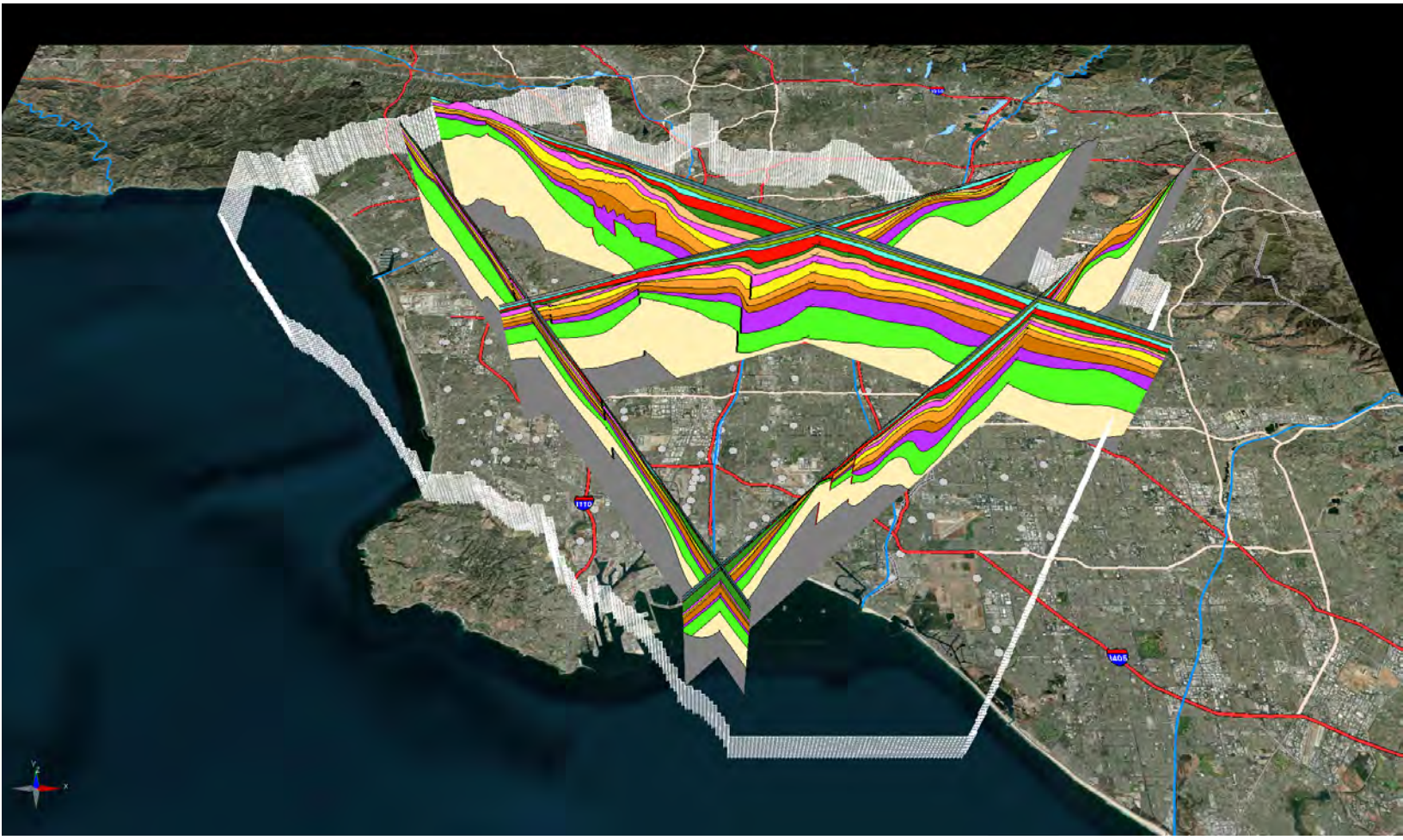
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Development of a Groundwater-Simulation Model in the Los Angeles Coastal Plain, Los Angeles County, California



Scientific Investigations Report 2021–5088
Version 1.1, May 2023

U.S. Department of the Interior
U.S. Geological Survey

Cover: Complex aquifer system simulated in the Los Angeles Coastal Plain, California.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm^3/yr)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32.$$

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

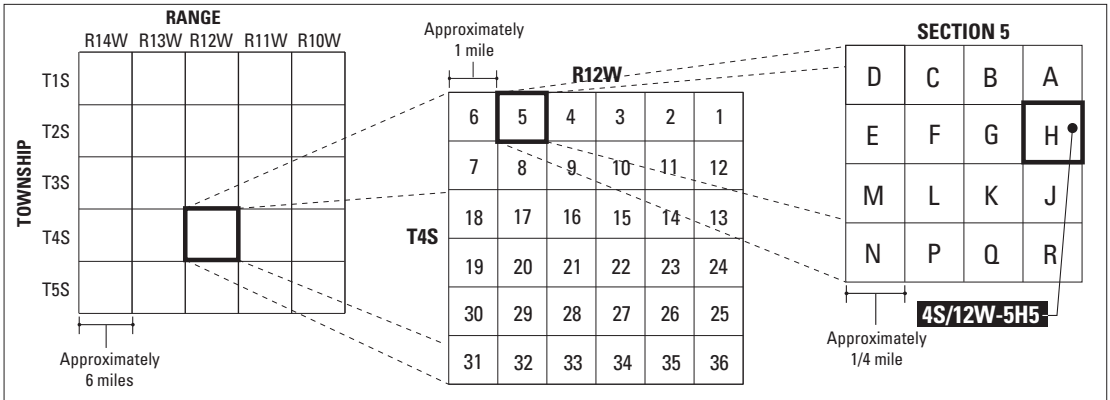
Altitude, as used in this report, refers to distance above the vertical datum.

Supplemental Information

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

Well-Numbering System

Wells are identified and numbered according to their location in the rectangular system for the subdivision of public lands. Identification consists of the township number, north or south; the range number, east or west; and the section number. Each section is divided into sixteen 40-acre tracts lettered consecutively (except I and O), beginning with "A" in the northeast corner of the section and progressing in a sinusoidal manner to "R" in the southeast corner. Within the 40-acre tract, wells are sequentially numbered in the order they are inventoried. The final letter refers to the base line and meridian. In California, there are three base lines and meridians; Humboldt (H), Mount Diablo (M), and San Bernardino (S). All wells in the study area are referenced to the San Bernardino base line and meridian (S). Well numbers consist of 15 characters and follow the format 004S012W05H005S. In this report, well numbers are abbreviated and written 4S/12W-5H5. Wells in the same township and range are referred to only by their section designation, 5H5. The following diagram shows how the number for well 4S/12W-5H5 is derived.



Well-numbering diagram (Note: maps in this report use abbreviated well numbers such as **"5H5"**)

Abbreviations

ABP	Alamitos Barrier Project
AIT	array induction 2-foot resistivity
bls	below land surface
CalGEM	California Geologic Energy Management Division
CDWR	California Department of Water Resources
CHD	time-variant specified head
CLN	connected linear network
CSS	composite scale sensitivity
DGBP	Dominguez Gap Barrier Project
DRN	drain package
EMF	East Montebello fault
GAMA	Groundwater Ambient Monitoring and Assessment
GHB	general-head boundary
GIS	geographic information system
GRIP	Groundwater Reliability Improvement Project
HFB	horizontal-flow barrier
HK	horizontal hydraulic conductivity
ka	thousand years
LA	Los Angeles
LACDPW	Los Angeles County Department of Public Works
LACFCD	Los Angeles County Flood Control District
LACP	Los Angeles Coastal Plain
LACPGM	Los Angeles Coastal Plain groundwater model
LADWP	Los Angeles Department of Water and Power
Ma	million years
NMR	nuclear magnetic resonance
NWIS	USGS National Water Information System
OCWD	Orange County Water District
OSL	optically stimulated luminescence
PCH	Pacific Coast Highway
PEST	parameter-estimation software
RCH	recharge package
RHSG	Rio Hondo spreading grounds
SCEC	Southern California Earthquake Center

SGRSG	San Gabriel River spreading grounds
SGRWM	San Gabriel River Water Master
SS	specific storage
SY	specific yield
TDS	total dissolved solids
TL	thermoluminescence
TU	tritium unit
USC	University of Southern California
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
VK	vertical hydraulic conductivity
WCBBP	West Coast Basin Barrier Project
WEL	well package
WND	Whittier Narrows Dam
WRD	Water Replenishment District of Southern California

Development of a Groundwater-Simulation Model in the Los Angeles Coastal Plain, Los Angeles County, California

Edited by Scott Paulinski

Executive Summary

The Los Angeles Coastal Plain (LACP) covers about 580 square miles and is the largest coastal plain of semiarid southern California. The LACP is heavily developed with mostly residential, commercial, and industrial land uses that rely heavily on groundwater for water supply. In 2010, the LACP was home to about 14 percent of California's population, or about 5.4 million residents. The LACP is also a major commercial and industrial hub with industries including manufacturing, aerospace, entertainment, and tourism.

There has been a heavy reliance on groundwater from the LACP for many years. An average of 305,000 acre-feet per year (acre-ft/yr) of groundwater was used annually from the LACP from 1971 to 2015. The need to replenish the groundwater basins within the LACP was recognized as far back as the 1930s, when spreading grounds were first used to replenish groundwater basins and store water underground during times of water surplus to meet demands in times of shortage. Seawater intrusion resulting from freshwater pumping was first observed in the 1940s. As a result, injection of imported water through wells at what is now the West Coast Basin Barrier Project began on an experimental basis in 1951. Managed aquifer recharge from the spreading grounds and barrier wells is now a substantial component of the LACP's groundwater supply. The average annual recharge from water spreading from 1971 to 2015 was about 120,000 acre-ft/yr, and the average annual injection into the barrier wells was about 33,000 acre-ft/yr. Other inflows include areal recharge, underflow from San Gabriel and San Fernando Valleys, and onshore flow from the ocean. The average annual recharge from these sources was 100,000 acre-feet (acre-ft) from 1971 to 2015. Additionally, cross-boundary flow from Orange County into the western Orange County subareas of the LACP was simulated as 48,000 acre-ft from 1971 to 2015.

This study, conducted in cooperation with the Water Replenishment District of Southern California (WRD), involved an assessment of the historical and present status of groundwater resources in the LACP and the development of tools to better understand the groundwater system. These efforts were built upon results from previous studies and incorporate new information and developments in modeling capabilities to provide a more detailed analysis of the aquifer systems.

This study includes a comprehensive compilation of geologic and hydrologic data (Chapter A), development of a chronostratigraphic model that provides a detailed description of the LACP aquifer systems (Chapter B), characterization of the groundwater hydrology of the LACP, including a down-hole analysis of grain size using lithologic and geophysical logs (Chapter C), and development and application of the Los Angeles Coastal Plain Groundwater-flow Model (LACPGM) to simulate past groundwater conditions, estimate groundwater-budget components and flow paths, and approximate future groundwater conditions under different scenarios (Chapter D).

Data Compilation

A geographic information system (GIS) was used to store, analyze, and visualize model input and output data. Data were compiled from multiple sources for the construction of the chronostratigraphic and groundwater-flow models including: (1) water levels in wells; (2) well-construction information; (3) volumes of pumping, injection, and water spreading; (4) information on areal recharge (Chapter C), water-chemistry data (appendix 1), geophysical logs (appendix 2), seismic cross sections (Chapter B), and data related to land subsidence. Various inputs to the LACPGM, including chronostratigraphic layer boundaries, fault locations, hydraulic heads, hydraulic properties, and water-budget calculations, were also incorporated into the GIS.

Chronostratigraphic Hydrogeologic-Framework Model

The stratigraphy and structure of the LACP was reevaluated for this study utilizing the concepts of sequence stratigraphy to develop a chronostratigraphic (time-based) hydrogeologic-framework model for the water-bearing sediments of the LACP. Sequence stratigraphy subdivides and links sedimentary deposits into unconformity-bound chronostratigraphic units (sequences) that represent cycles of deposition that are controlled by variations in base level (elevations relative to the North American Vertical Datum of 1988 [NAVD 88]), sediment supply, and accommodation space. Sequence-bounding unconformities separate sediments that are deposited within discrete time intervals. Within each sequence, the depositional processes result in layers of heterogeneous sediments. In general, the sediments are anisotropic, with the horizontal hydraulic conductivity of the sediments being greater than the vertical hydraulic conductivity. Because of the anisotropy in the layered sediments, groundwater preferentially flows within the sequence, limiting flow to overlying or underlying sequences. However, flow between sequences may not be as limited if vertical hydraulic gradients are high, or where coarse-grained deposits are juxtaposed across a sequence boundary or laterally because of incision, onlap, or faulting.

The chronostratigraphic hydrogeologic framework model developed for this study extended a study completed by Ponti and others (2007) in the Long Beach area to the entire LACP through compilation and analysis of 193 detailed geologic and geophysical logs, including logs from 57 WRD and U.S. Geological Survey (USGS) multiple-well monitoring sites, 183 seismic-reflection profiles, and surficial geology. The resulting chronostratigraphic-hydrogeologic framework model consists of 15 units, 13 of which compose the groundwater basin. The 13 chronostratigraphic units identified in the groundwater basin range in age from late Pliocene through Holocene (approximately 3 million years ago [Ma] to present). Chronostratigraphic unit boundaries were refined using water-level and water-quality data (appendix 1).

The chronostratigraphic units identified in this study often do not correlate with aquifers defined in previous investigations that used lithostratigraphic techniques to subdivide the sedimentary deposits based on their physical properties. The lithostratigraphically defined formations and aquifers contain sediments that were deposited at considerably different times from the basin margin to the basin center. This variability in deposition implies that many of the aquifers defined lithostratigraphically are composed of multiple depositional units and likely are not areally connected. For example, the lithostratigraphically defined older aquifers generally are associated with older chronostratigraphic units along the eastern and western margins of the Central Basin, whereas they are associated with younger chronostratigraphic units in the middle of the Central Basin. Seismic reflection data compiled and interpreted for this study demonstrated that the lower (older) chronostratigraphic units dip more deeply into the Central Basin than the lithostratigraphically defined aquifers and become much thicker toward the center of the basin. The improved understanding of the hydrodeological framework of the LACP was used to more accurately simulate groundwater flow in the LACP (Chapter D).

Basin Groundwater Hydrology

The LACP receives natural recharge primarily from the downward percolation of precipitation, underflow, and mountain-front recharge. Percolation of precipitation occurs where land uses and land-surface characteristics are conducive to infiltration. Underflow into the LACP occurs from the San Fernando Valley through the Los Angeles Narrows into the northwestern Central Basin, and from the San Gabriel Valley through the Whittier Narrows into the northern Central Basin. Mountain-front recharge occurs primarily along the base of mountains and hills bordering the north, northeast, and southwest boundaries of the LACP. The San Gabriel River, Rio Hondo, and Los Angeles River drain the San Gabriel and San Fernando Valleys and enter the LACP through the Whittier and Los Angeles Narrows. Under pre-development conditions, infiltration from streamflow was the main source of groundwater recharge to the LACP; however, these rivers have been channelized and lined in the LACP, limiting their contribution to recharge.

As the LACP became more urbanized and populous, the anthropogenic influences on the groundwater system greatly increased. Groundwater pumping increased from the early 1900s until the early 1960s, resulting in large water-level declines throughout most of the LACP. More than 100 ft of water-level decline were measured in parts of the Central Basin, and water levels declined more than 60 ft below NAVD 88 in parts of the West Coast and Santa Monica Basins. By the mid-1960s, the Central and West Coast Basins were adjudicated to address long-term issues associated with sustainability of the groundwater supply, including overdraft and seawater intrusion.

The complex chronographic stratigraphy, grain-size distribution, and geologic structure affects vertical and horizontal groundwater flow rates through the LACP. Sediment grain size varies in the LACP from coarse gravels to fine clays. The distribution of various sediments penetrated by numerous boreholes associated with multiple-well monitoring sites was determined based on an analysis of downhole geophysical logs and lithologic samples collected during the installation of these sites (appendix 2). These results, along with other data, were used to help estimate the hydraulic properties of each chronostratigraphic unit geographically throughout the study area.

An annual average of 305,000 acre-ft/yr of groundwater was pumped from the LACP from 1971 to 2015, with much of the pumping occurring in the Central and West Coast Basins (appendix 4). From 1971 to 2015, spreading grounds in northern Central Basin south of Whittier Narrows recharged about 123,000 acre-ft/yr and injection wells at the seawater barriers recharged about 33,000 acre-ft/yr to coastal areas of the West Coast and Central Basins.

Water levels measured from 1970 to 2015 varied by chronostratigraphic layer and location within the LACP. Long-term data from long-screened wells, paired with more recent data from multiple-well monitoring sites, were interpolated to approximate the spatial distribution of water levels in the LACP.

Hydrologic Modeling

The LACPGM represents a major update of a previous groundwater-flow model developed by Reichard and others (2003), incorporating new data, analyses, and modeling tools (Chapter D and appendix 3, 4). The LACPGM uses the USGS model code MODFLOW-USG, which enables the use of an unstructured finite-difference grid; this grid for the LACPGM contains nodes one-eighth mile (mi; 660 ft) in length and width. The LACPGM incorporates 12 layers for the 13 chronostratigraphic units, with the two bottom units modeled as a single layer. MODFLOW-USG was selected for its ability to effectively represent the discontinuous and faulted chronostratigraphic layers using an unstructured grid. The LACPGM simulates groundwater flow in the LACP using quarterly stress periods from 1971 to 2015.

The LACPGM incorporates no-flow, time-variant specified-head and general-head boundary conditions. A specified-head boundary simulates underflow from the San Fernando Valley through the Los Angeles Narrows using the constant head (CHD) package. General-head (GHD) boundaries in the GHD package simulate underflow from the San Gabriel Valley through the Whittier Narrows, flow between the eastern edge of the model and Orange County, underflow from the Palos Verdes Hills into the southwestern model area, and flow between the western and southern model area and the Santa Monica and San Pedro Bays. No-flow boundaries were simulated along the remaining edges of the model. The LACPGM simulates faults and folds believed to restrict groundwater flow as horizontal-flow barriers (HFB package). Pumping and injection were simulated using the connected linear network (CLN) package and the well (WEL) package. Spreading grounds were simulated using the well package, and areal recharge was simulated using the recharge (RCH) package.

The LACPGM was calibrated using PEST (parameter-estimation) software. Horizontal and vertical hydraulic conductivity, specific storage, and specific yield were parameterized using zones defined for each model layer. Areal recharge was parameterized using zones. General-head boundaries and horizontal-flow barriers were segmented; the conductance of each segment was parameterized. The LACPGM was calibrated to 27,860 water-level measurements from 464 wells and to yearly underflow estimates through Whittier Narrows.

The LACPGM simulation results included groundwater-flow direction and amount throughout the LACP (Chapter D and appendix 4). Groundwater in the LACP generally flowed from the northern regions of the model, including the Santa Monica and Hollywood Basins, the northern Los Angeles and Montebello Forebays, and the Whittier area toward the central and southern parts of the model (including the southern Los Angeles Forebay, the Central Basin Pressure Area, West Coast Basin, and parts of Orange County). The model simulated lateral flows between subareas, vertical flows between model layers, and underflow from adjacent groundwater basins.

The LACPGM was used to simulate water levels under future water-management scenarios, base case wet and dry scenarios, increased pumpage wet and dry scenarios, and optimized replenishment wet and dry scenarios. Scenarios included projected future pumping rates and estimated the increases in water spreading and injection that would be needed to maintain water levels. Scenarios also simulated expected future pumping rates and estimated needed increases in water spreading and injection in order to maintain water levels. Results of these scenarios showed that adding water at spreading grounds and seawater barrier injection wells reduced drawdowns in some areas but had limited effects on water levels in some wells in the eastern and northeastern Central Basin and the eastern West Coast Basin, leading to large drawdowns in these areas. The large drawdowns generally occurred in the lower aquifer systems in the West Coast Basin and in the upper and lower aquifer systems in the Central Basin, with more drawdown in the lower aquifer systems.

Chapter A. Introduction and Data Compilation

By Scott Paulinski, Claudia Faunt, Michael Land, Tracy Nishikawa, and Peter Martin

Introduction

The study area, referred to as the Los Angeles Coastal Plain (LACP) in this report, includes most of the Coastal Plain of Los Angeles County, which subdivided the LACP into four groundwater basins: Central, West Coast, Hollywood, and Santa Monica Basins (fig. A1; California Department of Water Resources, 1961). The LACP, the largest coastal plain of semiarid southern California, historically has relied on local groundwater supplies for a substantial portion of its water supply (fig. A1). In 2010 there were approximately 5.4 million residents, or about 14 percent of California's population, living in the LACP (U.S. Census Bureau, 2010). Groundwater development over the first half of the 20th century caused large groundwater declines throughout the LACP and subsequent seawater intrusion along the coastline. In the early 1950s, water-supply wells along the coast began to be abandoned because of seawater intrusion (Nishikawa and others, 2009). In 1959, the Water Replenishment District of Southern California (WRD) was formed for the purpose of protecting the groundwater resources of the Central and West Coast Basins (fig. A1). The WRD has supplemented natural recharge to the groundwater basins through the spreading of imported and recycled waters at spreading grounds and at seawater barrier injection wells along the coastline. In 2016–17, groundwater met over 40 percent (Water Replenishment District of Southern California, 2018) of the water demand for approximately 4 million people living in the Central and West Coast Basins.

To further enable the effective management of the groundwater resources of the LACP, the U.S. Geological Survey (USGS) and WRD have worked cooperatively to better understand the complex hydrogeology of the Central and West Coast Basins and to develop numerical models to help evaluate the relative effectiveness of different management alternatives. Since the early 1990s, the USGS has worked with the WRD and other agencies to develop a better understanding of the geology, hydrogeology, and geochemistry of the area. Although numerous studies have been completed on specific groundwater issues in the Central and West Coast Basins, there had been no regional studies using sequence stratigraphy to develop a better understanding of the hydrogeology of the groundwater basins. The sequence stratigraphy approach (time-based or chronostratigraphy) is a useful alternative to the lithostratigraphic approach utilized by previous investigations because the sequence stratigraphic approach can produce a more realistic representation of geologic structure, the distribution of lithologic facies, and aquifer architecture. This more realistic representation improves our understanding of and ability to predict the lateral distribution of coarse-grained aquifers and their fine-grained confining aquitards. Chronostratigraphic layering can better model anisotropic groundwater flow in areas with folding since the chronostratigraphic layering can better reflect the direction of anisotropy within that fold.

Purpose and Scope

The primary purpose of this report is to provide increased scientific understanding of the hydrogeologic system of the Los Angeles Coastal Plain that can be utilized to improve groundwater management. To achieve this objective, this report utilizes results of the study and the extensive literature on the Los Angeles Coastal Plain. The main tasks of the study involved (1) compiling hydrogeologic data to help characterize and conceptualize the hydrogeologic system, (2) developing a hydrogeologic-framework model using a sequence-stratigraphy approach, (3) developing a rainfall-runoff-infiltration model for the estimation of recharge in response to precipitation and irrigation, (4) developing a conceptual model and water budget, and (5) developing a regional three-dimensional groundwater-flow model to characterize the groundwater system and evaluate groundwater-management issues in the LACP. This study was completed by the USGS in cooperation with WRD.

The rainfall-runoff-infiltration model developed for this study (Task 3) was previously described in Hevesi and Johnson (2016). The remaining tasks are described in detail in four chapters of this report: Chapter A contains the introduction and a section on data compilation, Chapter B presents an overview of the geologic framework, Chapter C describes the groundwater hydrology of the study area and presents a conceptual model of the hydrologic cycle and a groundwater budget, and Chapter D describes the groundwater-flow model and simulations of future water-management scenarios.

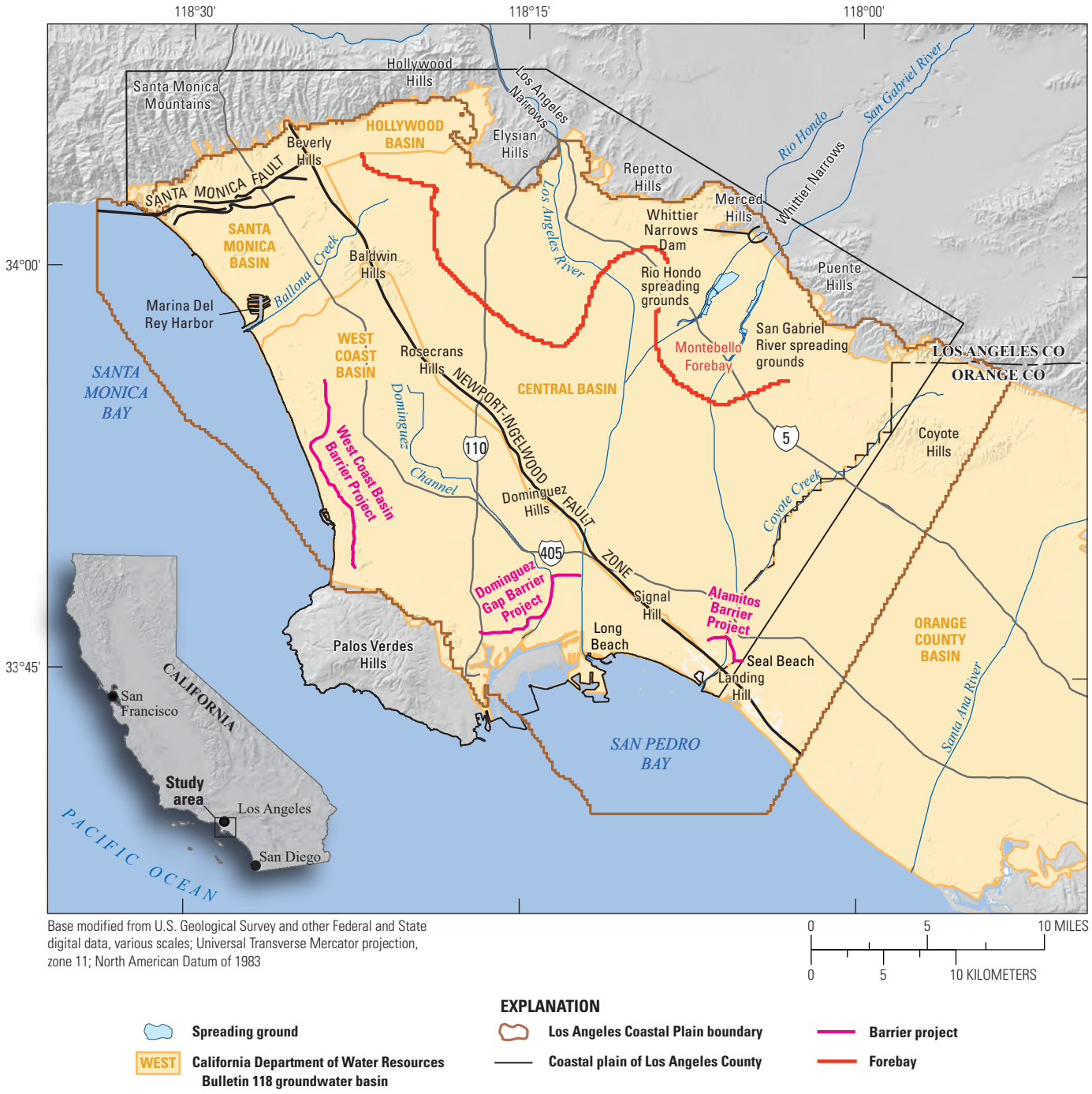


Figure A1. Groundwater basins in the Los Angeles Coastal Plain including the Central, West Coast, Hollywood, and Santa Monica Basins and part of Orange County Basin, Los Angeles and Orange Counties, California.

This report contains five appendixes, which contain additional supporting information including water-quality data, a grain-size analysis, and an explanation of a rainfall-recharge analysis. Appendix 1 provides background information for water-quality data used in the construction of a chronostratigraphic model (Chapter B) and in the construction and calibration of a groundwater flow model (Chapter D). Appendix 2 presents a grain-size analysis of geophysical logs from WRD/USGS multiple-well monitoring sites. This grain-size analysis was used as a guide when initially defining and calibrating the groundwater-flow model's hydraulic properties (Chapter D). Appendix 3 contains supporting figures and tables that describe how the groundwater flow model was set up (Chapter D). Appendix 4 contains detailed results of the groundwater flow model (Chapter D) including hydrographs, calibrated values, and water budgets. Appendix 5 contains a rainfall-recharge analysis, which can be used to approximate areal recharge for the groundwater flow model (Chapter D) based on rainfall data. The rainfall-recharge analysis is intended to be used in future updates to the groundwater flow model.

Description of Study Area

The study area, referred to in this report as the LACP (fig. A1), encompasses the coastal parts of the Los Angeles metropolitan area and parts of Orange County. It is bounded by the Santa Monica Mountains and Hollywood Hills to the north; the Elysian, Repetto, Merced, and Puente Hills to the northeast; and the Palos Verdes Hills to the west and southwest. The mountains and hills to the north, as well as the Palos Verdes Hills to the southwest are believed to act as flow barriers as layers fold steeply upward. The LACP covers about 580 square miles (mi^2), and extends up to 5 miles (mi) into the Santa Monica Bay to the west and the San Pedro Bay to the south, and approximately 5 mi into Orange County to the east (fig. A1) to better simulate flow to and from the Pacific Ocean and Orange County, respectively. The California Department of Water Resources (1961) subdivided the LACP into four groundwater basins: Central, West Coast, Hollywood, and Santa Monica Basins (fig. A1). The Central Basin is separated from the West Coast and Santa Monica Basins by the Newport-Inglewood fault zone (fig. A1). The Hollywood Basin is separated from the Central Basin by the Santa Monica fault (fig. A1) and from the Santa Monica Basin by the Newport-Inglewood fault zone. The West Coast and Santa Monica Basins are separated by the Baldwin Hills and an uplift to the south of Baldwin Hills. Land-surface elevation ranges from approximately 800 feet (ft) in the surrounding hills to sea level at the coast. Several low hills lie within the study area, including the Coyote Hills near the Orange County boundary and the Baldwin Hills, Rosecrans Hills, Dominguez Hills, Signal Hill, and Landing Hill which lie between the Central and West Coast Basins (fig. A1).

The LACP is heavily developed with mostly residential, commercial, and industrial land uses (fig. A2). Residential and commercial land use is scattered throughout the study area. Industrial land use is concentrated southeast of the city of Los Angeles and in and around the cities of Commerce, Norwalk, Carson, Wilmington, and Torrance (fig. A2). The land use and landscape have changed with development of the LACP leading to less open space over time.

Six river systems drain the study area: the Los Angeles and San Gabriel Rivers, Rio Hondo, the Dominguez Channel, and the Ballona and Coyote Creeks (fig. A1). The Los Angeles River flows from Simi Hills (not shown), Santa Monica and Santa Susana Mountains (not shown) south through the Los Angeles Narrows into the study area, where it flows south into the San Pedro Bay near Long Beach. The San Gabriel River and Rio Hondo flow from the San Gabriel Mountains (not shown) south and enter the study area at the Whittier Narrows. The Rio Hondo flows from Whitter Narrows southwest to its confluence with the Los Angeles River, while the San Gabriel River flows south from Whittier Narrows to the San Pedro Bay near Seal Beach. Ballona Creek drains the Santa Monica and Hollywood Basins in the northern part of the study area to the Santa Monica Bay. The Dominguez Channel is a small, local stream which drains most of the West Coast Basin to the San Pedro Bay. Coyote Creek, which drains the northeastern part of the study area, flows south from the Coyote Hills to its confluence with the San Gabriel River. Many of the rivers in the study area have been channelized and concrete-lined to reduce flood and erosion risk.

The study area is characterized by a Mediterranean climate with warm summers, cool winters, and marked precipitation seasonality. Most rain falls from late autumn to early spring; and almost no precipitation falls during the summer. The average annual precipitation on the coastal plain is about 15 inches (in.). Precipitation is highest in the surrounding hills and highlands and decreases progressively toward the ocean. Long-term average annual precipitation ranges from 18 in. in the foothills of the Santa Monica Mountains to 11 in. near the coast at the southern corner of the study area (Hevesi and Johnson, 2016). Potential evapotranspiration in the area exceeds precipitation on an annual basis (Hevesi and Johnson, 2016).

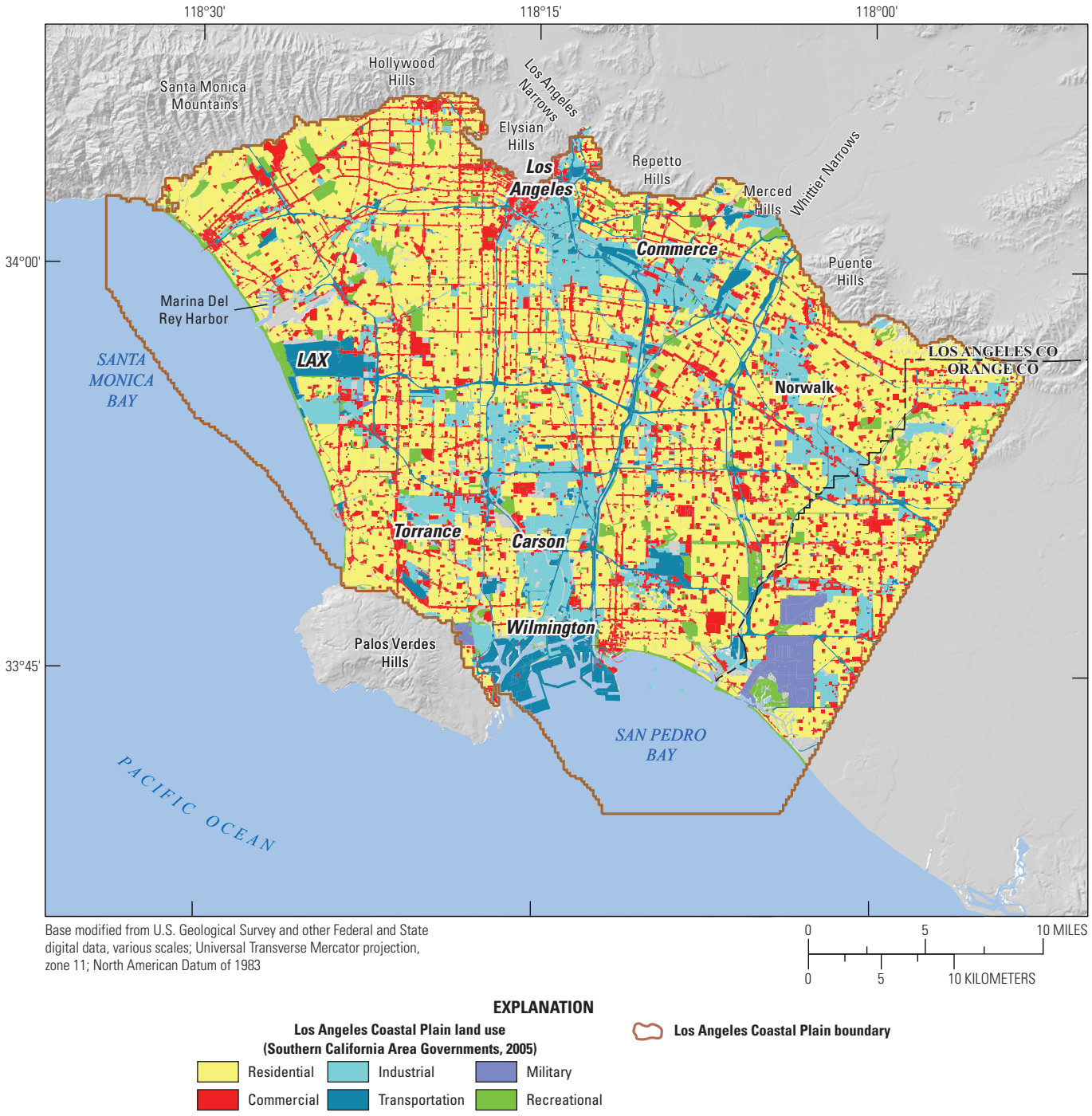


Figure A2. Land use in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California.

Previous Investigations

Over the last century, a substantial number of studies have been completed describing the geology, hydrology, and water chemistry of the LACP, including regional-scale, comprehensive studies as well as local studies of focused interests. Comprehensive regional-scale studies (Mendenhall, 1905a, 1905b, 1905c; Poland and Piper, 1956; Poland and others, 1959; California Department of Water Resources, 1961, 1962, 1966; Reichard and others, 2003) formed the foundation of the hydrogeological framework of the LACP and provided a regional context for local-scale groundwater studies. Mendenhall (1905a, 1905b, 1905c) provided the first regional assessment of groundwater conditions in the area. A detailed description of the geology, hydrogeology, and geochemistry was later provided by Piper and Garrett (1953), Poland and Piper (1956), and Poland and others (1959). The California Department of Water Resources (1961, 1962, 1966) built on these previous studies and further analyzed the regional hydrogeology. The tectonic history and geology of the Los Angeles Basin are described in Yerkes and others (1965) and Wright (1991).

In recent years, sequence stratigraphy has been used by investigators to better understand and describe the hydrogeologic framework of the Los Angeles Basin. Ponti and others (2007) used sequence stratigraphy to develop a chronostratigraphic framework for the Long Beach area. Ehman and others (2014) constructed a series of cross sections from seismic-reflection lines and well logs to expand the sequences first described by Ponti and others (2007) from the Long Beach area into the Central Basin. The chronostratigraphic framework developed for the Long Beach area was utilized by Ponti and others (2014) to characterize potential transport pathways and implications for groundwater management near Santa Fe Springs (not shown) in the Central Basin.

Several studies utilizing groundwater-simulation models to help evaluate regional management strategies have been completed by the USGS in cooperation with WRD. A regional assessment of the hydrogeology and geochemistry, and the development of a groundwater-flow model of the Central and West Coast Basins, was provided by Reichard and others (2003). This regional groundwater-flow model was used by Reichard and Johnson (2005) to assess regional management strategies in the LACP. Nishikawa and others (2009) developed a cross-sectional solute-transport model to evaluate the stratigraphic controls on seawater intrusion in the Long Beach area. Reichard and others (2010) used the regional groundwater-flow model (Reichard and others, 2003) to evaluate the emergency use of groundwater as a backup supply.

In addition to groundwater-flow modeling reports completed by the USGS, multiple modeling studies have been completed by consultants for WRD and other agencies in the LACP. Kennedy/Jenks/Todd, LLC and Lawrence Berkeley National Laboratory (2008) completed a study in the Montebello Forebay to evaluate the fate and transport of recycled water from water reclamation plants in the Whittier Narrows (fig. A1). AMEC Geomatrix (2009) described the development of a groundwater-flow and chemical-transport model for the West Coast Basin Barrier Project. Intera developed a groundwater-flow and transport model for the Dominguez Gap Barrier Project (Intera, 2011) and the Alamitos Barrier Project (Intera, 2010).

Other studies that were joint efforts of Federal, State and local water agencies include a report compiling geologic, hydrologic, and water-quality data in the Central and West Coast Basins (Land and others, 2002), a water augmentation study on storm-water infiltration in the greater Los Angeles area (Los Angeles and San Gabriel Rivers Watershed Council, 2010), and USGS reports assessing the status of groundwater quality of the coastal Los Angeles Basin (Mathany and others, 2008; Goldrath and others, 2012) as part of the Groundwater Ambient Monitoring and Assessment (GAMA) program.

Data Compilation

A major component of this study was the compilation of hydrogeologic data collected by multiple agencies in the LACP into a geographic information system (GIS). The GIS is a spatially relational database that serves as a tool for combining data and geographic features from a variety of sources. The GIS used for this study was originally developed by Reichard and others (2003). The major sources of data compiled in the GIS are the USGS, WRD, Orange County Water District (OCWD), Los Angeles Department of Water and Power (LADWP), City of Santa Monica, City of Beverly Hills, Los Angeles County Department of Public Works (LACDPW), Los Angeles County Flood Control District (LACFCD), San Gabriel River Water Master (SGRWM), California Department of Water Resources (CDWR), and California Geologic Energy Management Division (CalGEM). Data compiled in the GIS can be categorized into the following groups: (1) well-construction data, (2) geologic and geophysical logs, (3) groundwater recharge and discharge data, and (4) water-level measurements. Data compiled for this study are primarily from the period 1971 to 2015.

Most of the data compiled in the GIS are from production wells with long-screened intervals. To provide depth-dependent hydrogeologic data, the USGS, in cooperation with WRD, constructed 57 multiple-well monitoring sites comprising a total of 311 wells in the Central and West Coast Basins (fig. A3). These sites consist of monitoring wells installed at different depths in the same drill hole. The monitoring wells are screened over a small interval (usually 20–40 ft) and are isolated from one another by low-permeability bentonite grout. A detailed description of a typical multiple-well monitoring site is presented in Land and others (2002). Detailed hydrologic and water-quality data have been collected from wells composing these sites. Water-quality data collected for this study can be retrieved from the USGS National Water Information System (NWIS; U.S. Geological Survey, 2016). An important aspect of the drilling in recent years has been application of continuous coring techniques. Cores provided a direct observation of lithology and stratigraphy and were used to interpret the geophysical logs. Data collected from multiple-well monitoring sites constructed by the OCWD along the eastern edge of the LACP have also been incorporated into the GIS (fig. A3). Data collected from the multiple-well monitoring sites were used to help develop the hydrogeologic-framework model for this study, as described in Chapter B of this report. Water-level and water-quality data collected from these sites were used to construct and calibrate the groundwater-flow model described in Chapter D of this report.

Well-Construction Data

Well-construction data are basic information required to assign water-level, pumping, and other data collected from wells to specific areas and aquifers in the LACP groundwater basins. Information gathered includes well identification, common name, owner, spatial coordinates, depth and perforation interval, well use, and status (whether the well is active, abandoned, destroyed, and so forth). These data were downloaded from the USGS NWIS and other data repositories or archives of five local agencies—WRD, OCWD, Los Angeles County, City of Santa Monica, and City of Beverly Hills—and then imported and merged into the project GIS. The updated GIS includes about 9,250 wells; however, only 1,940 of the wells stored in the database were used in this study after reviewing the location, active period, and the quality of well data (1,466 pumping wells, 301 injection wells, and 173 monitoring sites). The monitoring sites are wells with water-level observation data. Most wells that were inactive during the entire model period (1971–2015) or lacked construction information were excluded from the project GIS.

Geologic and Geophysical Logs

Geologic and geophysical logs from the WRD/USGS multiple-well monitoring sites were used to determine the grain size of the formations penetrated at each site (appendix 2). Grain size was used to estimate the hydraulic conductivity, as described in Chapter C. Geophysical logs used to estimate formation grain size include nuclear magnetic resonance (NMR), resistivity, induction, and gamma ray. Nuclear magnetic resonance tools provide porosity estimates, which correlate with grain size (Coates and others, 1999). Resistivity and induction tools were used to provide estimates of the electrical properties of the formation and formation fluid. For the saturated deposits in the LACP, a high resistivity on the logs was interpreted as coarse-grained deposits that contain water with low concentrations of dissolved solids; low resistivity was interpreted as either groundwater of high salinity or fine-grained deposits, or both. Gamma-ray tools provide information about the mineralogy of the formation (Schlumberger Limited, 1972). Gamma-ray emissions are typically higher in clays than gravels but can also be high in feldspar-rich sand and gravel.

Groundwater Recharge and Discharge Data

Groundwater recharge and discharge data were used to estimate the hydrologic budget of groundwater basin(s) or subarea(s). Data gathered for this report include injection into and pumpage from wells and managed aquifer recharge in spreading grounds. Estimated groundwater underflows from or to the neighboring groundwater basins and offshore areas were also obtained.

Pumpage records were collected and compiled for all pumping wells that produced groundwater from 1971 through 2015. Pumping data for wells within the WRD boundary were downloaded from the WRD database. Pre-2007 pumping data for wells in the Santa Monica Basin and the Orange County Basin were obtained directly from the City of Santa Monica and OCWD, respectively; 2007 through 2015 pumping data from the City of Santa Monica and OCWD were obtained through the WRD. Pumping data for wells in the Hollywood Basin were obtained from the City of Beverly Hills through the WRD.

Injection data were available as estimated flow rates per injection well and as monthly totals per injection barrier. The LACFCD measures the injection rate of each well periodically, and WRD records the total amount of injection water being delivered to each of the three barrier projects (fig. A1) monthly. Injection data for the West Coast Basin Barrier Project (WCBBP), Dominguez Gap Barrier Project (DGBP), and Alamitos Barrier Project (ABP) were acquired from LACFCD through WRD. Surface-recharge data for spreading facilities (fig. A1) at the San Gabriel River spreading grounds (SGRSG), Rio Hondo spreading grounds (RHSG), and Whittier Narrows Dam (WND) were also acquired from LACFCD through the WRD.

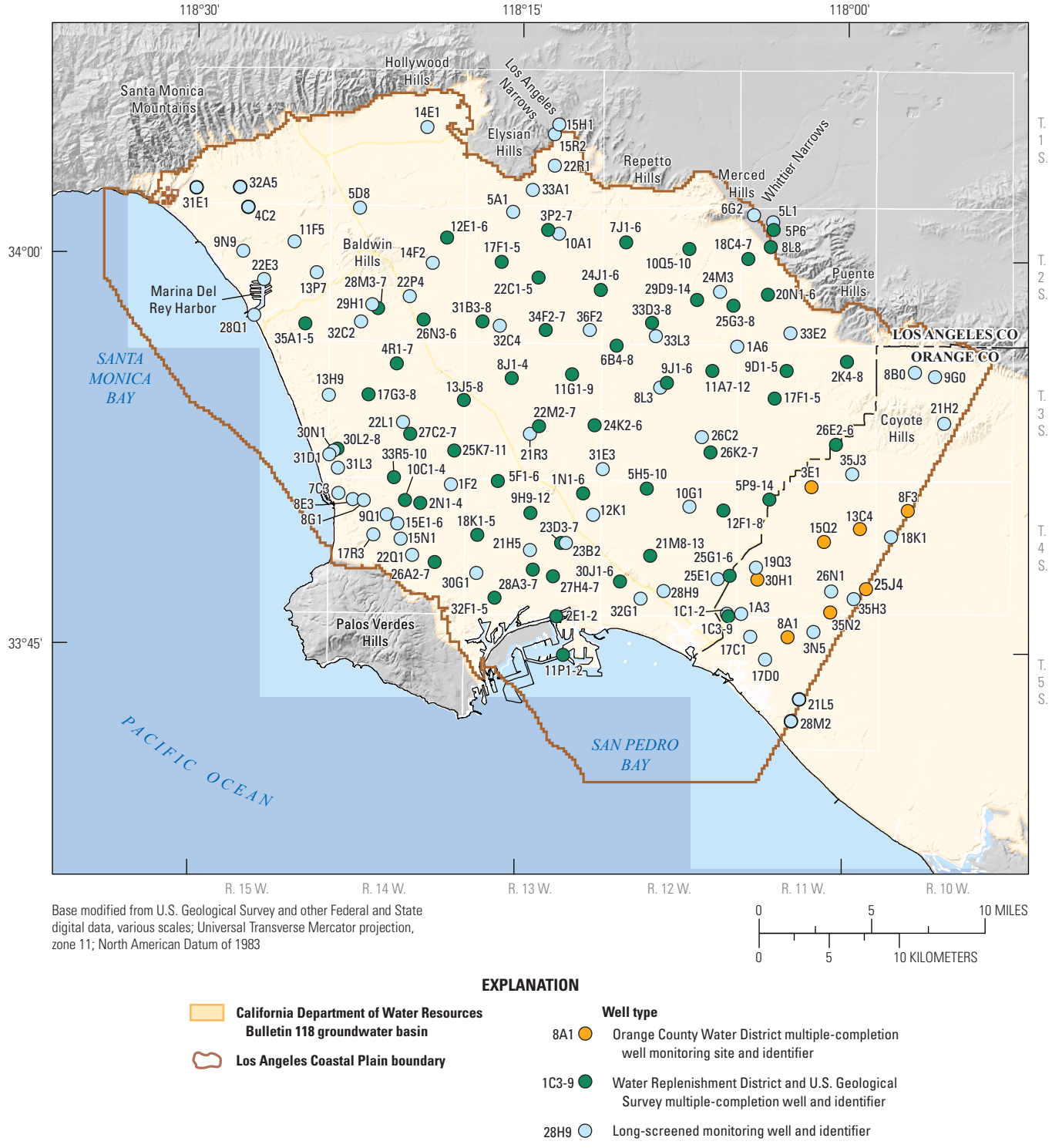


Figure A3. Monitoring wells in Los Angeles and Orange Counties, California, used to develop a groundwater-simulation model in the Los Angeles Coastal Plain.

Underflow estimates were collected and compiled from different sources. Seasonal underflow across Whittier Narrows from the San Gabriel Valley was estimated using water levels from the SGRWM. These estimates were also acquired through the WRD. Field data to estimate underflow across the Los Angeles Narrows from the San Fernando Valley were not available; modeling estimates of average underflow were obtained from the previous regional groundwater-flow model (Reichard and others, 2003). Estimates of onshore or offshore flows, as well as potential flows across the Orange County boundary, were also obtained from the groundwater-flow model by Reichard and others (2003).

Water-Level Measurements

Water levels are key indicators of groundwater conditions, including groundwater basin storage. Three types of water-level data were compiled and collected for this study: water-level contour maps; high-frequency measurements from short-screened wells composing multiple-well monitoring sites; and periodic measurements from long-screened observation or production wells (fig. A3).

Historical water-level contour maps of the Los Angeles Basin were digitized from available paper copies of the maps. More recent water-level contours were constructed using water levels from composite aquifers that were acquired from WRD and OCWD. Water-level measurements from multiple-well monitoring sites were provided by WRD and OCWD. Multiple-well monitoring sites provide depth-dependent or aquifer-dependent data that are the cornerstone of this study. Water-level data collected from long-screened monitoring and production wells were used to augment the data collected in areas where multiple-well monitoring sites are not present (Santa Monica and Hollywood Basins) and for the time period prior to the construction of the multiple-well monitoring sites.

Time-series of water-level data from long-screened observation or production wells were acquired from the Cities of Santa Monica and Beverly Hills in addition to the WRD and OCWD (fig. A3). Water-level data for wells within the WRD boundary and at the north end of the Central Basin were downloaded from the WRD database (Water Replenishment District of Southern California, 2018). Pre-2007 water-level data for wells in the Santa Monica Basin and the Orange County Basin were obtained directly from the City of Santa Monica and OCWD, respectively; 2007 through 2015 water-level data were obtained from the City of Santa Monica and OCWD through WRD.

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Chapter B. Development of a Chronostratigraphic Hydrogeologic Framework Model

By Daniel Ponti and Peter Martin

Reevaluation of the stratigraphy and geologic structure of the Los Angeles Coastal Plain (LACP) to better understand and refine its hydrogeologic framework was a large component of this study (fig. B1). This reevaluation involved applying the concepts of sequence stratigraphy to interpret available surface and subsurface information and develop a chronostratigraphic (time-based) framework model for the water-bearing sediments of the LACP. Previous investigators (Poland and Piper, 1956; Poland and others, 1959; California Department of Water Resources, 1961) utilized the lithostratigraphic approach, subdividing sedimentary deposits based on their physical characteristics. The sequence-stratigraphic approach used in this study is a useful alternative to the lithostratigraphic approach because the sequence-stratigraphic approach can produce a more realistic representation of geologic structure, distribution of lithologic facies, and aquifer architecture.

Sequence stratigraphy subdivides and links sedimentary deposits into unconformity-bound chronostratigraphic units that represent cycles of deposition that are controlled by variations in base level (sea level), sediment supply, and available accommodation space (Van Wagoner and others, 1990; Catuneanu, 2006). Within depositional sequences, facies and lithologic properties can change both laterally and vertically. These changes result from depositional processes that are mappable and predictable, thus the lateral distribution of coarse-grained aquifers and their fine-grained confining aquitards can be more readily understood and predicted. Sequences are defined by their bounding discontinuities. Within the LACP, the identified sequences are bounded on top and on the bottom by regionally unconformable surfaces, upon which there appears to be evidence for erosion or a depositional hiatus. While the sequence-bounding unconformities are not strictly surfaces of the same age (isochronous surfaces), they are important because sediment deposited above an unconformity is younger than sediment that underlies that unconformity. Thus, sequence-bounding unconformities separate sediments that are deposited within discrete time intervals.

In the LACP, the geologic sequences of Quaternary age generally formed in response to sea-level changes resulting from worldwide glaciation cycles (Imbrie and others, 1984). Most sediment accumulation likely occurred during interglacial periods when sea levels rose and coastlines prograded across the shelf. During glacial periods when sea levels were low, erosion on the exposed shelf occurred and thus produced the bounding unconformities. The sequences and their boundaries can be identified by characteristic cycles of coarsening- or fining-upward bed sets that reflect sediment progradation and retrogradation, respectively. These cycles are often recognized and correlated as characteristic vertical patterns in geophysical and lithologic logs. Evidence for bed truncation and onlap at sequence boundaries also can be observed in seismic-reflection profiles. In this study, a combination of borehole logs and seismic data were used for sequence identification and correlation. Water-level hydrographs and water-quality data collected from monitoring wells composing multiple-well monitoring sites were used to help constrain the identification of sequences.

The sequence-stratigraphy approach used in this study provides a robust framework for defining geologic structure, hydraulic properties, and aquifer connectivity. For example, within a given sequence, coarse-grained deposits that may serve as productive aquifers might transition toward the coastline from river channel sands and gravels, to coastal dunes and tidal-channel sands, and then to intertidal and neritic-marine sands. Within each sequence, the depositional processes result in layers of heterogeneous sediments. In general, the sediments are anisotropic, with the horizontal hydraulic conductivity of the sediments being greater than the vertical hydraulic conductivity. The primary cause of anisotropy on a small scale is the orientation of clay minerals in the sediments (Freeze and Cherry, 1979). The horizontal to vertical anisotropy in core samples of clays and shales seldom are greater than 10:1 and are usually less than 3:1 (Freeze and Cherry, 1979). However, on a larger field scale, it is not uncommon for layered heterogeneity to lead to regional anisotropy values on the order of 100:1 or larger (Freeze and Cherry, 1979). Because of the anisotropy in the layered sediments, groundwater preferentially flows within the sequence, limiting flow to overlying or underlying sequences. However, flow between sequences may not be as limited if vertical hydraulic gradients are high, or where coarse-grained deposits are juxtaposed across a sequence boundary or laterally because of incision, onlap, or faulting.

Previous Work and Formal Stratigraphic Nomenclature

Sediments that record the evolution of the LACP have been extensively mapped and studied since the late 1800s, culminating in a formal lithostratigraphic framework in the mid-20th century. The formal stratigraphic nomenclature for Pleistocene-age deposits (which contain most of the producing aquifers) was developed from work on the Palos Verdes Hills (fig. B2) by Woodring and others (1946), who recognized three formations of marine origin (the Lomita Marl, Timms Point Silt, and San Pedro Sand), unconformably overlain by a series of marine-terrace deposits, the youngest of which was named the Palos Verdes Sand. The angular unconformity separating the marine and non-marine units in the Palos Verdes Hills was attributed to a mid-Pleistocene orogenic event (Pasadenian orogeny[1]), and the marine and non-marine units were assigned by the authors to the lower and upper Pleistocene subepochs, respectively. This framework and nomenclature were first extended into the subsurface of the western coastal plain area in two groundwater geology investigations by Poland and Piper (1956) and Poland and others (1959). The various Pleistocene marine formations recognized on the Palos Verdes Hills could not be readily distinguished in the subsurface. Therefore, the Lomita Marl, Timms Point Silt, and San Pedro Sand of Woodring and others (1946) were combined into the marine San Pedro Formation. In addition, the upper Pleistocene marine-terrace deposits and the Palos Verdes Sand were included with paralic deposits (interfingered marine and continental deposits) and non-marine deposits identified in the subsurface and called the "upper Pleistocene." This subsurface framework was then extended into the Central Basin (fig. B2) by the California Department of Water Resources (1961). The California Department of Water Resources retained the term "San Pedro Formation" to represent the shallow marine deposits of Pleistocene age, but reassigned the unnamed upper Pleistocene of Poland and Piper (1956) and Poland and others (1959) to the informally named Lakewood Formation.

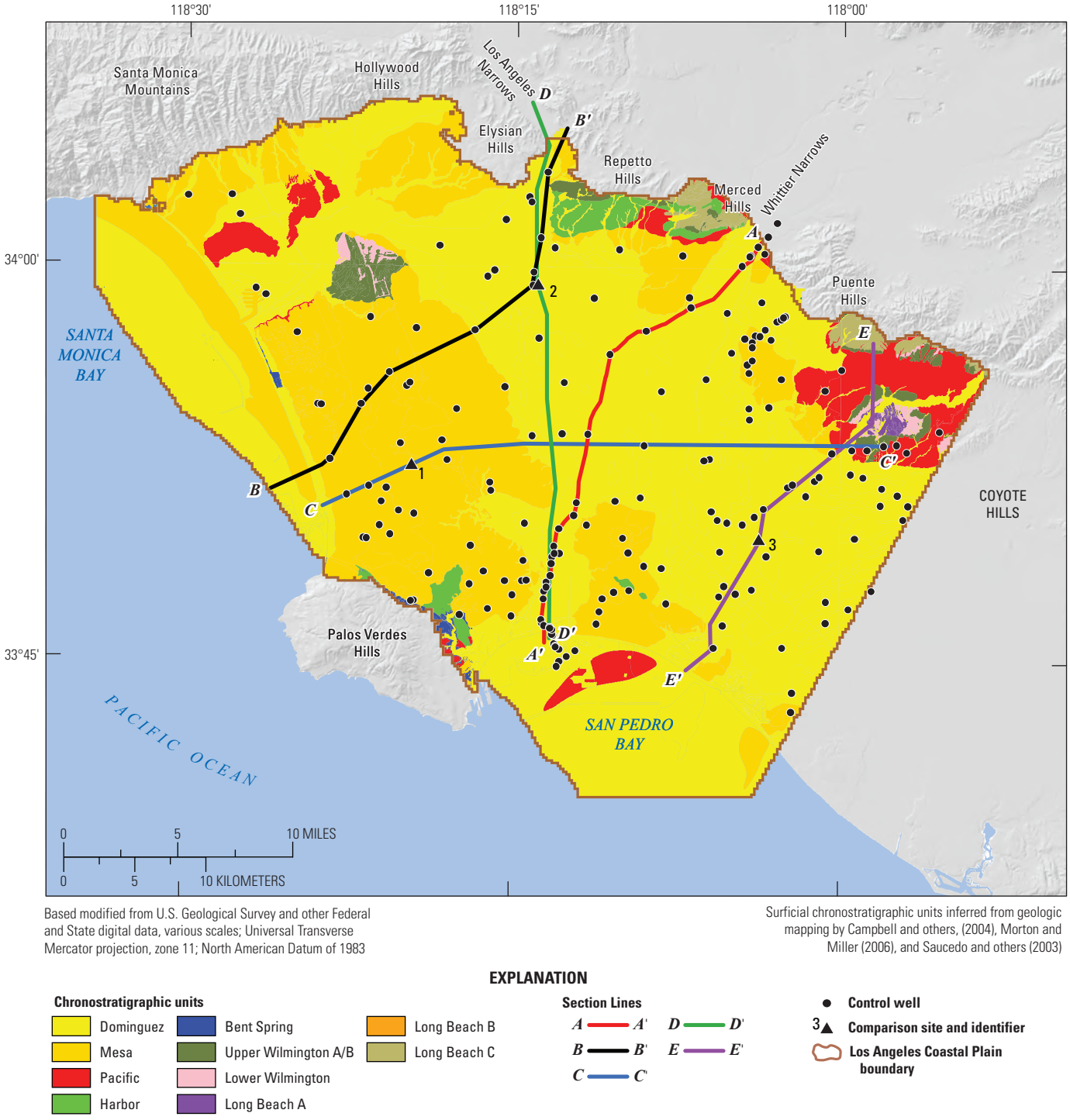
In the Puente Hills and Coyote Hills area (fig. B2), Durham and Yerkes (1964) and Yerkes (1972) defined three Pleistocene-age formations separated by unconformities. In succession from youngest to oldest, these formations are (1) the early Pleistocene San Pedro Formation of shallow-water marine origin, which was correlated to the subsurface San Pedro Formation of Poland and Piper (1956) and Poland and others (1959); (2) the early late-Pleistocene Coyote Hills Formation, consisting of intertidal and non-marine sediment, correlated to the lower part of the unnamed upper Pleistocene of Poland and Piper (1956) and Poland and others (1959); and (3) the late-Pleistocene La Habra Formation, a non-marine unit correlated to the upper part of the unnamed upper Pleistocene and the marine-terrace deposits on the Palos Verdes Hills.

More recent paleontological work in the Coyote Hills (fig. B2) by Powell and Stevens (2000) indicated that the San Pedro Formation in the Coyote Hills is substantial older than the San Pedro Sand in the Palos Verdes Peninsula (and by analogy, much of the subsurface San Pedro Formation). Ponti and others (2014) used seismic-reflection data to infer that the La Habra and Coyote Hills Formations are likely older than most of the upper Pleistocene deposits in the subsurface (unnamed upper Pleistocene or Lakewood Formation) as well.

In the Puente Hills area (fig. B2), Durham and Yerkes (1964) and Yerkes (1972) mapped younger alluvial fan deposits that overlie the La Habra and older Pleistocene formations. These are informally named old (Pleistocene) and young (Holocene) alluvium. More recent surficial mapping (Saucedo and others, 2003; Morton and Miller, 2006; Campbell and others, 2014) has further subdivided the surficial deposits of the LACP by relative age (based on topographic position, degree of dissection, and soil formation), depositional environment (alluvial fan, flood basin, channel, or eolian deposits), and average grain size, but still retained informal names. These deposits comprise the surface of nearly the entire LACP and are derived from the San Gabriel, Rio Hondo, Los Angeles, and Santa Ana River drainages, as well as from local drainages that have their headwaters in the Puente Hills, Santa Monica Mountains, Palos Verdes Hills, and the low hills along the Newport-Inglewood fault zone (fig. B2).

The hydrostratigraphic subsurface framework developed for the area of the LACP by California Department of Water Resources (1961) gives names to zones of sands and gravels, embedded within the lithostratigraphic formations, that serve as producing aquifers. Sand- and gravel-filled river channels near the base of the young Holocene deposits are primarily derived from the San Gabriel, Los Angeles, and Santa Ana Rivers, and constitute the Gaspur, Ballona, and Talbert aquifers, respectively. Pleistocene alluvial and intertidal deposits that constitute the Lakewood Formation of the California Department of Water Resources (1961) contain the Exposition, Artesia, Gardena, and Gage aquifers; permeable zones composing these aquifers probably represent coarser-grained fluvial and tidal-channel facies. The marine San Pedro Formation is inferred by the California Department of Water Resources (1961) to extend to a depth of greater than 1,000 feet (ft) and contains the Hollydale, Jefferson, Lynwood, Silverado, and Sunnyside aquifers. These aquifers likely include coastal beach, dune, nearshore-sand, and deltaic-channel deposits that tend to be more laterally homogeneous than non-marine sediment. Therefore, the Hollydale, Jefferson, Lynwood, Silverado, and Sunnyside aquifers are the aquifers most extensively exploited for public water supply.

[1]Although classically defined as mid-Pleistocene diastrophism (American Geological Institute, 1957), the term Pasadenian orogeny has subsequently been understood to be deformation and uplift within southern California resulting from north-south shortening that began in the early Pleistocene and continues to the present day (Nagle and Parker, 1971; Yeats, 1983; Namson, 1987). Our work shows that the unconformity separating marine and non-marine deposits within the LACP varies in age depending on location.



Based modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

Surficial chronostratigraphic units inferred from geologic mapping by Campbell and others, (2004), Morton and Miller (2006), and Saucedo and others (2003)

EXPLANATION

Chronostratigraphic units

- Dominguez
- Mesa
- Pacific
- Harbor
- Bent Spring
- Upper Wilmington A/B
- Lower Wilmington
- Long Beach A
- Long Beach B
- Long Beach C

Section Lines

- A — A'
- B — B'
- C — C'
- D — D'
- E — E'

- Control well
- 3 Comparison site and identifier
- Los Angeles Coastal Plain boundary

Figure B1. Los Angeles Coastal Plain area and cross-section locations and surficial chronostratigraphic units inferred from geologic mapping by Saucedo and others (2003), Morton and Miller (2006), and Campbell and others (2014). Numbered triangles are comparison sites described in table B2.

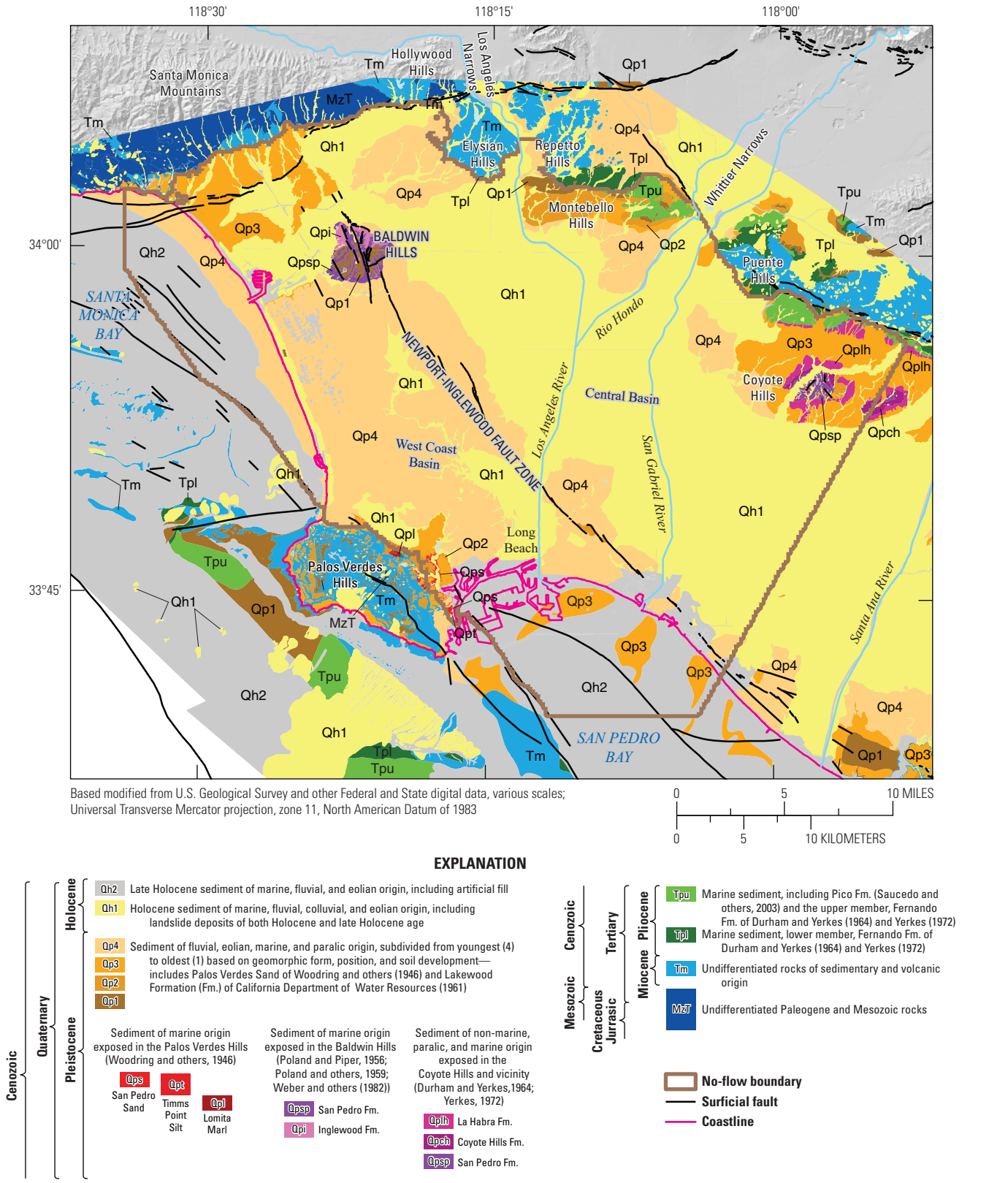


Figure B2. Surface geologic units and faults, Los Angeles Coastal Plain, California. Geology modified from compilations by Saucedo and others (2003), Morton and Miller (2006), U.S. Geological Survey and California Geological Survey (2006), and Campbell and others (2014).

Identification of Chronostratigraphic Unit Boundaries

The chronostratigraphic framework model developed for the LACP relied on a study completed by Ponti and others (2007) in the Long Beach area (fig. B2). The Long Beach study involved detailed analyses and age dating of continuously cored boreholes to identify key unconformities that bound 10 sequences spanning the Holocene through latest Pliocene epochs (Ponti and others, 2007). Through analysis of available well and seismic data, the authors constructed a digital three-dimensional chronostratigraphic framework model of the Long Beach area.

The current study extends the Long Beach chronostratigraphic framework model to the entire LACP through compilation and analysis of (1) geologic and geophysical logs from Water Replenishment District of Southern California (WRD) and U.S. Geological Survey (USGS) multiple-well monitoring sites; (2) oil- and water-well logs from various sources; (3) medium- to high-resolution seismic-reflection data collected by the USGS (offshore); and (4) the oil industry (onshore), and surficial geology (fig. B3). This model developed for this report incorporates the 10 sequences identified in the Long Beach model, plus 3 additional chronostratigraphic units that were recognized when the model was extended through the entire LACP. These new units may simply be conformable subdivisions within the sequences originally identified in Long Beach that have distinctive hydrologic characteristics, at least at local scales. Therefore, for this report we use the term chronostratigraphic unit to represent both the 10 previously defined sequences and the 3 additional chronostratigraphic units identified for this study. The LACP model also extends to greater depth than that in the Long Beach area (approximately –20,000 ft elevation versus –3,000 ft elevation for Long Beach) to capture the base of the oldest water-bearing units within the Central Basin.

Analysis of Lithologic and Geophysical Logs

High-quality lithologic and geophysical logs from the WRD/USGS multiple-well monitoring sites were the primary data used for identifying chronostratigraphic unit boundaries within the LACP. These data were supplemented by a second set of data composed of logs from previously drilled water, geotechnical, geoenvironmental, and oil wells and boreholes. Logs from non-USGS water wells are of varying quality; drillers' logs from wells constructed using rotary-wash and cable-tool methods tend to be quite general in nature and are therefore of limited value for sequence-stratigraphic analysis. Although rare, some of these wells have accompanying geophysical logs, which are valuable for identifying fining- or coarsening-upward sediment packages and bounding unconformities. A number of these wells were selected for areas where other data were lacking.

Logs derived from geotechnical and geoenvironmental wells and boreholes are of much higher quality, but they are fewer in number and more limited in depth (generally less than 200 ft) than water-well drillers' logs. Most logs derived from geotechnical and geoenvironmental wells and boreholes were made by geologists or engineers and were derived from examination of core samples either collected continuously or at regularly spaced intervals of 10 ft or less. However, a few descriptions came from drill cuttings supplemented by interpretation of geophysical logs. With few exceptions, lithologies from geoenvironmental and geotechnical boreholes were classified in the field using the Unified Soil Classification System (American Society for Testing and Materials, 1985), which provides consistency when comparing data from multiple boreholes and different investigations. Many of these logs also contain constituent information (for example, color, mineralogical components, and fossils) that can be useful for identifying potential unconformities. Some of these wells and boreholes also have geophysical logs.

The third type of well logs used were from oil wells filed with the California Geologic Energy Management Division (California Department of Conservation, 2017). These wells extend to great depths (thousands of feet), but they often lack recorded data in the upper few hundred feet, and only a few logs contain data recorded in the upper 1,000 ft. Oil wells typically only have electrical resistivity and spontaneous potential logs. These geophysical logs are valuable for determining stacking patterns and general lithologic character, but geologic descriptions of the sediment are rarely available.

Several thousand logs were collected and evaluated to develop the LACP chronostratigraphic framework model. A total of 193 logs were selected from these as primary controls for the model, including logs for 57 WRD/USGS multiple-well monitoring sites (fig. B3; table B1). Nearly 500 additional well logs were checked to ensure that the shape of modeled stratigraphic surfaces were appropriately constrained, but these logs were not used to specifically identify chronostratigraphic boundaries.

Existing descriptive lithologic logs were reclassified, and a median grain size for each described geologic layer was estimated from the descriptions to facilitate interpretation and identification of key boundaries and fining- or coarsening-upward sediment packages. For lithologic logs with Unified Soil Classification System assignments, the classifications were kept as assigned and median grain sizes were estimated from the Unified Soil Classification System group and other descriptive information, as available. For water-well and other logs where lithologic descriptions were more generic and did not use a prescriptive classification system, described geologic layers were classified into a simple five-level lithologic classification scheme consisting of gravelly sediment, coarse sands, medium to fine sands, silty and clayey sands, and silts/clays. Graphic logs were then constructed to display these lithologic data along with any accompanying electric logs.

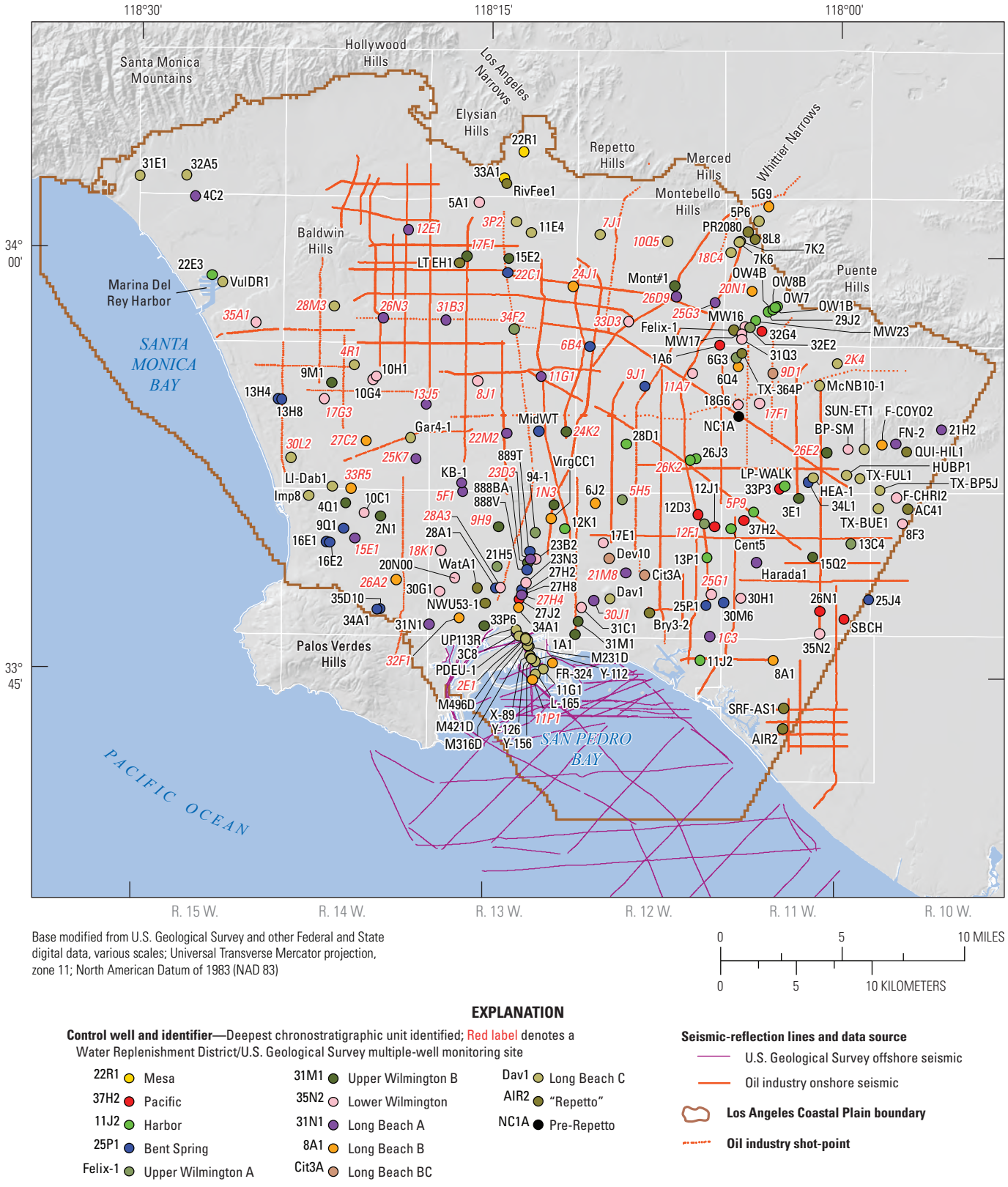


Figure B3. Location of control wells and seismic-reflection profiles used for the location of chronostratigraphic unit boundaries, Los Angeles Coastal Plain, California. Labels are well abbreviations described in table B1. Red labels are Water Replenishment District of Southern California and U.S. Geological Survey multiple-well monitoring sites.

Table B1. Control wells used for identification of chronostratigraphic unit boundaries, Los Angeles Coastal Plain, California.

[ID, identification; NAD 83, North American Datum of 1983; UTM, Universal Transverse Mercator; NAVD 88, North American Vertical Datum of 1988; N/A, not assigned]

State well number	Well abbreviation (fig. B3)	Well ID	Easting, NAD 83, UTM zone 11N (meters)	Northing, NAD 83, UTM zone 11N (meters)	Land surface elevation, NAVD 88 (feet)	Well depth below land surface (feet)	Oldest chronostratigraphic unit penetrated/ identified
1S/13W-22R1	22R1	2773	386,898.95	3,769,486.21	278.8	99	Mesa
1S/13W-33A1	33A1	2765	385,587.97	3,767,750.60	260.1	254	Mesa
1S/15W-31E1	31E1	2505	361,567.87	3,767,944.29	311.9	283	Long Beach C
1S/15W-32A5	32A5	2535J	364,640.75	3,767,965.83	241.3	236	Long Beach C
2S/11W-18C4	18C4	Pico Rivera1	400,577.65	3,762,839.18	182.8	930	Long Beach C
2S/11W-20N1	20N1	Whittier2	401,951.21	3,760,286.49	168.4	1,402	Long Beach B
2S/11W-29J2	29J2	MW24	402,993.50	3,758,908.73	162.4	200	Harbor
2S/11W-31Q3	31Q3	MW26	401,270.06	3,757,125.16	156.0	250	Lower Wilmington
2S/11W-32E2	32E2	MW25	401,814.58	3,757,890.60	148.3	230	Upper Wilmington A
2S/11W-32G4	32G4	MW18	402,590.55	3,757,631.05	144.3	166	Pacific
2S/11W-5G9	5G9	2947NN	403,036.20	3,765,873.27	212.3	878	Long Beach B
2S/11W-5P6	5P6	Whittier Narrows1	402,382.71	3,764,902.54	202.2	860	Long Beach C
2S/11W-7K2	7K2	Pico Rivera3	401,184.93	3,763,584.07	191.3	820	Long Beach C
2S/11W-7K6	7K6	Pico Rivera4	401,101.18	3,763,519.89	191.8	900	Long Beach C
2S/11W-8L8	8L8	Whittier Narrows2	402,151.88	3,763,690.61	210.9	760	“Repetto”
2S/12W-10Q5	10Q5	Montebello1	396,384.34	3,763,596.67	191.9	1,003	Long Beach C
2S/12W-25G3	25G3	Pico Rivera2	399,536.11	3,759,546.50	152.4	1,203	Long Beach A
2S/12W-26D9	26D9	Rio Hondo1	396,958.96	3,759,924.89	162.6	1,160	Long Beach A
2S/12W-33D3	33D3	Bell Gardens1	393,781.14	3,758,284.83	120.0	1,823	Lower Wilmington
2S/12W-7J1	7J1	Commerce1	391,933.00	3,764,029.98	163.3	1,401	Long Beach C
2S/13W-11E4	11E4	2788J	387,389.12	3,764,178.00	205.2	2,445	Long Beach C
2S/13W-15E2	15E2	1460X	385,898.56	3,762,458.79	191.4	1,443	Upper Wilmington B
2S/13W-17F1	17F1	Los Angeles1	383,115.85	3,762,626.70	176.5	1,389	Upper Wilmington B
2S/13W-22C1	22C1	Huntington Park1	385,828.52	3,761,513.98	179.4	1,020	Bent Spring
2S/13W-24J1	24J1	Bell1	390,128.83	3,760,612.23	148.4	1,804	Long Beach B
2S/13W-31B3	31B3	Los Angeles4	381,752.26	3,758,381.27	140.7	1,825	Long Beach A
2S/13W-34F2	34F2	South Gate2	386,239.99	3,757,790.00	122.0	2,020	Upper Wilmington A
2S/13W-3P2	3P2	Los Angeles2	386,408.36	3,764,888.65	222.6	1,400	Long Beach C
2S/13W-5A1	5A1	2747A	383,936.91	3,766,181.69	228.3	462	Lower Wilmington
2S/14W-12E1	12E1	Los Angeles3	379,258.46	3,764,352.54	145.7	1,609	Long Beach A
2S/14W-26N3	26N3	Inglewood2	377,617.44	3,758,537.68	219.5	882	Long Beach A
2S/14W-28M3	28M3	Inglewood1	374,384.48	3,759,325.81	117.4	1,420	Long Beach C
2S/15W-22E3	22E3	1251T	366,336.77	3,761,394.29	12.4	330	Harbor
2S/15W-35A1	35A1	Westchester1	369,225.60	3,758,249.28	129.0	898	Lower Wilmington
2S/15W-4C2	4C2	2546K	365,215.84	3,766,566.71	155.4	598	Long Beach A
3S/11W-17F1	17F1	Norwalk1	402,432.54	3,752,895.55	97.4	1,433	Lower Wilmington
3S/11W-18G6	18G6	003S011W18G006S	401,052.91	3,752,802.00	102.0	1,560	Lower Wilmington
3S/11W-26E2	26E2	La Mirada1	406,867.30	3,749,634.17	83.9	1,257	Upper Wilmington B
3S/11W-2K4	2K4	Whittier1	407,565.05	3,755,510.53	215.3	1,298	Long Beach C
3S/11W-30M6	30M6	004S011W30M006S	400,072.17	3,739,755.47	14.4	800	Bent Spring
3S/11W-33P3	33P3	1063K	403,759.69	3,747,238.59	29.3	753	Pacific

Table B1. Control wells used for identification of chronostratigraphic unit boundaries, Los Angeles Coastal Plain, California.—Continued

[ID, identification; NAD 83, North American Datum of 1983; UTM, Universal Transverse Mercator; NAVD 88, North American Vertical Datum of 1988; N/A, not assigned]

State well number	Well abbreviation (fig. B3)	Well ID	Easting, NAD 83, UTM zone 11N (meters)	Northing, NAD 83, UTM zone 11N (meters)	Land surface elevation, NAVD 88 (feet)	Well depth below land surface (feet)	Oldest chronostratigraphic unit penetrated/ identified
3S/11W-34L1	34L1	003S011W34L001S	405,631.49	3,747,664.38	58.4	1,430	Bent Spring
3S/11W-6G3	6G3	MW27	400,902.97	3,755,901.78	139.5	225	Upper Wilmington A
3S/11W-6Q4	6Q4	003S011W06Q004S	401,060.19	3,755,307.19	135.4	1,000	Long Beach B
3S/11W-9D2	9D1	Santa Fe Springs1	403,298.23	3,754,855.09	169.4	1,420	Long Beach BC
3S/12W-11A7	11A7	Norwalk2	398,041.80	3,754,862.06	117.4	1,502	Lower Wilmington
3S/12W-1A6	1A6	1615P	399,814.61	3,756,730.70	133.4	216	Pacific
3S/12W-26J3	26J3	Cerritos C-4	398,250.26	3,749,223.73	69.4	1,030	Harbor
3S/12W-26K2	26K2	Cerritos2	397,875.24	3,749,146.92	63.4	1,504	Harbor
3S/12W-28D1	28D1	951J	393,652.80	3,750,217.16	68.4	1,150	Harbor
3S/12W-6B4	6B4	South Gate1	391,244.46	3,756,669.78	103.4	1,493	Bent Spring
3S/12W-9J1	9J1	Downey1	394,893.75	3,754,010.90	100.4	1,200	Bent Spring
3S/13W-11G1	11G1	Lynwood1	388,042.82	3,754,652.88	87.4	3,023	Long Beach A
3S/13W-22M2	22M2	Compton2	385,779.41	3,750,931.72	77.4	1,500	Long Beach A
3S/13W-24K2	24K2	Compton1	389,696.02	3,751,020.32	68.4	1,435	Upper Wilmington B
3S/13W-8J1	8J1	Willowbrook1	383,849.91	3,754,373.97	100.4	1,000	Lower Wilmington
3S/14W-10G4	10G4	1367G	376,940.03	3,754,503.08	53.1	812	Lower Wilmington
3S/14W-10H1	10H1	1367H	377,188.03	3,754,698.29	61.0	811	Lower Wilmington
3S/14W-13J5	13J5	Gardena1	380,457.79	3,752,816.04	85.0	1,020	Long Beach A
3S/14W-17G3	17G3	Hawthorne1	373,701.58	3,753,211.86	87.5	1,001	Lower Wilmington
3S/14W-25K7	25K7	Gardena2	379,776.69	3,749,225.41	28.5	1,399	Long Beach A
3S/14W-27C2	27C2	Lawndale1	376,504.55	3,750,417.10	33.5	1,460	Long Beach B
3S/14W-30L2	30L2	Manhattan Beach1	371,511.22	3,749,352.16	135.2	2,000	Long Beach C
3S/14W-33R5	33R5	Torrance1	375,494.57	3,747,319.36	80.5	1,509	Long Beach B
3S/14W-4R1	4R1	Inglewood3	375,732.47	3,755,421.06	72.5	1,980	Long Beach C
3S/14W-9M1	9M1	1337F	374,242.56	3,754,287.94	82.5	600	Upper Wilmington B
3S/15W-13H4	13H4	1308H	370,682.03	3,753,214.52	103.5	555	Bent Spring
3S/15W-13H8	13H8	1308S	370,912.28	3,753,163.62	102.4	526	Bent Spring
4S/11W-37H2	37H2	1035H	401,407.93	3,745,162.40	38.4	822	Pacific
4S/11W-5P9	5P9	Cerritos1	402,050.21	3,745,724.59	42.4	1,221	Harbor
4S/12W-12D3	12D3	1005D	398,379.49	3,745,550.72	38.4	626	Pacific
4S/12W-12F1	12F1	Lakewood2	398,816.89	3,744,941.75	38.4	2,151	Upper Wilmington A
4S/12W-12J1	12J1	1016N	399,470.78	3,744,775.73	35.6	885	Pacific
4S/12W-13P1	13P1	1008L	398,975.60	3,742,690.33	22.9	810	Harbor
4S/12W-17E1	17E1	937A	392,134.58	3,743,687.69	68.5	1,030	Lower Wilmington
4S/12W-21M8	21M8	Long Beach6	393,640.60	3,741,731.59	36.5	1,550	Long Beach A
4S/12W-25G1	25G1	Long Beach1	399,249.81	3,740,291.52	11.7	1,498	Lower Wilmington
4S/12W-25P1	25P1	500E	398,897.68	3,739,571.19	10.0	645	Bent Spring
4S/12W-30J1	30J1	Long Beach8	391,479.43	3,739,900.30	18.5	1,515	Long Beach A
4S/12W-31C1	31C1	411	390,697.05	3,739,409.65	27.0	1,005	Lower Wilmington
4S/12W-31M1	31M1	411A	390,477.15	3,738,498.55	36.5	810	Upper Wilmington B

Table B1. Control wells used for identification of chronostratigraphic unit boundaries, Los Angeles Coastal Plain, California.—Continued

[ID, identification; NAD 83, North American Datum of 1983; UTM, Universal Transverse Mercator; NAVD 88, North American Vertical Datum of 1988; N/A, not assigned]

State well number	Well abbreviation (fig. B3)	Well ID	Easting, NAD 83, UTM zone 11N (meters)	Northing, NAD 83, UTM zone 11N (meters)	Land surface elevation, NAVD 88 (feet)	Well depth below land surface (feet)	Oldest chronostratigraphic unit penetrated/ identified
4S/12W-5H5	5H5	Lakewood1	393,407.55	3,746,519.06	50.9	1,020	Upper Wilmington A
4S/12W-6J2	6J2	924G	391,582.37	3,746,296.07	45.7	2,017	Long Beach B
4S/13W-12K1	12K1	906D	389,604.89	3,744,643.35	90.0	1,285	Harbor
4S/13W-18K1	18K1	Carson2	381,404.68	3,743,223.28	41.5	1,309	Lower Wilmington
4S/13W-1N3	1N3	Long Beach2	388,884.05	3,746,183.57	40.4	1,118	Upper Wilmington B
4S/13W-21H5	21H5	868H	385,116.16	3,742,116.60	23.5	721	Upper Wilmington A
4S/13W-23B2	23B2	888F	387,677.60	3,742,646.71	30.5	1,074	Lower Wilmington
4S/13W-23D3	23D3	Long Beach3	387,313.84	3,742,640.47	26.5	1,404	Long Beach A
4S/13W-23N3	23N3	889P	387,035.20	3,741,094.87	18.5	1,125	Lower Wilmington
4S/13W-27H2	27H2	370Z	386,767.56	3,740,603.31	18.0	343	Bent Spring
4S/13W-27H4	27H4	Long Beach7	386,760.65	3,740,255.17	17.5	1,412	Long Beach A
4S/13W-27H8	27H8	370AJ	386,789.66	3,740,359.07	17.5	415	Bent Spring
4S/13W-27J2	27J2	370W	386,581.23	3,739,961.20	17.5	199	Pacific
4S/13W-28A1	28A1	859C	385,028.11	3,740,699.55	31.0	445	Bent Spring
4S/13W-28A3	28A3	Wilmington1	385,319.61	3,740,733.55	41.8	1,038	Lower Wilmington
4S/13W-30G1	30G1	310C	381,341.57	3,740,496.30	39.4	682	Lower Wilmington
4S/13W-31N1	31N1	302B	380,609.23	3,738,343.02	44.7	1,050	Long Beach A
4S/13W-32F1	32F1	Wilmington2	382,632.29	3,738,743.67	31.5	1,040	Long Beach B
4S/13W-33P6	33P6	352F	384,275.86	3,738,220.04	13.8	453	Upper Wilmington B
4S/13W-34A1	34A1	371D	386,548.81	3,739,424.21	14.5	1,050	Long Beach B
4S/13W-5F1	5F1	Carson3	382,858.04	3,747,055.63	22.5	1,820	Long Beach A
4S/13W-9H9	9H9	Carson1	385,245.80	3,744,781.40	25.5	1,200	Upper Wilmington B
4S/14W-15E1	15E1	Torrance2	375,755.61	3,744,020.36	80.5	1,260	Long Beach A
4S/14W-16E1	16E1	Sepulveda 1	373,852.48	3,743,796.66	93.4	702	Upper Wilmington A
4S/14W-16E2	16E2	Sepulveda2	374,091.26	3,743,761.23	93.5	620	Bent Spring
4S/14W-26A2	26A2	Lomita1	378,457.08	3,741,270.15	79.5	1,340	Long Beach B
4S/14W-2N1	2N1	Madrid	377,453.13	3,745,487.40	74.5	812	Upper Wilmington B
4S/14W-34A1	34A1	Chandler-4	377,192.50	3,739,314.46	161.4	205	Bent Spring
4S/14W-35D10	35D10	Chandler-3	377,421.76	3,739,356.22	153.4	402	Bent Spring
4S/14W-4Q1	4Q1	Mariner	375,137.13	3,746,316.71	106.5	811	Upper Wilmington B
4S/14W-9Q1	9Q1	746	374,999.89	3,744,662.55	102.5	557	Bent Spring
4S13W-10C1	10C1	Columbia	376,366.30	3,745,672.25	81.5	793	Lower Wilmington
5S/12W-11J2	11J2	504F	398,513.18	3,735,919.79	11.3	705	Harbor
5S/12W-1C3	1C3	Seal Beach1	399,154.18	3,737,509.73	11.4	1,505	Long Beach A
5S/13W-11G1	11G1	394G	388,173.71	3,735,370.04	13.0	1,882	Long Beach C
5S/13W-11P1	11P1	Long Beach5	387,471.75	3,734,680.73	17.5	1,203	Long Beach B
5S/13W-1A1	1A1	412A	390,261.25	3,737,646.05	38.5	810	Upper Wilmington B
5S/13W-2E1	2E1	Long Beach4	386,982.71	3,737,429.04	3.5	1,401	Long Beach B
5S/13W-3C8	3C8	372F	386,429.93	3,737,751.66	-1.5	1,005	Long Beach A
N/A	20N00	004S013W20N000S	382,309.55	3,741,376.02	42.5	1,005	Lower Wilmington

Table B1. Control wells used for identification of chronostratigraphic unit boundaries, Los Angeles Coastal Plain, California.—Continued

[ID, identification; NAD 83, North American Datum of 1983; UTM, Universal Transverse Mercator; NAVD 88, North American Vertical Datum of 1988; N/A, not assigned]

State well number	Well abbreviation (fig. B3)	Well ID	Easting, NAD 83, UTM zone 11N (meters)	Northing, NAD 83, UTM zone 11N (meters)	Land surface elevation, NAVD 88 (feet)	Well depth below land surface (feet)	Oldest chronostratigraphic unit penetrated/ identified
N/A	888V	888V	387,098.73	3,741,925.33	22.5	480	Bent Spring
N/A	888BA	888BA	387,174.80	3,742,390.62	25.5	1,025	Upper Wilmington B
N/A	889T	889T	387,305.93	3,743,139.62	27.5	617	Bent Spring
N/A	94-1	Dom. Water94-1	387,626.82	3,744,375.75	39.5	1,013	Upper Wilmington A
N/A	AC41	CONT-AC41	412,229.34	3,745,905.06	125.5	10,539	“Repetto”
N/A	AIR2	HOC-AIR2	403,939.68	3,731,418.52	27.1	8,508	“Repetto”
N/A	AMD-8	AMD-8	408,464.24	3,743,618.96	79.2	2,080	Upper Wilmington A
N/A	BPM-1	BPM-1	405,048.48	3,746,616.75	58.4	2,210	Upper Wilmington B
N/A	BPM-2	BPM-2	405,943.53	3,742,722.02	58.4	2,227	Upper Wilmington B
N/A	BP-SM	BP-SM	408,282.27	3,749,841.10	113.6	1,038	Lower Wilmington
N/A	Bry3-2	CalRes Bryant32	395,175.91	3,739,067.24	30.9	9,922	“Repetto”
N/A	CB-1	CB-1	411,869.83	3,744,926.66	114.4	1,543	Lower Wilmington
N/A	Cent5	SCW Centralia5	400,564.45	3,744,640.71	33.4	1,215	Harbor
N/A	Cit3A	Citizens3A	394,851.66	3,741,559.05	21.5	2,360	Long Beach BC
N/A	Dav1	COLV-DAV1	392,581.84	3,739,998.78	178.1	3,690	Long Beach C
N/A	Dev10	LB Dev 10	392,516.41	3,742,665.49	51.5	2,185	Long Beach BC
N/A	F-CHRI2	F-CHRI2	411,470.16	3,746,677.18	115.2	1,504	Lower Wilmington
N/A	F-COYO2	F-COYO2	410,513.77	3,750,157.45	273.7	1,517	Long Beach B
N/A	Felix-1	Conoco Felix 1	400,736.56	3,757,721.06	160.9	11,109	“Repetto”
N/A	FM-6	FM-6	414,437.16	3,751,123.36	254.9	405	Long Beach A
N/A	FN-2	CHEV-FN2	411,450.34	3,750,218.15	258.9	743	Long Beach A
N/A	FR-324	FR-324	388,776.44	3,735,762.03	17.0	6,486	Long Beach B
N/A	Gar4-1	Gardena4-1	379,423.06	3,750,619.90	49.5	10,288	Long Beach C
N/A	GG-22	GG-22	406,419.86	3,739,181.92	46.4	1,040	Pacific
N/A	GGM-2	GGM-2	406,384.37	3,737,695.22	45.3	2,057	Lower Wilmington
4S/11W-25J4	GGM-3	GGM-3	409,651.26	3,739,920.27	78.1	2,025	Bent Spring
N/A	Harada1	Vaughn Harada 1	402,216.09	3,742,385.32	40.4	4,823	Long Beach A
N/A	HEA-1	MOBL-HEA1	405,994.21	3,747,973.64	61.4	6,689	Long Beach C
N/A	HUBP1	HUMB-BP1	408,199.05	3,748,140.19	80.2	9,564	Long Beach C
N/A	Imp8	Improv.8	372,695.60	3,746,845.14	109.2	3,629	Long Beach C
N/A	KB-1	Kim-Bell 1	382,788.95	3,747,652.61	26.5	8,090	Long Beach A
N/A	L-165	L-165	387,636.55	3,735,004.66	17.3	3,620	Long Beach C
N/A	LAM-1	LAM-1	401,204.52	3,740,038.64	22.4	2,211	Lower Wilmington
N/A	Ll-Dab1	Lloyd-Dabney 1	374,261.23	3,747,442.18	102.5	6,263	Long Beach C
N/A	LP-WALK	LP-WALK	404,079.79	3,747,455.52	48.2	1,020	Harbor
N/A	LT EH1	La Tijera E.H. 1	382,646.80	3,762,183.31	181.9	9,763	“Repetto”
N/A	M231D	M231D	387,239.61	3,736,876.29	13.5	3,895	Long Beach C
N/A	M316D	M316D	387,130.88	3,736,963.19	9.8	4,065	Long Beach C
N/A	M421D	M421D	387,120.64	3,737,240.66	7.5	6,060	Long Beach C
N/A	M496D	M496D	386,976.87	3,737,356.81	-0.8	2,952	Long Beach C

Table B1. Control wells used for identification of chronostratigraphic unit boundaries, Los Angeles Coastal Plain, California.—Continued

[ID, identification; NAD 83, North American Datum of 1983; UTM, Universal Transverse Mercator; NAVD 88, North American Vertical Datum of 1988; N/A, not assigned]

State well number	Well abbreviation (fig. B3)	Well ID	Easting, NAD 83, UTM zone 11N (meters)	Northing, NAD 83, UTM zone 11N (meters)	Land surface elevation, NAVD 88 (feet)	Well depth below land surface (feet)	Oldest chronostratigraphic unit penetrated/ identified
N/A	McNB10-1	McNally B 10-1	406,389.37	3,754,035.52	212.5	10,000	Long Beach C
N/A	MidWT	Midland Water Trust	387,876.63	3,751,072.36	67.4	875	Bent Spring
N/A	Mont#1	Montebello #1	396,846.70	3,760,665.88	168.4	660	Upper Wilmington B
N/A	MW16	MW16	401,492.78	3,757,951.13	153.5	182	Lower Wilmington
N/A	MW17	MW17	401,264.18	3,757,463.42	159.4	192	Lower Wilmington
N/A	MW23	MW23	402,203.78	3,758,349.18	149.4	192	Harbor
N/A	NC1A	CSOC-NC1A	401,092.75	3,752,028.98	93.9	14,971	Pre-Repetto Rocks
N/A	NWU53-1	NWU53-1	384,362.53	3,739,725.68	37.1	3,884	“Repetto”
N/A	OW1B	OW1B	403,542.85	3,759,236.76	207.4	132	Harbor
N/A	OW4B	OW4B	403,317.04	3,759,072.35	185.0	132	Harbor
N/A	OW7	OW7	403,600.40	3,759,301.60	217.9	92	Harbor
N/A	OW8B	OW8B	403,480.04	3,759,212.79	201.4	143	Harbor
N/A	PDEU-1	UP PD-EU-1	386,585.52	3,737,556.86	9.5	5,575	Long Beach C
N/A	PR2080	Pico Rivera2080	401,698.39	3,764,214.26	192.3	1,030	“Repetto”
N/A	QUI-HIL1	QUIN-HIL1	412,148.03	3,749,693.63	172.0	12,048	“Repetto”
N/A	RivFee1	LA River Fee 1	385,760.12	3,767,387.46	266.7	4,618	“Repetto”
N/A	SBCH	SCWC-SBCH	408,016.93	3,738,641.52	54.2	600	Pacific
N/A	SBM-1	SBM-1	403,361.92	3,735,933.99	18.4	2,023	Long Beach B
N/A	SRF-AS1	SURF-AS1	404,008.55	3,732,793.48	12.3	8,033	“Repetto”
N/A	SUN-ET1	SUN-ET1	409,326.60	3,749,853.50	191.0	10,671	Long Beach C
N/A	TX-364P	Texaco364P	401,282.64	3,756,174.36	158.4	7,820	“Repetto”
N/A	TX-BP5J	TEX-BP5J	410,402.80	3,747,143.32	102.2	9,577	Long Beach C
N/A	TX-BUE1	TEX-BUE1	410,280.36	3,745,970.51	105.2	9,020	Long Beach C
N/A	TX-FUL1	TEX-FUL1	409,076.44	3,747,930.18	87.2	10,010	Long Beach C
N/A	UP113R	3U5C UP113R	386,367.11	3,737,976.43	-0.5	3,629	Long Beach C
N/A	VirgCC1	Chevron Virg. CC 1	388,678.44	3,745,301.35	39.5	12,047	Long Beach B
N/A	VulDR1	Vulcan Del Rey 1	367,027.68	3,760,935.10	13.1	7,363	Long Beach C
N/A	WatA1	Watson A 1	383,810.27	3,740,698.32	54.5	4,501	“Repetto”
N/A	X-89	X-89	387,311.86	3,736,270.93	12.5	2,695	Long Beach C
N/A	Y-112	Y-112	387,646.38	3,735,880.07	12.5	3,951	Long Beach C
N/A	Y-126	Y-126	387,384.93	3,736,104.83	12.5	3,632	Long Beach C
N/A	Y-156	Y-156	387,385.92	3,736,016.97	24.0	3,135	Long Beach C

Chronostratigraphic unit boundaries were inferred from the logs using stacking patterns identified from the graphic and electric logs, and then tied to nearby mapped unconformities identified in the seismic-reflection profiles. Characteristics used to identify chronostratigraphic unit boundaries from lithologic and geophysical logs include (1) abrupt changes in lithologic character, often a coarse sand or gravel overlying a silt/clay; (2) changes in stacking pattern character, such as change from coarsening-upward cycles to fining- upward cycles; (3) changes in sediment color, typically reddening suggestive of soil rubification or oxidation; (4) the presence of organic material, carbonate, or both, or other cementation; (5) changes in described density, stiffness, or shear-wave velocity (where such data were available); (6) abrupt changes in drilling rate; and (7) changes in the character and trend with depth of spontaneous potential curves, all of which are possible indicators of buried soils, substantial changes in consolidation that likely would signify an unconformable boundary, or changes in water chemistry.

