Stormwater Flow and Capture Analysis - Active Recharge Project for the Tributaries of the Santa Ana River, San Bernardino Valley, California

DRAFT

PREPARED FOR:

San Bernardino Valley Municipal Water District

January 10, 2012

***GEOSCIENCE* Support Services, Inc.**

Ground Water Resources Development

P.O. Box 220, Claremont, CA 91711 | P (909) 451-6650 | F (909) 451-6638 | www.gssiwater.com

STORMWATER FLOW AND CAPTURE ANALYSIS - ACTIVE RECHARGE PROJECT FOR THE TRIBUTARIES OF THE SANTA ANA RIVER, SAN BERNARDINO VALLEY, CALIFORNIA

TABLE OF CONTENTS

DRAFT

DRAFT

FIGURES

DRAFT

FIGURES (CONT.)

DRAFT

FIGURES (CONT.)

DRAFT

FIGURES (CONT.)

DRAFT

FIGURES (CONT.)

DRAFT

FIGURES (CONT.)

DRAFT

FIGURES (CONT.)

DRAFT

TABLES

DRAFT

APPENDICES

Ltr.	Description
A	Field Infiltration Test Documentation
B	Engineer's Estimates for Proposed New Stormwater Capture Facilities – Prepared by Bonadiman and Associates

DRAFT

ABBREVIATIONS AND DEFINITIONS

acre-ft/yr	acre-feet per year
Alluvial	A geologic term describing beds of sand, gravel, silt, and clay deposited by flowing water.
amsl	above mean sea level
Aquifer	A geologic formation or group of formations which store, transmit, and yield significant quantities of water to wells and springs.
bgs	below ground surface
CDMG	California Division of Mines and Geology
CSWM	Calibrated San Bernardino Basin Area Watershed Model
CLOMAR/LOMAR	Conditional Letter of Map Revision/Letter of Map Revision- amendments to the Federal Emergency Amendment Agency's Flood Insurance Rate Maps
DEM	Digital Elevation Model
District	San Bernardino Valley Municipal Water District (SBVMWD)
Drawdown	The change in hydraulic head or water level relative to a background condition.
DWR	California Department of Water Resources
EPA	United States Environmental Protection Agency
ET	Evapotranspiration
Evapotranspiration	The combined loss of water from a given area by evaporation from the land and transpiration from plants.
eWRIMS	Electronic Water Rights Information Management System
Fault	A fracture in the earth's crust, with displacement of one side of the fracture with respect to the other.
Formation	A geologic term that designates a body of rock or rock/sediment strata of similar lithologic type or combination of types.

DRAFT

ABBREVIATIONS AND DEFINITIONS (CONT.)

ft	feet, foot
ft/day	feet per day
GEOSCIENCE	Geoscience Support Service, Inc.
gpm	gallons per minute
Ground Water	Water contained in interconnected pores located below the water table in an unconfined aquifer or located in a confined aquifer.
Head	Energy, produced by elevation, pressure, or velocity, contained in a water mass.
HSPF	Hydrologic Simulation Program - Fortran
Hydraulic Conductivity	The measure of the ability of the soil to transmit water, dependent upon both the properties of the soil and those of the fluid.
in.	inch
K	See Hydraulic Conductivity
mg/L	milligrams per liter
MODFLOW-2000	A modular finite-difference flow model developed by the United States Geologic Survey (USGS) to solve the groundwater flow equation.
MT3DMS	A modular three-dimensional solute transport model for simulation of advection, dispersion and chemical reactions of contaminants in ground water systems.
Permeability	The capability of soil or other geologic formations to transmit water. The term is used to separate the effects of the medium from those of the fluid on the hydraulic conductivity.
PEST	Parameter ESTimation software
SAR	Santa Ana River
SBBA	San Bernardino Basin Area
SBCFCD	San Bernardino County Flood Control District

DRAFT

ABBREVIATIONS AND DEFINITIONS (CONT.)

SBVMWD	San Bernardino Valley Municipal Water District
SBVWCD	San Bernardino Valley Water Conservation District
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TD&A	Tom Dodson and Associates
TIN	Triangulated irregular network
USGS	United States Geological Survey
yr(s)	year or years

DRAFT

STORMWATER FLOW AND CAPTURE ANALYSIS - ACTIVE RECHARGE PROJECT FOR THE TRIBUTARIES OF THE SANTA ANA RIVER, SAN BERNARDINO VALLEY, CALIFORNIA

EXECUTIVE SUMMARY

In order to better manage surface water available to the San Bernardino Basin area (SBBA), the San Bernardino Valley Municipal Water District (the District) commissioned this study to determine:

- The volume of surface water which has historically migrated out of the San Bernardino Basin Area (SBBA),
- The volume of surface water that is generated internally within the SBBA as the result of historical and on-going urbanization of the SBBA,
- The quantity of stormwater that is generated by the major tributary creeks to the Santa Ana River,
- The location and preliminary (conceptual) designs of potential new stormwater capture facilities that could maximize the capture and recharge of surface water flows,
- Potential modifications to existing retention basins and spreading grounds to further increase surface water capture and recharge, and
- The volume of potential additional recharge to the SBBA and the effect to surface water volumes leaving the SBBA that will occur as a result of implementation of an active recharge project.

To answer these questions a phased approach was used: First, it was necessary to construct a calibrated watershed model to calculate surface flow volumes generated from both outside and within the SBBA on the major tributaries to the Santa Ana River (SAR). This report includes a description of the construction of the calibrated SBBA Watershed Model (CSWM).

Second, the CSWM was used to provide annual average, wet and dry stormwater flows generated by the tributary creeks and to determine preliminary optimum locations where the flows could be captured.

Third, the District commissioned an analysis of potential environmental constraints for each of the selected tributary creeks. The environmental analysis showed that various environmental concerns exist for all of the tributary creeks when considering construction of new recharge facilities. The environmental analysis was used to select areas for new recharge facilities that will encounter the least amount of environmental constraints for construction and operation of the active recharge project. Sites with the least amount of potential environmental constraints and if possible, owned by the San

Bernardino Flood and Water Conservation District (SBCFCD), were selected for further analysis. The SBCFCD properties were selected, as the mission of SBCFCD and SBVMWD overlap in the desire and responsibility to manage and conserve surface water flow for beneficial uses. During the course of the study, it was determined that modification or revised operational strategies for existing basins was not considered "project" conditions for the active recharge project being that specific modifications and operational changes will require discussion, scoping, and consensus by stakeholders prior to implementation. The CSWM can be used to evaluate specific projects involving modifications or re-operation of specific existing facilities.

Fourth, field testing was conducted at existing and selected potential areas of new stormwater capture facilities to provide site specific data for design of new capture facilities.

Fifth, based on the environmental constraints analysis and field testing, conceptual designs for potential new capture facilities were prepared for facilities on eight of the tributary creeks.

Sixth, using the CSWM, further analysis was conducted to evaluate potential surface flows that can be captured under "project" conditions by new capture facilities, the amount of additional ground water recharge that would occur under "project" conditions and the effect on surface water outflow from the SBBA as a result of implementation of the project.

