La Paz and Talega Creeks, just east of the county line, are underlain by crystalline granitics and volcanics, where groundwater is considerably more available, and where numerous springs and seeps are used by wildlife and human residents of the Wheeler Ranch enclave alike. These portions of the two watersheds are so small that their effects on portions of the canyons further downstream are probably indiscernible.

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[13] We have observed heavy use of Lake Jerome and the watering trough at the confluence of La Paz and Gabino Creeks, two sources constructed by Rancho Mission Viejo staff.

6. UNIQUE ATTRIBUTES OF CHIQUITA AND GOBERNADORA VALLEYS

Most wetlands in this portion of southern Orange County are concentrated in the valleys of Chiquita and Gobernadora Creeks. These valleys have a number of unusual attributes which are in part responsible for the concentration of wetlands. Some of these same features also occur elsewhere, often to a more muted extent, contributing to wetlands or incipient wetlands in other valleys.

6.1 Sandy Soils and Sediments: Implications for Sustaining Recharge

Chiquita and Gobernadora Canyons are underlain primarily by sandy or silty sand soils and predominantly by the partially-consolidated, nearly flat-lying Santiago and Sespe sandstones, or unconsolidated deposits derived from the sandstones. Recharge of both direct rainfall and runoff through swales and small channels occurs at present in these areas. Since both processes occur and are locally important, a useful strategy for sustaining recharge will be to increase percolation through swales while concurrently maximizing percolation of rainfall before it concentrates into runoff.

Percolation through the existing swales can be increased by slowing the flow of water, both during periods of storm runoff and periods when late-season runoff from uplands generates persistent low (and rechargeable) flows in the swales. Among the means of slowing the water may be (a) revegetation with perennial grasses or other species which form hold water in swales, (b) creating seasonal wetlands or ponds, or (c) enhancing recharge with Nabataean steps[14] or other measures which create vegetated microberms that enhance recharge.

Direct recharge (which occurs by infiltration through the soil at or near the point of rainfall impact, at locations upstream of the point at which rainfall concentrates into runoff) can be maintained through various measures, most notably by encouraging on-site deep percolation of excess irrigation or other imported water. For residential areas, deep percolation of irrigation is frequently sustained at rates of 0.05 to 0.20 cubic feet per second per square mile (c.f., Hecht and Roberts, 1989; Hamilton, 2000), equivalent to 50 to 200 gallons per day per acre, or about 0.5 to 2.0 inches per year over a 270-day

[14] Slightly-terraced swales with low steps or berms

irrigation season, or somewhat more than the average annual recharge rate under existing conditions. Other land uses drawing upon imported water may recharge at other rates. Rainfall recharge can be augmented through other logical means. A number of measures now widely employed to improve runoff quality also serve to maximize recharge, such as de-coupling roof runoff from the storm drains or other means of encouraging runoff from impervious areas to pass over ground where it can infiltrate before the surplus is lost to the storm system.

In these sandy areas, it is much more likely that recharge will increase than it will diminish, at least at the watershed scale.[15] In fact, it is not clear that aquifers in the sandy areas will be able to accept all recharge available. It may be necessary to recycle some of the additional recharge as irrigation, to use it for sustaining created wetlands, recharge it, or export it from the major tributary valleys to the San Juan Creek alluvium.

These conclusions are likely to apply in some measure to other areas of sandy soils over permeable sandstone, such as occur in the Trampas and western portions of the Cristianitos watershed upstream of the Gabino confluence.

6.2 Low Natural Sediment Yields: Implications for Alluvial Aquifers

Alluvium filling the valleys in the sandy watersheds are considerably finer than the valley fill in watersheds underlain in whole or large part by granitic or other crystalline rocks. Subsurface channels filled with gravels, cobbles, and boulders are rarely, if ever, present, so the sandy alluvium often drains more slowly. Transmissivities in sandy alluvial aquifers lacking continuous gravel or cobble zones are often measured to be in the range of 200 to 5000 gallons per day per foot width of aquifer, in contrast to values of 10,000 to 200,000 gpd/ft reported from gravel- or cobble-filled alluvial aquifers. Additionally, sandy alluvial valleys tend to have a flatter downslope gradient. As a result, movement of water through the sandy alluvium may be an order of magnitude slower or even more, than those in most Southern California canyons. Flows through the sands persist much longer and can sustain wetlands and riparian vegetation for months or years longer than can be sustained by coarser, channeled alluvium.

[15] The San Juan Basin Authority's projects of an increase to 9000 ac ft per year from the existing 5600 ac ft per year implies that on the order of 3400 acre feet of percolation into the San Juan alluvial aquifer will occur, mainly from increased recharge from the SAMP study area.

6.3 Constricted Lower Reaches

Perhaps because natural rates of sedimentation in sandy areas are considerably slower, lake deposits occur in the lower reaches of Gobernadora and Chiquita Canyons.[16] The deposits seem to have formed because San Juan Creek aggraded more quickly than the two sandy side canyons, damming and ponding them. The fine-grained sediments deposited in the lakes or marshes impounded behind the more elevated valley fill of San Juan Creek are heavy, cohesive silts and clays, with extremely low permeabilities. These deposits form wedges extending the full depth of the valley, effectively damming the mouths of the valleys, and separating the alluvium of Gobernadora and Chiquita Canyons from those of San Juan Creek. In Chiquita Canyon, clayey landslide deposits originating in the fractured sedimentary rocks of Chiquita Ridge may also contribute to constricted flow near the canyon mouth. The formation and roles of these two types of deposits are shown in Figure 5.

Figure 5 is based in part on detailed work available on other sandy-alluvial canyons which have developed large wetlands or lakes in their lowermost reaches. Among these valleys ponded due to inability to fill as quickly as the impounding canyons are well-known wetlands throughout coastal California west of the San Andreas fault, including The Lagoon north of Point Arena; the lower Butano riparian forest (San Mateo County); Valencia and Corralitos Lagoons (Santa Cruz County), Pinto, College and Garin Lakes, plus Harkins and Struve Sloughs (Pajaro Valley), many lakes in the lower Salinas Valley, Warden and Eto Lakes (Los Osos area, San Luis Obispo County), Bradley, Cienaga and Black Canyon Lakes (Santa Maria Valley), Bixby and Dominguez Sloughs (Los Angeles County), and others (c.f., Gordon, 1974; Hecht and others, 1984; Nelson and others, 1916). In the Sacramento Valley, Beach and Stone Lakes have similar geomorphic origins. These features support some of the most stable and resilient coastal-valley wetlands or ponds in the state. In some cases, they provide the habitat for rare amphibians, reptiles, or plants.

The clay-rich constrictions likely separate the lower Chiquita and Gobernadora alluvial aquifers from the San Juan Creek alluvium. Many of the wetlands described in the prior

[16] Extensive lake deposits are mapped by Morton (1974) in lower Gobernadora Canyon. Their presence in Chiquita Canyon should be confirmed by careful analysis of soils sampled in ongoing drilling along the floor of the canyon, but is very likely based on geomorphic, longitudinal profile, wetland and water-quality evidence.

paragraph continue to maintain nearly all of their functions while the aquifers around them are pumped to static water levels 50 to 100 feet lower than the wetlands. It is likely that the same will hold true of the lower Chiquita and Gobernadora Canyons, which have maintained their wetlands during several decades of current heavy pumping from the San Juan alluvial aquifer. Further analysis and monitoring of the hydrogeologic conditions are warranted.

7. CONCLUSIONS AND RECOMMENDATIONS

1. This report identifies groundwater conditions and management opportunities at the landscape scale as a means of protecting riparian and aquatic habitat functions in the San Juan and San Mateo watersheds. It uses many of the same sources of information and concepts which customarily are applied in groundwater development or contamination investigations, but the emphasis is placed on processes which:

   - sustain groundwater at or near the surface
   - direct groundwater to emanate at locations where it supports wetlands or perennial riparian vegetation
   - extend cross-valley and down-valley habitat continuity or resilience
   - maintains groundwater of suitable quality to support riparian and aquatic habitat functions.

2. At this time, many of these functions have not been addressed in prior planning investigations. The role of groundwater levels, occurrence and fluctuations are addressed only in the context of public water supplies. On the other hand, the most recent Basin Plan recognizes the role of groundwater in sustaining wetland and riparian communities. The Basin Plan also recognizes that important differences exist in water chemistry by aquifer and terrain type within the watersheds of the San Juan basin. The SAMP provides an unusual opportunity to elaborate and quantify their role at a basin scale.

3. The vast majority of the aquatic and riparian habitats in the portions of the San Juan watersheds under investigation are supported by approximately 90,000 acre feet of groundwater stored in the alluvial and alluvial-terrace aquifers, and by unquantified (but probably only somewhat smaller) volumes of water within sandstone or other 'bedrock' aquifers, notably in the Chiquita and Gobernadora areas.

4. Information on groundwater conditions in the San Mateo watershed is quite limited. As Camp Pendleton and the TCA make information available, re-evaluation of some of the findings in this report may prove helpful. Substantial new information is expected for the San Juan watershed during the next few months as ongoing comprehensive geotechnical investigations progress and as studies of slope wetlands yield new data.

5. At the landscape scale, most of the riparian and aquatic habitat functions related to groundwater can be best sustained by (a) maintaining distance from and taking additional water from the existing alluvial aquifers only as additional recharge comes available, (b) recognizing differences in the properties of the alluvial aquifers in each valley, and the relative volumes of water stored in each, and incorporating these into site planning, plus (c) planning carefully at the site scale to maintain recharge, particularly of the sandy swales tributary to Chiquita and Gobernadora Canyons and other streams draining areas of sandy substrate.

6. Chiquita and Gobernadora Canyons contain some of the greatest volumes of alluvial-aquifer storage. These also support most of the slope wetlands in the area of study, all of which are sustained by groundwater. Water chemistry (especially salinity and major ionic constituents) and the degree of aquifer confinement in these sub-basins are also quite variable, affording opportunities to expand or enhance wetland and riparian areas if the variability is recognized.

7. Several of the bedrock geologic units are moderately sandy and largely uncemented, affording significant opportunities to accept and store water infiltrated from detention basins or shallow impoundments of varying types. These units contain tens of thousands of acre-feet of groundwater. In the San Juan watershed upstream of the confluence of Chiquita Canyon, these aquifers are nearly as continuous and capable of storing nearly as much water as the alluvial aquifers; in the San Mateo watershed, much less so. These sandstone units and the sandy alluvial aprons mantling portions of their outcrops in the San Juan watershed likely can be managed to maintain or increase recharge as the land is moved from grazing and agriculture to more urban uses, if several suitable approaches and measures are applied.

8. Other geologic units are composed of siltstones, shales, and mudstones, containing few or no beds of water-bearing sediments. In several cases, these units are appropriately considered aquicludes, which contain little or no usable water. Further, these finer-grained sediments contribute salts and other dissolved solids to groundwater, often rendering them impaired for most conventional human uses as well as many habitat functions. These units occur (a) generally east of Bell and Cristianitos Canyons, or eastward from the Mission Viejo fault, and (b) beneath Chiquita Ridge and Radio Tower Hill, or generally west of the Cristianitos fault.