Analysis of Seismic-Reflection Profiles

In addition to the well and borehole data, 183 seismic-reflection profiles collected by the USGS and the oil industry were used to help identify chronostratigraphic unit boundaries (fig. B3). The oil-industry profiles were either obtained by the Southern California Earthquake Center (SCEC) and made available for this study or were licensed and provided to the USGS by the WRD. These oil-industry profiles, however obtained, are proprietary and cannot be released without written permission from the owner.

Unconformities can be observed in the seismic data, based on the occurrence of onlap, downlap, toplap, and truncation of seismic reflectors (fig. B4). Unconformities and seismic reflectors correlative with these surfaces were identified and digitized using Landmark® seismic interpretation software (Halliburton Landmark in Houston Texas) in the time-domain, and then converted to elevations using the SCEC Community Velocity Model - Harvard (CVM-H) velocity model (Süss and Shaw, 2003; Plesch and others, 2007). Some uncertainties are inherent in the time-to-depth conversions of the seismic data, and in some instances, computed seismic horizon depths do not agree precisely with the chronostratigraphic unit boundary depths identified from boreholes. However, the depth discrepancies are less than 10 percent in most cases. Where borehole control exists near the seismic lines, chronostratigraphic boundaries defined from the seismic data were locally adjusted to conform with the borehole depths.

Analysis of Surficial Geology

Another purpose of identifying chronostratigraphic boundaries was to correlate mapped surficial geologic units with the chronostratigraphic units identified from subsurface data (figs. B1, B2). For the mapped young, old, and very old alluvial fans and eolian deposits, this correlation process is relatively straightforward because the original depositional surfaces of these deposits are preserved, and geologists have subdivided the deposits by relative stratigraphic position, not by lithologic character. Therefore, these map units are chronostratigraphic units, and the exposed depositional surfaces of these fans are unconformities that can be projected with some confidence into the subsurface.

For older map units that were defined lithostratigraphically, the associations with the chronostratigraphic units identified in the subsurface are less clear. For the older Pleistocene and Pliocene deposits exposed along the eastern margin of the LACP, Durham and Yerkes (1964) and Yerkes (1972) reported that they are unconformably bounded where exposed. Therefore, the ages of the mapped La Habra, Coyote Hills, and San Pedro Formations, and upper Fernando Formation deposits likely do not overlap, and while their original depositional surfaces are no longer entirely preserved, these formations can be reasonably projected to subsurface chronostratigraphic units by estimating the likely location of the original depositional tops using dip and thickness data. Correlation of mapped surficial deposits to the subsurface chronostratigraphic units in the southwestern part of the LACP was constrained by amino-acid dating and other chronostratigraphic controls (Ponti, 1989; Ponti and others, 2007; McDougall and others, 2012).

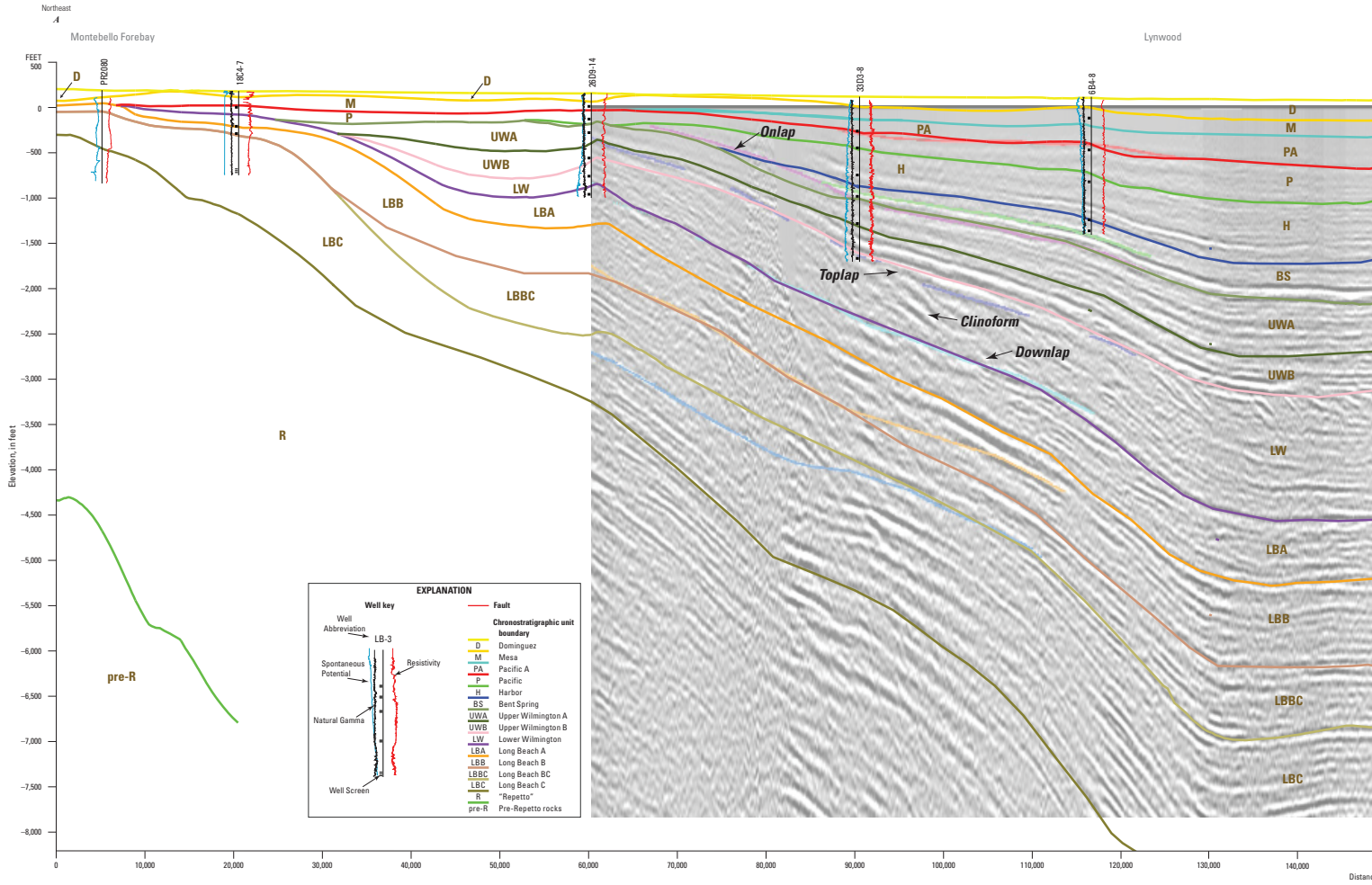
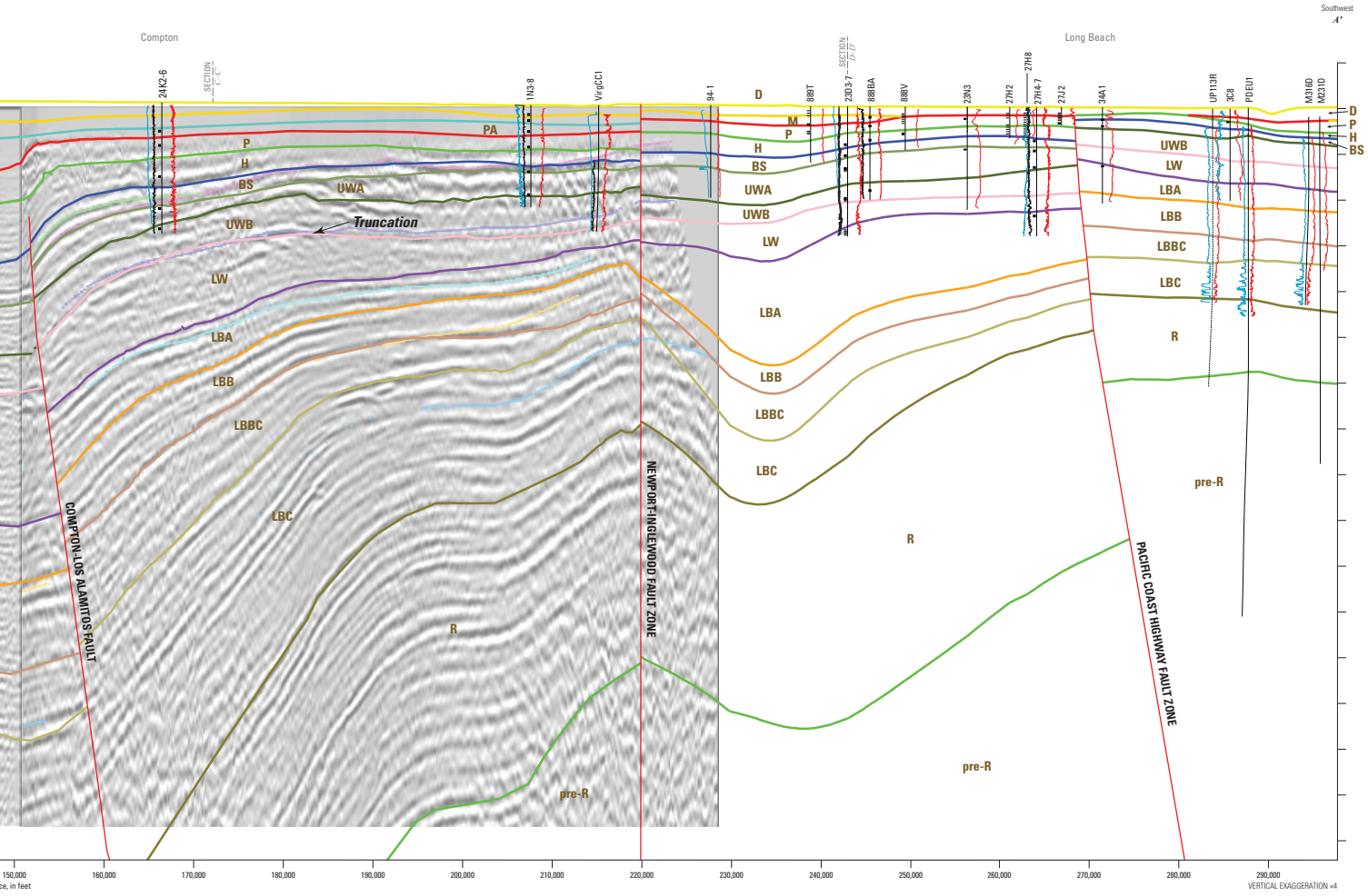


Figure B4. Chronostratigraphic unit boundaries on seismic profile along cross-section A–A', Los Angeles Coastal Plain, California. (Trace of section is shown in fig. B1; colored lines mark the top of each unit; unit identifier codes: D, Dominguez; M, Mesa; PA, Pacific A; P, Pacific; H, Harbor; BS, Bent Spring; UWA, Upper Wilmington A; UWB, Upper Wilmington B; LW, Lower Wilmington; LBA, Long Beach A; LBB, Long Beach B; LBBC, Long Beach BC; LBC, Long Beach C; R, "Repetto"; pre-R, pre-Repetto rocks). Examples of unconformable contacts shown with arrows. Seismic images (Texaco lines 8582-13 and 8582-14) courtesy of Southern California Earthquake Center and closely parallel section. See fig. B1 for section location; table B1 for more information on control wells. Vertical exaggeration 4:1.


Compton
Long Beach
Southwest
A'
SECTION C-C'
SECTION D-D'
24K2-6
1N3-8
VrgCC1
94-1
88BT
23D3-7
88BBA
88BV
23N3
27H2
27H8
27H4-7
27J2
34A1
UP113R
3C8
PDEU1
M316D
M231D
D
M
P
H
BS
PA
UWA
UWB
LW
LBA
LBB
LBBC
LBC
R
pre-R
Truncation
COMPTON-LOS ALAMITOS FAULT
NEWPORT-INGLEWOOD FAULT ZONE
PACIFIC COAST HIGHWAY FAULT ZONE
150,000
160,000
170,000
180,000
190,000
200,000
210,000
220,000
230,000
240,000
250,000
260,000
270,000
280,000
290,000
ce, in feet
VERTICAL EXAGGERATION ×4

Analysis of Water-Level and Water-Quality Data to Refine Chronostratigraphic Unit Boundaries

Following the initial identification of chronostratigraphic unit boundaries, their locations were refined using water-level hydrographs and water-quality data (appendix 1, fig. 1.2) collected from WRD/USGS multiple-well monitoring sites. Water-level hydrographs and water-quality data (dissolved-solids concentration, general chemical character, and isotopic composition) from nearby wells screened in the same chronostratigraphic unit were compared to check if they were similar. Wells in adjacent chronostratigraphic units could have similar water-level hydrographs and water-quality characteristics, but where nearby wells inferred to be in the same unit displayed different water-level hydrographs or water-quality characteristics, we assumed that there was a problem with the correlation, and adjusted boundaries accordingly. In most cases, only minor adjustments to boundary locations were needed to be consistent with the water-level and water-quality data while remaining consistent with structural constraints from the seismic data. However, in a few cases, chronostratigraphic unit boundary locations could not be adjusted without violating structural constraints. This usually occurred in areas near fold crests, where thinning and pinching out of reflectors in seismic profiles were commonly observed. As a result, these folds likely act as barriers to groundwater flow even though no fault is present. These potential barriers were noted so that they could be properly simulated in the groundwater-flow model developed as part of this study (see Chapter D).

Chronostratigraphic Model Construction

Modeled surfaces that represent the tops of the chronostratigraphic units, known as horizons, were constructed as grids using EarthVision® software (Dynamic Graphics, Alameda, California). The grids have a cell size of 492 by 656 ft (150 by 200 meters) and are rotated 42 degrees counter-clockwise from true north; this orientation was chosen in order to best reflect the structural grain of the northwest-trending faults and folds. Horizon gridding is the process used to produce these grids and was performed using EarthVision's minimum-tension gridding algorithm, which calculates a smooth surface that closely fits the input data values using a bicubic spline technique. Fault surfaces derived from the Southern California Earthquake Center Community Fault Model (Plesch and others, 2007), or identified as part of this study, were also gridded using minimum tension, and the resulting fault grids were used to divide the model space into fault blocks to control horizon gridding within each block. In addition to control points from boreholes, seismic-reflection profiles, and surficial outcrops, additional control points were added to the model as necessary to constrain interpolation and extrapolation of horizons in areas where data were sparse. Horizon gridding was an iterative process, where horizons were alternately calculated and then used as reference surfaces to constrain the gridding of adjacent horizons in order to preserve fold trends and to prevent inadvertent horizon pinchouts. Once the horizon grids within each fault block were constructed, the grids were intersected and assembled to produce a solid framework model that reveals the complexity of the underlying LACP's structure.

Modeled Chronostratigraphic Units

The chronostratigraphic framework model developed for this study includes 13 chronostratigraphic units of late Pliocene to Quaternary age and 2 units consisting of consolidated rocks of mid-Pliocene and older age, herein referred to as "bedrock units" (figs. B4–B6; table B2). The age of each unit, inferred depositional environments, and local correlations to lithostratigraphic units and previously published aquifer units are presented in table B2. Because the chronostratigraphic framework generally is described differently than the geologic formations and aquifer framework of the California Department of Water Resources (1961) that were defined lithostratigraphically, we use a different set of informal names for the Pliocene and Pleistocene chronostratigraphic units, following the nomenclature introduced in Ponti and others (2007) for the Long Beach area. We then correlate the Pleistocene units to the paleomagnetic and marine oxygen isotope records based on age estimates reported in Ponti and others (2007) and McDougall and others (2012).

Bedrock Units

The pre-Repetto Rocks and the "Repetto," the lowermost two units in the chronostratigraphic framework model, are consolidated rocks of mid-Pliocene and older age. They are included in the model to provide structural context and constraints for the overlying units that are the primary focus of this study. Data used to define these units come primarily from published sources (Wright, 1991; Saucedo and others, 2003; Morton and Miller, 2006), except where noted.

Pre-Repetto Rocks

The pre-Repetto Rocks unit serves as the base of the regional chronostratigraphic framework model. Its upper surface is derived from structure contours and cross-sections on the "Base of Repetto" of Wright (1991). This boundary is thought to be at about 4.5 million years (Ma) old (Wright, 1991). Below this surface, we do not subdivide the underlying rocks, so the volume of the pre-Repetto Rocks unit incorporates several Miocene formations, as well as Paleogene sediment and Mesozoic crystalline rocks that crop out along the margins of the LACP. The top of the pre-Repetto Rocks unit reaches a minimum elevation of greater than 18,000 ft below NAVD 88 in the Central Basin (Wright, 1991).

"Repetto"

The term "Repetto" has been used commonly since the 1930s to describe generally deep-water marine sediment of Pliocene age encountered in the subsurface of the Los Angeles area (Reed, 1933; Kew, 1937) and is defined on the basis of microfaunal zones (Natland, 1953; Natland and Rothwell, 1954; Blake, 1991). Therefore, as defined by these authors, the "Repetto" is a biostratigraphic unit and, because of the time-transgressive nature of the microfaunal zones, it is not a chronostratigraphic unit. Durham and Yerkes (1964) have argued for the term "lower Fernando Formation" to describe these rocks in outcrop. We use the term "Repetto" in this study to define rocks that lie between the "pre-Repetto" surface, and a horizon defined by an apparent unconformity identified in seismic reflection profiles in the Central Basin. Near the basin margins, this horizon appears correlative with the top of exposed lower Fernando Formation and with the top of the "Repetto," as represented in cross-sections by Wright (1991), but lies above (is younger than) Wright's top of the "Repetto" in the center of the Central Basin. The age of the "Repetto" unit generally is constrained to be between approximately 3 and 4.5 Ma. The top of the Repetto Rocks unit reaches a minimum elevation of more than 8,000 ft below NAVD 88 in the Central Basin (fig. B4; Wright, 1991).

Late Pliocene and Quaternary Chronostratigraphic Units

Thirteen chronostratigraphic units have been identified that overlie the bedrock units and range in age from latest Pliocene through Holocene (table B2). Chronostratigraphic units contain the water-bearing sediment within the LACP. Descriptions of the 13 units are based on work by Ponti and others (2007), McDougall and others (2012), Ponti and others (2014), and Ehman and others (2014). Descriptions of the units were refined as appropriate for this study based on geophysical and other data collected as part of USGS studies in the LACP. Overall, the distribution of various facies within the units reflects the shoaling of the Los Angeles Basin over time, which largely controls the distribution of coarse-grained deposits that form the aquifers. For each unit, we created facies maps showing the inferred distribution of various depositional environments (for example, non-marine, shallow marine and paralic, and deep marine slope and basin deposits), along with the likely location of coarse-grained sandy fan, delta and axial channel deposits that would likely comprise the more productive aquifers. Facies maps were constructed using grain-size descriptions from available geologic logs, geophysical log signatures, and microfossil data, along with selected water-quality data (for example, chloride-to-boron ratios and strontium isotope data; appendix 1, figs. 1.5, 1.6). Facies assignments for each unit were made at control wells based on the dominant lithology and geophysical log signature that was present over the entire thickness of the unit. Boundary locations were estimated from the control well locations supplemented by the strontium-isotope data, which were used to determine likely source drainages (appendix 1). Estimates of boundary locations were qualitative interpretations based on sparse data in many of the units and were not directly used in the groundwater-flow model (Chapter D).

Long Beach C

The Long Beach C chronostratigraphic unit was identified in the Long Beach area and characterized by a thin, fining-upward sand at its base, overlain by sediment that generally coarsens upward (Ponti and others, 2007). The Long Beach C unit is inferred to be of late Pliocene age (greater than 2.6 Ma) based on microfossil and paleomagnetic constraints from the younger Long Beach B unit in the Long Beach area (McDougall and others, 2012; table B2). The Long Beach C unit is present over nearly the entire LACP, except along a portion of the LACP's northern margin, where the unit was presumably uplifted and subsequently eroded (fig. B7). In the Puente Hills area, Long Beach C is believed to be correlative with the upper Fernando Formation and is inferred to have been deposited in the neritic zone (marine waters from the low tide level to a depth of approximately 650 ft; Yerkes, 1972). However, over most of the LACP, based on very limited borehole data, Long Beach C appears to consist of bathyal deposits (sediments deposited within a deep marine basin, from depths of 600 to 13,500 ft below the ocean surface). Overall, the unit is fine-grained and consistently dominated by hemipelagic (marine sediments deposited on continental shelves and rises) silts and clays (fig. B7). Although data are sparse, the sandy nature of the unit in the West Coast Basin and Whittier Narrows area suggests the presence of one or more narrow northeast-southwest trending zones of coarse-grained deposits, likely within canyon channel systems of submarine fans that sourced from near the Whittier Narrows area and flowed toward present-day Santa Monica Bay.

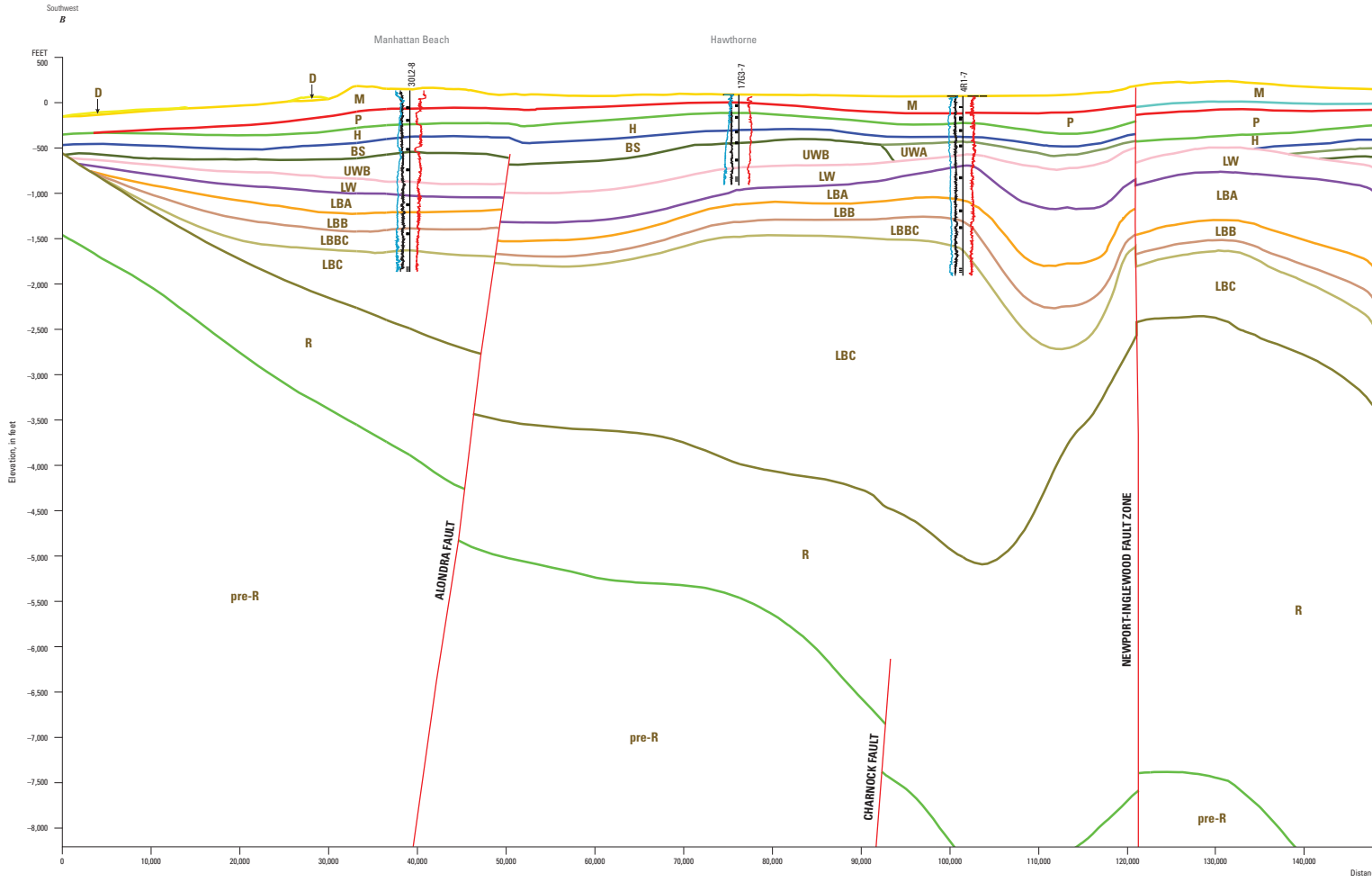
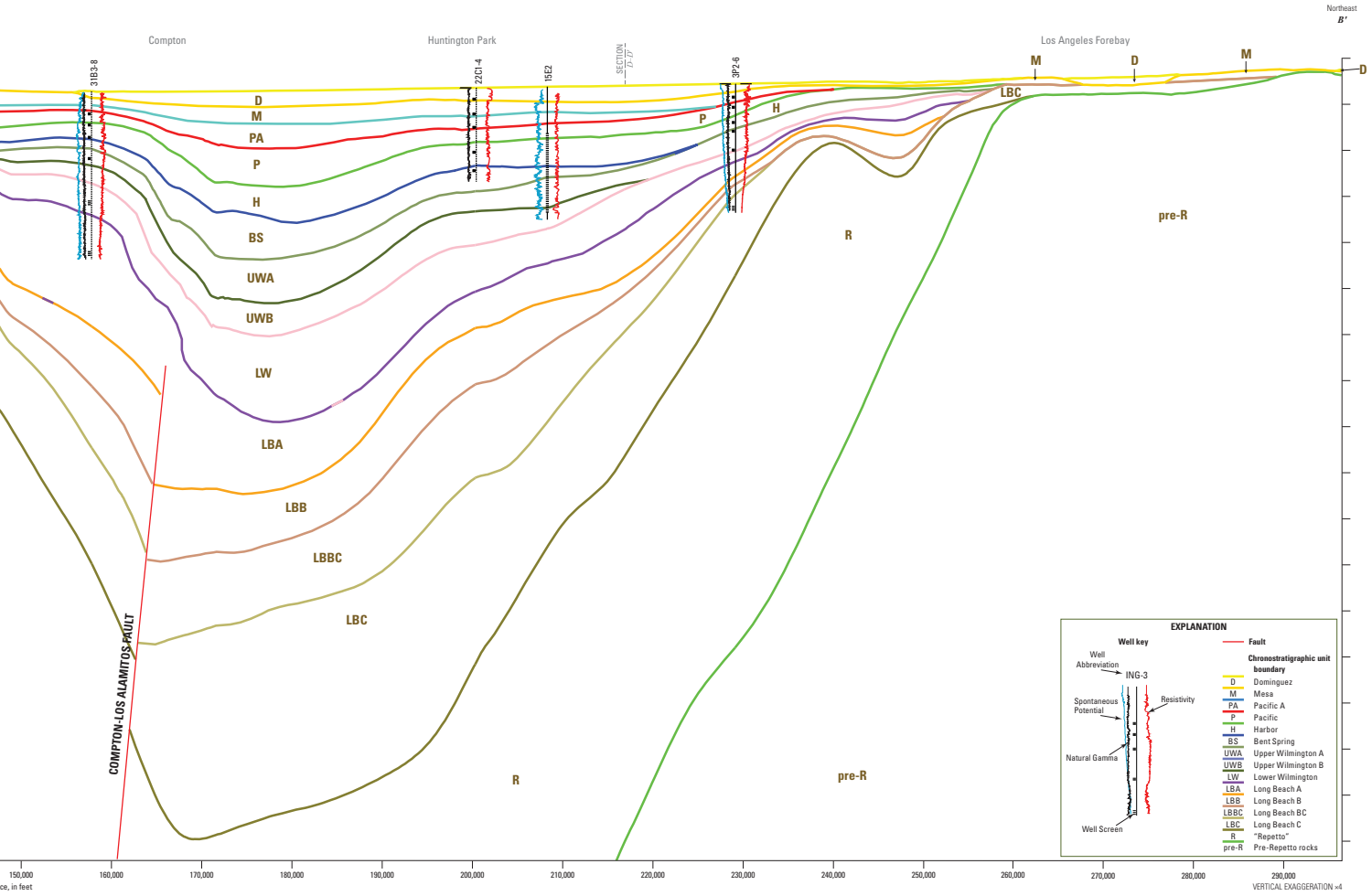


Figure B5. Modeled chronostratigraphic unit boundaries along cross-section B-B', Los Angeles Coastal Plain, California. (Trace of section is shown in fig. B1; colored lines mark the top of each unit; unit identifier codes: D, Dominguez; M, Mesa; PA, Pacific A; P, Pacific; H, Harbor; BS, Bent Spring; UWA, Upper Wilmington A; UWB, Upper Wilmington B; LW, Lower Wilmington; LBA, Long Beach A; LBB, Long Beach B; LBBC, Long Beach BC; LBC, Long Beach C; R, "Repetto"; pre-R, pre-Repetto Rocks.) Vertical exaggeration 4:1.


Northeast
B'
Compton
Huntington Park
Los Angeles Forebay
SECTION D-D'
3IB3-8
22D1-4
16E2
3P2-6
D
M
PA
P
H
BS
UWA
UWB
LW
LBA
LBB
LBBC
LBC
R
pre-R
COMPTON-LOS ALAMITOS FAULT
150,000
160,000
170,000
180,000
190,000
200,000
210,000
220,000
230,000
240,000
250,000
260,000
270,000
280,000
290,000
ce, in feet
VERTICAL EXAGGERATION ×4
EXPLANATION
Well key
Well Abbreviation
ING-3
Spontaneous Potential
Resistivity
Natural Gamma
Well Screen
Fault
Chronostratigraphic unit boundary
D Dominguez
M Mesa
PA Pacific A
P Pacific
H Harbor
BS Bent Spring
UWA Upper Wilmington A
UWB Upper Wilmington B
LW Lower Wilmington
LBA Long Beach A
LBB Long Beach B
LBBC Long Beach BC
LBC Long Beach C
R "Repetto"
pre-R Pre-Repetto rocks

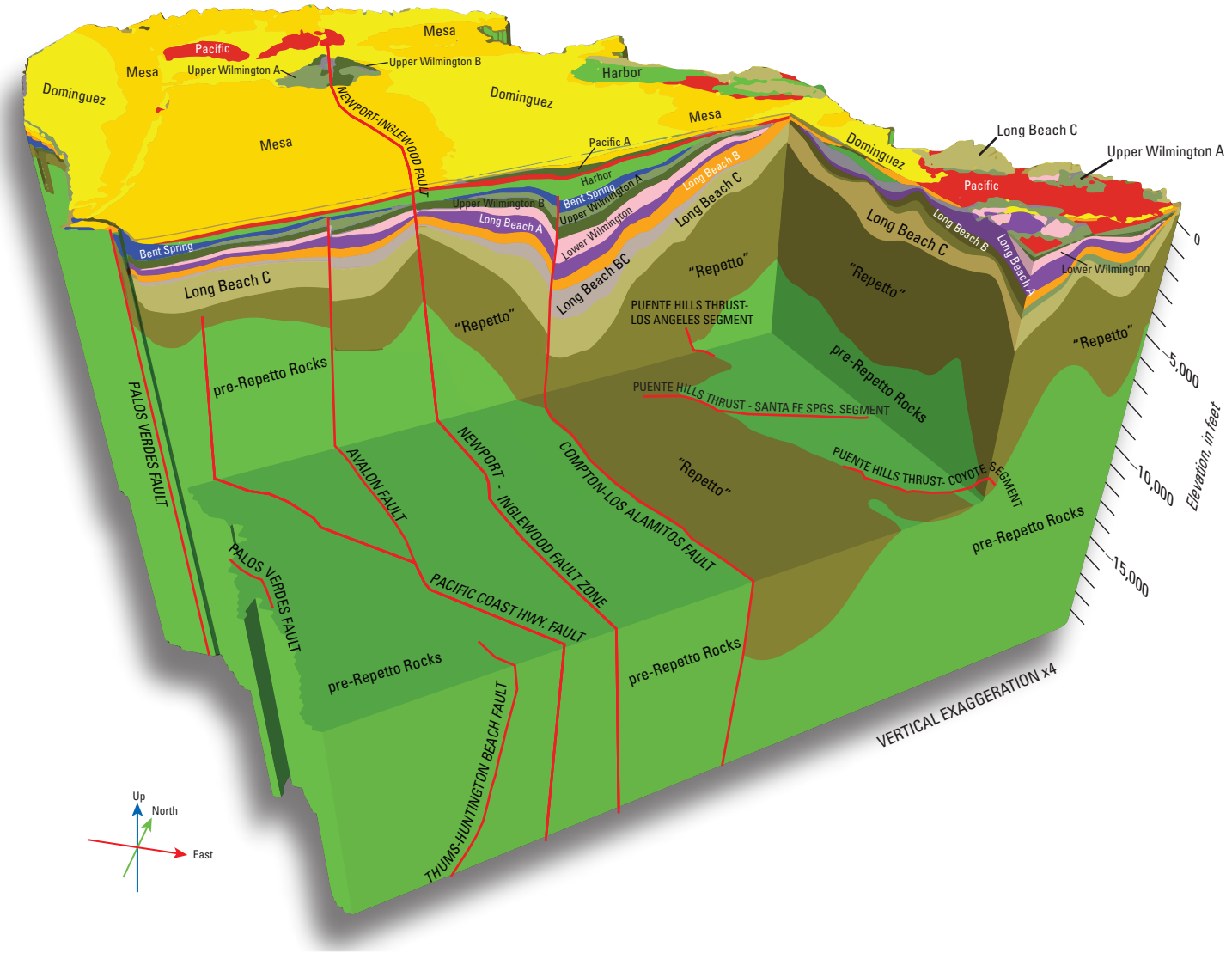


Figure B6. Three-dimensional structure model of the Los Angeles Coastal Plain study area, California.

Table B2. Modeled chronostratigraphic units, Los Angeles Coastal Plain (LACP), California.

[Unit names and age estimates derive from Ponti and others (2007) and McDougall and others (2012). Long Beach A, B, and C units are renamed here from original Pliocene A, B, and C (Ponti and others, 2007) as a result of recent redefinition in the age of the Pliocene-Pleistocene boundary (Gibbard and others, 2010). **Abbreviations**: <, less than; ≤, less than or equal to; >, greater than; ~, approximate; AAR, amino acid racemerization/epimerization; Fm., formation; ka, thousand years; Ma, million years; OSL, optically stimulated luminescence; TL, thermoluminescence; —, no data]

Unit	Estimated age range	Epoch	Age controls	Subsurface constraints	Probable correlative surficial map units (after Saucedo and others, 2003; Morton and Miller, 2006; Campbell and others, 2014)
Dominguez	<18 ka	Holocene/ latest Pleisto-cene	—	Very good; contains basal sand or gravel in many areas.	Young alluvial fan and valley deposits; alluvial wash deposits, active channel and wash deposits.
Mesa	~20–80 ka	late Pleisto-cene	OSL, possible Laschamp magnetic polarity event (~40 ka) present; AAR on marine-terrace outcrops.	Good; top surface usually marked by basal gravel of overlying Dominguez sequence.	Old alluvial fan and valley deposits (also mapped as Lakewood Fm. by California Department of Water Resources, 1961).
Pacific A	≤ 80 ka	late Pleisto-cene	Lower subdivision of Mesa sequence in Central Basin to account for variations in hydraulic character within the sequence.	Fair to poor; upper boundary arbitrary in some areas.	No known exposures.
Pacific	~97–133 ka	late Pleisto-cene	OSL, Blake magnetic polarity event (~115 ka); AAR estimates on marine-terrace outcrops.	Fair, top surface seen in seismic reflection data, but often difficult to pick due to poor resolution at depths where this horizon typically occurs.	Very old, old alluvial fan and terrace deposits (also mapped as Lakewood Fm. of California Department of Water Resources, 1961).
Harbor	~186–248 ka	middle Pleis-tocene	AAR estimates from shallow boreholes; macrofossils, TL; possible Pringle Falls magnetic polarity event (~200 ka).	No clear seismic reflector; unit often is marked by coarse-grained base and top with intervening fine-grained interval.	Very old, old alluvial fan and terrace deposits (also mapped as Lakewood Fm. of California Department of Water Resources, 1961).
Bent Spring	~295–340 ka	middle Pleis-tocene	TL; AAR estimates on terrace outcrops; Possible Pringle Falls magnetic polarity event (~200 ka) south of Pacific Coast Highway fault; otherwise unit appears to be older than ~300 ka.	Good, clear seismic reflector at top of unit in most areas.	San Pedro Sand of Palos Verdes Hills.
Upper Wilm-ington A	~340–434 ka	middle Pleis-tocene	Correlated to marine oxygen isotope record and constrained by bounding units.	Good, clear seismic reflector at top of unit in most areas.	San Pedro Formation in Baldwin Hills; La Habra Formation in Puente Hills area.
Upper Wilm-ington B	~434–536 ka	middle Pleis-tocene	Questionable Big Lost magnetic polarity event in Long Beach (~525–550 ka); correlated to marine oxygen isotope record and constrained by bounding units.	—	Inglewood Formation in Baldwin Hills.
Lower Wilm-ington	~625–780 ka (Long Beach); probably <1.0 Ma elsewhere	middle/early Pleisto-cene	Contains Lava Creek "B" ash (~0.64 Ma) in Long Beach area; Bishop ash (~0.76 Ma) and magnetically reversed sediment (>0.78 Ma) in a northern portion of the Central Basin is inferred to belong to this unit (Quinn and others, 2000).	Top surface is marked by a clear seismic reflector in most areas. Poorly defined lower boundary is likely older in Central Basin.	Coyote Hills Formation in Coyote Hills.

Table B2. Modeled chronostratigraphic units, Los Angeles Coastal Plain (LACP), California.—Continued

[Unit names and age estimates derive from Ponti and others (2007) and McDougall and others (2012). Long Beach A, B, and C units are renamed here from original Pliocene A, B, and C (Ponti and others, 2007) as a result of recent redefinition in the age of the Pliocene-Pleistocene boundary (Gibbard and others, 2010). **Abbreviations**: <, less than; ≤, less than or equal to; >, greater than; ~, approximate; AAR, amino acid racemerization/epimerization; Fm., formation; ka, thousand years; Ma, million years; OSL, optically stimulated luminescence; TL, thermoluminescence; —, no data]

Unit	Estimated age range	Epoch	Age controls	Subsurface constraints	Probable correlative surficial map units (after Saucedo and others, 2003; Morton and Miller, 2006; Campbell and others, 2014)
Long Beach A[1]	~0.9–1.2 Ma, possibly as old as ~1.9 Ma	early Pleistocene (?)	Apparent lower Pleistocene planktic fauna; but normal polarity indicates deposition during the Santa Rosa, Jaramillo, or Cobb Mountain chrons (0.92–1.18 Ma) or the Olduvai chron (1.77–1.95 Ma).	Poorly defined–not often distinguishable from Long Beach B or Lower Wilmington in seismic profiles.	San Pedro Formation in Coyote Hills.
Long Beach B[2]	~2.0 Ma or possibly >2.6 Ma	early Pleistocene to late Pliocene (?)	Apparent lower Pleistocene planktic fauna in Long Beach, but normal polarity paleomagnetic signature could place the unit within the Olduvai chron (1.77–1.95 Ma).	Fair, generally marked by thick sands in electric logs, top marked by clear seismic reflector.	No known exposures.
Long Beach BC	~2.0 Ma or possibly >2.6 Ma	early Pleistocene to late Pliocene (?)	Stratigraphically located between Long Beach B and Long Beach C. May be basal portion of Long Beach B and therefore closer to it in age.	Fair to poor. Upper boundary not clearly unconformable in seismic imaging.	No known exposures.
Long Beach C[3]	>2.6 Ma	late Pliocene	Probable Pliocene age based on microfossil and paleomagnetic constraints in overlying Long Beach B unit in Long Beach area. Normal polarity indicates unit is within the Gauss chron (>2.58 Ma).	Good, clear seismic reflector marks top of unit in most areas.	Fernando Formation, upper member.
"Repetto"	~3–4.5 Ma	Pliocene	Benthic fauna.	Based on cross-sections in Wright (1991) and clear seismic horizon in Central Basin; seismic horizon appears correlative with biostratigraphically-defined Repetto near margins of the basin, but may be younger elsewhere.	Not exposed within, but forms part of the boundary of the LACP within the Elysian, Repetto, and Puente Hills. Bounding surficial units include lower member of the Fernando Fm. and Repetto Fm. of Wright (1991)
Pre-Repetto Rocks	>4.5 Ma	Miocene and possibly older	Benthic fauna.	Based on sections and structure contours in Wright (1991).	Not exposed within, but forms part of the boundary of the LACP within the Santa Monica Mountains, Elysian, Repetto, Puente, and Palos Verdes Hills. Bounding surficial units include Mesozoic crystalline and metamorphic rocks, and Calabasas,Topanga, Modelo, Monterey, and Puente Formations.

Table B2. Modeled chronostratigraphic units, Los Angeles Coastal Plain (LACP), California.—Continued

[Unit names and age estimates derive from Ponti and others (2007) and McDougall and others (2012). Long Beach A, B, and C units are renamed here from original Pliocene A, B, and C (Ponti and others, 2007) as a result of recent redefinition in the age of the Pliocene-Pleistocene boundary (Gibbard and others, 2010). **Abbreviations**: <, less than; ≤, less than or equal to; >, greater than; ~, approximate; AAR, amino acid racemerization/epimerization; Fm., formation; ka, thousand years; Ma, million years; OSL, optically stimulated luminescence; TL, thermoluminescence; —, no data]

Unit	Comparison Site 1 (figs. B1 and B20)			Comparison Site 2 (figs. B1 and B21)			Comparison Site 3 (figs. B1 and B22)		
	Inferred depositional environments	Lithostratigraphic unit from California Department of Water Resources (1961)	Aquifer(s) from California Department of Water Resources (1961)	Inferred depositional environments	Lithostratigraphic unit from California Department of Water Resources (1961)	Aquifer(s) from California Department of Water Resources (1961)	Inferred depositional environments	Lithostratigraphic unit from California Department of Water Resources (1961)	Aquifer(s) from California Department of Water Resources (1961)
Dominguez	not present	—	—	Alluvial fan and stream channel	Recent alluvium	Gaspur	Alluvial fan/ flood basin	Recent alluvium/ Lakewood Fm.	Artesia
Mesa	Alluvial fan/ flood basin	Lakewood Fm.	perched water	Alluvial fan	Lakewood Fm.	Exposition	Alluvial fan/ flood basin	Lakewood Fm.	Artesia/ Gage
Pacific A	not present	—	—	Paralic/inner neritic	Lakewood Fm./ San Pedro Fm.	Gage	Paralic	San Pedro Fm.	Hollydale
Pacific	Alluvial fan/ flood basin	San Pedro Fm.	Gardena	Paralic/inner neritic	San Pedro Fm.	Hollydale	Inner neritic/ paralic	San Pedro Fm.	Lynwood/ Silverado
Harbor	Paralic/inner neritic	San Pedro Fm.	Lynwood	Paralic/inner neritic	San Pedro Fm.	Lynwood/ Silverado	Neritic	San Pedro Fm./ Pico Fm.	Sunnyside
Bent Spring	Inner neritic	San Pedro Fm.	Silverado	Inner neritic	San Pedro Fm.	Silverado	Neritic	—	—
Upper Wilmington A	not present			Inner neritic	San Pedro Fm.	Sunnyside	Neritic	Pico Fm.	—
Upper Wilmington B	Outer neritic	San Pedro Fm.	Silverado	Inner neritic	Pico Fm.	—	Bathyl marine (slope facies)	Pico Fm.	—
Lower Wilmington	Bathyl marine (slope facies)	San Pedro Fm.	Sunnyside (nearby)	Neritic	Pico Fm.	—	Bathyl marine (slope facies)	Pico Fm.	—
Long Beach A[1]	Bathyl marine	Pico Fm./San Pedro Fm.	—	Outer neritic/ upper slope	Pico Fm.	—	Bathyl marine	Pico Fm.	—
Long Beach B[2]	Bathyl marine	Pico Fm.	—	Bathyl marine (slope facies)	Pico Fm.	—	Bathyl marine	Pico Fm.	—
Long Beach BC	Bathyl marine	Pico Fm.	—	Bathyl marine (slope facies)	Pico Fm.	—	Bathyl marine	Pico Fm.	—
Long Beach C[3]	Bathyl marine	Pico Fm.	—	Bathyl marine	Pico Fm.	—	Bathyl marine	Pico Fm.	—
"Repetto"	Bathyl marine	Pliocene formations	—	Bathyl marine	Pliocene formations	—	Bathyl marine	Pliocene formations	—
Pre-Repetto Rocks	Marine	Miocene formations	—	Marine	Miocene formations	—	Marine	Miocene formations	—

[1]Upper-, [2]Middle-, and [3]Lower-Long Beach of McDougall and others (2012).

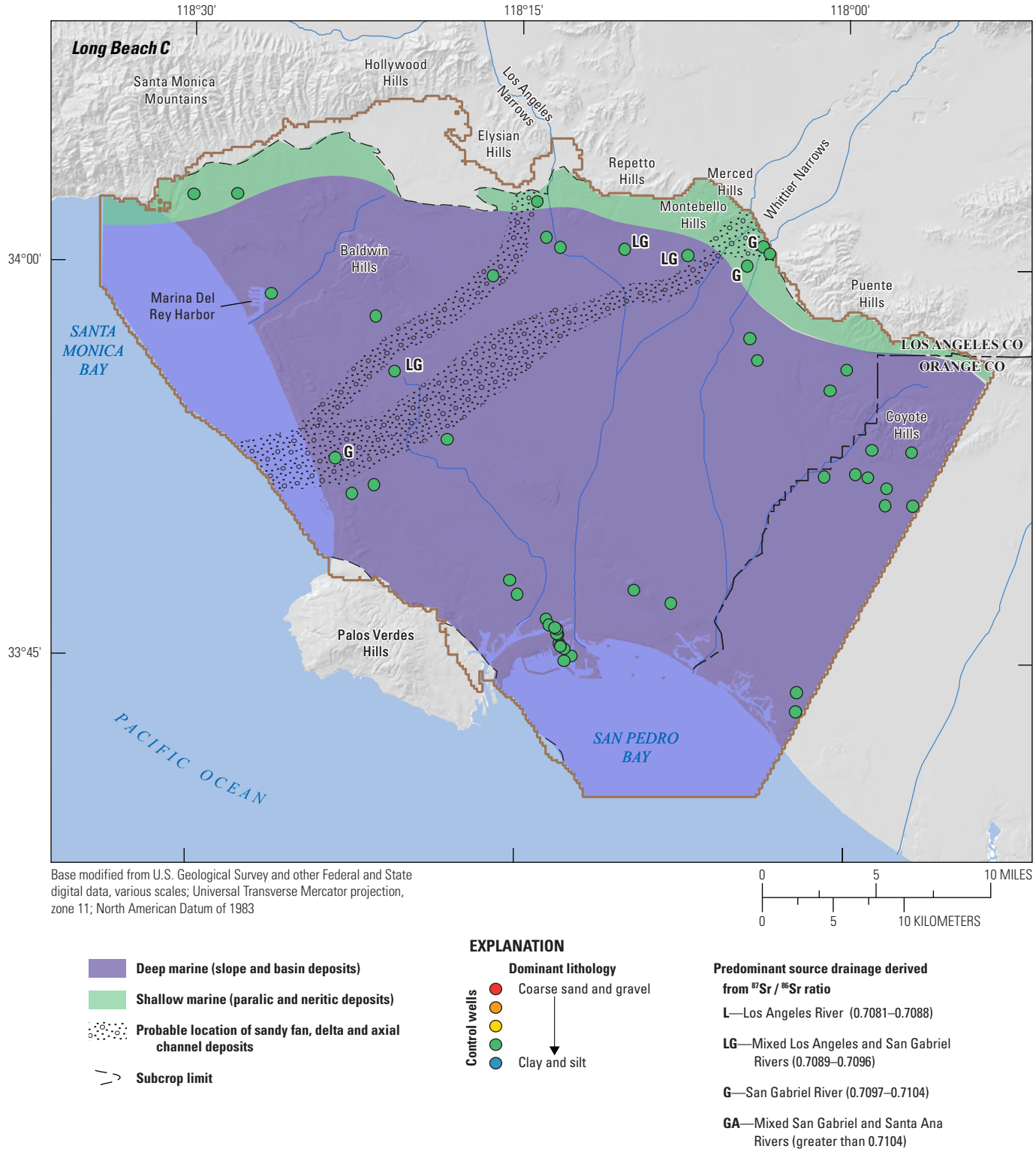


Figure B7. Inferred facies distribution of the Long Beach C chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

Long Beach BC

The Long Beach BC chronostratigraphic unit is dominantly composed of deep-marine deposits and was distinguished from Long Beach C using hydrographs from wells screened in Long Beach BC in the West Coast Basin. For example, 3S/14W-4R1 to 4R7 (4R1-7; fig. A3) and 3S/14W-30L2 to 30L8 (30L2-8; fig. A3) show the water levels in the Long Beach BC unit were consistently lower than in the underlying Long Beach C unit (by approximately 13 ft in 4R1-7) and consistently higher than in the overlying Long Beach B unit (by approximately 18 ft in 4R1-7). Evidence for erosion, onlap, or toplap at the top of the unit cannot be discerned from seismic reflection data, so we cannot determine if the Long Beach BC unit is bounded by unconformities or is just a conformal unit that comprises the lowermost part of the Long Beach B unit; therefore the ages of the Long Beach BC and Long Beach B units are comparable. The combined thickness of the Long Beach C and Long Beach BC units exceeds 2,500 ft in the Central Basin (fig. B6). The extents and inferred distributions of sedimentary facies and source areas of the Long Beach BC unit are likely similar to the Long Beach C unit (fig. B8), but our interpretation is limited because there are only a few data points available.

Long Beach B

The Long Beach B chronostratigraphic unit in the Long Beach area was described by Ponti and others (2007) as a generally fining-upward unit, possibly reflective of a marine transgression, with a sandy base eventually grading up into silts. In the northeastern part of the Central Basin, the unit is characterized by a basal fining-upward section overlain by a generally coarsening-upward package indicative of high-stand progradation. This coarsening-upward section of the unit is more than 150 ft thick, and, several production wells in the northeastern LACP are screened in this unit.

Microfossil and paleomagnetic data from two core holes in the Long Beach area indicate an early Pleistocene to late Pliocene age for the Long Beach B unit. Planktic foraminifera suggest correlation with a Northern Hemisphere glaciation from approximately 2.75 to 2.0 Ma and an early Pleistocene warm period at about 2 Ma. However, paleomagnetic analysis likely correlates the Long Beach B unit with the Olduvai Normal Polarity Subchron (1.95–1.77 Ma); this age range corresponds with the ages predicted by the planktic foraminifera, but substantially restricts the age range of this unit (McDougall and others, 2012). While the Long Beach B unit possibly could be of late Pliocene age (greater than 2.6 Ma) based on the microfossils, fossil reworking is probable, and the younger age for the unit (approximately 2 Ma) may be more likely.

The top of Long Beach B is marked by a well-defined seismic reflector that locally exhibits evidence of truncation. The unit reaches a maximum thickness of approximately 650 ft in the Central Basin (fig. B4). Based on the character of electric logs, compared with the Long Beach C and Long Beach BC units, there is evidence for a broader shelf of neritic deposits extending westward from the northeast margin of the LACP. Sandy sediment appears to have been transported dominantly from the Whittier Narrows area and likely flowed southward via submarine fan channels to San Pedro Bay based on the presence of coarse-grained turbidite sands in the Long Beach harbor area, (fig. B9).

Long Beach A

The Long Beach A chronostratigraphic unit was identified in the Long Beach area based on a distinctive electric-log signature and strong, regionally extensive reflector offshore in San Pedro Bay (Ponti and others, 2007). However, in the Central Basin, the top of the Long Beach A unit is difficult to discern in oil industry seismic-reflection data, and no clear unconformable seismic horizon corresponding to the top of this unit is recognized.

Microfossil and paleomagnetic data from the Long Beach A unit in the Long Beach area indicate an age similar to that of the Long Beach B unit (for example, approximately 2.0 Ma; McDougall and others, 2012). In Long Beach, the top of the Long Beach A unit represents a major hiatal surface and there is a substantial section missing above this horizon (Ponti and others, 2007). A substantial increase in clay stiffness below Long Beach A at multiple-well monitoring site 2E1-2 (5S/13W-2E1 to 2E2) suggests Long Beach A may be substantially younger than Long Beach B and was perhaps in part deposited during an interval of normal magnetic polarity between about 0.92 and 1.18 Ma (McDougall and others, 2012). In the Central Basin and the southern part of the study area where basin subsidence was greater and more of the section is presumably preserved, the Long Beach A unit likely is younger than in the Long Beach area, where this unit is probably representative of only the older part of the unit.

We tentatively infer the subsurface Long Beach A unit to be roughly correlative with exposures of the San Pedro Formation in the Coyote Hills, where analysis of macrofossils and a strontium-isotope age determination of 1.4 plus or minus (±) 0.4 Ma from a bivalve, *Patinopecten caurinus* (Gould, 1850), collected from the upper part of the San Pedro Formation indicates a lower Pleistocene age (Powell and Stevens, 2000). If this correlation is valid, the Long Beach A unit reflects an inner neritic environment in the Coyote Hills.

The presumed shelf/slope boundary during deposition of the Long Beach A unit, approximated as the boundary between inferred shallow marine (neritic) and deep marine (bathyal) deposits, appears similar to that of the Long Beach B unit (fig. B10). The main source of deposits is from the Whittier Narrows area, and overall, the unit is predominantly fine-grained (fig. B10). Available well data suggest that several linear zones of predominantly sandy deposits (likely submarine fan axial channel deposits) extend from the Whittier Narrows area to the south and southeast (fig. B10).

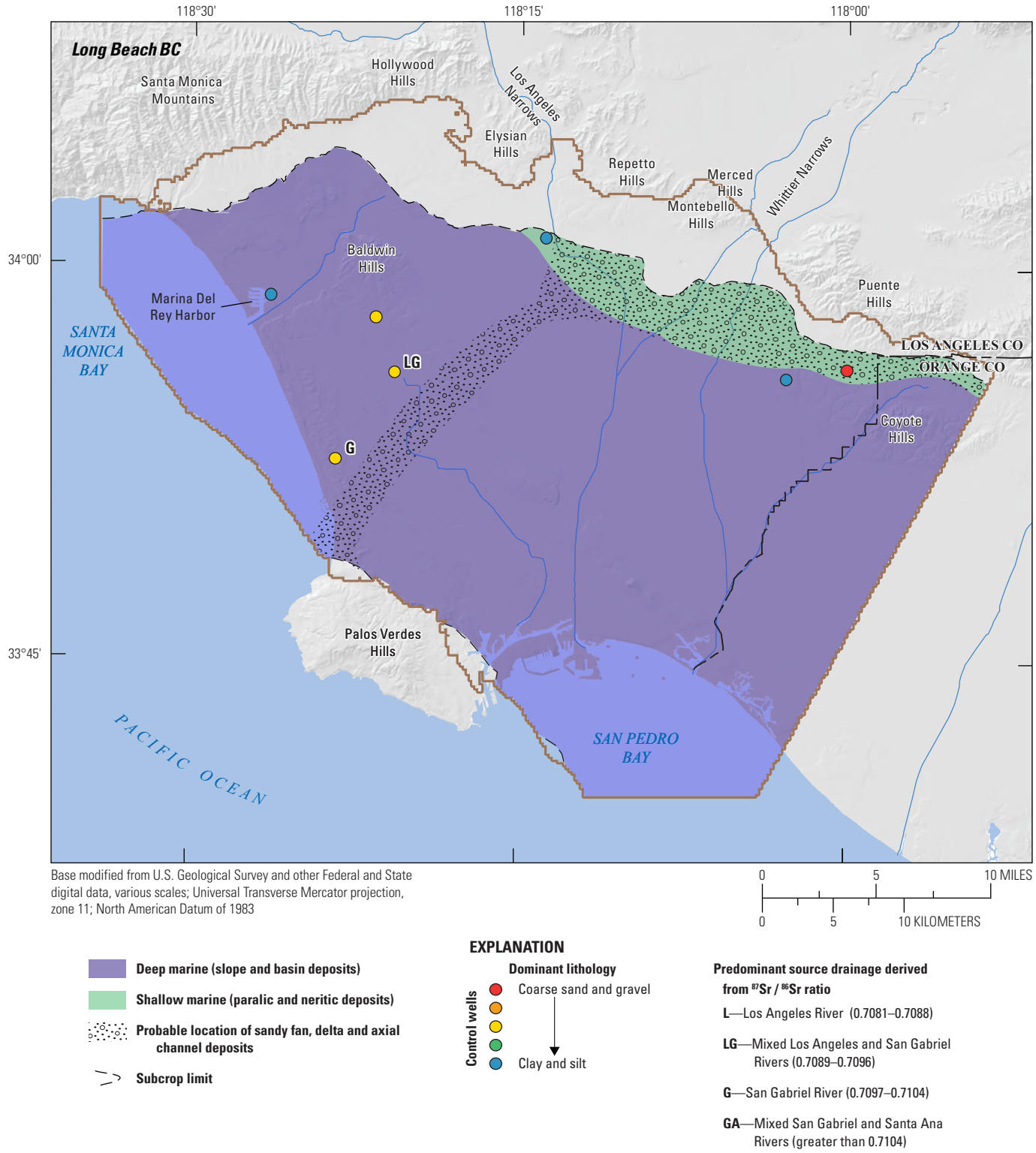


Figure B8. Inferred facies distribution of the Long Beach BC chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

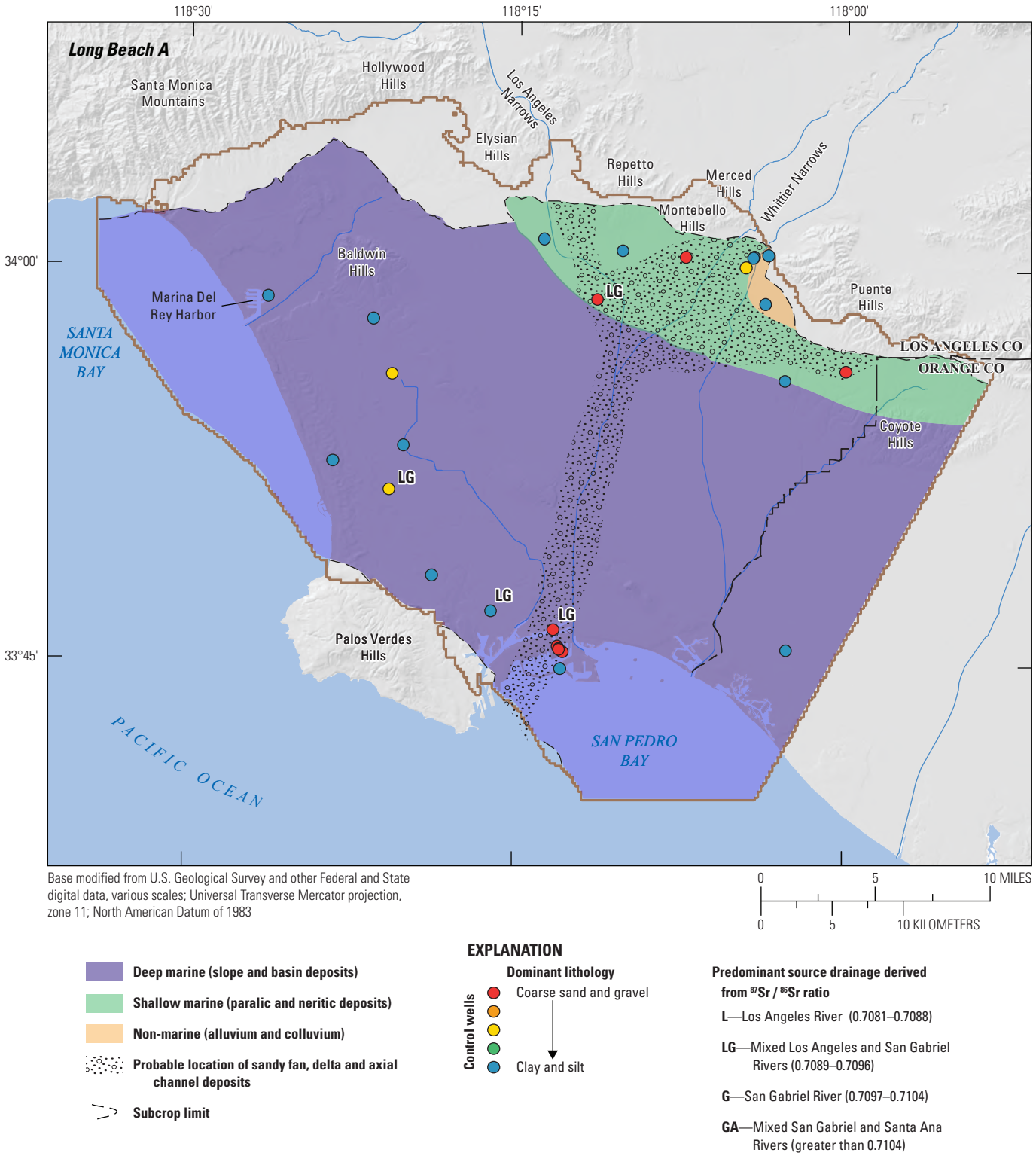


Figure B9. Inferred facies distribution of the Long Beach B chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

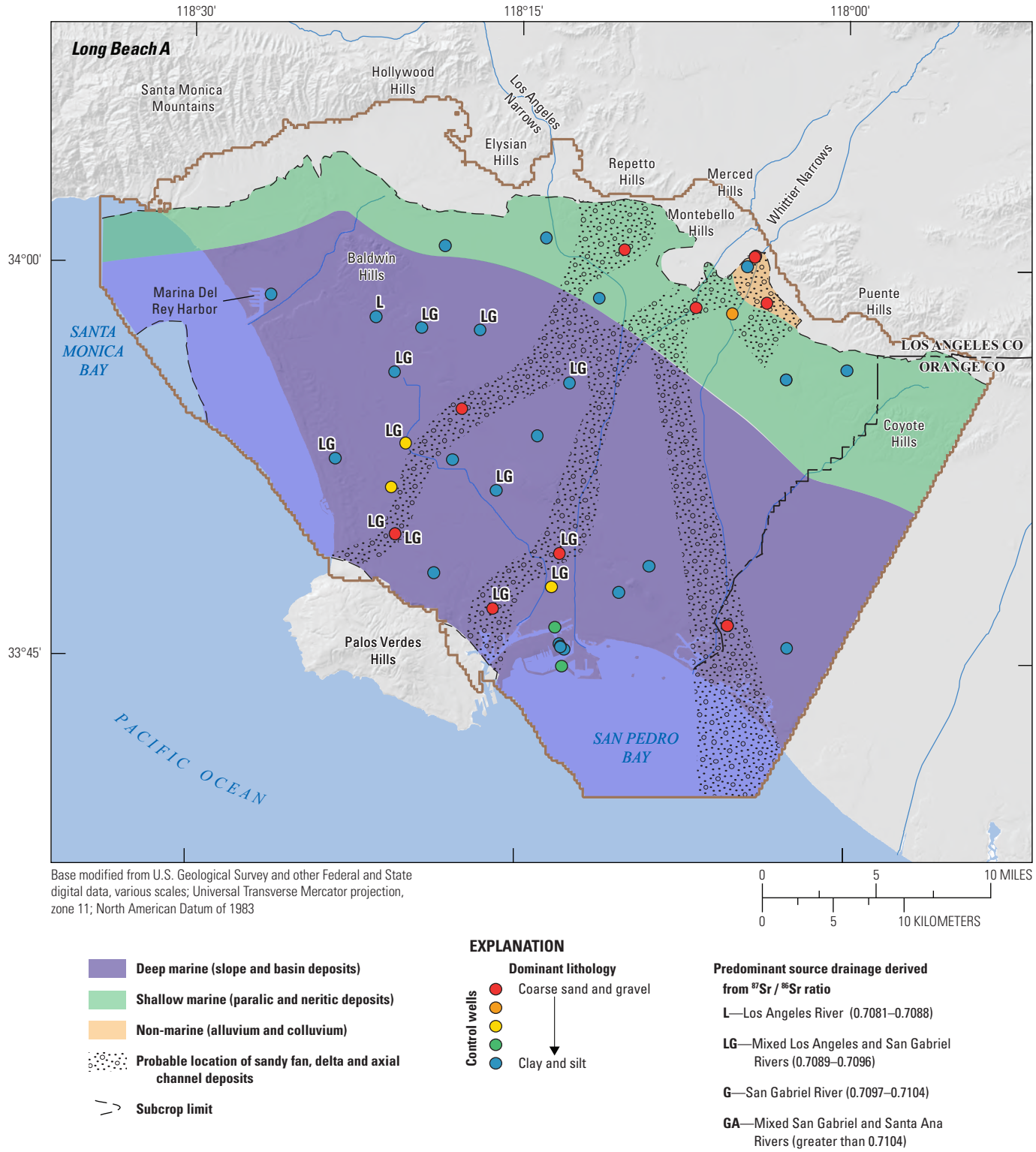


Figure B10. Inferred facies distribution of the Long Beach A chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

Lower Wilmington

The Lower Wilmington chronostratigraphic unit was described in the Long Beach area as consisting of basal blocky sands capped by thick muds with an overall coarsening-upward character (Ponti and others, 2007). In seismic-reflection profiles, the top of the unit is marked by a clear seismic reflector, and the sequence shows internal clinoform structure indicative of a prograding delta complex in the Central Basin (fig. B4). The ages and paleoecologic interpretations from cores in the Long Beach area indicate deposition in both warm- and cool-water intervals (McDougall and others, 2012). Paleomagnetic data from cores in the Long Beach area place this unit in the Brunhes Normal Polarity chron, which would restrict the age to 0.78 Ma or younger (McDougall and others, 2012). The Lava Creek B ash (639 ±2 thousand years; ka) occurs at 1,240 ft measured depth below land surface in the lower part of the Lower Wilmington unit in multiple-well monitoring site Long Beach-8 (4S/12W-30J1-6; 30J1 on fig. B3), and biostratigraphic data suggest an age of greater than 0.6 Ma (McDougall and others, 2012). Marine deposits of similar character that contain the Bishop ash (approximately 0.76 Ma) and sediment with reversed magnetic polarity in the northern Los Angeles Basin (Quinn and others, 2000) suggest that the base of the Lower Wilmington unit may extend into the lower Pleistocene in the Central Basin (less than or equal to approximately 1.0 Ma). We correlate the subsurface Lower Wilmington unit with outcrops of the Coyote Hills Formation in the Coyote Hills (Durham and Yerkes, 1964; Yerkes, 1972; table B2), where the formation is of paralic and non-marine origin.

Inferred facies distribution of the Lower Wilmington sequence (fig. B11) indicates that the unit likely is of non-marine origin near the northeastern margin of the LACP south of Whittier Narrows. Shallow marine (neritic) deposits encompass the northern half of the LACP, with a fairly extensive coarse-grained zone of likely deltaic channel deposits that extends westward from the Whittier Narrows area (fig. B11).

Upper Wilmington B

The Upper Wilmington B chronostratigraphic unit corresponds to the lower portion of the Upper Wilmington sequence as defined by Ponti and others (2007) in the Long Beach area. Subsequent analysis of borehole and seismic data elsewhere in the LACP reveals evidence of erosion and incision that warrants subdividing the original Upper Wilmington unit of Ponti and others (2007) into the Upper Wilmington B and Upper Wilmington A chronostratigraphic units. The Upper Wilmington B unit can be correlated to exposures of the Inglewood Formation in the Baldwin Hills (Weber and others, 1982; Saucedo and others, 2003) and appears to be of shallow marine origin.

Based on age constraints on the underlying Lower Wilmington unit and analysis of microfossils in the Long Beach area, the ages of both the Upper Wilmington B and A units are likely constrained to less than 600 ka old and greater than 340 ka old. Best estimate for the age of the Upper Wilmington B unit from correlation to marine oxygen isotope stages (Bassinot and others, 1994) is between 434 and 536 ka (table B2).

By Upper Wilmington B time, the LACP had sufficiently shoaled such that most of the Upper Wilmington B unit is of shallow marine or non-marine origin. Only in the southeastern part of the Central Basin is there evidence suggestive of deep marine deposition (bathyal depths; fig. B12). Coarse-grained zones indicative of delta progradation appear to source from both the Whittier Narrows and Los Angeles Narrows areas, with the Whittier Narrows area extending to the south and into the southern West Coast Basin, and the Los Angeles Narrows area extending to the west-southwest toward the present Baldwin Hills and the northern West Coast Basin into Santa Monica Bay. These coarse-grained axial channel deposits and shallow marine sands are relatively permeable compared to the underlying units, and these coarse-grained deposits are extensively pumped, especially in the Long Beach area. Uplift along the Newport-Inglewood fault zone southeast of Baldwin Hills likely caused Upper Wilmington B deposits to be eroded prior to deposition of the Upper Wilmington A unit. The Upper Wilmington B deposits in the central part of the West Coast Basin are dominantly fine-grained and likely of slightly deeper marine origin (fig. B12).

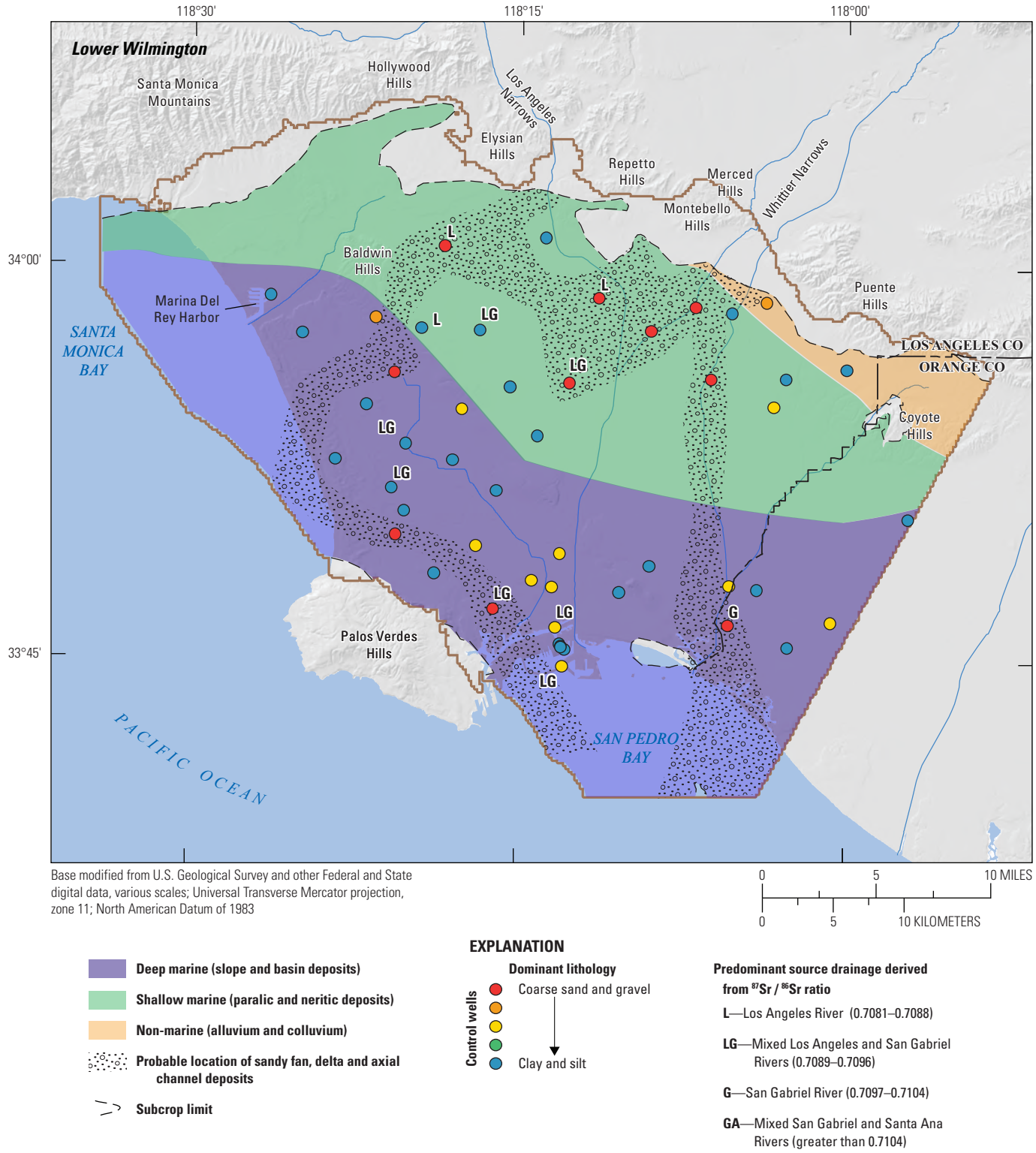


Figure B11. Inferred facies distribution of the Lower Wilmington chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

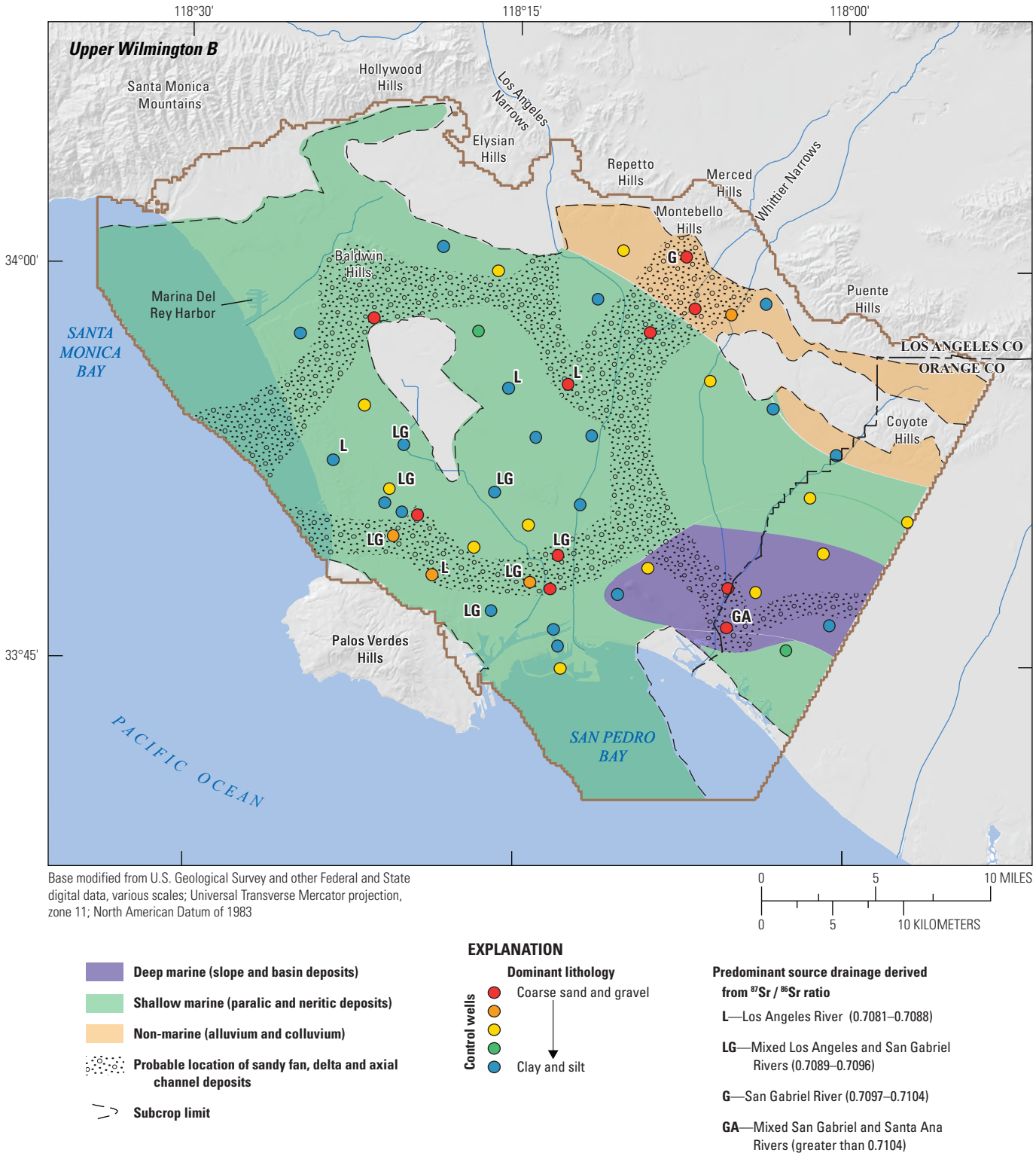


Figure B12. Inferred facies distribution of the Upper Wilmington B chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

Upper Wilmington A

The Upper Wilmington A chronostratigraphic unit comprises the uppermost part of Ponti and others' (2007) Upper Wilmington unit. The best estimate for the age of the Upper Wilmington A unit is between 340 and 434 ka (table B2) based on correlation to marine oxygen isotope stages (Bassinot and others, 1994).

In the Long Beach area and western Central Basin, the Upper Wilmington A unit contains the Silverado aquifer, which is a major producing aquifer (Reichard and others, 2003). As with the Upper Wilmington B unit, electric-log signatures and well logs from across the LACP indicate that the Upper Wilmington A unit was primarily deposited in shallow marine waters (inner to outer neritic). An episode of substantial delta progradation occurred southward across the shelf from the Whittier Narrows area toward San Pedro Bay before turning westward across Long Beach and north of the Palos Verdes Hills into Santa Monica Bay (fig. B13). There is also indication of another series of likely deltaic channel deposits that source from the Los Angeles Narrows and extend west across the Newport-Inglewood fault zone and then southward toward Long Beach (fig. B13). Seismic-reflection data indicate that in the eastern part of the West Coast Basin the Upper Wilmington A unit is incised into the underlying, generally finer-grained, Upper Wilmington B unit. The Upper Wilmington A unit locally completely erodes the Upper Wilmington B unit in this area. The Upper Wilmington A channel that laterally juxtaposes the coarse-grained Upper Wilmington A deposits from the generally finer-grained Upper Wilmington B unit at similar depths may explain water-level differences in wells that have previously been attributed to the inferred Charnock fault (a northwest-trending structure that has been mapped approximately coincident with the Upper Wilmington A channel's western margin; California Department of Water Resources, 1961). However, this study and previous studies (Wright, 1991; Legg Geophysical, Inc., 2016) have failed to find evidence of faulting within the Pleistocene section that could form such a hydrologic barrier.

Bent Spring

In the San Pedro area, the Bent Spring chronostratigraphic unit is correlated by Ponti and others (2007) to San Pedro Sand, Timms Point Silt, and Lomita Marl of Woodring and others (1946), where the Bent Spring unit represents a thick, prograding shallow marine delta that was deposited into a subsiding northwest-southeast trending basin along the north side of the Palos Verdes Hills. Over much of the Central Basin, however, the unit is quite thin (less than 350 ft), as evidenced in seismic-reflection profiles. Data from the Long Beach area provide an age estimate of between 200 and 500 ka for the Bent Spring chronostratigraphic unit (McDougall and others, 2012). Bounding constraints from the underlying Upper Wilmington A chronostratigraphic unit and thermoluminescence (TL) ages suggest that the age of Bent Spring is most likely between 295 and 340 ka (Bassinot and others, 1994; McDougall and others, 2012; table B2).

Strontium-isotope data suggest that the thick deltaic sands of the Bent Spring unit found near the Palos Verdes Hills were sourced from the Whittier Narrows and Los Angeles Narrows areas. Coarse-grained zones within the Bent Spring unit are also noted in the southern Central Basin (fig. B14). The Bent Spring unit is missing locally along the Newport–Inglewood fault zone of deformation—likely the result of subsequent uplift and erosion along this trend.

Harbor

In the Long Beach area, the Harbor chronostratigraphic unit is an areally extensive series of deposits that record a coastal progradation and encompass a number of sedimentary environments ranging from fluvial channels, fans, and floodplains to coastal beach and paralic environments like tidal flats and lagoons. In the Central Basin, electric-log signatures and well-log descriptions indicate that the Harbor unit probably is of shallow, open marine origin (fig. B15). The top of the Harbor unit is not clearly distinguishable as an unconformity in seismic-reflection profiles.

The age of the Harbor chronostratigraphic unit, based on macrofossils and TL (Aitken, 1985) dates from the Long Beach area (McDougall and others, 2012) is constrained between 100 and 275 ka, with a best estimate inferred from ages of underlying and overlying sequences of between approximately 186–248 ka (table B2). The Harbor unit reaches a thickness of more than 650 ft in the Central Basin and appears to mark an acceleration in the rate of basin subsidence in the Central Basin that continued through deposition of the Pacific A chronostratigraphic unit.