The following is a summary of report findings:

- Stormwater flow from the selected tributary creeks (not including the Santa Ana River) that enters the SBBA during wet, dry, and average hydrologic conditions is 212,790, 45,790, and 98,373 acre-ft/yr respectively,
- Stormwater flow from selected tributary creeks leaving the SBBA is 118,841, 14,576, and 53,712 acre-ft/yr for wet, dry, and average hydrologic conditions respectively,
- Additional stormwater flow is generated internally within the SBBA as the result of urbanization and changes to channels and basins. The annual stormwater flow generated within the SBBA for wet, dry, and average hydrologic conditions is 7,011, 2,041, and 4,275 acre-ft/yr respectively,
- Under 1963 land use conditions, the annual stormwater flow leaving the SBBA for wet, dry, and average conditions is 109,081, 11,099, and 47,602 acre-ft/yr respectively, and
- Under 2005 land use conditions, the annual stormwater flow leaving the SBBA for wet, dry, and average conditions is 118,841, 14,576, and 53,712 acre-ft/yr respectively.

The comparison of 1963 and 2005 land use conditions show increased stormwater flows leaving the SBBA during wet, dry and average hydrologic conditions as a result of growing urban conditions.

- Under "project" conditions annual net ground water recharge will increase to 24,829, 6,078, and 12, 954 acre-ft/yr for wet, dry, and average hydrologic conditions respectively.
- Under "project" conditions annual stormwater flows leaving the SBBA will decrease to 90,925, 9,922, and 40,917 acre-ft/yr for wet, dry, and average hydrologic conditions respectively. This is a decrease of 23%, 32%, and 24% for the wet, dry, and average conditions respectively.

The data shows that implementation of the active recharge project will result in a net increase in annual ground water recharge and supplies within the SBBA. However, a decrease in stormwater flows leaving the SBBA will occur as the result of the active recharge project.

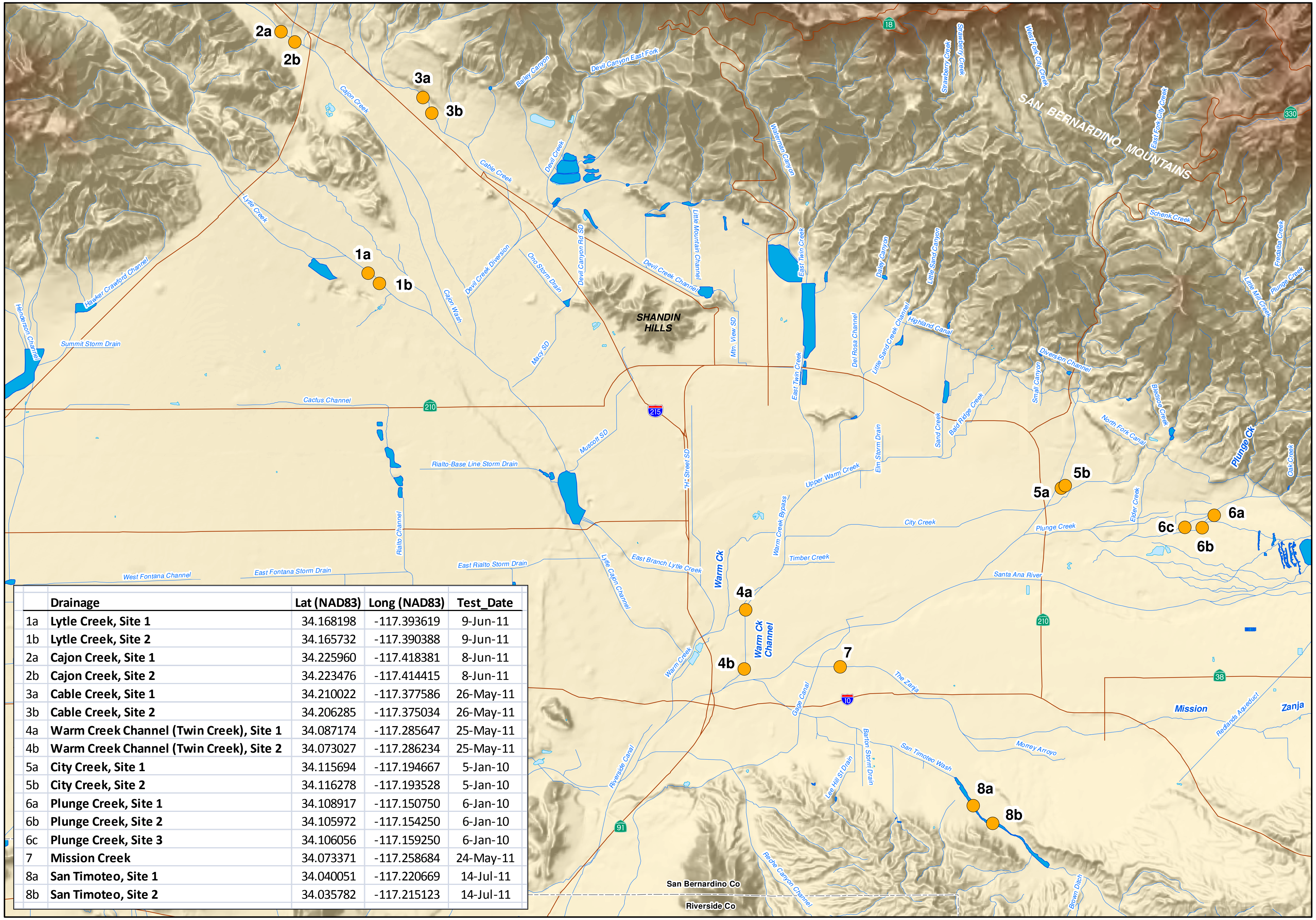
- The total estimated cost for construction of new recharge facilities on the selected tributary creeks is approximately $10,800,000. The total average annual net recharge of stormwater is calculated to be approximately 13,000 acre-ft/yr (see Section 5.2.1). The cost to develop additional water supplies with the proposed new recharge facilities is $832 per acre-ft. However, costs per acre-foot for recharge projects on individual creeks may be higher or lower than this reported value.

DRAFT

SAN BERNARDINO VALLEY
MUNICIPAL WATER DISTRICT

STORMWATER FLOW AND CAPTURE ANALYSIS - ACTIVE RECHARGE PROJECT FOR THE TRIBUTARIES OF THE SANTA ANA RIVER, SAN BERNARDINO VALLEY, CALIFORNIA

INFILTROMETER TEST LOCATIONS



	Drainage	Lat (NAD83)	Long (NAD83)	Test_Date
1a	Lytle Creek, Site 1	34.168198	-117.393619	9-Jun-11
1b	Lytle Creek, Site 2	34.165732	-117.390388	9-Jun-11
2a	Cajon Creek, Site 1	34.225960	-117.418381	8-Jun-11
2b	Cajon Creek, Site 2	34.223476	-117.414415	8-Jun-11
3a	Cable Creek, Site 1	34.210022	-117.377586	26-May-11
3b	Cable Creek, Site 2	34.206285	-117.375034	26-May-11
4a	Warm Creek Channel (Twin Creek), Site 1	34.087174	-117.285647	25-May-11
4b	Warm Creek Channel (Twin Creek), Site 2	34.073027	-117.286234	25-May-11
5a	City Creek, Site 1	34.115694	-117.194667	5-Jan-10
5b	City Creek, Site 2	34.116278	-117.193528	5-Jan-10
6a	Plunge Creek, Site 1	34.108917	-117.150750	6-Jan-10
6b	Plunge Creek, Site 2	34.105972	-117.154250	6-Jan-10
6c	Plunge Creek, Site 3	34.106056	-117.159250	6-Jan-10
7	Mission Creek	34.073371	-117.258684	24-May-11
8a	San Timoteo, Site 1	34.040051	-117.220669	14-Jul-11
8b	San Timoteo, Site 2	34.035782	-117.215123	14-Jul-11

EXPLANATION

- Infiltrometer Test Site
- Existing Spreading Ground or Recharge Basin

NORTH

0 1 2 Miles

10-Jan-12

Prepared by: DB. Map Projection: UTM 1927, Zone 11.