9. Approximately half of the slope wetlands are sustained in large part by water emanating directly from landslides. Generally, both the yields and the quality of groundwater vary considerably over the course of a season, unless the flows are sustained by deeper bedrock aquifers and merely conveyed through the landslides. About half of the wetlands at the bases of landslides are in fact sustained by discharges from the bedrock that they mantle; these may be distinguished by steadier discharges, salinity that is much more constant over the course the year, and seasonal and multi-year water-chemistry patterns that are similar to those in

bedrock seeps. The bedrock-sustained slope wetlands are generally more reliable and resilient than those drawing largely from groundwater originating within the landslides. Waters emanating from the locally-recharged landslides and slope deposits are locally significant mainly because they sustain wetlands; they have little or no role in supporting the larger, continuous riparian and aquatic systems .

10. Weathered and fractured crystalline rocks yield moderate amounts of water sustaining springs and baseflows, commonly in the more mountainous upper portions of the two watersheds and their neighboring basins. These flows support some of the more significant and continuous bands of riparian vegetation. They are typically the least mineralized and highest quality of the groundwaters in both watersheds, and their contributions to baseflows are often significant in maintaining water quality in the alluvial aquifers downstream within levels suitable for aquatic habitat functions. Baseflows from similar rock units in San Diego and Riverside Counties are the sole source of summer or dry-year water for the steelhead in San Mateo Creek upstream from the Orange County portion of this watershed (c.f., Lang and others, 1998; California Department of Fish and Game, 2000).

11. Development of groundwater from the alluvium of lower San Juan Creek by the San Juan Basin Authority and other large pumpers has been growing during the past 80 years or more. While the extent of riparian vegetation on the valley floor of San Juan Creek may have locally diminished, woody vegetation supported by wetlands in the main tributary valleys has not been reduced from the extent shown in 1938 aerial photographs, and in many cases has expanded. The riparian and baseflow reaches of the tributaries do not appear to show effects from existing pumping in the San Juan Creek alluvium. Geologic conditions also help limit the groundwater connections between the San Juan Creek alluvium and that of the main tributary valleys.

12. Pumping from the alluvium of San Juan Creek is projected to increase from approximately 7800 acre feet per year to about 9000 acre feet per year, which the pumpers anticipate will be met by increased return flows from the area under study. Use of groundwater from the San Juan Creek alluvium is planned and conducted by entities and through processes not presently part of the SAMP. Presence of clay lenses in the lower reaches of Gobernadora and Chiquita Canyons separate groundwater conditions in the alluvium of these tributaries to a substantial extent from those in San Juan Creek; likely effects on other named valleys (such as Bell or Trampas) are not yet known.

13. Once ongoing and follow-up geotechnical, wetlands, and habitat investigations are completed, it will prove useful to implement a monitoring program directed at least in part toward observing future changes in groundwater supply to the springs, seeps and baseflow reaches. In the interim, Balance Hydrologics habitat-hydrology specialists identified and sampled approximately 40 locations throughout the

portions of the San Juan and San Mateo watersheds under study where regular observations of flow (if any), specific conductance and general conditions affecting groundwater can be made periodically. These sites are listed and findings presented in Appendix A, with State Plane coordinates. At most sites, spring and fall measurements will prove useful to further elaborate the description of baseline conditions. More frequent and broader monitoring at selected individual slope wetlands, such as those assessed by ecological and soils specialists at PCR (c.f., Lee and Stein, 2000), will provide the detail needed at a number of the more complex sources.

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FIGURES

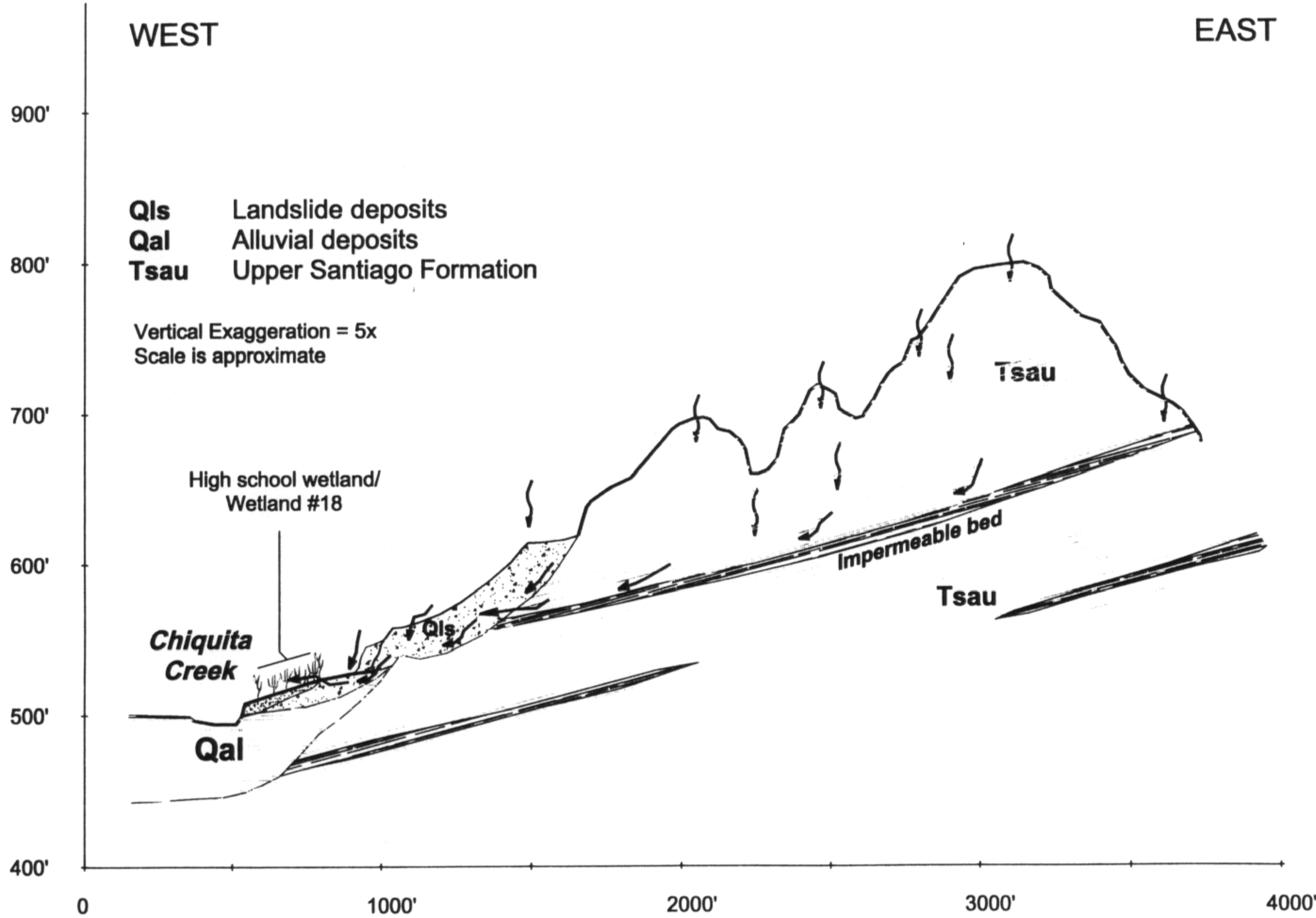

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Figure 2. Inferred nature of shallow ground water movement through the Upper Santiago Formation, San Juan/San Mateo SAMP, Orange County, California.

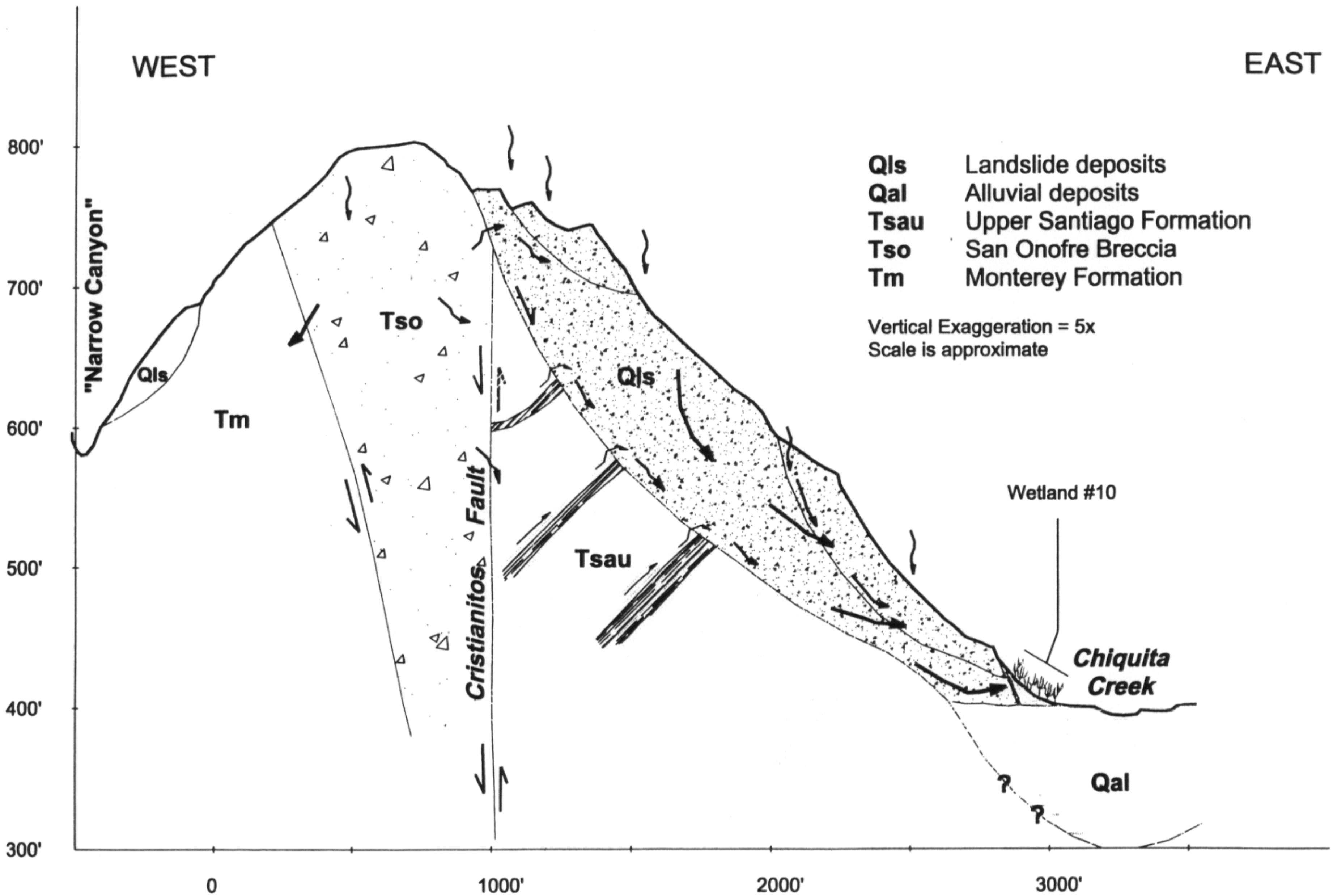

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Figure 3. **Inferred nature of shallow ground water movement through landslides and faulted bedrock near Wetland #10.**