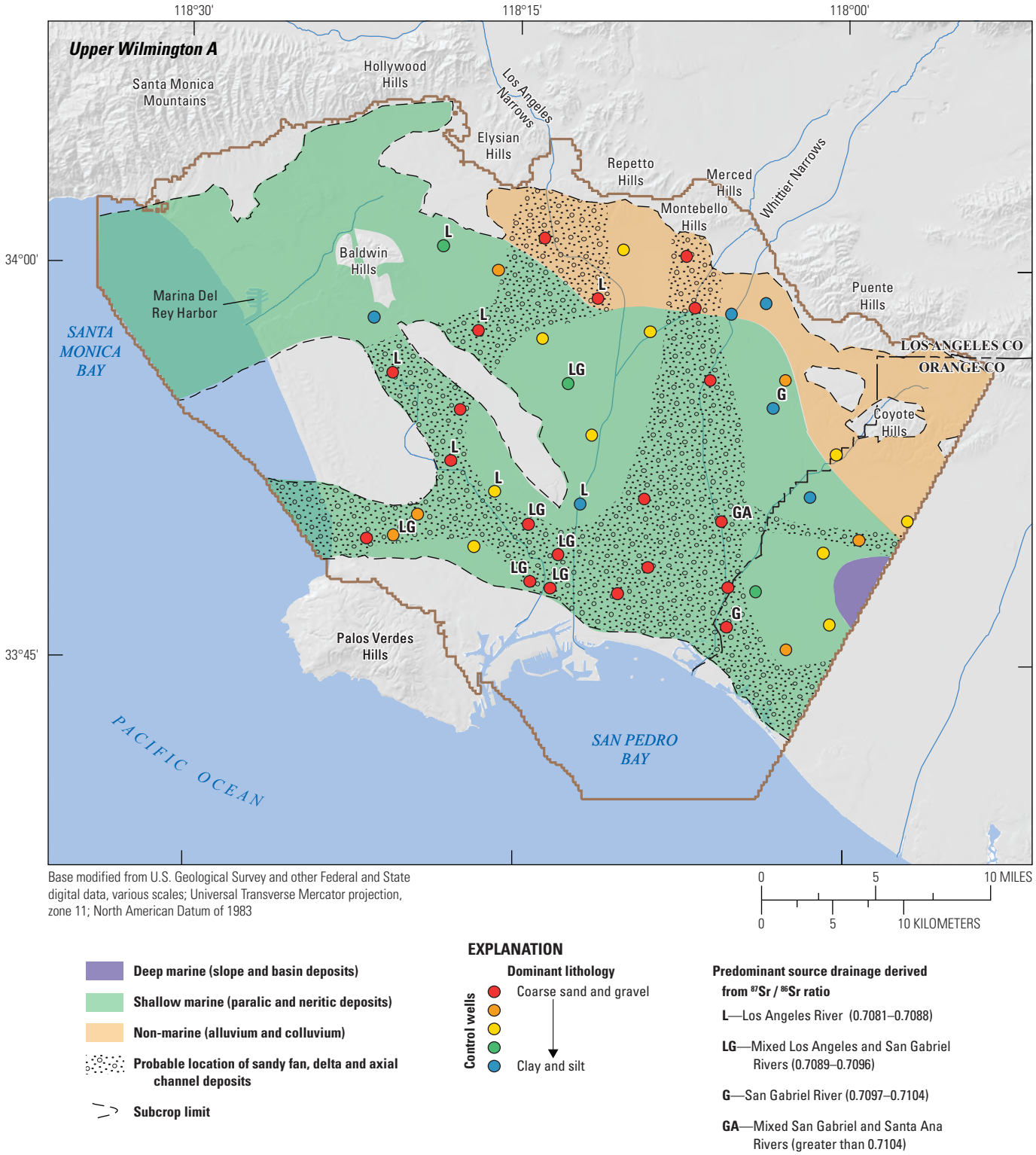


Figure B13. Inferred facies distribution of the Upper Wilmington A chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

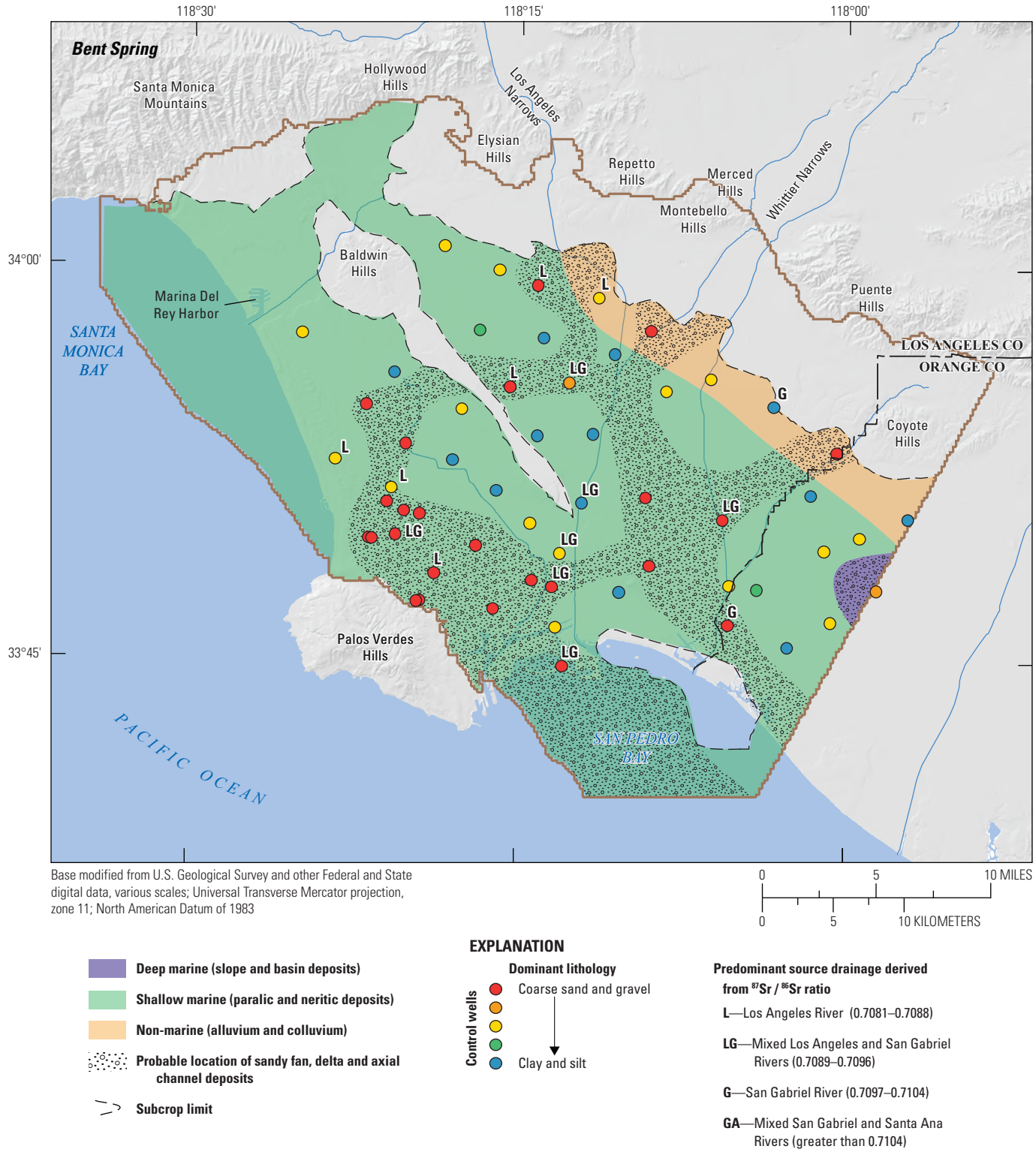


Figure B14. Inferred facies distribution of the Bent Spring chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

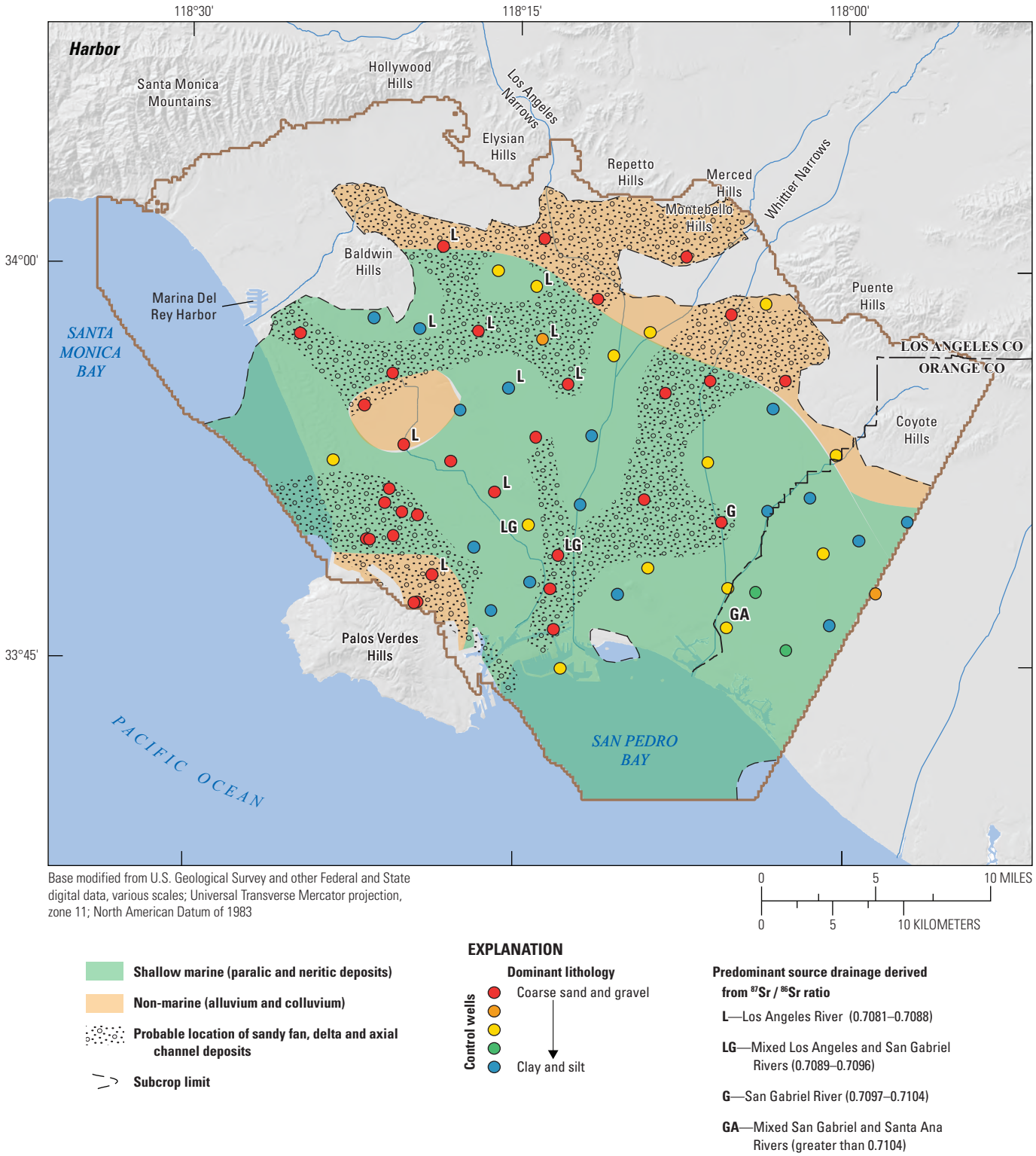


Figure B15. Inferred facies distribution of the Harbor chronostratigraphic unit with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

Pacific

In the Long Beach area, the Pacific chronostratigraphic unit is believed to have resulted from marine high-stand progradation during early $\delta^{18}O$ stage 5, (approximately 97–133 ka; Bassinot and others, 1994; $\delta^{18}O$ is a measure of the ratio of stable isotopes oxygen-18 [^{18}O] and oxygen-16 [^{16}O], see appendix 1), based on thermoluminescence ages, macrofossil data, amino-acid racemization ages on marine terrace deposits, and the presence of the Blake paleomagnetic event (McDougall and others, 2012). McDougall and others (2012) reported optically stimulated luminescence (OSL; Aitken, 1998) ages from the same unit that are as young as 28–33 ka, but these ages appear to be too young as they are contradicted by the weight of other evidence. The Pacific unit appears to correlate with exposed old alluvial fans that crop out near the Coyote Hills and Santa Monica Mountains, as well as marine terrace deposits in San Pedro and the Pacific Palisades area.

The top of the Pacific chronostratigraphic unit is defined by a distinctive seismic reflector in the Central Basin, but this reflector is often difficult to correlate on many seismic lines where the horizon reaches shallow depths. In much of the West Coast Basin, and along the northeast margin of the LACP, the unit expresses a fining-upward character indicative of a non-marine origin, typically with a basal sand that grades up to a silt or silty clay that caps the unit. However, in the Central Basin where the Pacific unit reaches a thickness of more than 500 ft, the Pacific unit appears to be of shallow maring origin (paralic or neritic; fig. B16).

Pacific A

The Pacific A chronostratigraphic unit was established to accommodate observed variations of water levels and hydrograph character in wells open to sediment bounded by the underlying Pacific and overlying Mesa units. The Pacific A unit is recognized in the Central Basin only and may represent the lowermost portion of the overlying Mesa chronostratigraphic unit where the Mesa unit thickens substantially into the Central Basin (figs. B4, B5). The top of Pacific A usually is identified at the base of a fining-upward package that is often observed within the Mesa unit, but in some cases, the top of the Pacific A is somewhat ambiguous in borehole or electric logs. As with the Long Beach BC unit, we cannot determine whether the top of the Pacific A represents an unconformity-bound sequence or just conformably underlies the Mesa unit where the boundary represents an upward transition from deposits of shallow marine origin (paralic or neritic) to deposits of non-marine origin typical of the overlying Mesa chronostratigraphic unit.

Based on age estimates for the Mesa chronostratigraphic unit, the Pacific A unit is late Pleistocene in age, most likely less than 80 ka, and may be coeval with paralic deposits of the Mesa sequence in the West Coast Basin. Most of the Pacific A unit appears to be of shallow marine origin (paralic), with some likely non-marine deposits located along the eastern and western margins of the unit's extent (fig. B17).

Mesa

The Mesa chronostratigraphic unit is the youngest of the Pleistocene units in the Los Angeles Basin. Onshore, the unit is primarily of non-marine origin (alluvial-fan and flood-basin deposits), except for deposits of dune sands in the western portion of the West Coast Basin (fig. B18). The offshore portions of the Mesa unit that lie beneath San Pedro and Santa Monica Bays, and along the southern margin of the West Coast and Central Basins, are of shallow marine origin. Borehole and electric logs indicate that the Mesa unit typically has a sandy base inferred to be deposited within fluvial channels, and grades finer up-section, culminating in probable overbank or flood-basin silts and clays that typically cap the unit. The surface of the Mesa unit is exposed along the margins of the Central Basin and in the West Coast Basin (figs. B1, B18). In the Long Beach area, the Mesa unit comprises young marine terrace deposits that are inferred to be approximately 80 ka old based on amino-acid racemization data (Ponti and others, 2007), but OSL, TL, and radiocarbon dates on fluvial deposits, and the occurrence of the Laschamp paleomagnetic event, indicate that much of the unit regionally is as young as 20–40 ka (table B2). In the subsurface, the top of the Mesa unit is readily picked at the base of a coarse sand or gravel deposit that generally marks the beginning of the Holocene progradation. The Mesa unit reaches a maximum thickness of about 300 ft in the Central Basin.

Dominguez

The Dominguez chronostratigraphic unit is the result of deposition that occurred in response to worldwide climate change that initiated the Holocene epoch. As the Pleistocene climate ameliorated, sea level began to rise, and vegetation assemblages in the mountains ringing the Los Angeles Basin shifted from conifer-dominated to the oak-grassland-chaparral-dominated sclerophyllous vegetation common on today's hillslopes in central and southern California (Bull, 1991). Consequently, the thick mantle of weathered rock and soil materials that accumulated on the hillslopes under coniferous forest conditions became unstable as the conifers died out and were replaced by oaks. Wildland fires also became more frequent, further serving to destabilize the landscape and expose the soil mantle to erosional processes. Resultant erosion caused mountain streams to aggrade rapidly and push sediment out onto the coastal plain, ultimately filling the eroded channels and blanketing the coastal plain with flood deposits. In offshore areas and just inland of the current coastline, sediments of the Dominguez chronostratigraphic unit are of shallow-marine origin (fig. B19).

The Dominguez chronostratigraphic unit reaches a thickness of more than 200 ft in the Central Basin. The Dominguez unit typically comprises a sandy or gravelly basal unit that grades up into silt, although in some areas, the basal unit is composed of fine sand or silty sand. OSL, TL, and radiocarbon dates, as well as macrofossil evidence from the Long Beach area, indicate that the Dominguez unit is younger than 18 ka (McDougall and others, 2012; table B2).

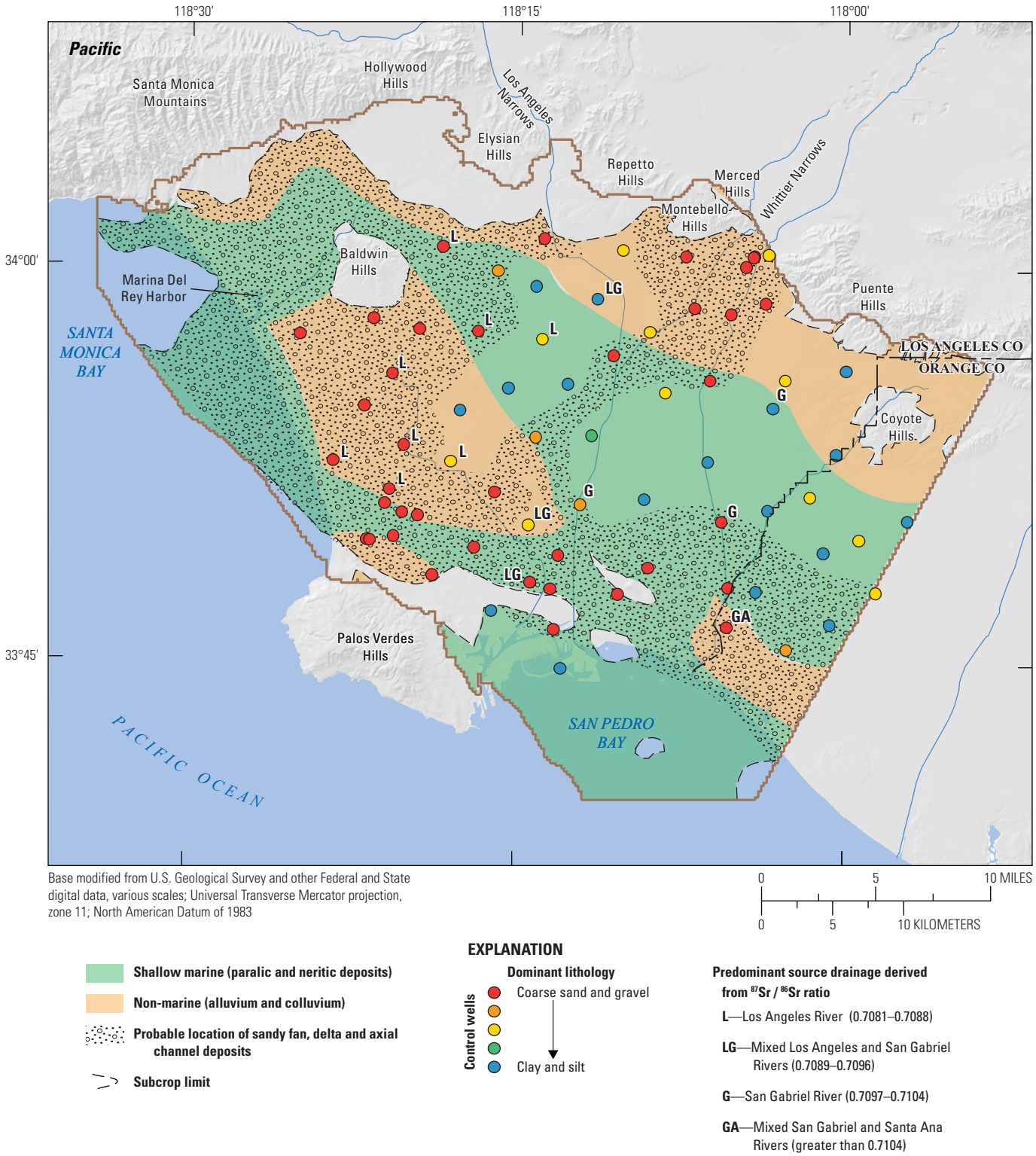


Figure B16. Inferred facies distribution of the Pacific chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

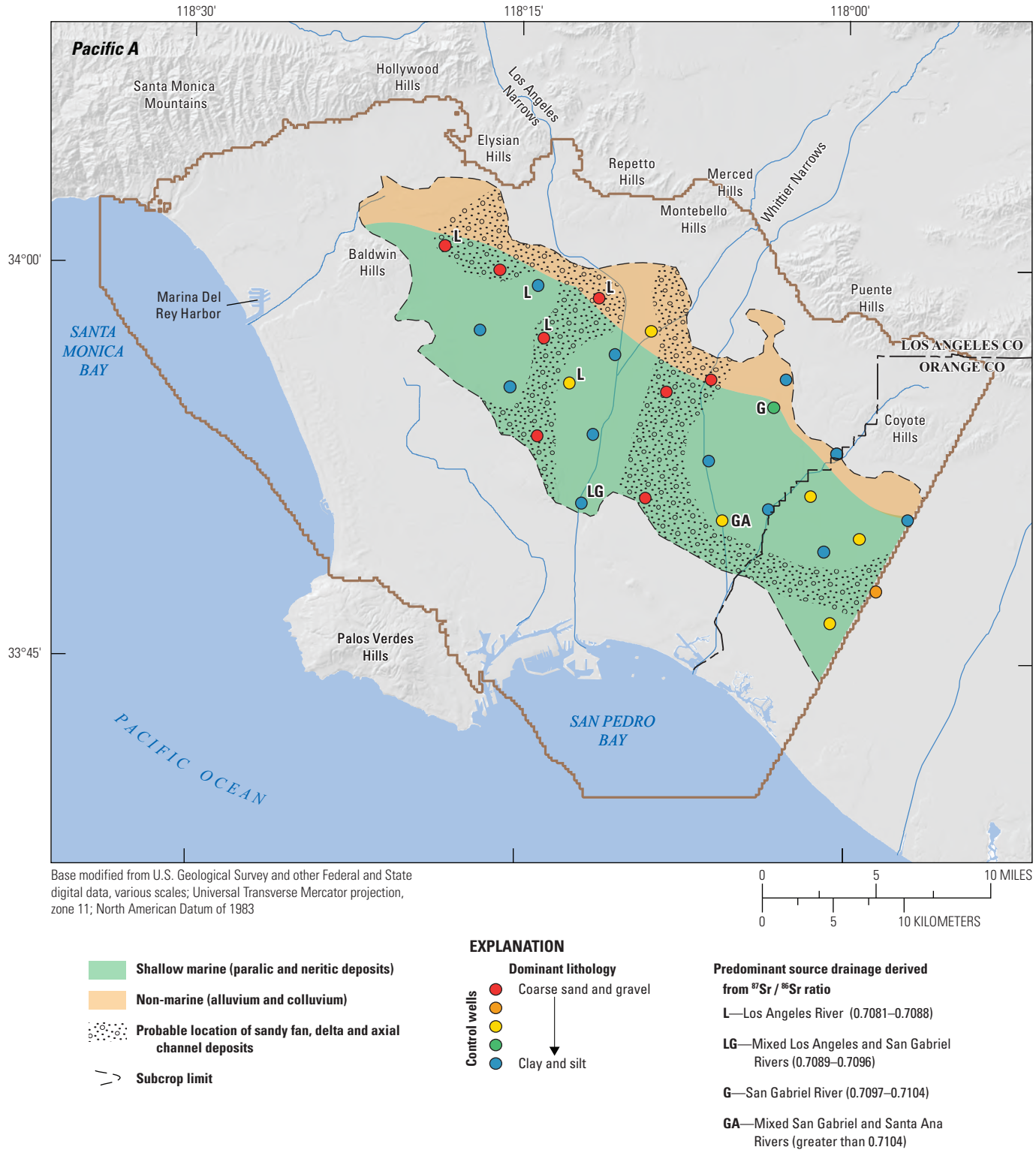


Figure B17. Inferred facies distribution of the Pacific A chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

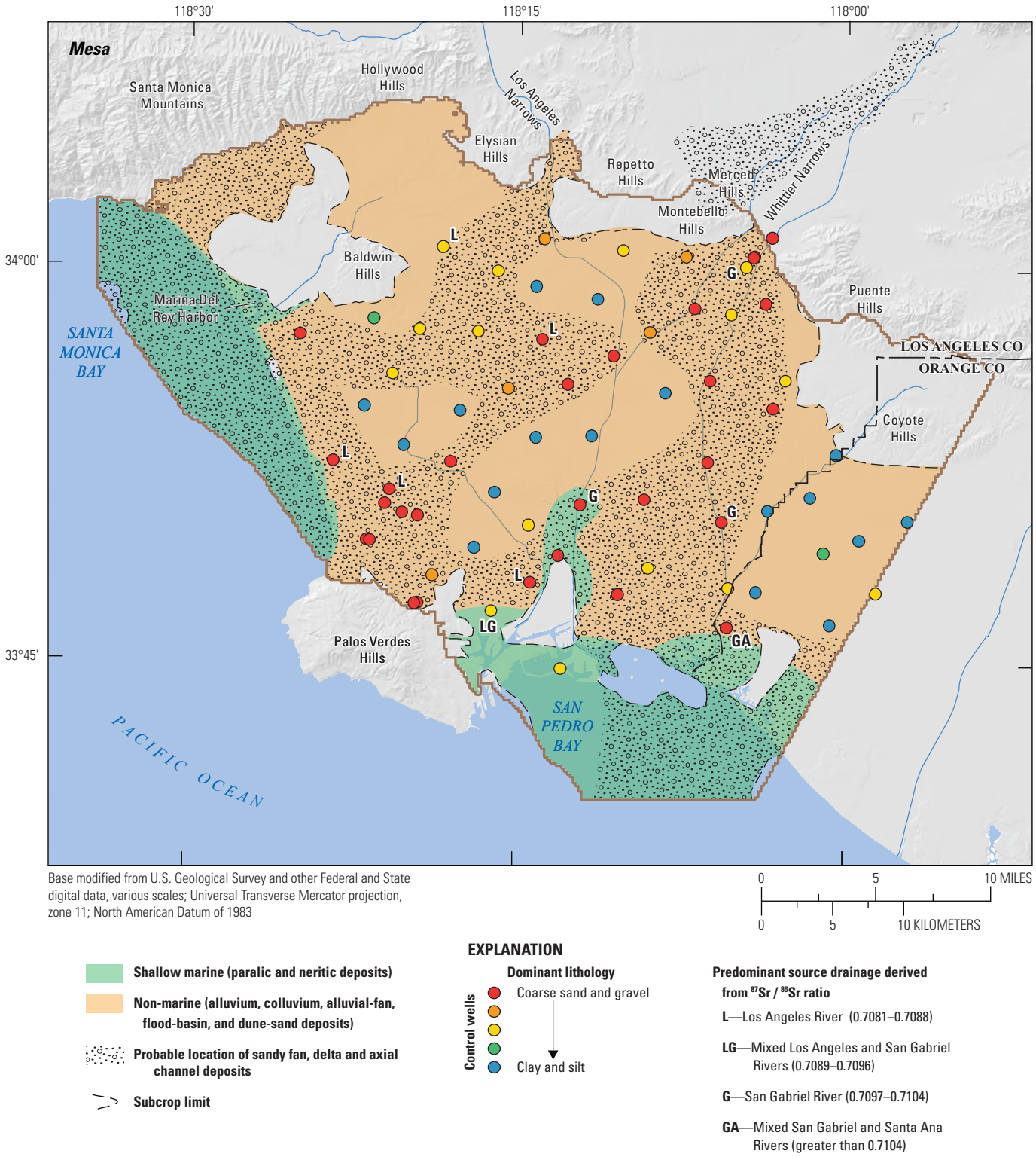


Figure B18. Inferred facies distribution of the Mesa chronostratigraphic unit, Los Angeles Coastal Plain, California, with dominant lithologies from control wells and source drainages derived from available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

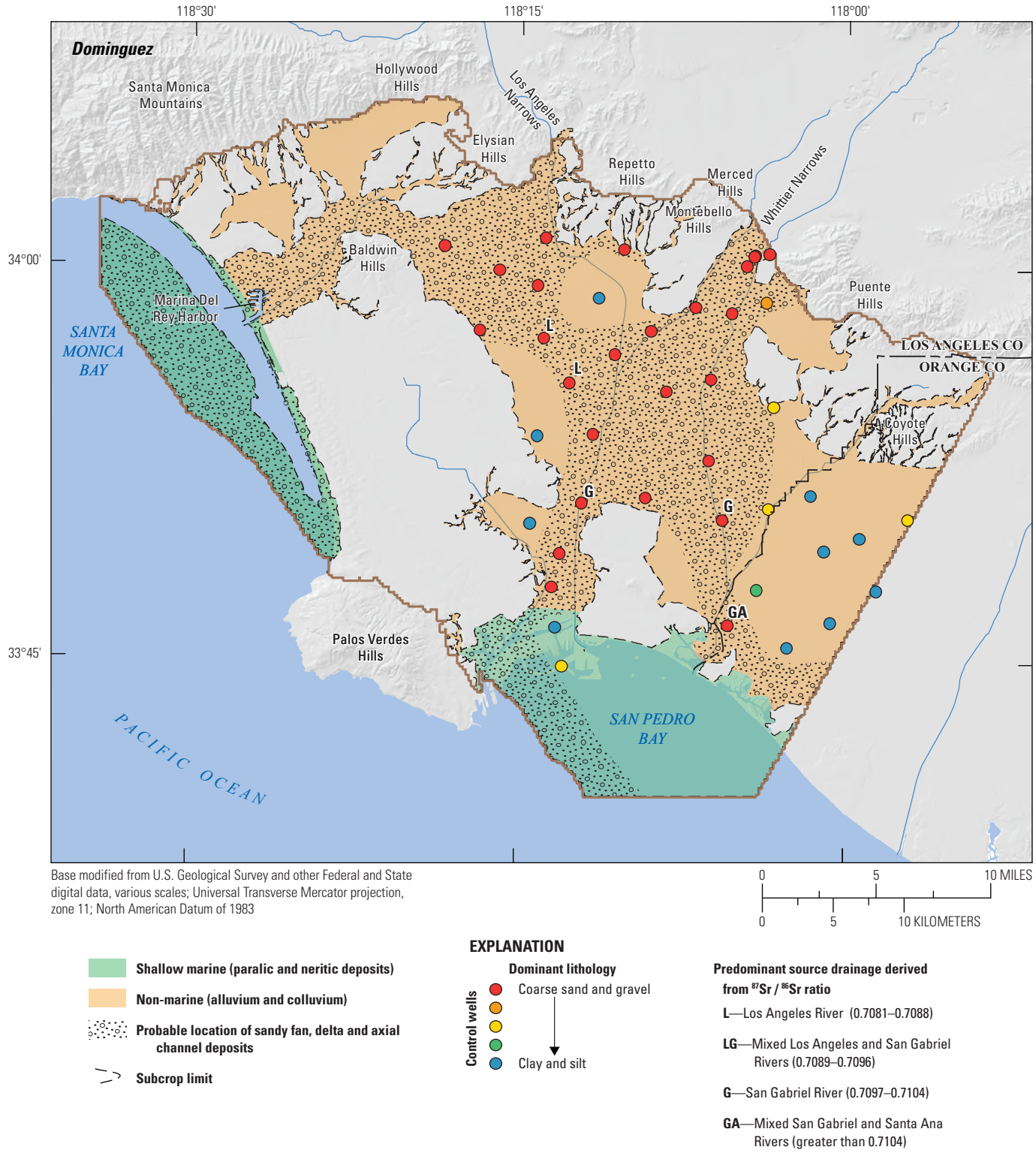


Figure B19. Inferred facies distribution of the Dominguez chronostratigraphic unit, Los Angeles Coastal Plain, California, with grain-size distribution from key wells and available strontium-isotope data. Abbreviation: $^{87}Sr / ^{86}Sr$, strontium [Sr] isotope ratio, dimensionless values; Sr has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]).

Comparison of the Chronostratigraphic Framework to Previous Hydrogeologic Units and Aquifer Nomenclature

Previously, the LACP was divided into five hydrogeologic units: (1) the Recent aquifer system, (2) the Lakewood aquifer system, (3) the Upper San Pedro aquifer system, (4) the Lower San Pedro aquifer system, and (5) the nontransmissive Pico unit (Reichard and others, 2003). These hydrostratigraphic units generally followed the architecture and geologic structure presented in the California Department of Water Resources (1961), modified slightly based on additional lithologic and borehole geophysical data collected by the USGS during construction of multiple-well monitoring sites in the LACP. In general, the Recent aquifer system corresponds to the shallow Gaspur, Ballona, and Talbert aquifers of the California Department of Water Resources (1961). The Lakewood aquifer system corresponds to a package of non-marine and marine (paralic) sediment that roughly correlates to the Lakewood Formation of the California Department of Water Resources (1961). The Upper San Pedro aquifer system corresponds to shallow marine deposits of the San Pedro Formation that contains the Lynwood and Silverado aquifers of the California Department of Water Resources (1961), and the Lower San Pedro aquifer system corresponds to shallow marine deposits of the lower portion of the San Pedro Formation that contains the Sunnyside aquifer of the California Department of Water Resources (1961). The Pico unit represents the base of the active groundwater system and corresponds to fine-grained marine deposits identified as the Pico Formation by the California Department of Water Resources (1961). Although there are slight differences in the location of unit boundaries between the framework of the California Department of Water Resources (1961) and that of Reichard and others (2003), there is essentially a one-to-one correspondence between the units across the entire LACP.

The chronostratigraphic framework model used for this study differs from frameworks of previous studies. In this study, chronostratigraphic units are defined and mapped based on their bounding unconformities and not based on lithologic characteristics and inferred depositional environments like in previous studies. Defining units based on bounding unconformities allows for a better understanding of the distribution of lithologic facies within each of the depositional units. The chronostratigraphic framework model also utilizes multiple seismic-reflection profiles collected throughout the LACP (fig. B3) to more accurately represent the geologic structure of the basin than the previous models (figs. B20–B22). Therefore, the chronostratigraphic layering can more accurately represent aquifer connectivity and the direction of anisotropy within the basin. Furthermore, a groundwater-flow model based on a chronostratigraphic model may more accurately model anisotropic flow and the connectivity of aquifer systems. Specific comparisons between the chronostratigraphic units defined for this study and the lithostratigraphic formations and aquifers defined by the California Department of Water Resources (1961) and Reichard and others (2003) are presented in table B2 for three specific locations in the basin (fig. B1).

Over much of the LACP, good agreement was observed between the youngest chronostratigraphic units (Dominguez and Mesa) and the youngest aquifers identified by California Department of Water Resources (CDWR; 1961; for example, Gaspur and Exposition aquifers; figs. B20–B22). This relation was not unexpected because in the previous frameworks, original depositional surfaces of Holocene and late Pleistocene alluvial-fan and basin deposits are mostly preserved and are delineated using geomorphology and stratigraphic position; thus, the CDWR youngest aquifer units are essentially equivalent to the chronostratigraphic units used for this study. However, the associations between the older chronostratigraphic units and the previously defined aquifer and formation boundaries became more complex from the basin margins to the Central Basin. The formations and aquifers, as represented in the lithostratigraphic frameworks of the California Department of Water Resources (1961) and Reichard and others (2003), cross timelines defined by the chronostratigraphic model and do not extend to the depths observed for the chronostratigraphic units. As a result, the structural relief of the Central Basin, and to a lesser extent the West Coast Basin, is considerably muted in the lithostratigraphic-framework models relative to the chronostratigraphic model (figs. B20–B22).

The chronostratigraphic units contain related packages of sediment that were deposited during the same time period in response to base-level change. However, the lithostratigraphically defined formations and aquifers contain sediments that were deposited at considerably different times from the basin margin to the basin center. This variability in deposition implies that many of the aquifers defined lithostratigraphically are composed of multiple depositional units and likely are not areally connected as inferred in the older models. For example, the Lynwood and Silverado aquifers of the California Department of Water Resources (1961; Upper San Pedro aquifer system of Reichard and others, 2003) generally are associated with the Bent Spring and Upper Wilmington A and B chronostratigraphic units along the eastern and western margins of the Central Basin, whereas the Lynwood and Silverado aquifers are associated with the Pacific and Harbor chronostratigraphic units in the middle of the Central Basin (fig. B22). Along the eastern edge of the Central Basin, the Silverado and Lynwood aquifers are typically associated with the Lower Wilmington and older chronostratigraphic units that have been uplifted to shallow depths (figs. B20–B22). In general, the Sunnyside aquifer (Lower San Pedro system of Reichard and others, 2003) is associated with the Lower Wilmington chronostratigraphic unit in the West Coast Basin but is within units as young as the Harbor unit in the Central Basin (figs. B20–B21).

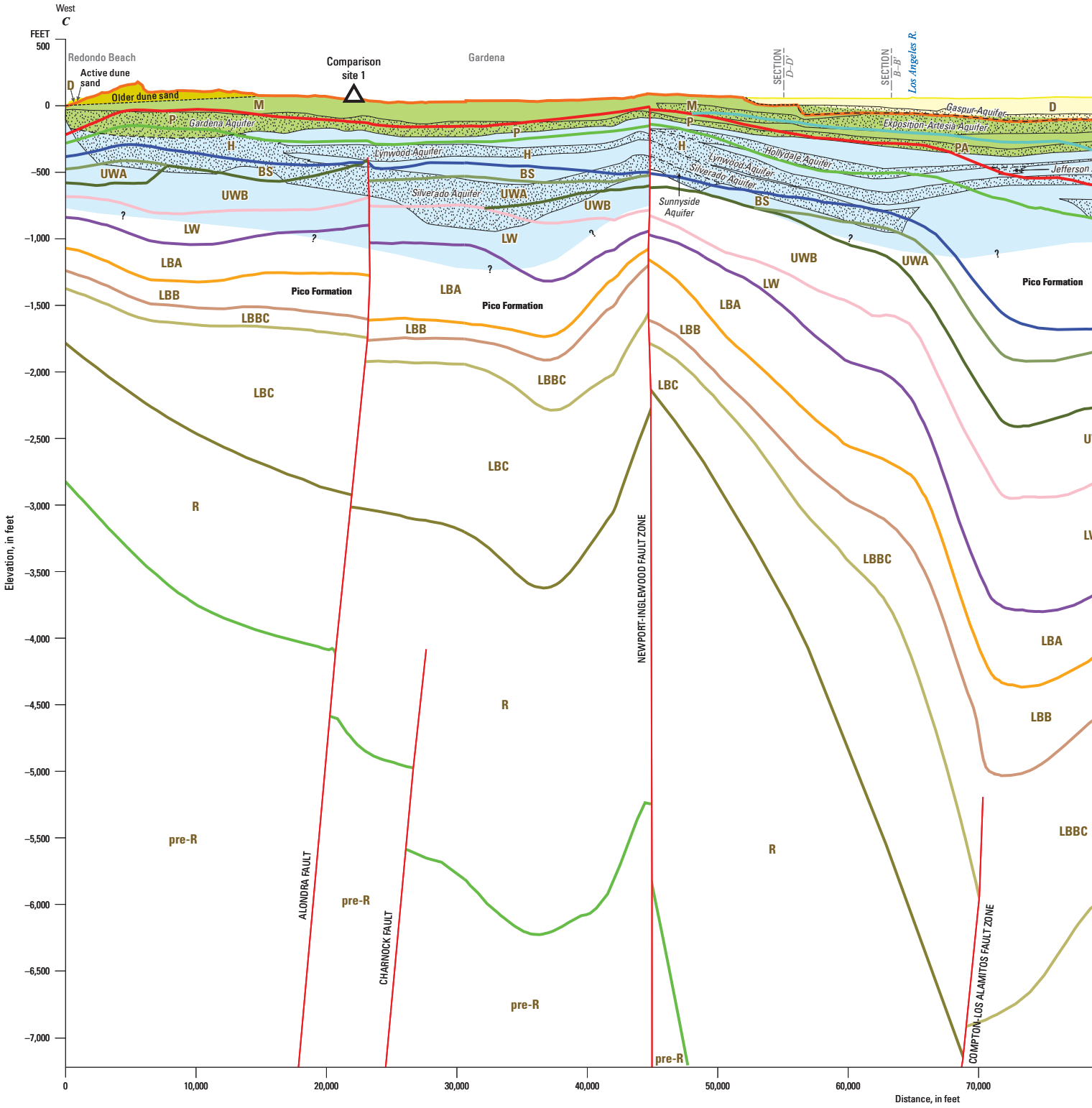
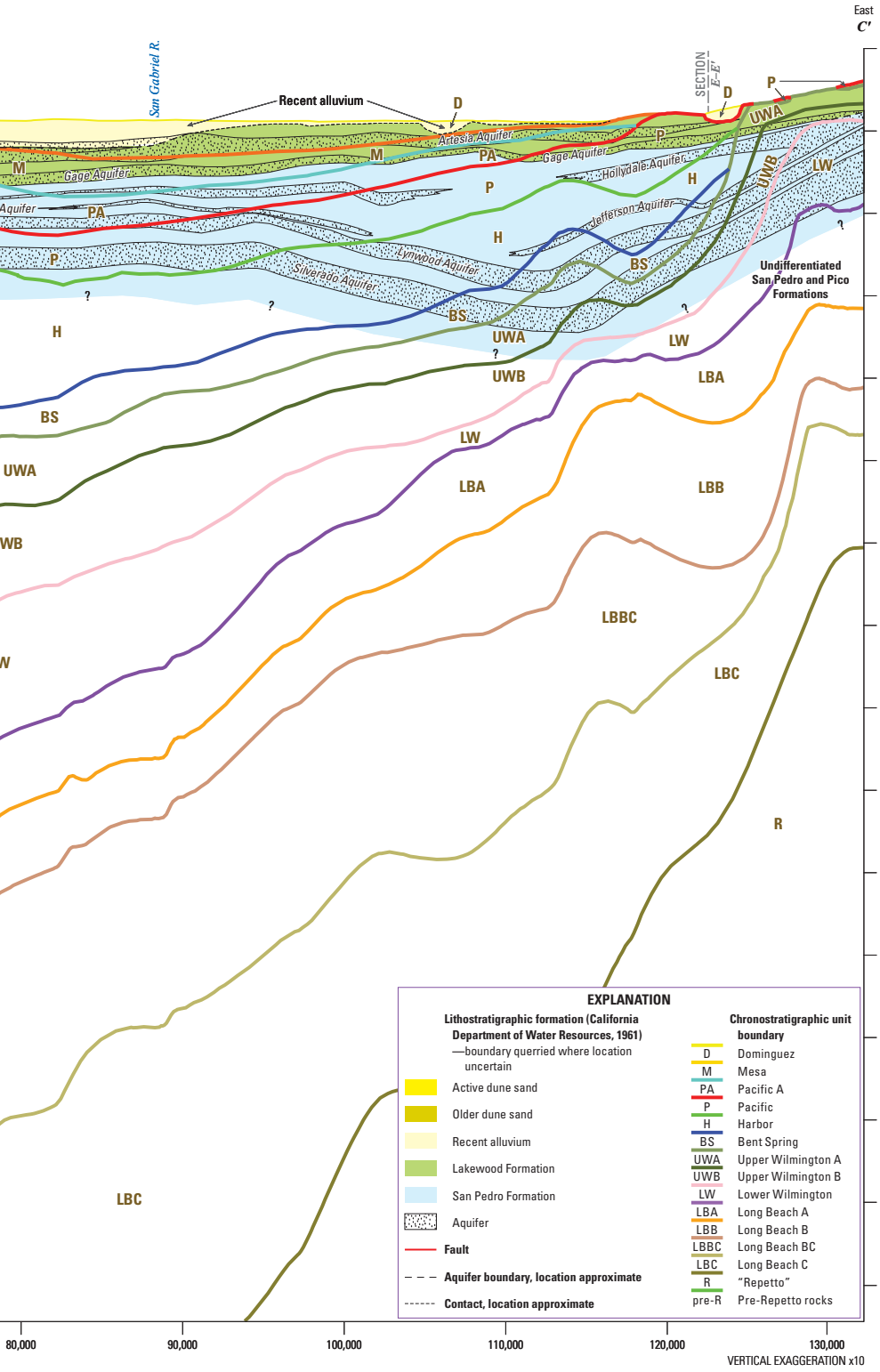


Figure B20. Modeled chronostratigraphic unit boundaries along cross-section C–C', this study, compared to lithostratigraphic formations (colored shading; queried where uncertain) and aquifers of the California Department of Water Resources (1961), Los Angeles Coastal Plain, California. (Trace of section is shown in fig. B1; colored lines mark the top of each unit; unit identifier codes: D, Dominguez; M, Mesa; PA, Pacific A; P, Pacific; H, Harbor; BS, Bent Spring; UWA, Upper Wilmington A; UWB, Upper Wilmington B; LW, Lower Wilmington; LBA, Long Beach A; LBB, Long Beach B; LBBC, Long Beach BC; LBC, Long Beach C; R, "Repetto"; pre-R, pre-Repetto.)


East
C′
San Gabriel R.
Recent alluvium
D
Artesia Aquifer
M
PA
Gage Aquifer
P
Hollydale Aquifer
H
Jefferson Aquifer
Lynwood Aquifer
Silverado Aquifer
BS
UWA
UWB
LW
LBA
LBB
LBBC
LBC
R
Undifferentiated San Pedro and Pico Formations
SECTION E–E′
EXPLANATION
Lithostratigraphic formation (California Department of Water Resources, 1961)
—boundary querried where location uncertain
Active dune sand
Older dune sand
Recent alluvium
Lakewood Formation
San Pedro Formation
Aquifer
Fault
Aquifer boundary, location approximate
Contact, location approximate
Chronostratigraphic unit boundary
D Dominguez
M Mesa
PA Pacific A
P Pacific
H Harbor
BS Bent Spring
UWA Upper Wilmington A
UWB Upper Wilmington B
LW Lower Wilmington
LBA Long Beach A
LBB Long Beach B
LBBC Long Beach BC
LBC Long Beach C
R "Repetto"
pre-R Pre-Repetto rocks
80,000
90,000
100,000
110,000
120,000
130,000
VERTICAL EXAGGERATION x10

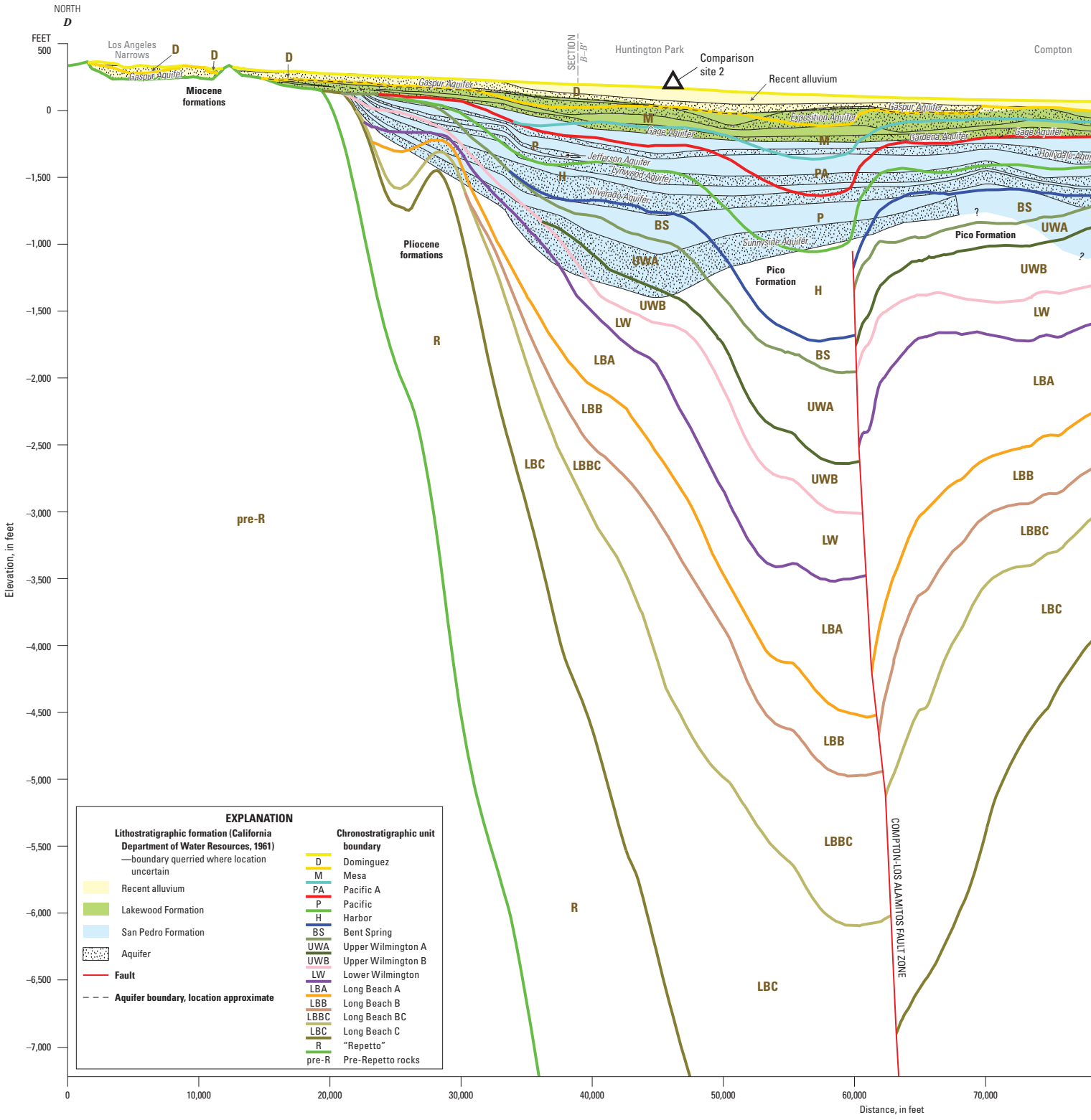
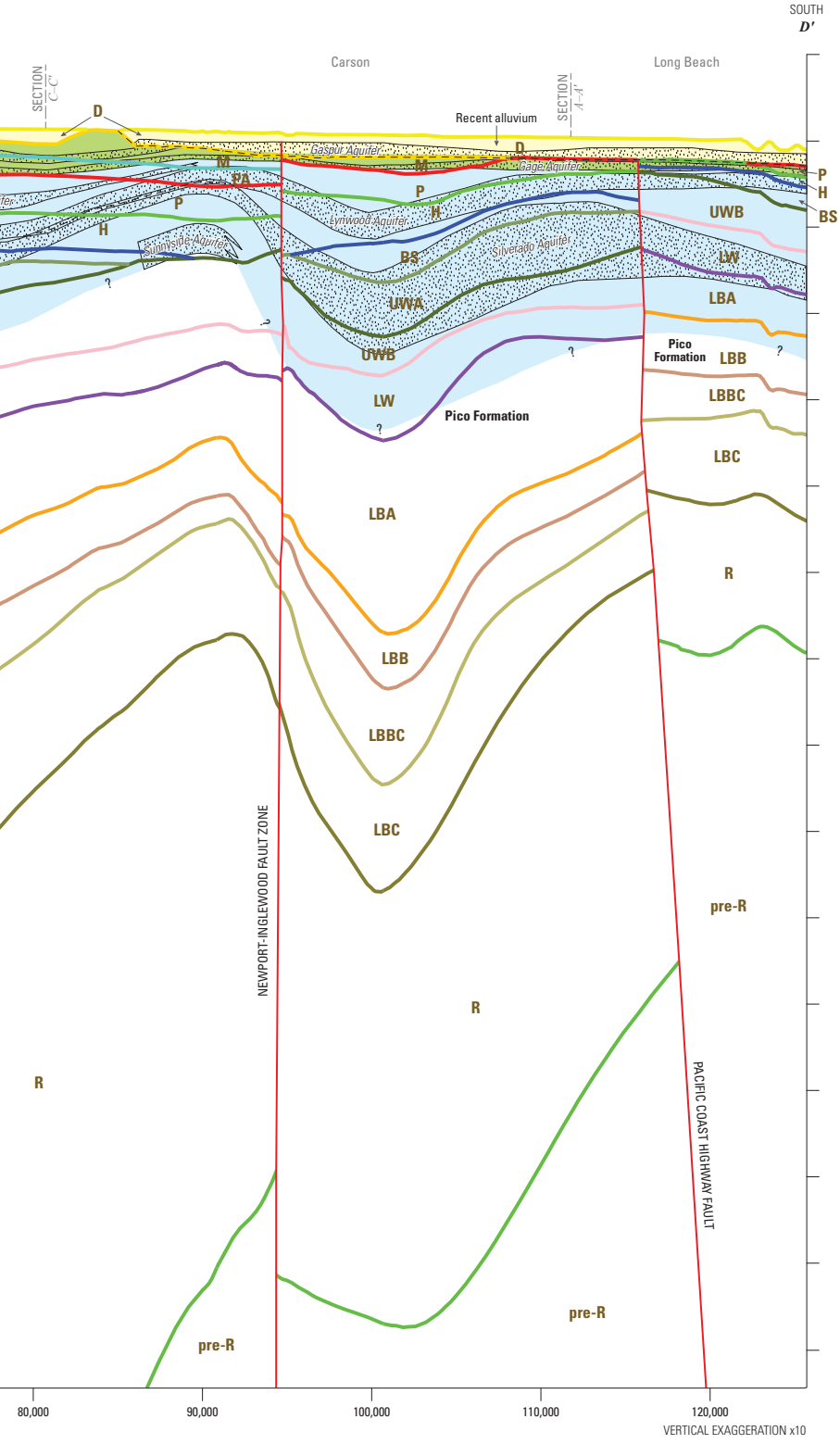


Figure B21. Modeled chronostratigraphic unit boundaries along cross-section D–D', this study, compared to lithostratigraphic formations (colored shading; queried where uncertain) and aquifers of the California Department of Water Resources (1961), Los Angeles Coastal Plain, California. Queried lithostratigraphic boundaries are as noted in California Department of Water Resources, 1961. (Trace of section is shown in fig. B1; colored lines mark the top of each unit; unit identifier codes: D, Dominguez; M, Mesa; PA, Pacific A; P, Pacific; H, Harbor; BS, Bent Spring; UWA, Upper Wilmington A; UWB, Upper Wilmington B; LW, Lower Wilmington; LBA, Long Beach A; LBB, Long Beach B; LBBC, Long Beach BC; LBC, Long Beach C; R, "Repetto"; pre-R, pre-Repetto.)


SOUTH
D′
Carson
Long Beach
SECTION C–C′
SECTION A–A′
Recent alluvium
D
Gaspur Aquifer
Gage Aquifer
M
P
H
BS
UWB
LW
LBA
LBB
LBBC
LBC
R
pre-R
Lynwood Aquifer
Silverado Aquifer
Sunnyside Aquifer
Pico Formation
NEWPORT-INGLEWOOD FAULT ZONE
PACIFIC COAST HIGHWAY FAULT
80,000
90,000
100,000
110,000
120,000
VERTICAL EXAGGERATION x10

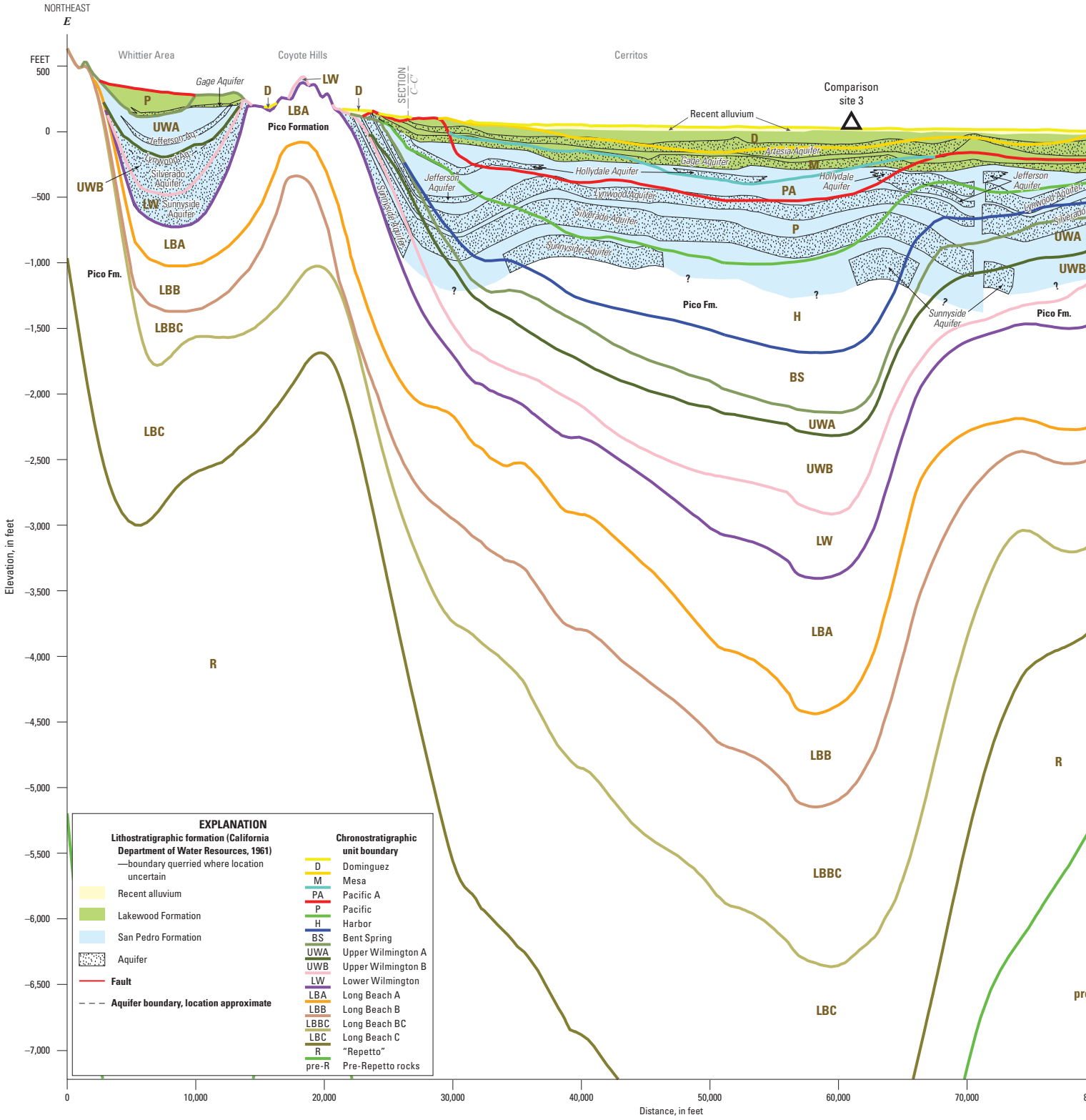
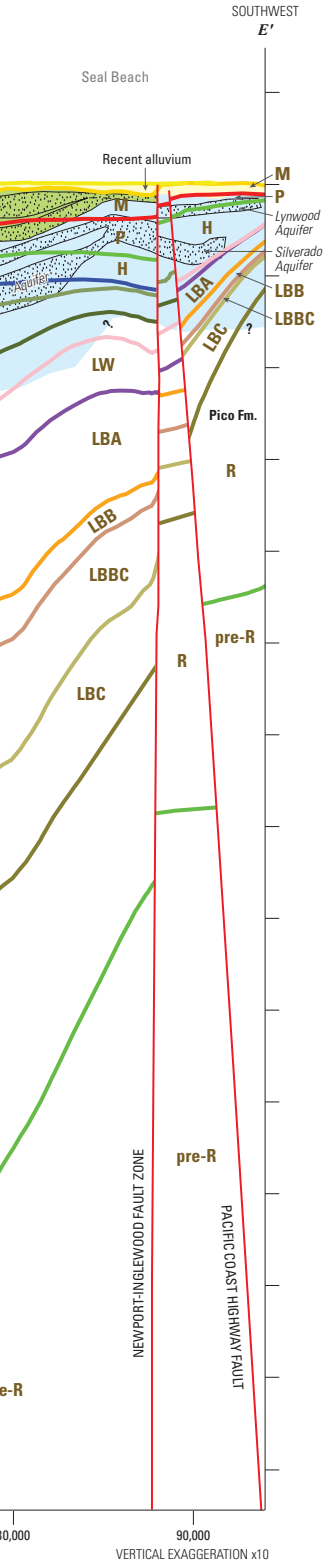


Figure B22. Modeled chronostratigraphic unit boundaries along cross-section E–E', this study, compared to lithostratigraphic formations (colored shading; queried where uncertain) and aquifers of the California Department of Water Resources (1961), Los Angeles Coastal Plain, California. (Trace of section is shown in fig. B1; colored lines mark the top of each unit; unit identifier codes: D, Dominguez; M, Mesa; PA, Pacific A; P, Pacific; H, Harbor; BS, Bent Spring; UWA, Upper Wilmington A; UWB, Upper Wilmington B; LW, Lower Wilmington; LBA, Long Beach A; LBB, Long Beach B; LBBC, Long Beach BC; LBC, Long Beach C; R, "Repetto"; pre-R, pre-Repetto.)


SOUTHWEST
E′
Seal Beach
Recent alluvium
M
P
H
LW
LBA
LBB
LBBC
LBC
R
pre-R
Lynwood Aquifer
Silverado Aquifer
Pico Fm.
NEWPORT-INGLEWOOD FAULT ZONE
PACIFIC COAST HIGHWAY FAULT
90,000
VERTICAL EXAGGERATION x10

Geological Structures

The current understanding of the structural and tectonic history of the Los Angeles Basin has been described by Wright (1991), who summarized a considerable body of previous work, including the seminal work of Yerkes and others (1965). The Los Angeles Basin is at the northern end of the Peninsular Ranges geomorphic province (not shown). Structurally, the Peninsular Ranges province is characterized by fault zones that trend northwest to west-northwest (Wright, 1991). The Los Angeles Basin's structural character makes it of considerable geologic interest as an area of major oil production and active seismicity.

The LACP lies within the central and southwestern structural blocks of the Los Angeles Basin (Reichard and others, 2003). The most prominent feature of the basins in the LACP is the steep-sided Central Basin syncline (or Paramount syncline), which appears prominently in the structure contour map constructed on the base of the Long Beach C chronostratigraphic unit (fig. B23). The syncline is bounded on the west by the Compton–Los Alamitos fault and on the east by the Puente Hills thrust system (Shaw and others, 2002), which is mostly blind, except for a small portion of the Los Angeles section that offsets the base of the Long Beach C unit (fig. B23). Segmentation of the Puente Hills blind-thrust system has produced a number of localized uplifts east of the east limb of the syncline, most notably the Santa Fe Springs anticline, which trends west-northwest and steps over to the West Coyote anticlines to the east (Myers and others, 2003). Reichard and others (2003) inferred the existence of the Norwalk fault, which was believed to occur on the southwest side of these anticlines. However, our analysis reveals no evidence for any discrete stratigraphic offsets that could be attributable to a shallow Norwalk fault; instead, we conclude that these basin margin anticlines have been active from the late Pliocene to the present (Shaw and Shearer, 1999; Pratt and others, 2002; Shaw and others, 2002), resulting in thinning, pinching out, or both, of the stratigraphic units over the crest of these anticlines (Ponti and others, 2014). The thinning of the stratigraphic units over the crest would undoubtedly restrict the movement of groundwater and be a partial barrier to groundwater flow, as simulated by Reichard and others (2003) with the Norwalk fault.

The Compton–Los Alamitos fault, as defined in this study (fig. B23), extends the Los Alamitos fault of Reichard and others (2003). The Compton–Los Alamitos fault appears as an oblique right-lateral fault that extends from the eastern edge of the study area, about 2 miles (mi) northeast of the Alamitos Gap (Bray and others, 2007) northwest to the city of Inglewood (Leon and others, 2009). Based on seismic-reflection data, the fault tip appears to drop below the base of the Long Beach C sequence southwest of the Cerritos area (fig. B23). Similarly, the fault tip drops below the base of Long Beach C unit in the Inglewood area near the Baldwin Hills where the Compton–Los Alamitos fault appears to merge with the Newport-Inglewood fault zone. Between these end points, the fault progressively offsets (up on the west) all chronostratigraphic units through the Bent Spring unit. The overlying Harbor, Pacific, Pacific A, and Mesa units are folded over the tip of the fault and indicative of the activity of the Compton–Los Alamitos fault through the Pleistocene and possibly into the Holocene. As a result of activity of the Compton-Los Alamitos fault, and possibly the postulated underlying Compton blind thrust (Shaw and Suppe, 1996), a northeast-dipping shelf is produced between the Compton-Los Alamitos fault and Newport-Inglewood fault zone that broadens to the south and pinches out near the northern end of the basin; the structure produced by these faults affects groundwater flow as a result of bed thinning over the fold limb.

The Newport-Inglewood fault zone is a predominantly right lateral strike-slip fault system that cuts through the entire LACP and separates the Central and West Coast Basins (figs. B23 and B24). The Newport-Inglewood fault zone is part of the larger Newport-Inglewood-Rose Canyon fault zone (not shown), which extends approximately 125 mi from the Santa Monica Mountains southeastward to San Diego Bay (Treiman and Lundberg, 1999). Although dominantly a strike-slip fault, the fault zone produces uplift and small-scale folds locally along its trend because of localized complexities in the fault zone near the surface in the Los Angeles Basin; the largest of these localized uplifts are the Baldwin Hills, Dominguez Hills, Signal Hill, and Landing Hill (fig. B24). Timing of the initiation of these uplifts appear to vary along the strike of the Newport-Inglewood fault zone, with the Baldwin Hills uplift affecting deposition beginning in Lower Wilmington time, whereas the Signal Hill uplift appears to have begun later, primarily after deposition of the Harbor sequence. The complicated nature of the fault zone and localized uplifts probably contributes to variability in fault zone permeability along its strike.

The Pacific Coast Highway (PCH) fault (figs. B23, B24) is a west-northwest trending, oblique-slip fault identified from borehole and gravity data in Ponti and others (2007) and is inferred to have a maximum vertical separation (down to the north) of approximately 800 ft. The fault offsets all units older than the Dominguez chronostratigraphic unit. The PCH fault runs mostly east-west in the West Coast Basin and is thought to merge with the Newport–Inglewood fault zone to the east. Few data constrain the modeled location of the PCH fault to the west of the Dominguez Gap Barrier Project; however, water-level and geochemical analyses for this study suggest that the fault may extend almost to the Palos Verdes fault to the west, with a possible left step (Pacific Coast Highway fault, Western Extension, figs. B23, B24).

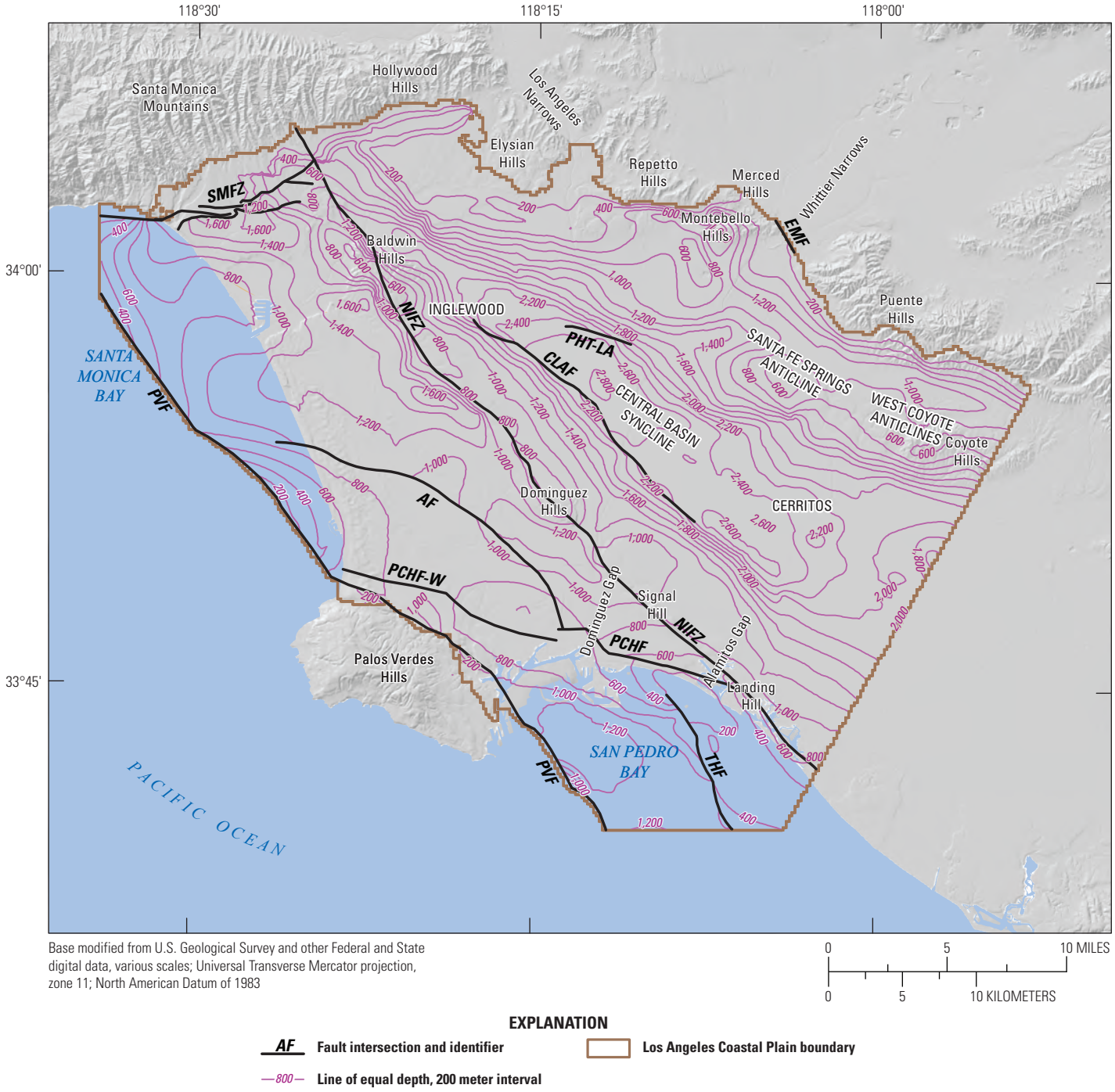


Figure B23. Depth from land surface to the base of water-bearing units (base of Long Beach C chronostratigraphic unit), Los Angeles Coastal Plain, California. (Fault identifiers: AF, Alondra fault; CLAF, Compton-Los Alamitos fault; EMF, East Montebello fault; NIFZ, Newport-Inglewood fault zone; PCHF, Pacific Coast Highway fault; PHT-LA, Puente Hills Thrust fault; SMFZ, Santa Monica fault zone; THF, Thums-Huntington Beach fault.)

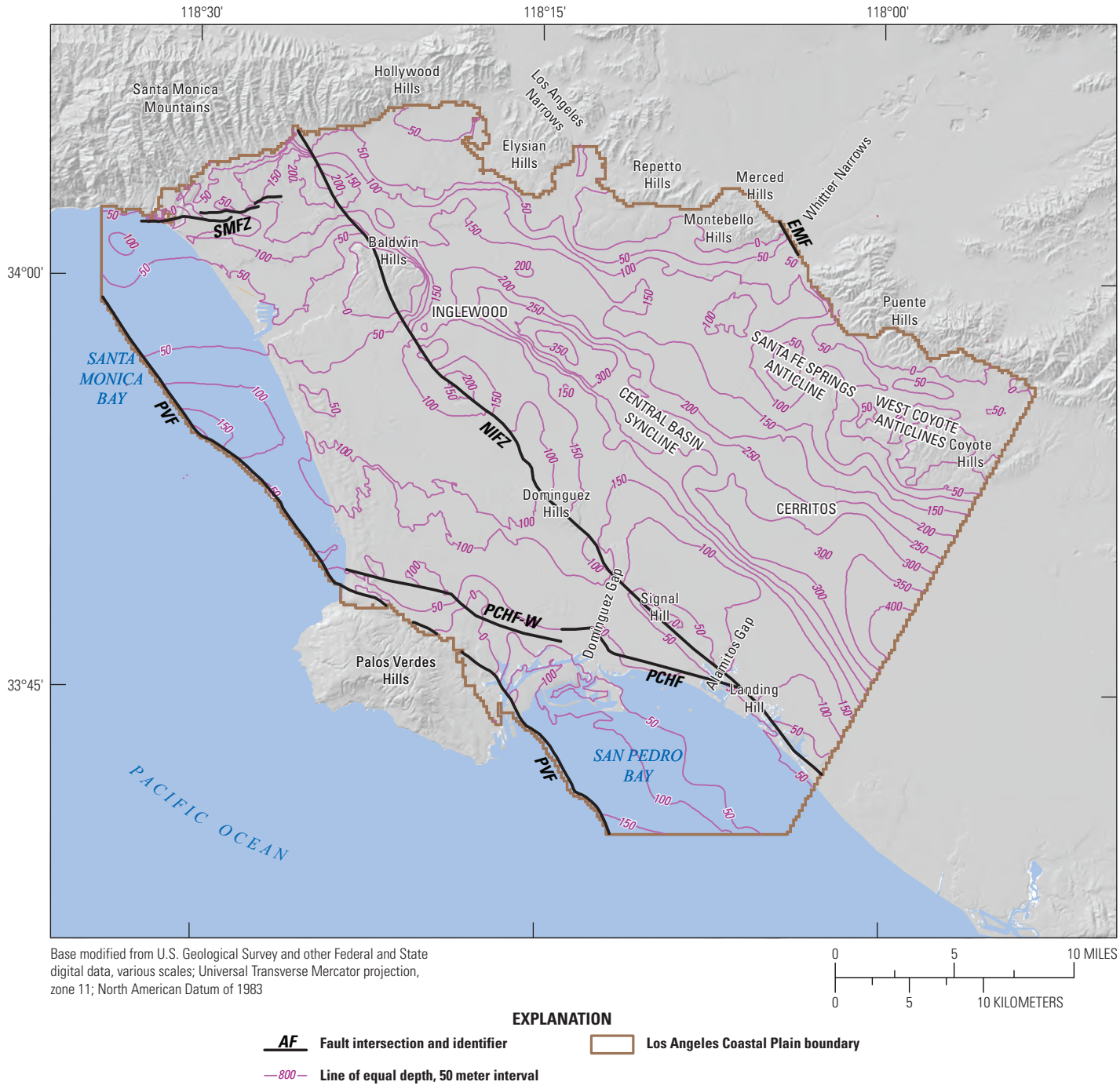


Figure B24. Depth from land surface to the base of the Pacific chronostratigraphic unit, Los Angeles Coastal Plain, California. (Fault identifiers: AF, Alondra fault; CLAF, Compton-Los Alamitos fault; EMF, East Montebello fault; NIFZ, Newport-Inglewood fault zone; PCHF, Pacific Coast Highway fault; PHT-LA, Puente Hills Thrust fault; SMFZ, Santa Monica fault zone; THF, Thums-Huntington Beach fault.)

As part of this study, the Alondra fault (fig. B23) was identified from interpretation of oil industry seismic-reflection profiles within the West Coast Basin. At its western end, the strike of the Alondra fault (a probable oblique-slip fault) approximately parallels the PCH fault, which is located approximately 6 mi to the south (fig. B23). Moving east along the Alondra fault, the strike changes to a northwest orientation and likely intersects the PCH fault along the trend of what Ponti and others (2007) initially interpreted as the Richfield fault. The Alondra fault appears to offset all sequences older than the Bent Spring unit, but little vertical separation (down to the north) is observed above the Lower Wilmington unit. Maximum vertical separation is estimated to be about 650 ft at the base of the Long Beach C chronostratigraphic unit (fig. B23).

The Thums–Huntington Beach fault occurs offshore in San Pedro Bay (fig. B23); based on our analysis of seismic data, we find the fault to be somewhat east of the location mapped by Saucedo and others (2003) and with a more northerly strike. The fault is located approximately 2−4 mi west of the Newport-Inglewood fault zone (fig. B23). We observe apparent vertical separation of as much as 2,000 ft (down to the west) at the base of the Long Beach C chronostratigraphic unit (fig. B23), although fault movement appears to have ceased by the time of Bent Spring deposition. Offset on the fault has caused several of the units to be missing on the east (upthrown) side of the fault.

The Santa Monica fault zone bounds the LACP on the north (fig. B23). The fault zone trends east-west along the southern flank of the Santa Monica Mountains, extending about 25 mi eastward from the coast (Dolan and Pratt, 1997). The Santa Monica fault zone consists primarily of two strands, an inactive southern strand and an active northern strand. The fault zone is a steeply dipping reverse/left-lateral fault and cuts through all chronostratigraphic units older than the Mesa; as modeled, the fault zone may have a combined vertical separation of as much as 4,000 ft.

The East Montebello fault bounds the LACP on the northeast (fig. B23). The fault is the northern extension of the Whittier fault (not shown; Plesch and others, 2007) and cuts through all chronostratigraphic units across the Whittier Narrows (fig. B23). As modeled, the East Montebello fault has (down to the northeast) separation of as much as 1,600 ft.

The Palos Verdes fault is a major, active strike-slip fault that forms most of the western boundary of the LACP. Although principally a strike-slip fault offshore, a left bend in the fault is coincident with uplift of the Palos Verdes Hills, and outcrops of Miocene rocks in the seafloor of Santa Monica Bay indicate that there is substantial west-side-up separation of as much as 1,300 ft that is associated with the fault along the western margin of the LACP.

Previous investigators have identified the Pico and Rio Hondo faults in the Montebello Forebay and the Charnock Fault in the West Coast Basin as barriers to groundwater flow (California Department of Water Resources, 1961; Reichard and others, 2003); however, we find little stratigraphic evidence for existence of the Pico and Rio Hondo faults within the water-bearing chronostratigraphic units modeled for this study. The existence and location of these faults primarily were inferred based on observed water-level variations. Seismic-reflection data used for this study showed no evidence of the Pico and Rio Hondo faults and indicated that the Charnock fault only offsets the “Repetto” and older rocks (fig. B20). As discussed previously in the case of the Charnock fault, observed water-level variations assumed to be attributable to these faults appear to be better explained by stratigraphic discontinuities that result from channel erosion and subsequent backfill of materials with different hydrogeologic properties.

Summary

The chronostratigraphic hydrogeologic-framework model was developed for this study by applying the concepts of sequence stratigraphy to interpret a wide variety of geologic, geophysical, and hydrologic data, much of which has been obtained recently. This approach has resulted in a more refined representation of the Quaternary geology and structure of the Los Angeles Coastal Plain (LACP) relative to previous studies. In particular, seismic reflection data were incorporated to identify and laterally correlate unconformities that bound the chronostratigraphic units. Seismic reflection data demonstrated that there is substantially greater structural relief in the water-bearing Quaternary sedimentary section than represented in earlier hydrogeologic studies, and several previously defined aquifers consist of deposits of different ages that are not lithologically correlated. The current framework model has identified several new faults or fault extensions that may function as groundwater barriers and additional folds and channel systems that also may restrict groundwater flow locally within the LACP.

The resulting chronostratigraphic hydrogeologic-framework model consists of 15 units, 13 of which compose the actively producing groundwater system. In comparison to the Reichard and others (2003) model, comprising five layers, the refined vertical discretization within the present framework model improved the capability of the resulting groundwater-flow model to match observed water-level data and simulate groundwater flowpaths.

Evaluations of stacking patterns in geophysical well logs were used to identify unit boundaries that were tied to seismic data and paired with lithologic descriptions to identify of various depositional facies that were correlated regionally within each chronostratigraphic unit; these interpretations informed parameterization of the resulting groundwater-flow model (Chapter C). Facies interpretations and correlations were aided by using water-level hydrographs and water-quality samples from short-screen wells at multiple-well monitoring sites to provide insight into groundwater source areas and likely groundwater flowpaths.

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Chapter C. Groundwater Hydrology

By Scott Paulinski, Peter Martin, Claudia Faunt, Rhett Everett, Whitney Seymour, and Michael Land

The groundwater hydrology of the Los Angeles Coastal Plain (LACP) was characterized by summarizing previously published research (Poland and Piper, 1956; Poland and others, 1959; California Department of Water Resources (CDWR), 1961, 1962, 1966; Reichard and others, 2003), compiling and analyzing available hydrogeologic data from local, State, and Federal agencies, and analyzing data collected as part of this study.

Groundwater Basins and Areas

The California Department of Water Resources (1961) subdivided the LACP into four groundwater basins: Central, West Coast, Hollywood, and Santa Monica Basins (fig. C1). A groundwater basin is defined by the CDWR (1975) as an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and a definable bottom. The lateral boundaries of the groundwater basins within the LACP generally are low-permeability rocks or faults. This study also includes the western portion of the adjacent Orange County Basin, which is physically connected to the Central Basin but is separated by the political boundary between Los Angeles and Orange Counties (fig. C1). For the purposes of this report, the four groundwater basins of CDWR (1961) in Los Angeles County, and the portion of the Orange County Basin included in the study area, are referred to as the LACP. In addition, the bottom boundary of the LACP is the top of the "Repetto" of Pliocene age, or older sediments if the "Repetto" is missing.

The groundwater basins of the LACP have been divided into 14 subareas based on hydrogeological characteristics and management interests for this study: six in the Central Basin, one in the West Coast Basin, three in the Orange County Basin, one in the Santa Monica Basin, one in the Hollywood Basin, and two offshore (fig. C1). The Central Basin is divided into the Los Angeles Forebay, Montebello Forebay, Whittier Area, and Central Basin Pressure Area. The Central Basin Pressure Area is deeper than the forebays with hydraulic heads varying more with depth (Chapter A; Chapter D). The forebays tend to have coarser sediments, especially in the upper units. The Central Basin Pressure Area and the Los Angeles Forebay have been further divided by administrative area (Water Replenishment District of Southern California [WRD] versus non-WRD; fig. C1). The groundwater basin or subarea boundaries of this study vary slightly from the boundaries defined by the CDWR (1975). The overall change is not substantial, and the size of each groundwater basin remains close to the size defined by the CDWR (fig. C1). The basins and associated subareas are discussed in Reichard and others (2003).

As stated above, the Central and Orange County Basins are separated by a political boundary. There are no known geologic boundaries that separate the two groundwater basins, and water-level data indicate that they are hydrologically connected. The Central Basin has been managed by WRD since 1959, and the Orange County Basin has been managed by the Orange County Water District (OCWD) since 1933. For this report, only the western part of the Orange County Basin was included as part of the investigation (fig. C1). The area extends about 5 mi to the southeast of the Los Angeles/Orange County boundary and is bounded by the Puente Hills to the north and the San Pedro Bay to the south (fig. C1). The boundary was chosen near several multiple-well monitoring sites, which allowed for a more accurate assessment of conditions along this boundary. The Orange County Basin within the study area is divided into three subareas: Orange County North, Orange County Central, and Orange County South subareas (fig. C1).

Definition of Aquifer Systems

The main water-bearing deposits in the LACP are the saturated portions of the late Pliocene and Quaternary chronostratigraphic units defined in the "Late Pliocene and Quaternary Chronostratigraphic Units" section of this report (Chapter B). Thirteen chronostratigraphic units (Long Beach C, Long Beach BC, Long Beach A, Lower Wilmington, Upper Wilmington B, Upper Wilmington A, Bent Spring, Harbor, Pacific, Pacific A, Mesa, and Dominguez) were identified overlying bedrock units, ranging in age from latest Pliocene through Holocene (table B2). For the purposes of this report, these chronostratigraphic units were considered as separate aquifer systems, except for the lower two units (Long Beach BC and Long Beach C), which were combined into a single aquifer system (Long Beach C).

The "Repetto" and pre-Repetto Rocks are consolidated sedimentary deposits of mid-Pliocene and older age. These low-permeability rocks yield only small quantities of water to wells. Although the lithologies of the older sedimentary rocks have considerable variability, they are similar in terms of the greater degree of compaction, consolidation, and cementation relative to the younger chronostratigraphic units defined for this study. For the purposes of this study, "Repetto" and older rocks form the base and, in many areas, the lateral boundaries of the groundwater basins of the LACP.

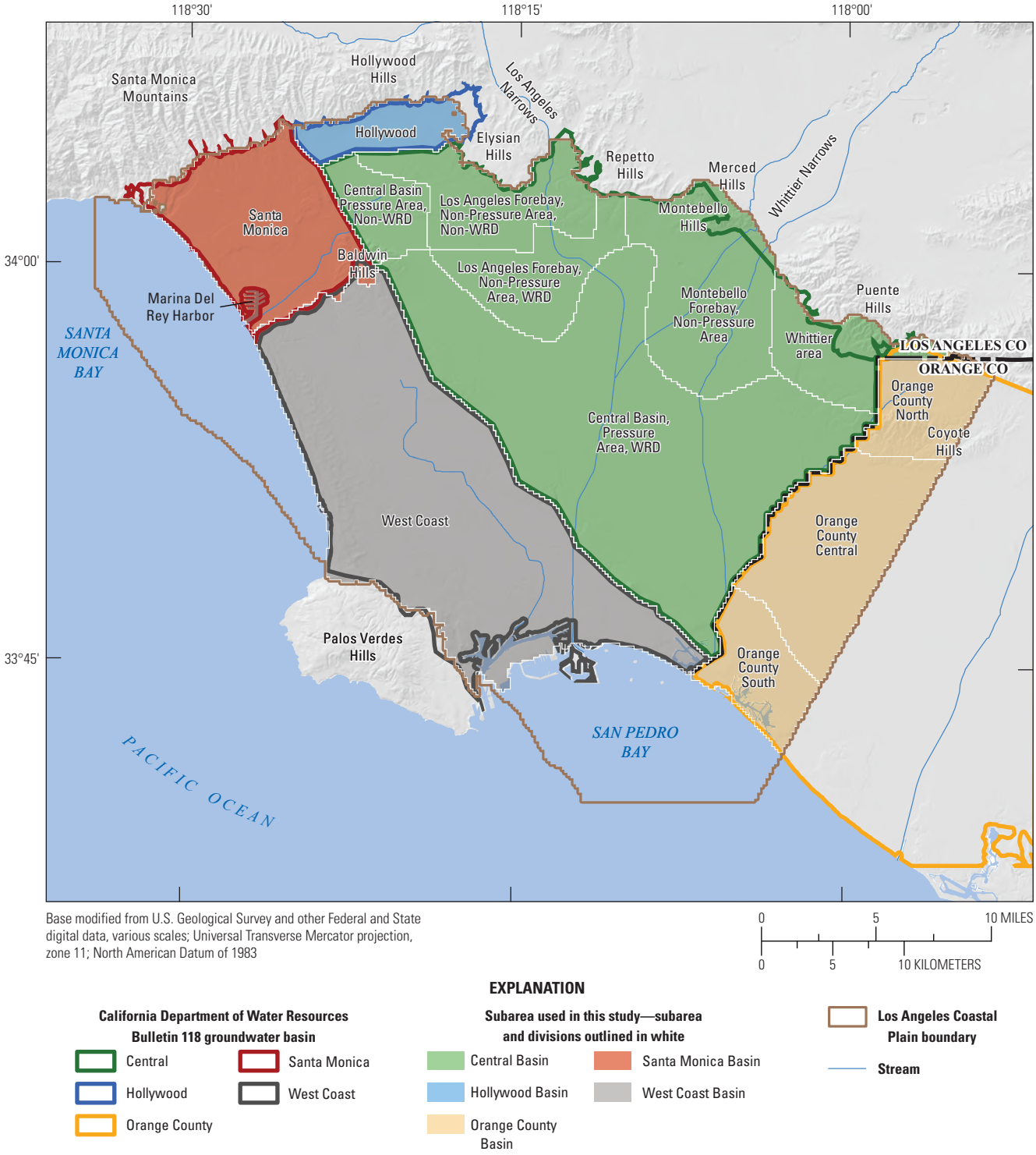


Figure C1. Groundwater basins and subareas of the Los Angeles Coastal Plain, California. California Department of Water Resources (CDWR) groundwater basins are from CDWR Bulletin 118 (1975).

The chronostratigraphic units delineate the aquifer systems for this study and consist of layers of coarse- and fine-grained sediments that vary laterally and vertically. As explained in Chapter B, these units generally were formed in response to sea-level changes resulting from worldwide glaciation cycles (Imbrie and others, 1984). During glacial periods, when sea levels were low, erosion on the exposed shelf occurred, forming a basal unconformity. The deposits overlying this basal unconformity are dominantly coarse-grained and regionally extensive on the groundwater basin floor (Van Wagoner and others, 1990); consequently, these deposits are often the most water-bearing of a particular aquifer system. The upper part of a chronostratigraphic unit represents the period when sea levels were high and starting to fall. If these deposits are not truncated by the overlying unit boundary, they are usually fine-grained (Van Wagoner and others, 1990) and confine the underlying aquifer system.

The predominant sediment grain size in the different aquifer systems was estimated by analyzing downhole lithologic and geophysical logs collected at the multiple-well monitoring sites constructed by the U.S. Geological Survey (USGS) in cooperation with WRD, as described in appendix 2. The downhole geophysical logs used in the analysis include nuclear magnetic resonance (NMR), array induction 2-foot (ft) resistivity (AIT), long-normal resistivity, short-normal resistivity, and gamma logs. Grain sizes were analyzed at 0.5 ft vertical intervals. The grain sizes from these intervals were averaged to determine the percentage of coarse-, medium-, and fine-grained sediment in each unit. The results of the analysis for the NMR and AIT methods were plotted for each chronostratigraphic unit to help identify high-permeability (coarse-grained) and low-permeability (fine-grained) zones in the different aquifer systems (appendix 2, fig. 2.1). The Harbor and Upper Wilmington A chronostratigraphic units have the greatest number of wells in which medium- to coarse-grained sediments dominate (appendix 2, figs. 2.1*E*, 2.1*G*). The Long Beach A, Long Beach, B, and Long Beach C chronostratigraphic units are, in general, finer-grained than the overlying aquifer systems (appendix 2, units; figs. 2.1*J–L*).

The results of the grain-size analysis show different patterns of spatial variability within the upper/middle and lower chronostratigraphic units. The upper and middle chronostratigraphic units tend to have coarser-grained sediments in the Montebello Forebay and along the western portion of the West Coast Basin and finer sediments in parts of the Central Basin Pressure Area and parts of the West Coast Basin (appendix 2, figs. 2.1*A–I*). The lower chronostratigraphic units contain mostly medium- and fine-grained sediments throughout most of the LACP, though some wells in the Montebello Forebay and West Coast Basin contain coarse-grained sediments (appendix 2, figs. 2.1*J–L*).

Groundwater Recharge

Sources of groundwater recharge in the LACP include (1) natural recharge in response to precipitation and percolation on the coastal plain, (2) natural mountain-front recharge, (3) infiltration of stream flow along river channels, (4) return flow from urban landscape irrigation, (5) return flow from leakage of water lines and sewer lines, (6) net underflow from adjacent groundwater basins, (7) net subsurface inflow from offshore, (8) managed aquifer recharge from spreading grounds, and (9) managed aquifer recharge through injection wells at seawater barriers. A rainfall-runoff-infiltration model was developed to estimate the spatial and temporal distribution of natural recharge on the coastal plain, mountain-front recharge, infiltration of streamflow, and return flow from urban landscape irrigation. The development, calibration, and results of this model are described in detail in Hevesi and Johnson (2016). The major results of the rainfall-runoff-infiltration model are presented in the following sections.

Natural Recharge on the Coastal Plain

Natural recharge is a result of downward percolation of precipitation that falls on the coastal plain of the study area. The distribution and magnitude of recharge change both spatially and temporally and are influenced by two main factors: climate and land cover. The mean annual precipitation at the University of Southern California (USC) campus near Los Angeles is 14.8 in. for the period 1914–2016 (Los Angeles Almanac, 2018). The cumulative departure from the mean for annual precipitation shows major and minor wet and dry periods which are typical of the long-term climate record for the Los Angeles Basin (fig. C2). Historically, the land cover of the LACP has changed as the area has urbanized. However, most development was completed prior to the beginning of the period of interest for this study (1971–2015); therefore, land-cover changes during the study period are small. Hevesi and Johnson (2016) estimated that the average annual precipitation for the LACP ranged from 11.1 to 15.7 inches per year (in/yr) for calendar years 1915–2014. Hevesi and Johnson (2016) also reported that precipitation falls primarily during the cooler months of October through May and that February is historically the wettest month. The average annual precipitation in the study area is about 13 in/yr or about 359,000 acre feet per year (acre-ft/yr), which along with urban irrigation contributes to 42,000 acre-ft/yr of average potential recharge to the LACP groundwater-flow system from 1915 to 2014 (Hevesi and Johnson, 2016).