© 2012, GEOSCIENCE Support Services, Inc. All rights reserved.

DRAFT

GEOSCIENCE
GEOSCIENCE Support Services, Inc.
P.O. Box 220, Claremont, CA 91711
Tel: (909) 451-6650 Fax: (909) 451-6638
www.gssiwater.com

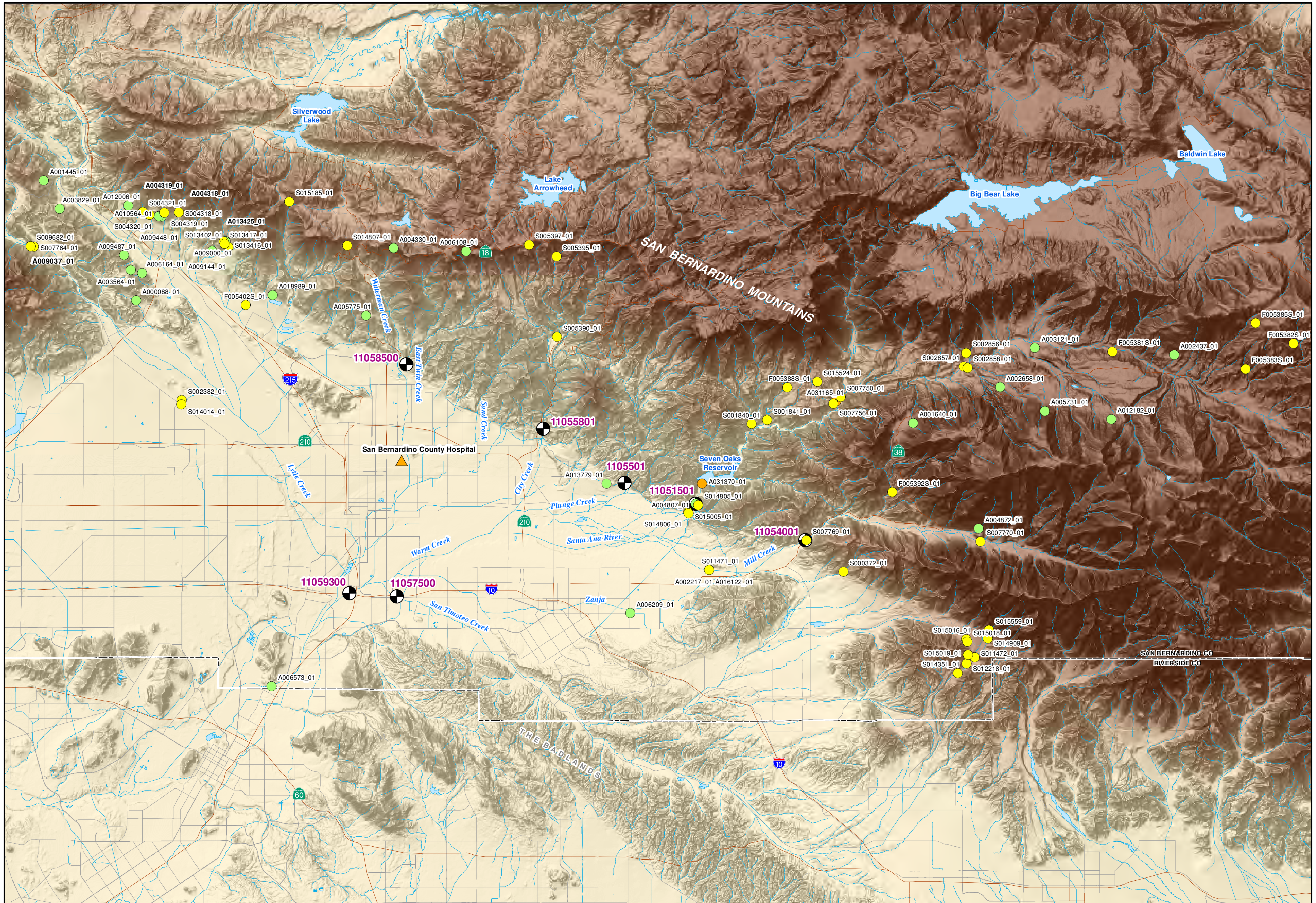
Figure 66

GIS_proj/sbvmwd_stormwater_capture_1-12/0_Fig_66_infiltration_loc_1-12.mxd

SAN BERNARDINO VALLEY
MUNICIPAL WATER DISTRICT

STORMWATER FLOW AND CAPTURE ANALYSIS - ACTIVE RECHARGE PROJECT FOR THE TRIBUTARIES OF THE SANTA ANA RIVER, SAN BERNARDINO VALLEY, CALIFORNIA

WATER RIGHTS POINTS OF DIVERSION - SBBA AND SAN BERNARDINO MOUNTAIN FRONT AREA



EXPLANATION

Water Right Diversion Classifications

- Claimed
- Licensed
- Pending

11055801 Selected USGS Gaging Station (See Appendix E for Station Number Description)

Selected Precipitation Station

County Boundary

NORTH

0 1.75 3.5 Miles

10-Jan-12

Prepared by: DB. Map Projection: UTM 1927, Zone 11.

© 2012, GEOSCIENCE Support Services, Inc. All rights reserved.

DRAFT

GEOSCIENCE
GEOSCIENCE Support Services, Inc.
P.O. Box 220, Claremont, CA 91711
Tel: (909) 451-6650 Fax: (909) 451-6638
www.gssiwater.com

Figure 67

GIS_proj/sbvmwd_stormwater_capture_1-12/0_Fig_67_diversion_pts_1-12.mxd

PLUNGE CREEK RECHARGE BASINS
DESIGN CONCEPT

APN 0290-262-10, 0290-262-11, 0290-271-06, 0290-271-07, 0291-111-09, & 0291-111-10
CITY OF HIGHLAND, COUNTY OF SAN BERNARDINO, CA

CONCEPTUAL DESIGN NOTES:

1.) BASIN RETENTION DEPTHS BASED ON LOWEST AVERAGE INFILTROMETER TEST RESULT OF 6.7 FEET-PER-DAY, WITH A SAFETY FACTOR OF 2, FOR A DESIGN INFILTRATION RATE OF 3.4 FEET-PER-DAY, OR 10.1 FEET RETENTION DEPTH FOR THE MAXIMUM ALLOWABLE DRAWDOWN OF 72 HOURS. INFILTROMETER TESTS PERORMED BY GEOSCIENCE SUPPORT SERVICES, INC.

2.) AN ADDITIONAL 1 FOOT OF FREEBOARD OVER BASIN SPILLWAYS HAS BEEN ADDED FOR A TOTAL DEPTH OF 11.1 FEET FROM FLOOR TO RIM.

3.) BASIN SIDE SLOPES TO BE 3:1 MAX. BERM SLOPES TO BE 2:1 MAX.