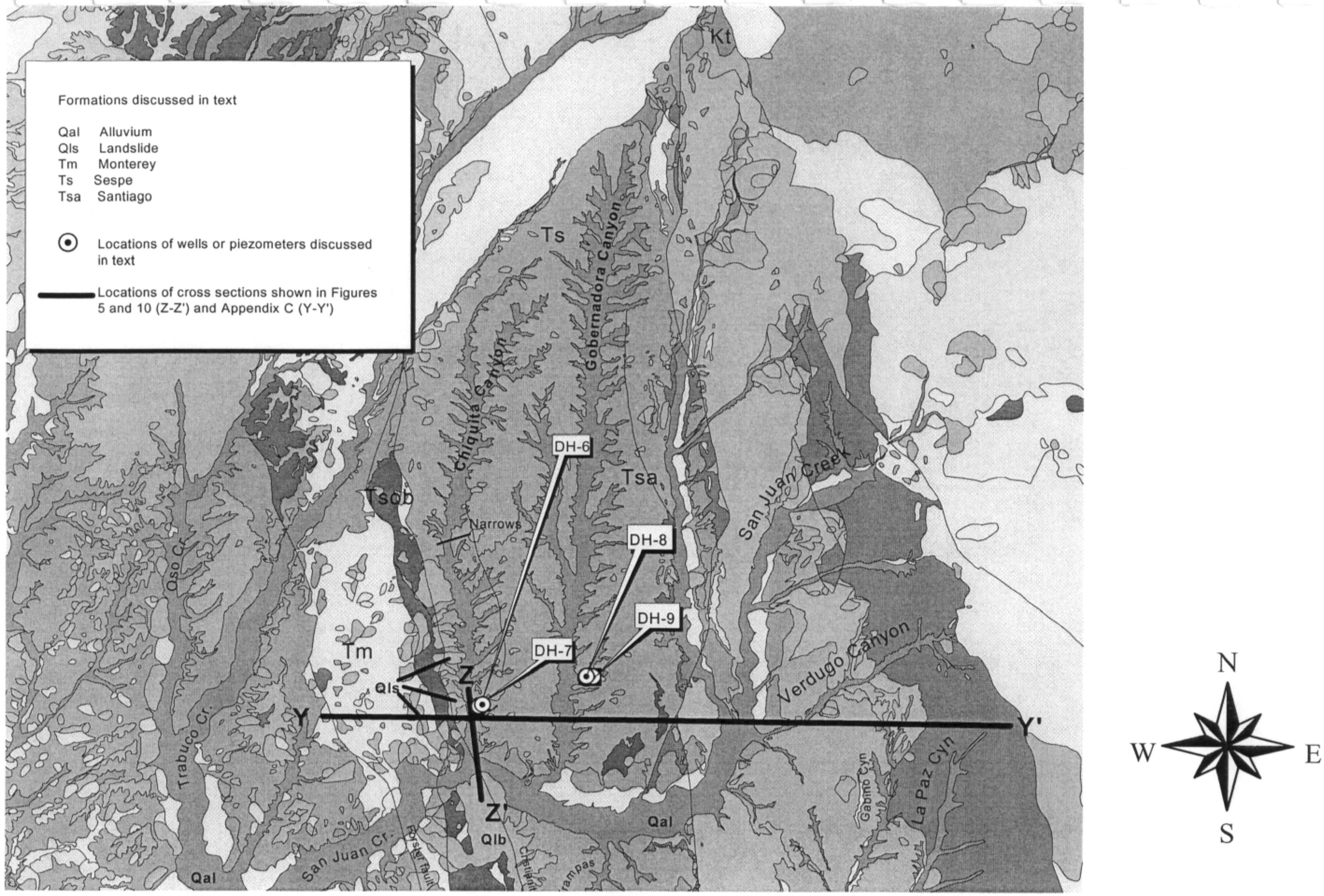

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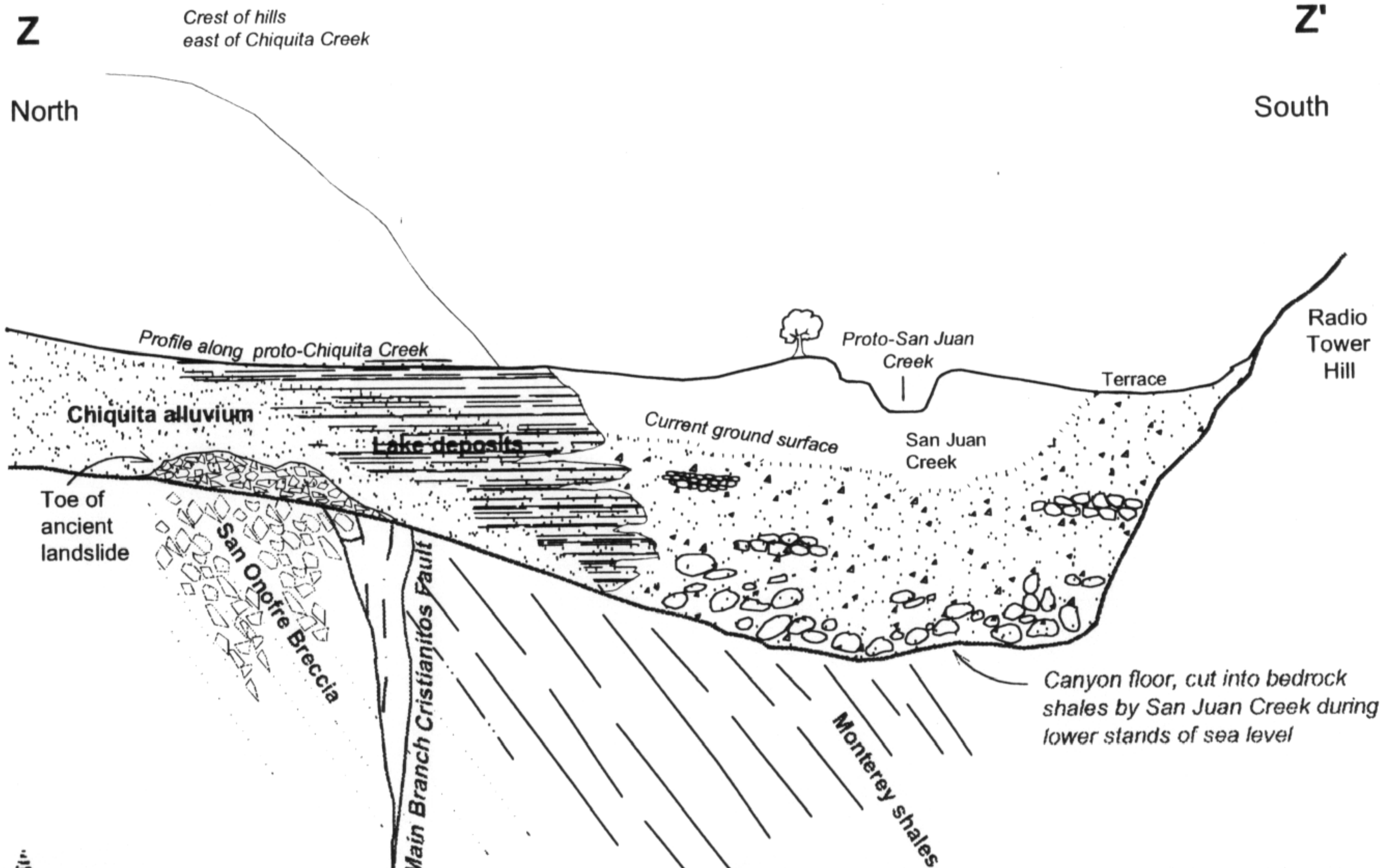
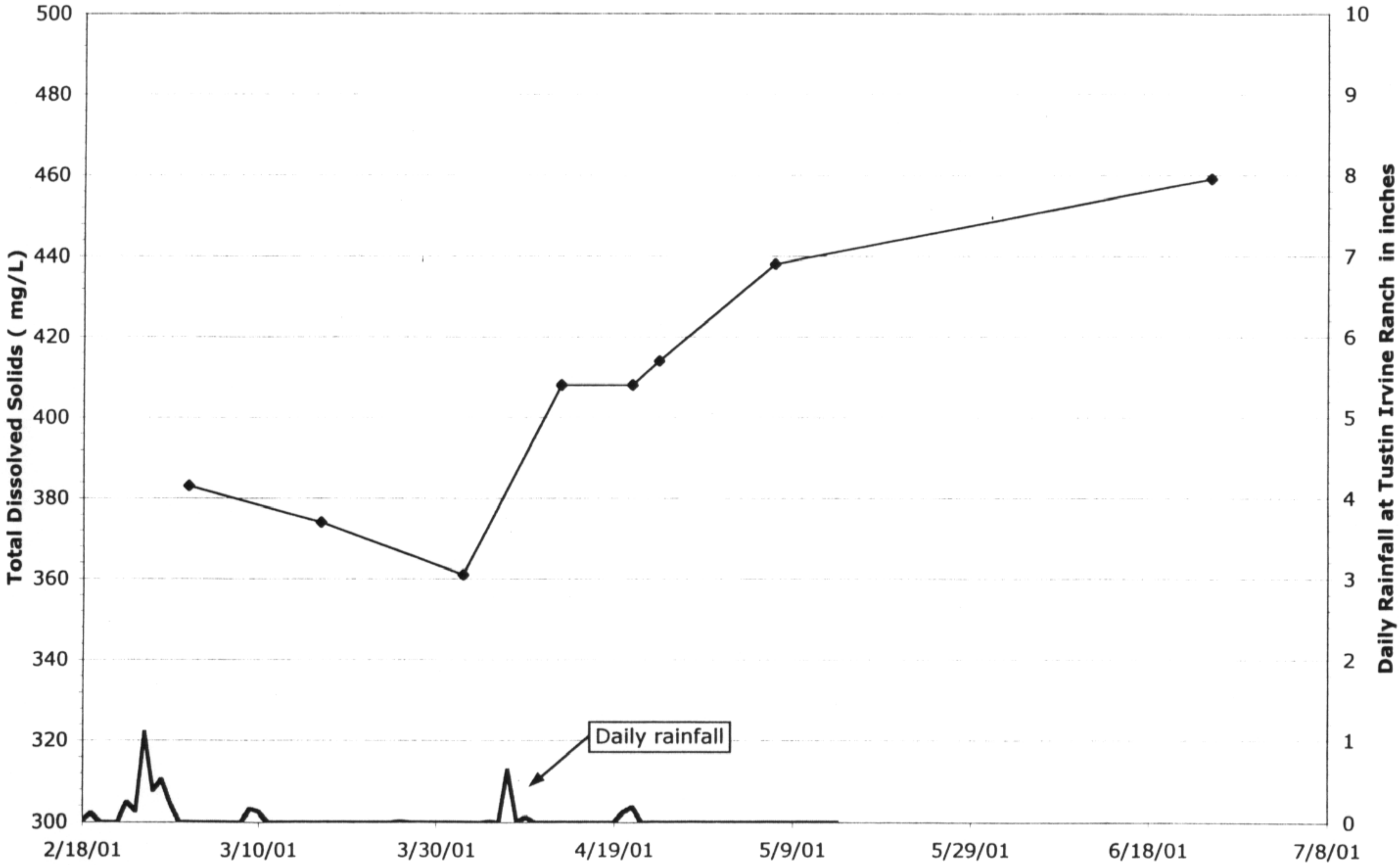
Figure 4. Regional hydrogeologic map



Balance Hydrologics, Inc.