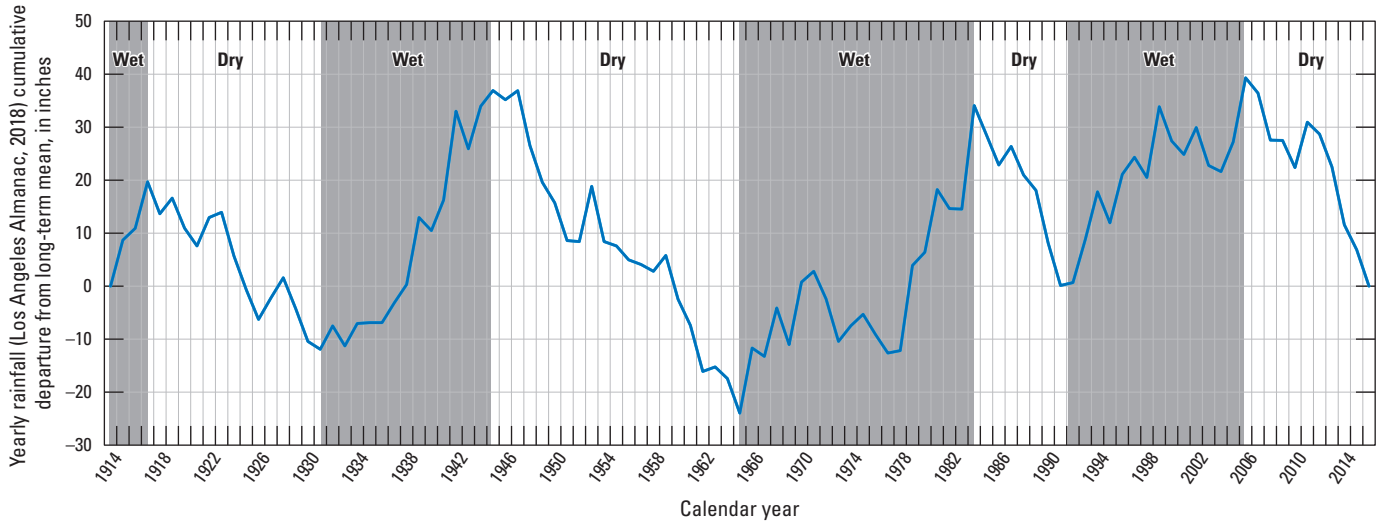


Figure C2. Cumulative departure from the long-term mean for annual precipitation based on annual rainfall totals measured at the University of Southern California (USC) campus (Los Angeles Almanac, 2018), Los Angeles County, California, 1914–2016.

Natural Mountain-Front Recharge

The magnitude of mountain-front recharge is related to the size, topography, precipitation, soil, and vegetation of the contributing watersheds in the uplands. Permeability of geologic units at the recharge areas influences the percolation rate of the mountain-front recharge. Similar to natural recharge on the coastal plain, natural mountain-front recharge is affected by climate and land cover of the contributing watersheds. Mountain-front recharge occurs primarily in areas bordering the mountains and hills, including the Santa Monica Mountains and Hollywood Hills to the north, the Elysian, Repetto, Merced, and Puente Hills to the northeast, and the Palos Verdes Hills to the southwest (fig. A1). These areas are at the edges of the groundwater basins where younger aquifer systems are often missing and the older aquifer systems are near the surface, which allows direct recharge of the older aquifer systems in the LACP. Hevesi and Johnson (2016) estimated the total potential annual mountain-front recharge to the LACP from 1915 to 2014 at about 22,000 acre-ft/yr.

Infiltration of Streamflow

The San Gabriel River, Rio Hondo, and Los Angeles River drain the San Gabriel and San Fernando Valleys and enter into the LACP coastal plain from the Whittier and Los Angeles Narrows (see fig. A1). The magnitude of the flows can be substantial because the drainage areas of the rivers extend into the higher elevations of the San Gabriel Mountains where the precipitation is substantially greater than on the coastal plain. Infiltration of streamflow was the main source of recharge to the LACP groundwater-flow system under pre-development conditions (Mendenhall, 1905c). However, urbanization of the study area as well as the upper San Gabriel and San Fernando Valleys over the 20th century has eliminated stream-flow infiltration in most parts of the study area because of stream channel and streamflow modifications.

The U.S. Army Corp of Engineers (USACE) has channelized the Los Angeles and San Gabriel Rivers for flood-control purposes. The USACE also constructed a number of dams in the mountainous areas and upper watersheds of the rivers, including the Whittier Narrows Dam, which is within the boundary of LACP (fig. A1). Since 1960, stream inflow from the San Gabriel and the San Fernando Valleys to the study area has been regulated.

Recharge from streambed infiltration is limited because most of the river channels in LACP have been lined with concrete. The Los Angeles River is lined throughout the study area except just upstream from the confluence with San Pedro Bay. The San Gabriel River is lined except in the upper parts of the Montebello Forebay and near the Alamitos Gap. The Rio Hondo also is lined throughout the study area. Most of Ballona Creek and the upper sections of Dominguez Channel also are lined (fig. A1). All infiltration of streamflow across LACP during the 1971-2015 study period is accounted for by the infiltration of water spreading at the San Gabriel River spreading grounds (SGRSG), Rio Hondo spreading grounds (RHSG), and behind the Rio Hondo side of the Whittier Narrows Dam. Infiltration of water spreading is described in the "Managed Aquifer Recharge from Spreading Grounds" report section. Recharge at the lower end of the Los Angeles River, Rio Hondo, and San Gabriel Rivers is assumed to be negligible.

Return Flow from Urban Landscape Irrigation

Return flow from urban landscape irrigation is a source of areal recharge to the LACP groundwater system. Urban irrigation can affect the natural precipitation and percolation process by increasing the amount of water available for infiltration through on-site percolation (Grimmond and others, 1986), and by affecting runoff rates from rainfall events (Sample and Heaney, 2006). The volume of urban irrigation being applied to the landscape has been substantial, exceeding natural rainfall in certain areas (California Department of Water Resources, 1975). The average annual rate of urban irrigation estimated by Hevesi and Johnson (2016) for the LACP is about 163,000 acre-ft, which is about 40 percent of the volume of average annual precipitation for the LACP.

Urban irrigation is highly influenced by the water demand of landscape vegetation and the availability of irrigation water. Because little precipitation falls during the summer months in the LACP, the highest irrigation demand typically occurs from July to September (Hevesi and Johnson, 2016).

Return Flow from Leakage of Water and Sewer Lines

The LACP, being one of the most populated metropolitan areas in the United States, has a network of underground sewer and water lines beneath it. For this report, sewer lines include storm drains and sanitary sewers. Although leakage from water and sewer lines could be another source of managed aquifer recharge to the LACP groundwater system, this component has not been well- studied and was not included in the rainfall-runoff-infiltration model developed for this study (Hevesi and Johnson, 2016). Therefore, the location and magnitude of managed aquifer recharge due to leakage from water and sewer lines is still largely unknown and is not explicitly accounted for in the groundwater-flow modeling section of this report, although total recharge (including return flow from leaking water and sewer lines as well as the other sources) was determined as part of model calibration. Given the aging sewer and water transmission system and the substantial volume of water being delivered through them, an improved understanding could improve estimates of return flow from leakage of water and sewer lines in the LACP.

Underflow from Adjacent Groundwater Basins

The Central Basin receives groundwater underflow from up-gradient groundwater basins in the San Gabriel and San Fernando Valleys, through the Whittier and Los Angeles Narrows, respectively (fig. A1). The San Gabriel River Watermaster's (SGRWM) responsibilities include the measuring of groundwater elevation and the estimating of groundwater underflow through the Whittier Narrows every spring and fall. The SGRWM estimates the quantity of underflow using a method based on Darcy's Law (San Gabriel River Watermaster, 1997). The average annual underflow estimated by the SGRWM is 26,000 acre-ft/yr for the period 1962 to 2015 (table C1). Similar measurements and estimates are not available regarding underflow through the Los Angeles Narrows because of the highly urbanized condition of the area.

Reichard and others (2003) estimated underflow through the Los Angeles and Whittier Narrows in a regional groundwater-flow model of the Los Angeles Basin. General-head boundaries were used at the Los Angeles and Whittier Narrows to represent groundwater underflow from the San Fernando and San Gabriel Valleys, respectively. These general-head boundaries were applied using average measured water levels over the simulation period at wells immediately upgradient of both boundaries (Reichard and others, 2003). The simulated average annual groundwater underflows through the Los Angeles and Whittier Narrows for the period of 1971 to 2000 were approximately 6,300 and 27,000 acre-ft, respectively (Reichard and others, 2003).

Managed Aquifer Recharge from Spreading Grounds

Spreading grounds have been used in the LACP since the 1930s as a means to replenish groundwater basins and store water underground during times of water surplus to meet demands in times of shortage. Spreading grounds were constructed at the Montebello Forebay, an area south of Whittier Narrows, where highly permeable, coarse-grained deposits allow substantial percolation of surface waters into the Central Basin (fig. A1). The RHSG are adjacent to the Rio Hondo channel and cover about 570 acres. The SGRSG are within and adjacent to the San Gabriel River channel. The off-channel portion of the SGRSG covers about 128 acres, and the in-channel portion, where inflatable rubber dams are used to promote groundwater recharge, covers about 308 acres. Both the RHSG and SGRSG are owned and operated by the Los Angeles County Flood Control District (LACFCD). The facilities have been improved to increase intake and storage capacity since they were built in the 1930s. The average annual recharge based on measured water delivery rates (Central Basin Watermaster, 2017) to the spreading grounds from RHSG and SGRSG for calendar years 1971 to 2015 was about 57,000 and 46,000 acre-ft, respectively (fig. C3).

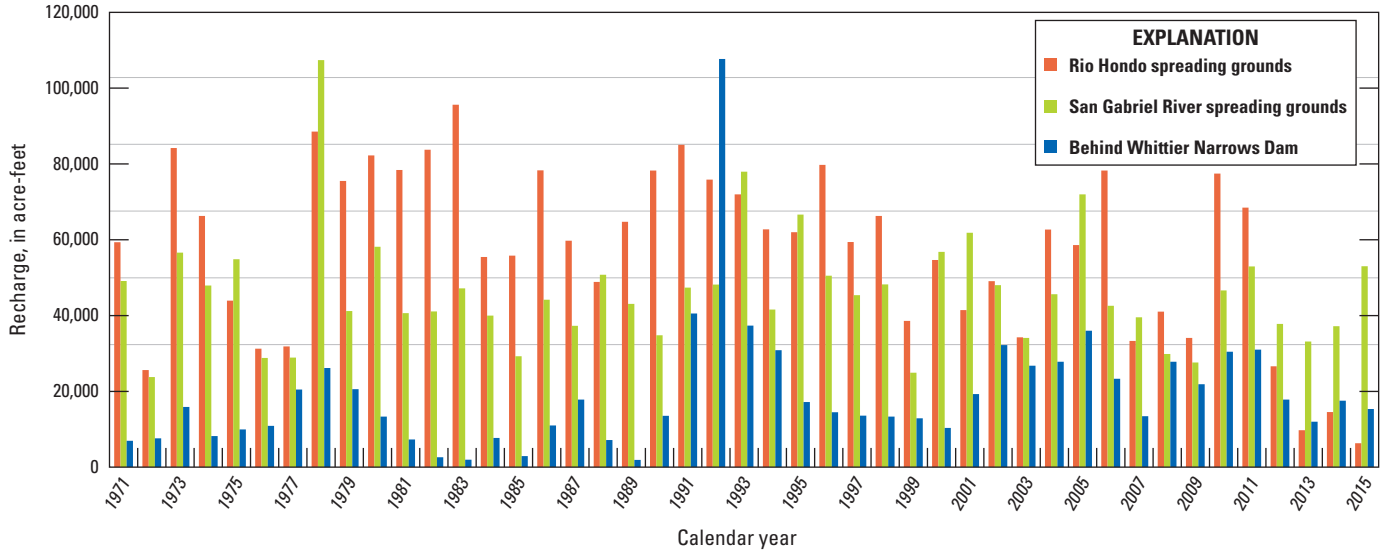


Figure C3. Annual recharge at Rio Hondo spreading grounds, San Gabriel River spreading grounds, and Whittier Narrows Dam for calendar years 1971 to 2015, Los Angeles County, California.

Table C1. Estimated underflow in acre-feet from the San Gabriel Valley into the Los Angeles Coastal Plain provided by the San Gabriel Water Master, Los Angeles County, California, 1962 to 2015.

[Data provided by San Gabriel River Watermaster.]

Year	Subsurface flow	Year	Subsurface flow	Year	Subsurface flow	Year	Subsurface flow
1962	21,600	1976	27,800	1990	32,100	2004	24,200
1963	20,050	1977	31,700	1991	26,200	2005	21,600
1964	21,000	1978	30,900	1992	22,700	2006	24,300
1965	18,800	1979	27,400	1993	21,600	2007	26,400
1966	17,000	1980	25,300	1994	24,000	2008	30,300
1967	17,500	1981	27,400	1995	25,300	2009	31,300
1968	20,700	1982	29,900	1996	27,400	2010	29,400
1969	24,400	1983	29,100	1997	28,100	2011	25,400
1970	23,900	1984	28,200	1998	27,900	2012	23,700
1971	22,900	1985	28,600	1999	27,000	2013	27,200
1972	24,000	1986	30,500	2000	27,200	2014	35,100
1973	25,900	1987	31,900	2001	27,900	2015	35,700
1974	26,600	1988	33,200	2002	27,400	**Average**	**26,296**
1975	25,600	1989	33,000	2003	24,000		

The reservoir behind the Whittier Narrows Dam (WND) on the Rio Hondo side collects and stores local runoff and the water released into the San Gabriel River from the upstream Santa Fe Dam (not shown). Both the dam and the reservoir are earthen; therefore, seepage occurs when water is impounded behind the dam after storm events. Seepage also occurs in the reservoir behind the dam throughout the year if water is present in the Rio Hondo or its tributaries. Groundwater recharge at the reservoir functions similarly to the RHSG and SRSG downstream. The average annual recharge at WND for calendar years 1971 to 2015 was about 19,000 acre-ft (fig. C3). In addition to local runoff, recycled and imported water is purchased by WRD for spreading at these recharge facilities. The total average annual spreading for RHSG, SGRSG, and WND was about 120,000 acre-ft for calendar years 1971 to 2015.

WND, RHSG, and SGRSG are also central elements of the San Gabriel River flood control and conservation system. Water collected and stored in the reservoir behind the WND is routed to the RHSG and SGRSG or released to the San Gabriel River in a regulated manner to facilitate groundwater recharge and minimize flooding downstream. Therefore, distribution of recharge water at the three facilities is determined not only by the total amount of excess water and the capacity of each facility, but also by the operation and maintenance schedule and other engineering-related factors.

Managed Aquifer Recharge Through Injection Wells at Seawater Barriers

Injection of freshwater through seawater-barrier wells has been used as a method of managed aquifer recharge in the LACP since the 1950s. Groundwater in the coastal aquifers of the LACP is in hydraulic connection with the Pacific Ocean. Under natural conditions, groundwater flows from the forebays to the ocean; however, the flow direction can be reversed when inland pumping of freshwater lowers the water-level elevation in the coastal groundwater basins below sea level. In the LACP, seawater intrusion resulting from freshwater pumping started to become a problem in the 1940s (Poland and others, 1959). As a result, injection of imported water through wells at what is now the West Coast Basin Barrier Project (WCBBP) began on an experimental basis in 1951 (Water Replenishment District of Southern California, 2007). Injecting water through wells allows fresh water to displace saltwater and creates a hydraulic pressure ridge (or barrier) along the line of injection wells. Three barrier projects have been constructed and operated near the shoreline of the Central and West Coast Basins (fig. A1). In the West Coast Basin, water is injected at WCBBP and the Dominguez Gap Barrier Project (DGBP). In the Central Basin, water is injected at the Alamitos Barrier Project (ABP). The alignment of each barrier project was based on geologic and hydrologic conditions at each location, as well as land availability. Factors such as seawater intrusion path, rate, and areal extent were also considered when each barrier was designed and constructed. The barrier wells allow injected water to reach depths up to 700 ft at the WCBBP (Water Replenishment District of Southern California, 2007).

Among the three barrier projects, the WCBBP is the largest, extending about 9 miles (mi) along the Santa Monica Bay shoreline in the West Coast Basin (fig. A1). The WCBBP consists of 153 injection wells and 302 observation wells (Water Replenishment District of Southern California, 2007). The DGBP is the second largest barrier project, extending over 6 mi along the Dominguez Gap, in the southern part of the West Coast Basin (fig. A1). The DGBP has 94 injection wells and 232 observation wells (Water Replenishment District of Southern California, 2007). The ABP is the smallest barrier project, extending about 2.2 mi through Long Beach and Seal Beach, in the southeastern part of the Central Basin and crosses the Los Angeles/Orange County line (fig. A1). The ABP includes injection wells that form a freshwater ridge, extraction wells that were intended to form a saltwater trough, and 239 observation wells (Los Angeles County Department of Public Works, 2005).

Similar to the spreading facilities, the LACFCD operates and maintains the barrier projects. The LACFCD owns the wells, WRD purchases the injection water for the WCBBP, the DGBP, and the Los Angeles County side of the ABP, and the Los Angeles County Department of Public Works pays for the operational costs. The OCWD owns the ABP injection and monitoring wells, purchases the water, and pays for the operational costs for the Orange County side of the ABP. Presently, both imported and recycled water are used for injection. The WRD reported (West Coast Basin Watermaster, 2017) average annual injection volumes for WCBBP, DGBP, and ABP from 1971 to 2015 were approximately 21,200, 6,500, and 5,300 acre-ft, respectively (fig. C4). The annual injection volume varied on an annual basis at all barrier projects during this period. For example, injection at the WCBBP ranged from more than 35,000 acre-ft/yr in 1976 to less than 10,000 acre-ft/yr in 2005 (fig. C4). The location and injection rates of barrier wells for 1971 to 1979 and 2010 to 2015 are shown on figure C5.

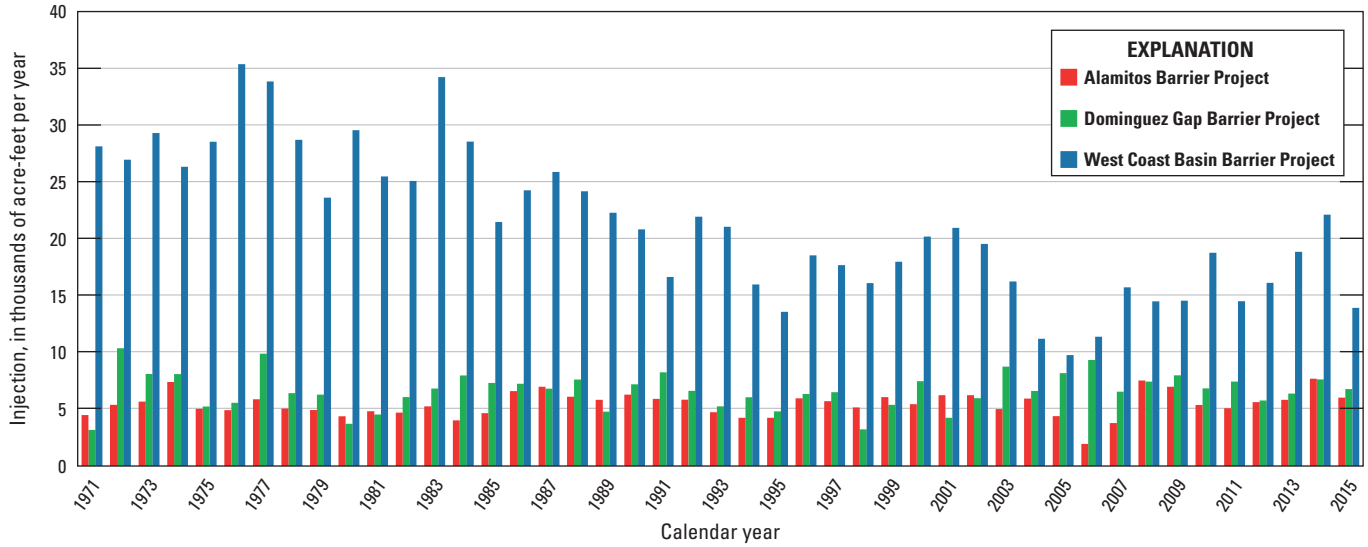


Figure C4. Annual injection during calendar years 1971–2015 at Alamitos, Dominguez Gap, and West Coast Basin Barrier Projects, Los Angeles Coastal Plain, California. Injection data provided by Water Replenishment District of Southern California.

Net Subsurface Inflow

Sources of subsurface inflow include underflow from the neighboring Orange County groundwater basin and from offshore. Under predevelopment conditions, there were artesian conditions along the county line (Mendenhall, 1905c) with flow discharging to the Pacific Ocean. After a century of groundwater development, water levels are no longer artesian in the two groundwater basins, and the natural hydraulic gradient and flow paths have been altered (Chapter D). A previous USGS regional groundwater-flow model simulated a net inflow of about 8,000 acre-ft/yr from the Orange County Basin into the Central Basin for the period from 1971 to 2000 (Reichard and others, 2003, fig. 34). However, the last five years of this simulation (1996–2000) indicated increased flow from the Central Basin to the Orange County Basin and a reduced amount of flow from the Orange County Basin to the Central Basin.

The location and magnitude of onshore or offshore groundwater flow varies depending on the amount of groundwater recharge and discharge to or from the coastal groundwater basins. Offshore flow occurs in areas where the groundwater elevation is higher than sea level because of injection or other managed aquifer recharge activities. In other areas, onshore flow occurs when groundwater elevation is lower than sea level due to the pumping of groundwater. A previous USGS regional groundwater-flow model simulated a net average annual inflow of about 3,000 acre-ft from the Pacific Ocean into the entire LACP for the period of 1971 to 2000 (Reichard and others, 2003, fig. 34). Simulated net average annual inflow from the Pacific Ocean into the West Coast Basin was about 7,100 acre-ft, with inflow of 8,900 acre-ft from the lower two model layers and 1,800 acre-ft of outflow from the upper two model layers (Reichard and others, 2003).

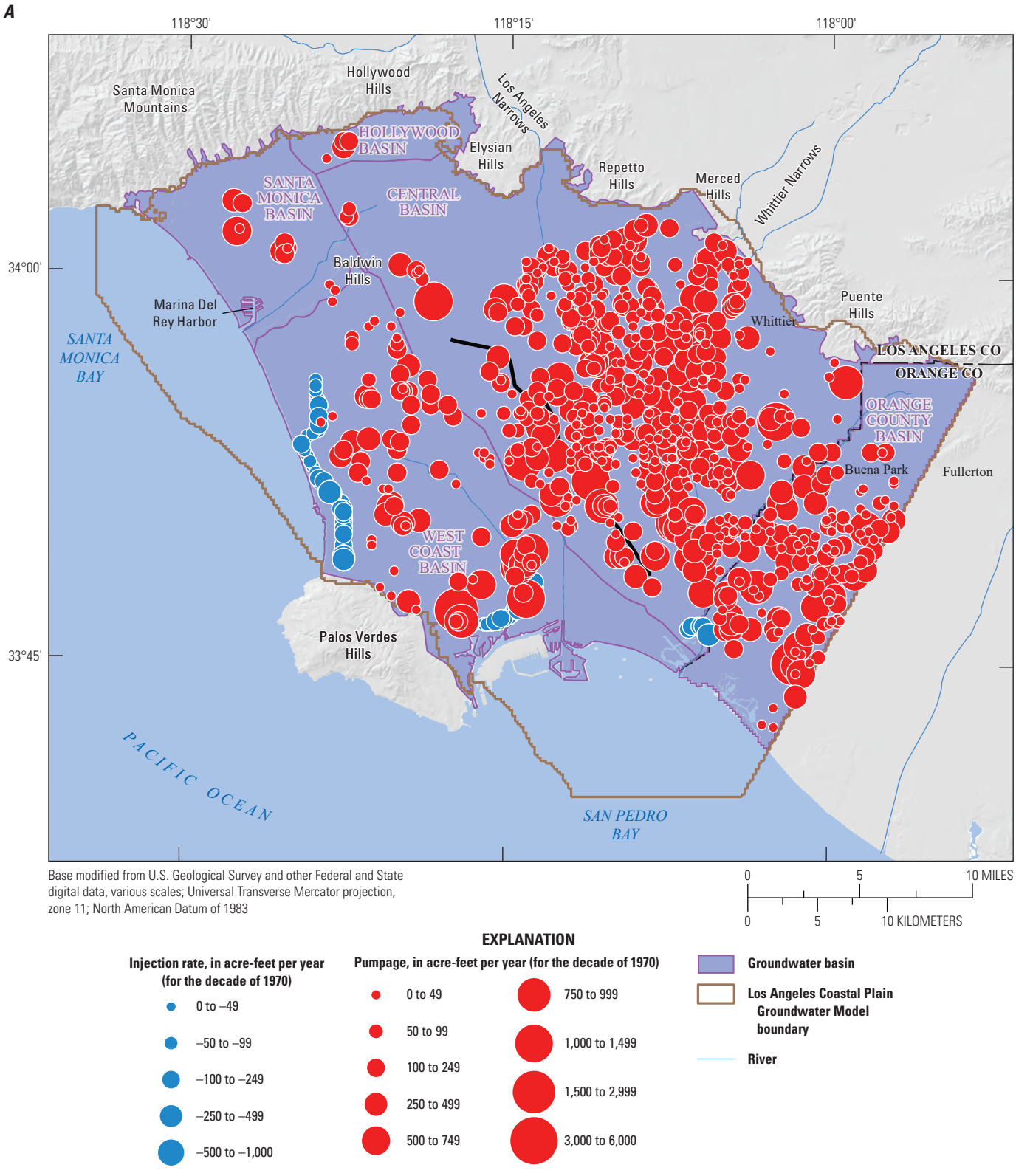


Figure C5. Average injections and pumpage for *A*, 1971 to 1979, and *B*, 2010 to 2015, in Los Angeles Coastal Plain, California. Data provided by Water Replenishment District of Southern California.

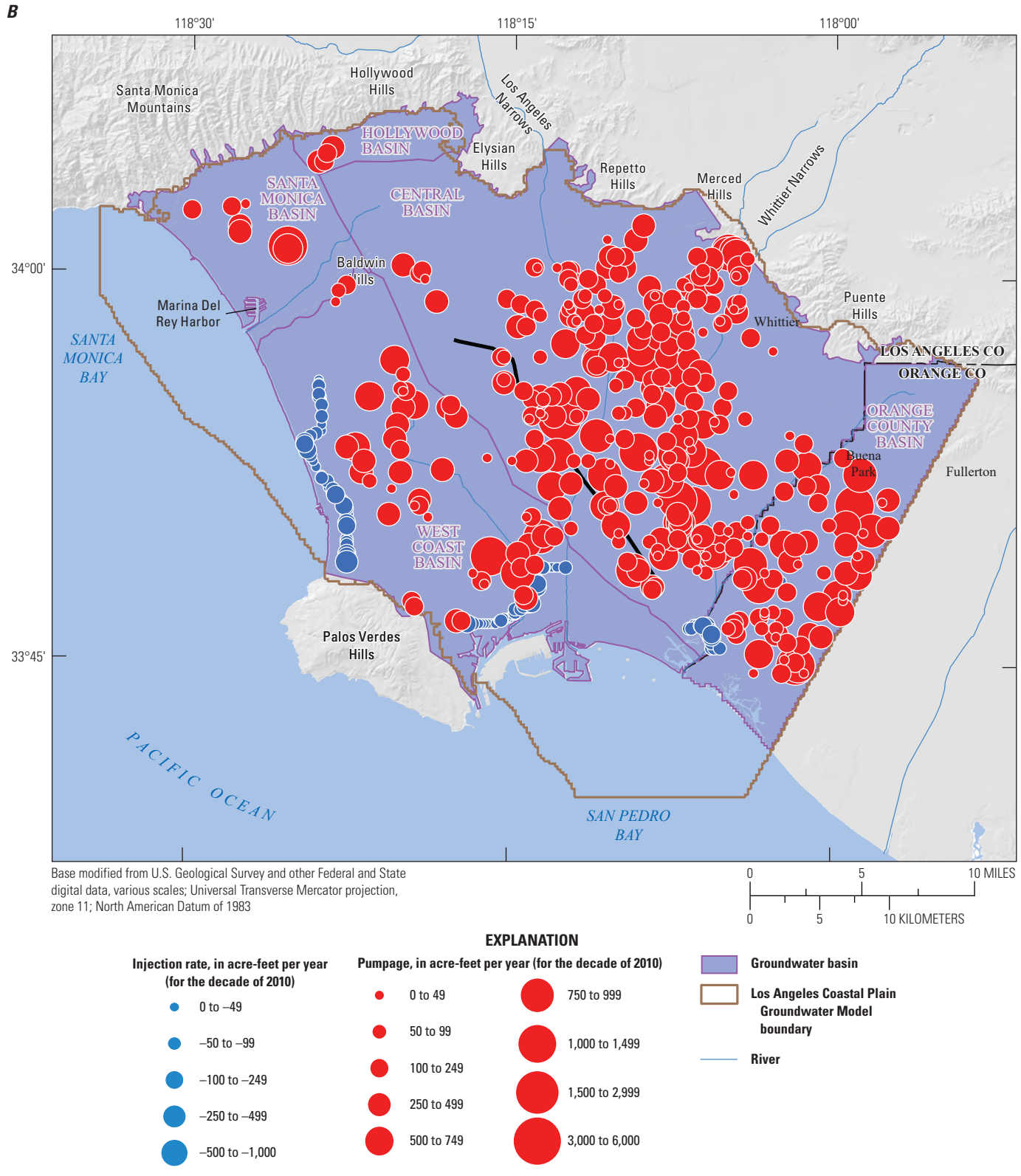


Figure C5.—Continued

Groundwater Discharge

Groundwater pumping is the primary discharge from the LACP groundwater basins. Other potential groundwater discharges include outflow to the ocean, underflow to adjacent basins, evapotranspiration, and baseflow to streams; however, evapotranspiration and baseflow are incorporated into the groundwater recharge estimates of Hevesi and Johnson (2016).

The first water wells were drilled in the mid-1800s, and by the early 1900s there were more than 4,000 wells in the LACP (Mendenhall, 1905a, b, c). From the early 1900s through the 1950s groundwater pumping from wells continued to increase because of increasing urban demand for water (Reichard and others, 2003, fig. 5). The groundwater pumping led to large water-level declines throughout the LACP. The continuing depletion of groundwater storage and water-level declines eventually led to the adjudication of both the Central and West Coast Basins in the early 1960s. The adjudications of both groundwater basins resulted in large decreases in pumping in both groundwater basins (Reichard and others, 2003). Approximately 4,000 wells are located within the LACP boundary; however, only about 1,500 wells were active at some time during 1971 to 2015 (fig. C6). Annual pumpage compiled for this study (see Chapter A) during this period ranged from a high of about 389,000 acre-ft in 1971 to a low of about 242,000 acre-ft in 1993, with an average of about 307,000 acre-ft (fig. C7; table C2).

Most of the production wells are screened over large intervals and withdraw water from multiple aquifers (fig. C6). The deepest production well record found was in the southern Central Basin, with a well depth of 2,200 ft below land surface (bls); however, the depth to the bottom perforation of most of the wells is 600 ft bls or less (fig. C6*B*). Unfortunately, some production wells lacked information on well depth and screened interval details. To accurately simulate the effects of pumping on water levels in the different aquifers, we had to assign a well depth and screened interval depths for each production well. If the well depth was known but information on the screened interval was missing, we assumed that the well was screened similarly to nearby wells constructed to a similar depth. The unknown screened interval depths were calculated by averaging the screened interval depths of nearby pumping wells with similar depths. If the depth and screened interval were both missing, we assumed that the well was screened similar to nearby wells that pumped about the same quantity of water.

The distribution of groundwater pumping across the LACP during the study period was not uniform (fig. C5). Active groundwater production wells were sparse in the Santa Monica Basin, Hollywood Basin, the northwestern portion of the Central Basin, the Whittier area in the Central Basin, and the area north of Buena Park and Fullerton in the Orange County Basin. The greatest density of active production wells is in the central and southeastern parts of the Central Basin and the southern part of the Orange County Basin (fig. C5).

Water Levels and Movement

Knowledge of water levels and how they vary spatially and temporally is fundamental to understanding and managing water resources. The shapes and relations among water tables and potentiometric surfaces can reveal important hydrogeologic characteristics of the watershed, such as locations of key areas of recharge and discharge and effects of geology on groundwater flow. Declining long-term hydrographs can indicate that an aquifer is being pumped in excess of recharge.

Pre- or Early Development Water Levels

Mendenhall (1905b, plate 1; 1905c, plate 1) presented water-level contour maps that included the LACP. The exact years represented by water-level contours are unknown, but by 1905 the groundwater basin had been pumped for about 50 years. In addition, the chronostratigraphic units represented by these water-level contours are unknown. Nonetheless, these maps are the most representative of pre-development conditions available. Groundwater generally flowed from the hills and foothills along the northern and eastern edges of the LACP toward the ocean to the southwest. Both Mendenhall (1905a, b, c) and Poland and others (1959) reported the presence of artesian conditions in the study area. Poland and others (1959) reported a flowing well 2 mi north of Signal Hill. Mendenhall (1905a, b, c) reported that about 30 percent of the area had flowing artesian conditions.

Post-Development Water Levels

Water-level hydrographs were constructed for eight well pairs located in the Central, West Coast, and Santa Monica Basins of the LACP to show long-term changes in water levels (figs. C8, C9). Water-level data collected by Los Angeles County were used to construct the long-term hydrographs. Measurements from some of these wells span 80 years, starting from the 1930s to present. Water levels were collected from most of these wells on a quarterly or semiannual basis. Most of these wells are production wells constructed with long screened intervals open to multiple aquifers; therefore, the water levels measured in such wells are a composite of the water levels present in the different aquifers open to the well. These long-term hydrographs were paired with short-term hydrographs from nearby WRD/USGS multiple-well monitoring sites, where available, to provide aquifer-dependent water-level data for the later time period (fig. C9). Water levels at most of the multiple-well monitoring sites are recorded on a continuous basis. These data were averaged and plotted as quarterly data on the hydrographs.

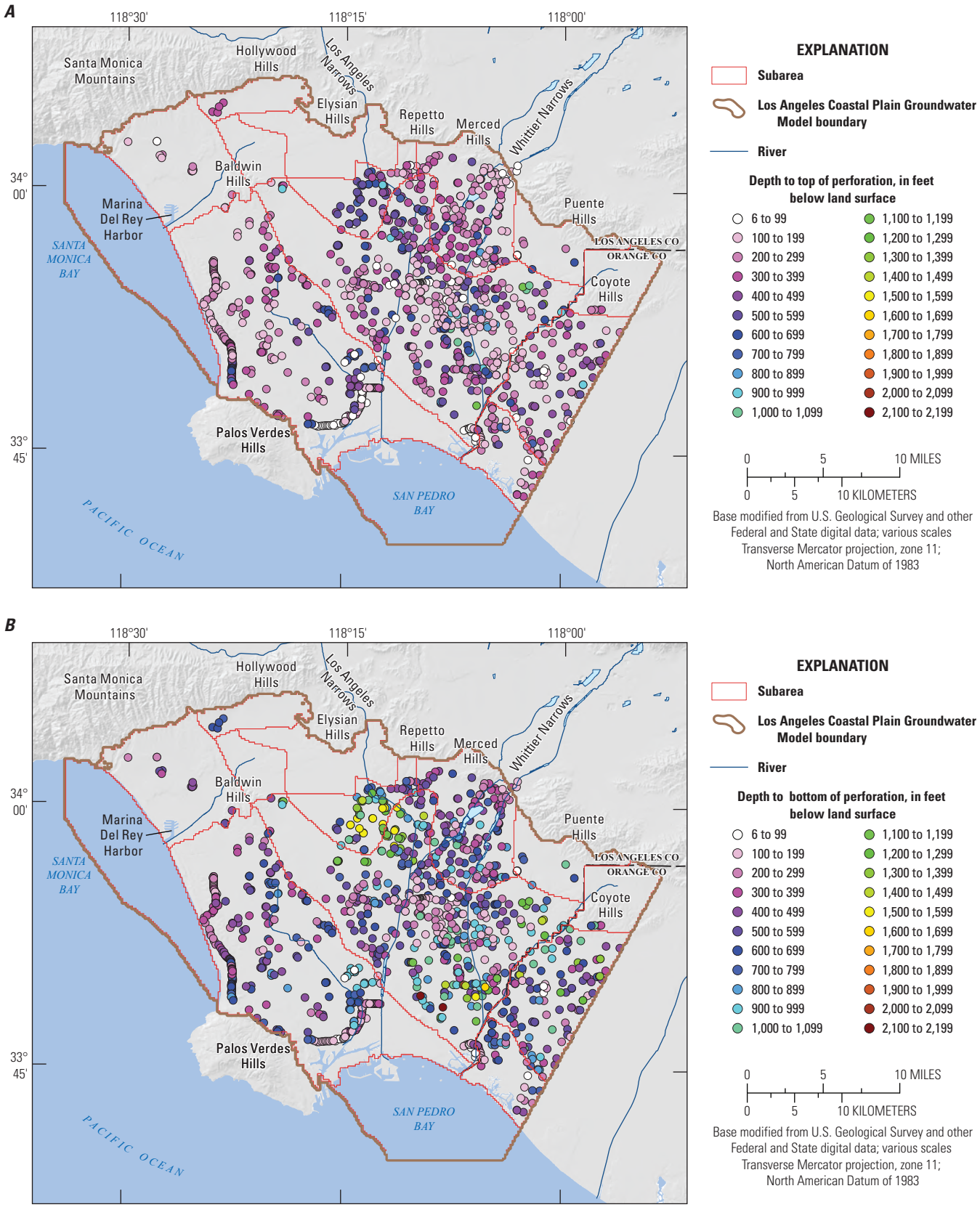


Figure C6. Depth to *A*, top of perforations, and *B*, bottom of perforations of production and injection wells active during 1971 to 2015, Los Angeles Coastal Plain, California.

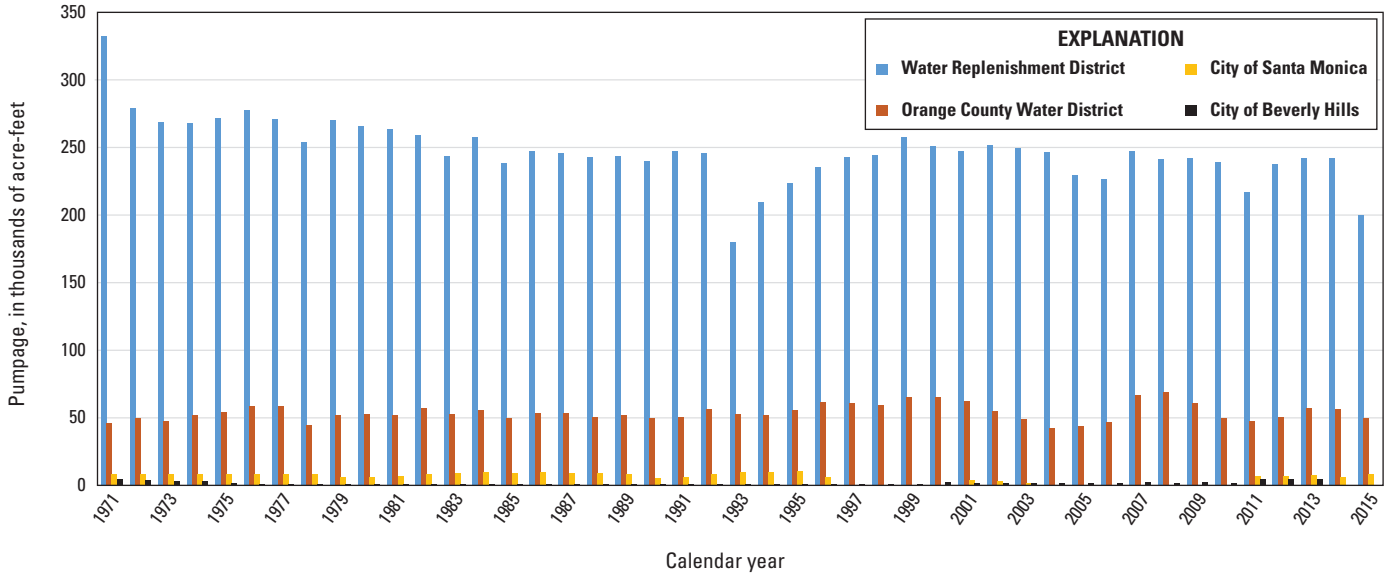


Figure C7. Annual pumpage by calendar year in the Los Angeles Coastal Plain by reporting agency. (Reporting agency codes: WRD, Water Replenishment District of Southern California; OCWD, Orange County Water District.)

Table C2. Estimated annual groundwater-flow budget in acre-feet of saturated zone, 1971 to 2015, Los Angeles Coastal Plain, California.

[Data from Reichard and others, 2003; Hevesi and Johnson, 2016; and local water agencies. **Abbreviations**: SG, San Gabriel; SF, San Fernando; SM, Santa Monica; SP, San Pedro; OC, Orange County]

Budget components	With irrigation
Estimated inflows	
Spreading	122,700
Areal recharge	55,200
Injection	32,500
Underflows from SG Basin	27,600
Underflows from SF Basin	6,200
Onshore flow from SM Bay	1,400
Onshore flow from SP Bay	7,500
Cross-boundary flow from OC	8,000
Total	**261,100**
Estimated outflows	
Pumpage	304,900
Offshore flow to SM Bay	4,500
Offshore flow to SP Bay	1,400
Total	**310,800**
Change in storage	**–49,700**

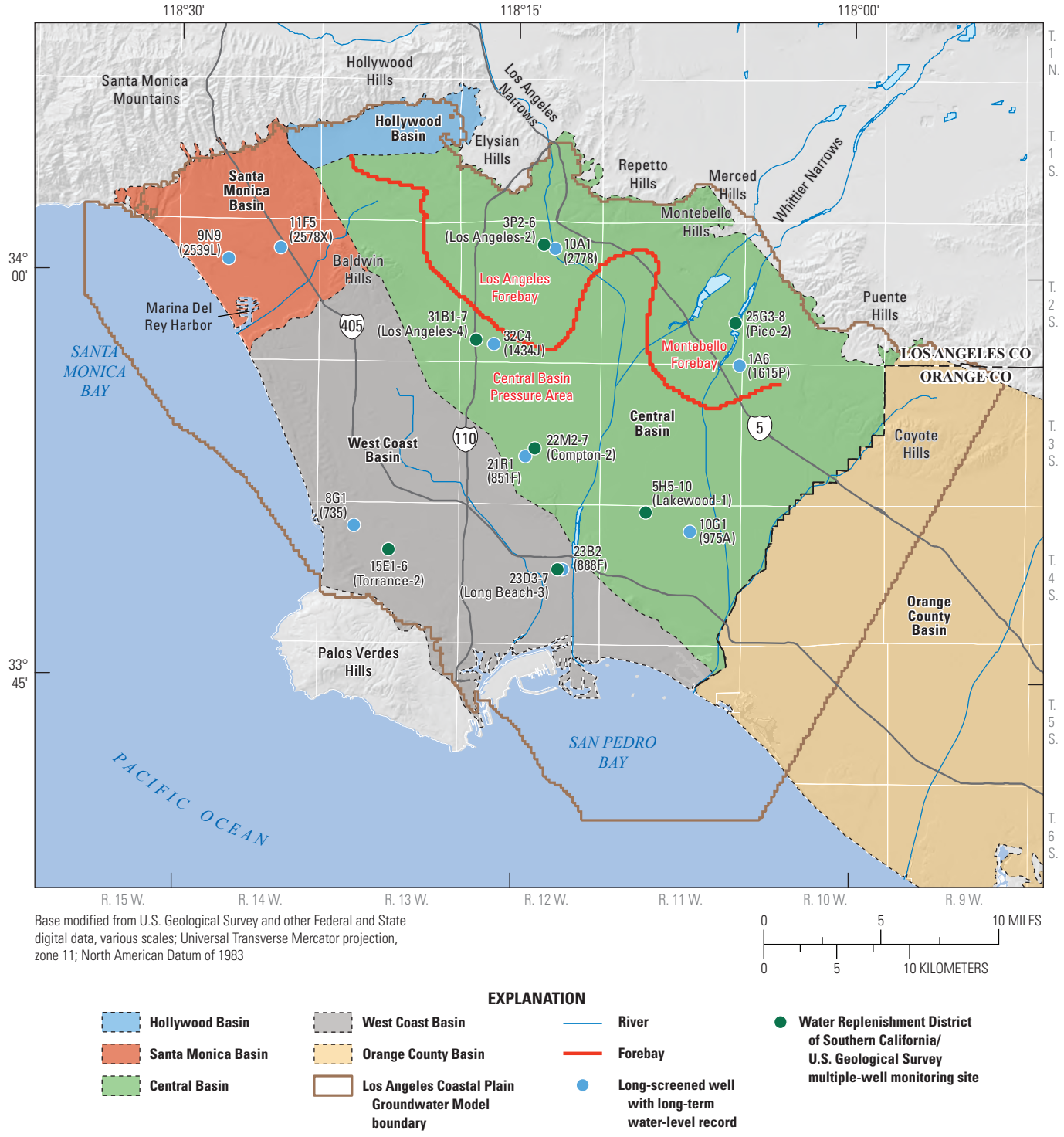


Figure C8. Locations of selected long-screened basin-monitoring wells and (generally) paired multiple-well monitoring sites in the Los Angeles Coastal Plain, Los Angeles County, California.

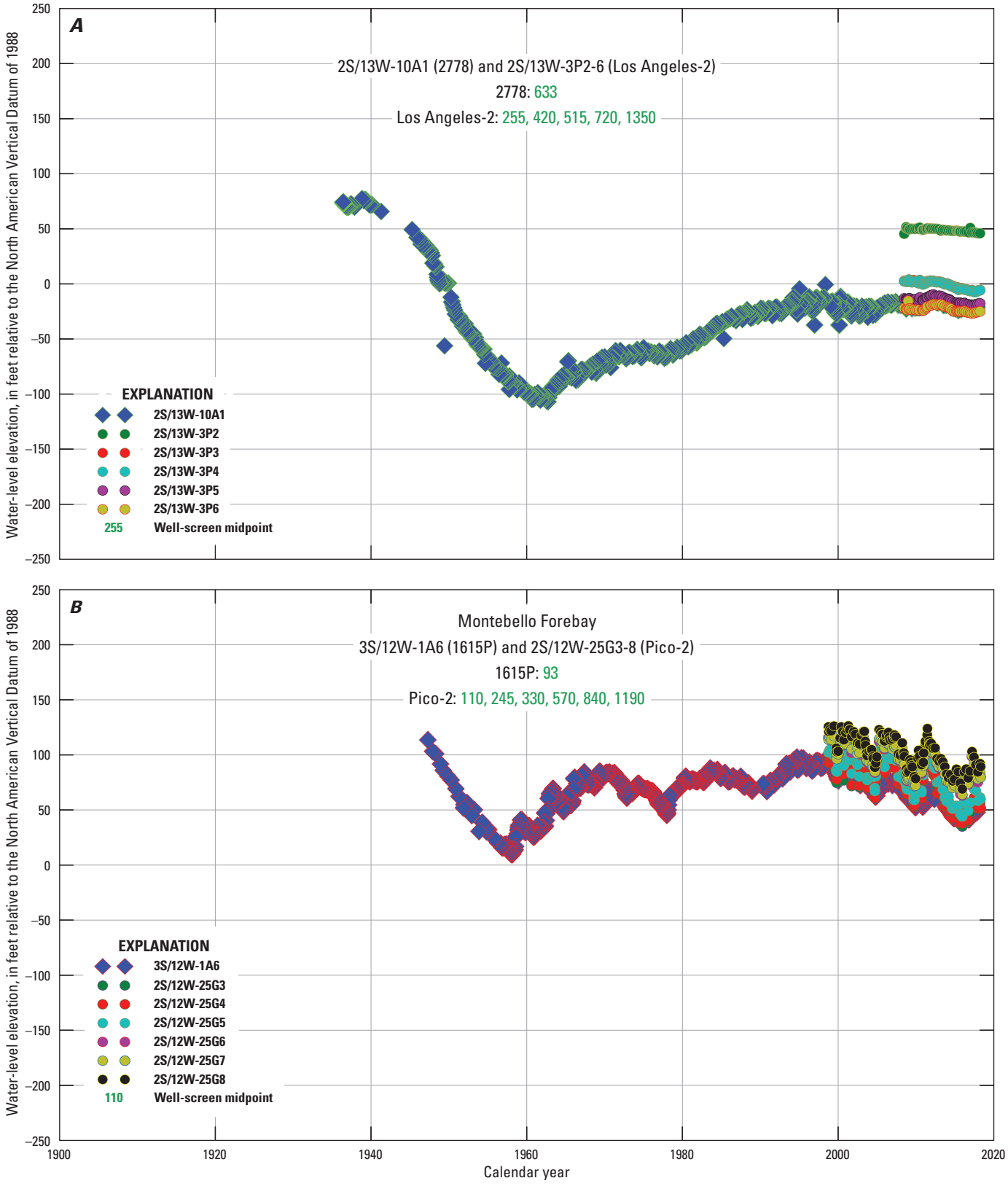


Figure C9. Long-term hydrographs for selected long-screened, basin-monitoring wells and (generally) paired multiple-well monitoring sites in the *A*, Los Angeles Forebay; *B*, Montebello Forebay; *C*, Central Basin Pressure Area (North); *D*, Central Basin Pressure Area (Central); *E*, Central Pressure Area (South); *F*, West Coast Basin (East); *G*, West Coast Basin (West); and *H*, Santa Monica Basin, Los Angeles Coastal Plain, Los Angeles County, California.

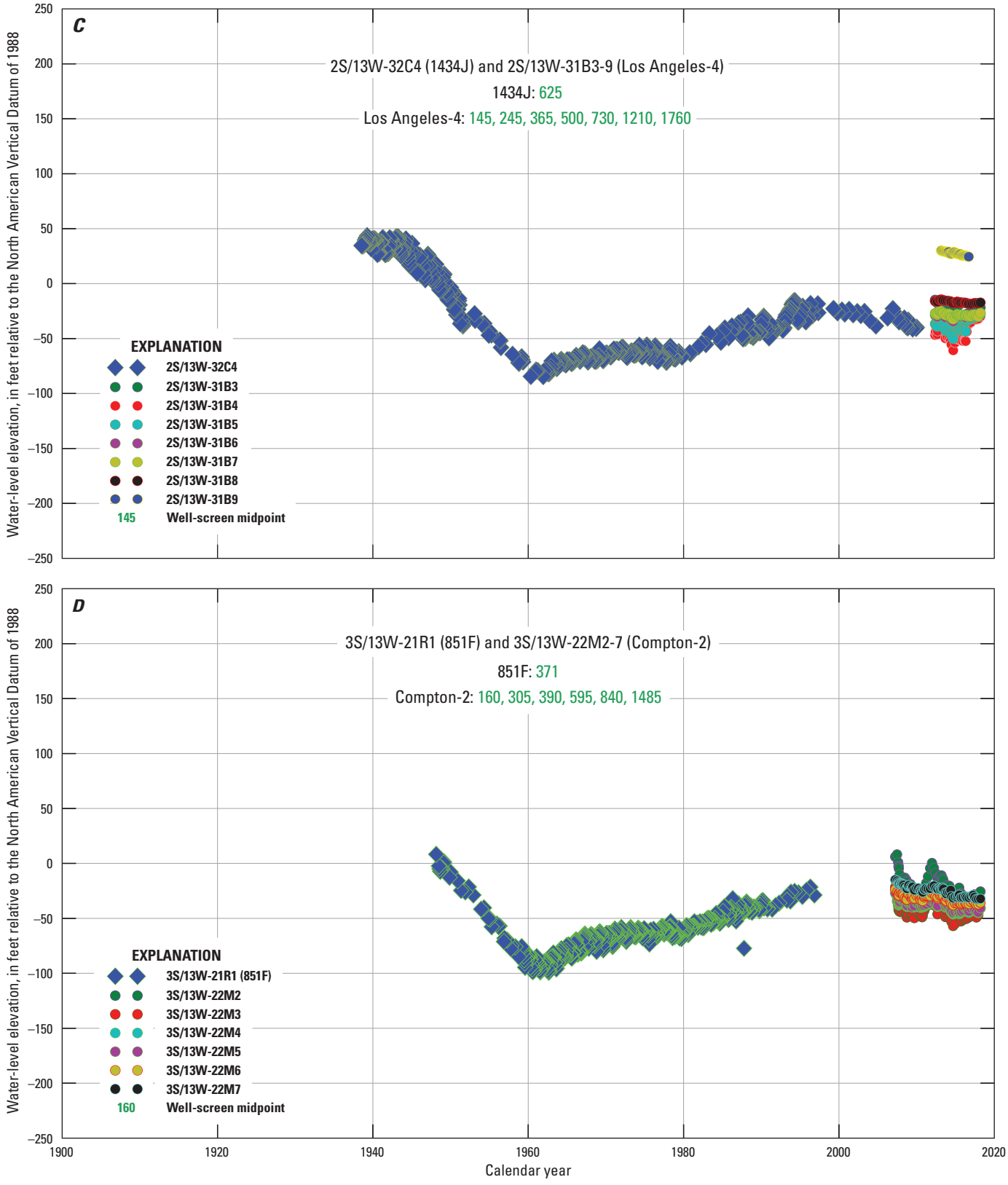


Figure C9.—Continued

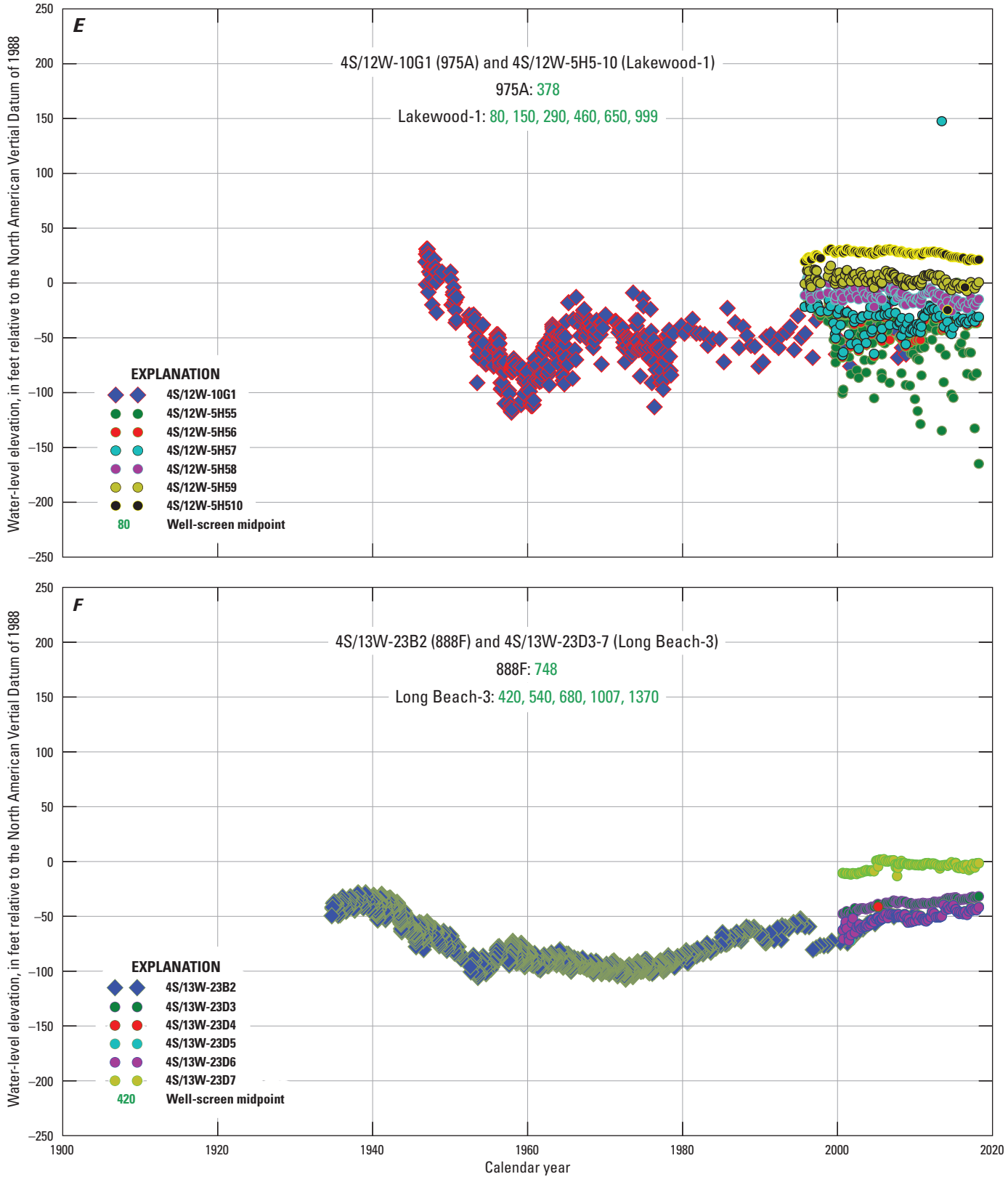


Figure C9.—Continued

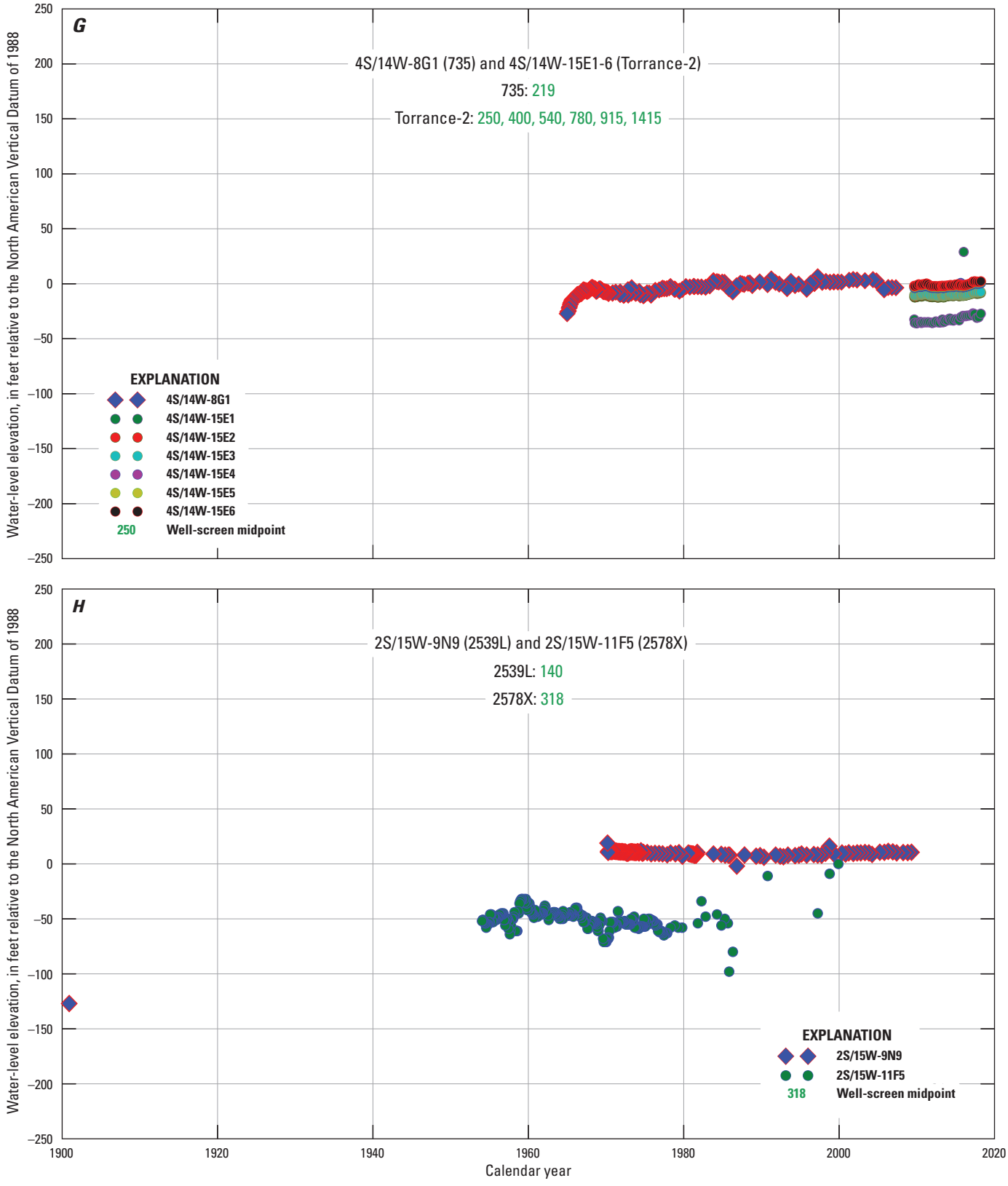


Figure C9.—Continued

Groundwater pumping from the early 1900s until the early-to-mid 1960s, when the Central and West Coast Basins were adjudicated, resulted in large water-level declines throughout most of the LACP (fig. C9). From 1930 to the early 1960s, pumping in excess of recharge resulted in water-level declines greater than 100 ft in the Los Angeles Forebay, Montebello Forebay, and the Central Basin Pressure Area (fig. C9*A*–*E*). Water levels in the West Coast Basin and Santa Monica Basins declined to more than 60 ft below NAVD 88 by 1960 (fig. C9*F*–*H*). Reduction in pumping and increased managed aquifer recharge as a result of the adjudications of the Central and West Coast Basins resulted in water-level rises throughout most of the LACP from the early 1960s to 1970 (fig. C9). Each of the paired monitoring sites is discussed in detail below.

Los Angeles Forebay

Well 10A1 (2S/13W-10A1; 2778) is a production well in the Los Angeles Forebay of the Central Basin (fig. C8) that is screened in the Pacific, Harbor, and Upper Wilmington A aquifer systems. Water levels have been measured at well 10A1 from 1936 to 2017 (fig. C9*A*). Water levels in this well declined more than 190 ft from the late 1930s to the early 1960s, from an altitude high of about 80 ft in the late 1930s to a low of about 114 ft below NAVD 88 in the early 1960s (fig. C9*A*). From the early 1960s until the mid 1990s, water levels recovered about 90 ft, to an elevation of about 20 ft below NAVD 88, in response to the reduction of pumping and increased replenishment activities in the LACP. Since 1990, water levels in the well have been relatively constant with likely seasonal changes in response to pumping. Water levels measured in 2017 in well 10A1 in the Los Angeles Forebay were about 100 ft lower than historical highs recorded in the late 1930s.

Monitoring wells 3P2-6 (2S/13W-3P2 to 3P6) compose the Los Angeles2 multiple-well monitoring site in the Los Angeles Forebay (fig. C8), and are screened in the Long Beach C (3P2), Upper Wilmington A (3P3, 3P4), Harbor (3P5), and Pacific (3P6) aquifer systems (appendix 1, table 1.1). Land-surface elevation at 3P2-6 is within 5 ft of the land-surface elevation at well 10A1. Water levels have been collected at wells 3P2-6 since the site was constructed in 2008. Water levels in well 10A1 are similar to those measured in the Pacific aquifer system at well 3P6 (fig. C9*A*), indicating that well 10A1 is receiving most of its water from the Pacific aquifer system even though it also is screened in the Harbor and Upper Wilmington A aquifer systems. Water levels in the Long Beach C aquifer system are about 50 ft higher than water levels in Upper Wilmington A aquifer system and about 70 ft higher than levels in the Harbor and Pacific aquifer systems. The total dissolved solids (TDS) of a sample from well 3P2 screened in Long Beach C was 18,000 milligrams per liter (mg/L; January 2013), or about one-half the concentration found in present-day seawater (35,000 mg/L); in contrast, wells 3P3–3P6 had TDS of 1,400 mg/L or less (June 2010 and April 2013; appendix 1, table 1.2).

The high water levels and high TDS concentration of a sample from well 3P2 indicate that the Long Beach C aquifer system at this location is not part of the active groundwater-flow system. Low-permeability clays in the Long Beach C aquifer system at the 3P2-6 wells likely limit the hydraulic connection to the overlying aquifer systems. Water levels in the Upper Wilmington A aquifer system (fig. C9A, 3P4) follow a similar pattern to the overlying Harbor (fig. C9A, 3P5) and Pacific (fig. C9A, 3P5) aquifer systems but are about 20 ft higher. As a result of folding and subsequent erosion, the Upper Wilmington A aquifer system is exposed to potential recharge from the Los Angeles River at a higher elevation than the Pacific and Harbor aquifer systems in the Los Angeles Narrows (fig. B5), which accounts for the higher water levels. A water sample from the Upper Wilmington A aquifer system (well 3P4) had tritium concentration in excess of 0.9 tritium unit (TU; appendix 1, table 1.2), indicating that the aquifer system is receiving at least some modern water recharge. The water-level difference between the overlying and underlying aquifer systems indicates that the Upper Wilmington A aquifer system is confined in this part of the Los Angeles Forebay.

Montebello Forebay

Well 1A6 (3S/12W-1A6; 1615P) is a production well in the Montebello Forebay (fig. C8) and is screened in the Mesa and Pacific aquifer systems. Water levels have been measured at well 1A6 from 1947 to 2017 (fig. C9*B*). Water levels in well 1A6 declined about 104 ft from the late 1940s to the late 1950s, from a high altitude of about 114 ft in 1947 to a low altitude of about 10 ft in 1958 (fig. C9*B*). From the late 1950s until about 1970, water levels recovered about 70 ft, to an altitude of about 80 ft. From 1970 until the mid 1990s, water levels rose during wet periods and declined during dry periods, for a net water-level rise of about 20 ft (figs. C2, C9*B*). Since the mid-1990s, water levels have declined by about 60 ft to an altitude of about 40 ft in 2015. During this period, water levels rose during wet cycles and declined during dry cycles (figs. C2, C9*B*). Water levels in the Montebello Forebay varied in response to nearby RHSG and SGRSG recharge and pumping (fig. C9*B*).

Monitoring wells 25G3-8 (2S/12W-25G3 to 25G8) compose the Pico Rivera2 multiple-well monitoring site in the Montebello Forebay (fig. C8) and are screened in the Long Beach A (25G3), Upper Wilmington B (25G4), Upper Wilmington A (25G5), Pacific (25G6), Mesa (25G7), and Dominguez (25G8) aquifer systems (appendix 1, table 1.1). Land-surface elevation at 25G3-8 is about 10 ft higher than well 1A6. Water-level data have been collected at the 25G3-8 wells since they were constructed in 1999 (fig. C9*B*). Water levels measured at the 25G3-8 wells follow a similar seasonal pattern and wet and dry cycle pattern as those in well 1A6 but are about 20 ft higher because the 25G3-8 wells are at a higher elevation in the Montebello Forebay (fig. C9*B*). Water levels decreased with depth from the Dominguez through Long Beach A aquifer systems within the Montebello Forebay, and the largest difference in water levels occurred between the Pacific and Upper Wilmington A aquifer systems. The downward vertical gradient indicates the potential for water to move from the overlying to the underlying aquifer systems.

The Dominguez, Mesa, and Pacific aquifer systems are relatively flat lying in the Montebello Forebay (fig. B4) and are predominantly coarse-grained (figs. B16, B18, B19), which allows for relatively unrestricted groundwater movement between the aquifer systems. Folding of the Upper Wilmington A and Long Beach A aquifer systems, and subsequent erosion or non-deposition of the Harbor, Bent Spring, Upper Wilmington B, and Lower Wilmington aquifer systems, puts the Upper Wilmington A and Long Beach A aquifer systems in direct connection with the Pacific aquifer system in the Montebello Forebay (fig. B4). Direct connection with the Pacific aquifer system allows groundwater from the Pacific to recharge the deeper aquifer systems, and water-chemistry data provide evidence of this connection. Samples from all aquifer systems contained tritium greater than 1 TU (appendix 1, table 1.2), indicating they are being recharged by modern water. Stable-isotope data indicate that managed aquifer recharge from the nearby spreading grounds is being sampled from the wells (appendix 1, table 1.2).

Central Basin Pressure Area, North

Well 32C4 (2S/13W-32C4; 1434J) is a production well in the northern part of the Central Basin Pressure Area (fig. C8) and is screened in the Harbor, Bent Spring, and Upper Wilmington A aquifer systems. Water levels have been measured at well 32C4 from 1938 to 2010 (fig. C9*C*). Water levels in this well declined about 125 ft from 1940 to 1960, from an altitude high of about 41 ft in 1940 to a low of about 84 ft below NAVD 88 in 1960 (fig. C9*C*). From 1960 until about 1980, water levels slowly recovered to about 60 ft below NAVD 88 (fig. C9*C*). From 1980 to the late 1990s, water levels continued to recover, at a faster rate, to about 20 ft below NAVD 88 (fig. C9*C*). By the end of the 1990s, water levels stopped recovering, and began to slowly decline. From the late 1990s until 2010, water levels declined about 20 ft, to about 40 ft below NAVD 88 in 2010 (fig. C9*C*).

Monitoring wells 31B3-8 (2S/13W-31B3 to 31B8) compose the Los Angeles4 multiple-well monitoring site in the northern part of the Central Basin Pressure Area (fig. C8) and are screened in the Long Beach A (31B3), Lower Wilmington (31B4), Upper Wilmington A (13B5), Harbor (31B6 and B7), and Pacific (31B8) aquifer systems (appendix 1, table 1.1). In addition to the wells installed at the 31B3-8 wells, a vibrating wireline piezometer was also installed to record water levels in the Mesa aquifer system (31B9); However, a well screen was not installed in the Mesa layer; therefore, the Mesa layer piezometer is not shown in table 1.1. Land-surface elevation at 31B3-8 is within 5 ft of the land-surface elevation at well 32C4. Water levels have been collected at the 31B3-8 wells since the wells were constructed in 2012. Because the 31B3-8 wells were not constructed until 2012, water-level measurements collected from this site do not overlap with measurements from well 32C4 (fig. C9*C*). However, water levels in the Upper Wilmington A and the Lower Wilmington aquifer systems had the same downward trend as observed in the later part of the record collected at well 32C4. Water levels at the 31B3-8 wells decreased with depth, with the exception of the Long Beach A aquifer system. Water levels in the Mesa aquifer system are about 25 ft above NAVD 88, which is more than 40 ft higher than water levels in the Pacific aquifer system. Water levels in both the Mesa and Pacific aquifer systems slowly declined less than 6 ft during the period of record, with minimal response to seasonal pumping or recharge. Water levels in the Harbor aquifer system are about 10 ft lower than water levels in the Pacific aquifer system. Water levels in the Upper Wilmington A and Lower Wilmington aquifer systems were about the same as those in the Harbor aquifer system in 2012 but declined to more than 10 ft lower in the Upper Wilmington A aquifer system and about 20 ft lower in the Lower Wilmington aquifer system by the end of 2015 (fig. C9*C*).

The largest water-level declines at the 31B3-8 wells were observed in the Lower Wilmington aquifer system even though there are only a few production wells that are screened in the Lower Wilmington aquifer system near the site. Most of the nearby production wells are screened in the Pacific A through Upper Wilmington A aquifer systems. The Lower Wilmington aquifer system is dominated by fine-grained deposits with a few isolated sand zones, one of which is open to well 31B4. Because these sand zones are tightly confined by fine-grained deposits, pressure responses caused by pumping in these zones can cause water-level changes over large distances.

The water levels in the Long Beach A aquifer system were similar to Pacific aquifer system water levels in 2012 and then declined about 10 ft by 2015 (fig. C9C). Water level declines in the Long Beach A aquifer system were probably responding to pumping in the overlying aquifer systems.

Central Basin Pressure Area, Central

Well 21R1 (3S/13W-21R1; 851F) is a production well in the Central Basin Pressure Area near the Newport-Inglewood fault zone (fig. C8) and is screened in the Harbor aquifer system (appendix 1, table 1.1). Water levels in well 21R1 declined from a high of about 8 ft above NAVD 88 in 1948 to a low of about 100 ft below NAVD 88 in 1960 (fig. C9*D*). From 1960 until about 1970, water levels recovered rapidly to about 60 ft below NAVD 88 (fig. C9*D*). From 1970 until about 1980, water levels were relatively constant, except for seasonally variable pumping. From about 1980 through the end of the record in 1996, water levels recovered about 40 ft but were still about 30 ft lower than the highest measured water level in 1948 (fig. C9*D*).

Monitoring wells 22M2-7 (3S/13W-22M2 to 22M7) compose the Compton2 multiple-well monitoring site in the central part of the Central Basin Pressure Area (fig. C8) and are screened in the Long Beach A (22M2), Upper Wilmington B (22M3), Harbor (22M4, 22M5), Pacific (22M6), and Pacific A (22M7) aquifer systems (appendix 1, table 1.1). Land-surface elevation at wells 22M2-7 is about 20 ft below well 21R1. Water levels have been collected at the 22M2-7 wells since they were constructed in 2007. Because the 22M2-7 wells were not constructed until 2007, water-level measurements collected from this site do not overlap with measurements from well 21R1. Water levels at wells 22M2-7 decreased with depth throughout most of the period of record, with the exception of the Long Beach A aquifer system, which has water levels higher than the Pacific A aquifer system during part of the record (fig. C9*D*). Water levels in all aquifer systems monitored at wells 22M2-7 declined more than 10 ft from 2007 to 2012, with seasonal fluctuations reflecting pumpage and recharge (fig. C9*D*). The largest water-level declines were observed in the Upper Wilmington B (about 30 ft) and Long Beach A (about 35 ft) aquifer systems, although nearby production wells are not screened to the depth of these aquifer systems. The Upper Wilmington B and Long Beach A aquifer systems are composed predominantly of fine-grained deposits with intermittent sand layers at wells 22M2-7. The nearest active production wells that are completed in these aquifer systems are more than 5 mi southeast of wells 22M2-7. The presence of large water-level fluctuations, caused by pumping at such a large distance, indicates that the vertical permeability of the confining layers is very low.

Central Basin Pressure Area, South

Well 10G1 (4S/12W-10G1; 975A) is a production well in the southern part of the Central Basin Pressure Area and is screened in the Pacific aquifer system (fig. C8). Water levels were measured at well 10G1 from 1946 to 2008 (fig. C9*E*). Water levels in this well declined about 147 ft from a high altitude of about 29 ft in 1947 to a low of about 118 ft below NAVD 88 in 1957 (fig. C9*E*). From the late 1950s until the mid-1960s, water levels recovered rapidly to about 20 ft below NAVD 88 (fig. C9*E*). From the mid-1960s until the end of the record in 2008, water levels fluctuated 50 ft or more on a seasonal basis but recovered to between 20 and 30 ft below NAVD 88 during wet periods when pumping was reduced (figs. C2, C9*E*).

Monitoring wells 5W5-10 (4S/12W-5H5 to 5H10) compose the Lakewood1 multiple-well monitoring site in the southern part of the Central Basin Pressure Area (fig. C8) and are screened in the Upper Wilmington A (5H5), Harbor (5H6–7), Pacific A (5H8), Mesa (5H9), and Dominguez (5H10) aquifer systems (appendix 1, table 1.1). Land-surface elevation at wells 5W5-10 is within 5 ft of the land-surface elevation at well 10G1. Water levels have been collected at wells 5W5-10 since its construction in 1995. None of the monitoring wells 5W5-10 is screened in the Pacific aquifer system, but water levels in the Harbor aquifer system are similar to those in well 10G1 (fig. C9*E*). Water levels at wells 5W5-10 indicated a downward hydraulic gradient between the aquifer systems, with the largest gradient between the Dominguez and Mesa aquifer systems. Water levels in the Dominguez aquifer system declined about 7 ft from 1999 to 2015, with minimal seasonal fluctuations. There are active production wells in the Dominguez aquifer system east of wells 5W5-10; therefore, the lack of large seasonal water-level fluctuations probably is the result of the unconfined properties of the Dominguez aquifer system. Water levels in the Mesa and Pacific A aquifer systems behaved similarly, with water levels in the Pacific A aquifer system about 15 ft lower than those in the Mesa aquifer system. Water levels in both aquifer systems had 10 to 15 ft seasonal water-level changes, with the Pacific A aquifer system having the larger fluctuations.

Water levels in the Harbor and Upper Wilmington A aquifer systems at 5W5-10 followed similar seasonal pattern and wet and dry cycle pattern from 1999 to about 2008, with large seasonal fluctuations (about 30 ft in the Harbor and more than 50 ft in the Upper Wilmington A aquifer systems). The large seasonal fluctuations indicated that both aquifer systems are confined and isolated from the overlying aquifer systems. From about 2008 to 2015, water levels in the Upper Wilmington A aquifer system started to diverge from the water levels in the Harbor aquifer system. In fact, in the summers of 2013 and 2014, water levels in the Upper Wilmington A aquifer system were the lowest recorded, about 80 ft lower than water levels measured in the Harbor aquifer system at the same time (fig. C9). Monitoring wells 5W5-10 are surrounded by wells screened in the Harbor aquifer system, but production wells screened in the Upper Wilmington A aquifer system only are present southwest of the site. The Pacific and underlying (older) aquifer systems are folded up to the west of 5W5-10; therefore, the Upper Wilmington A aquifer system is closer to land surface southwest of the site, and more production wells are withdrawing water from the deeper aquifer systems in this part of the LACP.

West Coast Basin, East

Well 23B2 (4S/13W-23B2; 888F) is a production well in the southeast part of the West Coast Basin (fig. C8; table 1.1) and is screened in the Upper Wilmington A aquifer system. Water levels were measured at well 23B2 from 1934 to 2010 (fig. C9*F*). Water levels in well 23B2 declined about 60 ft from a high of about 28 ft below NAVD 88 in 1939 to a low of about 106 ft below NAVD 88 in 1953 (fig. C9*F*). Seasonal water-level changes are about 20 ft during this period. From the mid-1950s until about 1958, water levels recovered to about 73 ft below NAVD 88, and then declined slowly to about 107 ft below NAVD 88 in the early 1970s (fig. C9*F*). From the early 1970s until the mid 1990s, water levels recovered almost 40 ft, reaching a high of 53 ft below NAVD 88 in 1995. In 1995, water levels declined by about 30 ft but recovered to about 50 ft below NAVD 88 in 2010, the end of the record (fig. C9*F*). Water levels in 2010 were more than 20 ft lower than the highest measured water level in 1939 (fig. C9*F*).

Monitoring wells 23D3-7 (4S/13W-23D3 to 23D7) compose the Long Beach3 multiple-well monitoring site in the southeastern part of the West Coast Basin (fig. C8) and are screened in the Long Beach A (23D3), Upper Wilmington B (23D4), Upper Wilmington A (23D5), Bent Spring (23D6), and Harbor (23D7) aquifer systems (appendix 1, table 1.1). Land-surface elevation at wells 23D3-7 is within 5 ft of well 23B2. Water levels have been collected at the 23D3-7 wells since the wells were constructed in 2000. Water levels in the Upper Wilmington A aquifer system are similar to water levels measured in well 23B2, and water levels in all except the Harbor aquifer system have been recovering since 2000, when wells 23D3-7 were constructed (fig. C9*F*). Water levels in the Harbor aquifer system were about 30 ft higher than water levels in the underlying Bent Spring aquifer system (fig. C9*F*). Injection wells of the Dominguez Gap Barrier Project inject recharge water into the Harbor aquifer system near wells 23D3-7 and, along with minimal pumping, help maintain the high water levels in the Dominguez, Mesa, Pacific, and Harbor aquifer systems in this area of the West Coast Basin. The effect of the northern extension of the barrier project in the mid-1990s is shown by the approximate 10 ft rise in water levels in the Harbor aquifer system between 2004 and 2005 (fig. C9*F*). However, even with the extension of the barrier project, water levels were below NAVD 88 in the Harbor aquifer system during most of the period of record, indicating continued potential for seawater intrusion into the Harbor aquifer system.

The Bent Spring, Upper Wilmington A, and Upper Wilmington B aquifer systems have similar water levels at wells 23D3-7 (fig. C9*F*). The geologic and geophysical logs collected at wells 23D3-7 indicated that these aquifer systems are all coarse grained, with few fine-grained layers to limit hydraulic connection between aquifer systems. However, the large water-level differences between the Harbor and Bent Spring aquifer systems indicated the presence of a low-permeability layer between these two aquifer systems. Water levels in the Long Beach A aquifer system at wells 23D3-7 were 10 to 15 ft higher than water levels in the Upper Wilmington B aquifer system and did not show seasonal fluctuations like the overlying aquifer systems (fig. C9*F*). Fine-grained layers in the overlying Lower Wilmington aquifer system limited hydraulic connection between the Long Beach A aquifer system and the overlying pumped aquifer systems.

West Coast Basin, West

Well 8G1 (4S/14W-8G1; 735) is an observation well in the western part of the West Coast Basin, about 1.6 mi east of the coastline (fig. C8; table 1.1) and is screened in the Pacific aquifer system. Water levels were measured at well 8G1 from 1964 to 2007 (fig. C9*G*). Water levels in well 8G1 rose rapidly about 20 ft from a low of 27 ft below NAVD 88 in 1964 to 7 ft below NAVD 88 in 1968 (fig. C9*G*). The rise in water levels resulted from water injected along the WCBBP and decreased pumping in areas affected by seawater intrusion. From the late 1960s to 2004, water levels in well 8G1 continued to rise to about 3 ft above NAVD 88 in 2004 (fig. C9*G*). In 2005, water levels declined to about 5 ft below NAVD 88 and remained below NAVD 88 until measurements at the well were discontinued in 2007 (fig. C9*G*).

Monitoring wells 15E1-6 (4S/14W-15E1 to 15E6) compose the PM-6 Torrance2 multiple-well monitoring site in the southwestern part of the West Coast Basin (fig. C8) and are screened in the Long Beach A (15E1), Upper Wilmington B (15E2), Upper Wilmington A (15E3), Bent Spring (15E4), Harbor (15E5), and Pacific (15E6) aquifer systems (appendix 1, table 1.1). Wells 15E1-6 are about 1.8 mi southeast of well 8G1 and has a land-surface elevation about 15 ft lower than well 8G1 (fig. C8). Water levels have been measured at wells 15E1-6 since the wells were constructed in 2009, and water-level measurements at this site did not overlap with measurements from well 8G1. However, water-level measurements from the Pacific, Harbor, and Bent Spring aquifer systems were similar to the last recorded measurements at well 8G1 (fig. C9*G*). Injection wells in the WCBBP near wells 15E1-6 injected water into the Mesa, Pacific, Harbor, and Bent Spring aquifer systems, which resulted in similar water levels in these aquifer systems. Water levels in the underlying Upper Wilmington A and B aquifer systems were about 10 ft below NAVD 88 from 2010 to 2015, indicating these aquifer systems are susceptible to seawater intrusion. Water-quality data collected from these aquifer systems at wells 15E1-6 indicated that these aquifer systems were affected by seawater intrusion (appendix 1, table 1.2). The Upper Wilmington A and B aquifer systems were probably being intruded by seawater entering through Redondo Canyon to the west of wells 15E1-6 (fig. C8). Water levels in the Long Beach A aquifer system were about 35 ft below NAVD 88 in 2010 and rose to about 30 ft below NAVD 88 in 2015 (fig. C9*G*). Production wells were not screened in the Long Beach A aquifer system near the wells 15E1-6; therefore, the water levels probably were still recovering from the late 1950s when the West Coast Basin was at its historical low water levels, prior to the initiation of the seawater barriers and water-management plans.

Santa Monica Basin

Since USGS multiple-well monitoring sites had not been constructed in the Santa Monica Basin until after this study completed, long-term water-level measurements from two wells completed in different aquifers were compared to examine water-level change with depth in this basin. Well 11F5 (2S/15W-11F5; 2578X) is a production well in the central part of the Santa Monica Basin (fig. C8) and is screened in the Bent Spring aquifer system (table 1.1). Water levels were measured at well 11F5 from 1954 to 1999 (fig. C9*H*). From the mid-1950s until the mid-1980s, water levels at well 11F5 averaged about 50 ft below NAVD 88, with highs of about 35 ft below NAVD 88 and lows of about 65 ft below NAVD 88 (fig. C9*H*). In 1985, water levels declined to a low of 100 ft below NAVD 88, but this measurement probably was affected by pumping from nearby wells; there was over 6,000 acre-ft of pumping from the nearby Santa Monica municipal well field in 1985. Water levels measured in the 1990s showed a considerable rise, with water levels in 1999 reaching NAVD 88 (fig. C9*H*). The low water levels measured at well 11F5 from the mid-1950s to mid-1980s probably were in response to pumping from a nearby Santa Monica municipal well field. Pumping from this well field was substantially reduced in the 1990s, which resulted in the observed water-level rise in well 11F5.

Well 9N9 (2S/15W-9N9; 2539L) is in the western part of the Santa Monica Basin (fig. C8) and is screened in the Pacific aquifer system (table 1.1). Land-surface elevation at well 9N9 is about 55 ft lower than well 11F5. Water levels were measured at well 9N9 from 1970 to 2009 (fig. C9*H*). Water levels in well 9N9 were at about 10 ft above NAVD 88 during the period of record. During the 1970s and 1980s, water levels in well 9N9 were more than 50 ft higher than water levels measured in well 11F5 (fig. C9*H*). The large difference in water levels indicated that there was minimal hydraulic connection between the Pacific and Bent Spring aquifer systems in the western part of the Santa Monica Basin. Depth-dependent data from a multiple-well monitoring site in the Santa Monica Basin can improve the understanding of the hydrogeology and water movement in this part of the LACP.

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Chapter D. Development of a Groundwater-Simulation Model and Future Water-Management Scenarios

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A regional groundwater-flow model was developed for the Los Angeles Coastal Plain (LACP) to better understand the groundwater-flow system that provides a large portion of the water supply for its millions of residents and to provide a tool to help inform groundwater-resources management decisions in the region. The U.S. Geological Survey (USGS) had previously developed a regional groundwater-flow model of the LACP (Reichard and others, 2003), which has been used by water-management agencies to help characterize groundwater flow and evaluate groundwater-management issues in the LACP during the past 17 years. The previous model simplified the complex groundwater-flow system of the LACP into four aquifer systems based on a lithostratigraphic approach (Reichard and others, 2003). Detailed hydrogeologic data collected from recently constructed Water Replenishment District of Southern California (WRD) and USGS multiple-well monitoring sites, in conjunction with available seismic-reflection profiles, provided the opportunity to reevaluate the hydrogeologic framework of the LACP using a sequence-stratigraphy approach (see Chapter B). Compared to the lithostratigraphic approach, the sequence-stratigraphy approach can produce a more realistic representation of geologic structure, the distribution of lithologic facies, and aquifer architecture—all of which can influence groundwater flow. Chronostratigraphic unit layering provides a more realistic representation of the geologic structure, the distribution of lithologic facies, and aquifer architecture, which improves our ability to predict the lateral distribution of coarse-grained aquifers and their fine-grained confining aquitards. A groundwater-flow model based on chronostratigraphic unit layering can

(1) Leverage knowledge of the distribution of grain size to better model groundwater flow within the aquifer systems.

(2) Apply a more realistic representation of geologic structure to better predict the direction of anisotropy within complex geologic structures (for example, folds), and can therefore better model anisotropy within these structures.

This chapter describes how the updated hydrogeologic framework was used to develop a new groundwater-flow simulation model of the LACP, which is referred to as the Los Angeles Coastal Plain Groundwater-flow Model (LACPGM).

Model Development

The active domain of the LACPGM covers 580 square miles, and includes the West Coast Basin, the Central Basin, the Santa Monica Basin, the Hollywood Basin, part of the Orange County Basin, and parts of Santa Monica and San Pedro Bays (fig. D1). Model inputs include boundary conditions, top and bottom elevations of each model cell, connections of each model cell to other model cells and conduits, cross-sectional area of each connection, hydraulic conductivities of each connection, storage properties of each model cell, conductance across faults, recharge, pumpage, and injection.

Modeling Software

The LACPGM uses MODFLOW-USG (Panday and others, 2013) for its unstructured grid, which can simulate geological layer pinch-outs because, “The gridding flexibility in MODFLOW-USG offers advantages for representing discontinuous (pinching) aquifer layers and faults compared to traditional MODFLOW approaches” (Panday and others, 2013). Also, MODFLOW-USG was used for its ability to model hydraulic properties by connection rather than by cell, which allowed vertical hydraulic conductivity (VK) between layers to be explicitly defined. This allowed us to explicitly state the VK connection values for layers containing confining aquitards near the top of the layer, with VK connection values to the unit above sometimes being orders of magnitude different than the VK connection values to the unit below.

MODFLOW-USG packages used in the LACPGM are shown in table D1. The LACPGM simulates areal recharge using the recharge (RCH) package. Pumping and injection were simulated using conduits from the connected linear network (CLN) package and the well (WEL) package. Faults and other flow barriers were simulated using the horizontal-flow barrier (HFB) package. Inflow from the Los Angeles (LA) Narrows (fig. D1) was simulated using the time-variant specified-head (CHD) package. Inflow from the Whittier Narrows, flow across the eastern Orange County edge of the model, and flow across the southern and western ocean boundaries were simulated using the general-head boundary (GHB) package (fig. D1). Model calibration was completed using PEST (Doherty, 2010), an automatic parameter inversion program.

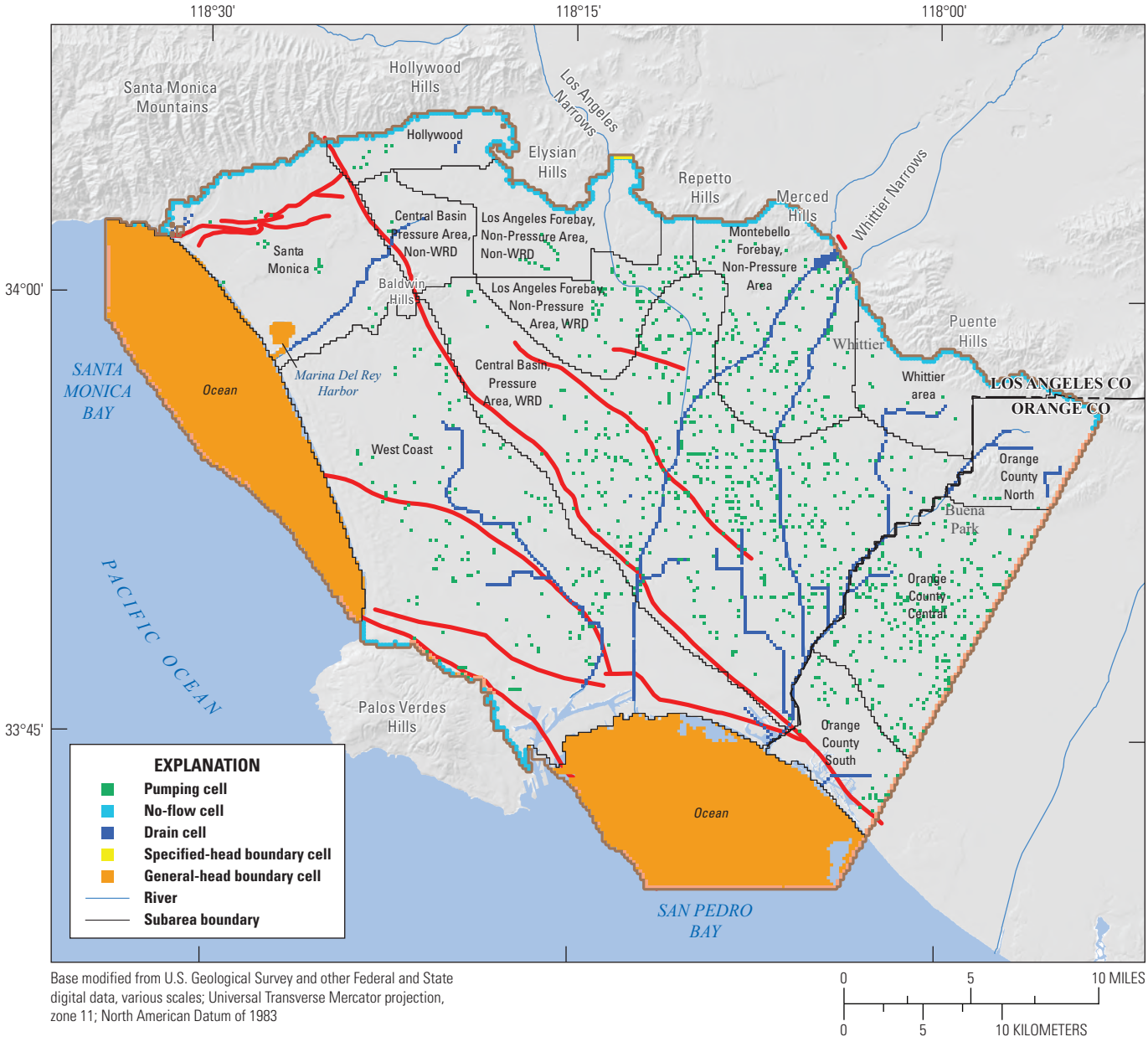


Figure D1. Pumping, drain, and boundary condition cells in the Los Angeles Coastal Plain Groundwater-flow Model as a composite of all model layers, Los Angeles and Orange Counties, California. (Abbreviation: WRD, Water Replenishment District of Southern California)

Table D1. MODFLOW-USG Version 1.3 packages and processes used with the Los Angeles Coastal Plain Groundwater-flow Model, California.