4.) BASIN INLET STRUCTURES SHALL INCLUDE DEBRIS/TRASH RACKS TO PREVENT TRASH, DEBRIS, AND SEDIMENT FROM COMPROMISING CALCULATED BASINS INFILTRATION.

5.) 30' SETBACKS HAVE BEEN DESIGNED TO ALLOW FOR ACCESS/MAINTENANCE ROADS AND BERMS.

6.) BASIN SIDE SLOPES AND BERMS TO BE STABILIZED TO PREVENT EROSION.

7.) BASIN INLETS AND OUTLETS/SPILLWAYS FLOW CAPACITY SHALL BE PURSUANT TO HYDROLOGY MODELS PREPARED BY GEOSCIENCE SUPPORT SERVICES, INC.

8.) IT MAY BE NECESSARY TO PREPARE CLOMR/LOMR FOR BASIN CONSTRUCTION THAT ENCROACHES INTO ANY ESTABLISHED FEMA FLOODPLAIN, PURSUANT TO THE DISCRETION OF THE SAN BERNARDINO COUNTY FLOOD CONTROL DISTRICT AND FEMA.

CONSTRUCTION NOTES:

1.) A NOTICE OF INTENT (NOI) AND STORM WATER POLLUTION PREVENTION PLAN (SWPPP) MUST BE APPROVED BY THE CALIFORNIA STATE WATER RESOURCES CONTROL BOARD (CSWRCB) PRIOR TO ANY LAND DISTURBANCE OR CONSTRUCTION ACTIVITIES.

2.) NECESSARY EROSION CONTROL AND SEDIMENT CONTROL BEST MANAGEMENT PRACTICES SHALL BE IMPLEMENTED PURSUANT TO CSWRCB GENERAL CONSTRUCTION PERMIT ORDER NO. 2009-0009-DWQ.

TYPICAL OPERATIONS & MAINTENANCE NOTES:

1.) INSPECT & MAINTAIN BASINS TO ENSURE THAT WATER INFILTRATES INTO THE SUBSURFACE COMPLETELY (WITHIN 72 HOURS MAX.) TO PREVENT THE CREATION OF MOSQUITO AND OTHER VECTOR HABITATS.

2.) OBSERVE DRAIN TIME FOR THE DESIGN STORM AFTER COMPLETION OR MODIFICATION OF BASINS TO CONFIRM THE DESIRED DRAIN TIME HAS BEEN MAINTAINED.

3.) SCHEDULE SEMIANNUAL INSPECTIONS FOR THE BEGINNING AND END OF THE WET SEASON TO IDENTIFY POTENTIAL PROBLEMS SUCH AS EROSION OF BASIN SIDE SLOPES AND INVERT, STANDING WATER, TRASH AND DEBRIS, AND SEDIMENT ACCUMULATION.

4.) REMOVE ACCUMULATED TRASH AND DEBRIS IN THE BASIN AND THE START AND END OF THE WET SEASON.

5.) INSPECT FOR STANDING WATER AT THE END OF THE WET SEASON.

6.) TRIM VEGETATION AT THE BEGINNING AND END OF THE WET SEASON TO PREVENT ESTABLISHMENT OF WOODY VEGETATION AND FOR AESTHETIC AND VECTOR REASONS.

7.) REMOVE ACCUMULATED SEDIMENT AND REGRADE IF/WHEN ACCUMULATED SEDIMENT VOLUME EXCEEDS 10% OF THE BASIN.

8.) IF EROSION OCCURS WITHIN THE BASIN, STABILIZE IMMEDIATELY WITH AN EROSION CONTROL MULCH OR MAT UNTIL PERMANENT STABILIZATION MEASURES CAN BE ESTABLISHED.

9.) TO AVOID REVERSING SOIL DEVELOPMENT, SCARIFICATION OR OTHER DISTURBANCE SHOULD ONLY BE PERFORMED WHEN THERE ARE ACTUAL SIGNS OF CLOGGING, RATHER THAN ON A ROUTINE BASIS. ALWAYS REMOVE DEPOSITED SEDIMENTS BEFORE SCARIFICATION.

MAP LEGEND:

- PROJECT SITE PARCEL BOUNDARIES
- EXISTING PROPERTY LINES AND/OR RIGHT-OF-WAY
- EXISTING STREET CENTERLINES
- EXISTING 5' INDEX CONTOURS (USGS)
- EXISTING 1' INTERVAL CONTOURS (USGS)
- EXISTING FLOWS
- PROPOSED BASIN RIM (FOOTPRINT)
- PROPOSED BASIN FLOOR
- PROPOSED 30' SETBACK

PROPERTY OWNER(S):

SAN BERNARDINO COUNTY FLOOD CONTROL DISTRICT (SBCFCD)

825 EAST THIRD STREET
SAN BERNARDINO, CA 92415

PHONE: (909) 387-7918

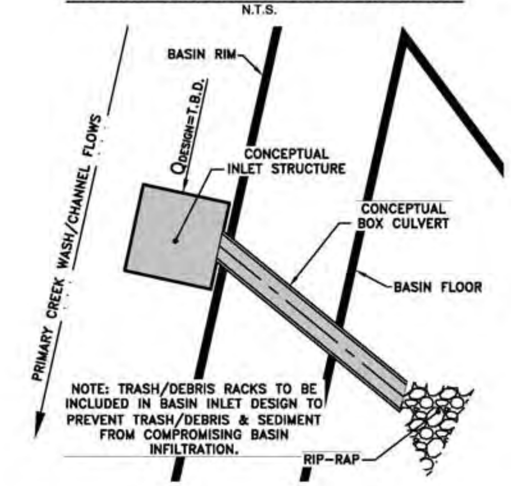
PROJECT LOCATION/ADDRESS:

APN: 0290-262-10, 0290-262-11, 0290-271-06, 0290-271-07, 0291-111-09, & 0291-111-10.

SECTIONS 9 & 10, TOWNSHIP 1 SOUTH, RANGE 3 WEST, S.B.M.

LOCATED IN THE CITY OF HIGHLAND, COUNTY OF SAN BERNARDINO, CA.

TYPICAL BASIN INLET STRUCTURE DETAIL
N.T.S.



VICINITY MAP
N.T.S.

NOTE: BASINS SHOWN ON THIS PLAN ASSUME COMPLETELY LEVEL EXISTING TOPOGRAPHY. ENGINEERED DESIGN WILL ACCOUNT FOR SLOPING TOPOGRAPHY BY USING A SERIES OF STEPPED SUB-BASINS & BERMS WITHIN THE BASIN FOOTPRINTS SHOWN. AS SUCH, THE ESTIMATED RETENTION VOLUMES INDICATED ARE 50% OF THE GEOMETRIC VOLUMES CALCULATED FOR THE BASINS SHOWN.

CONCEPTUAL NOT FOR CONSTRUCTION

The private engineer signing these plans is responsible for assuring the accuracy and acceptability of the design hereon. In the event of discrepancies arising after county approval or during construction, the private engineer shall be responsible for determining an acceptable solution and revising the plans for approval by the county.

DATE	BY	MARK	REVISIONS	APPR.	DATE
	ENGINEER				

DESIGNED BY: J.C.B. DRAWN BY: J.D.N. CHECKED BY: J.C.B.