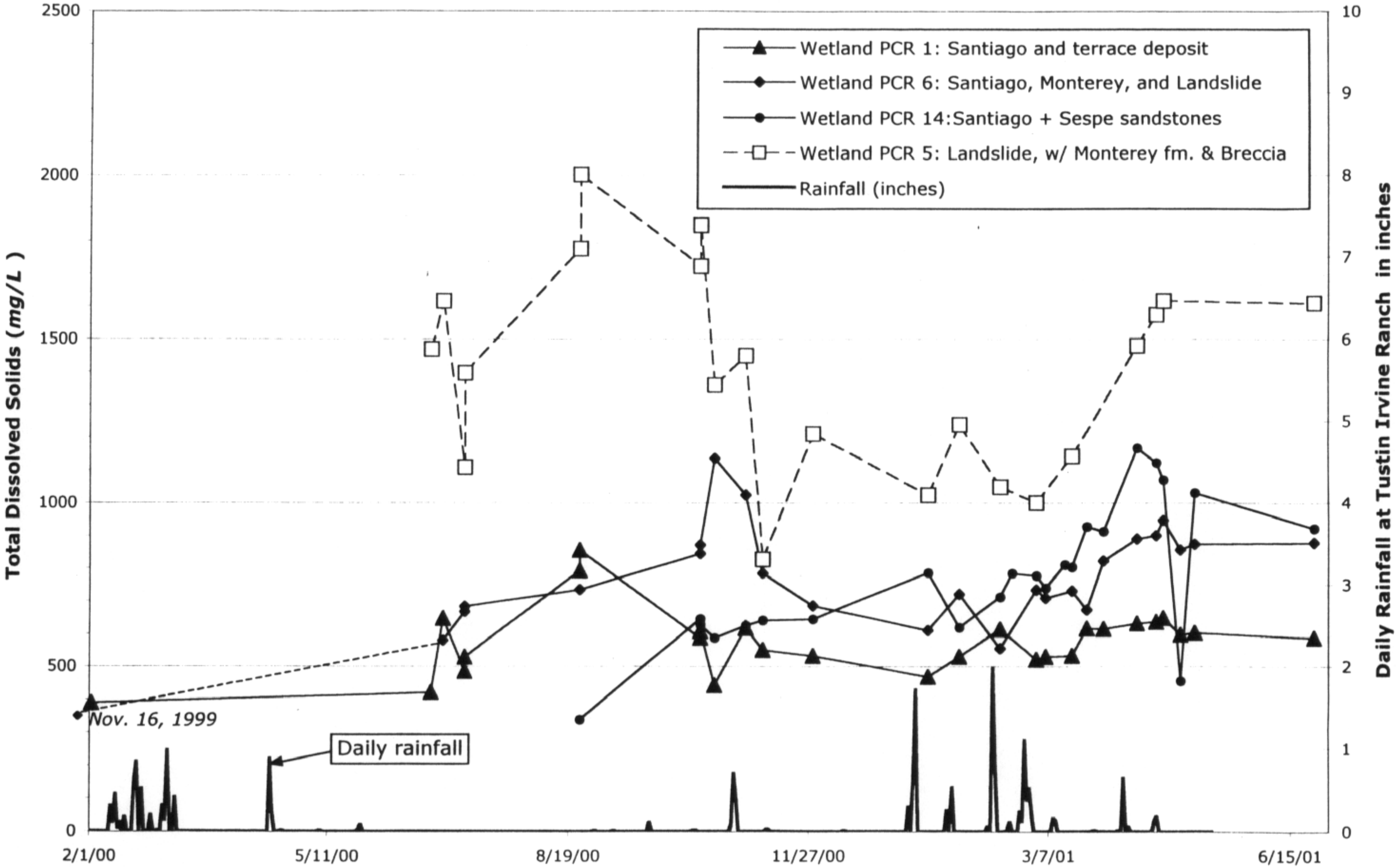
Figure 5. **Schematic illustrating how lake deposits in lowermost Gobernadora and Chiquita were formed by much more rapid accumulation of alluvium eroded from the granitic/crystalline hills of the upper San Juan watershed than the sandy alluvium of the two tributaries .** Both San Juan Creek and the tributaries downcut to lower sea levels during multiple Pleistocene glaciations; their valleys re-filled as sea level rose, with San Juan filling much faster, creating a lake or marsh which filled with quiet-water deposits from Chiquita Creek and (secondarily) overbank flows from San Juan Creek. Very similar processes are responsible for the lake deposits in lower Gobernadora.



Balance Hydrologics, Inc.

Figure 6. Total Dissolved Solids, DH-6, Chiquita

99058 EC data rev.xls, Figure TDS DH6 Chq

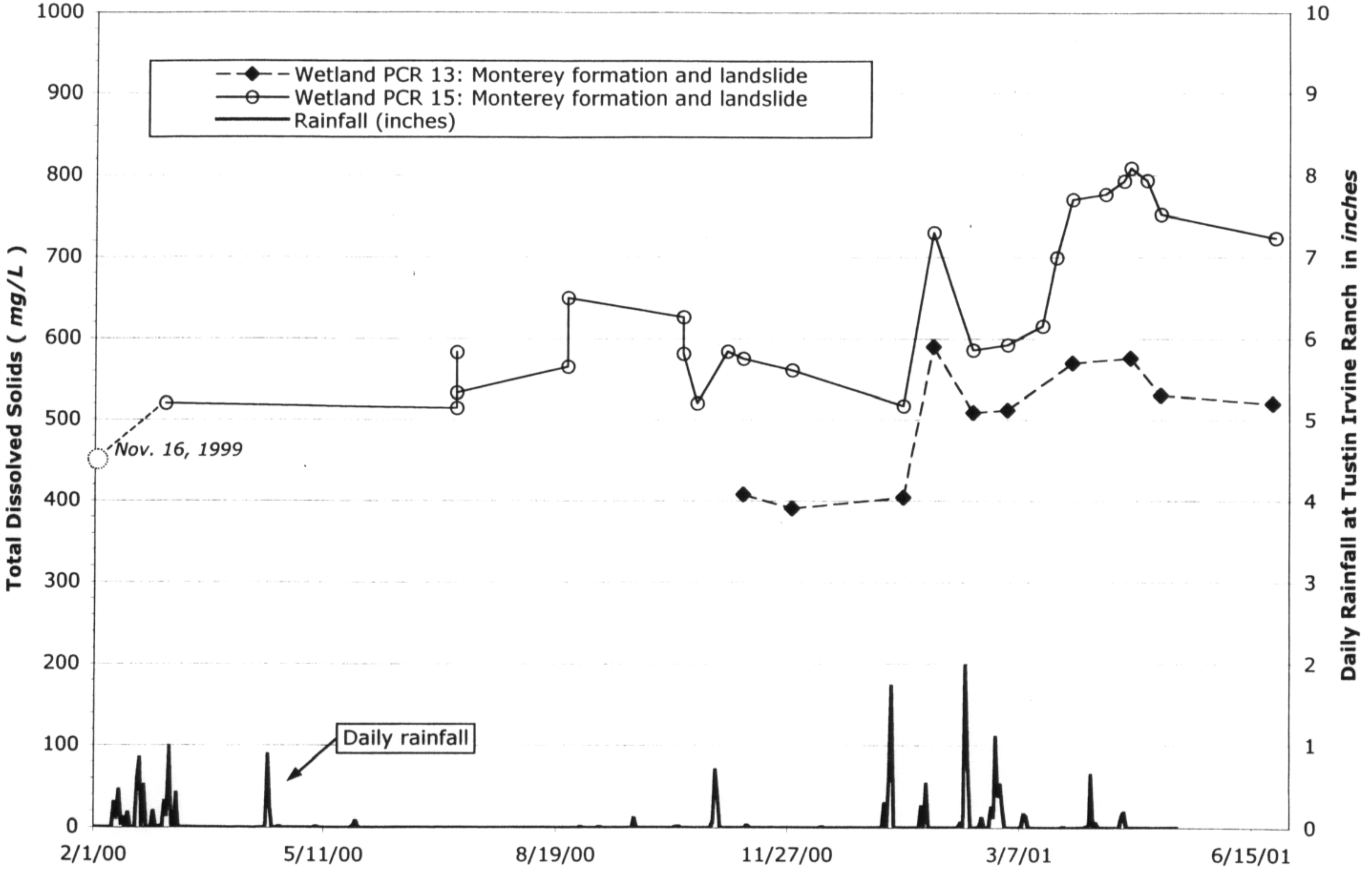


TDS data from PCR, except Nov. 16, 1999

Balance Hydrologics, Inc.

Figure 7. Trends in Total Dissolved Solids Over Time, Selected Chiquita Wetlands With Sandstone and Landslide Sources