[—, no data]

Package, process, or program name	Function	Reference
	Processes and solver	
Sparse Matrix Solver (SMS) Package	Solves the groundwater-flow equations.	Panday and others (2013)
Groundwater Flow (GWF)	Setup and solve equations simulating a basic ground-water flow model	Panday and others (2013)
	Files	
Name File (Name)	Controls the capabilities of MODFLOW-USG utilized during a simulation.	Panday and others (2013)
Parameter Value (PVAL)	Defines values that replace parameter values specified in the files where parameters are defined.	Panday and others (2013)
Output Control Option (OC)	Used to output head, drawdown, and budget information for specified time periods.	Panday and others (2013)
List File	Output file for allocation information, values used by the GWF process, and calculated results such as head, drawdown, and the water budget.	Panday and others (2013)
	Discretization	
Basic Package (BAS6)	Defines the initial conditions and some of the boundary conditions.	Harbaugh (2005)
Unstructured Discretization Package (DISU)	Defines how the model is spatially and temporally broken up into model cells, time steps, and stress periods.	Panday and others (2013)
Connected Linear Network (CLN)	Defines one-dimensional connected features into a three-dimensional GWF process grid.	Panday and others (2013)
	Aquifer properties	
Layer Property Flow Package (LPF)	Calculates the conductance between cell centers.	Harbaugh (2005)
Hydrologic Flow Barriers (HFB6)	Simulates a groundwater barrier using a hydraulic conductance between two adjacent cells.	Hsieh and Freckleton (1993)
	Boundary conditions	
General Head Boundaries (GHB)	Head-dependent boundary condition to allow groundwater to flow into or out of the model.	Harbaugh (2005)
Time-Variant Specified-Head (CHD)	—	Harbaugh (2005)
	Recharge and discharge	
Well (WEL)	Simulates a specified flux to individual cells.	Harbaugh (2005)
Drain (DRN)	Simulates a head-dependent flux boundary at specified cells. The flux from the drain drops to zero when the head in the cell falls below a threshold.	Harbaugh (2005)
Recharge (RCH)	Simulates a specified flux distributed over the top of the model.	Harbaugh (2005)

Model Discretization

The LACPGM simulates transient conditions of the LACP from January 1971 through December 2015. To numerically solve for the distribution of hydraulic heads within the aquifer system, the aquifer system must be spatially and temporally discretized.

Spatial Discretization and Layering

The LACPGM expands the model area of Reichard and others (2003), extending the eastern border of the model three to five miles (mi) into Orange County (fig. D1). The unstructured finite-difference grid of the LACPGM has 256 rows and 312 columns that are uniform in size; each cell has a length and width of 1/8 mile (660 feet [ft]). A total of 440,172 model cells were included in the grid. The model grid is parallel to the grid of the Universal Transverse Mercator (UTM) System; columns are oriented north-south, and rows are oriented east-west. The coordinates of the lower left corner of the model grid are 355046.48 meters (m) easting, and 3725532.39 m northing in North American Datum (NAD) 1983 UTM Zone 11N.

The LACPGM consists of 13 layers. The top layer is an inactive (IBOUND = 0) layer extending over the entire model grid. The inactive top layer extends from land surface to 30 ft above land surface. Flow does not occur through this inactive layer, and the sole purpose of the layer is to simulate areal recharge to the first active model layer as described in the "Simulated Areal Recharge" section of this chapter. The 12 other layers represent the Dominguez, Mesa, Pacific A, Pacific, Harbor, Bent Spring, Upper Wilmington A, Upper Wilmington B, Lower Wilmington, Long Beach A, Long Beach B, and the combined Long Beach BC and C aquifer systems (referred to hereinafter as the Long Beach C aquifer system), which represent the chronostratigraphic units previously defined in Chapter B. Long Beach BC and C aquifer systems were combined in the model because there was limited information available about the lower units, and combining the units improved numerical stability. An unstructured grid was used to explicitly represent any thinning or pinching-out of the layers. Aquifer systems only were included in the model in areas where their thickness exceeded 15 ft.

All layers except the top inactive layer were designated as convertible (either unconfined or confined); a cell in a convertible layer converts from confined to unconfined conditions when an overlying cell is simulated as being unsaturated. Specific storage and hydraulic conductivity are used in the flow equation when the model layer represents confined conditions. Specific yield and hydraulic conductivity are used in the flow equation when the model layer represents unconfined conditions, and transmissivity is computed using the hydraulic conductivity and saturated thickness of the layer. For the confined case, saturated thickness is equal to layer thickness; for the unconfined case, saturated thickness is calculated using an upstream weighting approach (Niswonger and others, 2011).

Temporal Discretization

The LACPGM uses 180 quarterly stress periods to simulate the 45-year period from calendar year 1971 through calendar year 2015. Quarterly stress periods were chosen to reduce computation time while still approximating seasonal stresses. A stress period is a time interval during which all stresses (for example, pumping rates) are considered constant for modeling purposes. Each stress period is discretized into five equal length time steps. The numerical stability of the model associated with this temporal discretization was evaluated by analyzing the time-varying mass-balance and cumulative mass-balance errors. In general, the time-varying mass-balance errors did not fluctuate in an unstable manner, and the cumulative mass-balance errors were less than 0.10 percent.

Boundary Conditions

Boundary conditions must be prescribed along the boundaries of the model domain and are used to represent flow conditions between the simulated groundwater-flow system and systems beyond the boundaries. Three general types of boundary conditions are used in the LACPGM: no-flow, CHD, and GHB. The lower boundary of the LACPGM and many of the lateral boundaries were simulated as no-flow boundaries (specified flow equal to zero; fig. D1). No-flow conditions were simulated along the boundary with Tertiary deposits to the north and northeast at the edge of the Santa Monica Mountains and Hollywood Hills; along the Elysian, Repetto, Merced, and Puente Hills; and to the southwest along the base of the Palos Verdes Hills in the Dominguez through Upper Wilmington B model layers (fig. D1). These lateral boundaries were simulated as no-flow boundaries because the bordering Tertiary deposits are believed to impede flow into the LACP. Additionally, no-flow boundaries were applied to the lateral edges of each of the aquifer systems that were not specified as another boundary type.

CHD boundaries were used at the Los Angeles Narrows to represent groundwater underflow through the Mesa aquifer system from the San Fernando Valley (fig. D1). The Mesa aquifer system is the only aquifer system that is spatially continuous in the Los Angeles Narrows (fig. D1). Time-varying heads were determined based on measured water levels at wells 1S/13W-15R2 (2772E) for 1971 to 2010 (appendix 3, fig. 3.1, table 3.2) and 1S/13W-15H1 (2771I; appendix 3, fig. 3.1). These wells were believed to accurately reflect water levels at the boundary because the wells are in close proximity to the boundary and the near-boundary region is narrow. Therefore, water levels at the boundary were set to measured water levels using time-varying specified-head boundaries. Water-level data from these wells were linearly interpolated over periods without measurements. Water-level data were not available for well 2772E for 2010–15 (appendix 3, fig. 3.1), so a linear relation was established between water levels from well 2772E and nearby well 2771I during the period of time that the wells had overlapping measurements, and that relation was used to approximate water levels at 2772E during these years.

Flow across boundaries at Whittier Narrows, Orange County, Palos Verdes Hills, San Pedro Bay, and Santa Monica Bay were simulated using a GHB (fig. D1). A GHB is a head-dependent flux boundary used to simulate a source of water outside the model area that either supplies water to, or receives water from, the general-head cells at a rate proportional to the hydraulic-head differences between the source and the model cell (McDonald and Harbaugh, 1988). The time-varying head values assigned to a GHB were estimated from available water-level data compiled for this study.

The East Montebello fault (EMF; fig. B23) forms the model boundary in the Whittier Narrows and cuts through all present aquifer systems. The Dominguez, Mesa, Long Beach B, and Long Beach C aquifer systems are the only aquifer systems that contact the EMF on the LACP side of the fault in the Whittier Narrows (fig. D1). Water-level data collected from multiple-well monitoring sites 5P6-14 (2S/11W-5P6 to 5P14; Whittier Narrows1) and 8L8-16 (2S/11W-8L9-16; Whittier Narrows2) indicated that the Dominguez and Mesa aquifer systems had similar water levels and the Long Beach B and Long Beach C aquifer systems had similar water levels.

A GHB was used in the Mesa layer to simulate groundwater flow across the EMF into the Dominguez and Mesa layers, and a second GHB was used in the Long Beach C layer to simulate groundwater flow into the Long Beach B and Long Beach C layers (fig. D1). Head values for the Whittier Narrows GHB in the Mesa layer were estimated using water-level measurements from well 6G2 (2S/11W-6G2; 2927A) for the northwestern end of the GHB and from site 5P7-15 (Whittier Narrows1_8) for the southeastern end of the GHB (appendix 3, fig. 3.1). Water-levels have only been collected at 5P7-14 since 1992, so a linear relation was established between water levels measured at wells 5P7-14 and 6G2 (2S/11W-6G2; 2927A) to estimate water levels at 5P7-14 from 1971 to 1992. Head values for GHB cells between these two wells were interpolated from data collected from these wells, based on the distance of the cell from either well. Head values for the Whittier Narrows GHB in the Long Beach C layer were estimated using water levels collected at well 8B1 (2S/11W-8B1; 2948C) for 1971 to 1992 and from 5P7-14 (Whittier Narrows1_1) for 1992 to 2015 (appendix 3, fig. 3.1). The heads assigned to the Whittier Narrows GHB in the Long Beach C layer were assumed to be the same along the entire length of the boundary. Conductance values for the GHB cells in the Whittier Narrows were determined during model calibration.

Groundwater underflow along the Orange County boundary (approximately 3 to 5 mi east of the Los Angeles/Orange County line) was simulated in all the model layers with GHB cells. The Orange County Water District (OCWD) has installed a series of multi-completion wells in the Orange County Basin to monitor water levels and water quality (fig. A3), and water-level data from multi-completion wells near the LACPGM boundary were used to assign time-varying heads to the GHB cells. Multi-completion wells were not constructed until the early 1990s; consequently, additional water-level data collected from monitoring and production wells along the boundary were used with water-level data from multi-completion wells to estimate the GHB heads for the period prior to the construction of the OCWD multi-completion wells. A more complete description of the methods used to construct the Orange County GHB is provided in appendix 3.

Groundwater underflow across the Palos Verdes fault at the base of the Palos Verdes Hills was simulated with GHB cells in the Lower Wilmington and Long Beach A–C layers for active cells at the boundary of Palos Verdes Hills. Groundwater underflow into the Dominguez through Upper Wilmington B layers from the Palos Verdes Hills was believed to be limited due to most of these layers pinching out around the Palos Verdes Hills. Water levels from well 5S/13W-7D (MW-1R) were used to assign the GHB heads for the Palos Verdes fault boundary (appendix 3, fig. 3.1). Underflow is likely restricted by the Palos Verdes fault; therefore, low conductance values were initially assigned to the GHB cells. Final conductance values were determined by parameter estimation using PEST (Doherty, 2010).

All offshore cells in the uppermost layer (the Dominguez layer, or the Mesa layer where the Dominguez is not present) were simulated with GHB cells to allow interaction with the overlying ocean (fig. D1). In addition, the Marina Del Rey Harbor was simulated with GHB cells in the Mesa layer. Model cells along the offshore edge of the LACPGM were simulated with GHB cells (fig. D1). All the offshore GHB cells were assigned a freshwater-equivalent head by multiplying the bathymetric depth of the midpoint of each cell by 0.025 to account for the relative density difference between seawater and freshwater. The assignment of a freshwater-equivalent head is a simplified way to account for the effect of higher-density overlying seawater on groundwater flow. The initial conductance values for the offshore GHB cells were based on previous model results (Reichard and other, 2003). Conductance values for the interior offshore GHB cells were about two orders of magnitude lower than for the outermost offshore cells (Reichard and others, 2003). The conductance values for the interior offshore GHB cells are lower because they simulate the vertical movement of groundwater through the uppermost aquifer system layer to or from the ocean; in contrast, the conductance values for the outermost offshore cells simulate the horizontal flow between the aquifer system layers and the ocean. Final conductance values were determined by parameter estimation using PEST (Doherty, 2010).

Model-Layer Elevations

Elevations for the tops and bottoms of the 12 aquifer system layers were determined from the geologic model described in Chapter B of this report. The top and bottom layer elevations from this geologic model were mapped onto the LACPGM cells. This mapping was done using the top and bottom layer elevations at the geographic center of each cell.

Model-layer thickness varies greatly throughout the model area. The Dominguez, Mesa, and Pacific A model layers are relatively thin throughout the model area, with average thicknesses of 115, 135, and 146 ft, respectively, and maximum thicknesses not exceeding 450 ft (table D2). Model-layer thickness generally increases from the upper layers to the lower layers, with the bottom two layers (Long Beach B and C) being considerably thicker than the other layers (table D2). Areal variation in layer thickness increases from the upper to lower layers. Maximum layer thickness is generally found near the center of the Central Basin syncline between the Compton-Los Alamitos fault and the Santa Fe Springs anticline. Layers are thinner or pinch out toward the northern edges of the model.

The chronostratigraphic model contains small regions at the edge of the model and near some faults, where the initial interpolation in the chronostratigraphic model resulted in unrealistic cell top and bottom elevations. These unrealistic elevations were thousands of feet deeper than neighboring cells on the same side of the fault, which translated into unrealistic groundwater-flow model top and bottom elevations. Quality-assurance checks were done to locate any cells with suspected interpolation error; these errors were corrected by interpolation from the nearest realistic neighbor cell(s). As indicated above, minimum model-layer thicknesses were set at 15 ft to achieve a numerically stable model. Where model layers were less than 15-ft thick, they were treated as if they had pinched out, and the thickness of the pinched-out layer was incorporated into the layer above the pinched out layer (or the layer below if the pinched out layer was the top-most layer).

Hydraulic Properties

Hydraulic properties assigned to the LACPGM include horizontal and vertical hydraulic conductivity, specific yield, and specific storage. These properties affect the rate at which groundwater moves through an aquifer system, the volume of water in storage, and the rate and areal extent of groundwater response to aquifer system stresses. Horizontal and vertical hydraulic conductivities were initially estimated by dividing each layer into areal zones, with different zones for each layer. Each zone's hydraulic conductivities were estimated based on an analysis of well-log data (see "Calibration Results" section), regional depositional patterns, and local lithologic variations of groundwater basin sediments reported in previous investigations (Reichard and others, 2003). During calibration, hydraulic conductivities were modified by parameter estimation, and zones were modified based on model results and re-examination of well logs, water-quality data, and other relevant data. Hydraulic-conductivity zone maps with final calibrated values are shown and discussed in the "Model Calibration" section of this chapter.

Table D2. Los Angeles Coastal Plain Groundwater-flow Model layer average and maximum thickness.

[ft, foot]

Layer	Average thickness (ft)	Maximum thickness (ft)
Dominguez	115	337
Mesa	135	449
Pacific A	146	399
Pacific	178	809
Harbor	249	1,031
Bent Spring	221	1,516
Upper Wilmington A	230	781
Upper Wilmington B	264	1,294
Lower Wilmington	307	1,276
Long Beach A	414	2,164
Long Beach B	812	3,231
Long Beach C and BC	1,284	4,555

Chronostratigraphic units generally consist of finer sediments near the top and coarser sediments on bottom. Representing each chronostratigraphic unit as a single model layer and defining a single vertical hydraulic conductivity value for each cell can lead to modeling errors because the top of the cell often consists of finer sediments than the bottom of the cell. To limit these modeling errors, additional confining layers could have been added to the model. However, additional confining layers would have added to the model's runtime. Instead, modeling errors were limited by defining vertical hydraulic conductivities for each cell connection (IKCFLAG=1). Each connection's vertical hydraulic conductivity was defined by the vertical hydraulic conductivity assigned to the zone of the lower of the two connected layers. The lower layer was chosen to define the vertical connection properties because the lower layer usually represents the finer sediments in the connection. The zones constructed for horizontal hydraulic conductivity were also used for vertical hydraulic conductivity.

Specific storage and specific yield were defined using the same zones as used for hydraulic conductivity. Initial storage values were based on calibrated values from Reichard and others (2003). The final values were determined by parameter estimation using PEST (Doherty, 2010).

Horizontal-Flow Barriers

The MODFLOW-USG HFB package based on Hsieh and Freckleton (1993) was used to simulate faults and folds within the model domain that are believed to restrict groundwater flow. The HFB package simulates these features as thin, vertical, low-permeability geologic features that impede the horizontal flow of groundwater. Flow across a simulated HFB is proportional to the hydraulic-head difference between adjacent cells where the constant of proportionality is the hydraulic characteristic. For unconfined aquifers, the hydraulic characteristic equals the hydraulic conductivity of the flow barrier divided by the width of the barrier and has dimensions of per time (T^{-1}). For confined aquifers, the hydraulic characteristic equals the transmissivity of the flow barrier divided by the width of the barrier and has dimensions of length per time (LT^{-1}).

The LACPGM uses HFBs to simulate groundwater flow across the Newport–Inglewood fault zone, Santa Monica, Compton-Los Alamitos, Pacific Coast Highway (PCH), and Alondra faults, and the Santa Fe Springs anticline and related structures. The locations and areal extents of the flow barriers were identified from geological information (as described in Chapter B) or inferred from localized hydraulic-head (water-level) gradients. Some of the longer HFBs were broken into segments and assigned different hydraulic-characteristic values for each segment. Initially, the hydraulic-characteristic values were set to large values to allow groundwater to flow freely across fault segments. Final calibrated values were determined through PEST calibration and are shown in the "Calibration Results" section of this chapter.

Simulated Areal Recharge

The LACPGM simulates areal recharge using the RCH package (Harbaugh, 2005). The quantity and distribution of areal recharge were based on a watershed-scale, precipitation-runoff infiltration model developed for this study (Hevesi and Johnson, 2016). Areal recharge represents both mountain-front recharge on the perimeter of the model from bordering tributary drainages and direct precipitation. The recharge estimates from Hevesi and Johnson (2016) were used as initial quarterly areal recharge values from 1971 through 2014 for each model cell. Initial quarterly areal recharge for 2015 was estimated by using a correlation developed between historical precipitation data and recharge estimates (described in appendix 5).

Recharge estimates from Hevesi and Johnson (2016) were allowed to vary during model calibration. Recharge estimates were allowed to vary by first dividing the model area into 17 recharge zones based on geographical features (fig. D2*A*). Recharge estimates from Hevesi and Johnson (2016) were modified with a multiplier applied to each recharge zone. The recharge zone multipliers were calibrated as PEST parameters. The calibrated recharge-zone multipliers changed the distribution of recharge in some regions of the study area, but only had a minor effect on the overall model-area recharge estimates of Hevesi and Johnson (2016).

Water levels in the Dominguez aquifer system, south of Merced Hills, indicate that the Dominguez aquifer system is receiving local recharge. Runoff from the Merced Hills probably is a source of recharge to the Dominguez aquifer system in this part of the LACPGM, and the Dominguez aquifer system probably extends through recharge zone 18 to the Merced Hills. Because the chronostratigraphic model does not extend the Dominguez unit all the way to the Merced Hills, recharge estimated for zone 18 by Hevesi and Johnson (2016) was transferred to zone 14 to simulate recharge from the Merced Hills to the Dominguez aquifer system (fig. D2*A*).

Areal recharge varies throughout the model area, with the highest recharge generally occurring near the Santa Monica Mountains and the hills bordering the model area to the north and northeast (fig. D2*B*). Simulated areal recharge in the model area varied greatly between wet and dry periods (fig. D3), reaching a high of about 190,000 acre-feet per year (acre-ft/yr) during 1978 and a low of about 5,500 acre-ft/yr during 2014.

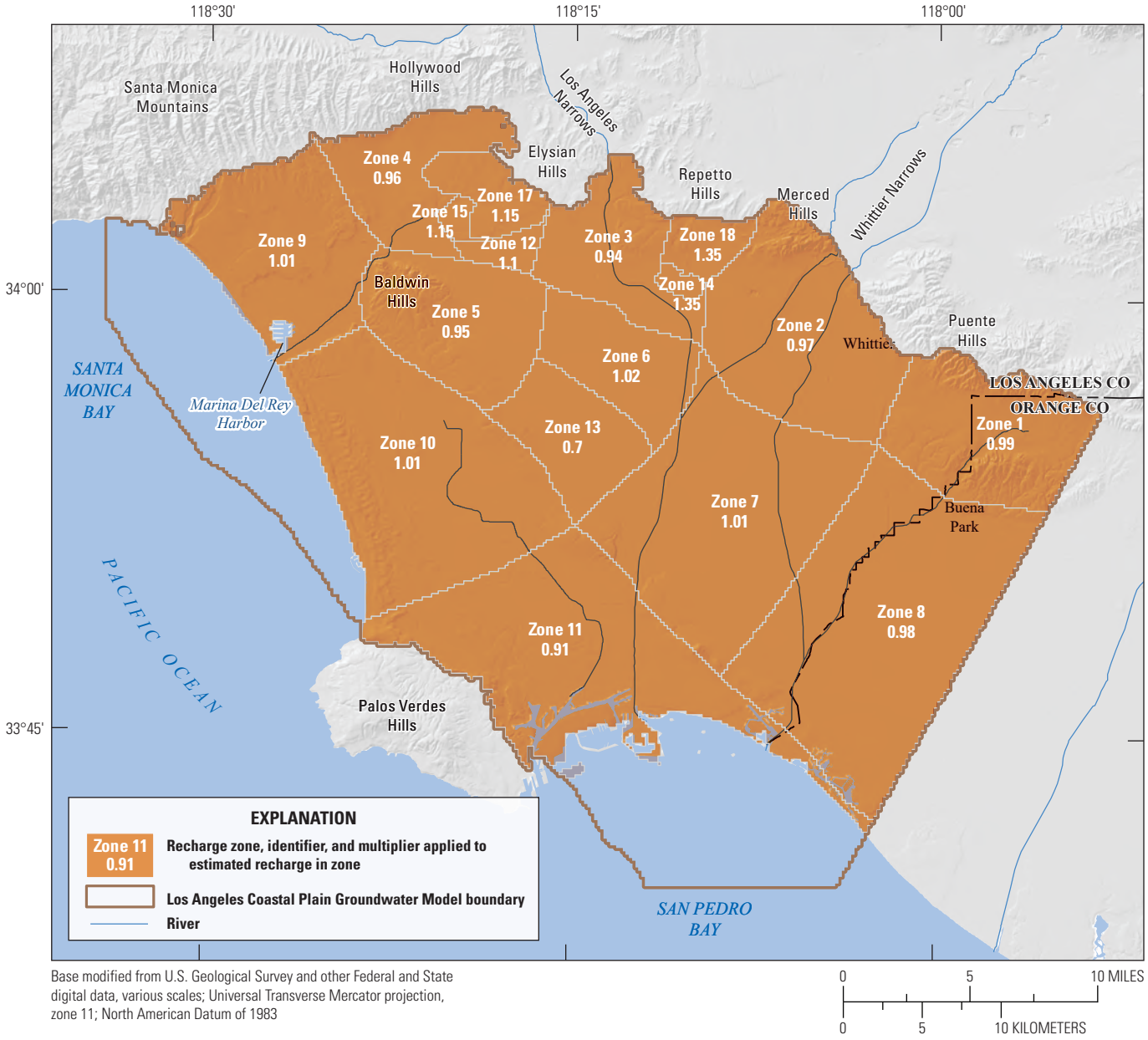
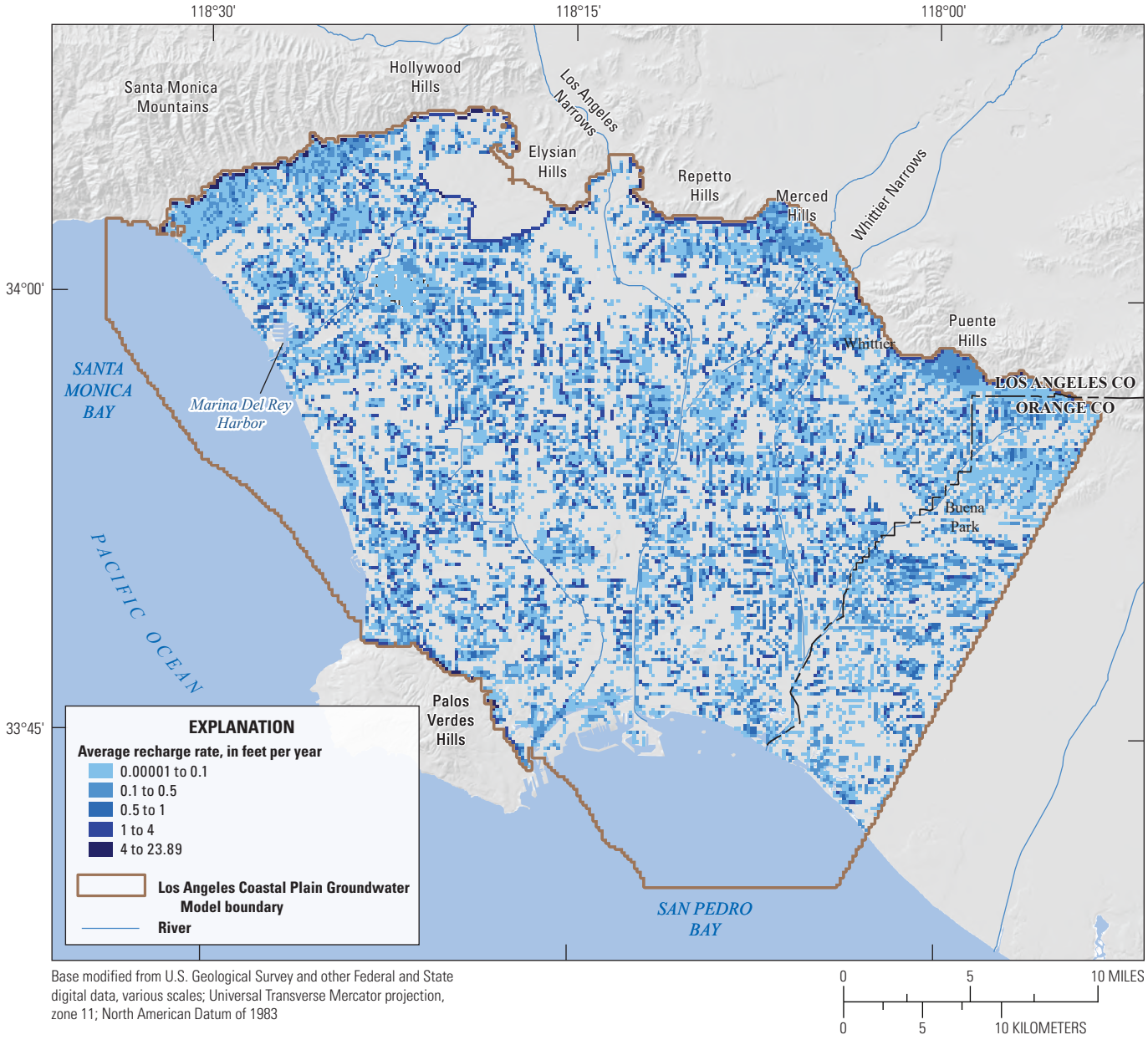


Figure D2. Areal recharge as *A*, areal recharge zones and multipliers, and *B*, simulated average areal recharge rates, calendar years 1971 to 2015, of the Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California.

The Mesa model layer is the topmost layer (and mostly the only layer) in recharge zone 17 (fig. D2*A*). Folding and subsequent erosion of the aquifers older than the relatively flat-lying Mesa aquifer system has resulted in the Mesa aquifer system directly overlying low permeability Repetto Rocks throughout most of the recharge zone. Due to the low permeability of the Repetto Rocks, recharge in recharge zone 17 probably moves laterally through the Mesa model layer in zone 17 and then downward into the surrounding aquifer system. The base of the Mesa layer in zone 17 is higher than the groundwater elevation of the surrounding aquifers; therefore, the aquifers are not in direct hydraulic connection. Consequently, pumping from the surrounding aquifers should not induce groundwater flow from recharge zone 17. However, in the LACPGM, the Mesa model layer in recharge zone 17 is contiguous with the Mesa model layer in the surrounding model zones. The Mesa model layer in recharge zone 17 was assigned a very low specific yield (0.0075) to limit the quantity of groundwater flow from the Mesa model layer in recharge zone 17 to the surrounding recharge zones. Areal recharge was not applied to recharge zone 17 to avoid water levels rising above land surface in this model zone. Instead, the areal recharge intended for recharge zone 17 was distributed equally around the south and west perimeter of zone 17, which is along the southern and eastern edges of recharge zone 17 (fig. D2*A*).



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

Figure D2.—Continued

Areal recharge was assumed to occur in the uppermost active model layer and was applied using the RCH package. Areal recharge was added to uppermost active model layer by first creating an inactive top layer that extends over the entire model area, which was the simplest way to use the RCH package with the LACPGM's unstructured grid. Simulated recharge passes through this layer to the uppermost active model layer, which is the Dominguez or Mesa layer throughout most of the LACPGM (fig. D4).

Water Spreading

The LACPGM simulates water spreading from three spreading grounds in the model area: the San Gabriel River spreading grounds (SGRSG), Rio Hondo spreading grounds (RHSG), and the west side of the reservoir behind Whittier Narrows Dam (WND; fig. D5).

The WRD provided monthly water spreading data, which were processed into a quarterly recharge rate for each model cell in the spreading grounds. Spreading amounts were assumed to be spatially uniform within each set of spreading grounds. Given the quantity and duration of the recharge and the highly permeable nature of the sediments under the facilities, retention of recharge water and transit time in the unsaturated zone was expected to be minimal. Water spreading was simulated using the WEL package (Harbaugh, 2005) by injecting water into the uppermost active model layer.

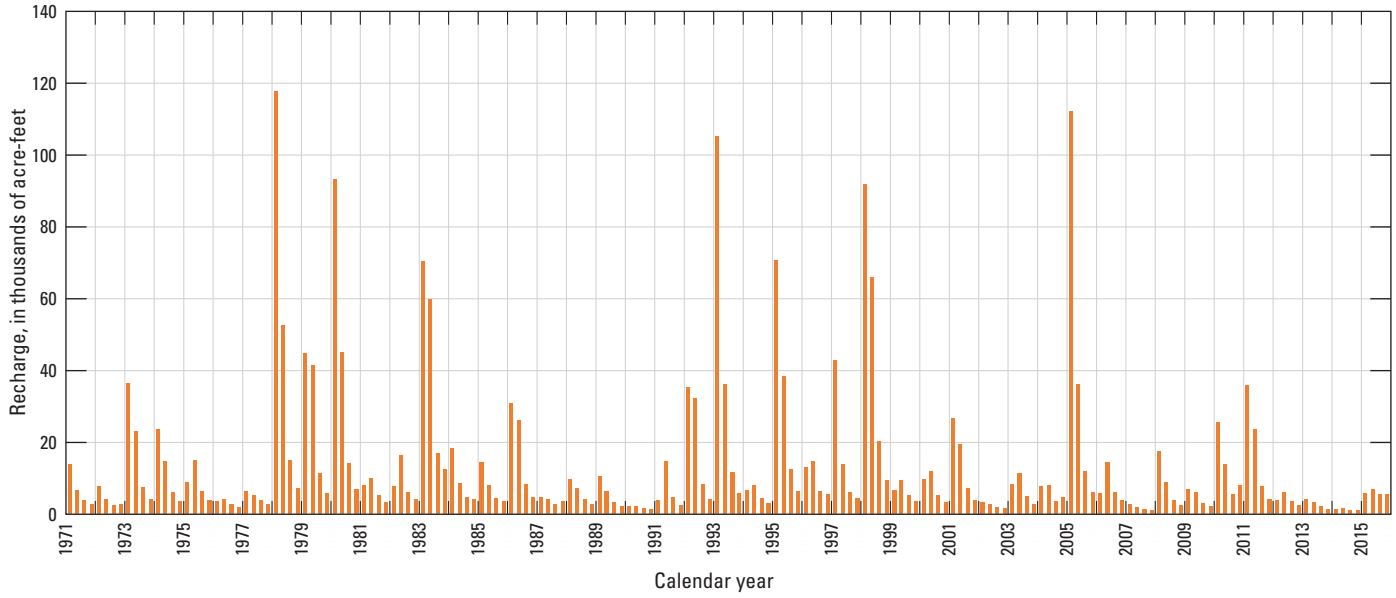


Figure D3. Areal recharge applied to the Los Angeles Coastal Plain Groundwater-flow Model, quarterly estimates from 1971 to 2015, Los Angeles and Orange Counties, California.

Water-Supply and Injection Wells

Injection and production wells were simulated throughout the model area. Injection wells were simulated for the three barrier projects in the study area: the West Coast Basin Barrier Project (WCBBP), the Dominguez Gap Barrier Project (DGBP), and the Alamitos Barrier Project (ABP; fig. D5). Injection and production wells were simulated using the MODFLOW-USG CLN package (Panday and others, 2013) and the WEL package (Harbaugh, 2005). The LACPGM uses the CLN process to simulate flow through vertical conduits that represent injection and production wells and uses the WEL package to inject/pump water to/from each conduit. Each well was represented by a single vertical conduit segment. Conduits representing wells constructed during the model period (1971 to 2015) were set to no-flow for stress periods prior to well construction and were set to variable head such that flow can occur through the conduit for stress periods after construction. Conduits are connected to one or more model layers.

Within the CLN package, the option to use the Thiem equation was selected, which simulated flow between each CLN node and matrix node with the inclusion of skin effects. The CLN package using the Thiem equation is similar to the approach used by the revised Multi-Node Well package of MODFLOW-2005 (Konikow and others, 2009). Flow between a conduit and each connected model cell is computed across the wetted perimeter of the conduit and can occur both during periods of pumping and when the well is idle. Conduit properties, including skin resistance, hydraulic conductivity, and radius, are used to compute the effective leakance between a conduit and its connected model cells. For the LACPGM, the radius of the conduit was determined from well-construction logs. A conduit skin factor was used to regulate borehole flow between layers. A conduit skin factor of 16,000 was used. The skin factor of 16,000 led to a numerically stable model in all but one conduit, and the skin factor was reduced for this conduit. Reducing the skin factor of one conduit had minimal effect on model results because that conduit is only connected to one model layer.

The conduit skin factor and conduit hydraulic conductivity were initially set as parameters and were calibrated to minimize the difference between observed and simulated head values. Conduit skin factor and conduit hydraulic conductivity were also manually calibrated to maximize model numerical stability. The skin factor was determined based on an initial calibration and not varied for the remainder of the calibration due to the sensitivity of the model's numerical stability to high skin factor values.

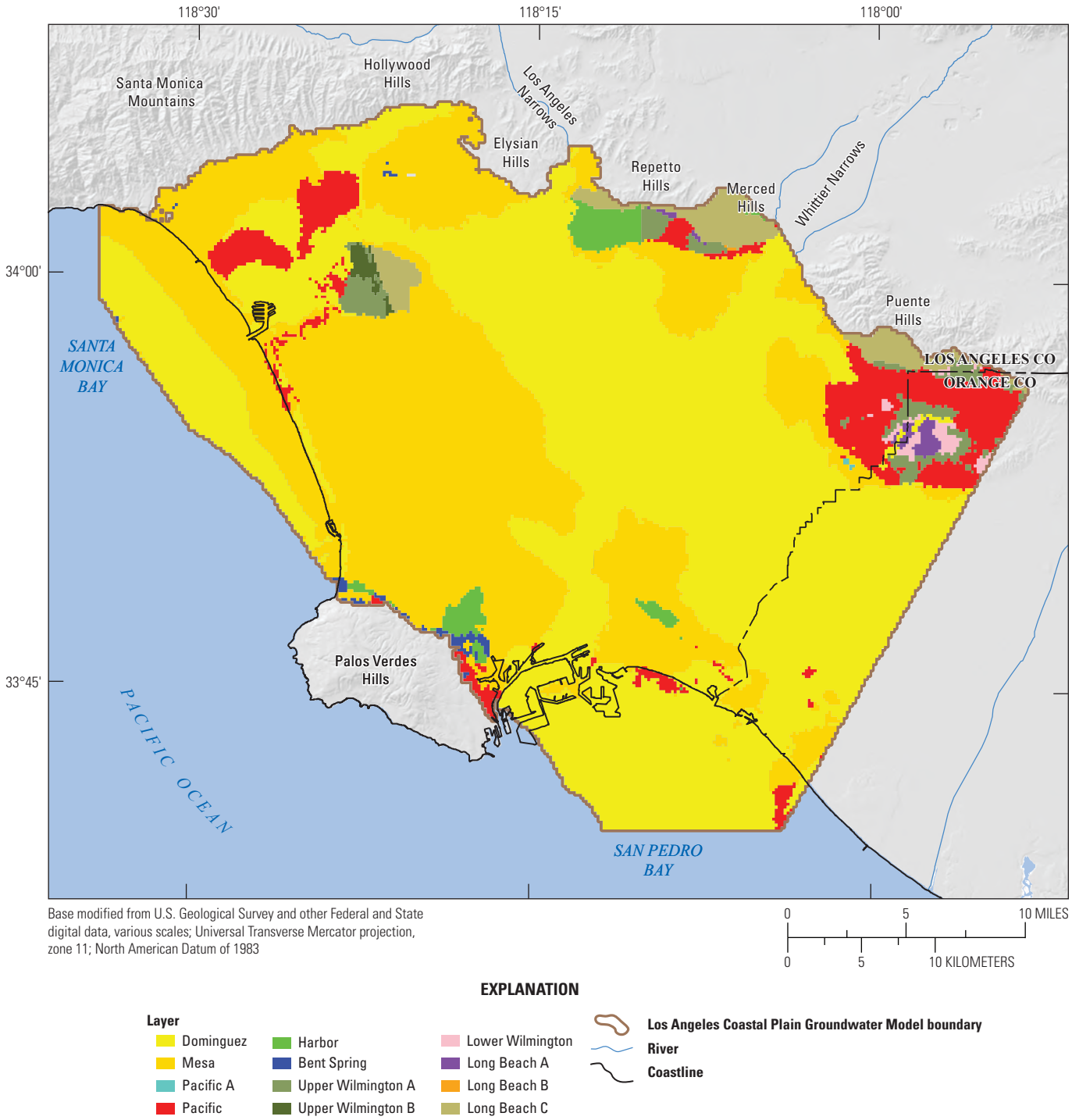


Figure D4. Uppermost model layer in the Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California.

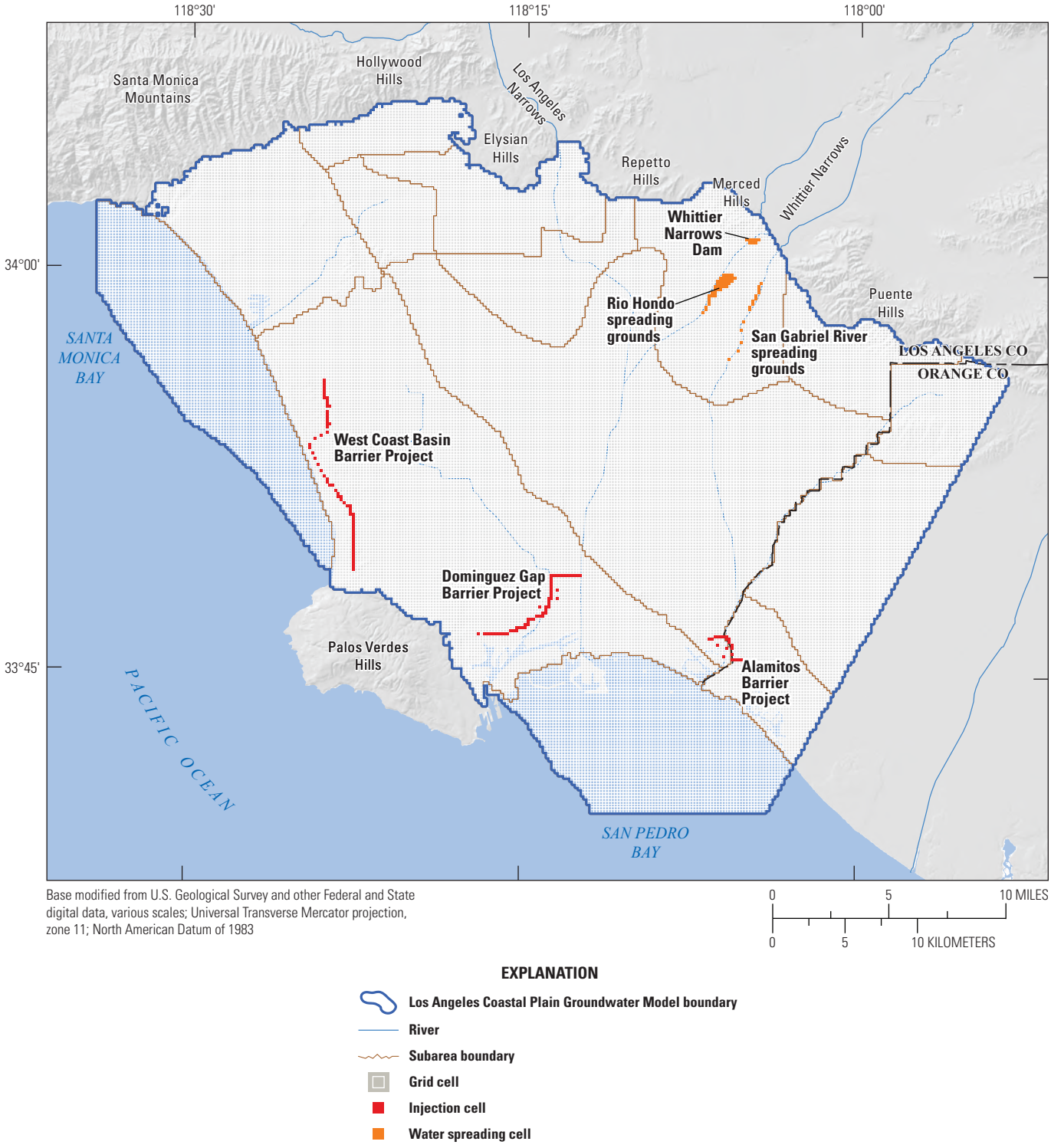


Figure D5. Cells with injection or spreading for all layers of the Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California.

Drains

The MODFLOW-USG drain (DRN) package was used to represent drained runoff caused by rising water levels from the WND spreading grounds, the San Gabriel River, Rio Hondo, Dominguez Channel, the northern part of Ballona Creek, Coyote Creek, and areas of runoff in the foothills of the Santa Monica Mountains (figs. A1, D1, D5). These areas were simulated as drains because creek flow is ephemeral and water levels are near land surface in many of the creek beds. A drain is a head-dependent flux boundary condition that allows water to drain from a model cell at a rate proportional to the difference between the simulated head in the cell and some specified drain head or elevation, as long as the simulated head is above the specified head or elevation. The drain has no effect on the model cell if the simulated head falls below the specified drain elevation (McDonald and Harbaugh, 1988). The constant of proportionality is termed the drain conductance (L2T-1). Drain elevation was set to 230 ft at the WND spreading grounds, slightly below the top of Whittier Narrows Dam. This drain elevation was selected to simulate flow out of the WND spreading grounds when water levels approach the top of the dam. Drain elevations in other areas were set to the bottom of the river/drainage being simulated. Drain conductance values were determined during the calibration process.

Model Calibration

The LACPGM was calibrated using a combination of automated inverse modeling with PEST (Doherty, 2010) and manual trial-and-error calibration for the simulation period January 1971 through December 2015. Initial estimates of aquifer hydraulic properties, HFB hydraulic-characteristic values, GHB conductance values and heads, CLN parameters, DRN conductances, and the distribution and quantity of areal recharge were iteratively adjusted to improve the match between simulated and measured hydraulic heads (water-level elevations).

The LACPGM parameterized horizontal and vertical hydraulic conductivity, specific storage, and specific yield using zones defined for each model layer. Zones were based on well-log data, flow-barrier locations, and geographical features. HFB hydraulic-characteristics and GHB conductance values were also parameterized by model layer for each flow barrier. Longer HFBs or model boundaries, such as the Newport-Inglewood fault zone and the Orange County GHB, were broken up and parameterized by segments. Recharge was parameterized with a recharge multiplier for each of the 17 recharge zones (fig. D2).

Initial hydraulic-conductivity and specific-storage values were based on geologic features and borehole logs. Initial specific-yield values were based on the calibrated values of a previous groundwater-flow model (Reichard and others, 2003). Initial HFB hydraulic-characteristic values were set to large values to allow groundwater to flow freely across the barrier segments. Conductance values for the Whittier Narrows and Orange County GHB cells were initially assigned large values to allow unrestricted flow across the boundary cells. The offshore and Palos Verdes GHB conductance values were initially assumed to allow only minimal flow, and their conductance values were initially set to small values. Initial recharge-zone multiplier parameters were set to 1.0, which left the recharge estimates from Hevesi and Johnson (2016) unchanged. Initial conductance values for the DRN cells were initially assigned large values to allow drainage of groundwater near land surface. Using conduit skin factor as a PEST parameter was found to cause model instability. The conduit skin factor for CLN conduits was therefore determined by manual calibration prior to PEST calibration.

Initial Conditions

Initial conditions define the state of the groundwater-flow system state at the beginning of a transient simulation. Ideally, initial conditions would represent pre-development conditions; however, groundwater resources development within the LACP began in the 19th century, and sufficient historical water levels and data for estimating stresses were not available until about the 1960s. Therefore, the simulation began with initial conditions representing relatively static hydrologic conditions during the modern period when data are available. Analysis of the long-term water-level hydrographs (see "Water Levels and Movement" section in Chapter C) indicated that water levels measured in 1971 were the earliest on record, after the adjudication of the Central and West Coast Basins in the early 1960s, when the water levels were relatively constant. Water levels collected in early 1971 were used to provide the initial conditions for the LACPGM because water levels were relatively constant and sufficient data are available to simulate the quantity and distribution of stresses to the system.

Initial heads were determined for each model layer based on an interpolation of available water-level data collected in 1971. Aquifer-dependent water-level data were limited in the LACP prior to the construction of WRD/USGS multiple-well monitoring sites in the late 1990s; therefore, the assigned initial heads are uncertain, especially in the deeper aquifer systems, which could potentially lead to initial-condition errors. In areas of the model where these errors were likely to be small because data were plentiful, the model usually established a new equilibrium within several stress periods, resulting in only minimal error. However, some areas had sparse water-level data collected around 1971, including parts of the Santa Monica Basin, northern West Coast Basin, and Hollywood Basin. In areas where initial-condition errors were likely to be large because of sparse data, the inconsistent specified initial heads could take multiple stress periods to equilibrate in the model simulation, especially in aquifer systems with low hydraulic conductivities. To minimize the error associated with initial heads, these heads were modified in areas of the model in which initial model simulations showed major head changes in the early stress periods, which indicated that the initial heads in those areas were inconsistent with our initial conceptualization of the groundwater-flow system. If production wells were present and active in 1971 in the area, additional estimated water-level measurements were added to the water-level data being interpolated at cells representing the production wells and surrounding cells to reflect the initial heads at the pumping wells and approximately interpolate the drawdown around the wells.

Observations Used in Model Calibration

Four types of observation data were used during model calibration: water levels, changes in water level, vertical differences in water levels between layers, and estimated annual flow rates across the Whittier Narrows. The water-level-based calibration criteria were developed using 27,860 water-level measurements from 464 wells. Measurements were averaged for each stress period, and the averages were used to compute changes in water levels for each stress period. Vertical differences in water levels between layers were computed from water levels collected at 32 multiple-well monitoring sites. Locations of wells used for model calibration are shown in figure A3. The LACPGM was also calibrated to yearly estimated underflow across Whittier Narrows by the San Gabriel River Watermaster (San Gabriel River Watermaster, 1997).

Calibration Process

Calibration of the LACPGM was initially accomplished primarily with automated calibration, and a combination of automated and trial-and-error methods toward the end of calibration. PEST (Doherty, 2010) was used for automated calibration. The model was calibrated to achieve the best possible match to measured water levels, water-level drawdowns, vertical differences in water levels between different monitoring wells in the multiple-well monitoring sites, and underflow estimates at the Whittier Narrows, subject to a range of parameter values that realistically represent the geology of the groundwater basin. Each water-level measurement and estimated flow rate was considered a single data point. Data points were assigned different weights depending on whether they were collected from key multiple-well monitoring sites (table D3). Most water-level measurements from non-key wells were assigned a weight of 1.0; most measurements from key multiple-well monitoring sites were assigned a weight of 3.0. Key multiple-well monitoring sites (table D3) were chosen and assigned a higher weight due to their location, data quality (confidence in the measurements), number of wells at the site, and the temporal distribution of the data. Key wells were chosen to provide a good geographic distribution of key wells and avoid clustering of key wells in any given area. Key wells were primarily chosen within the WRD service area.

Calibration of the LACPGM was an iterative process that involved three steps:

(1) Running PEST to calibrate the model.

(2) Analyzing the results, including parameter values and their sensitivities, changes in objective function, and hydrographs. If the results indicated an inaccuracy with the groundwater or chronostratigraphic models, data used to build these models were reviewed to identify the specific problem. The most common chronostratigraphic model inaccuracies were layer boundaries at incorrect depths, which sometimes led to groundwater-flow model production wells pumping from the wrong layer.

(3) Changes were made based on the analysis in step 2 to any combination of PEST input, the groundwater-flow model, or the chronostratigraphic model. These changes included the following:

   a. PEST observation weights and parameter-value bounds,

   b. The hydraulic conductivity zones in the groundwater-flow model,

   c. The initial conditions (hydraulic head in each cell),

   d. The geometry of the chronostratigraphic layers.

Table D3. Key multiple-well monitoring sites used during Los Angeles Coastal Plain Groundwater-flow Model calibration.

State well number	Common name
2S/12W-33D3-8	Bell Garden1
3S/12W-26K2-7	Cerritos2
3S/12W-9J1-6	Downey1
3S/14W-25K7-11	Gardena2
3S/14W-17G3-8	Hawthorne1
2S/13W-22C1-4	Huntington Park1
2S/14W-12E1-6	Los Angeles3
4S/12W-30J1-6	Long Beach8
4S/12W-5H5-10	Lakewood1
2S/11W-18C4-7	Pico Rivera1
2S/12W-25G3-8	Pico Rivera2
4S/14W-15E1-6	Torrance1
5S/12W-1C3-9	Seal Beach1
3S/11W-2K4-8	Whittier1
4S/13W-28A3-7	Wilmington1

Additional steps were also performed when necessary. These included (4) manually running the model to test model adjustments prior to running PEST, and (5) updating and rebuilding the chronostratigraphic and groundwater-flow model layering as new information became available. All five steps were repeated until the model was reasonably calibrated. The majority of the calibration adjustments involved modifying the hydraulic-conductivity zones. In addition, the chronostratigraphic layer geometry was modified as needed, especially in the West Coast Basin, where small errors in the chronostratigraphic model could lead to placing production or injection wells in the wrong layer. Chronostratigraphic layer geometry was also modified at the northern and eastern edges of the LACPGM where steeply sloping model layers caused numerical instability.

Calibration Results

A total of 27,860 hydraulic-head (water-level elevation) measurements at 464 wells in the model area from 1971 through 2015 were compared to simulated heads to help calibrate the model (fig. D6). The simulated and measured heads closely follow a 1:1 correlation line, with a root-mean-squared error of 11.3 ft (fig. D6*A*). About 76 percent of simulated heads are within 10 ft of measured values and about 96 percent are within 25 ft. The simulated versus measured hydraulic-head residuals were mostly between –6 and 6 ft, with a very slight skew toward negative residual values (fig. D6*B*). A better match between simulated and measured heads was achieved for values greater than 0 ft (fig. D6*A*). As values dropped below 0 ft, simulated heads were on average skewed slightly lower than measured heads. This skew is most likely due to model limitations when estimating heads in close proximity to production wells that produce substantial water-level drawdown. Measured heads in the Santa Monica Basin near the Santa Monica Mountains fluctuated seasonally by up to 150 ft. The model was not able to simulate this much fluctuation, possibly due to the complex geology along the Santa Monica fault.

Calibrated Horizontal Conductivity

Geologic and geophysical logs from WRD/USGS monitoring sites were used to determine grain sizes of the chronostratigraphic units. Grain sizes were used to help determine initial horizontal hydraulic conductivity and were also used as part of the calibration process.

The calibrated horizontal hydraulic conductivity (HK) for each layer and the interpretation of well data used to help constrain the calibrated HK values are shown in figure D7. Calibrated horizontal HK values were generally higher in the upper model layers and decreased with depth (fig. D7). The highest calibrated HK values in the model were 785 ft/d in the Dominguez layer along the Montebello Forebay near Whittier Narrows (figs. D1, D7*A*). This is consistent with the coarse- and medium-grain size of sediment at site 11A7-12 (3S/12W-11A7 to 11A12; Norwalk-2; fig. D7*A*). In general, the calibrated HK values were the highest in the Montebello Forebay for all layers, with HK values decreasing toward the coast (fig. D7). The Upper Wilmington B and lower layers have considerably lower calibrated HK values than the overlying layers, with most calibrated HK values of 25 ft/d or less (figs. D7*B*, D7*C*). These layers are predominantly compacted shallow to deep marine deposits, which accounts for their lower HK values (figs. B7–B11). These layers also are very thick, exceeding 2,000 ft in the Long Beach A–C layers in the central part of the Central Basin. Although these layers are thick, permeable deposits compose only a small percentage of the total thickness of these layers and generally are present at the base of these layers. The LACPGM calculates the transmissivity of a layer by multiplying the calibrated HK of a layer by the thickness of the layer. Therefore, a thick layer with a small percentage of coarse-grained deposits would have a lower calibrated HK value than would the thinner, coarse-grained zone of the layer. Consequently, the calibrated HK values for the Long Beach layers in the Central Basin, where the layers are the thickest, are some of the lowest calibrated HK values (1 ft/d or less) in the LACPGM (fig. D7*C*).

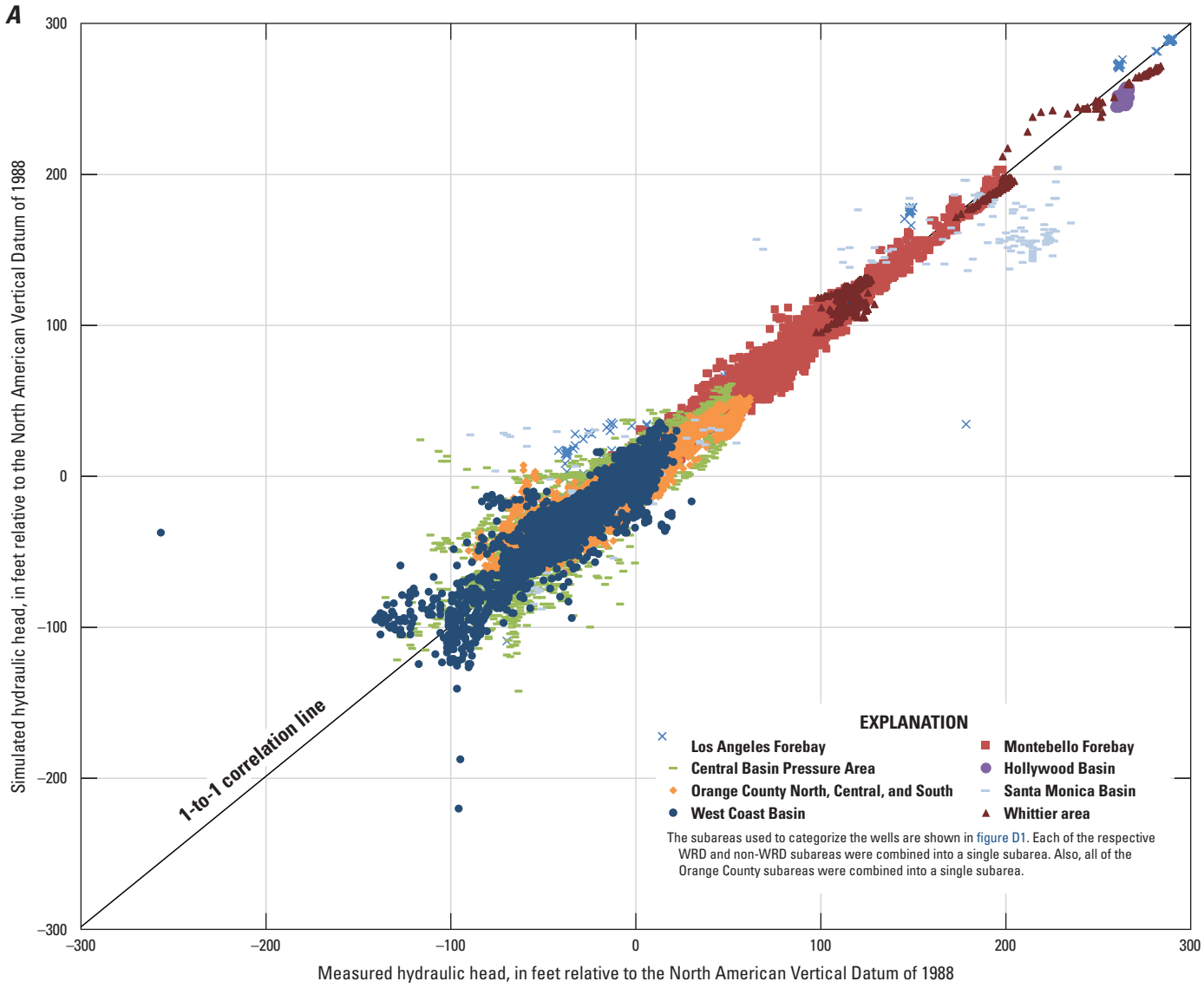


Figure D6. Simulated versus measured hydraulic heads of the Los Angeles Coastal Plain Groundwater-flow Model for 1971 through 2015, as *A*, scatter plot; and *B*, histogram of residual errors.

Grain-size analyses in well bores were used to guide calibration of horizontal hydraulic conductivity. As a result, calibrated horizontal hydraulic conductivities were generally consistent with grain-size analyses. Inconsistencies between the final calibrated horizontal hydraulic conductivities and grain-size analyses were allowed when there was reasonable justification. For example, at wells 22M2-7 (3S/13W-22M2 to 22M7; Compton2; fig. C8), we determined that the Dominguez and Mesa chronostratigraphic units contained only fine sediments; however, the LACPGM could not simulate production well 21J2 (3S/13W-21J2; screened entirely in the Dominguez and Mesa units near 22M2-7) at its recorded pumping rates using low modeled HKs in this area. Therefore, the Dominguez and Mesa chronostratigraphic units likely contained grain sizes other than fine sediments at wells 22M2-7. As a result, wells 22M2-7 were included in a zone with intermediate modeled HKs. We also recognized that coarse-grained sediment in the lower units (Lower Wilmington and Long Beach A through C) did not necessarily indicate high HK values because HK may be primarily affected by other factors at depth, such as level of induration.

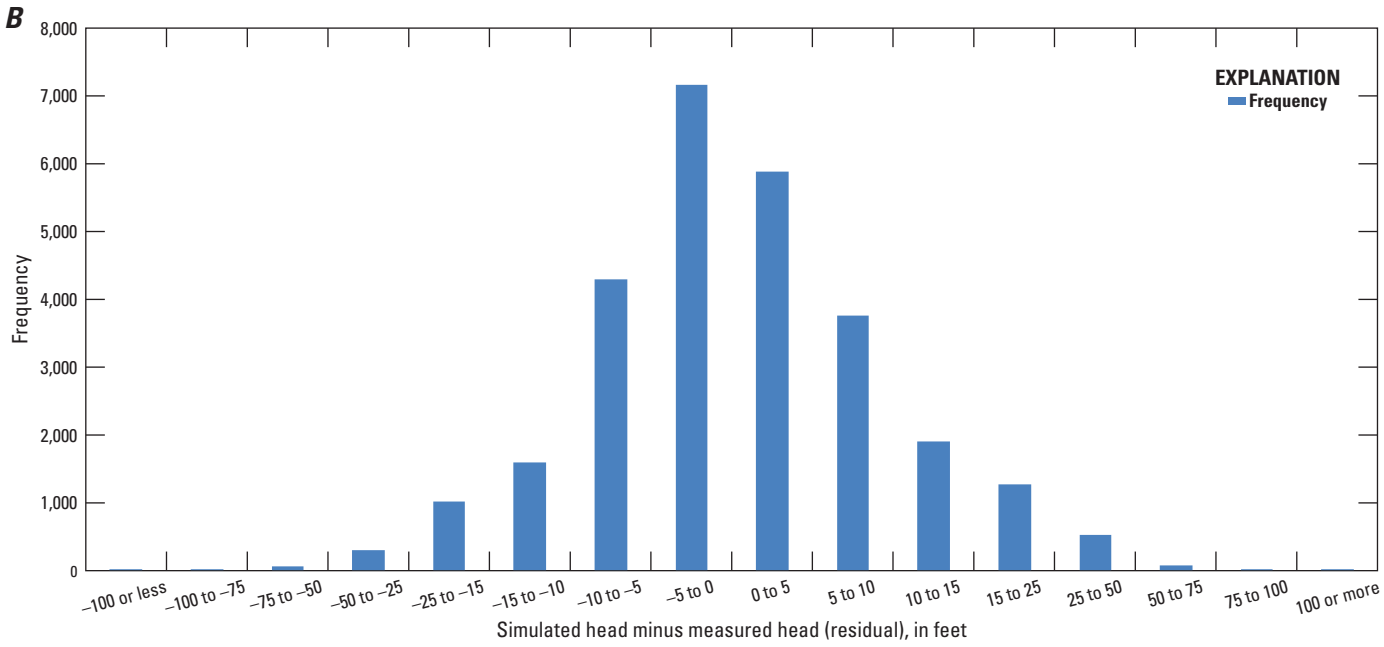


Figure D6.—Continued

Calibrated Vertical Hydraulic Conductivity

In the LACPGM, VK was defined by connection between adjacent model layers. VK connection values were directly assigned based on PEST parameters, as opposed to the VK value of each connection being calculated based on VK values of the two connecting model cells. The calibrated VK values in Central Basin generally are higher in the Montebello Forebay, lower in the Central Basin Pressure Area and Orange County Basin, and variable in the Los Angeles Forebay (figs. D1, D8*A–K*). The calibrated VK values between the non-marine Dominguez and Mesa layers generally were higher than the calibrated VK between the underlying layers. The Pacific A layer, which is predominantly of shallow marine origin (fig. B17), had calibrated VK values about one order of magnitude lower than the VK values of the Mesa layer (figs. D8*A–B*). The calibrated VK values in the Pacific A and lower layers in the Central Basin Pressure Area generally were low (0.009 ft/d or less); these values represent the fine-grained sediments commonly found in the upper part of the chronostratigraphic units (Van Wagoner and others, 1990) that these model layers represent.

In the West Coast Basin, calibrated VK values were variable but consistently low in the Mesa layer, with most zones having values of 0.007 ft/d or less (figs. D1, D8*A*). The calibrated VK values of the Pacific and Harbor layers generally were higher than those in the Mesa layer, with some zones having values in excess of 1.0 ft/d (figs. D8*B–D*). Calibrated VK values are low (0.004 ft/d or less) in the Bent Spring layer throughout most of the West Coast Basin, except for the zones near the Palos Verdes Hills, which had values in excess 0.2 ft/d (fig. D8*E*). The Long Beach layers had the consistently lowest calibrated VK values, with values less than 0.0005 ft/d throughout most of the West Coast Basin (figs. D8*I–K*).

Calibrated Groundwater-Flow Barrier Hydraulic-Characteristic Values

Groundwater flow barriers were simulated in all layers except for the Dominguez layer (figs. D8*A–K*). Simulated HFB hydraulic-characteristic values were generally higher for the upper model layers and lower for the deeper model layers. The lowest hydraulic-characteristic values were simulated along the eastern section of the Santa Fe Springs anticline, where values are as low as 5.7 E-10 per day (1/d; fig. D8k). The Newport–Inglewood fault zone, and Alondra, Santa Monica, Compton-Los Alamitos, and PCH faults also are simulated as flow barriers in the deeper units, with hydraulic-characteristic values as low as 3.7 E-6, 8.8 E-8, 6.3 E-7, 8.3 E-5, and 2.6 E-5 feet squared per day (ft^2/d), respectively. These low hydraulic-characteristic values severely restrict the flow across the fault zones in the deeper model layers where faults can have large vertical and/or horizontal offsets at depth (fig. B6).

Calibrated Specific Storage and Specific Yield

Calibrated model specific-storage values varied from 1.0 E-5 to 1.0 E-6 per foot (ft^{-1}) across all layers, with most of the values equal to 1.0 E-6 ft^{-1} (Paulinski and others, 2021). The highest specific-storage values generally occurred in the Mesa aquifer system.

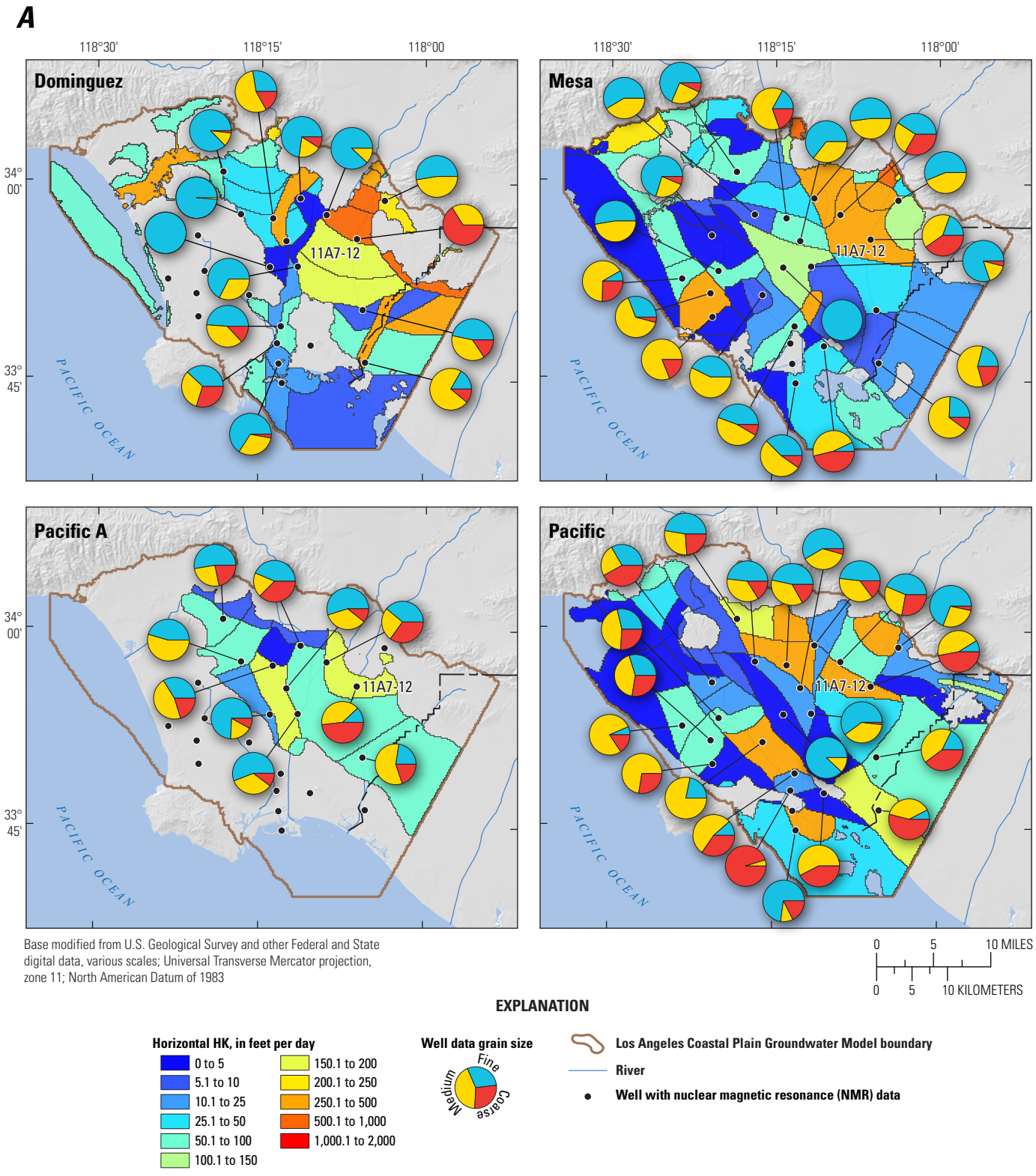


Figure D7. Calibrated horizontal hydraulic conductivities (HK) and grain-size distributions in well boreholes for model layers: *A*, Dominguez; Mesa; Pacific A; Pacific; *B*, Harbor; Bent Spring; Upper Wilmington A; Upper Wilmington B; and *C*, Lower Wilmington; Long Beach A; Long Beach B; Long Beach C, Los Angeles and Orange Counties, California. (NMR, nuclear magnetic resonance.)

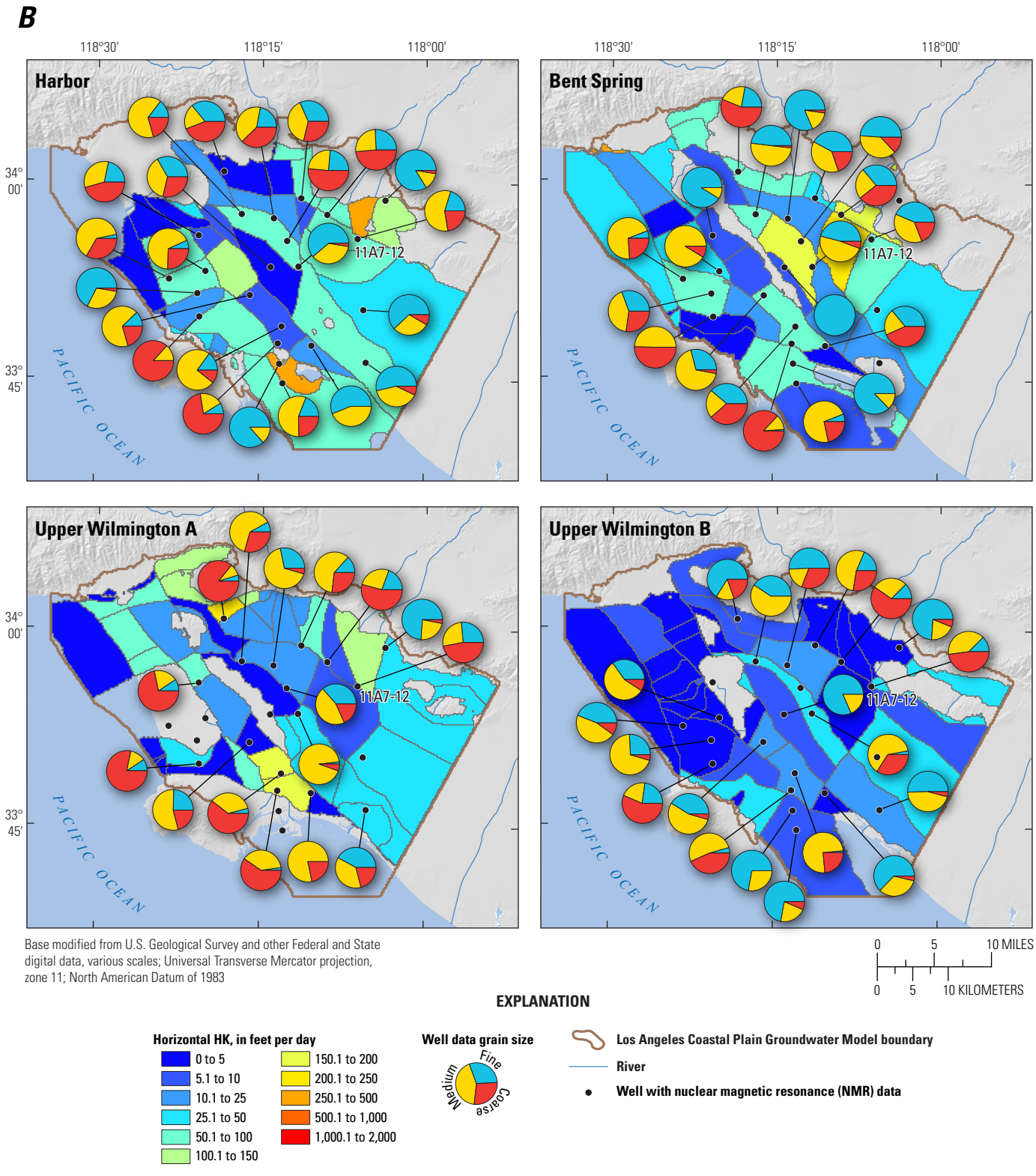


Figure D7.—Continued

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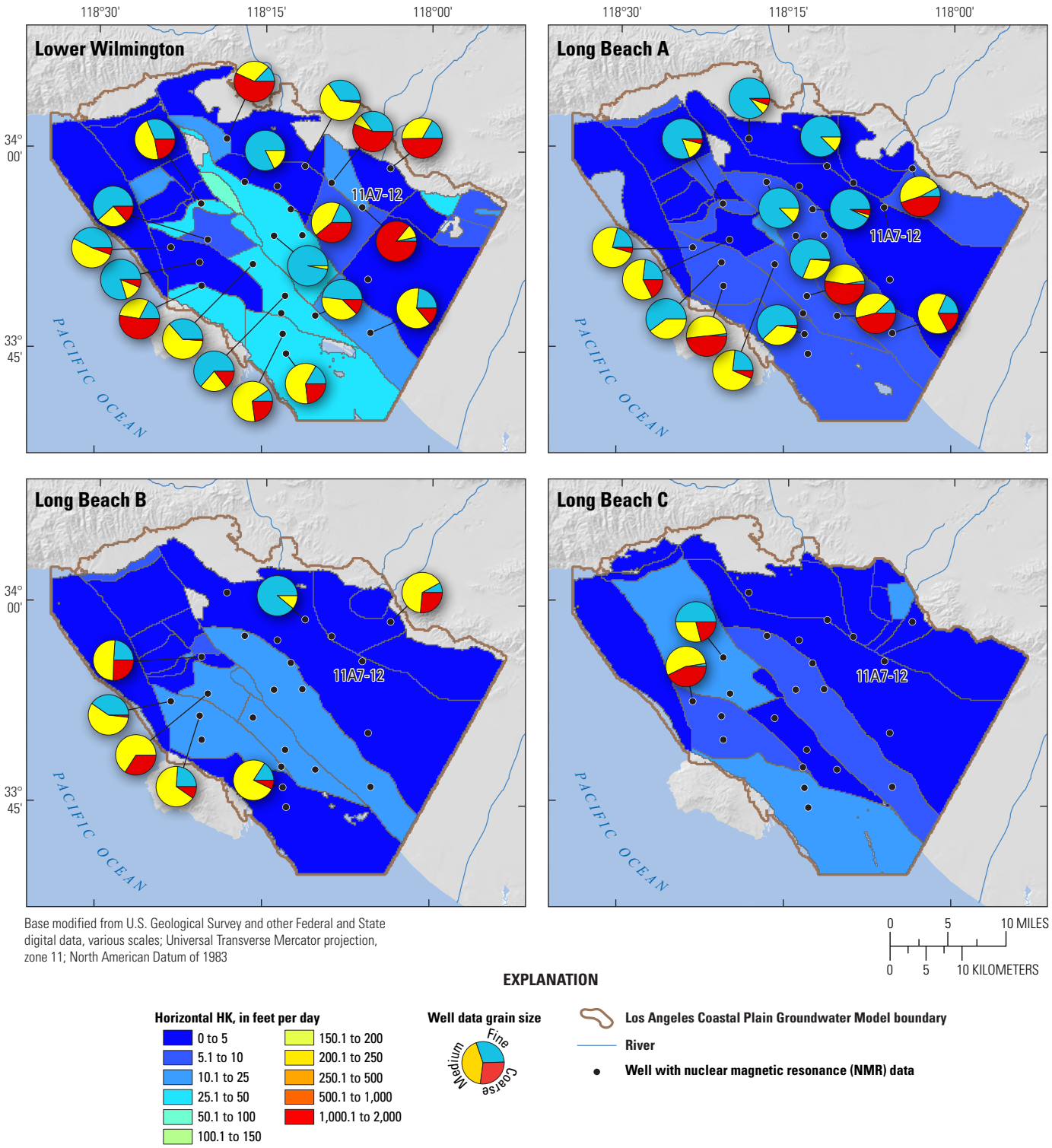


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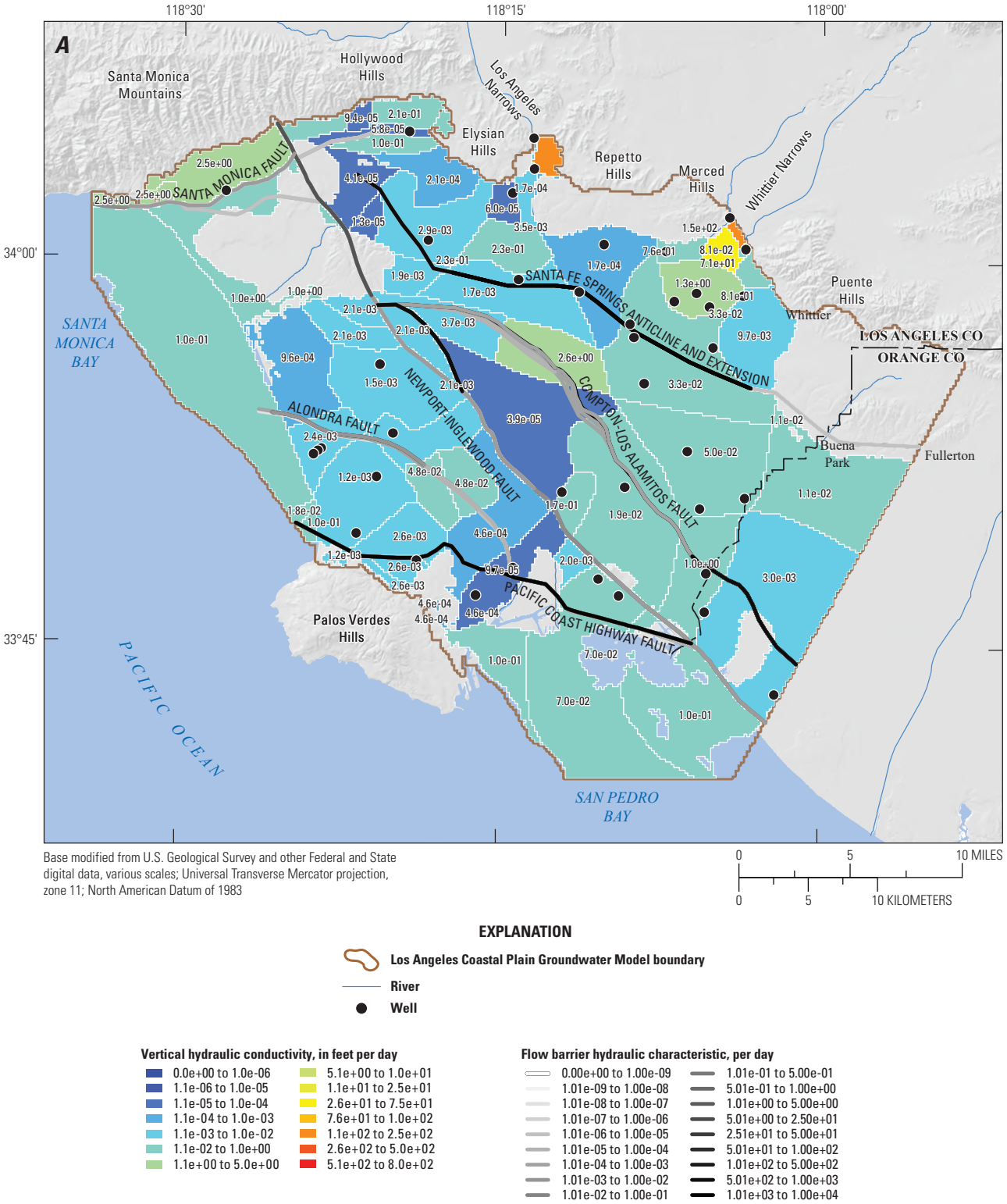


Figure D8. Calibrated vertical hydraulic conductivities (VK), specific yield (SY), and flow-barrier hydraulic characteristic values, for layers 2 to 13 of the Los Angeles Coastal Plain Groundwater-flow Model. The hydraulic characteristic is the horizontal-flow barrier's hydraulic conductivity divided by its width and has units of per day: *A*, VK Mesa; *B*, VK Pacific A; *C*, VK Pacific; *D*, VK Harbor; *E*, VK Bent Spring; *F*, VK Upper Wilmington A; *G*, VK Upper Wilmington B; *H*, VK Lower Wilmington; *I*, VK Long Beach A; *J*, VK Long Beach B; *K*, VK Long Beach C; *L*, SY Dominguez; *M*, SY Mesa; *N*, SY Pacific A; *O*, SY Pacific; *P*, SY Harbor; *Q*, SY Bent Spring; *R*, SY Upper Wilmington A; *S*, SY Upper Wilmington B; *T*, SY Lower Wilmington; *U*, SY Long Beach A; *V*, SY Long Beach B; and *W*, SY Long Beach C; Los Angeles and Orange Counties, California. (Abbreviation: PCH, Pacific Coast Highway).\

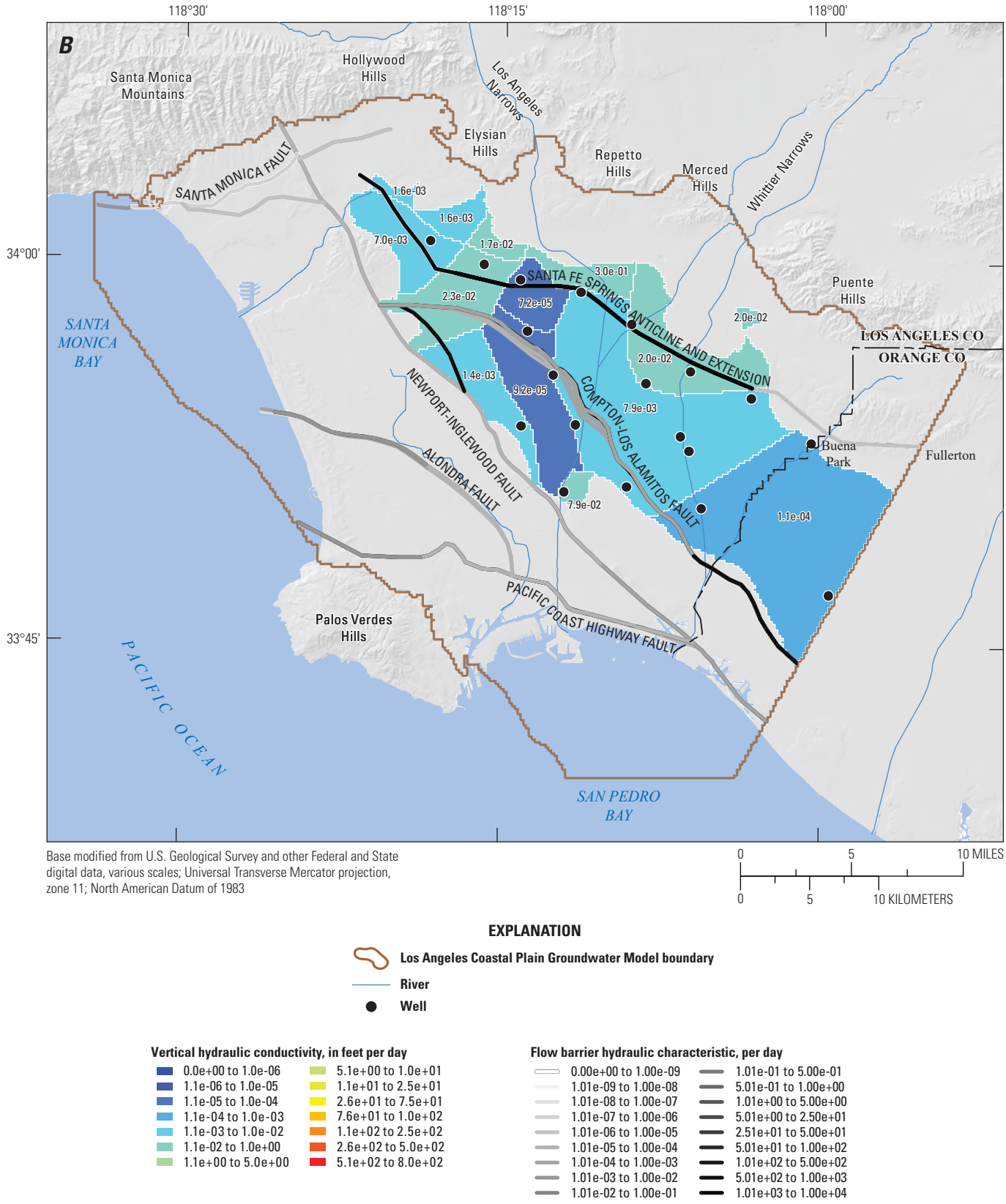
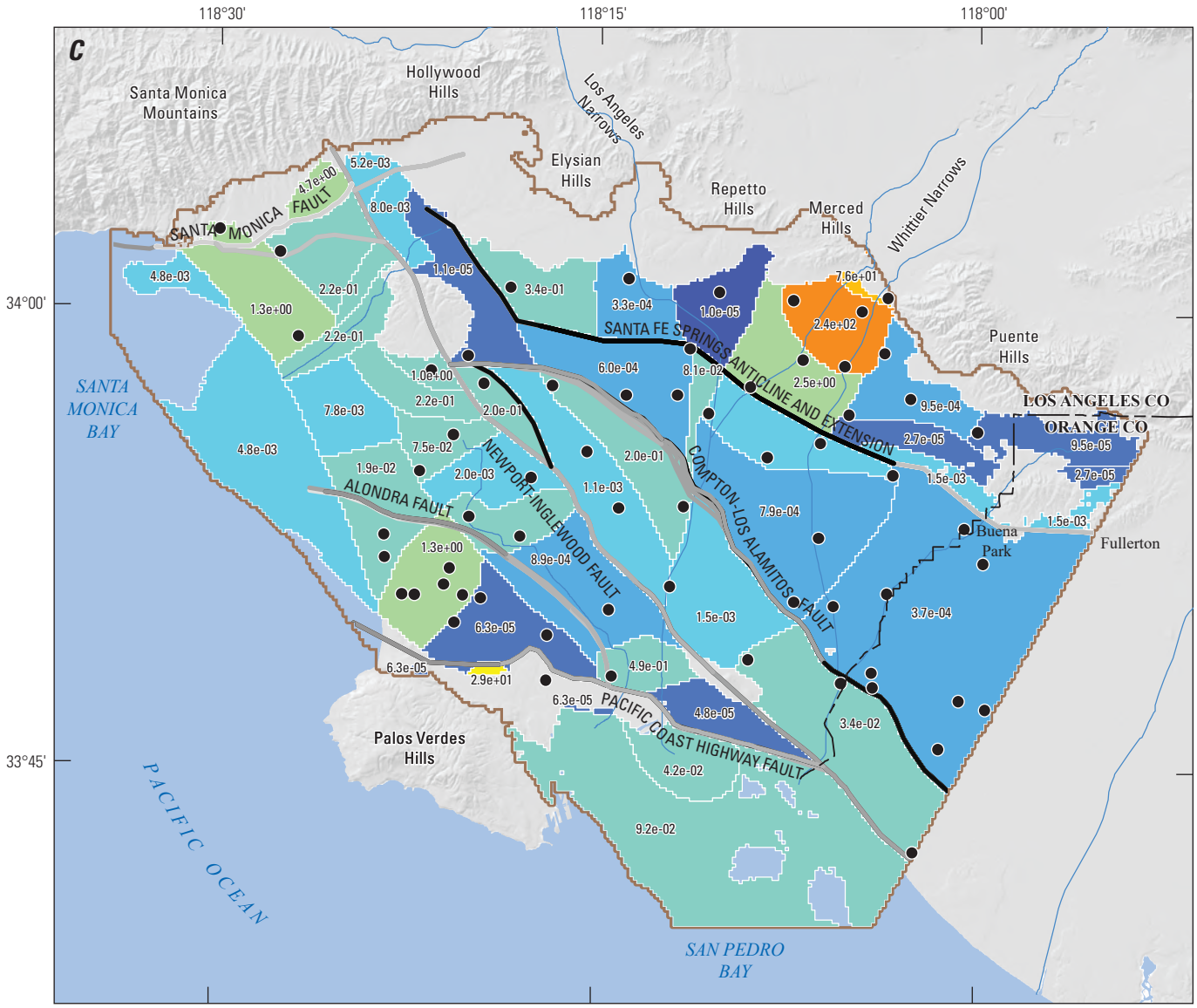


Figure D8.—Continued



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

EXPLANATION

- Los Angeles Coastal Plain Groundwater Model boundary
- River
- Well

Vertical hydraulic conductivity, in feet per day

- 0.0e+00 to 1.0e-06
- 1.1e-06 to 1.0e-05
- 1.1e-05 to 1.0e-04
- 1.1e-04 to 1.0e-03
- 1.1e-03 to 1.0e-02
- 1.1e-02 to 1.0e+00
- 1.1e+00 to 5.0e+00
- 5.1e+00 to 1.0e+01
- 1.1e+01 to 2.5e+01
- 2.6e+01 to 7.5e+01
- 7.6e+01 to 1.0e+02
- 1.1e+02 to 2.5e+02
- 2.6e+02 to 5.0e+02
- 5.1e+02 to 8.0e+02

Flow barrier hydraulic characteristic, per day

- 0.00e+00 to 1.00e-09
- 1.01e-09 to 1.00e-08
- 1.01e-08 to 1.00e-07
- 1.01e-07 to 1.00e-06
- 1.01e-06 to 1.00e-05
- 1.01e-05 to 1.00e-04
- 1.01e-04 to 1.00e-03
- 1.01e-03 to 1.00e-02
- 1.01e-02 to 1.00e-01
- 1.01e-01 to 5.00e-01
- 5.01e-01 to 1.00e+00
- 1.01e+00 to 5.00e+00
- 5.01e+00 to 2.50e+01
- 2.51e+01 to 5.00e+01
- 5.01e+01 to 1.00e+02
- 1.01e+02 to 5.00e+02
- 5.01e+02 to 1.00e+03
- 1.01e+03 to 1.00e+04