RECOMMENDED FOR APPROVAL
APPROVAL
CHECKED BY
DATE

SEAL

SEAL: REGISTERED PROFESSIONAL ENGINEER, JOSEPH S.C. BONADIMAN, No. C-30236, Exp. 3-31-12, CIVIL, STATE OF CALIFORNIA

APPROVED BY DATE
R.C.E. NO. EXP. DATE
PREPARED BY DATE
R.C.E. NO. 30238 EXP. DATE 03-31-12

SBVMWD
SAN BERNARDINO VALLEY MUNICIPAL WATER DISTRICT

PLUNGE CREEK RECHARGE BASINS

DESIGN CONCEPT

JOSEPH E. BONADIMAN & ASSOCIATES INC.
consulting engineers land surveyors
588 W. 6th Street, San Bernardino, CA. 92410
Phone:(909)885-3806 - Fax:(909)381-1721

SCALE 1" = 300'
DATE 10-Jan-12

Figure 83

FILE NO.

Annual Percolation at Plunge Creek Spreading Basins from Stormwater Capture - 1934 to 2008

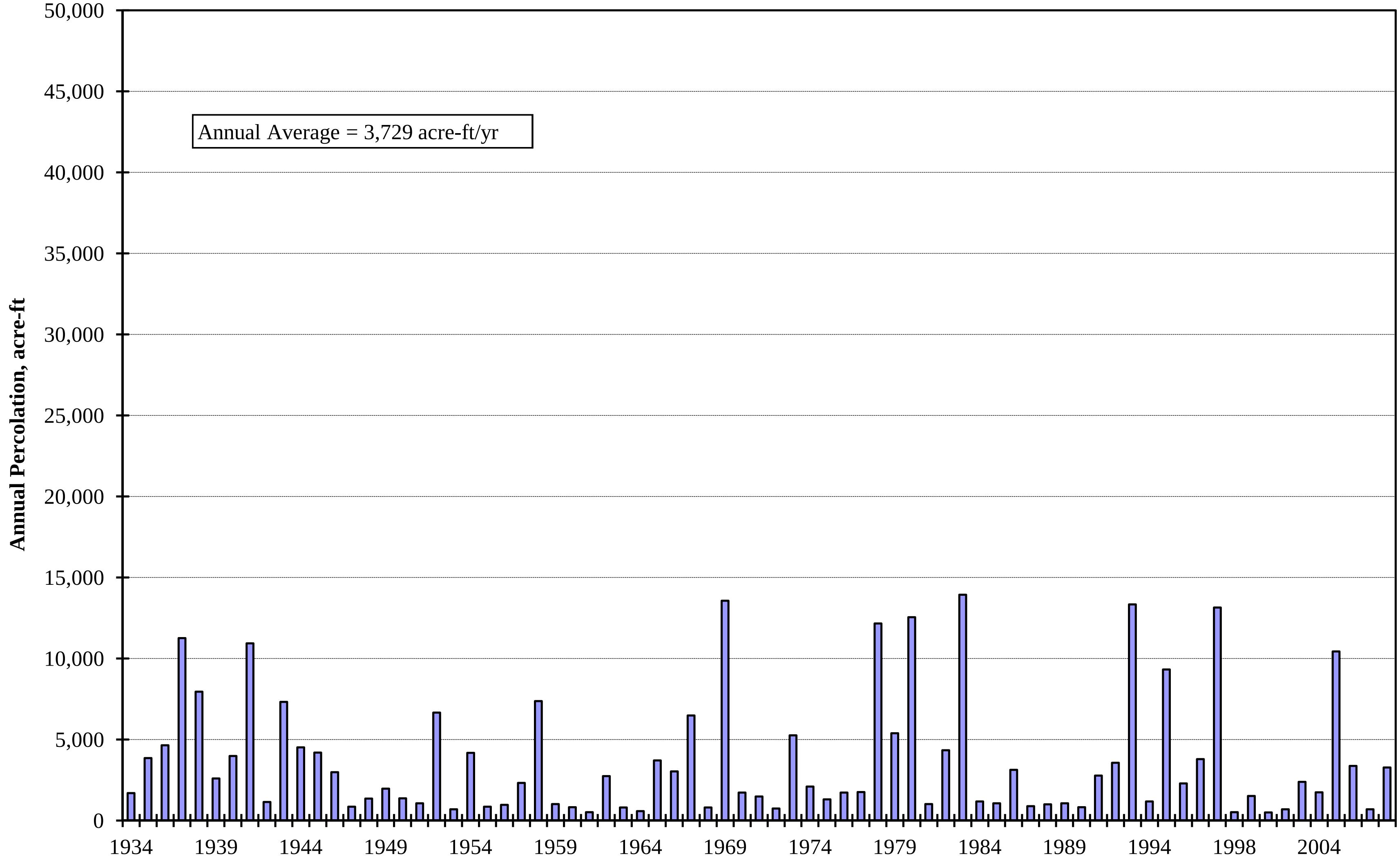
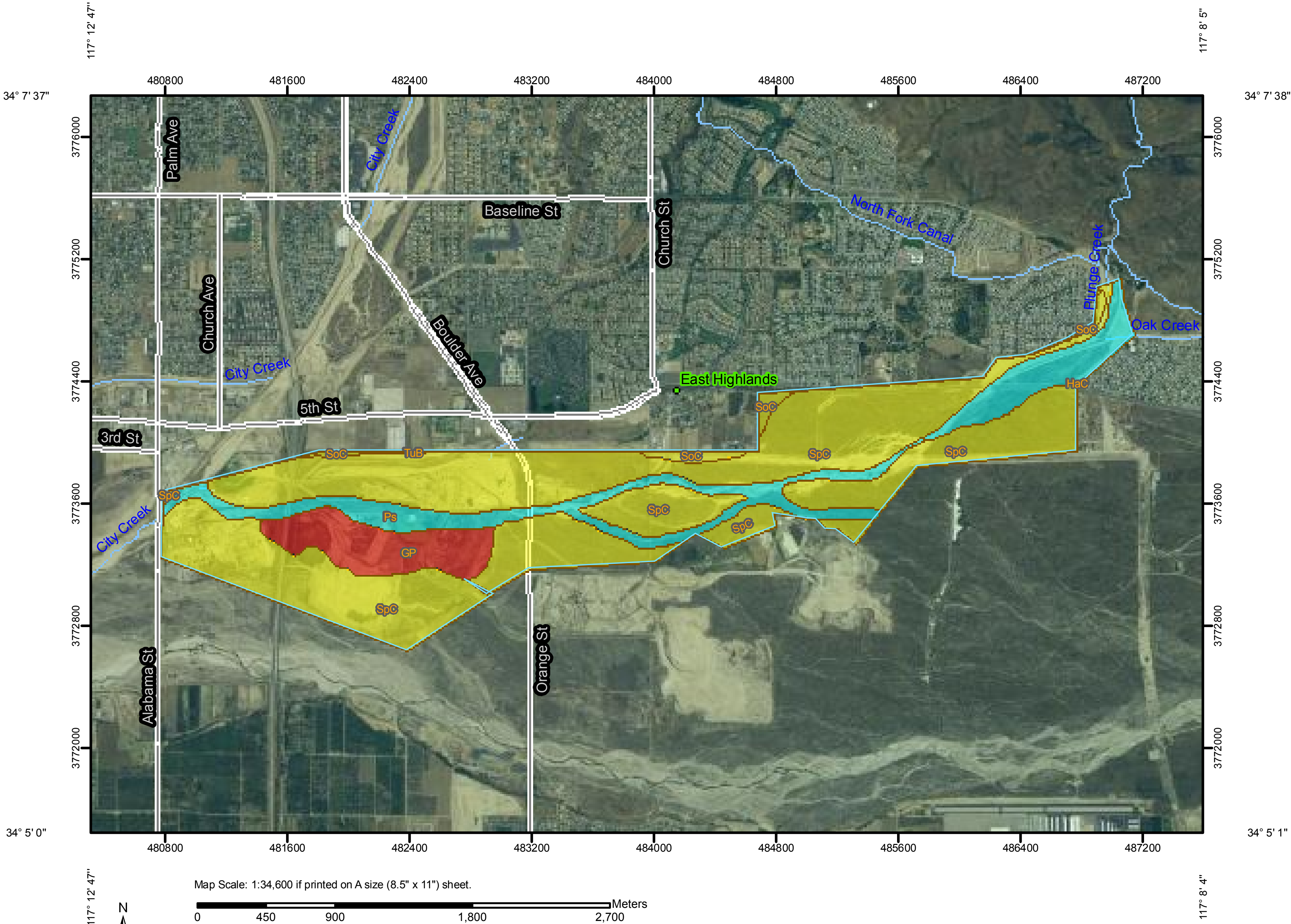