99058 EC data rev.xls, Figure 7 Wetland TDS

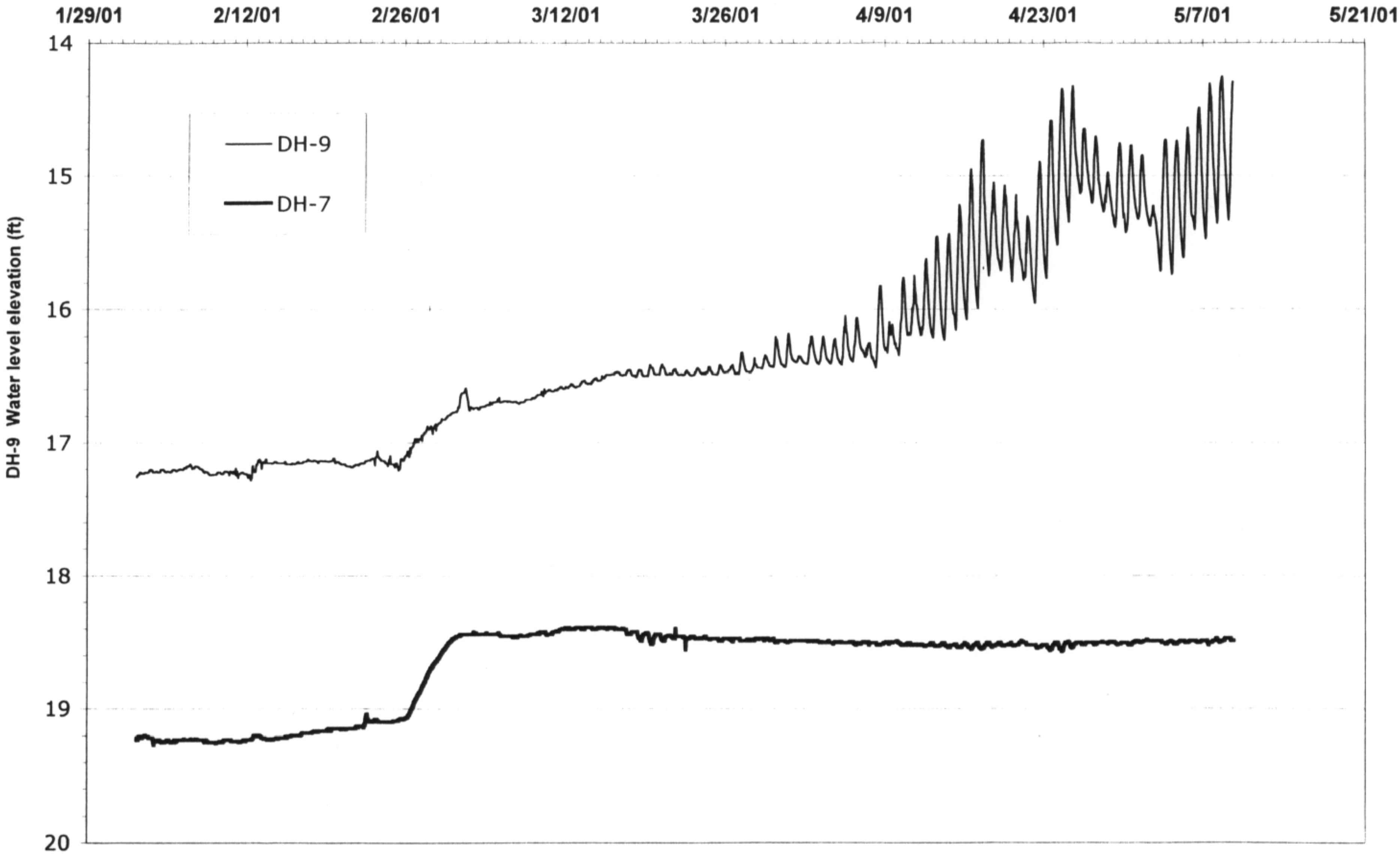


TDS data from PCR, except Nov. 16, 1999.

Balance Hydrologics, Inc.

Figure 8. Trends in Total Dissolved Solids Over Time, Selected Shale-Influenced Wetlands on Radio Tower Hill

99058 EC data rev.xls, Figure 8 Wetland 13&15 TDS



Balance Hydrologics, Inc.

Figure 9. Water level fluctuations in piezometers DH-7 and DH-9 during the latter part of WY2001. See Fig. 4 for piezometer locations in sandy alluvium of tributaries to Chiquita and Gobernadora Canyons respectively. The records show daily water-level fluctuations, which occur in response to evaporation and transpiration from the wetland. Note that maximum fluctuations occur on the same days in both records, during heat spells. The April rise in water levels of DH-9 may be late-season arrival of water recharged at the head of a swale; alternatively, it may be instrument error.

99058 98-66 gwlevels_May23.xls, GWL fluctuations (2)

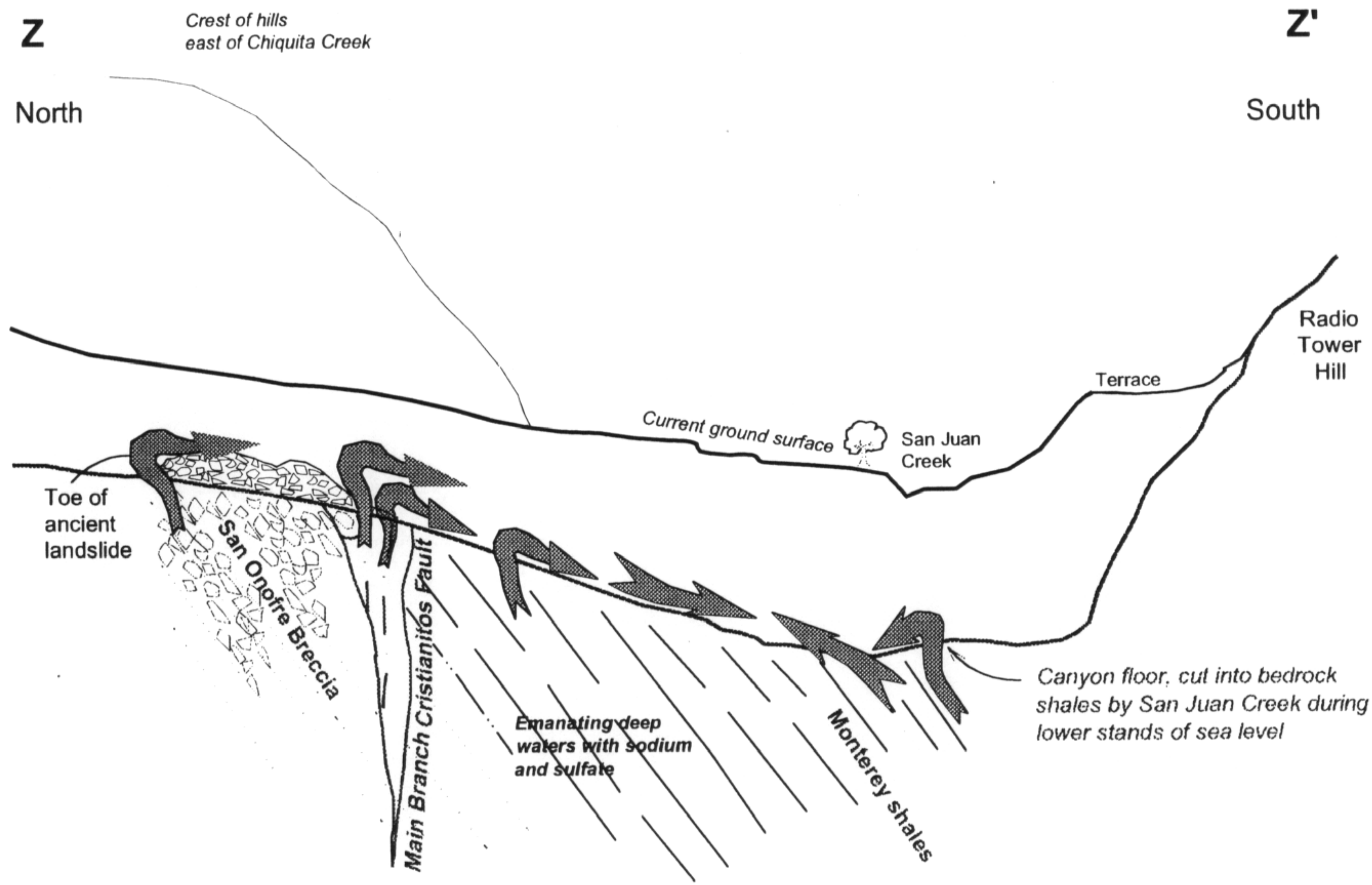


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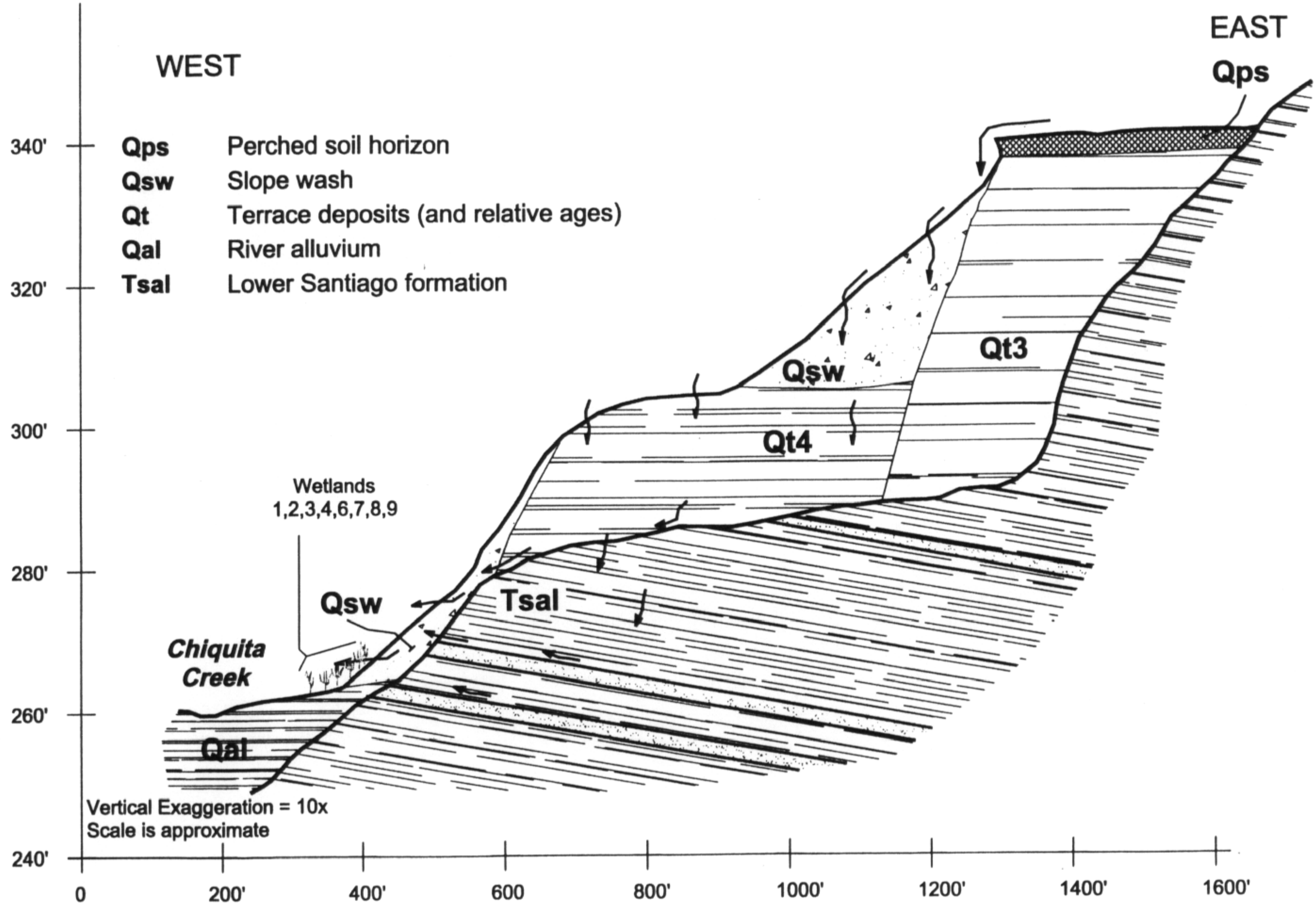
Figure 10. **Schematic of inferred flow paths of sodic and sulfate-bearing deep groudwater near the mouth of Chiquita Canyon.**