Figure D8.—Continued

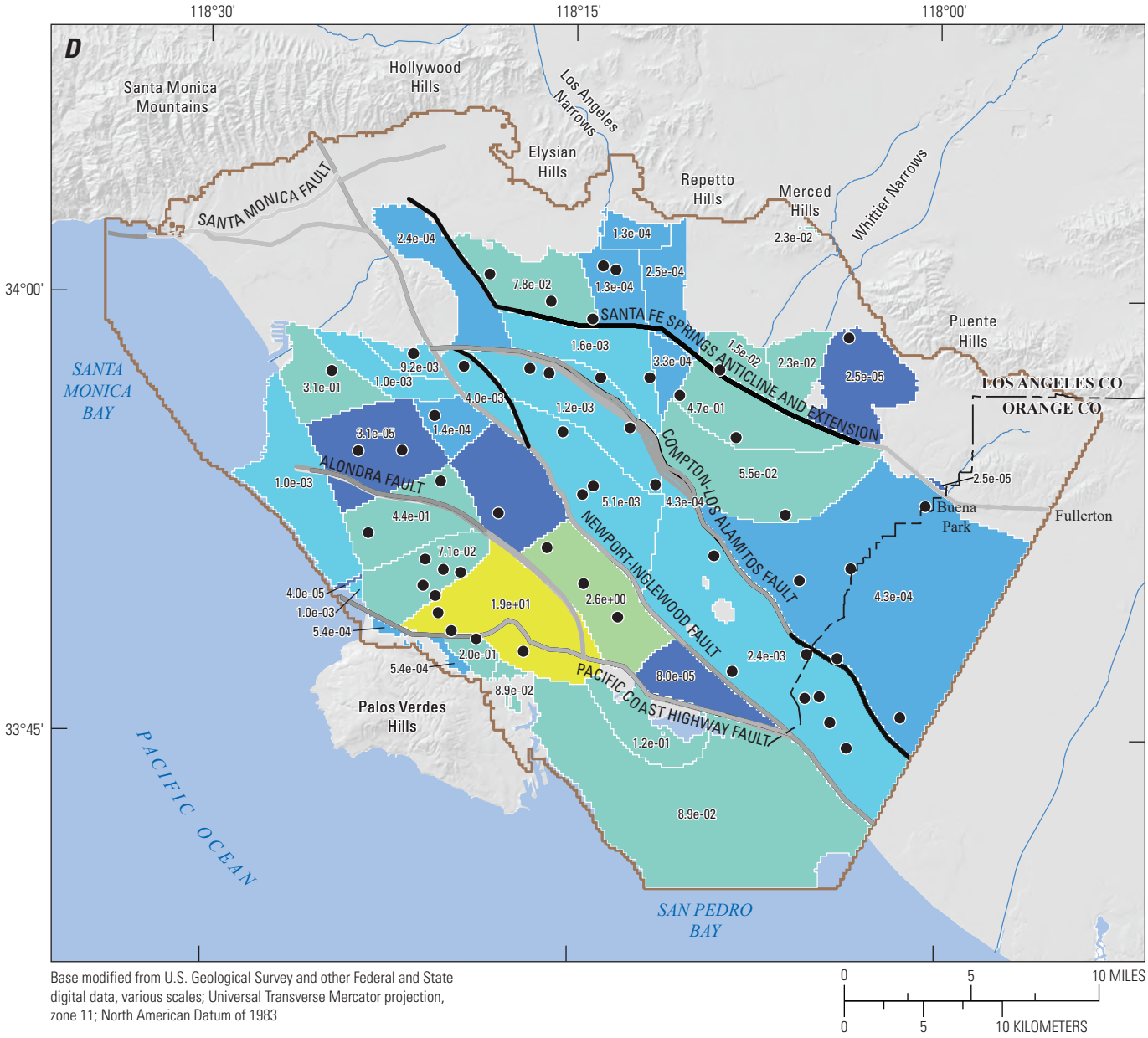


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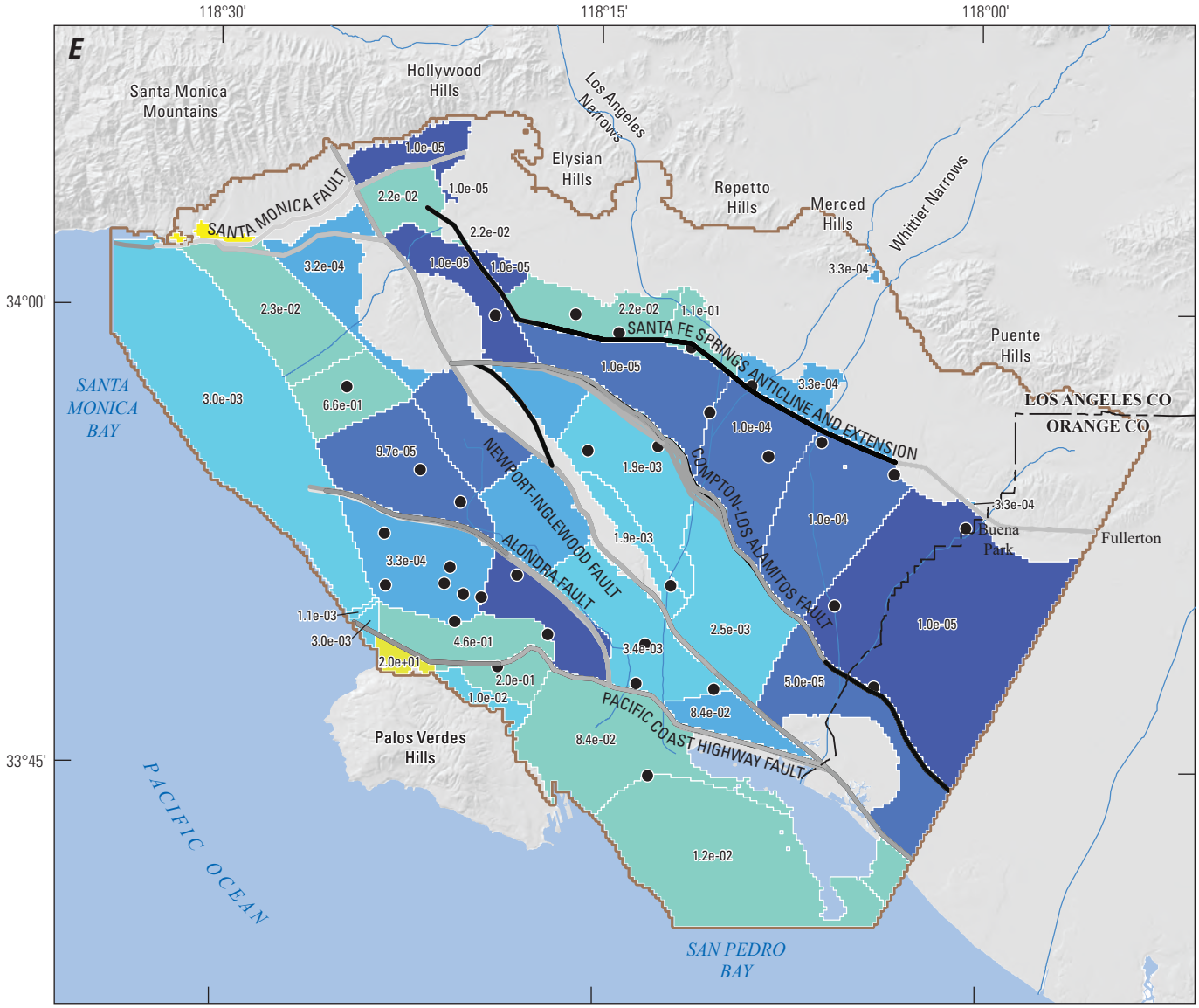


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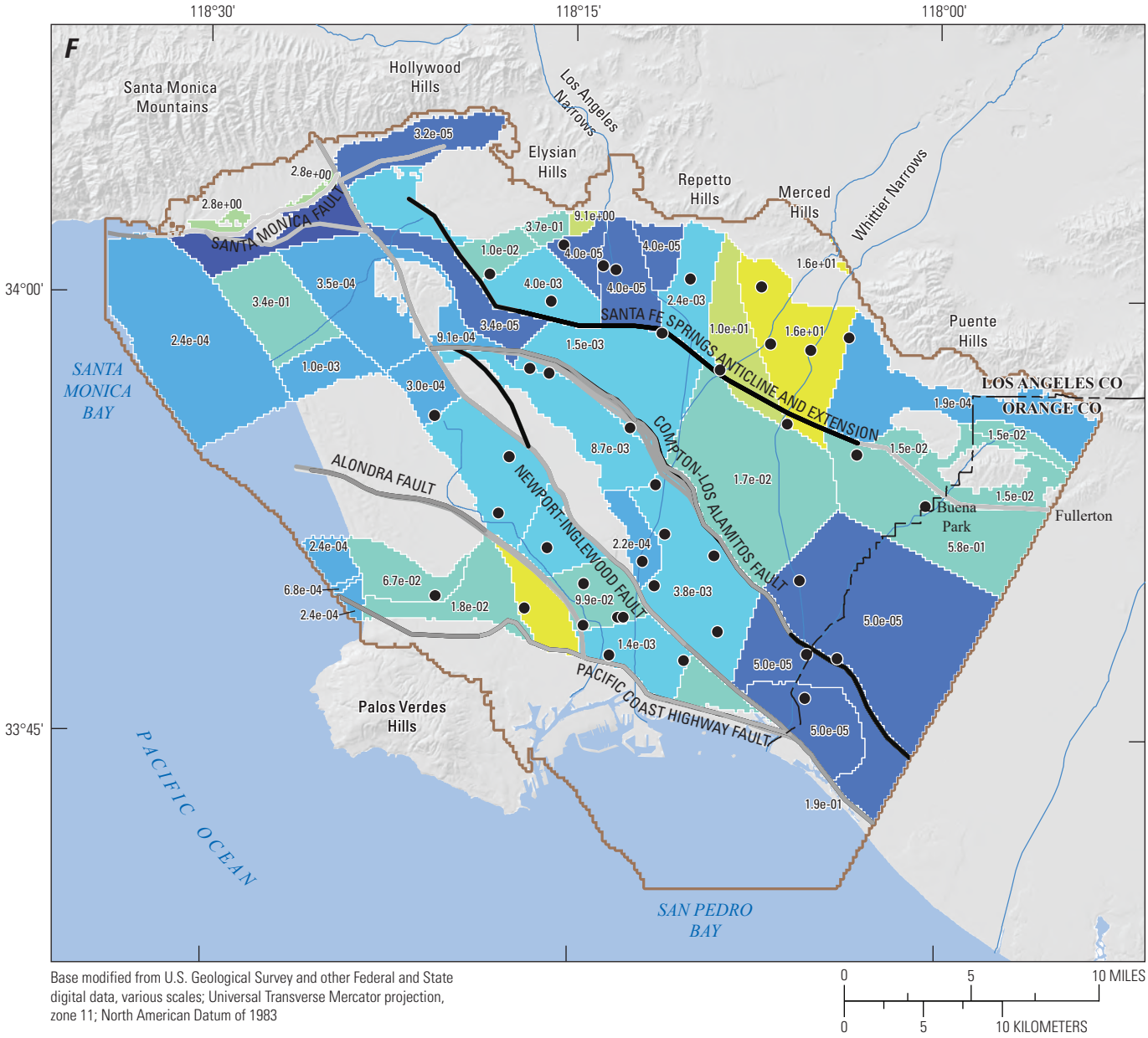


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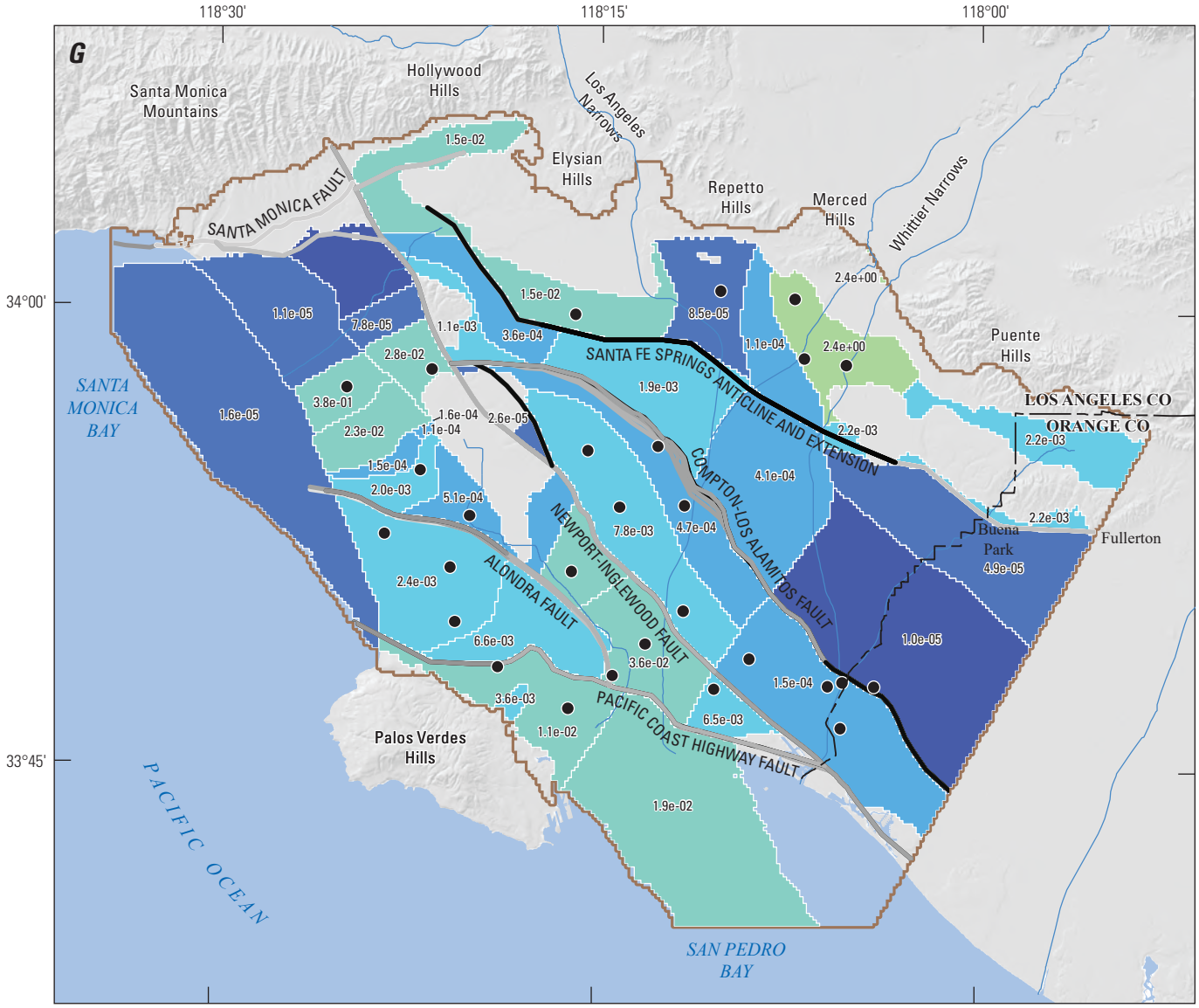
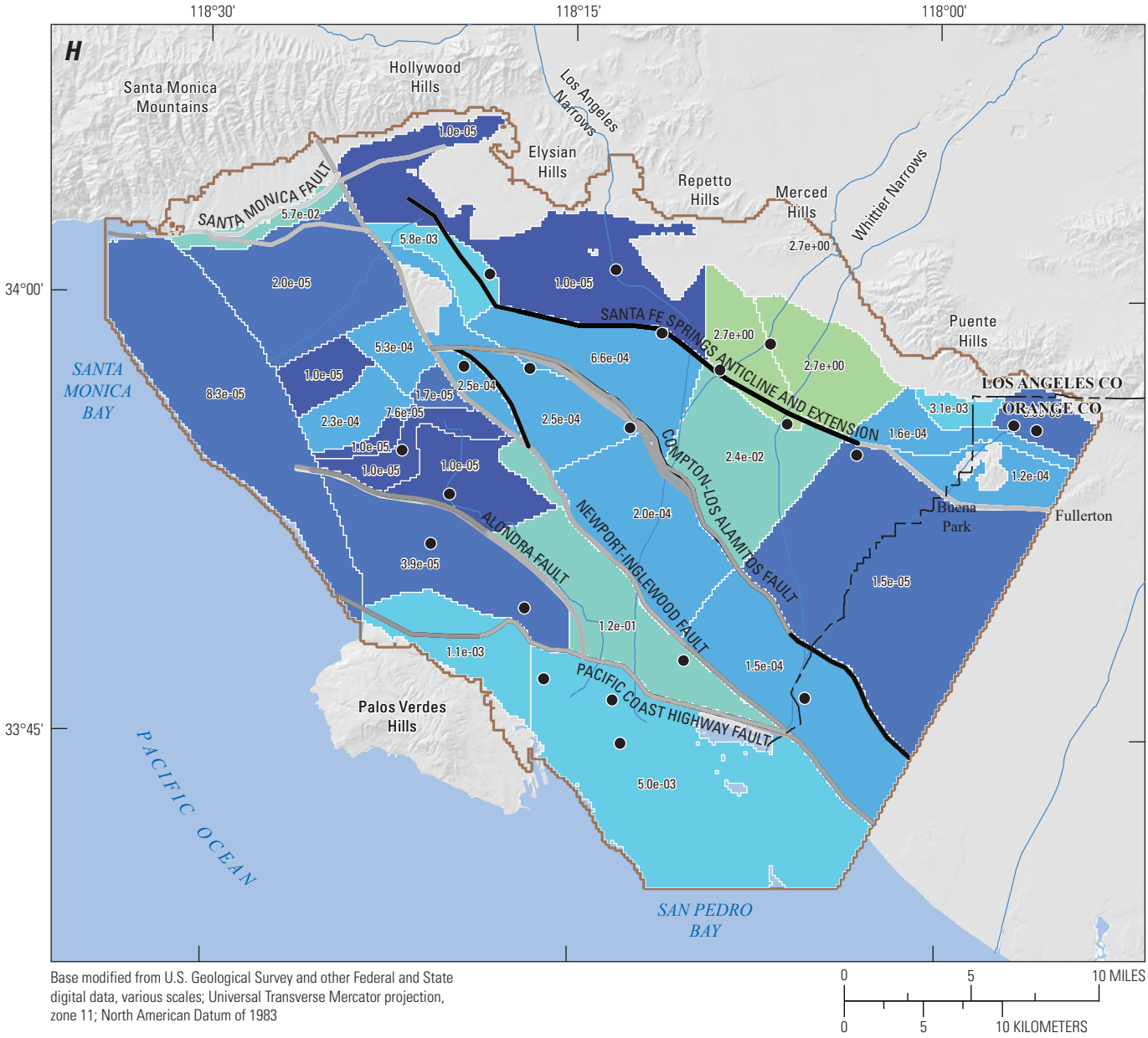


Figure D8.—Continued



EXPLANATION

- Los Angeles Coastal Plain Groundwater Model boundary
- River
- Well

Vertical hydraulic conductivity, in feet per day

- 0.0e+00 to 1.0e-06
- 1.1e-06 to 1.0e-05
- 1.1e-05 to 1.0e-04
- 1.1e-04 to 1.0e-03
- 1.1e-03 to 1.0e-02
- 1.1e-02 to 1.0e+00
- 1.1e+00 to 5.0e+00
- 5.1e+00 to 1.0e+01
- 1.1e+01 to 2.5e+01
- 2.6e+01 to 7.5e+01
- 7.6e+01 to 1.0e+02
- 1.1e+02 to 2.5e+02
- 2.6e+02 to 5.0e+02
- 5.1e+02 to 8.0e+02

Flow barrier hydraulic characteristic, per day

- 0.00e+00 to 1.00e-09
- 1.01e-09 to 1.00e-08
- 1.01e-08 to 1.00e-07
- 1.01e-07 to 1.00e-06
- 1.01e-06 to 1.00e-05
- 1.01e-05 to 1.00e-04
- 1.01e-04 to 1.00e-03
- 1.01e-03 to 1.00e-02
- 1.01e-02 to 1.00e-01
- 1.01e-01 to 5.00e-01
- 5.01e-01 to 1.00e+00
- 1.01e+00 to 5.00e+00
- 5.01e+00 to 2.50e+01
- 2.51e+01 to 5.00e+01
- 5.01e+01 to 1.00e+02
- 1.01e+02 to 5.00e+02
- 5.01e+02 to 1.00e+03
- 1.01e+03 to 1.00e+04

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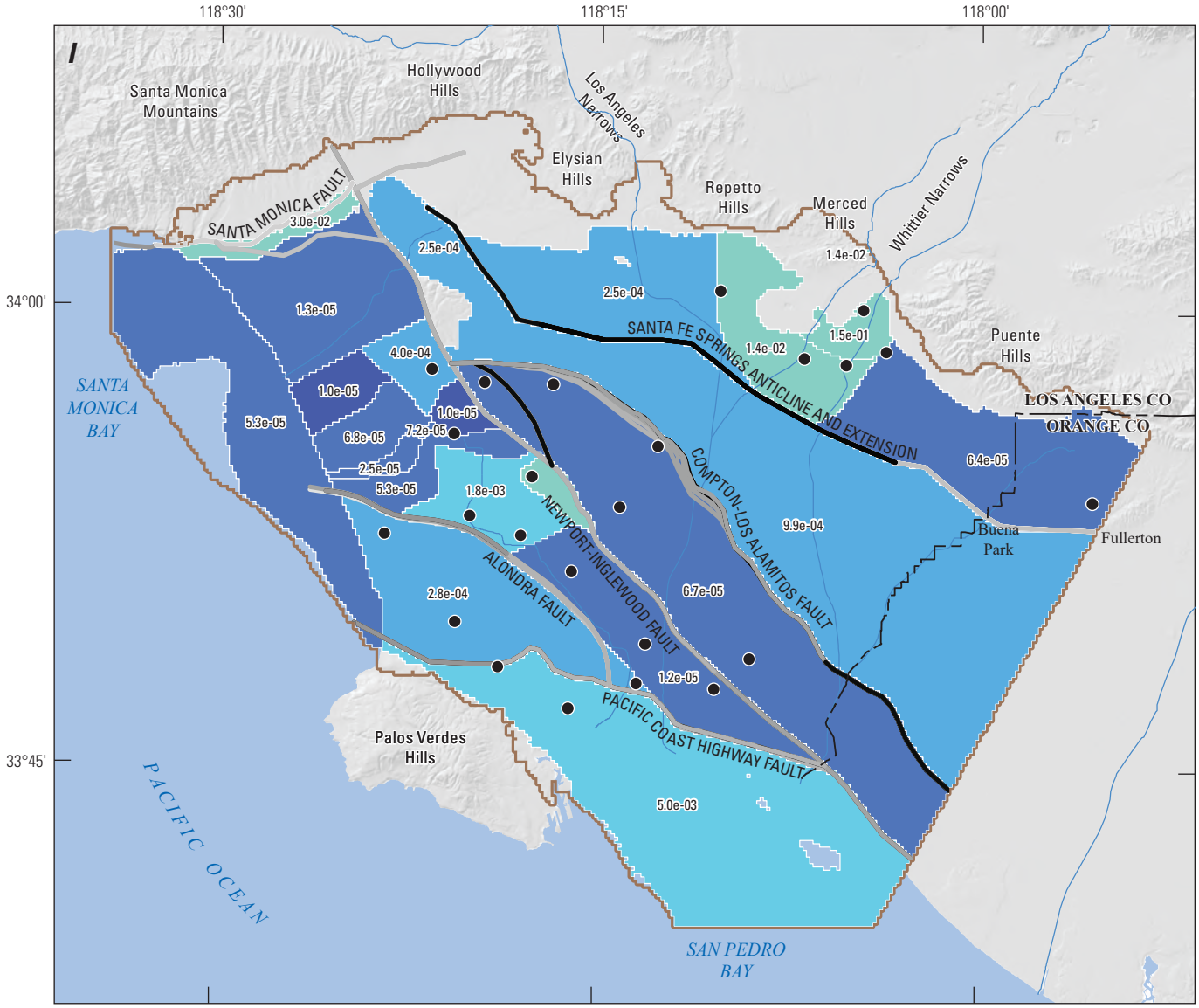


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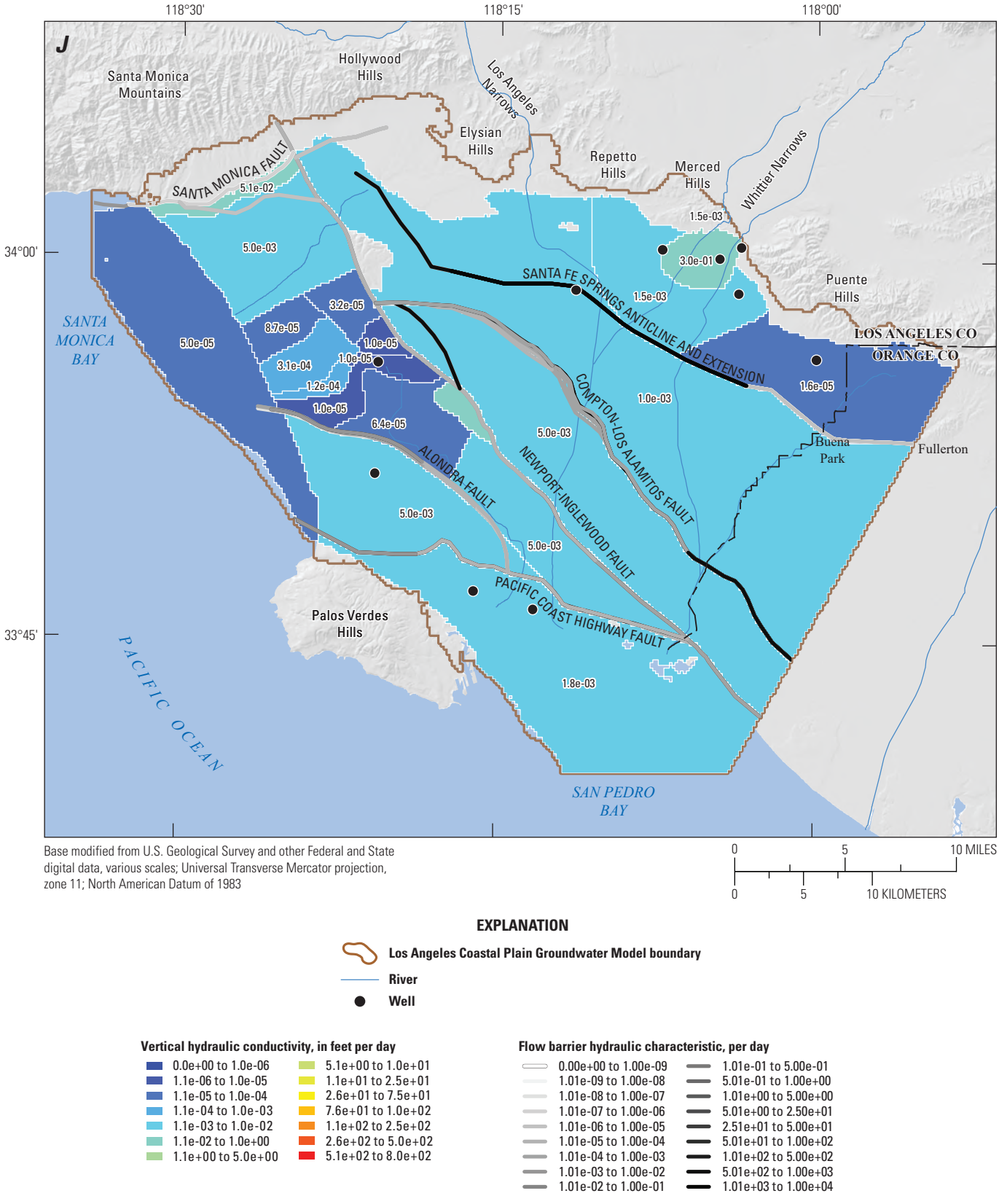


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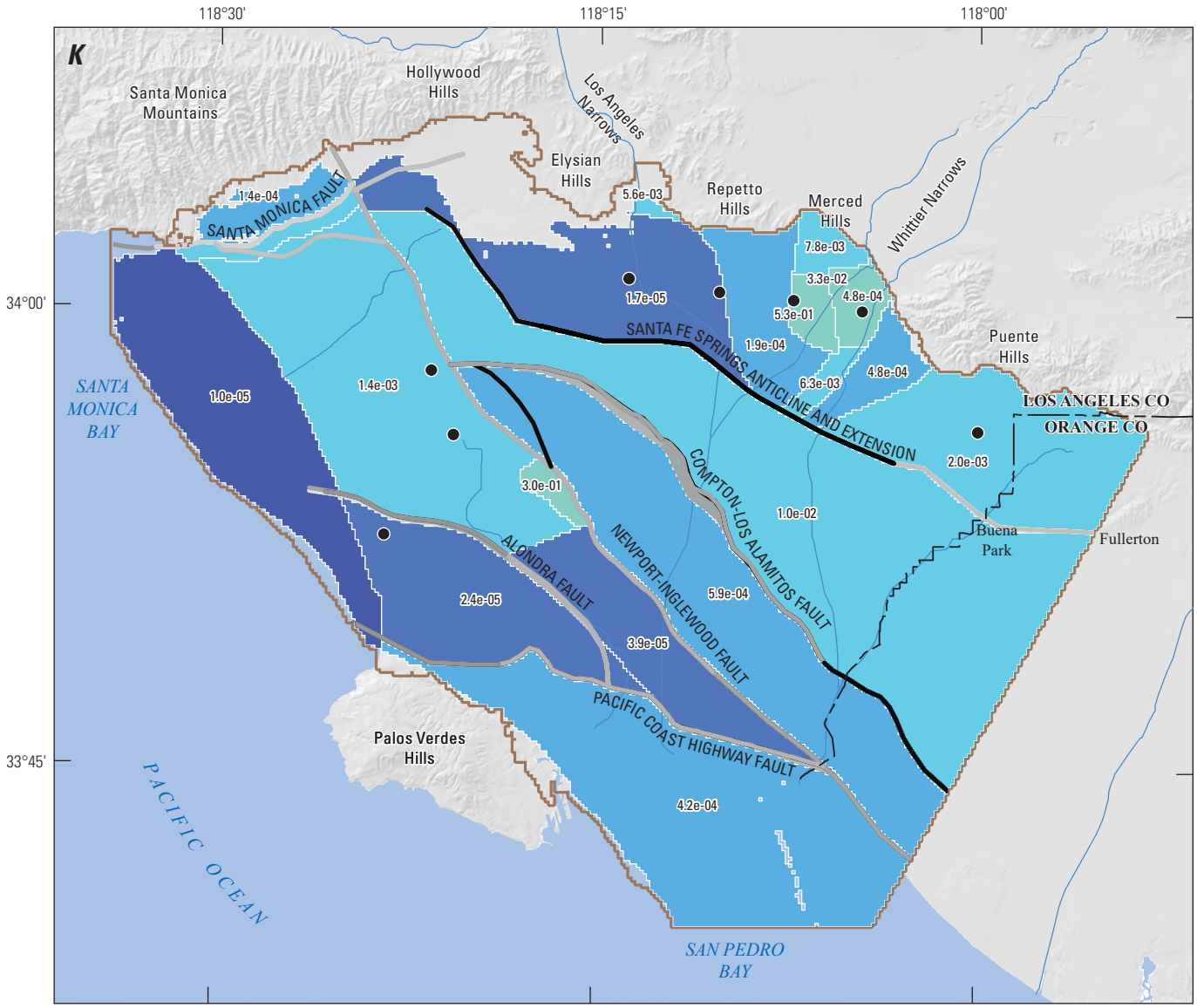


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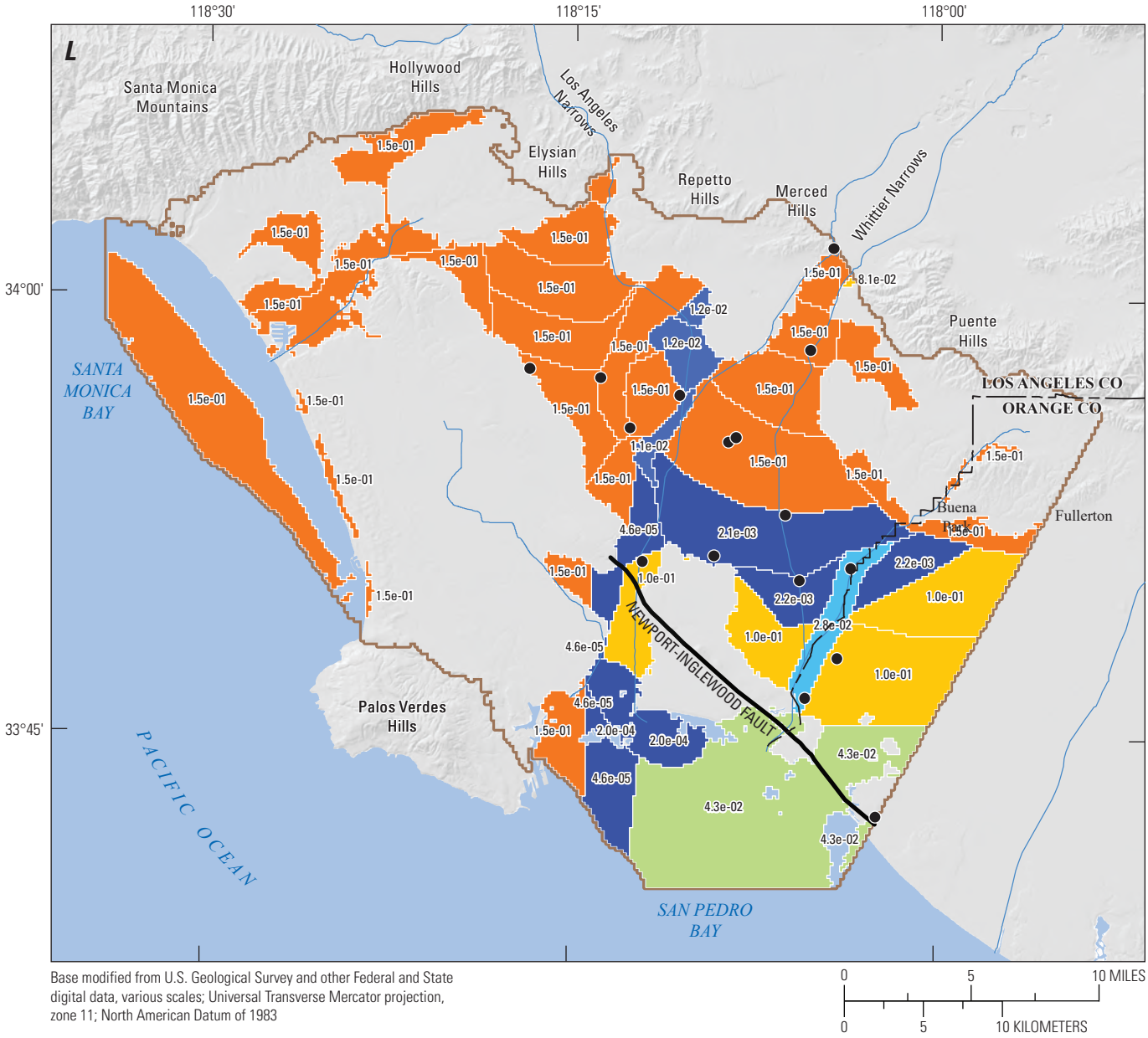
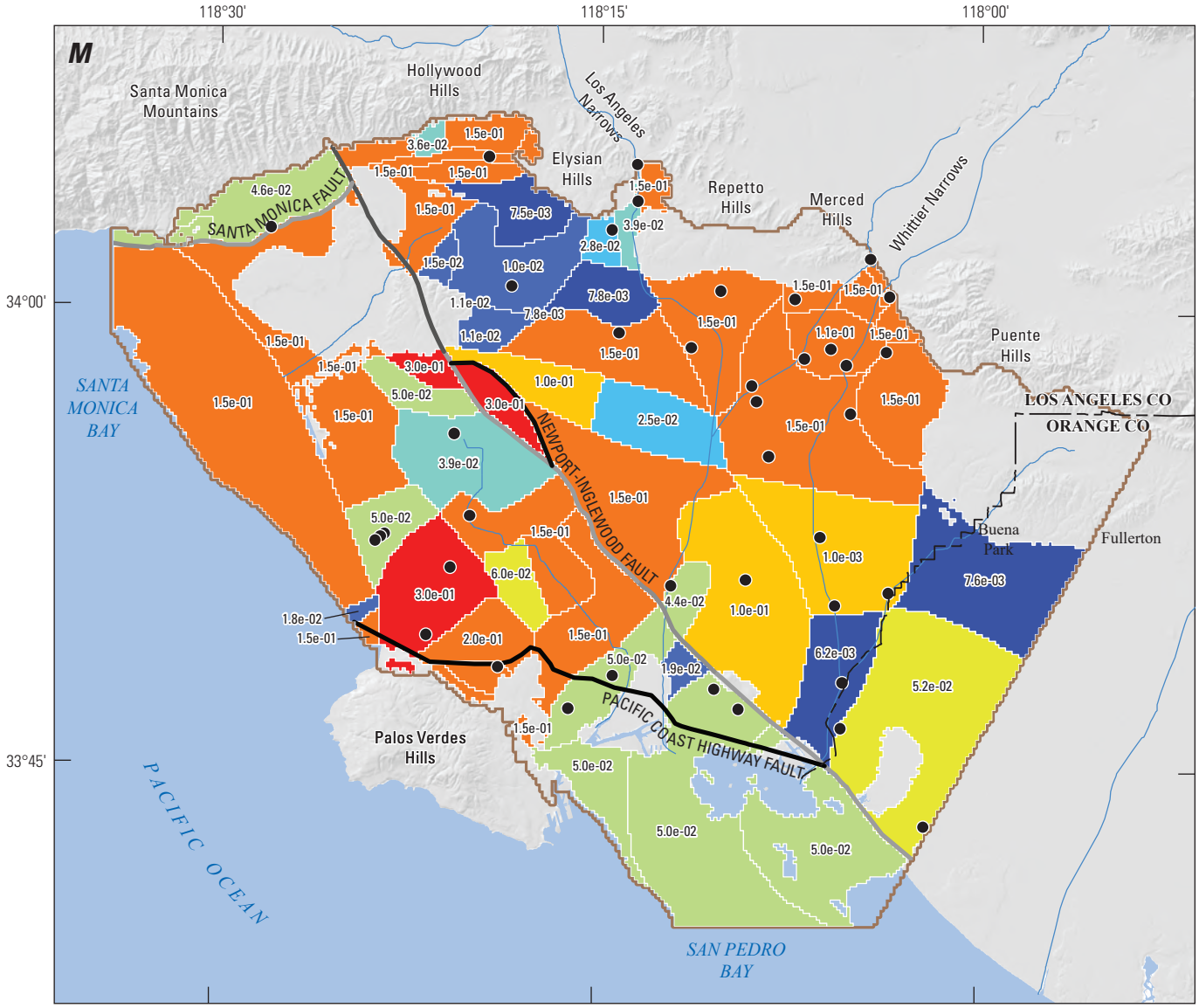


Figure D8.—Continued



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

EXPLANATION

- Los Angeles Coastal Plain Groundwater Model boundary
- River
- Well

Specific yield

- 0.0e+00 to 1.0e-02
- 1.1e-02 to 2.0e-02
- 2.1e-02 to 3.0e-02
- 3.1e-02 to 4.0e-02
- 4.1e-02 to 5.0e-02
- 5.1e-02 to 8.0e-02
- 8.1e-02 to 1.0e-01
- 1.1e-01 to 2.0e-01
- 2.1e-01 to 3.0e-01

Flow barrier hydraulic characteristic, per day

- 0.00e+00 to 1.00e-09
- 1.01e-09 to 1.00e-08
- 1.01e-08 to 1.00e-07
- 1.01e-07 to 1.00e-06
- 1.01e-06 to 1.00e-05
- 1.01e-05 to 1.00e-04
- 1.01e-04 to 1.00e-03
- 1.01e-03 to 1.00e-02
- 1.01e-02 to 1.00e-01
- 1.01e-01 to 5.00e-01
- 5.01e-01 to 1.00e+00
- 1.01e+00 to 5.00e+00
- 5.01e+00 to 2.50e+01
- 2.51e+01 to 5.00e+01
- 5.01e+01 to 1.00e+02
- 1.01e+02 to 5.00e+02
- 5.01e+02 to 1.00e+03
- 1.01e+03 to 1.00e+04

Figure D8.—Continued

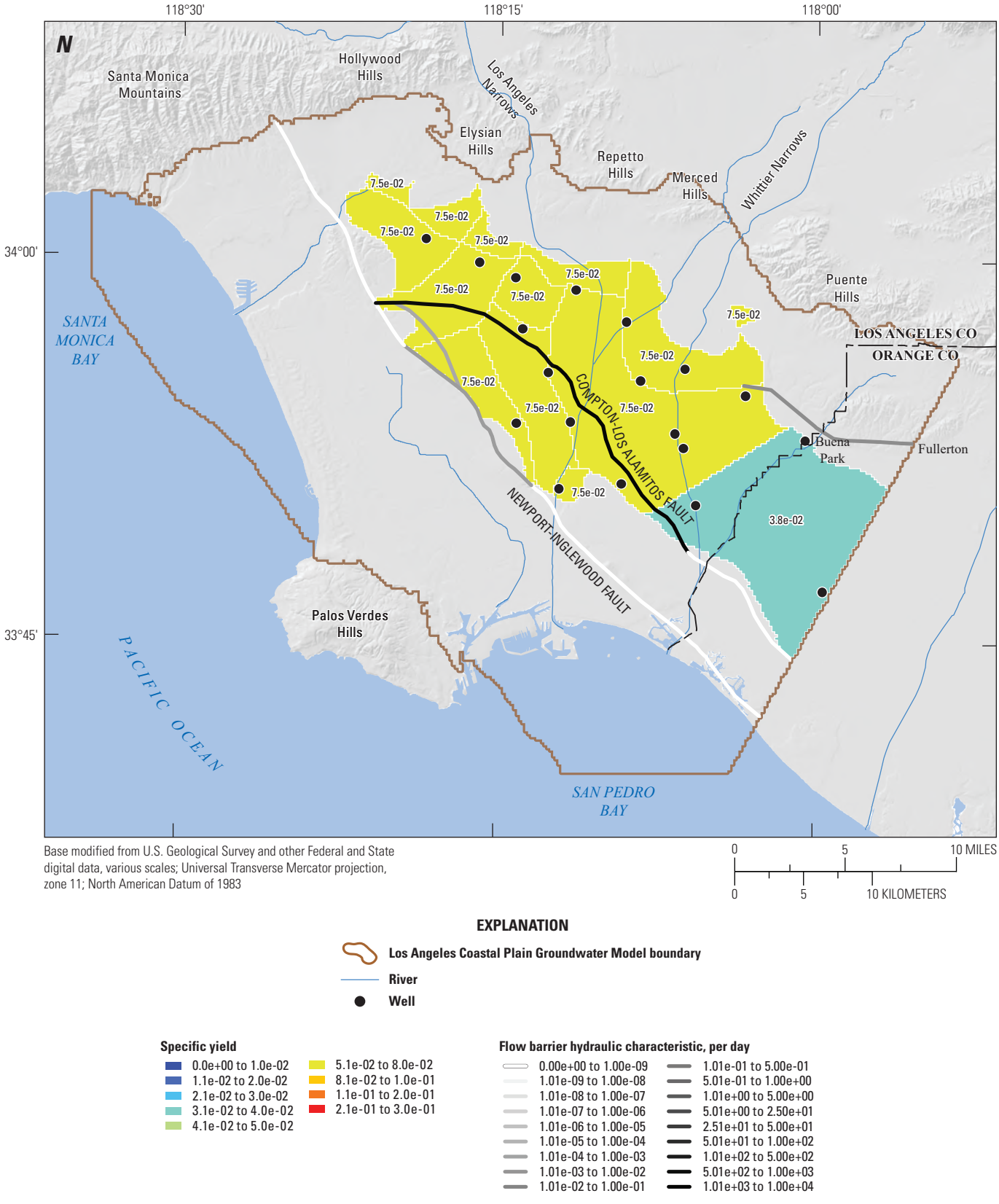


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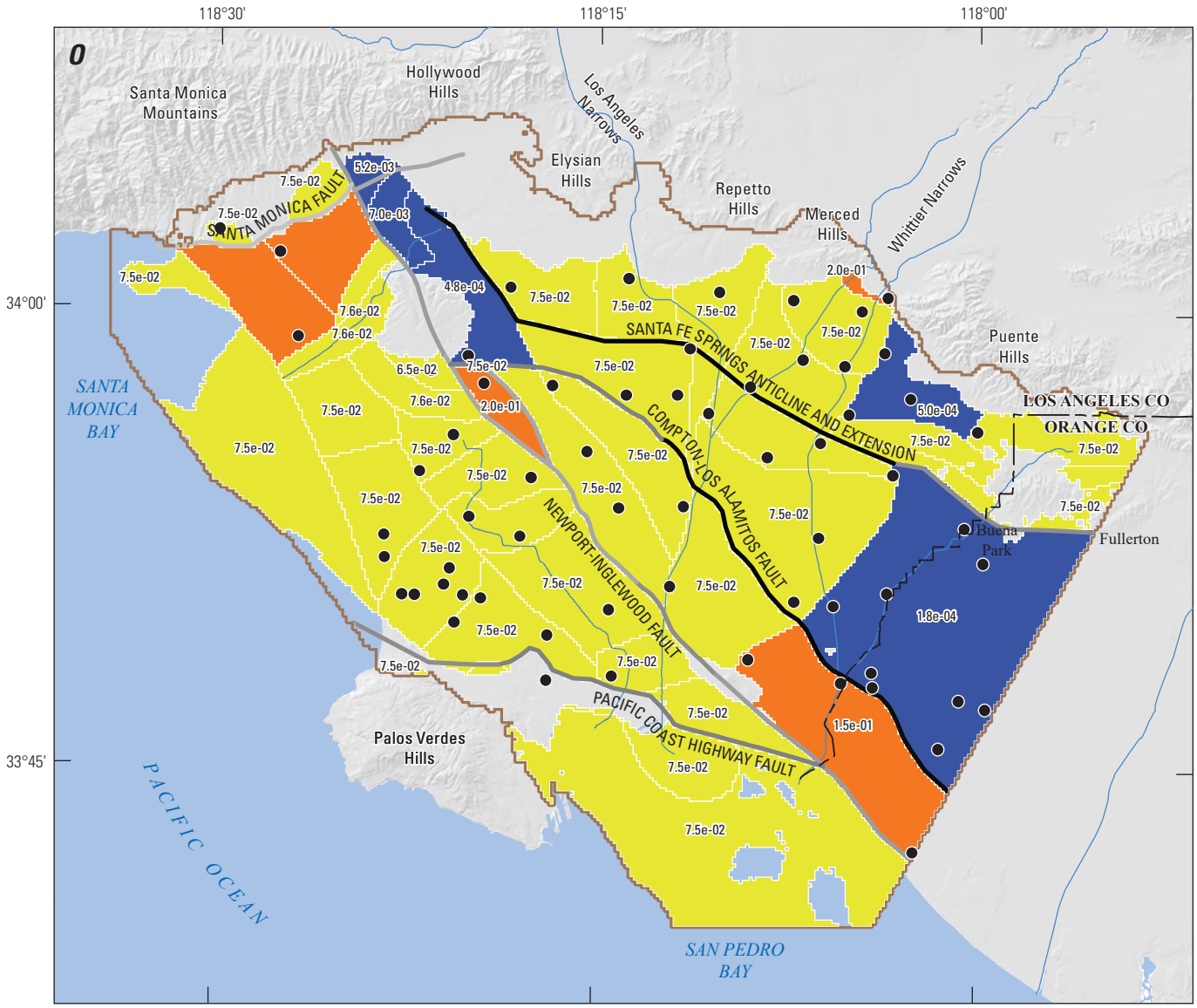
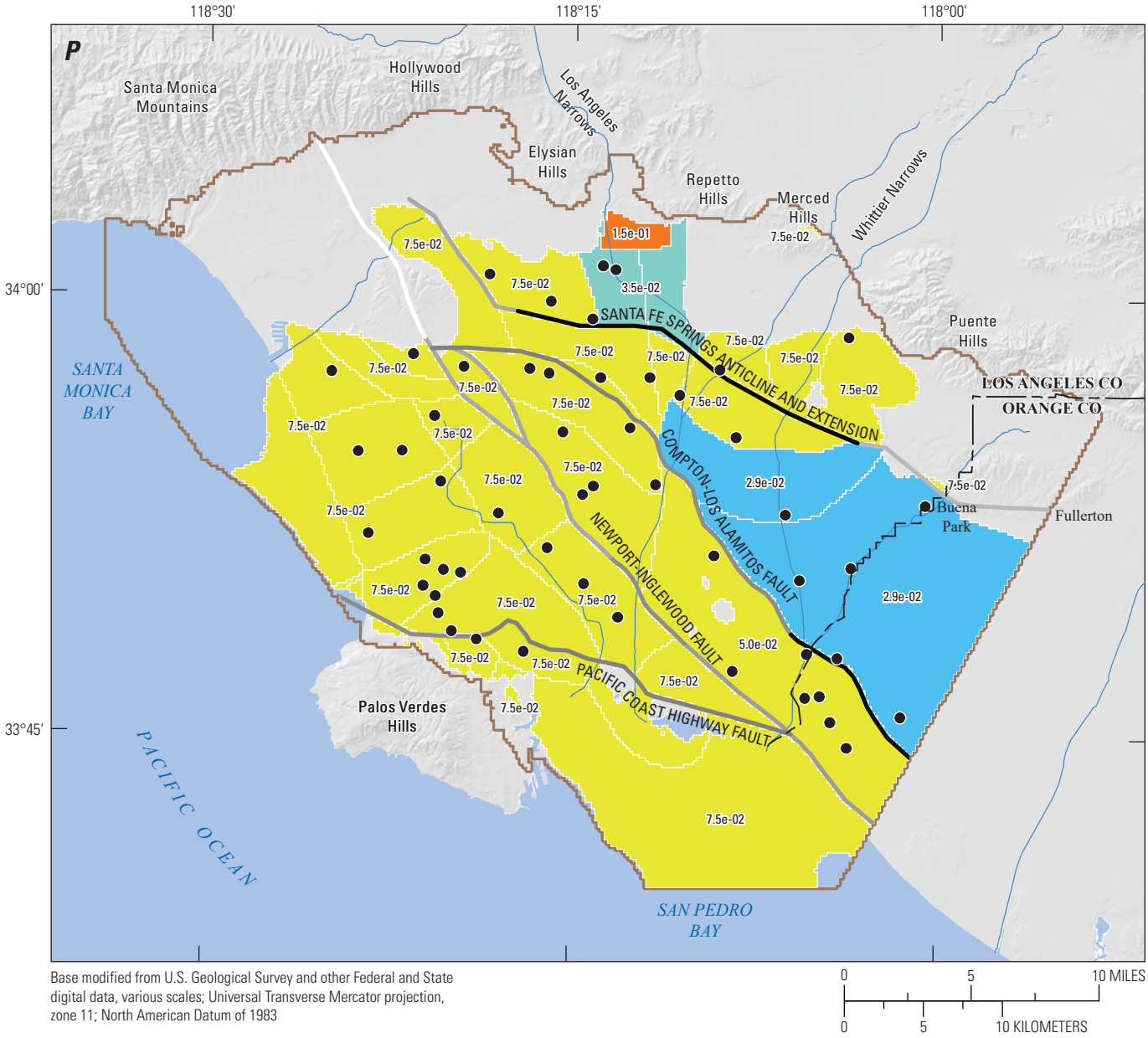


Figure D8.—Continued



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

0 5 10 MILES
0 5 10 KILOMETERS

EXPLANATION

- Los Angeles Coastal Plain Groundwater Model boundary
- River
- Well

Specific yield

- 0.0e+00 to 1.0e-02
- 1.1e-02 to 2.0e-02
- 2.1e-02 to 3.0e-02
- 3.1e-02 to 4.0e-02
- 4.1e-02 to 5.0e-02
- 5.1e-02 to 8.0e-02
- 8.1e-02 to 1.0e-01
- 1.1e-01 to 2.0e-01
- 2.1e-01 to 3.0e-01

Flow barrier hydraulic characteristic, per day

- 0.00e+00 to 1.00e-09
- 1.01e-09 to 1.00e-08
- 1.01e-08 to 1.00e-07
- 1.01e-07 to 1.00e-06
- 1.01e-06 to 1.00e-05
- 1.01e-05 to 1.00e-04
- 1.01e-04 to 1.00e-03
- 1.01e-03 to 1.00e-02
- 1.01e-02 to 1.00e-01
- 1.01e-01 to 5.00e-01
- 5.01e-01 to 1.00e+00
- 1.01e+00 to 5.00e+00
- 5.01e+00 to 2.50e+01
- 2.51e+01 to 5.00e+01
- 5.01e+01 to 1.00e+02
- 1.01e+02 to 5.00e+02
- 5.01e+02 to 1.00e+03
- 1.01e+03 to 1.00e+04

Figure D8.—Continued

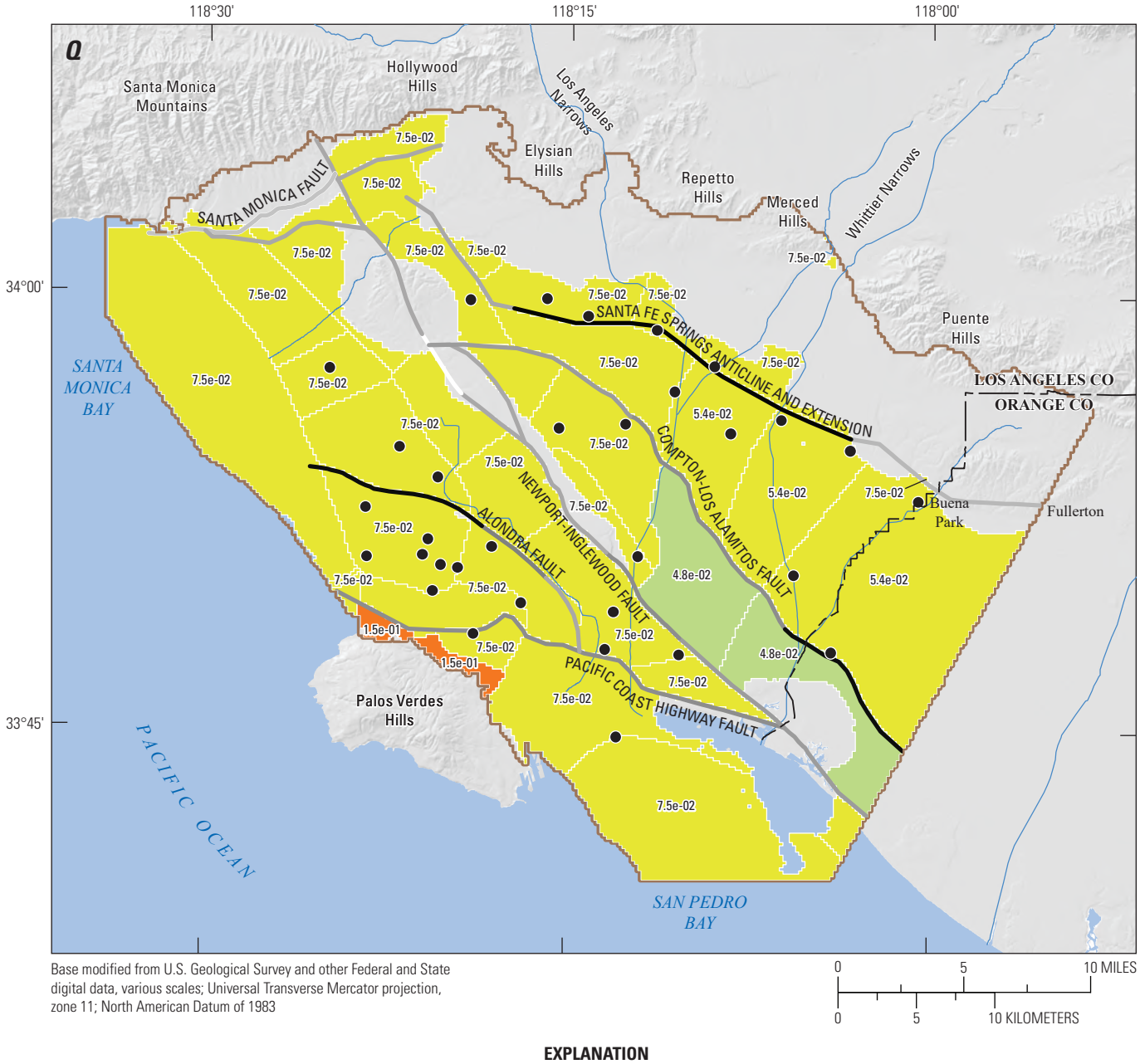


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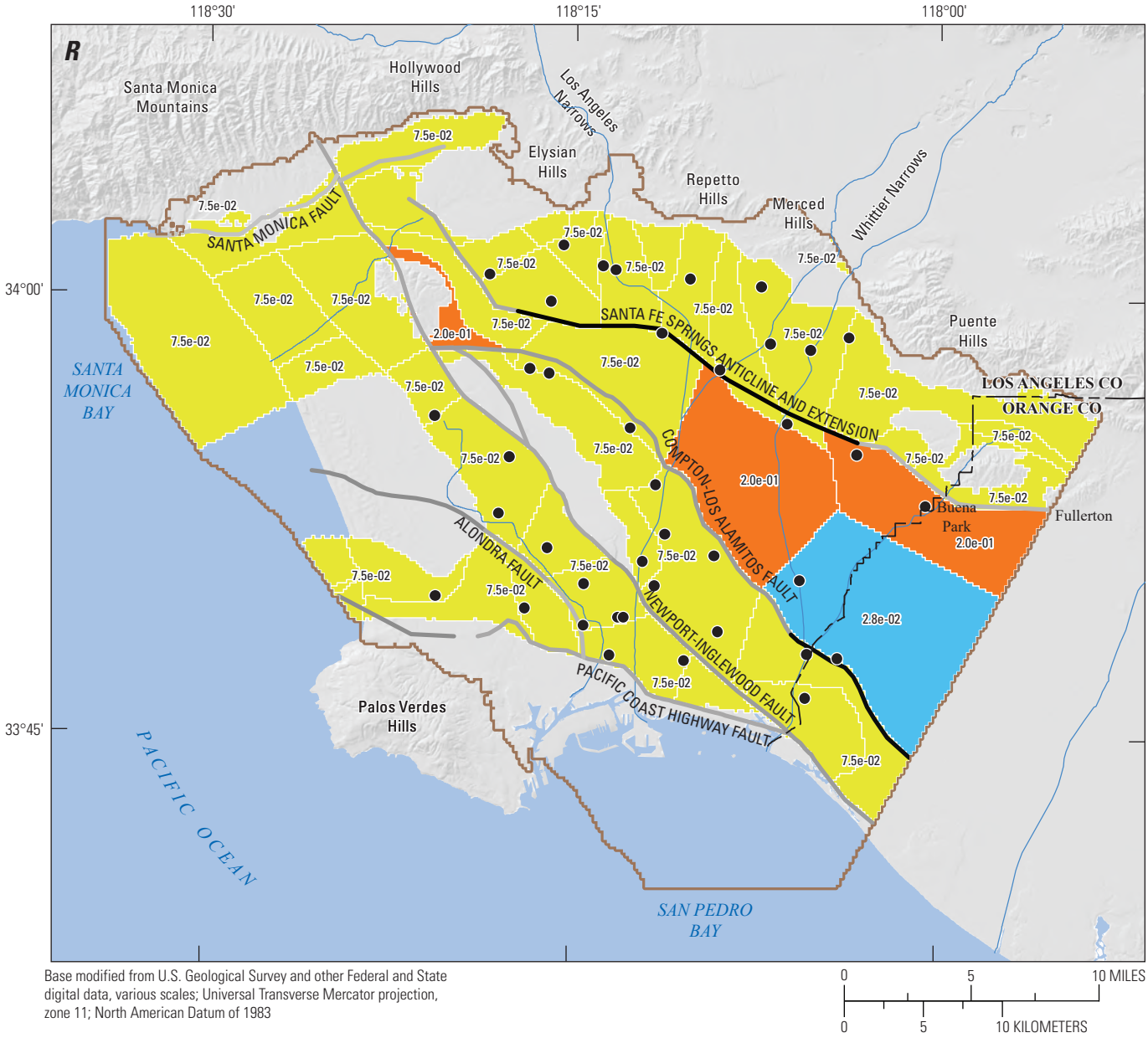


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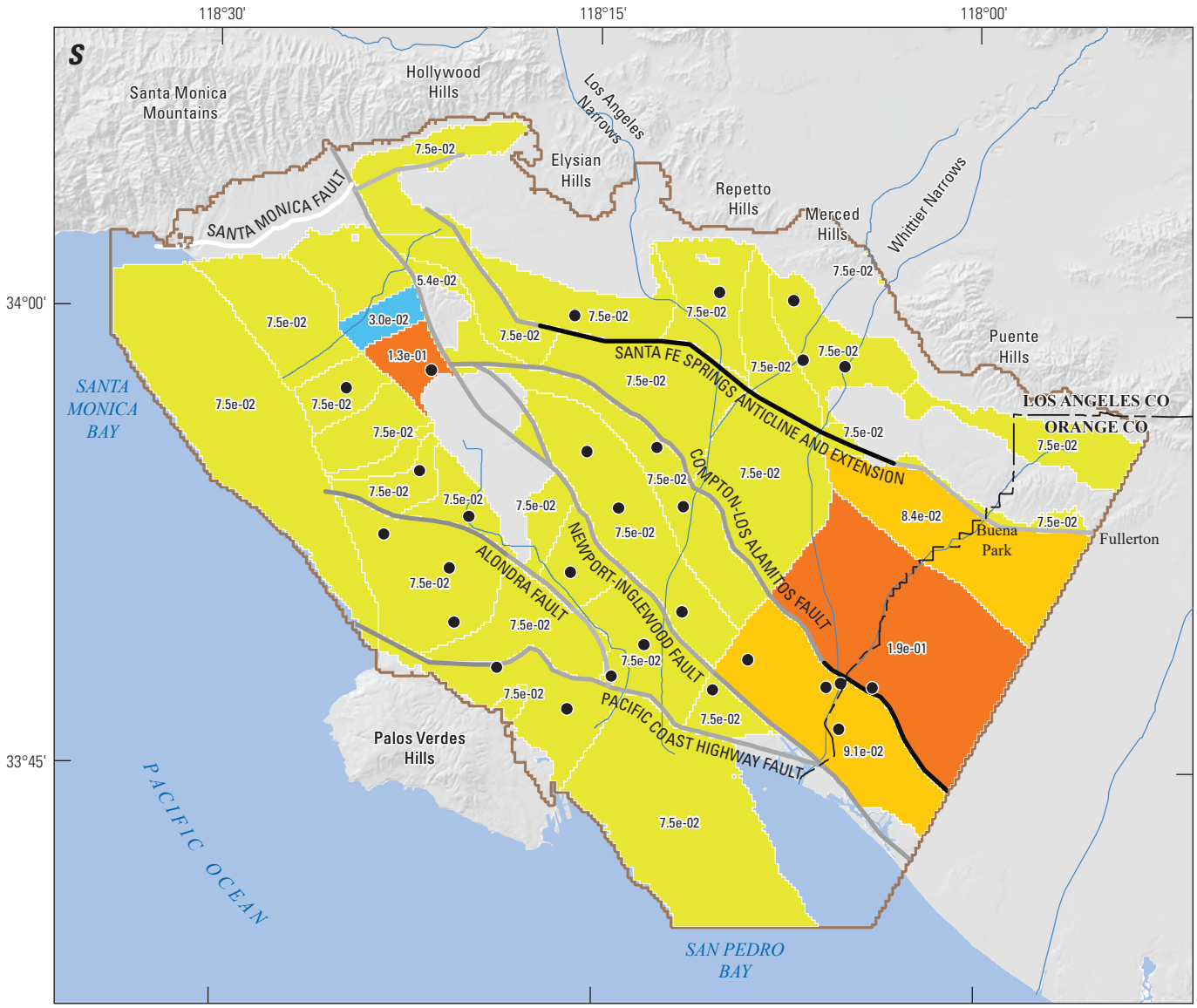


Figure D8.—Continued

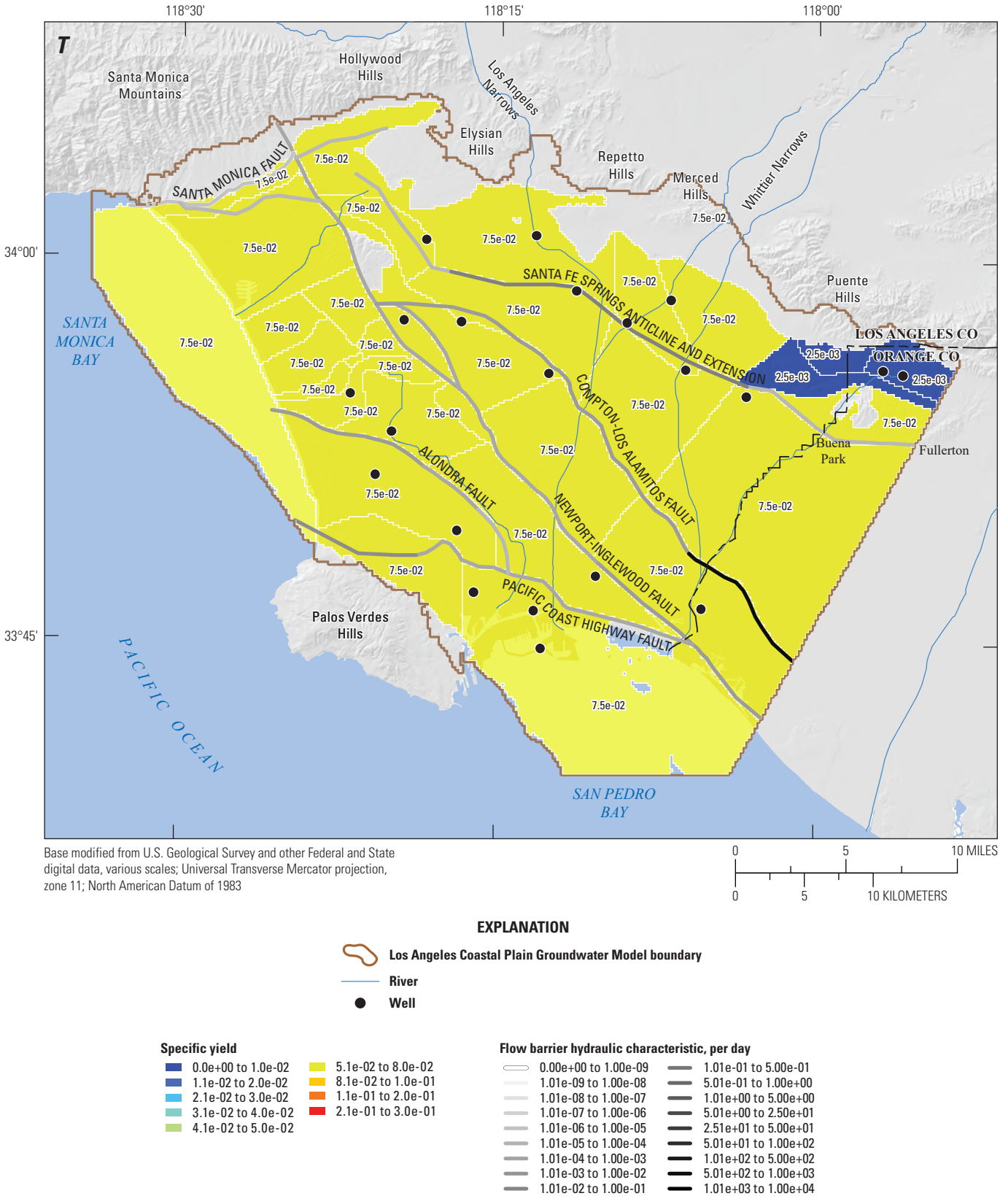


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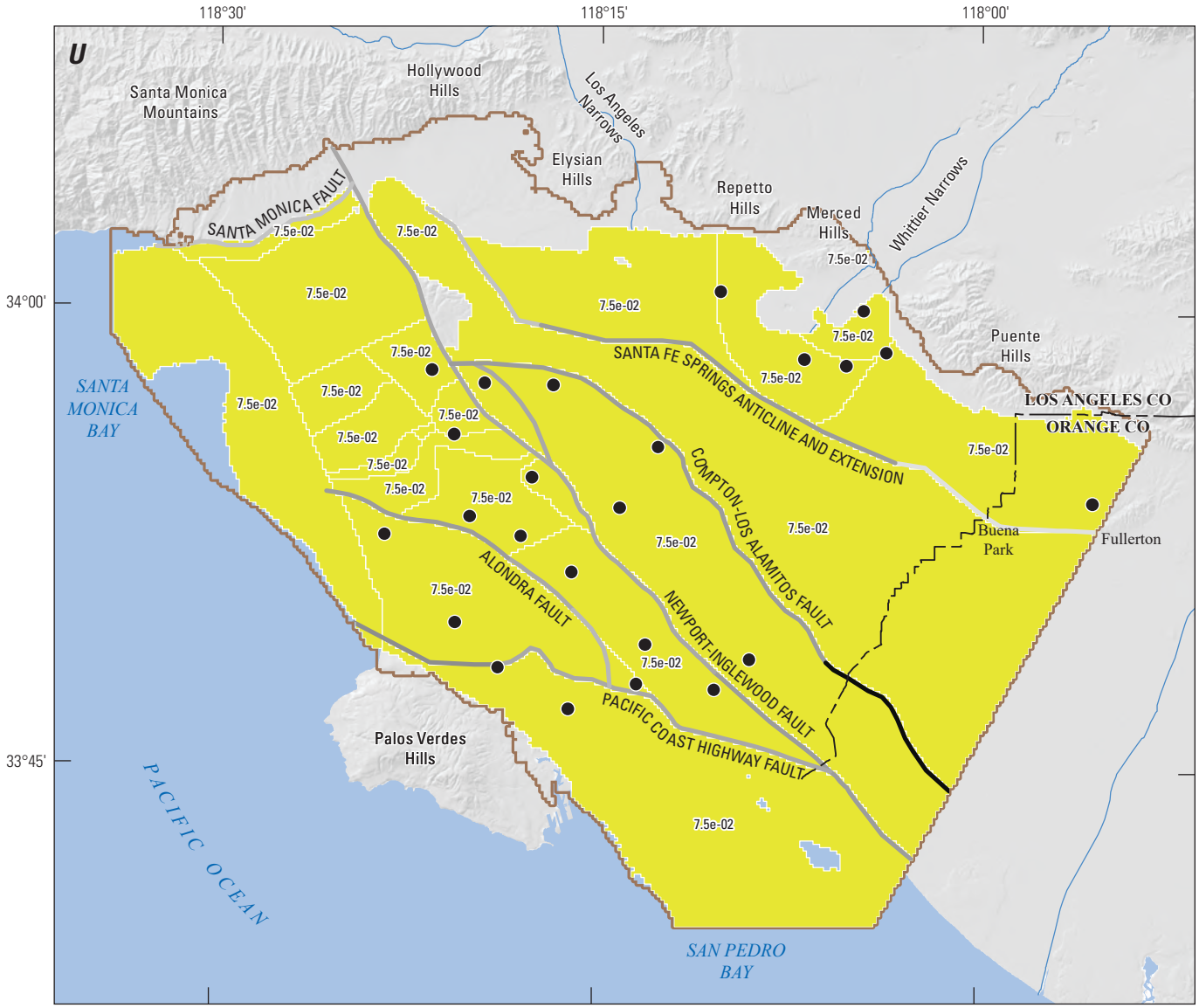


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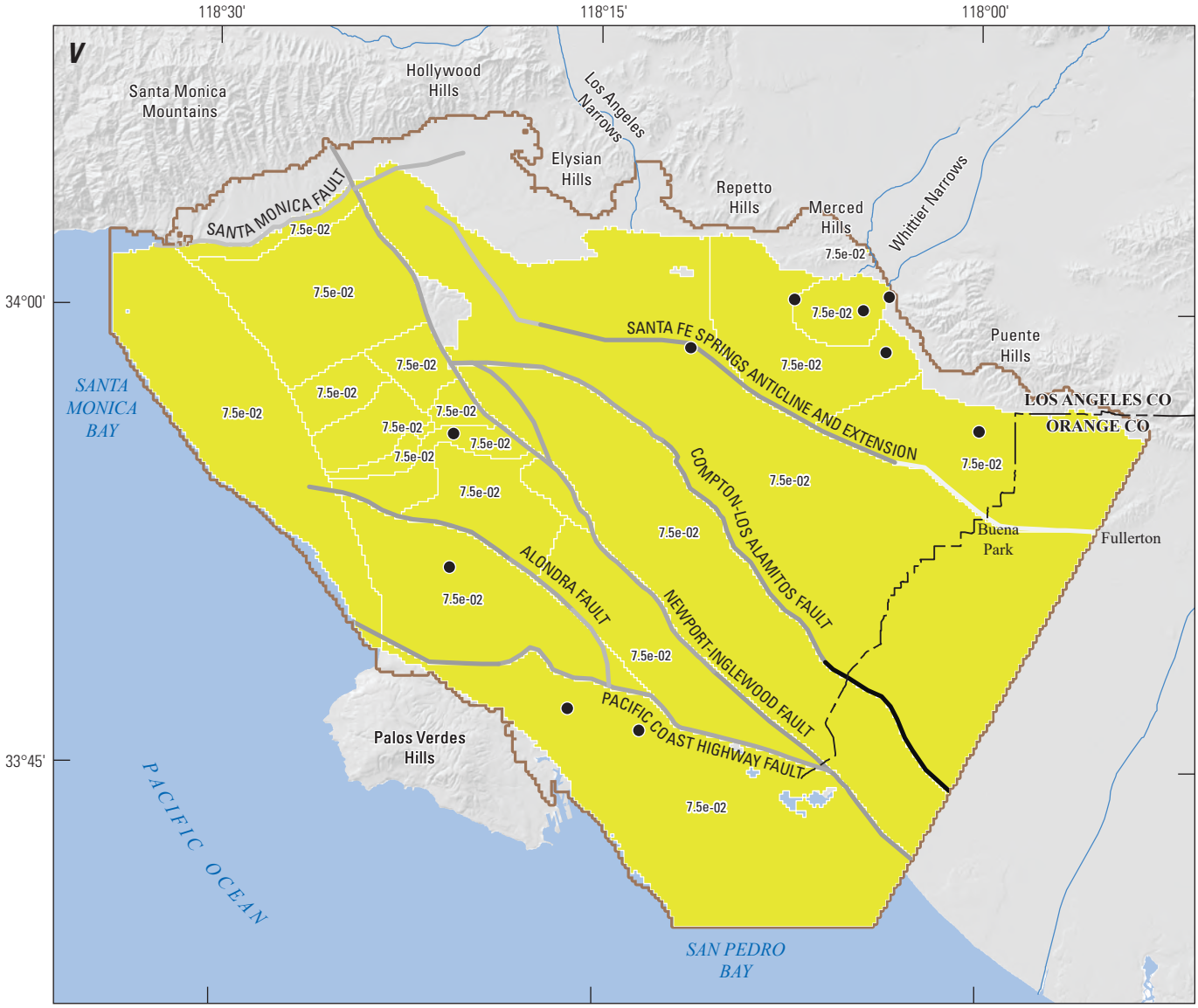


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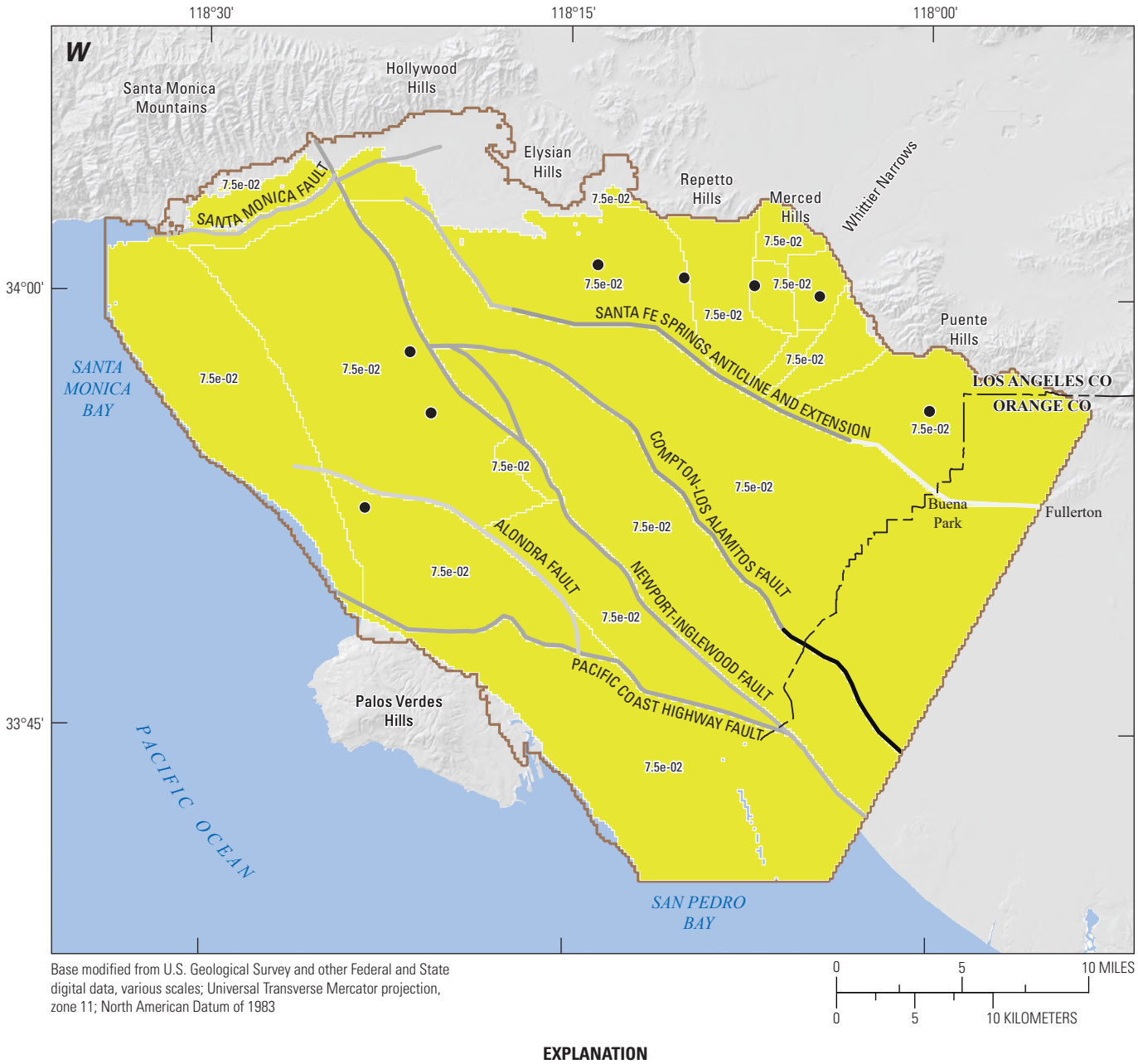


Figure D8.—Continued

Specific-yield values were assigned to all model layers; however, specific yield was applied to a model cell only if that cell is the top-most active cell at a given row-column location in the model (if the cell was under a water-table condition; fig. D8*L–W*). The Dominguez and Mesa layers were the top-most active layers throughout most of the model domain (fig. D4). Calibrated specific-yield values (dimensionless) in the Dominguez layer varied from 0.15 in the Montebello Forebay to 0.00046 in parts of the Central Basin Pressure Area (figs. D1, D8*L*). Calibrated specific-yield values in the Mesa layer varied from 0.3 in the southwestern West Coast Basin to 0.0062 in the far southeastern portion of Central Basin (fig. D8*M*). The high specific-yield values in some zones of the West Coast Basin may be due to high-yield sandy beach deposits. The low specific-yield values were in zones where the top-most active model layer was effectively semi-confined to confined by overlying fine-grained deposits in that layer.

Hydrographs Comparing Simulated Head and Measured Water Levels

Simulated and measured hydraulic heads were compared at selected long-screened wells and multiple-well monitoring sites for 1971 to 2015 (figs. A3, C8, D9). In general, the simulated heads followed the long-term trends of measured heads and reflected the vertical differences in heads between aquifer systems. Where the model did not reproduce measured heads in individual aquifer systems or vertical differences in heads between aquifer systems, simulation of pumpage from the different aquifer systems may be inaccurate. The total quantity of pumpage from a well was known; however, the distribution of pumpage from the different aquifer systems to which a well is open must be estimated. The distribution of pumpage among the aquifer systems open to a well was simulated in the model based on the calibrated transmissivity of each aquifer system and the length of the screened interval in each aquifer system. Inaccurate estimates of the screened interval, well efficiency, incorrect assignments of the chronostratigraphic units, and scaling errors due to cell size and the respective locations of monitoring and pumping wells within cells can cause errors in the simulated pumpage from a particular aquifer system.

Initial simulated heads were approximated based on available measured heads data at the beginning of the model runtime. Errors in initial simulated heads were attributed to interpolation errors in layers with sparse data. In most areas of the model, where errors in initial simulated heads were suspected, initial simulated heads equilibrated within a few years of model runtime.

The comparison between simulated and measured heads is briefly discussed for eight sites in the LACP that have long-term and nearby short-term aquifer-system-dependent water-level data (fig. C8). The sites discussed are the same sites that are discussed in detail in the "Water Levels and Movement" section of Chapter C.

Los Angeles Forebay

Well 10A1 (2S/13W-10A1; 2778) is a production well in the Los Angeles Forebay of the Central Basin (fig. C8) that is screened in the Pacific, Harbor, and Upper Wilmington A aquifer systems. Monitoring wells 3P2-6 (2S/13W-3P2 to 3P6) compose the multiple-well monitoring site Los Angeles2, which is adjacent to well 10A1, and has wells screened in the Long Beach C (3P2), Upper Wilmington A (3P3, 3P4), Harbor (3P5), and Pacific (3P6) aquifer systems. Simulated heads in the Pacific and Harbor aquifer systems followed measured heads closely at well 10A1 and the wells completed in the Pacific and Harbor systems at wells 3P2-6 (fig. D9*A*). Simulated heads in the Upper Wilmington A aquifer system were about 20 ft higher than measured heads at well 10A1 and about the same as measured heads in monitoring wells 3P2-6. Simulated heads were about 10 ft lower than measured heads in well 3P2 completed in the Long Beach C system. Although the simulated and measured heads did not match exactly, the gradient direction between Harbor, Upper Wilmington A, and Long Beach C aquifer systems was simulated correctly.

Montebello Forebay

Well 1A6 (3S/12W-1A6; 1615P) is a production well in the Montebello Forebay (fig. C8) that is screened in the Mesa and Pacific aquifer systems. Monitoring wells 25G3-8 (2S/12W-25G3 to 25G8) compose the Pico Rivera2 multiple-well monitoring site, which is near well 1A6 and has wells screened in the Long Beach A (25G3), Upper Wilmington B (25G4), Upper Wilmington A (25G5), Pacific (25G6), Mesa (25G7), and Dominguez (25G8) aquifer systems. Simulated heads in the Mesa and Pacific aquifer systems followed the trends in measured heads at well 1A6 but were about 10 ft lower than measured heads (fig. D9*B*).

In general, simulated heads at wells 25G3-8 reasonably matched measured heads, head temporal trends, and head differences between wells (fig. D9*B*). Simulated heads did not have as much seasonal variation as measured heads, especially in the deeper aquifer systems. Reduced seasonal variation was probably the result of quarterly stress periods and scaling errors due to cell size and the respective locations of monitoring and pumping wells within cells. Simulated heads were higher than measured heads for the Long Beach A aquifer system, and the gradient between the Long Beach A aquifer system and the Upper Wilmington A and B aquifer systems was reversed compared to head measurements at 25G3-8 (fig. D9*B*). The differences in simulated and measured heads probably were the result of how underflow at the Whittier Narrows was simulated in the model. As stated in the "Boundary Conditions" section of this chapter, underflow from the San Gabriel Valley was simulated in the Mesa and Long Beach C aquifer systems. The model simulated too much upward leakage to the Long Beach A aquifer system from the underlying Long Beach C aquifer system through the Whittier Narrows.

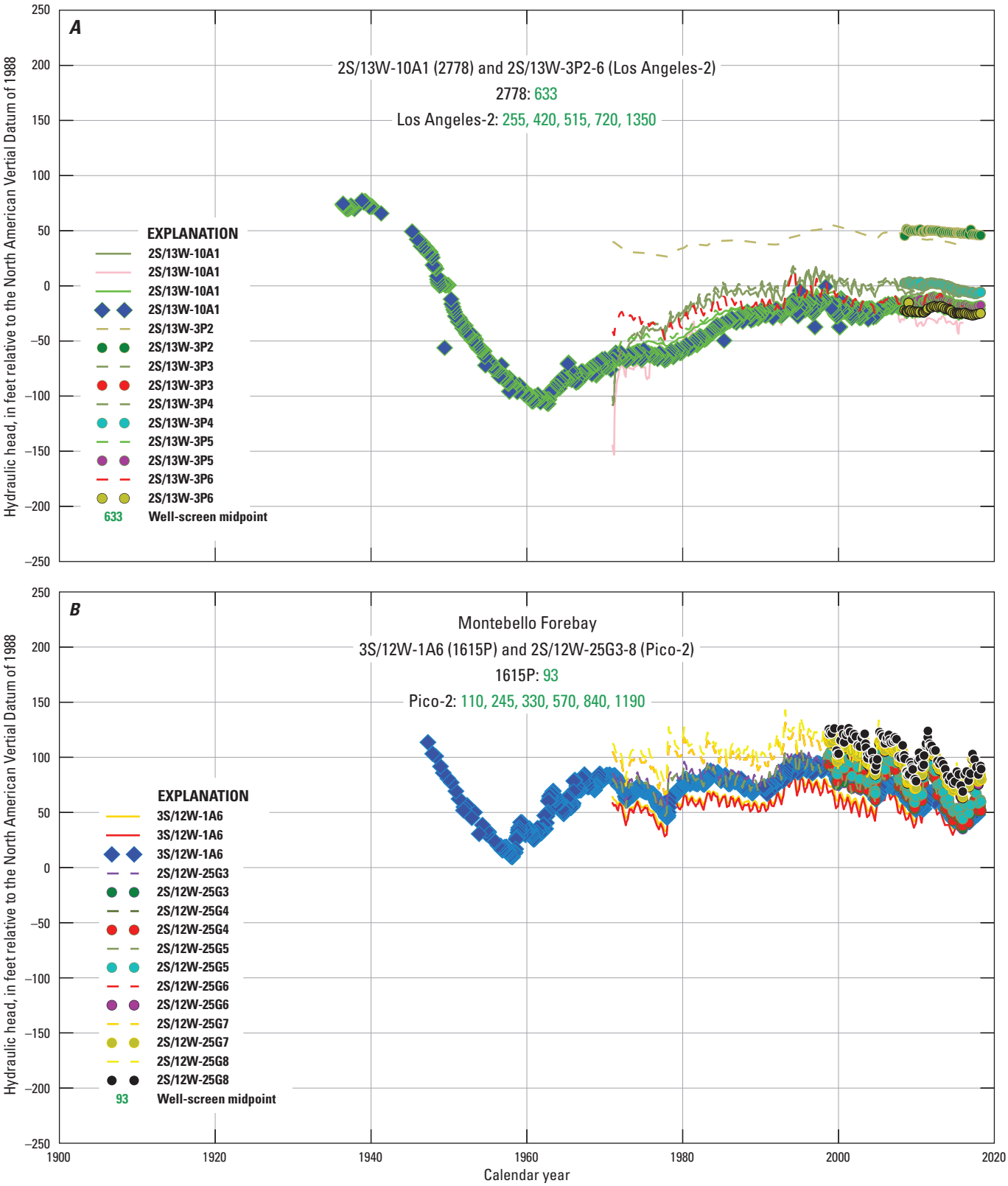


Figure D9. Measured (dots) and simulated (lines) hydraulic heads for selected long-screened basin-monitoring wells and paired multiple-well monitoring sites in the *A*, Los Angeles Forebay; *B*, Montebello Forebay; *C*, Central Basin Pressure Area (North); *D*, Central Basin Pressure Area (Central); *E*, Central Basin Pressure Area (South); *F*, West Coast Basin (East); *G*, West Coast Basin (West); and *H*, Santa Monica Basin, Los Angeles and Orange Counties, California. For long-screened monitoring wells screened in multiple layers, simulated heads are shown as separate lines for each layer.