Figure 92

APPENDIX A2

Percent Clay—San Bernardino County Southwestern Part, California
(Plunge)



Map Scale: 1:34,600 if printed on A size (8.5" x 11") sheet.

Meters: 0, 450, 900, 1,800, 2,700

Feet: 0, 1,500, 3,000, 6,000, 9,000

N

MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Soil Ratings

- <= 0.5
- > 0.5 AND <= 2.5
- > 2.5 AND <= 11.3
- > 11.3 AND <= 12.5
- Not rated or not available

Political Features

- Cities

Water Features

- Oceans
- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads

MAP INFORMATION

Map Scale: 1:34,600 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 11N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: San Bernardino County Southwestern Part, California
Survey Area Data: Version 4, Jan 3, 2008

Date(s) aerial images were photographed: 6/18/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Percent Clay

Percent Clay— Summary by Map Unit — San Bernardino County Southwestern Part, California				
Map unit symbol	**Map unit name**	**Rating (percent)**	**Acres in AOI**	**Percent of AOI**
GP	QUARRIES AND PITS	0.5	103.5	8.4%
HaC	HANFORD COARSE SANDY LOAM, 2 TO 9 PERCENT SLOPES	12.5	0.3	0.0%
Ps	PSAMMENTS AND FLUVENTS, FREQUENTLY FLOODED	11.3	215.5	17.4%
SoC	SOBOBA GRAVELLY LOAMY SAND, 0 TO 9 PERCENT SLOPES	2.5	23.6	1.9%
SpC	SOBOBA STONY LOAMY SAND, 2 TO 9 PERCENT SLOPES	2.5	893.3	72.2%
TuB	TUJUNGA LOAMY SAND, 0 TO 5 PERCENT SLOPES	2.5	0.7	0.1%
Totals for Area of Interest			**1,236.9**	**100.0%**

Description

Clay as a soil separate consists of mineral soil particles that are less than 0.002 millimeter in diameter. The estimated clay content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter. The amount and kind of clay affect the fertility and physical condition of the soil and the ability of the soil to adsorb cations and to retain moisture. They influence shrink-swell potential, saturated hydraulic conductivity (Ksat), plasticity, the ease of soil dispersion, and other soil properties. The amount and kind of clay in a soil also affect tillage and earth-moving operations.

Most of the material is in one of three groups of clay minerals or a mixture of these clay minerals. The groups are kaolinite, smectite, and hydrous mica, the best known member of which is illite.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used.

Rating Options

Units of Measure: percent

Aggregation Method: Dominant Component

Component Percent Cutoff: *None Specified*

Tie-break Rule: Higher

Interpret Nulls as Zero: No

Layer Options: All Layers

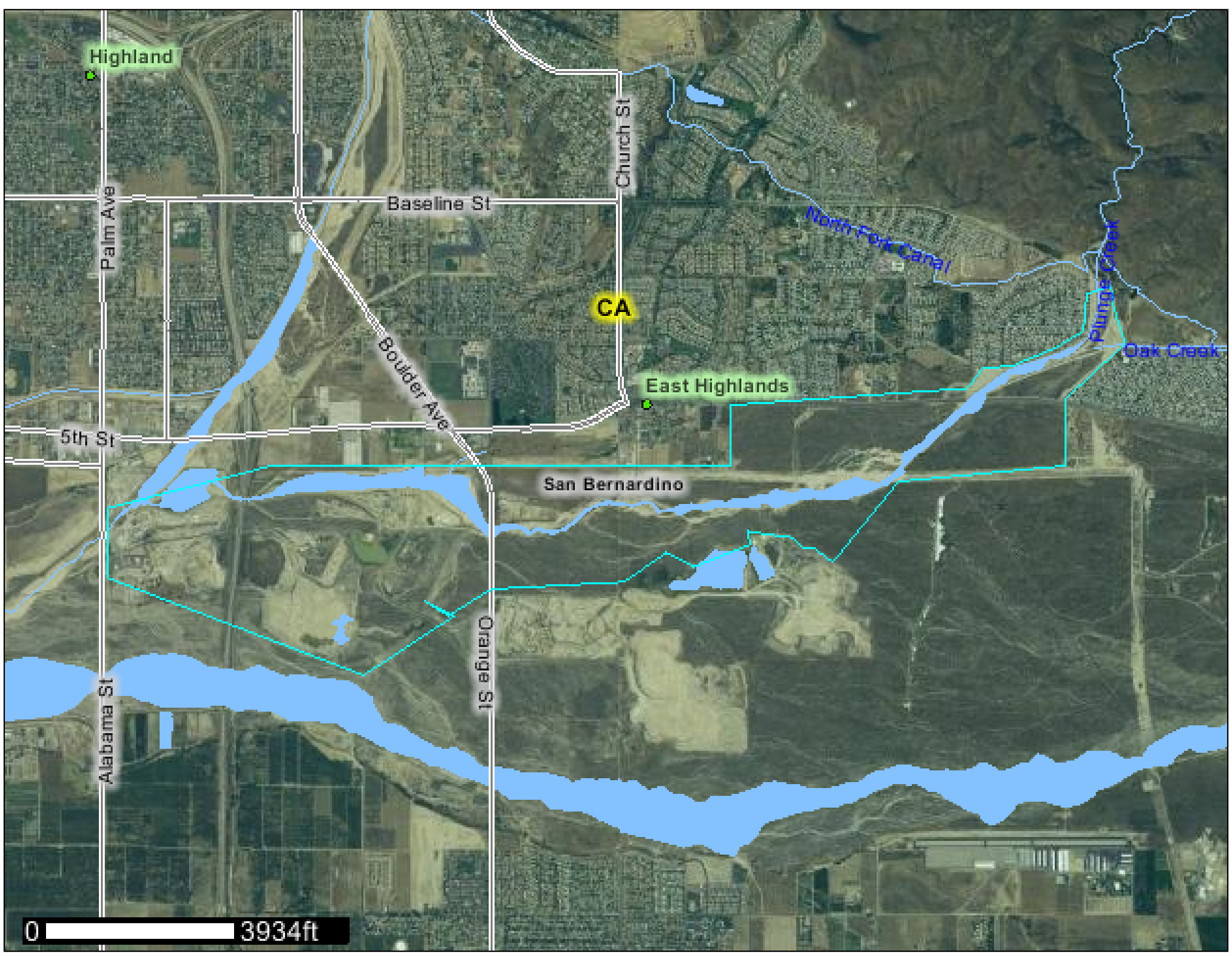
USDA
United States Department of Agriculture