Rev. 11/21/2000

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Figure 1. **Inferred nature of shallow ground water movement through slope wash and terrace deposts near the mouth of Chiquita Creek.**

APPENDICES

APPENDIX A

Observers Log: Reconnaissance monitoring of seeps, springs, and live summer streams, San Juan and San Mateo Creek watersheds, Orange County, California: Summer 1999 and spring 2000

Site Conditions				Streamflow			Water Quality Observations				Remarks
Date/Time	Observer	Stage	Hydrograph	Measured Discharge	Instrument Used	Estimated Accuracy	Water Temperature	Field Specific Conductance	Adjusted Specific Conductance	Additional sampling?	
(mm/dd/yr)		(feet)	R/F/S/B)	(cfs)	(AA/PY)	(e/g/f/p)	(oC)	(µmhos/cm)	(at 25 oC)	(Qbed, etc.)	
1. Upper Chiquita, upstream of debris basin (HWM) (614920, 2163710)											
5/4/00 0:00	bh, lce			dry							full coverage of bed by this years grasses, 1998 and 2000 HWM
2. Upper Chiquita, downstream of debris basin (HWM) (6147930, 2162960)											
5/4/00 0:00	bh, lce			dry							1998 HWM noted
3. "Long" wetland, in canyon near red beds (with horseshoe grass) (6148010, 2151390)											
11/16/99 15:16	bh, jo, ejf		b	0.1 gpm	v. est	p	17.0	695	829		below ground flow in tunnels 2-3' under grass
11/16/99 15:16	bh, jo, ejf		b	0.1 gpm	v. est	p	18.8	617	704		near head of wetland
4. Chiquita Creek next to high school site (6146230, 2155140)											
11/16/99 13:22	bh, jo, ejf		b	pooled			15.8	682	839		
2/10/00 9:00	bh, ejf, ks		r?	1.50	v. est	p	16.0	600	735		
5. Wetland next to Creek at SE corner of high school site (6146330, 2155360)											
11/16/99 13:30	bh, jo, ejf		b	0.1 gpm	v. est	p	18.2	640	741		lush
6. Chiquita Creek upstream of SE corner of high school site (6146010, 2153970)											
11/16/99 13:50	bh, jo, ejf		b	0.3-0.5	v. est	p	17.3	627	742		
7.Chiquita Creek at narrows (HWM) (6145570, 2151710)											
5/4/00 11:22	jo, ejf		b	0.29	float	p	17.5		709		bulls grazing in channel; lots of willows in stream
8. Bouncing bog (6145380, 2150490)											
11/18/99 8:00	jo, ejf			ponded			9.6	1867	2709		
9. Tributary north of Chiquita water treatment plant (6149440, 2147350)											
5/4/00 12:50	jo, ejf			dry							deeply incised below berm; unchanneled above gully
10. Lower Chiquita (HWM) (6146910, 2141510)											
11/17/99 17:00	jo, ejf		b	0.20	v. est	p	18.7	1182	1351		sand bed, wide willow channel, cattle like this area
11/18/99 7:00	jo, ejf		b				10.7	775			formerly scoured reach that has filled back in?
5/4/00 10:30	jo, ejf		b	0.33	PY	p	16.8		1084		little or no fresh sediment deposited, good WY 2000 HWM
11.Wetland next to right bank at Lower Chiquita (6146810, 2141380)											
11/17/99 17:00	jo, ejf		b	ponded			16.1	1605	1960		
12.Wetland in lower Chiquita, on east side of canyon (6147720, 2139730)											
11/18/99 9:00	jo, ejf			ponded			12	1080	1469		heron frequently seen in this wetland
13. Chiquita Ridge Vernal Pool (6143480, 2147690)											
11/16/99 12:00	bh, jo, ejf			dry							Deep cracks in clay, no ponding in 2000. No overflow in 1998?

Site Conditions				Streamflow			Water Quality Observations				Remarks
Date/Time	Observer	Stage	Hydrograph	Measured Discharge	Instrument Used	Estimated Accuracy	Water Temperature	Field Specific Conductance	Adjusted Specific Conductance	Additional sampling?	
(mm/dd/yr)		(feet)	R/F/S/B)	(cfs)	(AA/PY)	(e/g/f/p)	(oC)	(µmhos/cm)	(at 25 oC)	(Qbed, etc.)	
											HWM from 1998 1" to 6" below outlet; outlet raised recently? outlet elevation now controlled by gopher holes?
14. Tributary at San Antonio Parkway (Narrow Canyon) (HWM) (6145520, 2137610)											
5/3/00 17:30	bh, jo, ejf			dry							right bank graded post-1998
15. "Area 12" tributary, west of Canada Gobernadora (HWM) (6150950, 2138150)											
5/3/00 14:30	jo, ejf			dry							no flow in WY 2000, many leaves in channel
16. Gobernadora just below Coto de Caza (6154430, 2150270)											
11/18/99 9:40	jo, ejf		b	0.2-0.3	v. est	p	14.3	1014	1298		sandy channel, trapezoidal, appears to have been graded
5/3/00 12:00	by, jo, ejf		b	0.50	v. est	p	20.6		1350		summer 1999 cattails buried beneath 6-8" of sand
17. Gobernadora below Coto de Caza (HWM), just upstream of x-ing (6153360, 2147620)											
11/16/00 0:00	bh, jo, ejf		b								
11/18/99 10:00	jo, ejf		b	pooled			13.2	1179	1554		flow rapidly soaks in; stationary wetting front
5/3/00 10:46	bh, jo, ejf		b	0.50	v. est.	p					flow downstream is 0.2-0.25 cfs (more flow closer to CDC) road washed out on east approach to crossing
18. Gobernadora below CDC, just downstream of x-ing (6153340, 2147350)											
5/3/00 9:00	bh, jo, ejf		b	0.25	v. est	p	18.5		1331		no evidence of backwater from culvert; pool us of culvert has fish;
19. Lower Gobernadora (HWM) (61552830, 2138950)											
11/16/99 16:45	bh, jo, ejf		b	1.80	v. est	p	16.8	1136	1363		bed and lower banks dk gray clay and coarse sand, little silt
5/4/00 9:00	bh, jo, ejf		b	0.25	PY	p	18.3	1210	1397		fine sand deposited, forms dunes and bars
20. Seep on bank at lower Gobernadora (6152830, 2138930)											
11/16/99 16:00	bh, jo, ejf						17.7	1062	1245		SC in hole dug
21. Wetland in lower Gobernadora, on east side of canyon, below Color Spot (6152880, 2137100)											
11/18/99 9:15	jo, ejf			ponded			15	1292	1624		lots of water, flowers and very green vegetation, no cow damage
5/3/00 16:14	jo, ejf		b	0.20			21.3		17		SC msmt at lower end of wetland; drier upstream
5/3/00 16:20	jo, ejf		b	ponded			19.2		2100		SC in hoofprints at upper end of wetland; channel above dry
22. Wagon Wheel Creek at General Riley Park (HWM), near entry road (6152750, 2154820)											
5/3/00 14:20	bh			4 gpm	v. est	p	22.90	910	941		outsides of bends and all straight segments are eroding
23. Sulfur Canyon Creek (in valley south of Wagon Wheel), near log jam (6152490, 2148030)											
11/18/99 11:00	jo, ejf		b	1-3 gpm	v. est	p	13.7	266	346		flowing, shady, verdant. Near old wooden water tank.
5/3/00 10:30	bh, jo, ejf		b	2 gpm	v. est	p	16.8		835		
24. Seep on west side of Sulfur Canyon, 0.25 mi upstream of Gobernadora (6152390, 2147230)											

Stream Gaging Observer Log, San Juan and San Mateo Creek Watersheds, Orange County, California, Water Years 1999 and 2000

Site Conditions				Streamflow			Water Quality Observations				Remarks
Date/Time	Observer	Stage	Hydrograph	Measured Discharge	Instrument Used	Estimated Accuracy	Water Temperature	Field Specific Conductance	Adjusted Specific Conductance	Additional sampling?	
(mm/dd/yr)		(feet)	R/F/S/B)	(cfs)	(AA/PY)	(e/g/f/p)	(oC)	(μmhos/cm)	(at 25 oC)	(Qbed, etc.)	
11/18/99 11:00	jo, ejf			pooled			13.8	925	1200		fairly deep water, not flowing. Seep at base of hill under trees.
5/3/00 10:00	bh, jo, ejf			pooled 0.5' deep			18.5		782		marshy, no flow
25. Seep at mouth of Sulfur Canyon (round, very green grassy seep) (6152880, 2146980)											
11/18/99 11:00	jo, ejf			pooled			18.2	686	794		no visibile flow, ponded in depressions
5/3/00 9:30	bh, jo, ejf			pooled			18.1		787		marshy, pooled in hoofprints, no flow
26. Tributary east of Color Spot (HWM), east of nursery and west of orchard, 200' upstream from washed out road (6158840, 2137100)											
5/3/00 15:30	jo, ejf			dry							clear WY 2000 and WY 1999 HWMs
27. Bell Creek, adjacent to northermost day use parking area in Caspers County Park (HWM) (6161300, 2145400)											
11/18/99 13:00	jo, ejf			dry							cobbly, braided channel
28. Lower Verdugo Creek (HWM) (6168260, 2140820)											
5/4/00 14:15	jo, ejf		b	0.12	py	f/p	20.3		767		many leaf dams and HWM from 2000
29. Verdugo Crk at RMV boundary (6177720, 2146500)											
11/17/99 13:00	jo, ejf			dry							not incised, mixed lithology bed is cobbles and boulders, braided
30. First wetland up Radio Tower Road (20 x 40 feet) (6147280, 2134860)											
11/18/99 14:45	jo, ejf			ponded in hoofprint			16.3	1572	1910		many hoofprints, heavy cow use
31. Duck blind stock pond up Radio Tower Road (6148100, 2134790)											
11/18/99 14:50	jo, ejf						19.8	796	885		many mallards in pond
32. Grazed wetland with spring box on Radio Tower Road 6148450, 2133350)											
11/18/99 14:52	jo, ejf			ponded			13.8	872	1131		heavily grazed, many hoofprints, seepage out of slope?
33. San Juan Creek mainstem at Fire Station, north of RMV along Ortega HWY (6178000, 2161000)											
11/18/99 14:00	jo, ejf		b	20 gpm	v. est	p	15.6	485	600		flowing water in granitic terrrain, dry in sandy gravelly areas ds
34. San Juan Creek mainstem at west end of Aeropuerto Ave. downstream of San Juan Capistrano											
2/11/00 15:00	bh, ejf		r	40	v. est	p	12.2	960	1299		
2/11/00 15:00	bh, ejf						10.0	240	345		standing water in storm drain that empties into creek
35. Upper Cristianitos Canyon (6162760, 2128210)											
11/17/99 7:00	jo, ejf			dry							sandy undefined channel w/ mulefat, dry
36. Cristianitos Creek upstream from Gabino (HWM), 30' downstream from bedrock notch (6160890, 2117110)											
11/17/99 8:00	jo, ejf			dry							oak and willow on banks, channel relatively clear
37. Gabino Creek above La Paz (HWM) (6170630, 2125630)											
11/17/99 11:00	jo, ejf			dry							willows in channel, oaks on bank; survey WY 1998 HWM