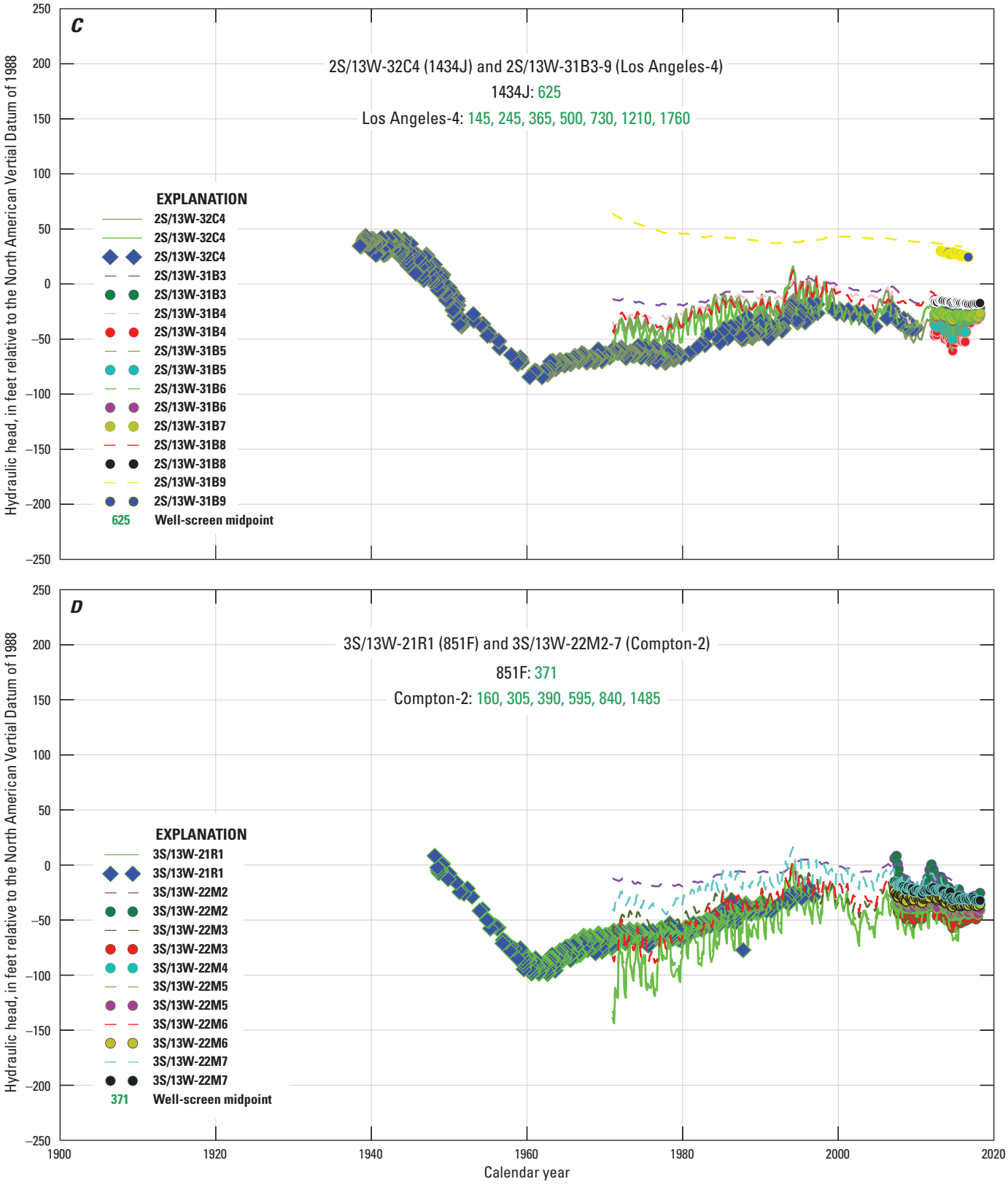


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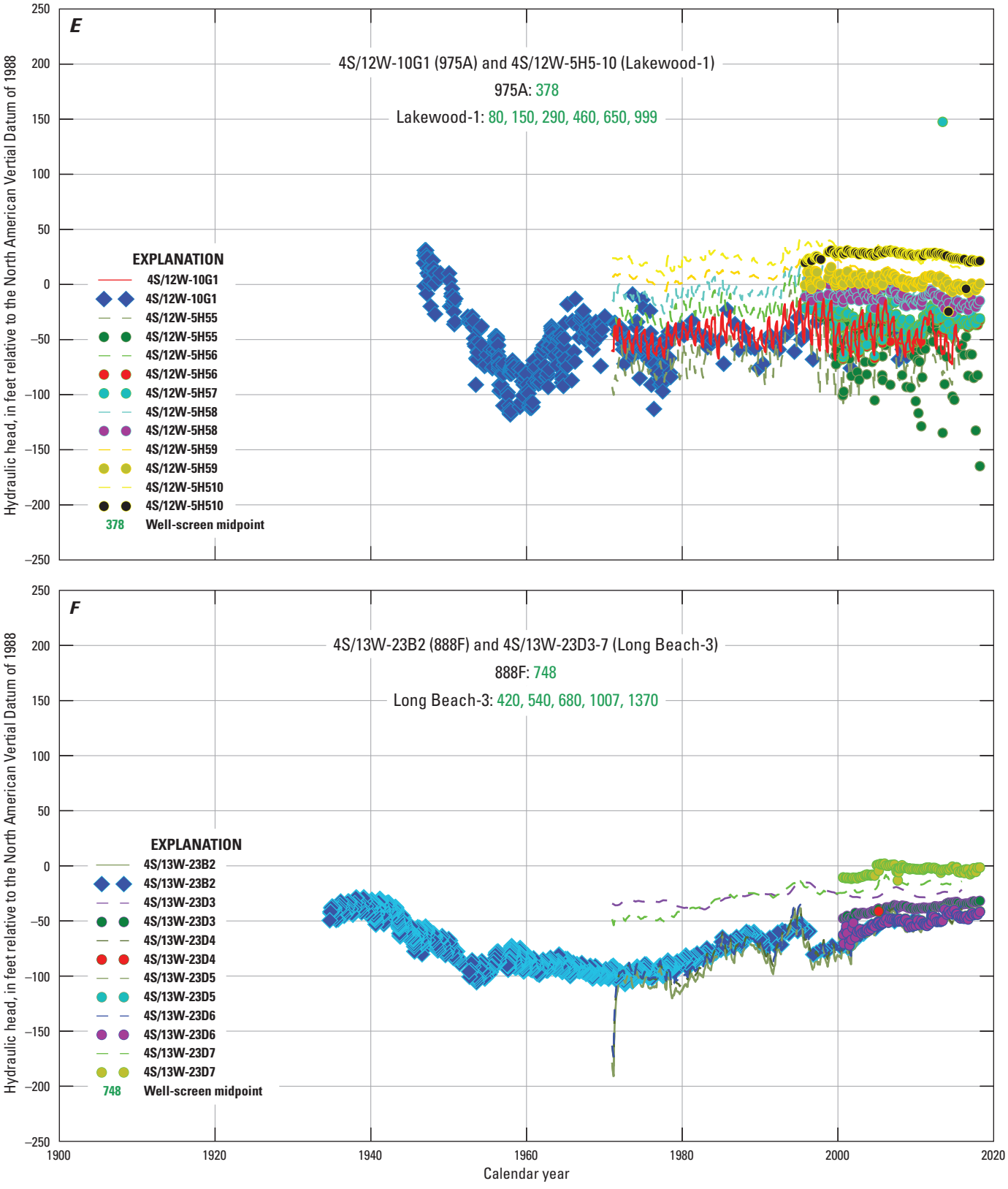


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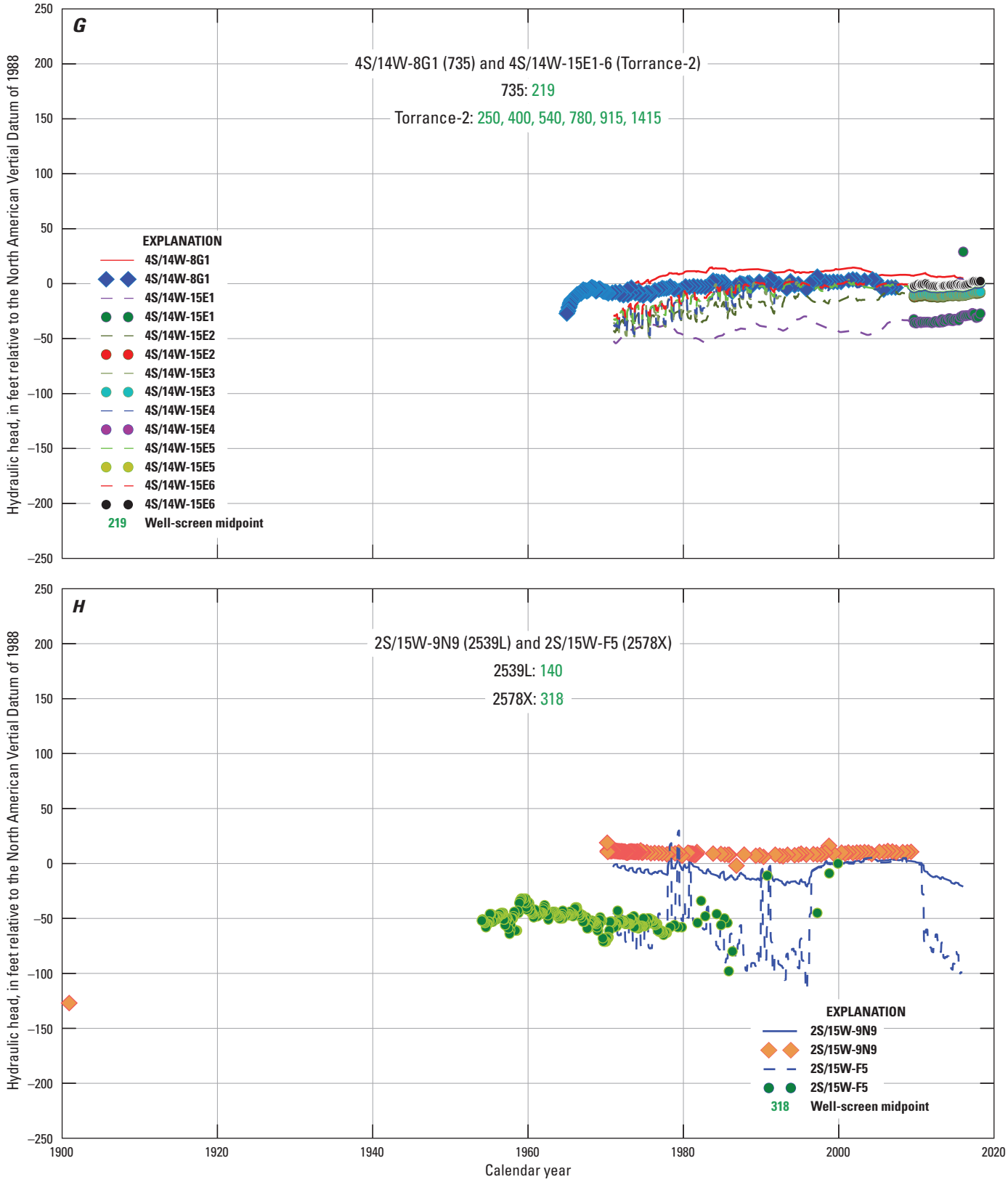


Figure D9.—Continued

Central Basin Pressure Area, North

Well 2S/13W-32C4 (1434J) is a production well in the northern part of the Central Basin Pressure Area (fig. C8) and is screened in the Harbor, Bent Spring, and Upper Wilmington A aquifer systems (table 1.1). Wells 31B3-8 (2S/13W-31B3 to 31B8) compose the Los Angeles4 multiple-well monitoring site, which is near well 32C4 and has wells screened in the Long Beach A (31B3), Lower Wilmington (31B4), Upper Wilmington A (31B5), Harbor (31B6, 31B7), and Pacific (31B8) aquifer systems, with a vibrating wire piezometer in the Dominguez aquifer system (31B9; appendix 1, table 1.1). Simulated heads in the Pacific, Harbor, and Upper Wilmington A aquifer systems closely followed the trends in measured heads from the mid-1990s until the end of the period of record in 2009 (fig. D9*C*). The simulated heads overestimated measured heads at well 32C4 by as much as 20 ft for 1971 to 1993. However, the model accurately simulated the measured heads in well 32C4 in the period from the 1995 to 2009, so pumpage in the period from 1971 to 1993 may not have been estimated accurately.

Simulated heads closely matched measured heads and gradients in the Pacific, Harbor, and Upper Wilmington A aquifer systems at wells 31B3-8 (fig. D9*C*). However, simulated heads were higher than measured heads in the Dominguez, Lower Wilmington, and Long Beach A aquifer systems (fig. D9*C*). Measured heads in the Lower Wilmington aquifer system at wells 31B3-8 were the lowest and showed the most seasonal variation. Nearby pumping from the Lower Wilmington aquifer system could have caused the low and minimally variable heads. However, wells with perforations extending down into the Lower Wilmington aquifer system were not pumping near wells 31B3-8 during the time period of the head measurements. The nearest deep pumping well was only screened as deep as the Upper Wilmington B aquifer system. If the assumed elevation of the top of the Lower Wilmington was higher in this part of the LACPGM, some of the deep pumping would have been withdrawn from the Lower Wilmington, which might have allowed the model to more accurately simulate heads at 31B3-8.

Central Basin Pressure Area, Central

Well 21R1 (3S/13W-21R1; 851F) is a production well in the Central Basin Pressure Area (fig. C8) near the Newport-Inglewood fault zone that is screened in the Harbor aquifer system (table 1.1). Monitoring wells 22M2-7 (3S/13W-22M2 to 22M7) compose monitoring site Compton2, which is near well 21R1 and has wells screened in the Long Beach A (22M2), Upper Wilmington B (22M3), Harbor (22M4, 22M5), Pacific (22M6), and Pacific A (22M7) aquifer systems (table 1.1, fig. D9*D*). Simulated heads in the Harbor aquifer system followed the general trends of measured heads at well 21R1; however, variations in simulated seasonal head were much higher than variations in measured heads (fig. D9*D*). Simulated heads at wells 22M2-7 were similar to measured heads in the Pacific A, Pacific, and Harbor aquifer systems, except the simulated heads had greater seasonal variation than measured heads (fig. D9*D*). The higher simulated seasonal head variations indicated that the calibrated storage coefficient and/or VK values may have been too low in the model domain near wells 22M2-7.

The simulated and measured heads for the Upper Wilmington B aquifer system are similar at wells 22M2-7; however, the simulated seasonal response was slightly muted compared to the measured seasonal response (fig. D9*D*). The measured seasonal response indicated that a nearby well was pumping from the Upper Wilmington B aquifer system. However, nearby wells were not simulated to pump from the Upper Wilmington B aquifer system. The nearest simulated deep pumping wells were screened in the Bent Spring aquifer system. Well 22M3 is screened near the top of the Upper Wilmington B aquifer system. The measured head response indicated that model results could be improved in this area by modifying either the chronostratigraphic model to include well 22M3 in the Bent Spring aquifer system or the screened intervals of nearby pumping wells in the Upper Wilmington B aquifer system. Wells 22M2-7 are about 1 mi east-northeast of the Newport-Inglewood fault zone, where the chronostratigraphic units dip from the Newport-Inglewood fault zone to the Compton-Los Alamitos fault (fig. B20). Slightly modifying the local steepness of this dip would move the screen in well 22M3 from the Upper Wilmington B to the Bent Spring chronostratigraphic unit. A local change like this would most likely result in minimal effects on adjacent areas of the LACPGM.

The simulated heads for the Long Beach A aquifer system were about 10 ft higher than the lowest measured heads in well 22M2 screened in the Long Beach A aquifer system, at wells 22M2-7, and did not show the large (25 ft) variations observed at wells 22M2-7 (fig. D9*D*). The nearest active production well that withdrew water from the Long Beach A aquifer system is more than 5 mi southeast of wells 22M2-7 (fig. C6). The presence of large head fluctuations, caused by pumping at such a large distance, indicated that the VK of the Long Beach A aquifer system may be lower than the one used in the currently calibrated model.

Central Basin Pressure Area, South

Well 10G1 (4S/12W-10G1; 975A) is a production well in the southern part of the Central Basin Pressure Area that is screened in the Pacific aquifer system (fig. C8; table 1.1). Monitoring wells 5H5-10 (4S/12W-5H5 to 5H10) compose multiple-well monitoring site Lakewood1, which is near well 10G1 and has wells screened in Upper Wilmington A (5H5), Harbor (5H6, 5H7), Pacific A (5H8), Mesa (5H9), and Dominguez (5H10) aquifer systems (table 1.1; fig. D9*E*). Simulated heads in the Pacific aquifer system closely followed measured heads in well 10G1 (fig. D9*E*). The simulated heads, seasonal head changes, and head differences among aquifer systems at site 5H5-10 matched measured heads in the Dominguez, Harbor, and Upper Wilmington A aquifer systems at the site (fig. D9*E*). Simulated heads in the Mesa and Pacific A aquifer systems were about 10 ft higher than measured heads but followed the same temporal trends.

The previous USGS groundwater-flow model for the LACP reasonably simulated heads in the wells (5H6–5H10) shallower than the Upper Wilmington A at wells 5H5-10 but was less successful in simulating heads in the deepest well (5H5; Reichard and others, 2003). The previous model did not account for the steepness of the upward folding of the Pacific and older aquifer systems near wells 5H5-10 (figs. B4, B22), which resulted in multiple wells producing water from the Upper Wilmington A aquifer system in the southwestern part of the Central Basin (fig. C6). Finer discretization and more accurate simulation of the aquifer structure in the LACPGM, compared to the previous USGS model, undoubtedly contributed to improved simulation of measured heads at wells 5H6-5H10. A production well was installed in the late 1990s near well 5H5-10 (site Lakewood1). Pumping from production wells in the vicinity of 10G1 resulted in large seasonal head declines in well 5H5 (site Lakewood1) screened in the Upper Wilmington A aquifer system (fig. D9*E*). Measured seasonal head declines were slightly underpredicted by the LACPGM.

West Coast Basin, East

Well 23B2 (4S/13W-23B2; 888F) is a production well in the southeast part of the West Coast Basin (fig. C8) that is screened in the Upper Wilmington A aquifer system (table 1.1). Monitoring wells 23D3-7 (4S/13W-23D3 to 23D7) compose multiple-well monitoring site Long Beach3, which is near well 23B2 and has wells screened in the Long Beach A (23D3), Upper Wilmington B (23D4), Upper Wilmington A (23D5), Bent Spring (23D6), and Harbor (23D7) aquifer systems (fig. D9*F*). Simulated heads in the Upper Wilmington A aquifer system reasonably matched measured heads and temporal trends at well 23B2, especially from 1998 to 2015 (fig. D9*F*). Simulated heads matched measured heads and head differences between the Bent Spring and Upper Wilmington A aquifer systems at wells 23D3-7 (fig. D9*F*). Simulated heads for the Harbor aquifer system at wells 23D3-7 closely tracked measured heads but were about 15 ft lower than the measured heads (fig. D9*F*). Simulated heads for the Long Beach A aquifer system also closely tracked measured heads but were about 15 ft higher than the measured heads (fig. D9*F*). The calibrated VK of the Bent Spring aquifer system probably was too high in this part of the West Coast Basin. Additionally, the initial heads for the Bent Spring and Upper Wilmington A aquifer systems were too low in this area of the West Coast Basin, though simulated heads recovered and stabilized within a year.

West Coast Basin, West

Well 8G1 (4S/14W-8G1; 735) is an observation well in the western part of the West Coast Basin, about 1.6 mi east of the coastline (fig. C8), that is screened in the Pacific aquifer system (table 1.1). Monitoring wells 15E1-6 (4S/14W-15E1 to 15E6) compose multiple-well monitoring site Torrance2, which is near well 8G1 and has wells screened in the Long Beach A (15E1), Upper Wilmington B (15E2), Upper Wilmington A (15E3), Bent Spring (15E4), Harbor (15E5), and Pacific (15E6) aquifer systems (fig. D9*G*). Simulated heads for the Pacific aquifer system matched measured heads within 10 ft at well 8G1 (fig. D9*G*). Simulated heads for the Pacific, Harbor, Bent Spring, and Upper Wilmington A aquifer systems at wells 15E1-6 plotted together closely (fig. D9*G*). Heads measured in the Pacific, Harbor, and Bent Spring aquifer systems at wells 15E1-6 also plotted together closely, within 5 ft of simulated heads (fig. D9*G*). Measured heads in all four of these aquifer systems were similar at wells 15E1-6 because the nearby West Coast Basin Barrier Project injects water into these aquifer systems (fig. D5). The measured differences between heads in the Bent Spring and Upper Wilmington A aquifer systems indicated that the VK of the Upper Wilmington A aquifer system is low enough to retard movement of water between the Bent Spring and underlying Upper Wilmington A aquifer systems. In contrast, the calibrated VK values for the Upper Wilmington A aquifer system (0.07 ft/d) probably were too high to sufficiently retard the simulated movement of water between these two aquifer systems in this part of the West Coast Basin (fig. D9*G*). Simulated heads for the Long Beach A aquifer system were within 5 ft of measured heads (fig. D9*G*).

Santa Monica Basin

Well 11F5 (2S/15W-11F5; 2578X) is a production well in the central part of the Santa Monica Basin (fig. C8) that is screened in the Bent Spring aquifer system (table 1.1). USGS multiple-well monitoring sites have not been constructed in the Santa Monica Basin, so head measurements from well 9N9 (2S/15W-9N9; 2539L; table 1.1) were compared to head measurements at well 11F5 to illustrate changes in heads with depth in the Santa Monica Basin. Well 9N9 is in the western part of the Santa Monica Basin (fig. C8) and screened in the Pacific aquifer system. Simulated heads in the Bent Spring aquifer system reproduced the large head fluctuations observed at well 11F5 (fig. D9*H*). Simulated heads in the Pacific aquifer system remained within 25 ft of observed heads in well 9N9 (fig. D9*H*). The simulated difference in head between the Pacific and Bent Spring aquifer systems was within 15 ft of measured head differences between wells 9N9 (Pacific aquifer system) and 11F5 (Bent Spring aquifer system; fig. D9*H*).

Simulated Hydraulic Heads for Fall 2013 and Spring 2006

Simulated hydraulic heads were compared to measured heads for fall 2013 (a dry time) and spring 2006 (a wet time) to ensure similarity between the areal distributions of simulated and measured heads and of hydraulic gradients between aquifer systems (fig. D10). For measured heads, we selected the earliest available head measurements from September 2013 and March 2006, respectively. The density of head measurements was substantially greater in shallow aquifer systems than in deeper aquifer systems. Most data from deeper aquifer systems are from WRD/USGS multiple-well monitoring sites in the Central and West Coast Basins and OCWD multi-completion wells in the Orange County Basin.

Dominguez Aquifer System

Fall 2013 simulated hydraulic heads in the Dominguez aquifer system indicated that groundwater flows from the surrounding highlands toward the Central Basin Pressure Area then flows in a southeasterly direction toward the Dominguez Gap and the San Gabriel River (fig. A1, C1, D10A). Simulated heads were highest at the Los Angeles Narrows in the Los Angeles Forebay (approximately 320 ft) and Whittier Narrows in the Montebello Forebay (approximately 160 ft; figs. D10*A*, D10*C*). Fall 2013 simulated head gradient declined steeply from a high of about 320 ft in the Los Angeles Narrows to about 30 ft in the southern part of the Los Angeles Forebay, and then continued to gently decline into the northern part of the Central Basin Pressure Area. Simulated heads in the Montebello Forebay declined from a high of about 160 ft in the Whittier Narrows to about 40 ft at the southern end of the Montebello Forebay. The simulated hydraulic heads indicated that groundwater flows from the southeastern margin of the model in the Orange County Basin toward the San Gabriel River.

Spring 2006 simulated heads were about 5 to 15 ft higher than simulated heads for fall 2013 in the Central Basin Pressure Area, as much as 20 to 30 ft higher in the Montebello Forebay, and less than 5 ft higher throughout most of the Los Angeles Forebay (figs. D10*A*, D10*C*). Simulated heads were in good agreement with available measured heads. Based on simulations, groundwater flow in the Dominguez aquifer system was minimally impacted by the Newport-Inglewood fault zone.

Mesa Aquifer System

Fall 2013 simulated hydraulic heads in the Mesa aquifer system were highest in the Central Basin at Whittier Narrows and Los Angeles Narrows, at about 160 ft and 280 ft, respectively (fig. D10*A*). Pumping in the Mesa and deeper aquifer systems in the Los Angeles Forebay and northern part of the Central Basin Pressure Area resulted in a depression in the fall 2013 simulated heads, with heads lower than 0 ft in the center of the depression (fig. D10*A*). Simulated heads declined steeply from 160 ft at the Whittier Narrows to about 30 ft at the edge of the Central Basin Pressure Area then declined to a low of about –20 ft in the southeastern part of the Central Basin Pressure Area (fig. D10*A*). Similar to the Dominguez aquifer system, the simulated heads indicated that groundwater in the Mesa aquifer system flows from the southeastern model margin in the Orange County Basin toward the San Gabriel River. In the West Coast Basin, simulated and measured heads were below NAVD 88 except in the northern part of the groundwater basin and along the West Coast Basin Barrier Project (fig. D10*A*). Simulated hydraulic heads below NAVD 88 along the coast in the southern part of the West Coast Basin indicated potential for seawater intrusion into the Mesa aquifer system. Large differences in simulated heads across the Newport-Inglewood fault zone reflected the barrier effect of the fault zone on groundwater flow in this part of the Mesa aquifer system (fig. D10*A*).

Spring 2006 simulated hydraulic heads in the Montebello Forebay were up to 25 ft higher than fall 2013 simulated heads, up to 15 ft higher in the Central Basin Pressure Area, from 15 ft higher to 15 ft lower in the Los Angeles Forebay, and from about 20 ft higher to 5 ft lower in the West Coast Basin (figs. D10*A*, D10*C*). Available measured heads agreed well with simulated heads in the Central and West Coast Basins (fig. D10*A*). Groundwater flow within the Mesa aquifer system was impeded by (1) the Newport-Inglewood fault zone, and (2) the Santa Monica fault.

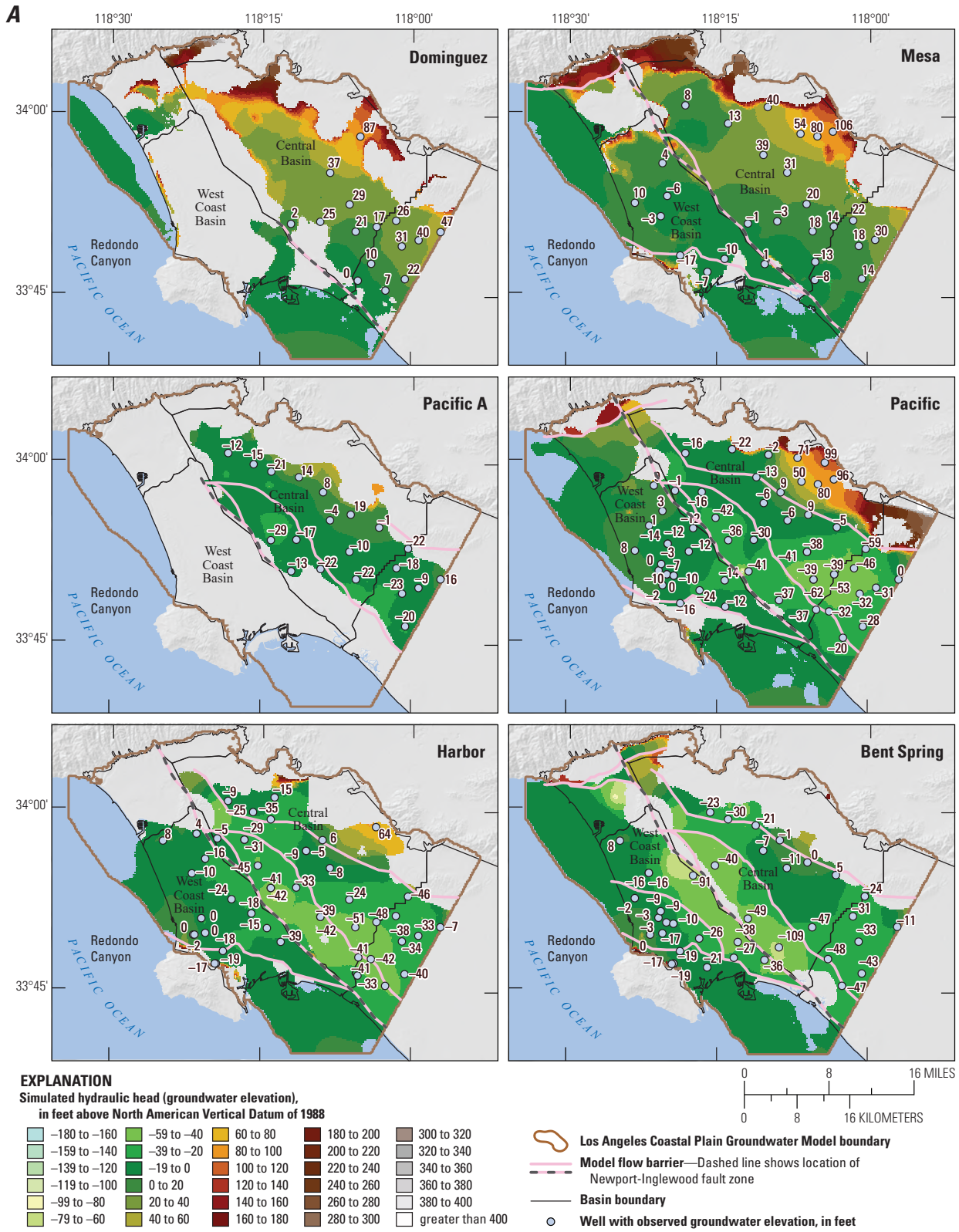


Figure D10. Simulated hydraulic head for Fall of 2013 and Spring of 2006 for layers 2 through 13 of the Los Angeles Coastal Plain Groundwater-flow model, California: *A*, Fall of 2013 Dominguez, Mesa, Pacific A, Pacific, Harbor, Bent Spring; *B*, Fall of 2013 Upper Wilmington A, Upper Wilmington B, Lower Wilmington, Long Beach A, Long Beach B, and Long Beach C; *C*, Spring of 2006 Dominguez, Mesa, Pacific A, Pacific, Harbor, Bent Spring; and *D*, Spring of 2006 Upper Wilmington A, Upper Wilmington B, Lower Wilmington, Long Beach A, Long Beach B, and Long Beach C aquifer systems.

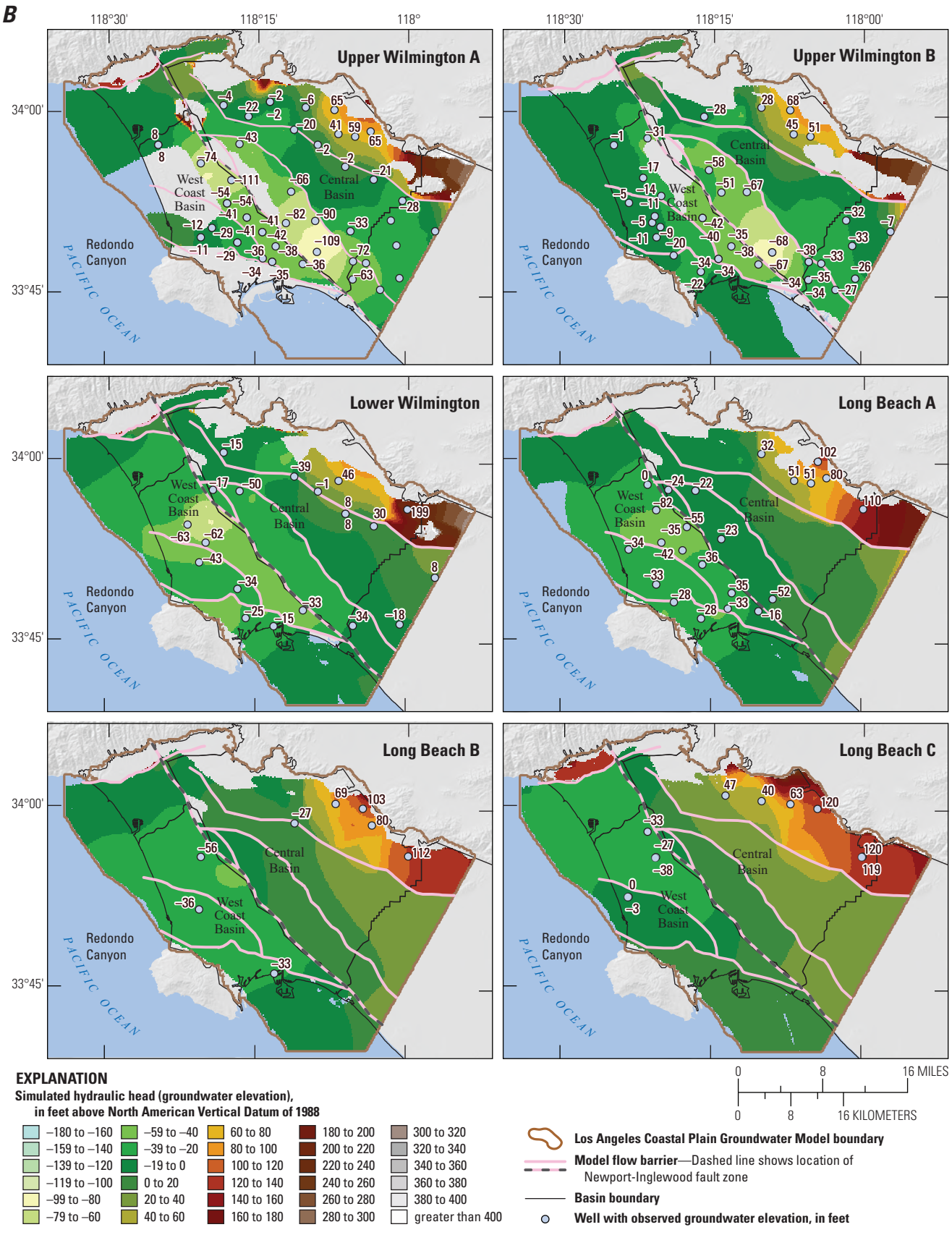


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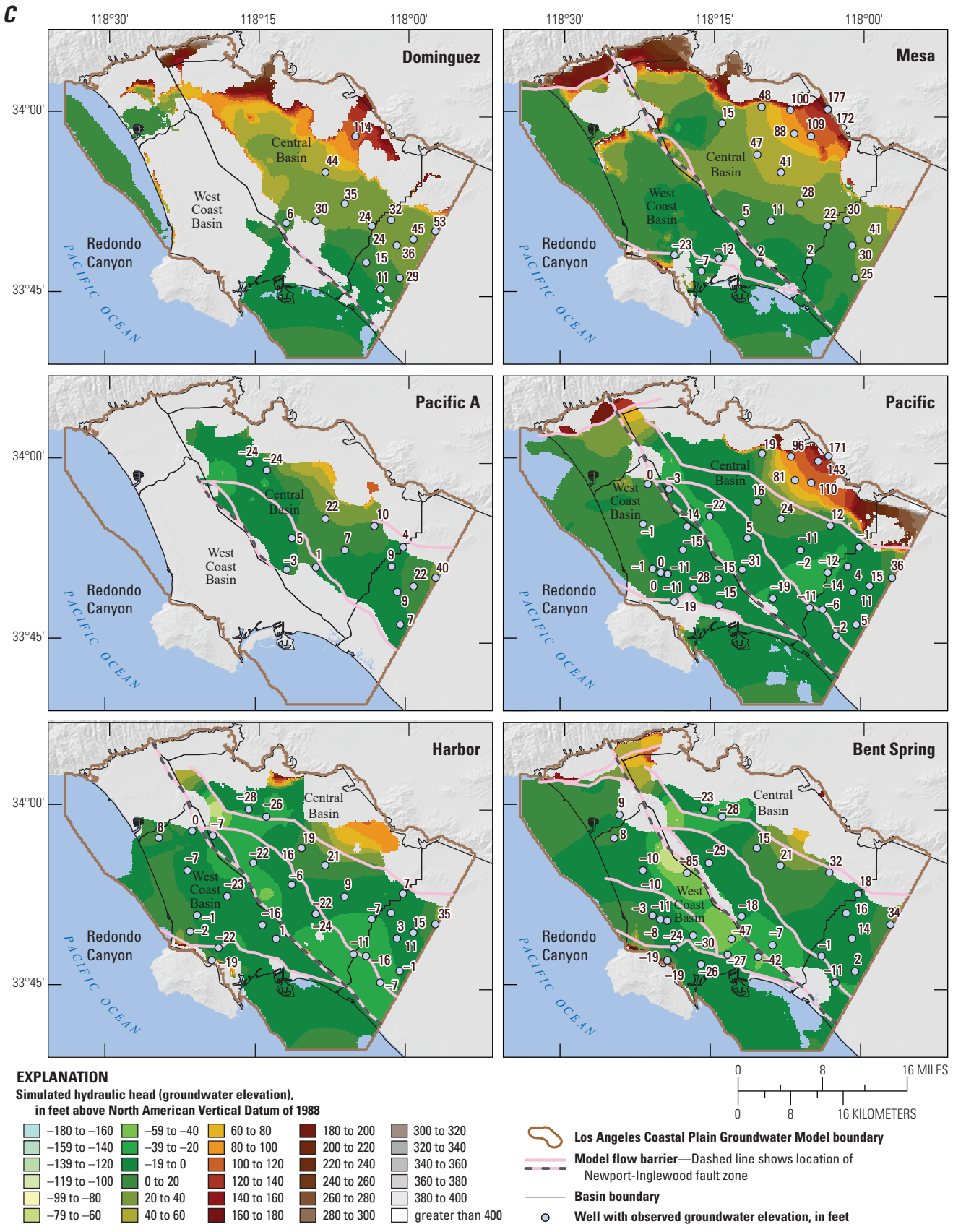


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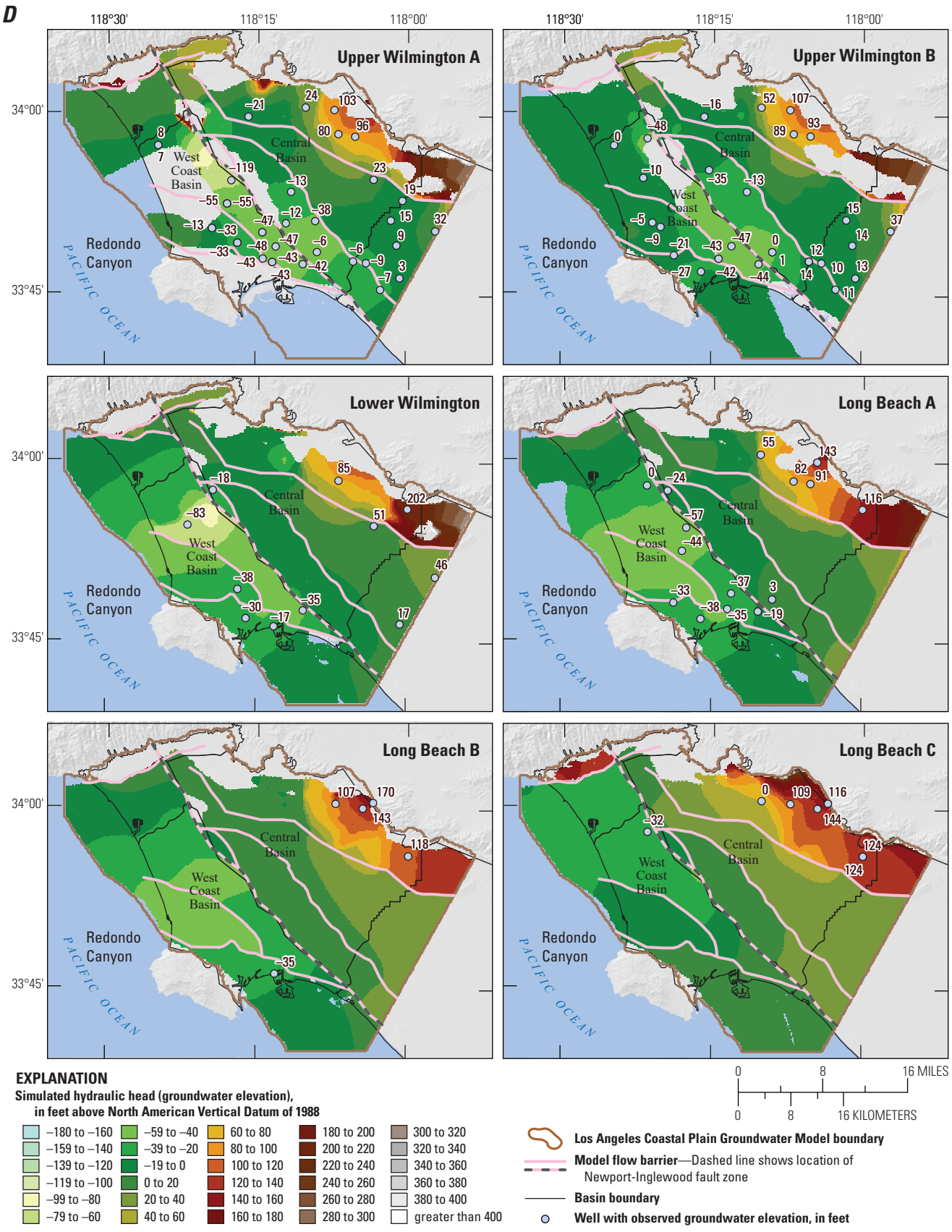


Figure D10.—Continued

Pacific A Aquifer System

The Pacific A aquifer system does not extend into the Los Angeles or Whittier Narrows; therefore, fall 2013 simulated hydraulic heads in the Los Angeles and Montebello Forebays were not as high as in the overlying aquifer systems. Simulated heads were as high as 95 ft on the northeastern edge of the aquifer system (fig. D10*A*). With the exception of the northeastern edge of the Pacific A aquifer system, simulated hydraulic heads were below NAVD 88 throughout the aquifer system extent, as low as about –25 ft near the southwestern edge (fig. D10*A*).

Spring 2006 simulated heads were about the same as fall 2013 simulated heads in the Los Angeles Forebay, up to 15 ft lower in the northern Central Basin Pressure Area, and as much as 30 ft higher in the central and southern Central Basin Pressure Area (figs. D10*A*, D10*C*). In general, simulated heads agreed well with measured heads (fig. D10*A*). Groundwater flow within the Pacific A aquifer system was impeded by (1) the Newport-Inglewood fault zone and (2) the Santa Fe Springs anticline and related structures (figs. D10*A*, B4). These two structural features do not cross much of the Pacific A aquifer system and, therefore, likely had a limited effect on groundwater flow.

Pacific Aquifer System

The Pacific aquifer system extends to the Whittier Narrows in the Montebello Forebay but does not extend to the Los Angeles Narrows in the Los Angeles Forebay (fig. D10*A*). Fall 2013 simulated hydraulic heads in this system were highest in the Montebello Forebay, exceeding 150 ft in the northernmost part of the Forebay (fig. D10*A*). Simulated heads are 5 to 20 ft higher than measured heads in the Montebello Forebay (fig. D10*A*). Simulated heads declined steeply to about 10 ft at the western edge of the Montebello Forebay, then continued to decline in high-pumping areas in the southeastern part of the Central Basin Pressure Area, where simulated heads were as low as –45 ft (fig. D10*A*). Simulated heads indicated that groundwater flows from the southeastern model margin in the Orange County Basin toward the pumping depression in the southwestern part of the Central Basin Pressure Area (fig. D10*A*).

Spring 2006 simulated heads were more than 20 ft higher than simulated fall 2013 heads in much of the Montebello Forebay, 20 to 35 ft higher in much of eastern Central Basin Pressure Area, and 5 ft higher to 10 ft lower in the Los Angeles Forebay and far western Central Basin Pressure Area (figs. D10*A*, D10*C*). Simulated heads in the pumping depression were about 10 ft lower than measured heads (fig. D10*A*), which may have been because the LACPGM averages pumping quarterly; therefore, intra-quarterly fluctuations in pumping and corresponding effects on heads in nearby monitoring wells were not simulated.

In the West Coast Basin, fall 2013 simulated heads were above sea level in the northwestern part of the groundwater basin and along the West Coast Basin Barrier Project in the western part of the basin (fig. D10*A*). In the interior and along the southern coastline of the West Coast Basin, simulated heads were mostly below NAVD 88, as low as about –20 ft (fig. D10*A*). Simulated heads below NAVD 88 along the coast indicated that there was a potential for seawater intrusion into the Pacific aquifer system.

Spring 2006 simulated heads in the West Coast Basin were about 0 to 10 ft higher than fall 2013 simulated heads (fig. D10*C*). The PCH fault juxtaposes the Pacific aquifer system opposite older aquifer systems on the ocean side of the fault, which probably retards lateral migration of intruding seawater (see figs. B1, B4, B21). Simulated heads in much of the West Coast Basin were mostly within 5 ft of measured heads (fig. D10*A*). Groundwater flow in the Pacific aquifer system was impeded by (1) the Newport-Inglewood fault zone; (2) Santa Monica, PCH, and (parts of) the Compton-Los Alamitos fault; and (3) Santa Fe Springs anticline and related structures. The Los Alamitos fault does not cut the Pacific aquifer system, but the steep fold of the system at this fault may have impeded flow (fig. B4).

Harbor Aquifer System

Fall 2013 simulated hydraulic heads in the Harbor aquifer system followed the same general patterns as simulated hydraulic heads in the Pacific aquifer system, except that heads in the Harbor aquifer system generally were slightly lower (fig. D10*A*). Simulated heads in the Central Basin Pressure Area were mostly within 10 ft of measured heads (fig. C1, D10*A*). Simulated heads along the Newport-Inglewood fault zone were about 20 ft lower on the Central Basin side of the fault zone than on the West Coast Basin side, indicating the fault zone acts as a barrier to groundwater flow (fig. D10*A*). Simulated heads were at or below NAVD 88 throughout most of the West Coast Basin and generally decreased in altitude near the West Coast Basin Barrier Project to less than –20 ft in the eastern part of the groundwater basin (fig. A1, D10*A*).

Spring 2006 simulated heads were 20 ft to more than 40 ft higher than fall 2013 heads in the Montebello Forebay and throughout all but the northern part of the Central Basin Pressure Area (figs. C1, D10*A*, D10*C*). Spring 2006 simulated heads agreed closely with fall 2013 heads in the Los Angeles Forebay and northern Central Basin Pressure Area, and up to 10 ft higher than fall 2013 simulated heads in West Coast Basin. Simulated heads in the Harbor aquifer system were mostly within 10 ft of measured heads in the West Coast Basin (fig. C1, D10*A*). Groundwater flow in the Harbor aquifer system was impeded by (1) the Newport-Inglewood fault zone; (2) PCH fault; and (3) parts of the Compton-Los Alamitos fault and Santa Fe Springs anticline and related structures.

Bent Spring Aquifer System

In the Central Basin, the Bent Spring aquifer system is present mainly in the Central Basin Pressure Area (fig. C1, D10*A*). Simulated fall 2013 hydraulic heads were as high as about 50 ft in the northeastern part of the Central Basin where the Bent Spring aquifer system extends into the western part of the Montebello Forebay (fig. C1, D10*A*). From the northeastern edge of the Central Basin, simulated fall 2013 heads steeply declined from the northeastern edge of the Central Basin to below NAVD 88 in the southern part of the groundwater basin, where they reached a low of near –70 ft (fig. C1, D10*A*). Simulated heads were within 10 ft of measured heads throughout most of the Central Basin. Spring 2006 simulated heads were up to 50 ft higher than fall 2013 heads everywhere in the Central Basin Pressure Area and the Los Angeles Forebay except in the northwestern Central Basin Pressure Area where heads were up to 10 ft lower than fall 2013 heads (figs. C1, D10*A*, D10*C*).

In the West Coast Basin, simulated fall 2013 heads were below NAVD 88 throughout most of the groundwater basin, ranging from near NAVD 88 along the western coast to as low as –70 ft in the northeastern part of the West Coast Basin (fig. C1, D10*A*). In the eastern part of the West Coast Basin, simulated heads were at least 20 ft lower than simulated heads in the overlying Harbor aquifer system (fig. C1, D10*A*). Simulated heads were within 10 ft of measured heads in most of West Coast Basin, with the exception of the northeastern part of the groundwater basin at well 13J7 (3S/14W-13J7; fig. C1, D10*A*), where measured heads were more than 30 ft lower than simulated heads. Cell size and an active production well near well 13J7 may have caused scaling errors that contributed to large differences between measured and simulated heads in the northeastern part of the West Coast Basin (fig. A3, C5*B*). Spring 2006 simulated heads were mostly within 10 ft of fall 2013 heads, with heads up to 10 ft higher in the central part of the West Coast Basin and heads within 5 ft near multiple-well monitoring site 4R1-7 (3S/14W-4R1 to 4R7; fig. A3; figs. D10*A*, D10*C*). Groundwater flow in the Bent Spring aquifer system was impeded by (1) the Newport-Inglewood fault zone; (2) the Santa Monica, Compton-Los Alamitos, PCH, and Alondra faults; and (3) parts of the Santa Fe Springs anticline and related structures impede groundwater flow in the Bent Spring aquifer system.

Upper Wilmington A Aquifer System

In the Central Basin, the Upper Wilmington A aquifer system extends to higher elevations in the Los Angeles and Montebello Forebays compare to the overlying Bent Spring aquifer system; consequently, fall 2013 simulated hydraulic heads in the forebays were higher in the Upper Wilmington A aquifer system than in the Bent Spring aquifer system (figs. D10*A*, D10*B*). Simulated heads were as high as about 200 and 100 ft in the upper parts of the Los Angeles and Montebello Forebays, respectively, but declined steeply to below NAVD 88 in the eastern part of the Central Basin Pressure Area (fig. D10*B*). Simulated heads were the highest in the Whittier area of the Central Basin, where the Santa Fe Springs anticline effectively retards groundwater flow from the Whittier area to the Central Basin Pressure Area. Simulated heads were nearly 290 ft in the northeastern part of the Whittier area but were –20 ft in the Central Basin Pressure Area south of the Santa Fe Springs anticline (fig. D10*B*). Simulated heads declined to as low as –95 ft on the west side of the Compton-Los Alamitos fault. Simulated declines likely resulted from (1) the barrier effect of the Compton-Los Alamitos fault and the Newport-Inglewood fault zone to the west, which compartmentalizes the western part of the Central Basin Pressure Area and (2) folding that uplifted the Upper Wilmington A aquifer system in this part of the groundwater basin to a shallow enough depth such that wells are producing water from this aquifer system (see figs. B1, B4, B21). In the southwestern part of the Central Basin, the Compton-Los Alamitos fault does not cut the Upper Wilmington A aquifer system (fig. B22), which allowed the drawdown from pumping in the Seal Beach area to extend into the south-central part of the groundwater basin (fig. D10*B*). Simulated hydraulic heads were 0 to 10 ft above measured heads in the Montebello Forebay and southern Central Basin (fig. D10*B*). Spring 2006 simulated heads ranged from within 1 foot of fall 2013 simulated heads in the northwestern Los Angeles Forebay and Central Basin Pressure Area to over 70 ft higher than fall 2013 simulated heads in parts of the southwestern Central Basin (figs. D10*B*, D10*D*).

In the West Coast Basin, fall 2013 simulated heads ranged from 10 ft to less than –80 ft of NAVD 88 and only exceeded NAVD 88 near the barrier wells (fig. D10*B*). Simulated heads in the West Coast Basin were mostly within 10 ft of measured heads, with the exception of monitoring well 13J6 (3S/14W-13J6; fig. A3) in the northeastern part of the groundwater basin (fig. D10*B*). In well 13J6, measured heads were –111 ft and simulated heads were about –90 ft. Well 13J6 is in close proximity to a production well, which probably caused scaling errors that resulted in differences in simulated and measured heads, as described previously. Spring 2006 simulated heads ranged from about 15 ft lower than fall 2013 simulated heads in the northwestern West Coast Basin to about 5 ft higher than fall 2013 simulated heads in the central and southern West Coast Basin (figs. D10*B*, D10*D*). Groundwater flow in the Upper Wilmington A aquifer system was impeded by (1) the Newport-Inglewood fault zone; (2) the Santa Monica, Compton-Los Alamitos, PCH, and Alondra faults; and (3) parts of the Santa Fe Springs anticline and related structures.

Upper Wilmington B Aquifer System

Fall 2013 simulated hydraulic heads in the Upper Wilmington B aquifer system in the Central Basin were similar to fall 2013 simulated hydraulic heads in the Upper Wilmington A aquifer system, with the exception of the Central Basin Pressure Area west of the Compton-Los Alamitos fault (fig. D10*B*). In the area west of the Compton-Los Alamitos fault, simulated heads for the Upper Wilmington B aquifer system ranged from –40 to –90 ft, which was slightly higher than simulated heads in the Upper Wilmington A aquifer system. Spring 2006 simulated heads ranged from about the same as fall 2013 simulated heads in northwestern Central Basin to more than 45 ft higher than fall 2013 simulated heads in the southeastern Central Basin (figs. D10*B*, D10*D*).

Fall 2013 simulated heads for the Upper Wilmington B aquifer system in the West Coast Basin were similar to or slightly higher than simulated heads for the Upper Wilmington A aquifer system, where both aquifer systems are present (fig. D10*B*). The Upper Wilmington B aquifer system is not present in the northeastern part of the groundwater basin, where simulated pumping in the Upper Wilmington A aquifer system resulted in simulated heads of –70 ft (fig. D10*B*). Pumping in the northeastern West Coast Basin did not cause declines in the Upper Wilmington B aquifer system, where the system is present west of the pumping center at well 17G4 (3S/14W-17G4; figs. A3, D10*B*). Reichard and others (2003) concluded that a southeastern extension of the Charnock fault caused water-level offsets and prevented head changes in response to pumping. However, the chronostratigraphic model developed for this study indicated that the Charnock fault only extends up into the "Repetto" rock unit and does not cut the overlying units (see Chapter B; fig. B5). Data collected for this study indicated that the deposition of the Upper Wilmington A chronostratigraphic unit coincided with erosion and complete removal of the Upper Wilmington B unit in the northeastern West Coast Basin, forming a channel with different hydraulic properties on either side of the channel wall. This channelization is the suspected reason for observed water-level offsets and the lack of response to pumping in wells west of the pumping center in the Upper Wilmington B aquifer system (fig. D10*B*). Spring 2006 simulated heads were mostly about 0 to 10 ft higher than fall 2013 heads, with the exception of the northeastern West Coast Basin where spring 2006 simulated heads were up to 10 ft lower than fall 2013 simulated heads (figs. D10*B*, D10*D*). Groundwater flow in the Upper Wilmington B aquifer system was impeded by (1) the Newport-Inglewood fault zone; (2) the Compton-Los Alamitos, PCH, and Alondra faults; and (3) parts of the Santa Fe Springs anticline and related structures.

Lower Wilmington Aquifer System

Fall 2013 simulated hydraulic heads in the Lower Wilmington aquifer system in the Central Basin were similar to fall 2013 simulated hydraulic heads in the Upper Wilmington B aquifer system. However, fall 2013 simulated hydraulic heads in the Lower Wilmington aquifer system were slightly lower in the Montebello Forebay and 20 to 40 ft higher in the Central Basin Pressure Area west of the Compton-Los Alamitos fault compared to fall 2013 simulated hydraulic heads in the Upper Wilmington B aquifer system (fig. D10*B*). Simulated heads were 0 to 10 ft higher than measured heads in the Montebello Forebay and within 15 ft of measured heads in most of the Central Basin Pressure Area (fig. D10*B*). Spring 2006 simulated heads were mostly higher than fall 2013 simulated heads in the Central Basin, with simulated heads 0 to 15 ft higher in the northwestern Central Basin, 15 to 50 ft higher in the central Central Basin, and 10 to 25 ft higher in the southwestern and southeastern Central Basin (figs. D10*B*, D10*D*).

Fall 2013 simulated hydraulic heads in the Lower Wilmington aquifer system in the West Coast Basin ranged from as high as –25 ft on the northwest and southeastern ends of the groundwater basin to as low as –80 ft in the northeastern end of the groundwater basin (fig. D10*B*). Pumping in the northeastern part of the groundwater basin caused a drawdown cone in both simulated and measured heads that extends to the west (fig. D10*B*). The presence of the drawdown cone provided further evidence that the Charnock fault is not a barrier to flow in the West Coast Basin. Instead, the groundwater barrier effect observed in the overlying Upper Wilmington A and B aquifer systems likely is related to the previously discussed channelization in those units. In general, simulated hydraulic heads reasonably matched measured heads in the West Coast Basin (fig. D10*B*). Spring 2006 simulated heads were up to 10 ft lower than fall 2013 simulated heads in the northern West Coast Basin and up to 10 ft higher than fall 2013 simulated heads in the southern West Coast Basin (figs. D10*B*, D10*D*). Groundwater flow in the Lower Wilmington aquifer system was impeded by (1) the Newport-Inglewood fault zone; (2) the Compton-Los Alamitos, PCH, and Alondra faults; and (3) parts of the Santa Fe Springs anticline and related structures.

Long Beach A Aquifer System

Fall 2013 simulated hydraulic heads in the Long Beach A aquifer system were similar to fall 2013 simulated hydraulic heads in the Lower Wilmington aquifer system but were 10 to 20 ft higher in the Central Basin Pressure Area west of the Compton-Los Alamitos fault (fig. D10*B*). In the West Coast Basin, simulated heads in the Long Beach A aquifer system were similar in the overlying Lower Wilmington aquifer system but were about 20 ft higher in the pumping depression in the northeastern part of the groundwater basin (fig. D10*B*). Simulated heads were mostly between 0 and 20 ft higher than measured heads, except for the northwestern West Coast Basin where simulated heads were more than 30 ft higher than measured heads (fig. D10*B*). Spring 2006 simulated heads were 10 to 25 ft higher in the Montebello Forebay than fall 2013 simulated heads, 0 to 10 ft higher in the Los Angeles Forebay and Central Basin Pressure Area, and 5 ft lower to 5 ft higher in West Coast Basin (figs. D10*B*, D10*D*). Groundwater flow in the Long Beach A aquifer system was impeded by (1) the Newport-Inglewood fault zone; (2) the Compton-Los Alamitos, PCH, and Alondra faults; and (3) parts of the Santa Fe Springs anticline and related structures.

Long Beach B Aquifer System

Fall 2013 simulated heads in the Long Beach B aquifer system were similar to fall 2013 simulated hydraulic heads in the overlying Long Beach A aquifer system in the Central and West Coast Basins but generally were higher and showed less response to pumping (fig. D10*B*). Simulated heads were up to 35 ft higher than measured heads in the Central Basin Pressure Area but were mostly within 10 ft of measured heads in the remainder of the model area (fig. D10*B*). Spring 2006 simulated heads were 5 to 25 ft higher than fall 2013 simulated heads in the Montebello Forebay, 5 to 15 ft higher in the northeastern Central Basin, 0 to 5 ft higher in the central and southern Central Basin, and 0 to 10 ft lower in the West Coast Basin. Groundwater flow in the Long Beach B aquifer system was impeded by (1) the Newport-Inglewood fault zone; (2) the Compton-Los Alamitos, PCH, and Alondra faults; and (3) parts of the Santa Fe Springs anticline and related structures.

Long Beach C Aquifer System

Simulated hydraulic heads in the Long Beach C aquifer system in the Central and West Coast Basins were higher than simulated heads in the Long Beach B aquifer system (fig. D10*B*). Simulated heads were highest in the Montebello Forebay, where they were above 220 ft in some areas, and lowest in the northwestern West Coast Basin, where they were below –20 ft (fig. D10*B*). Simulated heads in the Long Beach C aquifer system were mostly within 10 ft of measured heads in the Montebello Forebay and were within 5 ft of measured heads in the northeastern West Coast Basin (fig. D10*B*). Spring 2006 simulated heads were 5 to 25 ft higher than fall 2013 simulated heads in the northern Central Basin, 0 to 5 ft higher than fall 2013 simulated heads in the southern Central Basin, and within 5 ft of fall 2013 simulated heads in the West Coast Basin. Groundwater flow in the Long Beach C aquifer system was impeded by (1) the Newport-Inglewood fault zone; (2) the Santa Monica, Compton-Los Alamitos, PCH, and Alondra faults; and (3) parts of the Santa Fe Springs anticline and related structures.

Model-Parameter Sensitivity

A sensitivity analysis evaluates the sensitivity of model results to variations in model input parameters. The input parameters for the LACPGM included (1) areal recharge, (2) aquifer system properties (HK, VK, specific yield, and specific storage), (3) HFB hydraulic-characteristic values, (4) GHB conductances and heads, (5) CLN parameters, and (6) drain conductance. Each of the input parameters was assigned according to zones or segments for each layer of the mode1 (figs. D1, D2*A*, D7, D8). Because there were 12 active model layers, there were a large number of parameters (1,726) to estimate for the LACPGM: 17 areal recharge, 381 HK, 381 VK, 381 specific yield, 381 specific storage, 147 HFB, and 88 GHB parameters.

Model-parameter sensitivity analyses were done using PEST, an automatic parameter inversion program. PEST calculates an objective-function value based on the weighted sum of squared differences between measured and simulated results (Doherty, 2010). Parameter sensitivity is determined by the amount the objective function changes when a parameter is varied incrementally. The more the objective function changes when a parameter is varied, the more sensitive the objective function is to that parameter. There were three main types of observations—or values derived from observations—used to calibrate the model: (1) hydraulic-head, (2) change in hydraulic-head, and (3) vertical difference in hydraulic-head. Sensitivities with respect to each parameter were computed for contributions to the objective function from four subsets of observations: (1) all observations (the complete objective function), (2) head observations only, (3) drawdown observations only, and (4) vertical head difference observations only.

Composite scale sensitivity (CSS), described in Doherty (2010), can help evaluate the relative sensitivities with respect to groups of parameters (for example, all horizontal hydraulic conductivity parameters). The groups of parameters evaluated for composite scale sensitivity were (1) HK, (2) VK, (3) specific storage, (4) specific yield, (5) general-head boundary, and (6) recharge, and horizontal-flow barrier parameters. Composite scale sensitivities help show relative sensitivities with respect to parameter groups that may not be obvious from an evaluation of sensitivities with respect to single parameters. For example, recharge parameters were among the most sensitive parameters, but their composite sensivitity was lower than other parameter groups. The fewer parameters there are in a parameter group, the greater the average individual sensitivity of each parameter. Since there are considerably fewer recharge parameters than there are HK and VK parameters, individual recharge parameters have a higher sensitivity as a percentage of the recharge group sensitivity than the HK and VK parameters sensitivities as a percentage of the HK and VK group sensitivities.

The parameter types and their upper and lower bounds are shown in table D4, and the naming convention of the parameters is described in table D5. The types of parameters to which the composite of all observations (the complete objective function) was most sensitive were HK parameters and areal-recharge parameters (fig. D11*A*). The five most sensitive individual parameters were rch_mlt_1 (areal-recharge multiplier zone 1; fig. D2A), geohk05-34 (HK layer 5 zone 34), rch_mlt_10 (areal-recharge multiplier zone 10), geohk03-01 (HK layer 3 zone 1), and geohk03-07 (HK layer 3 zone 7). Parameter geohk05-34 controlled the HK of Pacific layer in the eastern Central Basin and the Orange County. Observations were most likely sensitive to geohk05-34 because it regulated flow between the Central Basin and Orange County. Parameters rch_mlt_1 and rch_mlt_10 controlled the amount of areal recharge in the eastern Whittier and northern Orange County areas and the northern West Coast Basin, respectively. Observations were most likely sensitive to rch_mlt_1 (Zone 1, fig. D02A) due to its upgradient location and rch_mlt_10 (Zone 10, fig. D02A) due to the large area of recharge it controls. Parameters geohk03-01 and geohk03-07 controlled the HK of the Mesa layer in the northern and southern regions of the Montebello Forebay, respectively. Observations were sensitive to geohk03-01 and geohk03-07 because they are two of the key parameters that regulated the rate of flow from the spreading grounds and the Whittier Narrows into the Central Basin.

The 30 parameters that observations were most sensitive to also included one VK parameter (geovk04-03) and one GHB conductance parameter (ghbwht_mes). Geovk04-03 controlled VK between the Pacific A layer and the layer above it in the Central Basin Pressure Area just south of the Montebello Forebay. Heads between the Pacific A layer and the layer above it were up to 50 ft different in this area. Observations were sensitive to geovk04-03 because it controlled the VK between the Pacific A layer and the layer above it and therefore influenced the vertical separation in heads in this area. Parameter wht_mes controlled the conductance of the Whittier Narrows GHB in the Mesa layer, where the majority of the 36,000 acre-ft/yr of underflow from the San Gabriel Valley entered the model.

The most sensitive parameters for hydraulic-head observations were those for areal recharge (for example, rech_mult 1, 10 and 11) and HK (fig. D11*B*). The most sensitive parameters for change in hydraulic-head observations included a variety of different types, including (1) areal-recharge parameters, (2) specific-yield parameters, (3) specific-storage parameters, (4) HK and VK parameters, and (5) horizontal-flow barrier conductance parameters (fig. D11*C*). Sensitivities varied much less for the change in hydraulic-head observations than any other observation type. The most sensitive parameters for vertical difference in hydraulic-head observations were HK, VK, and areal recharge (fig. D11*D*). More of the areal-recharge parameters were sensitive for the hydraulic-head observations than for all simulated values. The two most sensitive parameters for hydraulic-head observations and 8 of the top 30 most sensitive parameters to hydraulic-head observations were areal recharge parameters (fig. D11*B*). In contrast only 6 of the top 30 most sensitive parameters for all simulated values were areal recharge.

CSS values are shown in figure D12. Observations were most sensitive to the HK parameter group, followed by VK, specific-yield, and GHB/RCH parameter groups (fig. D12). Observations were considerably less sensitive to the horizontal-flow barrier parameter group. While recharge parameters were among the most sensitive (fig. D11), the composite sensivitity of the recharge parameter group was lower than the composite sensitivities of most other parameter groups (fig. D12).

Simulated Regional Groundwater Budget and Flow Between Subareas

The calibrated LACPGM was used to evaluate the average annual groundwater budget by model layer and subarea, averaged over the 45-year simulation period, 1971 to 2015 (table D6) and for a shorter 10-year simulation period, 2006–15 (table D7). The average-annual budget also was simulated for the entire model area and each model subarea for 1971 to 2015 to show changes in the major budget components over time (fig. D13 and appendix 4, fig. 4.1). Average annual model-simulated lateral flows between model subareas and vertical flows between model layers were used to quantify groundwater flow within the LACPGM (fig. D14 and appendix 4, fig. 4.2).

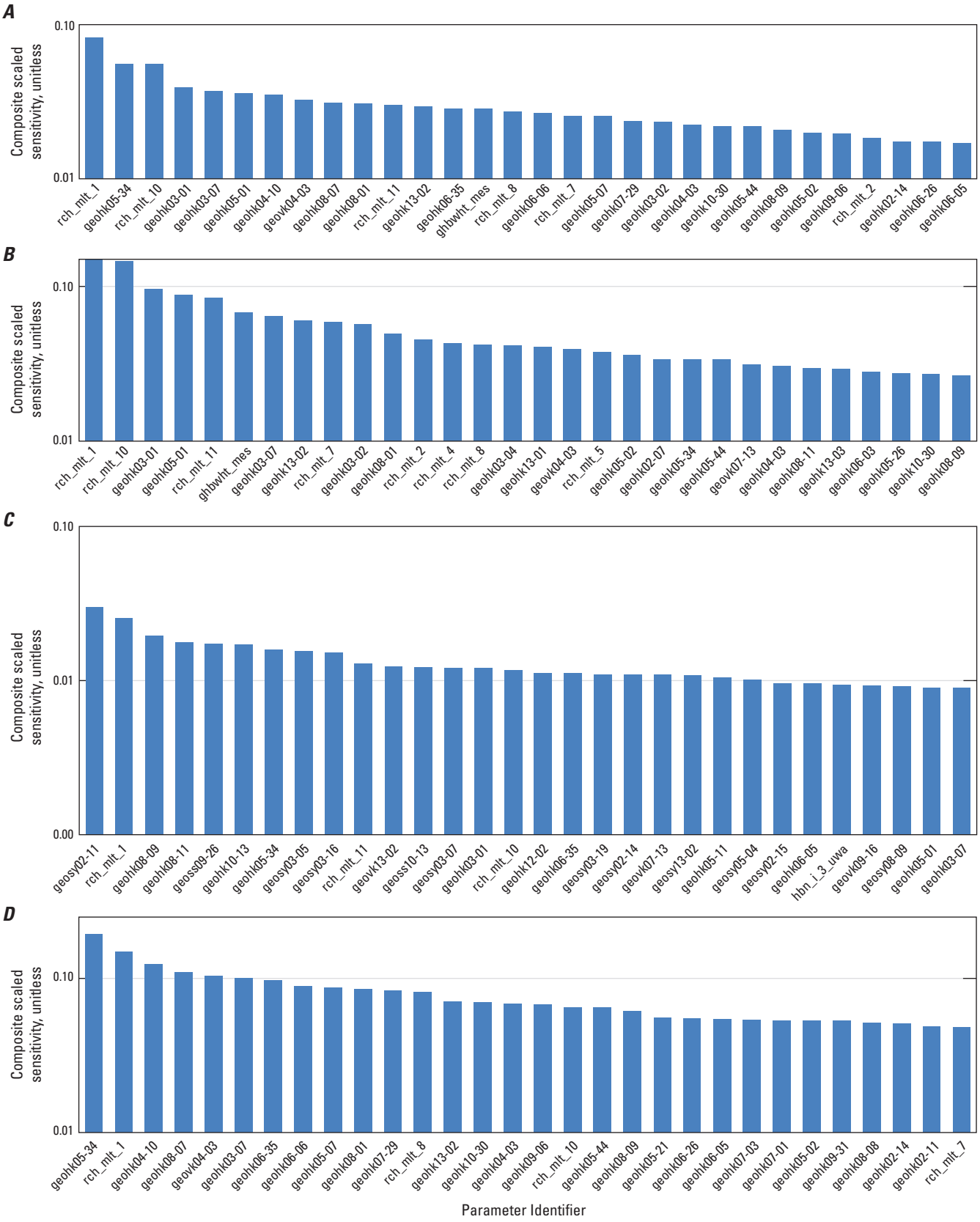


Figure D11. Top 30 parameters with high observation sensitivity values for *A*, all simulated values; *B,* hydraulic heads only; *C*, changes in hydraulic head only; and *D*, vertical differences in hydraulic head only, Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California.

Table D4. Parameter type and upper and lower bound for parameters in the Los Angeles Coastal Plain Groundwater-flow Model.

[ft^2/day, square foot per day; ft/day, foot per day; ft^{-1}, per foot]

Parameter type	Lower bound	Upper bound
Drain (DRN) conductance (ft^2/day)	1.00E–04	1.00E+06
General head boundary (GHB) conductance (ft^2/day)	1.00E–04	1.00E+06
Horizonal flow barrier (HFB) conductance (ft^2/day)	1.00E–10	1.00E+05
Horizontal hydraulic conductivity (HK; ft/day)	1.00E–09	1.50E+03
Areal recharge (RCH) multiplier (unitless)	5.00E–01	2.00E+00
Specific storage (SS) (ft^{-1})	1.00E–06	1.00E–04
Specific yield (SY)	1.00E–06	3.00E–01
Vertical hydraulic conductivity (VK; ft/day)	1.00E–09	1.50E+03

Table D5. Parameter code explanation for the Los Angeles Coastal Plain Groundwater-flow Model.

Parameter type	Name construction	Example	Example description
General head boundary (GHB) conductance	ghb<name>_<layer>_<subname>	ghboc_dm_mn	GHB for Orange County Dominguez layer mid-north
General head boundary (GHB) increased head	ghb<name>_<layer>_<subname>_a	ghboc_pc_n_a	GHB for Orange County Pacific layer north
Horizonal flow barrier (HFB) conductance	hb<name>_<layer>	hbpch_lw	HFB for Pacific Coast Highway fault in Lower Wilmington
Horizontal hydraulic conductivity (HK)	geohk<layer>-<zone>	geohk05-34	HK for layer 5 zone 34
Areal recharge (RCH) multiplier	rch_mlt<zone>	rch_mlt_11	RCH multiplier for recharge zone 11
Specific storage (SS)	geoss<layer>-<zone>	geoss06-08	SS for layer 6 zone 8
Specific yield (SY)	geosy<layer>-<zone>	geosy03-15	SY for layer 3 zone 15
Vertical hydraulic conductivity (VK)	geovk<layer>-<zone>	geovk04-03	VK for layer 4 zone 3

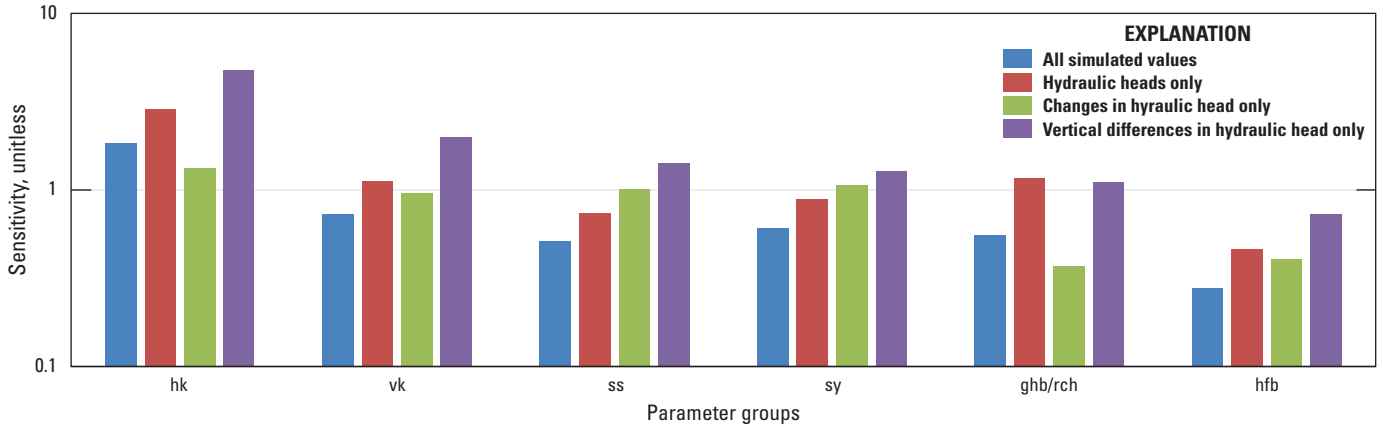


Figure D12. Composite scale sensitivity values for all simulated values, hydraulic heads only, changes in hydraulic head only, and vertical differences in hydraulic head only, for selected parameter types, Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California.

Table D6. Simulated average 45-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 1971 to 2015, Los Angeles County, California.

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone. Pumping and injection by layer includes interborehole flow from all wells. Pumping and injection totals without interborehole flow included separately in this table. **Abbreviation**: WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Pumping and net interborehole flow out														
Dominguez	2	0.00	–8,970	–4,090	–32.4	0.00	0.00	–9.5	–308	0.00	0.00	0.00	–44.8	–13,500
Mesa	3	0.00	–8,200	–4,040	–1,060	–403	0.00	–2,470	–6,190	–8.3	–8.01	0.00	–73.0	–22,400
Pacific A	4	0.00	–33,500	–10,800	–6.39	0.00	0.00	–641	–2,390	0.00	0.00	0.00	0.00	–47,400
Pacific	5	0.00	–23,600	–21,500	–7,570	–1,100	–92.5	–7,250	–18,900	–63.5	–47.4	0.00	–3,220	–83,400
Harbor	6	0.00	–28,600	–6,300	–8,370	0.00	0.00	–1,250	–6,540	–1.59	–46.8	0.00	–1,210	–52,300
Bent Spring	7	0.00	–8,240	–1,100	–6,720	–4,580	–400	–3,130	–1,280	0.00	–137	0.00	–99.5	–25,700
Upper Wilmington A	8	–1,220	–16,100	–3,180	–18,800	–78.2	–344	–4,490	–6,590	–10.2	0.00	–15.1	–992	–51,800
Upper Wilmington B	9	0.00	–6,530	–410	–2,400	–131	–4.52	–755	–384	–25.5	0.00	–28.2	0.00	–10,700
Lower Wilmington	10	0.00	–1,920	0.00	–5,770	–86.6	0.00	–791	–635	–329	0.00	–503	0.00	–10,000
Long Beach A	11	0.00	–453	0.00	–687	0.00	0.00	–6.78	–421	–1.34	0.00	–122	0.00	–1,690
Long Beach B	12	0.00	–296	0.00	–153	0.00	0.00	–99.2	–152	–697	0.00	0.00	0.00	–1,400
Long Beach C	13	0.00	0.00	0.00	0.00	–2.24	0.00	–11.5	–2,940	0.00	0.00	0.00	0.00	–2,950
Total		–1,220	–136,000	–51,500	–51,500	–6,380	–841	–20,900	–46,800	–1,140	–239	–668	–5,640	–323,000
Pumping without interborehole flow														
Total		0.00	–130,224	–47,681	–49,763	–6,704	–809	–18,535	–45,498	–986	–238	–649	–5,101	–306,188
Net flow from adjacent inland zones														
Dominguez	2	–459	11,600	–2,690	17.4	12.9	–99	235	–10,900	–82.6	73.7	6.37	2,250	–3.68E–11
Mesa	3	–1,130	25,700	–317	976	–303	–1,030	3,690	–28,500	–670	669	0.00	931	4.23E–11
Pacific A	4	–259	11,200	1,630	–65.9	0.00	0.00	–2,210	–9,020	–243	–1,030	0.00	0.00	–3.09E–11
Pacific	5	–3,010	18,600	8,590	–366	261	–219	6,100	–24,500	–360	–542	–533	–3,980	–6.68E–11
Harbor	6	–322	19,300	1,420	–692	–9.25	0.00	–78.8	–17,500	–77.6	–271	0.00	–1,820	–6.82E–13
Bent Spring	7	–801	11,600	672	365	372	–1,150	1,320	–13,200	0.00	910	0.00	–59.5	2.57E–11
Upper Wilmington A	8	–1,930	6,300	–654	1,830	–1,390	–33.4	5,050	–7,540	–202	–129	–738	–550	–1.73E–11
Upper Wilmington B	9	–119	3,460	–2,660	320	120	–19.3	570	–1,440	296	–238	–349	56.8	–4.03E–12
Lower Wilmington	10	–61.1	2,960	–463	1,900	–257	4.62	690	–4,090	113	–161	–475	–168	–3.04E–12
Long Beach A	11	–0.181	662	15.4	801	–143	–0.0162	41.5	314	–18.5	–1.15	–1,110	–556	6.82E–13
Long Beach B	12	37.7	782	–203	546	–103	0.968	–1.67	–300	316	10.2	–447	–639	1.93E–12
Long Beach C	13	–662	1,880	108	1,070	–340	–0.311	48.6	–1,030	–916	–43.2	23.4	–134	3.41E–13
Total		–8,720	114,000	5,450	6,690	–1,780	–2,540	15,500	–118,000	–1,840	–758	–3,630	–4,670	–9.82E–11

Table D6. Simulated average 45-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 1971 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone. Pumping and injection by layer includes interborehole flow from all wells. Pumping and injection totals without interborehole flow included separately in this table. **Abbreviation**: WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Water spreading														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82,800	0.00	0.00	0.00	0.00	82,800
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37,500	0.00	0.00	0.00	0.00	37,500
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,400	0.00	0.00	0.00	0.00	2,400
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	123,000	0.00	0.00	0.00	0.00	123,000
Injection and net interborehole flow in														
Dominguez	2	0.00	7.33E–05	0.000192	28.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.0
Mesa	3	0.00	631	220	2,760	0.00	0.00	0.00	11.6	0.00	0.00	0.00	758	4,380
Pacific A	4	0.00	1,520	2,530	0.00	0.00	0.00	0.00	549	0.00	0.00	0.00	0.00	4,590
Pacific	5	0.00	4,560	1,000	9,720	0.00	0.00	1,180	137	0.00	0.00	0.00	1,190	17,800
Harbor	6	0.00	1,020	41.3	5,460	0.00	0.00	980	377	0.00103	0.00	0.00	1,240	9,110
Bent Spring	7	0.00	414	0.00	9,860	45.3	31.6	199	19.0	0.00	0.549	0.00	0.792	10,600
Upper Wilmington A	8	1,220	376	0.00	1,110	0.00	0.00	13.5	170	2.27	0.00	1.42	13.4	2,910
Upper Wilmington B	9	0.00	199	3.06	16.1	0.724	0.00	0.00	3.48E–05	0.899	0.00	9.54	0.00	229
Lower Wilmington	10	0.00	14.1	0.00	51.8	0.00	0.00	0.00	5.70	0.793	0.00	5.64	0.00	78.0
Long Beach A	11	0.00	0.00211	0.00	0.0878	0.00	0.00	0.00	0.00119	25.9	0.00	2.26	0.00	28.2
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00158	120	0.00	0.00	0.00	120
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.03E–05	0.00	0.00	0.00	0.00	4.03E–05
Total		1,220	8,730	3,800	29,000	46.1	31.6	2,370	1,270	150	0.549	18.9	3,200	49,800

Table D6. Simulated average 45-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 1971 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone. Pumping and injection by layer includes interborehole flow from all wells. Pumping and injection totals without interborehole flow included separately in this table. **Abbreviation**: WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Injection without interborehole flow														
Total		0.00	2,615	0.00	27,253	365	0.00	0.00	0.00	0.00	0.00	0.00	2,660	32,893
Areal recharge														
Dominguez	2	1,160	8,280	2,900	1,110	1,400	1,730	1,400	2,070	281	435	25.3	423	21,200
Mesa	3	1,660	3,490	23.7	8,990	6,380	1,030	40.2	1,000	362	788	0.00	208	24,000
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	315	41.3	701	902	0.0458	0.00	200	464	177	752	0.00142	3,550
Harbor	6	197	3.29	0.00	237	0.00	0.00	182	1.34	0.00	0.00	0.00	0.00	620
Bent Spring	7	14.9	0.00	0.00	779	6.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	801
Upper Wilmington A	8	0.00	27.1	8.07	136	61.3	0.00	33.4	176	46.7	0.00	198	0.00	686
Upper Wilmington B	9	0.00	0.00	0.00	16.5	8.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.2
Lower Wilmington	10	0.00	20.6	0.00	0.00	0.00	0.00	0.00	0.00	23.8	0.00	68.9	0.00	113
Long Beach A	11	0.00	5.82	0.00	0.00	0.00	0.00	0.00	24.8	1.34	0.00	62.7	0.00	94.6
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.22	0.00	0.00	0.00	0.00	6.22
Long Beach C	13	209	95.1	0.00	93.7	2.99	0.00	125	1,190	1,090	54	112	0.00	2,980
Total		3,240	12,200	2,970	12,100	8,760	2,760	1,780	4,670	2,270	1,450	1,220	631	54,000
Flow from Santa Monica Bay														
Dominguez	2	0.00	0.00	0.00	0.00	0.00068	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00068
Mesa	3	0.00	0.00	0.00	–74.3	–156	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–230
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	–74.6	21.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–53.1
Harbor	6	0.00	0.00	0.00	–58.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–58.7
Bent Spring	7	0.00	0.00	0.00	187	29.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	216
Upper Wilmington A	8	0.00	0.00	0.00	–5.59	95.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	89.8
Upper Wilmington B	9	0.00	0.00	0.00	–61.6	–14.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–75.7
Lower Wilmington	10	0.00	0.00	0.00	180	–38.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	142
Long Beach A	11	0.00	0.00	0.00	–3.68	–15.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–18.8
Long Beach B	12	0.00	0.00	0.00	2.85	–7.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–4.40
Long Beach C	13	0.00	0.00	0.00	2.08	9.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.5
Total		0.00	0.00	0.00	93.5	–74.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.6

Table D6. Simulated average 45-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 1971 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone. Pumping and injection by layer includes interborehole flow from all wells. Pumping and injection totals without interborehole flow included separately in this table. **Abbreviation**: WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Flow from San Pedro Bay														
Dominguez	2	0.00	0.00	0.00	344	0.00	0.00	0.00	0.00	0.00	0.00	0.00	42.3	386
Mesa	3	0.00	0.00	0.00	43.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	188	232
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	1,380	0.00	0.00	0.00	0.00	0.00	0.00	0.00	310	1,690
Harbor	6	0.00	0.00	0.00	1,320	0.00	0.00	0.00	0.00	0.00	0.00	0.00	851	2,170
Bent Spring	7	0.00	0.00	0.00	540	0.00	0.00	0.00	0.00	0.00	0.00	0.00	73.3	613
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	222	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	222
Lower Wilmington	10	0.00	0.00	0.00	1,650	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82.6	1,730
Long Beach A	11	0.00	0.00	0.00	327	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–341	–14.3
Long Beach B	12	0.00	0.00	0.00	340	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–101	238
Long Beach C	13	0.00	0.00	0.00	98.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–332	–233
Total		0.00	0.00	0.00	6,270	0.00	0.00	0.00	0.00	0.00	0.00	0.00	775	7,050
Underflow from Orange County														
Dominguez	2	0.00	0.00	6,200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	78.5	6,280
Mesa	3	0.00	0.00	2,080	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	569	2,640
Pacific A	4	0.00	0.00	6,590	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6,590
Pacific	5	0.00	0.00	10,500	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–42.1	824	11,200
Harbor	6	0.00	0.00	4,040	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	282	4,330
Bent Spring	7	0.00	0.00	131	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	78.2	209
Upper Wilmington A	8	0.00	0.00	6,020	0.00	0.00	0.00	0.00	0.00	0.00	0.00	934	1,500	8,450
Upper Wilmington B	9	0.00	0.00	3,070	0.00	0.00	0.00	0.00	0.00	0.00	0.00	321	–41.2	3,350
Lower Wilmington	10	0.00	0.00	276	0.00	0.00	0.00	0.00	0.00	0.00	0.00	890	40.6	1,210
Long Beach A	11	0.00	0.00	62.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,270	941	2,270
Long Beach B	12	0.00	0.00	106	0.00	0.00	0.00	0.00	0.00	0.00	0.00	136	771	1,010
Long Beach C	13	0.00	0.00	41.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	138	483	662
Total		0.00	0.00	39,100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3,640	5,520	48,200

Table D6. Simulated average 45-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 1971 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone. Pumping and injection by layer includes interborehole flow from all wells. Pumping and injection totals without interborehole flow included separately in this table. **Abbreviation**: WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Underflow from San Gabriel Valley														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30,200	0.00	0.00	0.00	0.00	30,200
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6,120	0.00	0.00	0.00	0.00	6,120
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	36,300	0.00	0.00	0.00	0.00	36,300
Underflow from Palos Verdes Hills														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	2.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.95
Long Beach A	11	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93
Long Beach B	12	0.00	0.00	0.00	0.502	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.502
Long Beach C	13	0.00	0.00	0.00	26.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.1
Total		0.00	0.00	0.00	30.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.5

Table D6. Simulated average 45-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 1971 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone. Pumping and injection by layer includes interborehole flow from all wells. Pumping and injection totals without interborehole flow included separately in this table. **Abbreviation**: WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Flow from Marina Del Rey														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	147	0.00	0.00	0.00	0.00	0.00	0.00	0.00	147
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	147	0.00	0.00	0.00	0.00	0.00	0.00	0.00	147
Flow from Port of Long Beach														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	–0.000962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–0.000962
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	–0.000962	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–0.000962

Table D6. Simulated average 45-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 1971 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone. Pumping and injection by layer includes interborehole flow from all wells. Pumping and injection totals without interborehole flow included separately in this table. **Abbreviation**: WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Underflow from San Fernando Valley														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	5,410	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5,410
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		5,410	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5,410
							Drains							
Dominguez	2	0.00	–133	–12.3	–7.31	–298	0.00	0.00	–1,430	0.00	–421	–32.2	–3.50	–2,340
Mesa	3	0.00	–66.8	0.00	0.00	–850	0.00	0.00	0.00	0.00	0.00	0.00	–0.291	–917
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	–228	0.00	0.00	–1,020	–6.85	0.00	–266	0.00	–1,520
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	–1,390	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–1,390
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–384	0.00	–384
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–49.5	0.00	–49.5
Long Beach A	11	0.00	–614	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–15.1	0.00	–629
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	–814	–12.3	–7.31	–2,770	0.00	0.00	–2,450	–6.85	–421	–747	–3.79	–7,230
Total net flow		–73.5	–2,240	–207	2,630	–2,060	–598	–1,300	–1,880	–565	35.8	–161	–190	–6,600

Table D6. Simulated average 45-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 1971 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone. Pumping and injection by layer includes interborehole flow from all wells. Pumping and injection totals without interborehole flow included separately in this table. **Abbreviation**: WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
						Change in storage								
Dominguez	2	–461	–1,850	29.9	45.0	–687	–75.4	–1,180	–969	–42.3	–210	24.8	–135	–5,510
Mesa	3	22.5	–331	–4.94	2010	–628	–165	–252	–902	–260	206	0.00	–36.1	–343
Pacific A	4	12.6	205	–1.35	0.686	0.00	0.00	0.733	–8.05	–5.67	3.88	0.00	0.00	208
Pacific	5	7.77	–226	–8.81	82.0	–739	–5.25	40.1	–69.8	–131	2.48	–98.8	–10.8	–1,160
Harbor	6	4.86	1.52	–5.83	99.6	–0.00753	0.00	51.6	–21.7	–39.3	0.410	0.00	–1.33	89.8
Bent Spring	7	6.34	0.811	–7.17	219	–14.6	–99.4	2.15	–0.547	0.00	11.9	0.00	–0.206	118
Upper Wilmington A	8	242	6.35	–145	30.9	46.2	–257	29.3	24.0	4.97	5.02	–179	–0.505	–193
Upper Wilmington B	9	2.90	20.0	–3.19	33.1	6.83	–2.03	4.06	–1.60	0.975	10.9	–3.65	–0.974	67.3
Lower Wilmington	10	20.9	9.05	–1.98	67.6	1.84	6.40	5.97	–2.41	–0.293	3.54	–0.0903	–0.416	110
Long Beach A	11	–2.97	9.54	–7.71	26.6	0.968	0.00372	–2.95	–18.4	12.7	0.0503	117	–0.617	135
Long Beach B	12	–0.440	–27.6	–24.5	17.9	2.35	0.0294	–1.83	–17.0	–1.92	0.920	–3.92	–1.81	–57.7
Long Beach C	13	70.3	–63.6	–28.0	0.758	–48.6	–0.0741	–1.33	101	–103	–0.297	–16.9	–3.05	–92.9
Total		–74.0	–2,250	–208	2,630	–2,060	–598	–1,300	–1,880	–565	35.5	–161	–191	–6,630

Table D7. Simulated average 10-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 2006 to 2015, Los Angeles County, California.