NRCS
Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for San Bernardino County Southwestern Part, California

Plunge Creek



August 13, 2010

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://soils.usda.gov/sqi/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means

for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

Contents

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

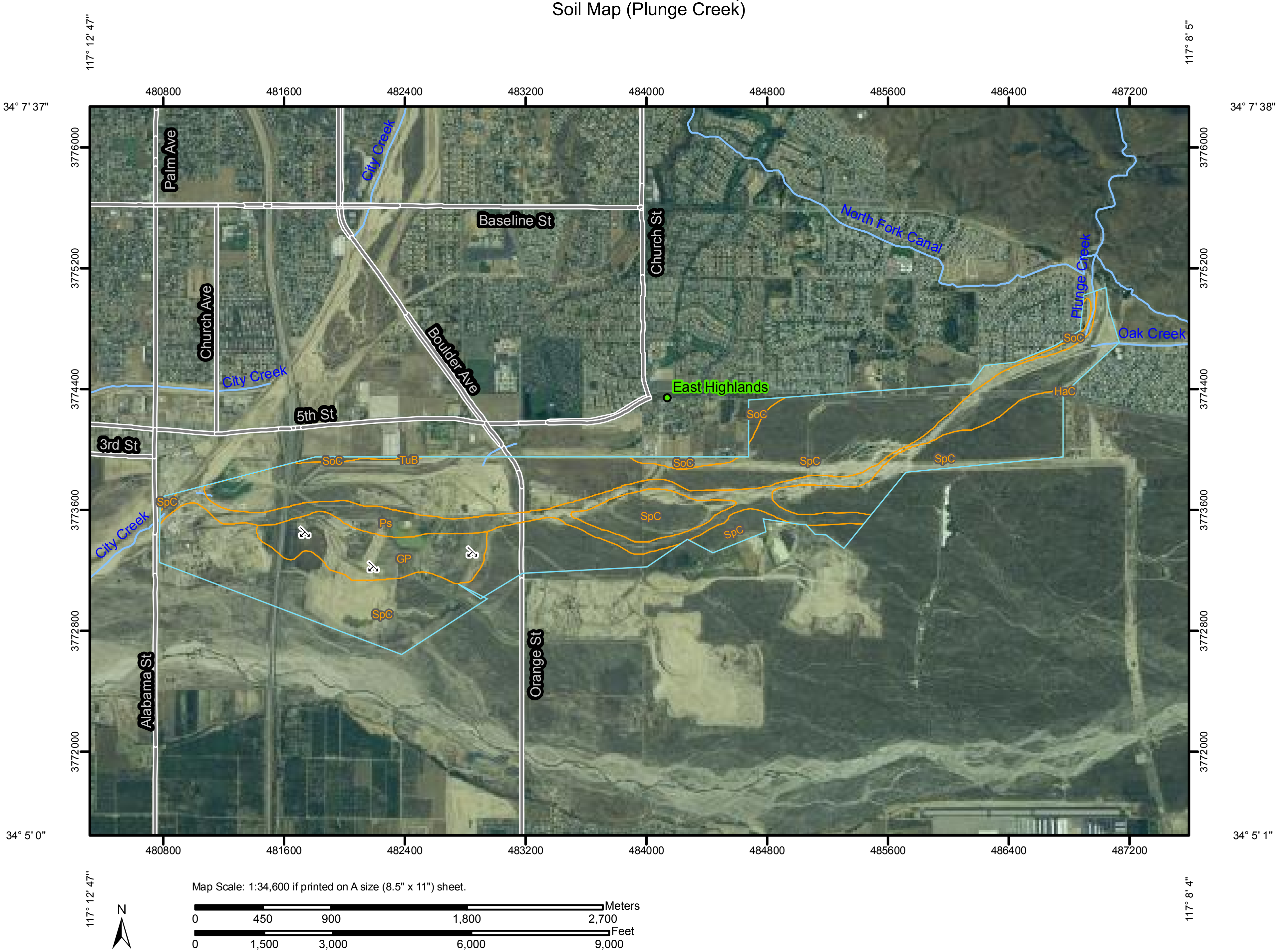
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Soil Map (Plunge Creek)



Map Scale: 1:34,600 if printed on A size (8.5" x 11") sheet.

MAP LEGEND

Area of Interest (AOI)
Area of Interest (AOI)

Soils
Soil Map Units

Special Point Features
Blowout
Borrow Pit
Clay Spot
Closed Depression
Gravel Pit
Gravelly Spot
Landfill
Lava Flow
Marsh or swamp
Mine or Quarry
Miscellaneous Water
Perennial Water
Rock Outcrop
Saline Spot
Sandy Spot
Severely Eroded Spot
Sinkhole
Slide or Slip
Sodic Spot
Spoil Area
Stony Spot
Very Stony Spot
Wet Spot
Other

Special Line Features
Gully
Short Steep Slope
Other

Political Features
Cities

Water Features
Oceans
Streams and Canals

Transportation
Rails
Interstate Highways
US Routes
Major Roads

MAP INFORMATION

Map Scale: 1:34,600 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 11N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: San Bernardino County Southwestern Part, California
Survey Area Data: Version 4, Jan 3, 2008

Date(s) aerial images were photographed: 6/18/2005

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend (Plunge Creek)

San Bernardino County Southwestern Part, California (CA677)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
GP	QUARRIES AND PITS	103.5	8.4%
HaC	HANFORD COARSE SANDY LOAM, 2 TO 9 PERCENT SLOPES	0.3	0.0%
Ps	PSAMMENTS AND FLUVENTS, FREQUENTLY FLOODED	215.5	17.4%
SoC	SOBOBA GRAVELLY LOAMY SAND, 0 TO 9 PERCENT SLOPES	23.6	1.9%
SpC	SOBOBA STONY LOAMY SAND, 2 TO 9 PERCENT SLOPES	893.3	72.2%
TuB	TUJUNGA LOAMY SAND, 0 TO 5 PERCENT SLOPES	0.7	0.1%
Totals for Area of Interest		**1,236.9**	**100.0%**

Map Unit Descriptions (Plunge Creek)

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

San Bernardino County Southwestern Part, California

GP—QUARRIES AND PITS

Map Unit Composition
Pits: 50 percent
Quarries: 50 percent

Description of Quarries

Setting
Parent material: Residuum

Typical profile
0 to 6 inches: Very gravelly coarse sand
6 to 60 inches: Extremely gravelly sand, extremely gravelly coarse sand, very gravelly coarse sand

Description of Pits

Setting
Parent material: Sandy and gravelly alluvium

Typical profile
0 to 6 inches: Very gravelly coarse sand
6 to 60 inches: Extremely gravelly sand, extremely gravelly coarse sand, very gravelly coarse sand