Stream Gaging Observer Log, San Juan and San Mateo Creek Watersheds, Orange County, California, Water Years 1999 and 2000

Site Conditions				*Streamflow*			*Water Quality Observations*				*Remarks*
Date/Time	Observer	Stage	Hydrograph	Measured Discharge	Instrument Used	Estimated Accuracy	Water Temperature	Field Specific Conductance	Adjusted Specific Conductance	Additional sampling?	
(mm/dd/yr)		*(feet)*	*R/F/S/B)*	*(cfs)*	*(AA/PY)*	*(e/g/f/p)*	*(oC)*	*(µmhos/cm)*	*(at 25 oC)*	*(Qbed, etc.)*	
5/4/00 15:30	jo, ejf			dry							survey WY 2000 HWM
38. Windmill on Gabino at La Paz Confluence (sampled at stock trough) (6169630, 2121370)											
5/3/00 18:50	bh, jo, ejf						24.8		2077		
39. La Paz Creek ("La Paz A"), 0.9 miles upstream of Gabino (HWM) (6173470, 2122590)											
11/17/99 10:00	jo, ejf			dry							rounded cobbles, d50 fist sized
5/3/00 18:35	bh, jo, ejf			dry							
40. La Paz Creek ("La Paz B") 0.4 miles upstream of Gabino (HWM) (6172090, 2121050)											
5/3/00 18:30	bh, jo, ejf			dry							

Observer Key: (bh) is Barry Hecht, (eb) is Ed Ballman, (ejf) is Elise Foster, (gp) is Gustavo Porras, (jo) is Jonathan Owens, (lce) is Laura Coley-Eisenberg
Stage: Water level observed at outside staff plate
Hydrograph: Describes stream stage as rising (R), falling (F), steady (S), or baseflow (B)
Instrument: If measured, typically made using a standard (AA) or pygmy (PY) bucket-wheel ("Price-type") current meter. If estimated, from rating curve (R) or visual (V).
Estimated measurement accuracy: Excellent (E) = +/- 2%; Good (G) = +/- 5%; Fair (F) = +/- 9%; Poor (P) estimated percent accuracy given
High-water mark (HWM): Measured or estimated at location of the staff plate
Specific conductance: Measured in micromhos/cm in field; then adjusted to 25degC by equation (1.8813774452 - [0.050433063928 * field temp] + [0.00058561144042 * field temp^2]) * Field specific conductance
Additional Sampling: Qbed = Bedload, Qss = Suspended sediment, Nutr = nutrients; other symbols as appropriate
Approximate coordinates of each observation location are provided in the state plane coordinate system.

11/16/99 0:00 BH, JO, EJF, Eric Stein (PCR) and Amy Henderson (Glenn Lukos & Associates). Sunny, 75 degrees. Orientation site visit to get aquainted with the property.
SCT meter is YSI Model 30 SN# 97KO193AJ. On site from 1 PM through late afternoon.

11/17/99 0:00 JO, EJF on site to measure cross sections and high water marks for 1998 indirect discharge calculations.
Also to conduct inventory for late dry season water in channels, seeps, and springs. Cool, cloudy, light sprinkles in morning.
SCT meter is YSI Model 30 SN# 97KO193AJ. On site from 7 AM until too dark to work.

11/18/99 0:00 JO, EJF on site to measure cross sections and high water marks for 1998 indirect discharge calculations.
Also to conduct inventory for late dry season water in channels, seeps, and springs. Clear and sunny, 70 degrees.
SCT meter is YSI Model 30 SN# 97KO193AJ. On site from 7 AM until 3 PM.

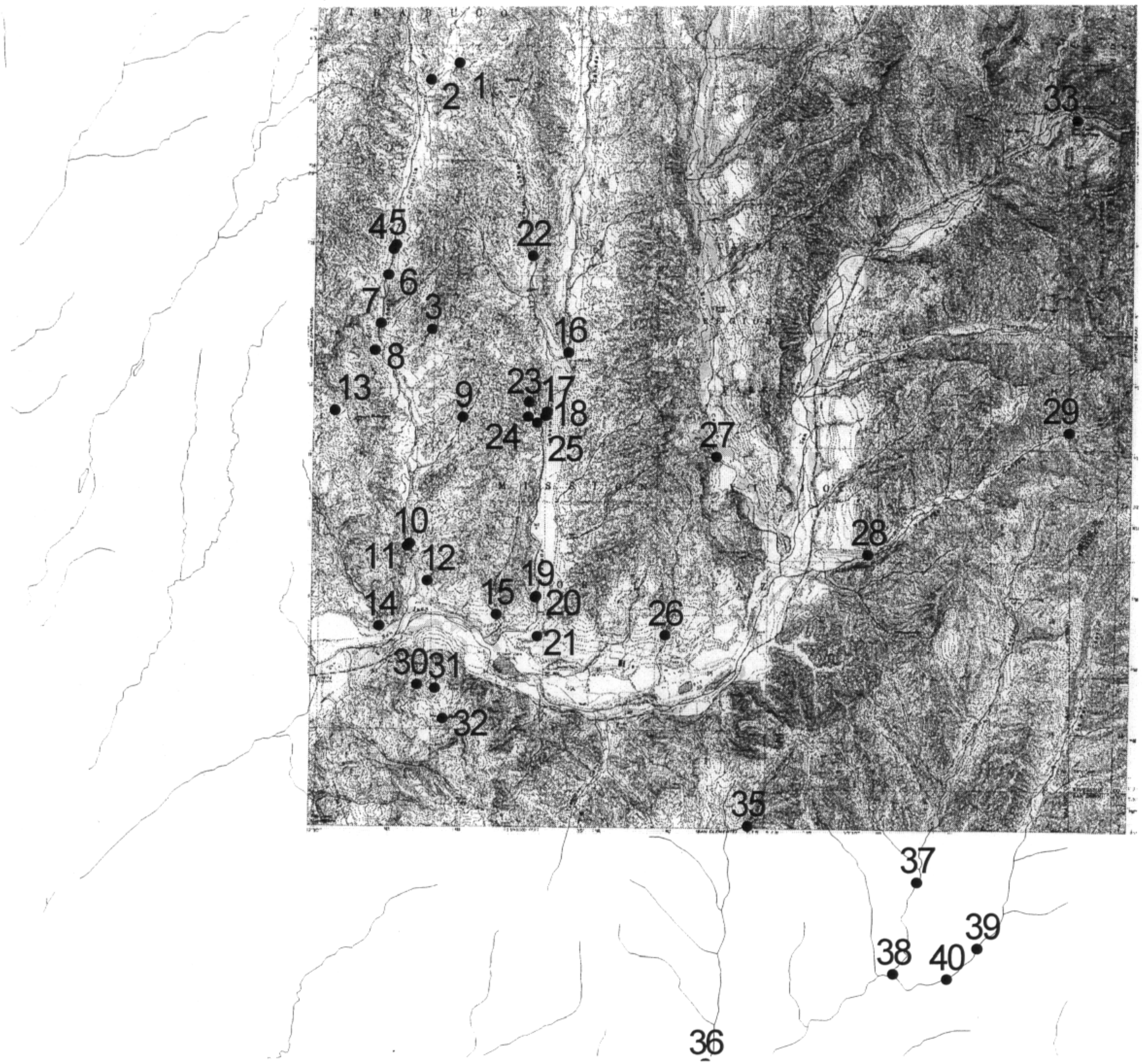
2/10/00 0:00 BH, EJF, Ken Schwarz (PWA). Geomorphology trip to become familiar with soils, learn lacustrine beds, identify sandy terrace chronology,
learn geology. Cool, overcast, 60 degrees. Showers turn to steady rain, heavy at times.
On site 8 AM through mid afternoon.

5/3/00 0:00 BH, JO, EJF on site to measure cross sections and high water marks for 1998 and 2000 indirect discharge calculations.
Foggy, then clearing. Warm later in day, 75-80 degrees.

Stream Gaging Observer Log, San Juan and San Mateo Creek Watersheds, Orange County, California, Water Years 1999 and 2000

Date/Time	Observer	Stage	Hydrograph	Measured Discharge	Instrument Used	Estimated Accuracy	Water Temperature	Field Specific Conductance	Adjusted Specific Conductance	Additional sampling?	Remarks
Site Conditions				*Streamflow*			*Water Quality Observations*				*Remarks*
(mm/dd/yr)		*(feet)*	*R/F/S/B)*	*(cfs)*	*(AA/PY)*	*(e/g/f/p)*	*(oC)*	*(µmhos/cm)*	*(at 25 oC)*	*(Qbed, etc.)*	
											SCT meter used by EJF and JO is YSI model 30 SN# 97KO193AJ. BH uses YSI model 33 SN# HO16726, probe # 94685904. On site 9 AM through 8 PM.
5/4/00 0:00											BH, JO, EJF and Laura Coley Eisenberg (RMV) on site to measure cross sections and high water marks for 1998 and 2000 indirect discharge calculations. Foggy, then clearing. Warm later in day, 75-80 degrees. SCT meter used by EJF and JO is YSI model 30 SN# 97KO193AJ. BH uses YSI model 33 SN# HO16726, probe # 94685904. Meet LCE at Ranch HQ at 8: 30 AM. On site 9:30 AM to 4 PM.
6/6/00 0:00											BH and EJF. Early morning reconnaisance of channels downstream from existing development before noon meeting at RMV. Clear, sunny, 70 degrees. In Gen. Riley Park 8: 30 AM until 10:30.

SAMP Stream Gaging & Observation Stations



APPENDIX B

Growth of irrigated acreage in the San Juan and El Toro Water Districts- - Excerpts from a tabulation by Mr. A. B. Perkins, Orange County Agricultural Agent, October 3, 1935

Planted Acreage In San Juan And El Toro Water Districts
(Does Not Include Acreage Within The Rancho Santa Margarita)

Compiled October 3, 1935
From
Records of Mr. A. B. Perkins, Orange County Agricultural Agent

SAN JUAN WATER DISTRICT:	Number of Acres
Age of Planting	
1 year old	16.5
2 " "	113.0
3 " "	42.0
4 " "	413.5
5 " "	321.0
6 " "	85.3
7 " "	175.4
8 " "	185.2
9 " "	77.3
10 " "	255.1
10 to 15 years old	203.4
15 to 20 " "	60.5
20 to 25 " "	86.5
25 to 30 " "	53.2
30 to 35 " "	115.5
35 to 40 " "	46.8
40 to 45 " "	11.5
45 to 50 " "	10.0
50 to 55 " "	29.0
	2300.7

EL TORO WATER DISTRICT:	
Age of Planting	
Since 1928	479.3
Prior to 1929	456.5
	935.8

Total Planted Acreage - San Juan & El Toro	3236.5

APPENDIX C

East-west hydrogeologic cross section through the central SAMP area

Introduction to Appendix C: Hydrogeologic Cross Section

The following cross section is the work of Paul Morton, California Divisions of Mines and Geology, published in 1974 as part of his geology of the southern half of the Canada Gobernadora quadrangle. To keep the cross section at the scale at which it was originally printed, we have divided it into four separate pages, beginning at its western edge (near Narrow Canyon and the present-day Antonio Parkway) and extending eastward through Chiquita, Governadora, the mouth of Bell Canyons, and across San Juan and Verdugo Creeks to La Paz Creek, and the Orange/Riverside county line. Figure 4 shows the location of this cross section. We have tried to provide sufficient overlap so that readers can easily orient themselves, and gain the effect of the original document.