HaC—HANFORD COARSE SANDY LOAM, 2 TO 9 PERCENT SLOPES

Map Unit Setting
Elevation: 150 to 900 feet
Mean annual precipitation: 10 to 20 inches
Mean annual air temperature: 63 degrees F
Frost-free period: 250 to 280 days

Map Unit Composition
Hanford and similar soils: 85 percent
Minor components: 15 percent

Description of Hanford

Setting
Landform: Alluvial fans
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from granite

Properties and qualities
Slope: 2 to 9 percent

Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water capacity: Very high (about 20.3 inches)

Interpretive groups
Land capability classification (irrigated): 2e
Land capability (nonirrigated): 3e

Typical profile
0 to 12 inches: Sandy loam
12 to 60 inches: Fine sandy loam, sandy loam, coarse sandy loam

Minor Components

Greenfield sandy loam
Percent of map unit: 10 percent

Tujunga loamy sand
Percent of map unit: 5 percent

Ps—PSAMMENTS AND FLUVENTS, FREQUENTLY FLOODED

Map Unit Setting
Elevation: 10 to 1,500 feet
Mean annual precipitation: 10 to 25 inches
Mean annual air temperature: 59 to 64 degrees F
Frost-free period: 250 to 350 days

Map Unit Composition
Fluvents and similar soils: 50 percent
Psamments and similar soils: 50 percent

Description of Psamments

Setting
Landform: Drainageways
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Riser
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Sandy alluvium

Properties and qualities
Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained

Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Available water capacity: High (about 9.1 inches)

Interpretive groups
Land capability (nonirrigated): 8w

Typical profile
0 to 12 inches: Sand
12 to 48 inches: Loamy sand, fine sand, sand
48 to 60 inches: Stratified gravelly sand to gravelly loamy sand

Description of Fluvents

Setting
Landform: Drainageways
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Riser
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium

Properties and qualities
Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Capacity of the most limiting layer to transmit water (Ksat): High (1.98 to 5.95 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Frequent
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 2.0 mmhos/cm)
Available water capacity: Moderate (about 6.1 inches)

Interpretive groups
Land capability (nonirrigated): 8w

Typical profile
0 to 10 inches: Gravelly sand
10 to 30 inches: Stratified gravelly sand to gravelly loam
30 to 60 inches: Stratified gravelly sand to gravelly loam

SoC—SOBOBA GRAVELLY LOAMY SAND, 0 TO 9 PERCENT SLOPES

Map Unit Setting
Elevation: 30 to 4,200 feet
Mean annual precipitation: 10 to 20 inches
Mean annual air temperature: 61 to 63 degrees F
Frost-free period: 175 to 250 days

Map Unit Composition

Soboba and similar soils: 85 percent
Minor components: 15 percent

Description of Soboba

Setting

Landform: Alluvial fans
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from granite

Properties and qualities

Slope: 0 to 9 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.0 mmhos/cm)
Available water capacity: Low (about 3.2 inches)

Interpretive groups

Land capability classification (irrigated): 4s
Land capability (nonirrigated): 6s

Typical profile

0 to 12 inches: Gravelly loamy sand
12 to 36 inches: Very gravelly loamy sand
36 to 60 inches: Very stony sand

Minor Components

Delhi fine sand

Percent of map unit: 5 percent

Unnamed

Percent of map unit: 5 percent

Tujunga gravelly loam

Percent of map unit: 3 percent

Unnamed

Percent of map unit: 2 percent
Landform: Drainageways

SpC—SOBOBA STONY LOAMY SAND, 2 TO 9 PERCENT SLOPES

Map Unit Setting

Elevation: 30 to 4,200 feet
Mean annual precipitation: 10 to 20 inches
Mean annual air temperature: 61 degrees F
Frost-free period: 210 to 330 days

Map Unit Composition

Soboba and similar soils: 85 percent
Minor components: 15 percent

Description of Soboba

Setting

Landform: Alluvial fans
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from granite

Properties and qualities

Slope: 2 to 9 percent
Surface area covered with cobbles, stones or boulders: 0.1 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Maximum salinity: Nonsaline (0.0 to 1.0 mmhos/cm)
Available water capacity: Very low (about 2.5 inches)

Interpretive groups

Land capability classification (irrigated): 4s
Land capability (nonirrigated): 6s

Typical profile

0 to 10 inches: Very stony loamy sand
10 to 60 inches: Very stony sand

Minor Components

Ramona

Percent of map unit: 5 percent

Tujunga gravelly loamy coarse sand

Percent of map unit: 5 percent

Hanford

Percent of map unit: 5 percent

TuB—TUJUNGA LOAMY SAND, 0 TO 5 PERCENT SLOPES

Map Unit Setting

Elevation: 10 to 2,500 feet
Mean annual precipitation: 10 to 25 inches
Mean annual air temperature: 59 to 64 degrees F
Frost-free period: 280 to 350 days

Map Unit Composition

Tujunga and similar soils: 85 percent
Minor components: 15 percent

Description of Tujunga

Setting

Landform: Alluvial fans
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Tread
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Alluvium derived from granite

Properties and qualities

Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (5.95 to 19.98 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: Rare
Frequency of ponding: None
Available water capacity: High (about 10.0 inches)

Interpretive groups

Land capability classification (irrigated): 3e
Land capability (nonirrigated): 4e

Typical profile

0 to 18 inches: Gravelly loamy sand
18 to 60 inches: Loamy sand, coarse sand, loamy coarse sand

Minor Components

Unnamed

Percent of map unit: 5 percent
Landform: Drainageways

Tujunga gravelly loamy sand

Percent of map unit: 5 percent

Hanford sandy loam

Percent of map unit: 5 percent

References

American Association of State Highway and Transportation Officials (AASHTO). 2004. Standard specifications for transportation materials and methods of sampling and testing. 24th edition.

American Society for Testing and Materials (ASTM). 2005. Standard classification of soils for engineering purposes. ASTM Standard D2487-00.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service FWS/OBS-79/31.

Federal Register. July 13, 1994. Changes in hydric soils of the United States.

Federal Register. September 18, 2002. Hydric soils of the United States.

Hurt, G.W., and L.M. Vasilas, editors. Version 6.0, 2006. Field indicators of hydric soils in the United States.

National Research Council. 1995. Wetlands: Characteristics and boundaries.

Soil Survey Division Staff. 1993. Soil survey manual. Soil Conservation Service. U.S. Department of Agriculture Handbook 18. http://soils.usda.gov/

Soil Survey Staff. 1999. Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys. 2nd edition. Natural Resources Conservation Service, U.S. Department of Agriculture Handbook 436. http://soils.usda.gov/

Soil Survey Staff. 2006. Keys to soil taxonomy. 10th edition. U.S. Department of Agriculture, Natural Resources Conservation Service. http://soils.usda.gov/

Tiner, R.W., Jr. 1985. Wetlands of Delaware. U.S. Fish and Wildlife Service and Delaware Department of Natural Resources and Environmental Control, Wetlands Section.

United States Army Corps of Engineers, Environmental Laboratory. 1987. Corps of Engineers wetlands delineation manual. Waterways Experiment Station Technical Report Y-87-1.

United States Department of Agriculture, Natural Resources Conservation Service. National forestry manual. http://soils.usda.gov/

United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. http://www.glti.nrcs.usda.gov/

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://soils.usda.gov/

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://soils.usda.gov/

United States Department of Agriculture, Soil Conservation Service. 1961. Land capability classification. U.S. Department of Agriculture Handbook 210.