The cross section was drawn at this location, apparently, because the author was able to utilize information from the four test wells drilled by Shell and Humble (now Exxon). Typically, such information includes geophysical logs and drilling reports that are proprietary, but are sometimes made available to state geologists. The validity of this section at depth is thus greater than might be attained at present by conventional engineering geology or geotechnical investigations using near-surface data.

Hydrogeologic features of meriting particular note include (from west to east):

- The Forster, and West and Main Branches of the Cristianitos faults, which have fractured and offset the indurated beds of Monterey shale (**Tm**) and Topanga sandstone/San Onofre breccia (**Tso,** or **Tsob**), conveying from Chiquita Ridge into landslides lining Narrow and Chiquita Canyons.

- Near-continuous outcrop of water-bearing Santiago sandstone from the base of Chiquita Ridge eastward to near Bell Canyon. The lower member **(Tsal)** of the Santiago formation is coarser and contains fewer continuous shale or mudstone beds than the upper member **(Tsau)**, although both sustain multiple springs and seeps.

- Extensive lenses of slopewash **(Qsw)**– or sandy aprons – and alluvium **(Qal)** in Gobernadorā and Chiquita Canyons, through which considerable recharge may occur.

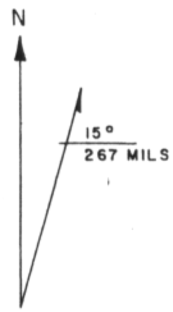
- Numerous discontinuous horizons of old duripans (hardpans) and other remnants of perched soils **(Qps)**, pockets of low permeability that generate high runoff and low recharge within the otherwise high-recharge Santiago sandstone outcrop area. Morton's detailed mapping show that outcrops of Qps are of equal and intermediate density on the ridges both west and east of Gobernadora Canyon, although the cross section makes it appear they are quite dense and occur only east of the canyon.

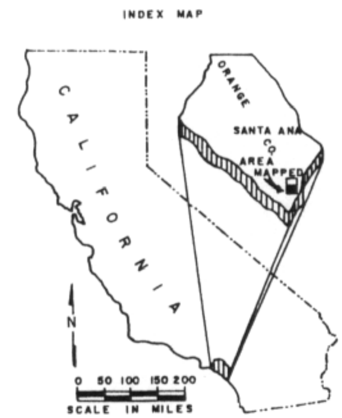
- Wide areas of alluvium **(Qal)** and alluvial terraces **(Qtr)** adjoining Bell Canyon and San Juan Creek, where considerable rainfall and infiltration recharge of the alluvium along the two streams may occur, except in areas where claypans limit deep percolation of rain (see Figure 5 of the Baseline Report, and the Terrains Report).

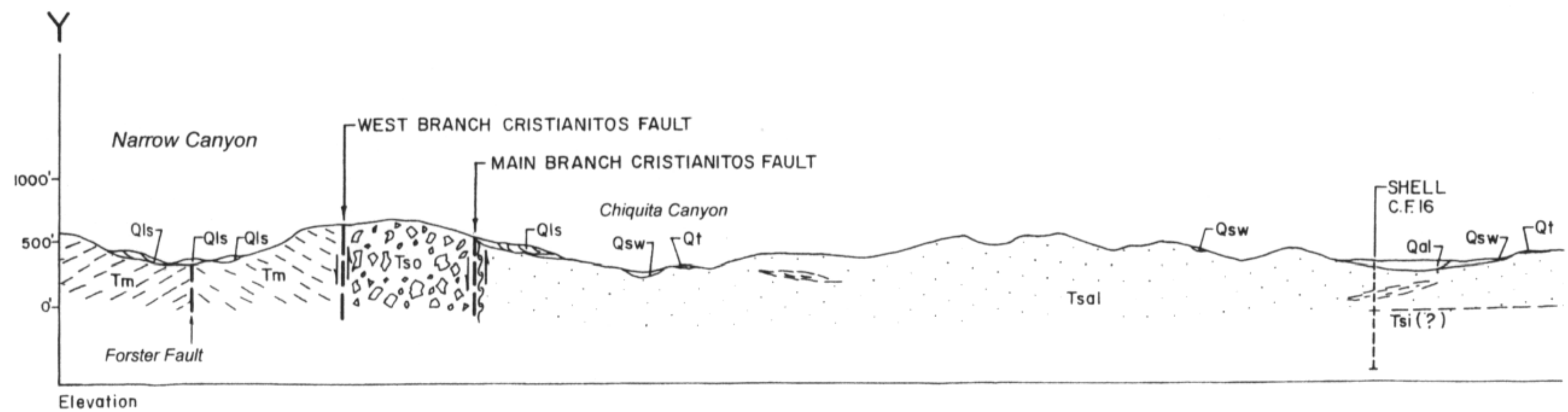
- Extensive outcrops of minimally permeable Cretaceous and older sedimentary rocks **(Kw, Klbc,Kt),** eastward from San Juan Creek, where groundwater storage and flow are generally too small to sustain summer baseflows or springs and seeps.

Readers may wish to note that this section is drawn at true scale, i.e., without vertical exaggeration.

Morton conducted field mapping in 1969 and 1970, shortly after the record February 1969 floods. His maps contain many indications as to where runoff was generated or recharge generated during these heavy rains, information likely to prove useful for site-scale planning.

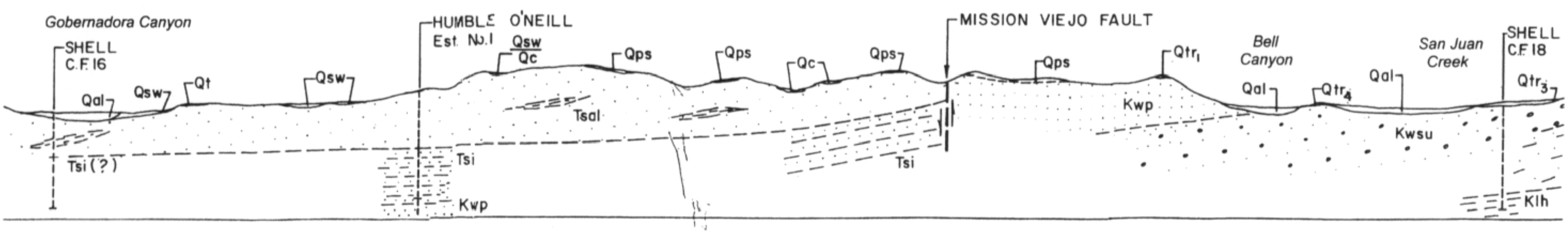

N
15°
267 MILS


INDEX MAP
CALIFORNIA
ORANGE
SANTA ANA
CO.
AREA
MAPPED
N
0 50 100 150 200
SCALE IN MILES


Y
Narrow Canyon
WEST BRANCH CRISTIANITOS FAULT
MAIN BRANCH CRISTIANITOS FAULT
Chiquita Canyon
SHELL
C.F. 16
1000'
500'
0'
Qls
Qls
Qls
Qls
Tm
Tm
Tso
Qsw
Qt
Qsw
Qal
Qsw
Qt
Tsal
Tsi (?)
Forster Fault
Elevation

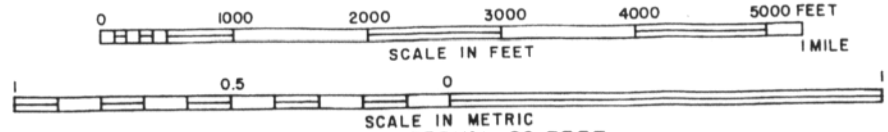
EXPLANATION

QUATERNARY	Holocene	af	Artificial fill
		Qal, Qalb, Qal2, Qal1	Alluvium, undifferentiated; Qalb where boulders predominate; subscripts denote order of deposition
		Qsw, Qswb, Qswe	Slopwash debris; Qswb, where boulders predominate; Qswe, where noted to be expansive
		Qls, Qls(?)	Landslide debris; Qls (?), Questionable landlide debris; parentheses where present denote predominate geologic unit composing debris
		Qoal	Older alluvium
		Ql	Lake or pond deposits
		Qps, Qpse	Perched soil or colluvium; Qpse where noted to be expansive
		Qt	Terrace deposits, undifferentiated
	Pleistocene	Qtr4, Qtr3, Qtr2, Qtr1	River terrace deposits; subscripts denote order of deposition
		Qc	Nonmarine sand of undetermined origin
TERTIARY	Pliocene	Tc	Capistrano Formation
	Miocene	Tm	Monterey Formation
		Tt, Ttso, Tts	Topanga Formation; Ttso, San Onofre Breccia; Tts, siltstone
		Ts	Sespe Formation
	Eocene	Tsau, Tsal	Tsau, upper beds; Tsal, lower beds } Santiago Formation
	Paleocene	Tsi	Silverado Formation
UPPER CRETACEOUS		Kwp	Pleasants Sandstone Member } Williams Formation
		Kwsu, Kwsl, Kws2	Schulz Ranch Member; Kwsu, upper beds; Kwsl, lower beds; Kws2, conglomerate-fanglomerate facies } Williams Formation
		Kl, Klh, Klb, Klbc	Ladd Formation, undifferentiated; Klh, Holz Shale Member; Klb, Baker Canyon Member; Klbc, conglomerate
		Kt	Trabuco Formation
UPPER JURASSIC		Jsp	Santiago Peak Volcanics



SECTION Y – Y' *

1:12,000



CONTOUR INTERVAL 20 FEET

SYMBOLS

- Contacts; dotted where concealed or altered by development; dashed where approximated, queried where inferred; solid where located with certainty
- Denotes Claymont Clay Bed in the Silverado Formation
- Fault; dashed where approximately located, dotted where concealed, queried where conjectural; U-upthrown side, D-downthrown side; arrow indicates attitude. Double line indicates width of zone
- Shears
- Landslide. See also Qls under descriptions of units. Queried where questionable
- Landslide scarp or pull away
- Surficial slide or mudflow
- Creep
- Attitude of beds, regional
- Attitude of beds, local
- Attitude of joints or minor shears
- Vertical joint or shear
- Horizontal beds
- Approximate attitude of beds
- Invertebrate fossil locality
- Fossil plant locality
- Prospect pit; boundary
- Mineral prospect
- Spring or seep
- Anticline
- Syncline
- Indicates upper unit thinly overlying lower unit
- Resevoir
- Exploratory drill hole for petroleum
- Exploratory drill hole for petroleum converted to water well