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone.]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Pumping and net interborehole flow out														
Dominguez	2	0.00	–8,220	–3,080	–24.1	0.00	0.00	–0.00216	–252	0.00	0.00	0.00	–31.4	–11,600
Mesa	3	0.00	–7,910	–3,350	–1,480	–333	0.00	–2,170	–5,230	–13.5	0.00	0.00	–184	–20,700
Pacific A	4	0.00	–28,400	–7,880	–0.00031	0.00	0.00	–644	–2,420	0.00	0.00	0.00	0.00	–39,300
Pacific	5	0.00	–25,200	–25,500	–5,080	–1,160	–173	–5,600	–18,000	–16.9	–0.603	0.00	–3,210	–83,900
Harbor	6	0.00	–32,600	–9,610	–9,190	0.00	0.00	–686	–7,910	–7.13	0.00	0.00	–1,000	–61,000
Bent Spring	7	0.00	–11,100	–2,090	–4,130	–4,390	–799	–3,310	–2,390	0.00	–20.7	0.00	–62.2	–28,300
Upper Wilmington A	8	–1,260	–17,600	–3,630	–14,200	–113	–974	–3,770	–5,530	0.00	0.00	0.00	–353	–47,400
Upper Wilmington B	9	0.00	–6,730	–485	–1,730	–297	–14.9	–630	–423	0.702	0.00	0.00	0.00	–10,300
Lower Wilmington	10	0.00	–2,210	0.00	–5,690	–146	0.00	–655	–459	–172	0.00	–141	0.00	–9,470
Long Beach A	11	0.00	–470	0.00	–761	0.00	0.00	–5.59	–252	0.00	0.00	0.00	0.00	–1,490
Long Beach B	12	0.00	–226	0.00	–155	0.00	0.00	–96.0	–246	0.00	0.00	0.00	0.00	–723
Long Beach C	13	0.00	0.00	0.00	0.00	–2.88	0.00	–21.8	–4,130	0.00	0.00	0.00	0.00	–4,150
Total		–1,260	–141,000	–55,600	–42,500	–6,440	–1,960	–17,600	–47,200	–210	–21.3	–141	–4,850	–318,000
Net flow from adjacent inland zones														
Dominguez	2	–325	10,600	–3,570	12.5	7.64	–75.3	127	–9,170	–82.1	33.9	4.72	2,400	–2.86E–11
Mesa	3	–794	21,500	–663	716	–160	–1,010	3,310	–23,100	–963	241	0.00	917	–2.93E–11
Pacific A	4	–133	8,880	958	–52.7	0.00	0.00	–1,100	–7,350	–221	–990	0.00	0.00	–2.21E–11
Pacific	5	–2,810	20,200	7,120	–674	287	–185	4,430	–22,600	–316	–617	–399	–4,460	4.55E–12
Harbor	6	–276	20,700	1,100	–1,030	–6.87	0.00	–865	–16,100	–216	–289	0.00	–3,000	1.23E–11
Bent Spring	7	–813	11,900	413	–78.5	400	–1,060	880	–12,400	0.00	825	0.00	–82.6	6.61E–11
Upper Wilmington A	8	–2,110	7,930	–488	1,480	–1,680	39.9	4,400	–7,290	–273	–157	–711	–1,140	6.59E–11
Upper Wilmington B	9	–141	3,480	–2,000	–179	169	–11.4	237	–1,300	267	–242	–329	57.6	–9.31E–13
Lower Wilmington	10	–166	3,200	–342	1,380	–230	–15.2	503	–3,560	58.2	–202	–492	–139	–2.13E–12
Long Beach A	11	–0.262	898	14.1	758	–142	–0.0131	34	359	–76.5	–1.33	–1,340	–506	–2.79E–12
Long Beach B	12	28.0	916	–192	493	–94.9	0.461	–20.4	–258	–177	12.9	–153	–556	1.48E–12
Long Beach C	13	–739	1,770	112	1,020	–292	–4.81	57.4	–919	–674	–36.1	–197	–98.0	–1.15E–12
Total		–8,280	112,000	2,470	3,850	–1,740	–2,320	12,000	–104,000	–2,670	–1,420	–3,610	–6,600	2.73E–11

Table D7. Simulated average 10-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 2006 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone.]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Water spreading														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	71,400	0.00	0.00	0.00	0.00	71,400
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26,100	0.00	0.00	0.00	0.00	26,100
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2,630	0.00	0.00	0.00	0.00	2,630
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	100,000	0.00	0.00	0.00	0.00	100,000
Injection and net interborehole flow in														
Dominguez	2	0.00	1.07	0.000685	35.4	0.00	0.00	0.000061	0.0000582	0.00	0.00	0.00	0.00	36.5
Mesa	3	0.00	709	244	1,950	0.000164	0.00	0.00	87.5	0.00	2.54	0.00	995	3,990
Pacific A	4	0.00	2,090	2,520	0.00	0.00	0.00	28.7	605	0.00	0.00	0.00	0.00	5,250
Pacific	5	0.00	6,060	1,920	7,940	0.00885	0.00	1,010	180	0.00	3.47	0.00	1,160	18,300
Harbor	6	0.00	1,620	97.3	5,010	0.00	0.00	1,170	555	0.00141	13.5	0.00	1,620	10,100
Bent Spring	7	0.00	793	0.00	8,430	148	29.1	564	25.7	0.00	0.604	0.00	4.12	10,000
Upper Wilmington A	8	1,260	842	0.879	1,270	0.00	19.6	27.5	183	11.4	0.00	31.6	62.5	3,710
Upper Wilmington B	9	0.00	360	11.7	68.1	2.80	0.00	4.78	1.11	0.933	0.00	25.7	0.00	475
Lower Wilmington	10	0.00	38.6	0.00	109	0.00	0.00	20.7	24.1	0.824	0.00	0.00	0.00	194
Long Beach A	11	0.00	2.40	0.00	0.223	0.00	0.00	0.00	0.0239	56.8	0.00	83.5	0.00	143
Long Beach B	12	0.00	0.54	0.00	0.00	0.00	0.00	0.00	3.92	89.1	0.00	0.00	0.00	93.6
Long Beach C	13	0.00	0.00	0.00	0.00	0.715	0.00	0.00	0.000464	0.00	0.00	0.00	0.00	0.715
Total		1,260	12,500	4,790	24,800	152	48.7	2,830	1,670	159	20.1	141	3,840	52,200

Table D7. Simulated average 10-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 2006 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone.]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Areal recharge														
Dominguez	2	576	4,590	1,460	586	688	784	795	1,030	145	236	10.6	210	11,100
Mesa	3	792	1,890	7.82	4,760	2,930	456	21.2	437	169	401	0.00	98.0	12,000
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	165	12.1	307	383	0.00201	0.00	97.6	228	105	340	0.00	1,640
Harbor	6	93.7	0.774	0.00	108	0.00	0.00	101	0.123	0.00	0.00	0.00	0.00	304
Bent Spring	7	7.15	0.00	0.00	328	0.344	0.00	0.00	0.00	0.00	0.00	0.00	0.00	335
Upper Wilmington A	8	0.00	11.6	2.39	71.1	25.7	0.00	12.7	86.0	14.9	0.00	78.9	0.00	303
Upper Wilmington B	9	0.00	0.00	0.00	7.31	0.669	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.98
Lower Wilmington	10	0.00	10.1	0.00	0.00	0.00	0.00	0.00	0.00	11.1	0.00	24.2	0.00	45.4
Long Beach A	11	0.00	1.36	0.00	0.00	0.00	0.00	0.00	13.6	0.121	0.00	24.2	0.00	39.2
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	0.00	0.00	0.00	0.00	2.10
Long Beach C	13	99.4	36.9	0.00	44.1	0.132	0.00	55.2	504	456	13.7	48.7	0.00	1,260
Total		1,570	6,710	1,480	6,210	4,020	1,240	986	2,180	1,020	755	527	308	27,000
Flow from Santa Monica Bay														
Dominguez	2	0.00	0.00	0.00	0.00	0.000132	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000132
Mesa	3	0.00	0.00	0.00	–58.9	–133	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–192
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	–43.9	–11.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–55.6
Harbor	6	0.00	0.00	0.00	–38.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–38.6
Bent Spring	7	0.00	0.00	0.00	130	61.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	191
Upper Wilmington A	8	0.00	0.00	0.00	–8.74	130	0.00	0.00	0.00	0.00	0.00	0.00	0.00	122
Upper Wilmington B	9	0.00	0.00	0.00	–56.6	–5.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–62.5
Lower Wilmington	10	0.00	0.00	0.00	161	–32.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	129
0Long Beach A	11	0.00	0.00	0.00	–2.72	–8.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–11.0
Long Beach B	12	0.00	0.00	0.00	2.60	–2.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.286
Long Beach C	13	0.00	0.00	0.00	–3.73	2.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–1.55
Total		0.00	0.00	0.00	80.4	0.696	0.00	0.00	0.00	0.00	0.00	0.00	0.00	81.1

Table D7. Simulated average 10-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 2006 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone.]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Flow from San Pedro Bay														
Dominguez	2	0.00	0.00	0.00	183	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40.6	224
Mesa	3	0.00	0.00	0.00	25.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	163	188
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	752	0.00	0.00	0.00	0.00	0.00	0.00	0.00	232	984
Harbor	6	0.00	0.00	0.00	756	0.00	0.00	0.00	0.00	0.00	0.00	0.00	717	1,470
Bent Spring	7	0.00	0.00	0.00	181	0.00	0.00	0.00	0.00	0.00	0.00	0.00	67.1	248
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	126	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126
Lower Wilmington	10	0.00	0.00	0.00	1,520	0.00	0.00	0.00	0.00	0.00	0.00	0.00	73.9	1,600
Long Beach A	11	0.00	0.00	0.00	317	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–321	–3.57
Long Beach B	12	0.00	0.00	0.00	318	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–94.8	224
Long Beach C	13	0.00	0.00	0.00	85.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–316	–231
Total		0.00	0.00	0.00	4,270	0.00	0.00	0.00	0.00	0.00	0.00	0.00	562	4,830
Underflow from Orange County														
Dominguez	2	0.00	0.00	6,770	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	66.5	6,840
Mesa	3	0.00	0.00	1,750	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	403	2,150
Pacific A	4	0.00	0.00	4,400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4,400
Pacific	5	0.00	0.00	15,200	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–7.99	1,600	16,700
Harbor	6	0.00	0.00	7,160	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	931	8,090
Bent Spring	7	0.00	0.00	1,100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	88	1,190
Upper Wilmington A	8	0.00	0.00	6,510	0.00	0.00	0.00	0.00	0.00	0.00	0.00	946	1,360	8,820
Upper Wilmington B	9	0.00	0.00	2,450	0.00	0.00	0.00	0.00	0.00	0.00	0.00	300	–66.2	2,690
Lower Wilmington	10	0.00	0.00	142	0.00	0.00	0.00	0.00	0.00	0.00	0.00	773	30.0	944
Long Beach A	11	0.00	0.00	58.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1,160	861	2,080
Long Beach B	12	0.00	0.00	99.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	103	680	883
Long Beach C	13	0.00	0.00	38.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	134	429	602
Total		0.00	0.00	45,600	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3,410	6,390	55,400

Table D7. Simulated average 10-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 2006 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone.]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Underflow from San Gabriel Basin														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31,600	0.00	0.00	0.00	0.00	31,600
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6,440	0.00	0.00	0.00	0.00	6,440
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00	38,000	0.00	0.00	0.00	0.00	38,000
Underflow from Palos Verdes Hills														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	2.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.80
Long Beach A	11	0.00	0.00	0.00	0.876	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.876
Long Beach B	12	0.00	0.00	0.00	0.474	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.474
Long Beach C	13	0.00	0.00	0.00	25.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.8
Total		0.00	0.00	0.00	30.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30.0

Table D7. Simulated average 10-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 2006 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone.]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whittier	Central Basin	North Orange County	South Orange County	Total
Flow from Marina Del Rey														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	126	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	126	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126
Flow from Port of Long Beach														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00074	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–0.00074
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	–0.00074	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–0.00074

Table D7. Simulated average 10-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 2006 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone.]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
Underflow from San Fernando Basin														
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	5,470	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5,470
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00.00	0.00.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		5,470	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5,470
Drains														
Dominguez	2	0.00	–5.91	0.00	0.00	–220	0.00	0.00	–31.1	0.00	–233	–37.2	0.00	–526
Mesa	3	0.00	–109	0.00	0.00	–273	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–382
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	–195	0.00	0.00	–604	–0.624	0.00	–179	0.00	–978
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	–530	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–530
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–353	0.00	–353
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–183	0.00	–183
Long Beach A	11	0.00	–881	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	–58.5	0.00	–940
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	–997	0.00	0.00	–1,220	0.00	0.00	–635	–0.624	–233	–811	0.00	–3,890
Total net flow		–1,240	–10,400	–1,260	–3,200	–5,100	–2,990	–1,780	–9,570	–1,700	–901	–485	–353	–39,000

Table D7. Simulated average 10-year water budget (acre-feet per year) by model layer and subarea of the Los Angeles Coastal Plain Groundwater-flow Model, 2006 to 2015, Los Angeles County, California.—Continued

[Negative numbers represent groundwater removed from the model/zone, and positive numbers represent groundwater added to the model/zone.]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
						Change in storage								
Dominguez	2	–453	–5,090	–640	–40.6	–926	–224	–847	–3,980	–81.2	–146	–6.72	–165	–12,600
Mesa	3	–326	–3,950	–22.5	–2,550	–1,450	–1,410	–546	–3,530	–814	–654	0.00	–110	–15,400
Pacific A	4	–7.39	–77.9	–9.26	0.000415	0.00	0.00	–1.06	–38.1	–24.8	–1.71	0.00	0.00	–160
Pacific	5	–7.66	–259	–35.4	–473	–2,340	–21.6	–79.6	–280	–204	–22.6	–221	–37.3	–3,980
Harbor	6	–60.5	–138	–33.4	–65.3	–0.0361	0.00	–124	–99.0	–177	–0.388	0.00	–7.12	–705
Bent Spring	7	–47.2	–122	–63.5	–244	–60.0	–526	–2.49	–4.10	0.00	–21.2	0.00	–2.36	–1,090
Upper Wilmington A	8	–99.2	–139	–352	5.52	–118	–790	–56.5	–486	–44.1	–2.28	–111	–7.66	–2,200
Upper Wilmington B	9	0.525	–266	–30.2	–54.3	–88.6	–5.80	–7.50	–8.74	–0.476	–20.1	–2.67	–6.33	–491
Lower Wilmington	10	–86.4	–92.9	–26.3	98.7	–50.4	–13.9	–13.4	–13.2	–6.51	–5.02	–11.3	–5.21	–226
Long Beach A	11	–3.60	–69.1	–18.7	48.8	–9.54	–0.0141	–8.73	–52.0	–5.47	–4.00	–79.3	–3.62	–205
Long Beach B	12	–1.65	–75.5	–17.9	31.9	–14.8	–0.159	–13.5	–64.2	–0.645	–9.19	3.33	–4.21	–166
Long Beach C	13	–148	–101	–14.5	32.9	–33.8	–4.68	–78.7	–1,010	–343	–14.8	–56.0	–3.88	–1,780
Total		–1,240	–10,400	–1,260	–3,200	–5,100	–2,990	–1,780	–9,570	–1,700	–901	–485	–353	–39,000

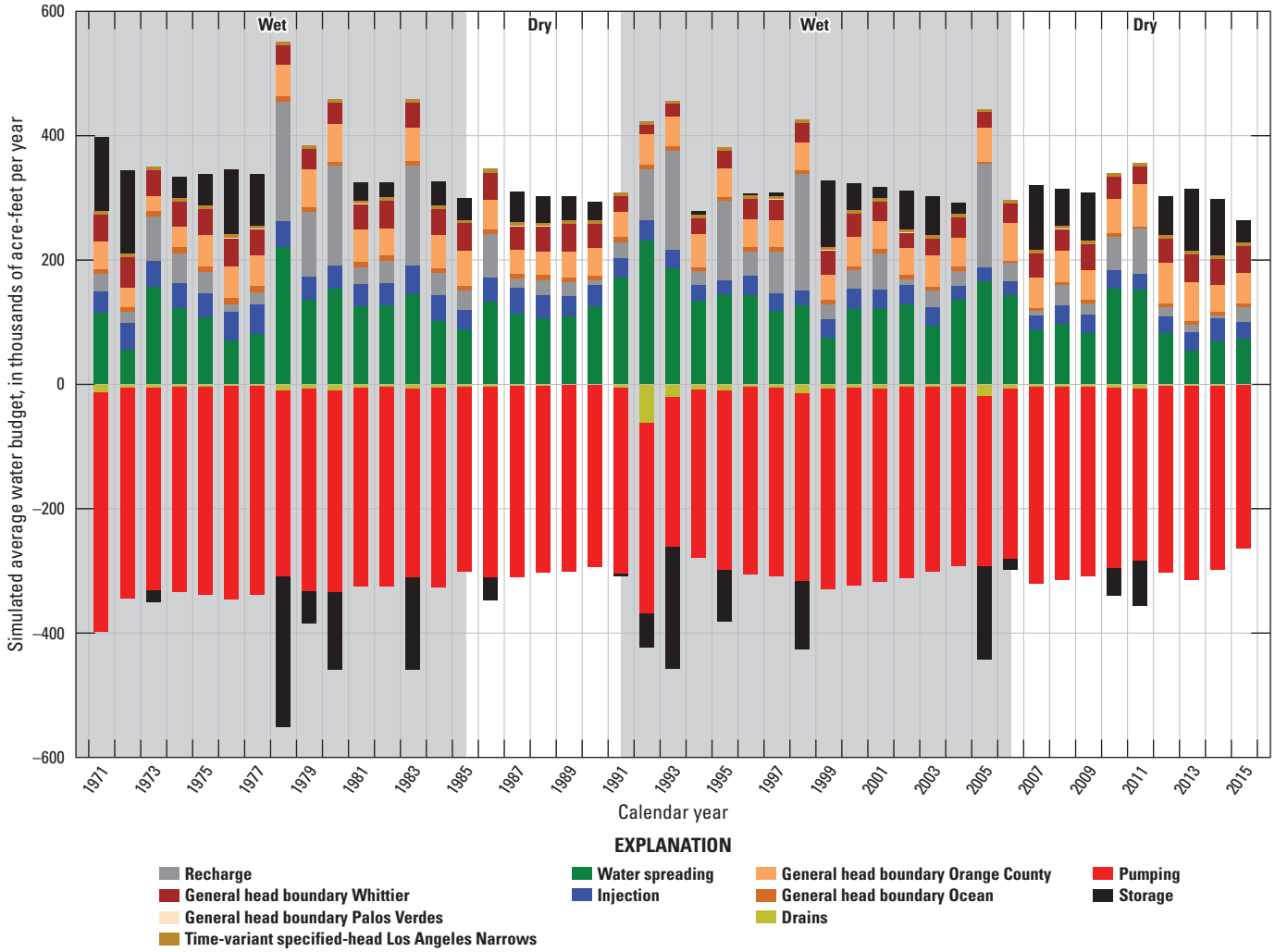
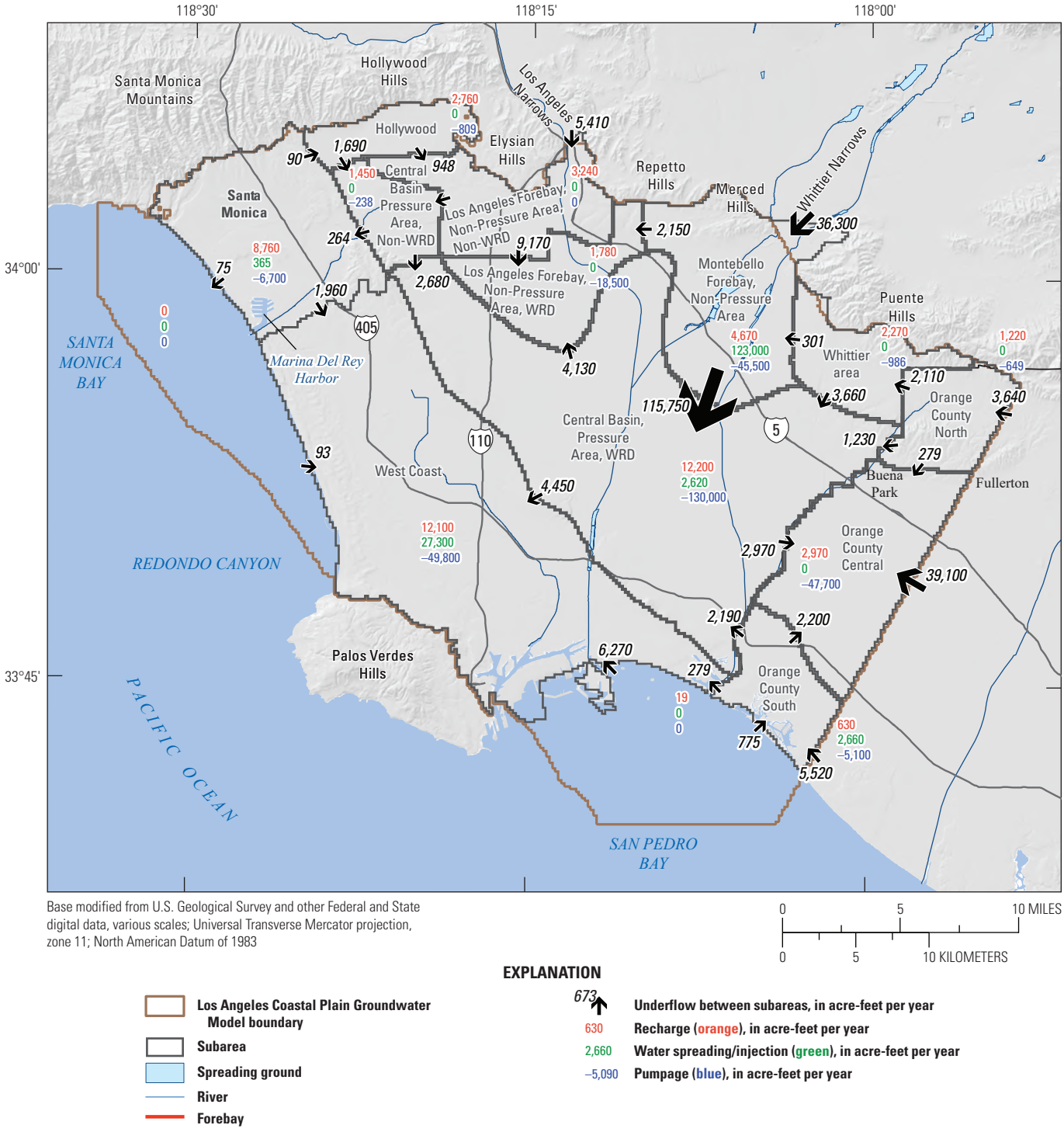


Figure D13. Simulated annual groundwater-flow budget for the Los Angeles Coastal Plain, 1971 to 2015, Los Angeles and Orange Counties, California.



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

EXPLANATION

- Los Angeles Coastal Plain Groundwater Model boundary
- Subarea
- Spreading ground
- River
- Forebay

- 673 — Underflow between subareas, in acre-feet per year
- 630 — Recharge (orange), in acre-feet per year
- 2,660 — Water spreading/injection (green), in acre-feet per year
- –5,090 — Pumpage (blue), in acre-feet per year

Figure D14. Simulated average annual groundwater flow between subareas in the Los Angeles Coastal Plain, 1971 to 2015, Los Angeles and Orange Counties, California. (Abbreviation: WRD, Water Replenishment District of Southern California)

Simulated Average Groundwater Budget, 1971 to 2015

Total simulated groundwater inflows averaged 312,800 acre-ft/yr for the 45-year simulation period, 1971 to 2015. Water spreading, which was specified in model input, was the largest inflow component, averaging 123,000 acre-ft/yr (table D6). Areal recharge is the next largest component, averaging 54,000 acre-ft/yr (table D6), which is 1,200 acre-ft/yr less than estimated by Hevesi and Johnson (2016; table C2). Injection was specified as model input and averaged 32,900 acre-ft/yr (table C2). Average underflows from San Fernando Valley and San Gabriel Valley were simulated as 5,410 and 36,300 acre-ft/yr, respectively (table D6). The simulated San Fernando Valley underflow is similar to previously estimated values of 6,200 acre-ft/yr (table C2); however, the simulated San Gabriel Valley underflow was about 8,700 acre-ft/yr higher than previous estimates of 27,600 acre-ft/yr (table C2). San Gabriel River Watermaster estimates of San Gabriel Valley underflow through the Whittier Narrows were included as observations in the calibration of the LACPGM (San Gabriel River Watermaster, 1997). Although the total simulated San Gabriel Valley underflow was greater than previous estimates, the average simulated underflow in the Mesa layer (30,200 acre-ft/yr) was approximately equal to previous estimates of underflow through the Whittier Narrows (table D6). The remaining 6,120 acre-ft/yr of underflow was simulated in the Long Beach C aquifer system (table D6), which was not estimated by previous investigators. Simulated inflows between the Pacific Ocean and the LACPGM averaged 7,070 acre-ft/yr (combined flow from Santa Monica and San Pedro Bays, table D6) and were similar to previous estimates (table C2).

The simulated underflow entering the model domain along the eastern edge of the LACPGM in Orange County averaged 48,336 acre-ft/yr (table D6), although most of this underflow was removed through pumping in Orange County prior to the underflow crossing into the Central Basin. The eastern edge of the LACPGM is approximately 5 mi east of the previous model boundary (Reichard and others, 2003), and the previous model simulated underflow across this boundary at 8,000 acre-ft/yr from 1971 to 2000. Underflow estimates are not directly comparable given the 5-mi separation in model boundaries.

Total simulated groundwater outflows average 313,400 acre-ft/yr (that is, about 306,200 acre-ft/yr of pumping and 7,200 acre-ft/yr from drains; averaged yearly values from tables 4.14–4.19) and were similar to previous estimates of outflow (310,800 acre-ft/yr, table C2). Pumpage, by far the largest component of outflow, is specified in the model input and averages 306,200 acre-ft/yr (tables 4.14–4.19). Simulated discharge to drains in LACP averaged 7,230 acre-ft/yr (table D6). Most of the simulated drain discharge occured in the Santa Monica Basin (2,770 acre-ft/yr) and the Montebello Forebay (2,450 acre-ft/yr; table D6). In the Montebello Forebay, the discharge included some of the underflow through the Whittier Narrows.

During the 45-year simulation period, average groundwater outflow exceeded inflow by about 6,600 acre-ft/yr (table D6). The total simulated depletion of storage for the 45-year period was about 298,000 acre-ft (multiplying the average yearly value by 45). In just the WRD service area, the total simulated average storage depletion was 3,400 acre-ft/yr (adding up each of the subareas in the WRD service area), for a total depletion of 155,000 acre-ft over the 45-year simulation period (table D6). The simulated total depletion was close to the calculated 140,000 acre-ft/yr of depletion by the WRD over the same time period (Water Replenishment District of Southern California, 2018).

Simulated Annual Groundwater Budget

The simulated annual groundwater budget is provided in detail in appendix 4 (tables 4.1*A* through 4.1*M*). Simulated inflow varied from about 211,000 acre-ft in 1972 to about 551,000 acre-ft in 1978 and is shown graphically in figure D13. Simulated annual groundwater outflow from pumping and drains varied from about 262,000 acre-ft in 1993 to about 398,000 acre-ft in 1971 (fig. D13). In some years, simulated inflows exceeded outflows, resulting in increases in simulated storage (figs. D13, D15); in other years simulated outflows exceeded inflows, resulting in simulated storage depletion (figs. D13, D15). Simulated storage decreased from 1971 through 1978 by about 504,000 acre-ft and then increased from 1979 through 1984 by about 513,000 acre-ft (fig. D15). Storage decreased by about 193,000 acre-ft from 1985 through 1991, and then increased by about 433,000 acre-ft from 1992 through 1999 (fig. D15). From 2000 through 2015, storage decreased by 546,000 acre-ft (fig. D15). Periods of increasing storage generally corresponded to wetter periods when there was more water spreading, more areal recharge, and less pumpage; periods of decreasing storage generally corresponded to drier periods associated with less water spreading and less areal recharge (figs. D13, D15).

Simulated inflow and outflow components showed considerable multi-year variability in the different subareas (appendix 4, fig. 4.1). Much of this variability was driven by wet and dry periods (fig. D15). For example, drain flows were highest during the wet years in the Santa Monica Basin (appendix 4, fig. 4.1*J*), and almost all drain flows in the Montebello Forebay occurred in 1992, which was one of the largest water-spreading years on record (fig. D13).

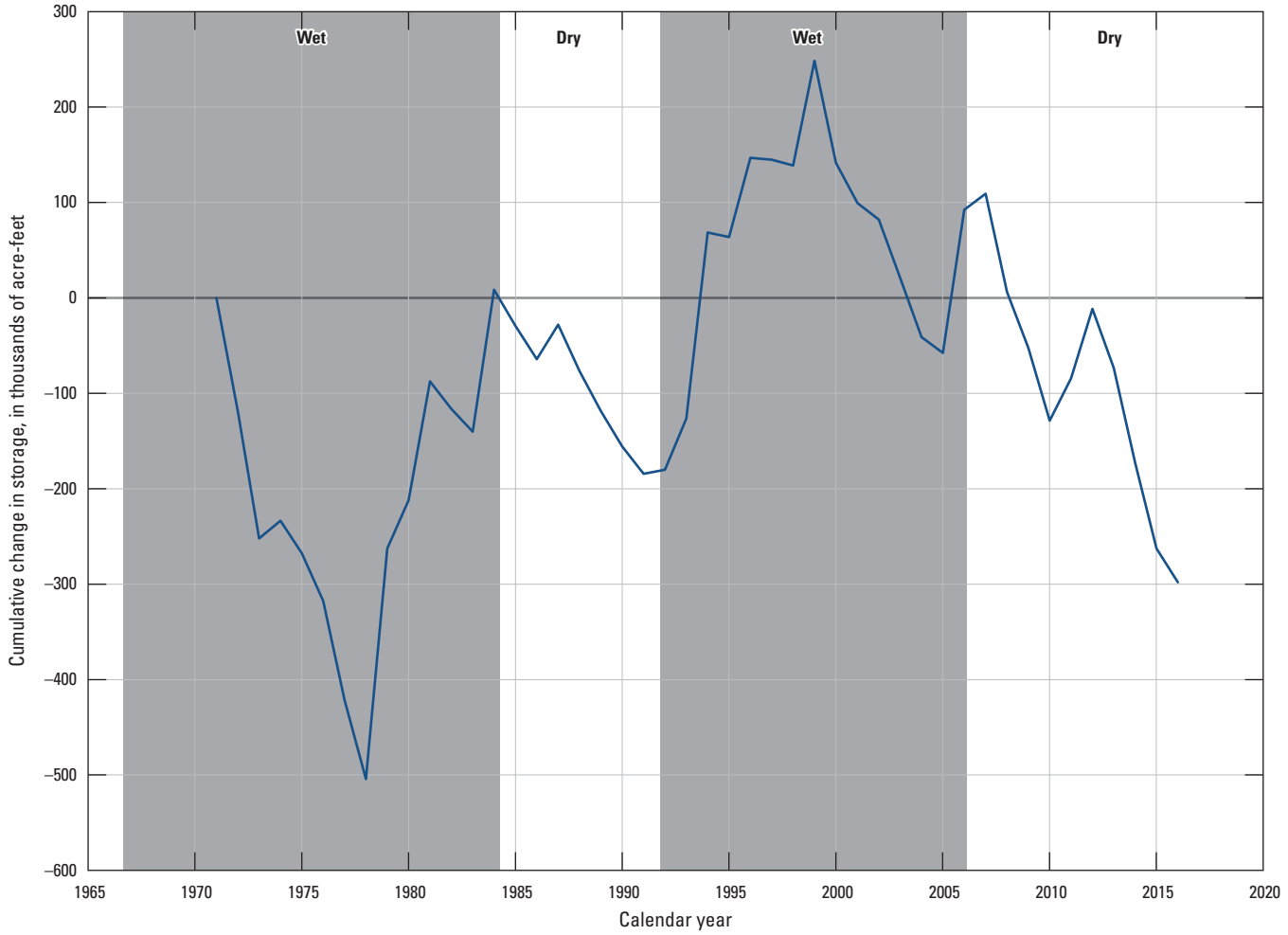


Figure D15. Simulated cumulative change in storage, 1971–2015, Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California.

Simulated Flow between Subareas and Layers

The calibrated model was used to simulate average lateral flow between the 14 model subareas and vertical flow between the 12 model layers for 1971 to 2015 (fig. D14 and appendix 4, fig. 4.2). The largest lateral and vertical flows were simulated in the Montebello Forebay (fig. D14 and appendix 4, fig. 4.2). Most of the flow into the model came from the Montebello Forebay and entered the model as water spreading (123,000 acre-ft/yr) and underflow through the Whittier Narrows (36,300 acre-ft/yr; fig. D14). In the Montebello Forebay, groundwater mostly flowed downward from the Dominguez to the Harbor aquifer systems (appendix 4, figs. 4.2*A–F*). The major outflow from the Montebello Forebay was lateral flow to the Central Basin Pressure Area (116,000 acre-ft/yr; fig. D14). Most of this outflow occured through the Mesa, Pacific, Harbor, and Bent Spring aquifer systems.

Simulated average annual inflow from the southeastern edge of the model into the Orange County Central subarea of 39,100 acre-ft/yr is the largest simulated boundary flow (fig. D14). More than 25 percent of this inflow was simulated in the Pacific aquifer system (appendix 4, fig. 4.2*D*). Simulated pumping in the Orange County Central subarea (47,700 acre-ft/yr) exceeded the simulated boundary flow, resulting in a small amount of lateral flow (3,000 acre-ft/yr) entering the Orange County Central subarea from the Central Basin Pressure Area (WRD; fig. D14). Although flow crosses the Orange County/Los Angeles County boundary from the Central Basin into the Orange County Central subarea (and a small amount—279 acre-ft/yr— crosses from the West Coast Basin subarea into the Orange County South subarea), in Orange County South and Orange County North subareas flow crosses from Orange County into the Central Basin Pressure Area. The net simulated flow from the Orange County subareas (Orange County North, Central, and South) into Los Angeles County subareas (Whittier area, Central Basin Pressure Area, and West Coast) averaged about 2,300 acre-ft/yr for 1971 to 2015 (fig. D14).

The modeled average net simulated flow across the county line for 1971 to 2000 was calculated from the model output and compared to the results of Reichard and others (2003). The modeled average net simulated flow was 1,400 acre-ft/year, which is 6,600 acre-ft/year less than the modeled simulated net inflow from Reichard and others (2003). Within, the LACP, the county line separating Orange County and Los Angeles County is over 17 mi long and crosses an alluvial basin that is over 8,000-ft thick in some areas; furthermore, there are over 200 production wells within 2 mi of the county line. Given the size and complexity of the groundwater system near the county line, small differences in the two groundwater-flow models could account for a difference of 6,600 acre-ft/year in simulated flow from Orange County to Los Angeles County. Differences that might have affected this simulated inflow include the LACPGM's Orange County general-head boundary, located approximately 5 mi east of the corresponding boundary in the model of Reichard and others (2003), and the LACPGM use of chronostratigraphic layering (13 model layers), in contrast to Reichard and others' (2003) use of lithostratigraphic layering (4 model layers).

The net simulated average groundwater flow from the Central Basin to the West Coast Basin was about 4,450 acre-ft/yr (fig. D14). The net direction of flow was from the Central Basin to the West Coast Basin in all aquifer systems except for the Pacific A, Pacific, and Harbor aquifer systems (appendix 4, figs. 4.2*A–L*). The relatively small average simulated groundwater flow between the Central and West Coast Basins reflected the large proportion of recharge water pumped from the Central Basin and the partial barrier effect of the Newport-Inglewood fault zone that separates the two groundwater basins, especially in the deeper layers.

The simulated lateral flows between the offshore and onshore subareas indicated potential onshore movement of seawater. Most of the simulated lateral flows between offshore and onshore subareas were small compared to the overall groundwater budget. Small changes in the groundwater budget could reverse offshore or onshore flow directions in many cases. In the West Coast Basin, the net simulated average flow moved onshore at a relatively small rate of about 93 acre-ft/yr from the Santa Monica Bay to the west, but at a substantially higher rate of about 6,270 acre-ft/yr from the San Pedro Bay to the south (fig. D14). Along the west coast of the West Coast Basin, the simulated average net flow was offshore or close to no flow in all aquifer systems except for the Bent Spring and Lower Wilmington aquifer systems, where the simulated average net flow was onshore (appendix 4, figs. 4.2*A–L*). Along the south coast of the West Coast Basin, the simulated average net flow was onshore in all aquifer systems, with the greatest rates simulated for the Pacific, Harbor, and Lower Wilmington aquifer systems (appendix 4, figs. 4.2*A–L*). In the Santa Monica Basin, the net simulated average flow was moving offshore at a relatively small rate of about 80 acre-ft/yr (fig. D14). Simulated average net flow was offshore or close to zero in all aquifer systems except for the Pacific, Bent Spring, Upper Wilmington A, and Long Beach C aquifer systems, where the simulated average net flow was onshore (appendix 4, figs. 4.2*A–L*).

Model Limitations

A groundwater-flow model is a valuable tool for testing the conceptualization of groundwater-flow systems and for predicting the response of the systems to changes in aquifer system stresses. However, a groundwater-flow model is only an approximation of the thirteen actual aquifer systems and therefore will not exactly represent the actual systems simulated. The model relied on estimates of aquifer system hydrogeologic structure, aquifer properties, and stresses, which had some degree of uncertainty.

The LACPGM chronostratigraphic model layers were based on seismic lines, well bore data, and other data. The chronostratigraphic model was interpolated between data points. In some areas of the model, available data were sparse, and interpolation occurred over distances of several miles. Interpolation error associated with sparse data regions in the chronostratigraphic model can cause mismatches between production well screens and result in incorrect estimation of the amount of pumping coming from each layer, which may cause errors in the LACPGM results. Some of these interpolation errors were corrected by analyzing pumping and monitoring-well data and correcting the layering based on this analysis. The LACPGM model layers represented mostly fining-upward units, which may contain a coarse-grained basal zone and a fine-grained upper zone. These zones were simulated together as a single model layer with specific hydraulic properties. Modeling a fining-upward sequence as a single layer containing the same hydraulic properties was a possible source of model error.

Areal recharge in the LACPGM accounted for about 16 percent of the total model recharge and was based on precipitation-runoff estimates from Hevesi and Johnson (2016). Therefore, many of the model limitations from Hevesi and Johnson (2016) precipitation-runoff model also apply to the LACPGM. Model limitations included not accounting for unregulated streamflow, certain cases of stream channel storage, water and sewer line leakage, and dispersive streamflow. These limitations could have led to errors in the precipitation-runoff estimates used as initial areal recharge in the LACPGM. Final areal recharge values were determined by model calibration.

Underflow through Whittier Narrows accounted for approximately 11 percent of the total model recharge and was based on underflow estimates from San Gabriel River Watermaster (San Gabriel River Watermaster, 1997) and model calibration. Underflow estimates were based on observed heads in the Whittier Narrows area, hydraulic conductivity estimates for the area, and an estimated cross-sectional area of flow for the Whittier Narrows, all possible sources of error for the underflow estimate. Given the imprecise nature of the underflow estimate, it was only used as a starting point for model calibration and changed from the estimated 27,600 acre-ft/yr to about 30,200 acre-ft/yr of underflow from the upper Mesa aquifer system during parameter estimation. In addition, about 6,100 acre-ft/yr of underflow was simulated from the lower Long Beach C aquifer system. The San Gabriel River Watermaster did not estimate underflow for the deeper Long Beach C aquifer system.

Underflow data were not available for Los Angeles Narrows. Underflow across Los Angeles Narrows was determined by estimated layer thicknesses in Los Angeles Narrows, available water-level data, and calibrated hydraulic conductivities in the Los Angeles Narrows area. Underflow across Los Angeles Narrows only accounted for about 2 percent of the total model recharge but was the primary source of recharge to the Los Angeles Forebay. Errors in the underflow estimate across Los Angeles Narrows could have led to inaccurately simulated water levels in the Los Angeles Forebay.

The eastern edge of the LACPGM, 3 to 5 mi into the Orange County Basin, was simulated as a GHB. This boundary was simulated using water-level data from OCWD multi-completion wells during 1992 to 2015. Water-level data from 1971 to 1990 were sparse around the LACPGM's eastern boundary for some of the model layers. Combinations of spatial interpolation, temporal interpolation, and extrapolation of data were used to estimate water levels along this boundary for all layers (appendix 3). These interpolations and extrapolations may have resulted in some model error in the eastern area of the model from 1971 to 1990.

Pumpage occurred on both sides of the eastern edge of the LACPGM, with some pumpage occurring as close as 200 ft from the eastern edge. The GHB water-levels were interpolated between monitoring wells along the boundary and may not have accurately reflected the effects of pumping wells close to the boundary. Additionally, this GHB may need to be modified for predictive scenarios in order to accurately reflect changes in pumping that occur just outside the eastern boundary of the LACPGM.

The model does not simulate subsidence. Minimal subsidence was expected since most measured water levels during the LACPGM simulation period were above historical low values. However, some water levels were near historical lows during the LACPGM simulation period, including seasonal low water levels during the 1990s in the Long Beach area. If subsidence had occurred in the LACP during the simulation period, this could affect groundwater flow in the LACP and therefore effect the accuracy of the LACPGM results.

Most conduits in the LACPGM were assigned a high skin factor of 16,000. A high skin factor was necessary to represent the large vertical head gradients observed in some areas of the model. A high skin factor can result in very low flows within conduits that are simulating production or injection wells. However, the water budget indicates that even with a high skin factor nearly all the water pumped from the conduits is coming from model cells connected to the conduit (only a very small fraction of water pumped from conduits is coming from conduit storage).

Changes to the groundwater-flow model by future users may result in numerical instability. The LACPGM included over 400,000 cells and 12 active layers with a complex geology of synclines, anticlines, faults, and layer pinchouts. The LACPGM also included about 1,500 production wells. Due to these factors, model cells often alternately dried and rewetted, processes under which certain conditions can lead to numerical instability.

Simulation of Future Water-Management Scenarios

The WRD is responsible for the management of the Central and West Coast Basins. Although the annual pumping amounts in these groundwater basins are adjudicated, pumping permitted under the adjudications exceeds the natural replenishment to the groundwater basins (Water Replenishment District of Southern California, 2017). If the natural recharge was not supplemented by managed aquifer recharge in spreading grounds in the Montebello Forebay and injection wells in the Central and West Coast Basins, water levels in the groundwater basins would decline (Water Replenishment District of Southern California, 2017). The adjudicated production rates are 217,637 acre-ft/yr in the Central Basin and 64,468.25 acre-ft/yr in the West Coast Basin (Water Replenishment District of Southern California, 2017). During water year 2014–15 (a water year is the annual period from October 1 through September 30 and is designated by the year in which the period ends), production rates averaged about 194,190 acre-ft/yr in the adjudicated subareas of the Central Basin (about 23,450 acre-ft/yr less than maximum adjudicated rates) and about 42,920 acre-ft/yr in the West Coast Basin (about 21,550 acre-ft/yr less than maximum adjudicated rates; Water Replenishment District of Southern California, 2017). The WRD is considering future production rate increases to reach maximum adjudicated rates with plans to increase production from existing wells and to construct new well fields in the Central Basin, including wells at WRD's new Groundwater Reliability Improvement Project (GRIP) facility just south of Whittier Narrows (fig. D16), which has recently been renamed the Albert Robles Center for Water Recycling and Environmental Learning (Water Replenishment District of Southern California, 2016; fig. D16).

The calibrated LACPGM was used to help evaluate the effects of pumpage at the maximum adjudicated production rates on water levels and flows in the Central Basin and West Coast Basin under two different climatic scenarios: wet conditions and dry conditions. These increased-pumpage scenarios were compared to base-case scenarios, which were the model-simulated conditions assuming production rates remained the same as the average for water years 2012 to 2014. A base-case scenario was run for both wet and dry conditions. Each of the water-management scenarios started at the end of water year 2015 (September 30, 2015), with initial heads set to LACPGM-simulated hydraulic heads for the end of the summer quarter (July–September) of 2015. The simulation period for each of the scenarios was 25 years, or water years 2016 through 2040.

Description of Future Water-Management Scenarios

To simulate different climatic conditions for the future water-management scenarios, the 45-year calibration period (1971 to 2015) was evaluated to find the 25 contiguous-year periods that have the wettest and driest simulated areal recharges. These were considered the best- and worst-case scenarios for future water management through 2040. The base-case and increased-pumpage scenarios with wet climatic conditions used the areal-recharge rates, runoff entering the spreading grounds, and heads along the specified-head and general-head boundaries simulated for water years 1977 to 2001. The wet-period areal recharge averaged 69,000 acre-ft/yr, and the runoff entering the spreading grounds averaged about 65,000 acre-ft/yr. The base-case and increased-pumpage scenarios with dry climatic conditions used the areal-recharge rates, runoff entering the spreading grounds, and heads along the specified-head and general-head boundaries simulated for water years 1991 to 2015. The dry-period areal recharge averaged about 53,000 acre-ft/yr, and the runoff entering the spreading grounds averaged about 57,000 acre-ft/yr.

WRD has targeted for purchase 71,000 acre-ft/yr of imported and recycled spreading water in future years. This future purchased water was divided between the spreading grounds, receiving 66,000 acre-ft/yr, and the Groundwater Reliability Improvement Project (GRIP) facility injection wells, receiving 5,000 acre-ft/yr. (fig. D16; table D8). Spreading grounds recharge rates were divided between the different spreading grounds based on historical recharge rates. Seawater-barrier injection rates were the seasonally averaged rates for water years 2012 through 2014. The GRIP facility is in the Montebello Forebay and includes three new injection wells (SRW1, SRW2, and SRW3; fig. D16). A simulated injection rate of 5,000 acre-ft/yr was used for the GRIP facility, with 1,700 acre-ft/yr injected into wells SRW1 and SRW2 and 1,600 acre-ft/yr injected into well SRW3.

Pumping rates for the base-case scenarios were set based on seasonally averaged pumpage for water years 2012 to 2014 and were the same for each year of the future simulations. This rate is 306,200 acre-ft/yr, which was the same as the average pumping rate for the 45-year calibration period (306,200 acre-ft/yr). Pumping rates for the increased-pumpage scenarios included the base-case rates plus the planned production from six wells (about 9,000 acre-ft/yr) representing well fields recently constructed or soon to be constructed, and the projected increased pumpage (about 36,000 acre-ft/yr) from 75 existing wells (tables D9, D10; fig. D17). The projected increased pumping rates for the existing wells were scaled up to maximum adjudicated production rates, reaching maximum adjudicated production rates in the 10th year: for water years 2016 to 2019, pumping rates were the same as initial rates; for water years 2020 to 2024, pumping rates were halfway between the initial rates and the maximum adjudicated rates; and for water years 2025 to 2040, pumping rates were the maximum adjudicated rates (table D10).

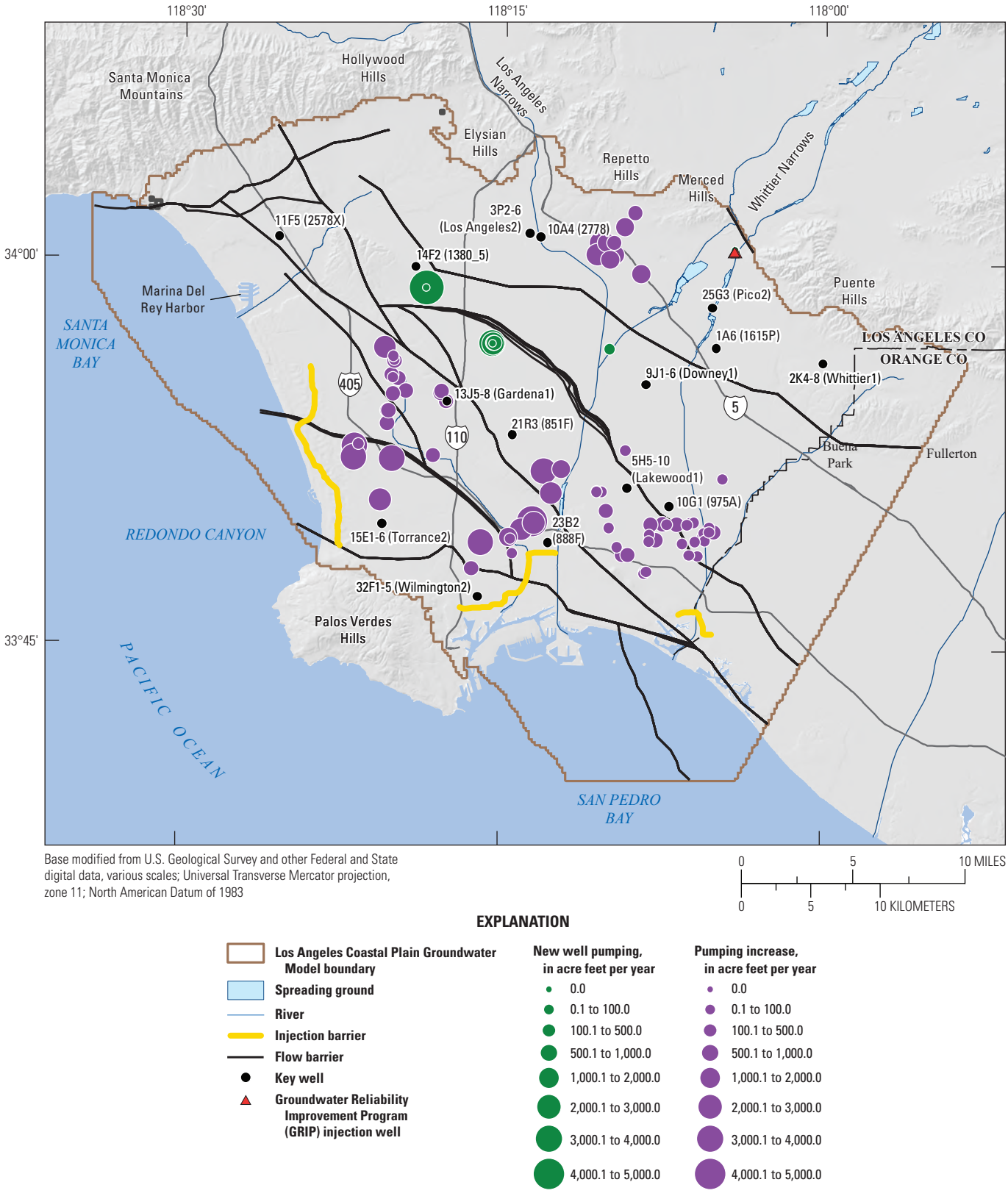


Figure D16. Groundwater Reliability Improvement Project (GRIP) injection wells, existing production wells whose pumping rates were increased during the management scenarios, and production wells that were added to the management scenarios, Los Angeles and Orange Counties, California.

Table D8. Summary of inputs in acre-feet per year for future water-management scenarios.

[acre-ft/year; acre-foot per year; GRIP, Groundwater Reliability Improvement Program]

Scenario	Spreading grounds (acre-ft/year)	GRIP injection (acre-ft/year)	Barrier well injection	Areal recharge	General- and constant-head boundary water levels	Pumping
Base-dry	66,000 + runoff water (1991–2015)	5,000	Averaged seasonal injection rates (2012–14)	Areal recharge estimates (1991–2015)	Estimated boundary heads (1991–2015)	Averaged seasonal pumping rates (2012–14)
Increased pumpage-dry	66,000 + runoff water (1991–2015)	5,000	Averaged seasonal injection rates (2012–14)	Areal recharge estimates (1991–2015)	Estimated boundary heads (1991–2015)	Averaged seasonal pumping rates (2012–14) scaled up to new rates over 10 years
Increased pumpage/ replenishment-dry	66,000 + runoff water (1991–2015) + additional imported water determined by optimization	5,000	Averaged seasonal injection rates (2012–14) + additional imported water determined by optimization	Areal recharge estimates (1991–2015)	Estimated boundary heads (1991–2015)	Averaged seasonal pumping rates (2012–14) scaled up to new rates over 10 years
Base-wet	66,000 + runoff water (1977–2001)	5,000	Averaged seasonal injection rates (2012–14)	Areal recharge estimates (1977–2001)	Estimated boundary heads (1977–2001)	Averaged seasonal pumping rates (2012–14)
Increased pumpage-wet	66,000 + runoff water (1977–2001)	5,000	Averaged seasonal injection rates (2012–14)	Areal recharge estimates (1977–2001)	Estimated boundary heads (1977–2001)	Averaged seasonal pumping rates (2012–14) scaled up to new rates over 10 years
Increased pumpage/ replenishment-wet	66,000 + runoff water (1977–2001) + additional imported water determined by optimization	5,000	Averaged seasonal injection rates (2012–14) + additional imported water determined by optimization	Areal recharge estimates (1977–2001)	Estimated boundary heads (1977–2001)	Averaged seasonal pumping rates (2012–14) scaled up to new rates over 10 years

Table D9. Planned new pumping wells and simulated pumping rates for future water-management scenarios, Los Angeles Coastal Plain Groundwater-flow Model.

[acre-ft/yr; acre-feet per year; WRDID, Water Replenishment District of Southern California identification]

State well number	New pumping (acre-ft/yr)	WRDID
2S/14W-23H17	4,290	200220
2S/13W-32R20	2,269	202904
2S/13W-32R19	1,916	202903
3S/12W-5D5	68	200294
2S/13W-32R15	205	200199
2S/13W-32R16	268	200200

Table D10. Projected increased pumping rates for existing wells for future water-management scenarios, Los Angeles Coastal Plain Groundwater-flow Model.

[acre-ft/yr; acre-feet per year; WRDID, Water Replenishment District of Southern California identification]

State well number	Additional pumping added to base pumping rate (acre-ft/yr)	WRDID
2S/12W-4C1	410	200029
2S/12W-5J1	523	200031
2S/12W-7G2	1,293	203136
2S/12W-7H1	546	200042
2S/12W-7Q4	1,109	200044
2S/12W-8F1	246	200046
2S/12W-8P1	673	200047
2S/12W-16L1	892	200069
2S/12W-17D2	541	200071
3S/11W-31N2	10	200277
3S/12W-29J2	<0.1	200395
3S/13W-35F1	2,000	200479
3S/13W-35H2	800	200721
3S/14W-3D3	1,582	202955
3S/14W-3F2	1	202832
3S/14W-3K4	141	202820
3S/14W-3L2	87	202819
3S/14W-10F2	277	200494
3S/14W-10G3	63	200495
3S/14W-10G4	381	200496
3S/14W-13B3	168	202821
3S/14W-13B4	201	202965
3S/14W-13J9	216	201056
3S/14W-13J10	325	202823
3S/14W-14D2	356	202899
3S/14W-15B3	282	200505
3S/14W-15P1	175	200506
3S/14W-15P2	315	200507
3S/14W-22L1	186	200512
3S/14W-25P4	185	200515
3S/14W-29H1	3	200518
3S/14W-29J1	2,631	200519
3S/14W-32A2	2,021	200520
3S/14W-34C3	2,293	203135
4S/12W-6J2	70	200547
4S/12W-6K1	64	200548
4S/12W-6K2	33	200549
4S/12W-8M1	184	200552
4S/12W-13B4	94	200719
4S/12W-13F2	65	202900
4S/12W-13G1	9	200566
4S/12W-13H1	107	200720
4S/12W-13K1	185	202901
4S/12W-13N2	0.2	200568
4S/12W-13Q1	48	202902
4S/12W-14A2	85	200569
4S/12W-14A4	76	200570
4S/12W-14B2	11	200571
4S/12W-14D4	290	200572
4S/12W-15A1	69	200575
4S/12W-15B3	192	200576
4S/12W-15N1	116	202948
4S/12W-16A1	115	202947
4S/12W-16J3	22	200578
4S/12W-16R1	12	200579
4S/12W-17E1	33	200580
4S/12W-20G1	27	200582
4S/12W-20K1	272	200583
4S/12W-21M7	114	200584
4S/12W-23C1	60	200585
4S/12W-23K3	0.2	200586
4S/12W-24M8	26	200588
4S/12W-28H1	69	200592
4S/12W-28H6	58	200593
4S/12W-28H12	42	200594
4S/13W-2G2	1,347	202833
4S/13W-15A11	1,313	200608
4S/13W-15A14	3,237	202818
4S/13W-15F1	1,478	200610
4S/13W-16J5	508	200614
4S/13W-16R2	0.1	200615
4S/13W-20C1	2,130	200619
4S/13W-21J2	89	200624
4S/13W-29E6	341	200642
4S/14W-9A1	1,823	201059

Results

Future water-management scenarios were evaluated by analyzing the simulated average 25-year budgets (appendix 4, tables 4.14–4.19), simulated average annual water budgets (fig. D17), cumulative change in storage graphs (fig. D18), simulated hydraulic-head change maps (fig. D19), and hydrographs of simulated heads at selected calibration wells for 2016 to 2040 (fig. D20). For the purposes of this evaluation, only the simulated hydraulic-head change maps and hydrographs for the Pacific and Bent Spring aquifer systems are discussed in the report. The Pacific and Bent Spring aquifer systems were the two more heavily pumped aquifer systems in the LACPGM (appendix 4, tables 4.14–4.19). Hydraulic heads in the Pacific aquifer system were similar to the Pacific A and Harbor aquifer systems and were considered representative of the upper aquifer systems, the aquifer systems above the Bent Spring aquifer system. Hydraulic heads in the Bent Spring aquifer system were similar to heads in the Upper Wilmington A, Upper Wilmington B, and Lower Wilmington aquifer systems, and were considered representative of the lower aquifer systems, the aquifer systems below and including the Bent Spring aquifer system.

The simulated head-change maps are the difference between the lowest simulated head in each of the active model cells in the scenario being evaluated and the lowest simulated head in each of the active model cells in the corresponding base-case scenario (fig. D19). The simulated head-change maps show the maximum drawdown caused by increased pumping in each active model cell, which provides a useful comparison for water managers who wish to limit the maximum amount of drawdown throughout the study area (fig. D19). A positive hydraulic-head change indicates that hydraulic head increased compared to the base case (water level rising) and a negative hydraulic-head change indicates that hydraulic head decreased compared to the base case (water level declining).

Base-Case Scenario with Wet Conditions

The base-case scenario with wet conditions used the areal-recharge rates, runoff entering the spreading grounds, and heads along the specified-head and general-head boundaries simulated for water years 1977 to 2001 (table D8). Simulated inflows exceeded outflows in years 2017–19, 2022, 2025, 2031–32, 2034, 2037. During the base-case scenario with wet conditions, more water went into storage for 35 of the quarter-year stress periods and more water came out of storage for 65 of the quarter-year stress periods. Total gain in storage during the 25-year base case was about 142,000 acre-ft (average of 5,660 acre-ft per year; fig. D18). In general, simulated hydraulic heads declined during dry years and rose during wet years (fig. D20).

Base-Case Scenario with Dry Conditions

The base-case scenario with dry conditions used the areal-recharge rates, runoff entering the spreading grounds, and heads along the specified-head and general-head boundaries simulated for water years 1991 to 2015 (table D8). Simulated inflows exceeded outflows in years 2017, 2018, 2020, 2023, 2030, and 2036 (fig. D18). More water went into storage for 29 of the quarter-year stress periods and more water came out of storage for 71 of the quarter-year stress periods. Total loss from storage during the 25-year base case was about 285,000 acre-ft (average of 11,400 acre-ft per year; fig. D18). In general, simulated hydraulic heads declined during dry years and rose during wet years (fig. D20).

Increased-Pumpage Scenario with Wet Conditions

The increased-pumpage scenario with wet conditions used the areal-recharge rates, runoff entering the spreading grounds, and heads along the specified-head and general-head boundaries simulated for water years 1977 to 2001, the same as for the base-case scenario with wet conditions (table D8). For the increased-pumpage scenario with wet conditions, simulated average outflows were greater than inflows, with about 385,000 acre-ft coming from storage (average of 15,400 acre-ft per year, fig. D18; appendix 4, table 4.16). Simulated hydraulic-head change maps for the Pacific aquifer system showed that the increased pumpage resulted in hydraulic-head declines throughout the aquifer system compared to the base-case scenario with wet conditions (fig. D19*A*). Hydraulic-head declines ranged from less than 10 ft in the Los Angeles Forebay to more than 100 ft in the West Coast Basin (fig. D19*A*). Simulated hydraulic-head change maps for the Bent Spring aquifer system also showed that the increased pumpage resulted in hydraulic-head declines throughout the aquifer system compared to the base-case scenario with wet conditions (fig. D19*A*). Hydraulic-head declines ranged from less than 10 ft in the Los Angeles Forebay and southern West Coast Basin to more than 50 ft in the parts of West Coast Basin and Central Basin Pressure Area (fig. D19*A*).

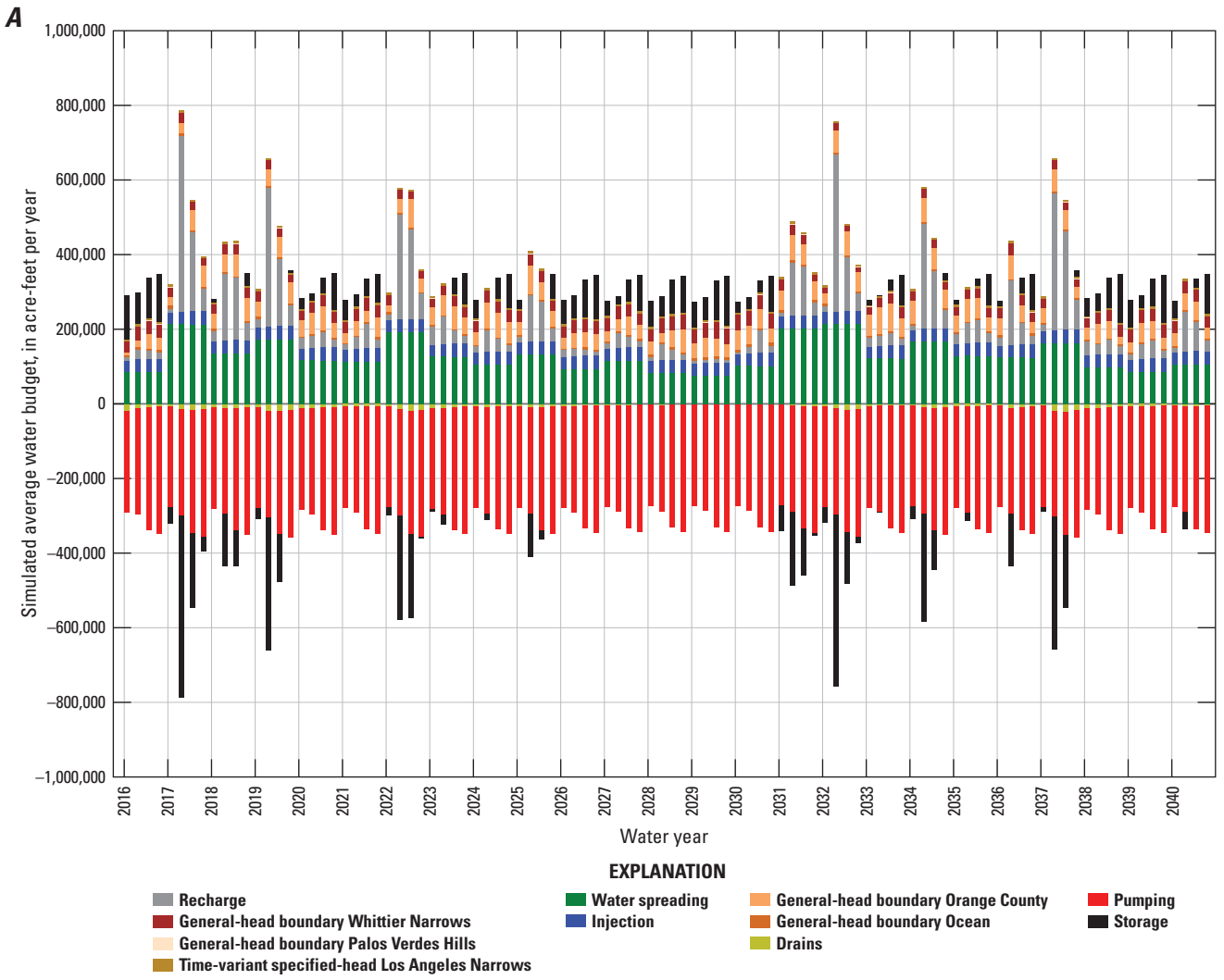


Figure D17. Simulated annual water budgets, 2016–40, for the *A*, base-case scenario with wet conditions; *B*, base-case scenario with dry conditions; *C*, increased-pumpage scenario with wet conditions; *D*, increased-pumpage scenario with dry conditions; *E*, optimized increased-pumpage and replenishment scenario with wet conditions; and *F*, optimized increase-pumpage and replenishment scenario with dry conditions, Los Angeles Coastal Plain Groundwater-flow Model.

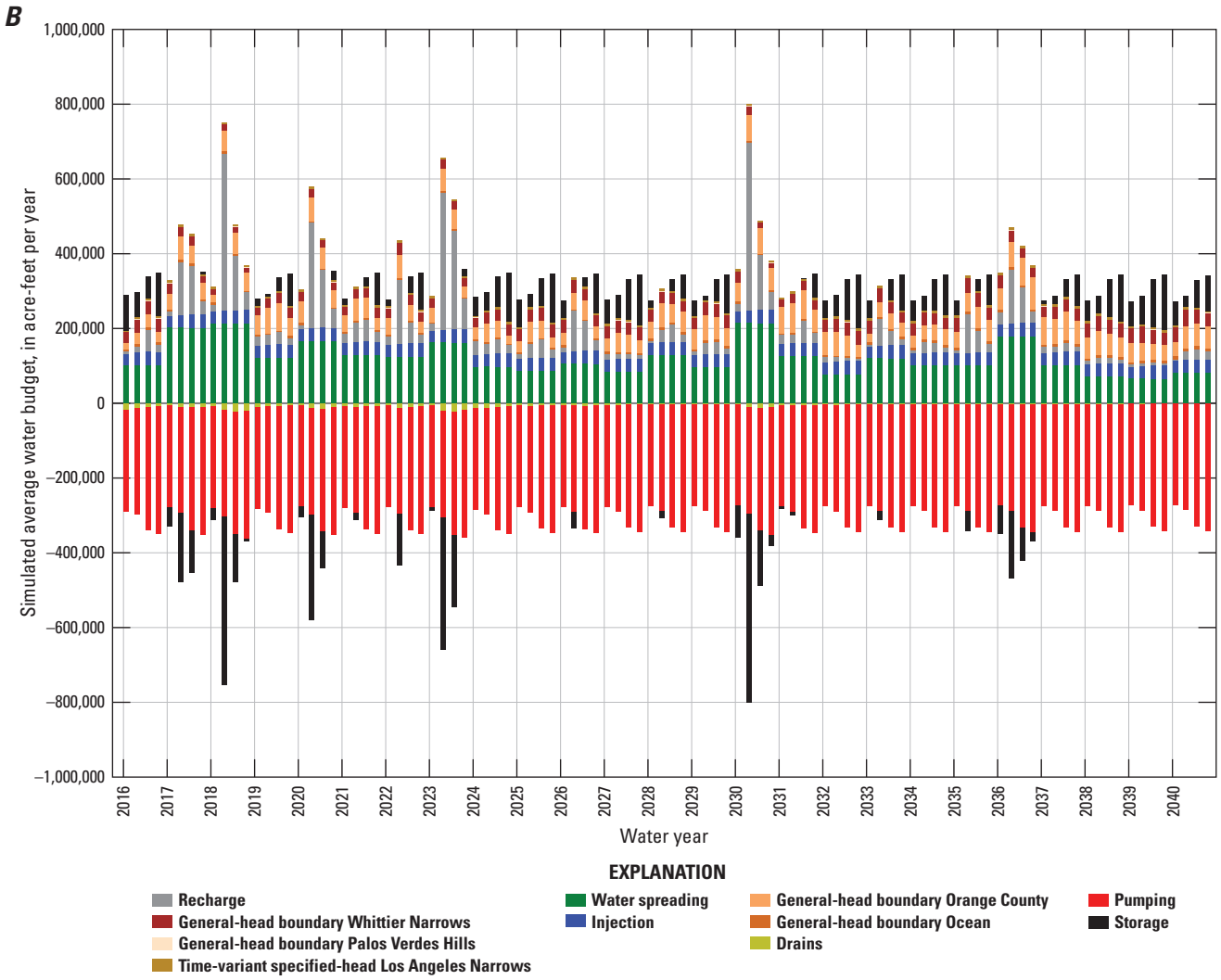


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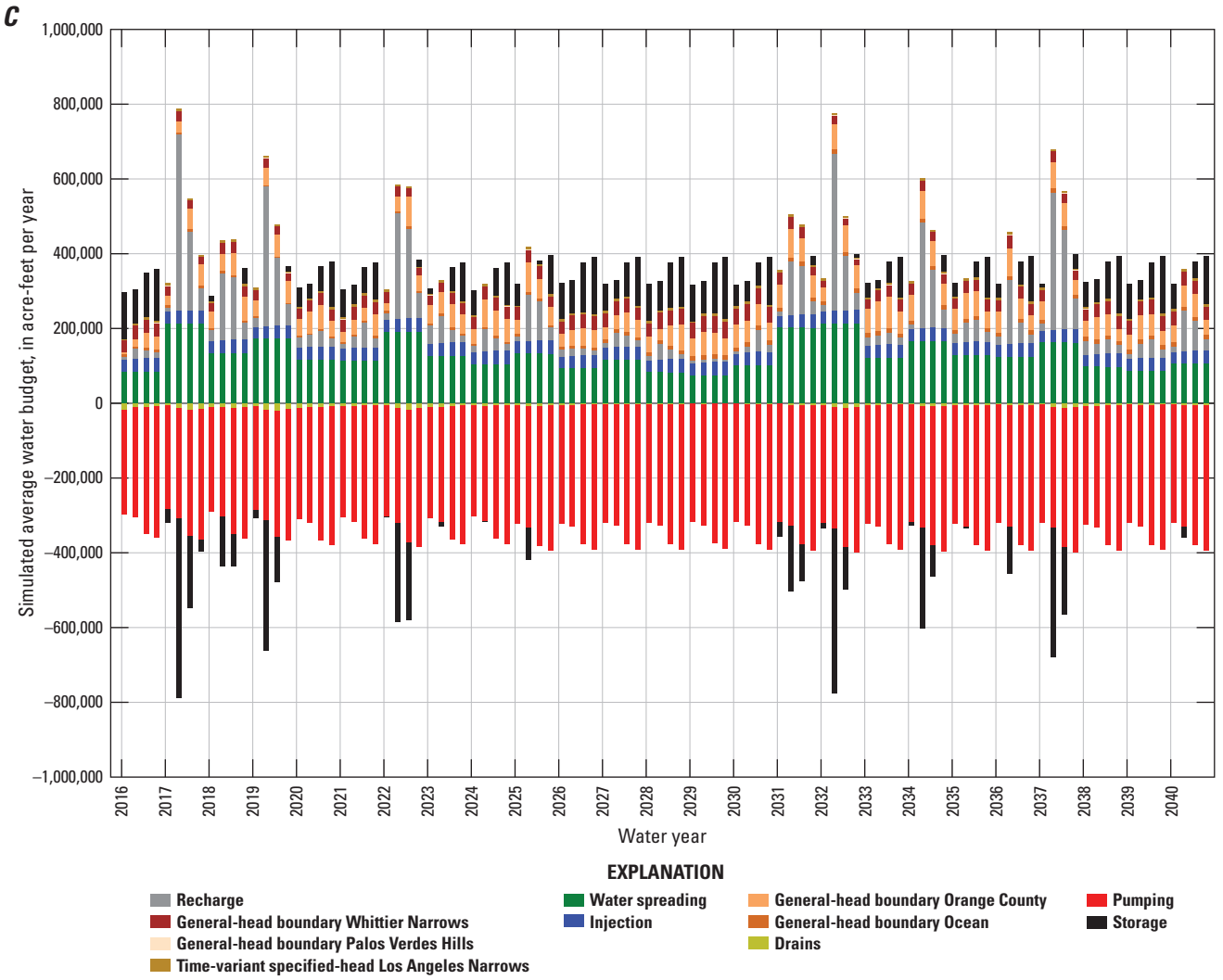


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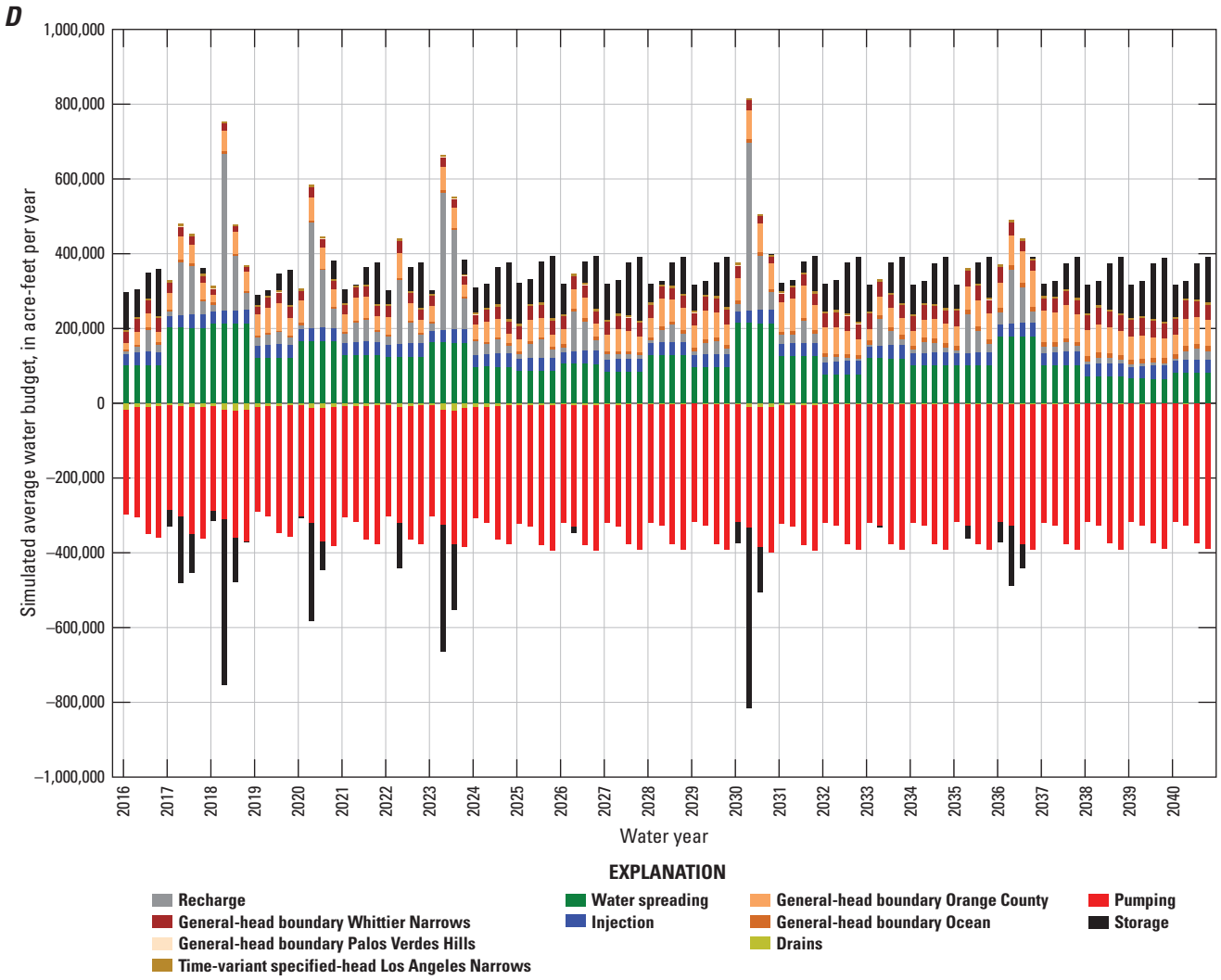


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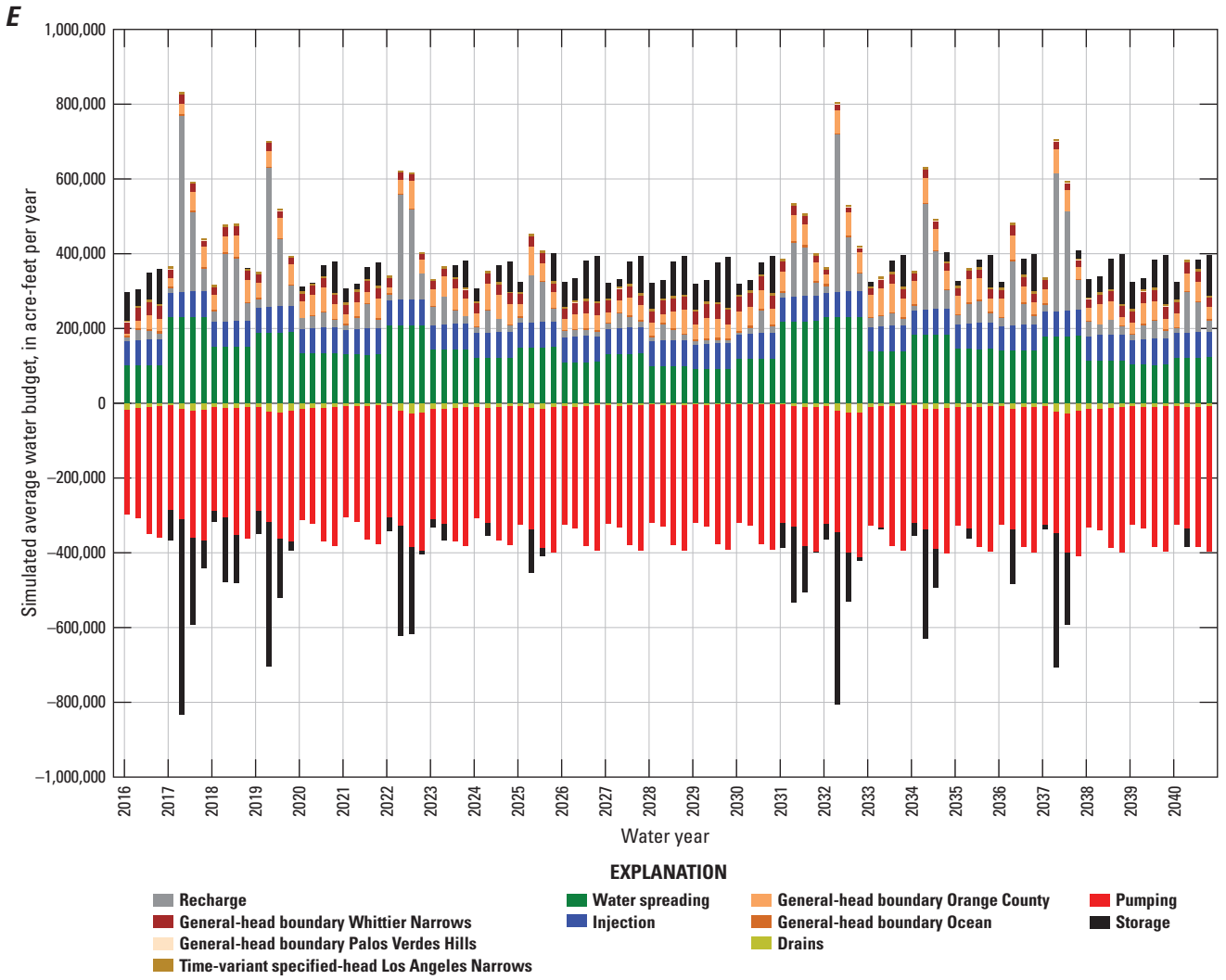


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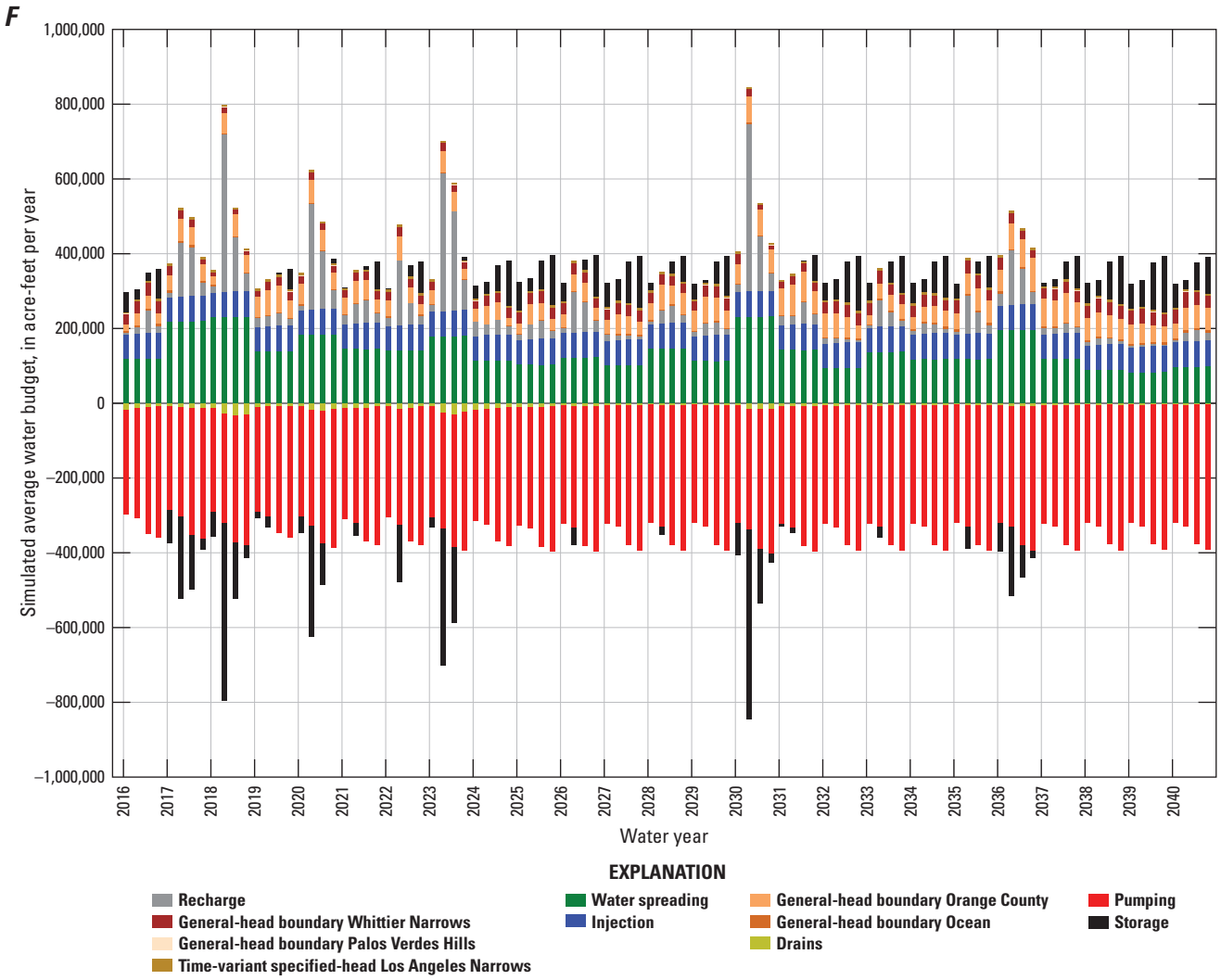


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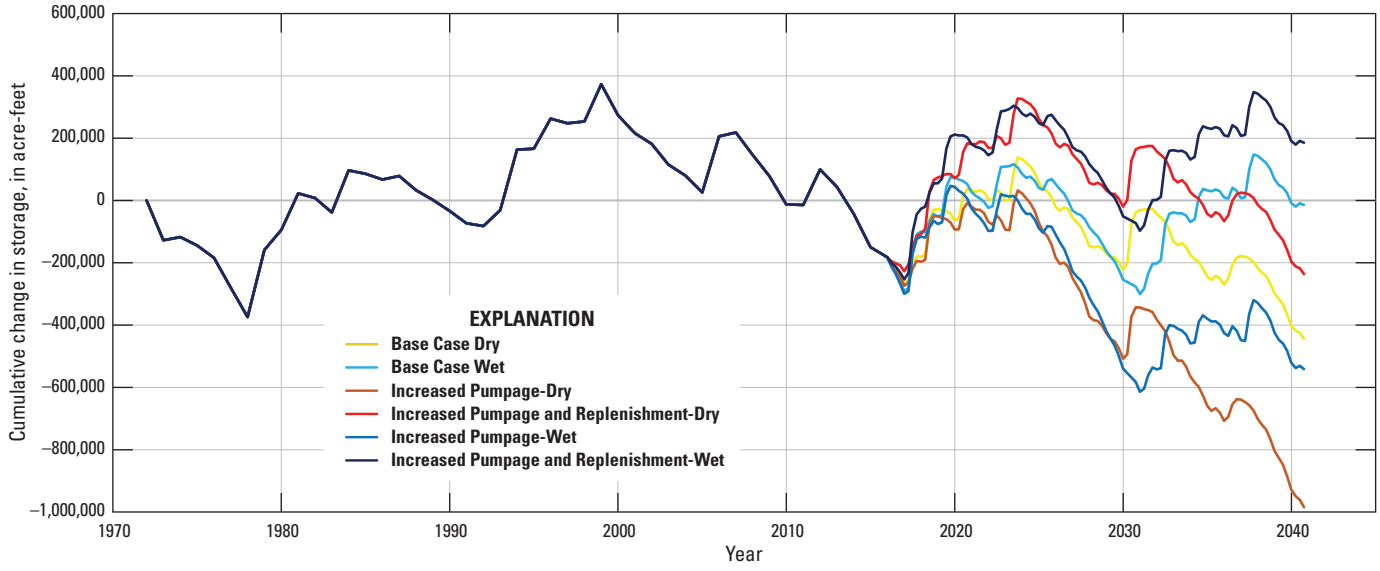


Figure D18. Cumulative change in storage for period 1971 through 2040, including future water-management scenarios, Los Angeles Coastal Plain Groundwater-flow Model.

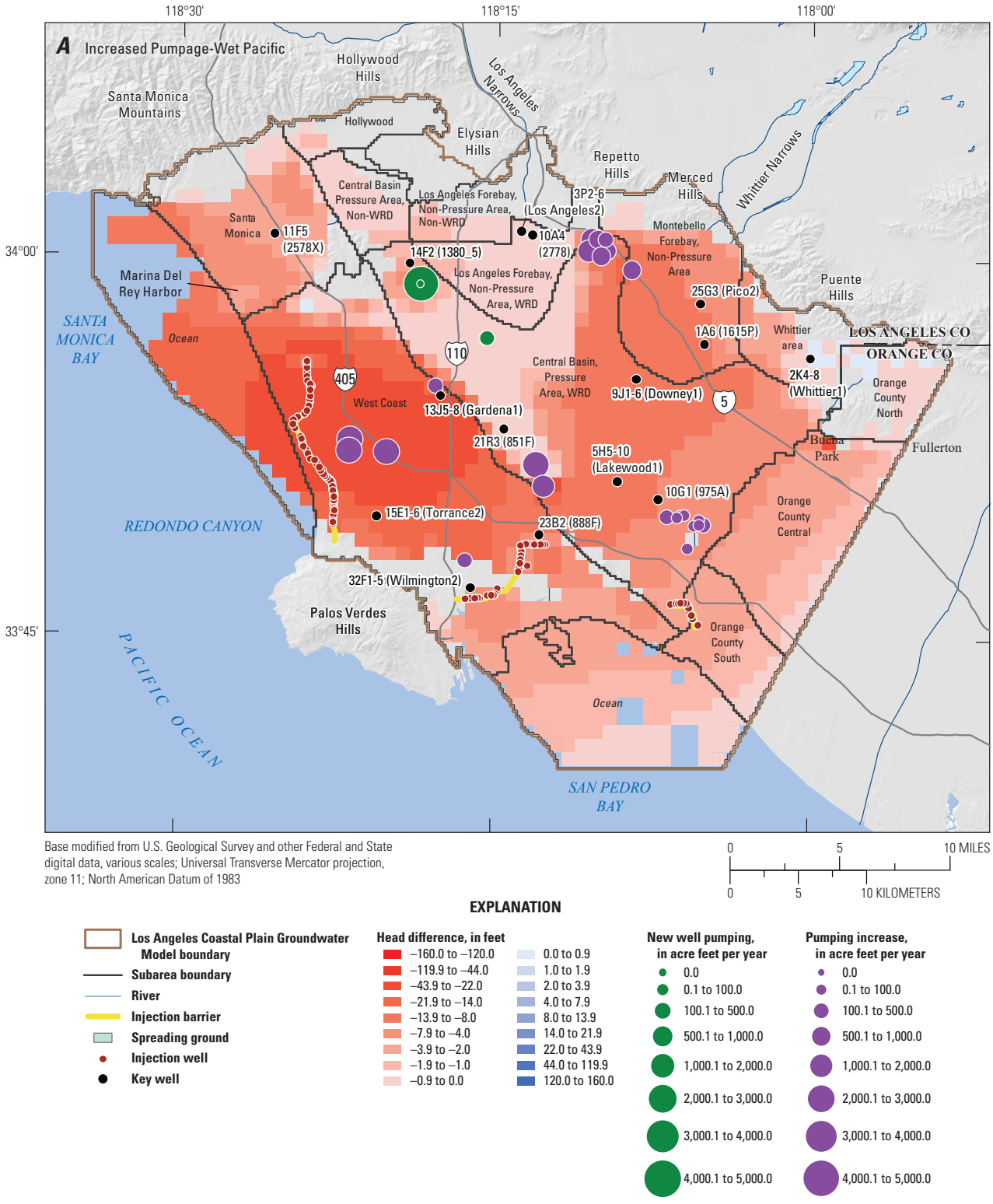


Figure D19. Simulated maximum relative difference in drawdown of hydraulic head in the Pacific and Bent Spring aquifer systems (map pages 1 and 2, respectively, of each lettered part of figure) for *A*, increased pumpage scenario with wet conditions compared to the base-case scenario with wet conditions; *B*, increased pumpage scenario with dry conditions compared to the base-case scenario with dry conditions; *C*, optimized increased-pumpage and replenishment scenario with wet conditions compared to the base-case scenario with wet conditions; and *D*, optimized increased-pumpage and replenishment scenario with dry conditions compared to the base-case scenario with dry conditions, Los Angeles Coastal Plain Groundwater-flow Model. (Negative head difference signifies a drawdown relative to the base-case scenario; positive head difference signifies a rise in head.)

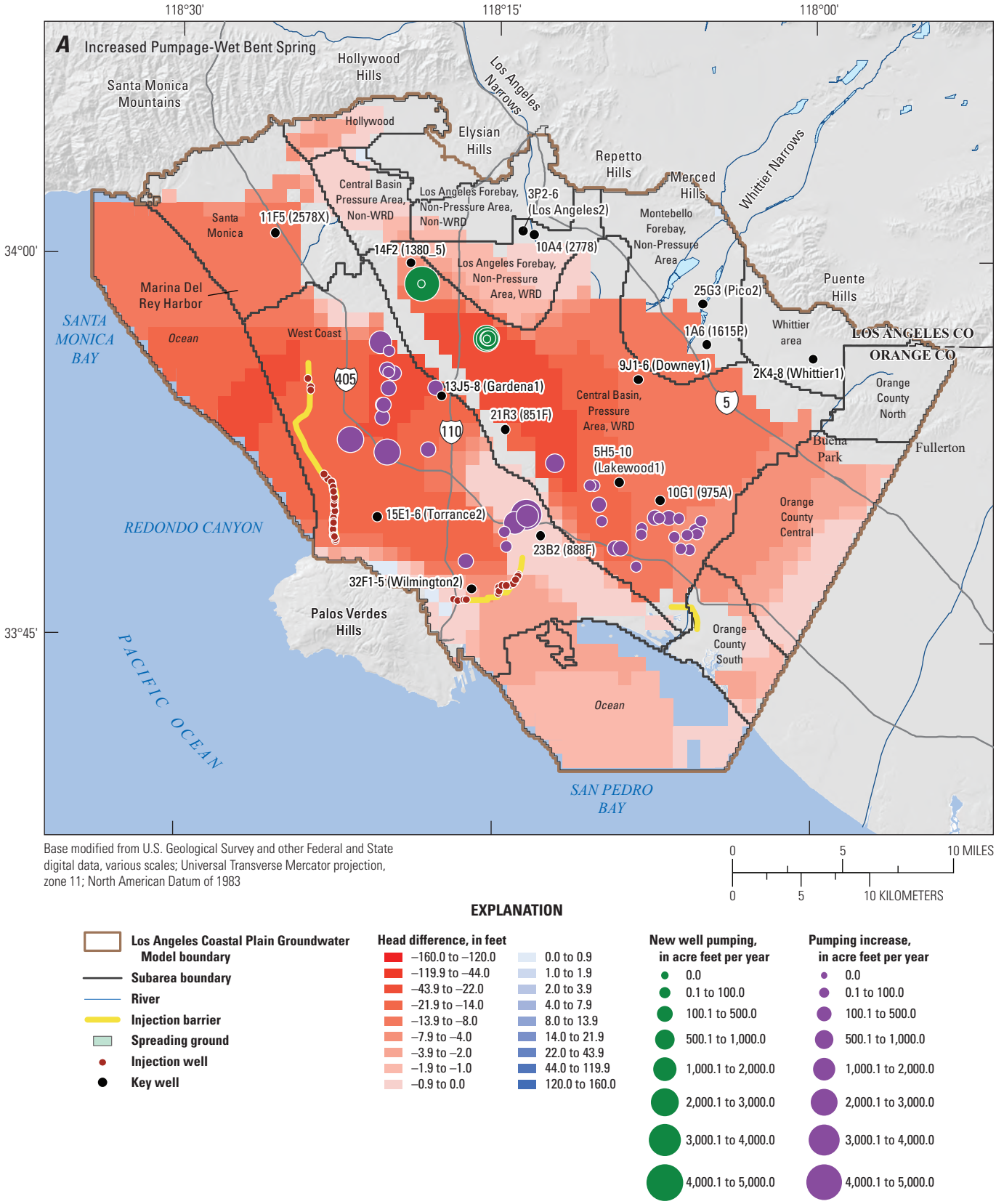


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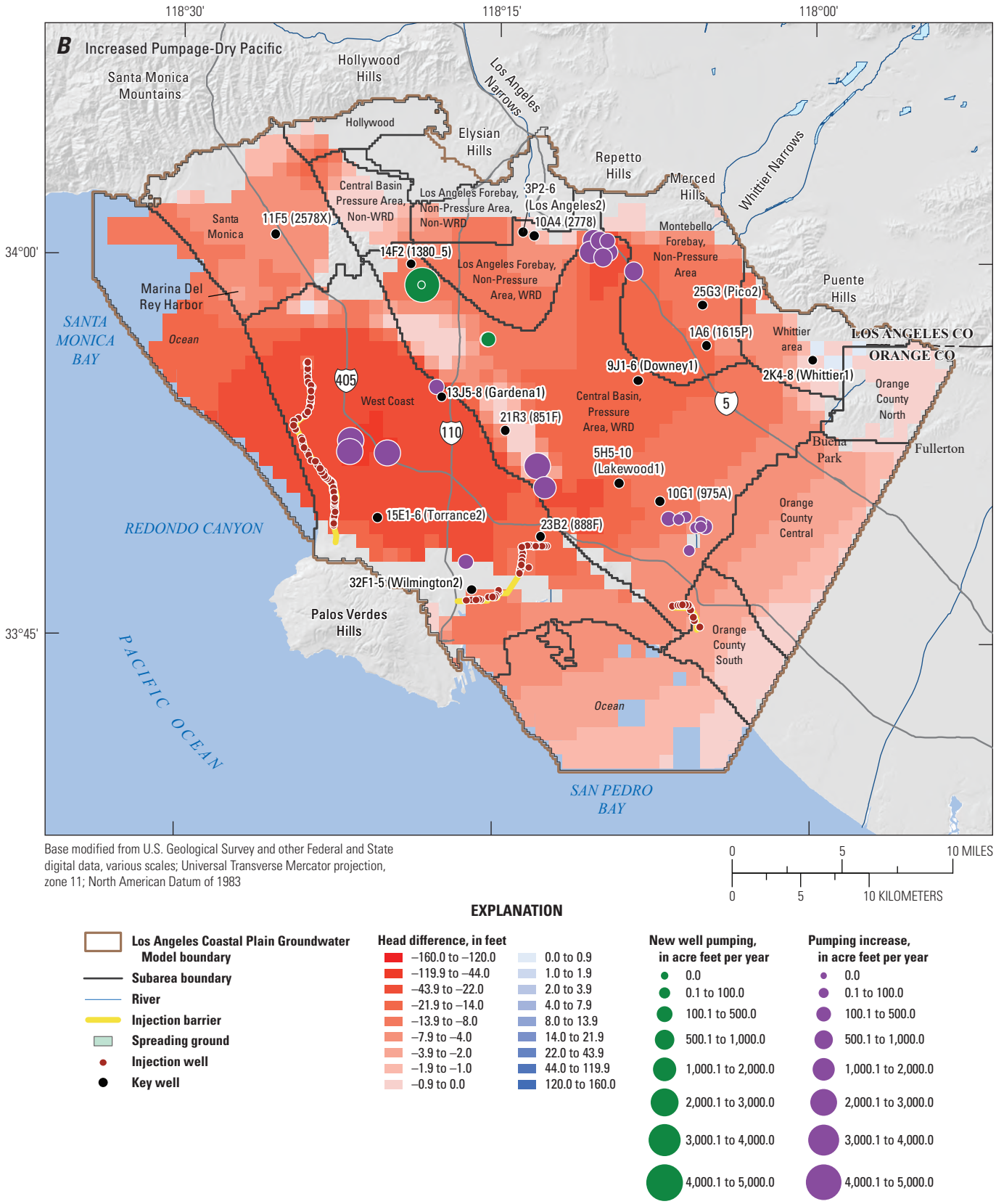


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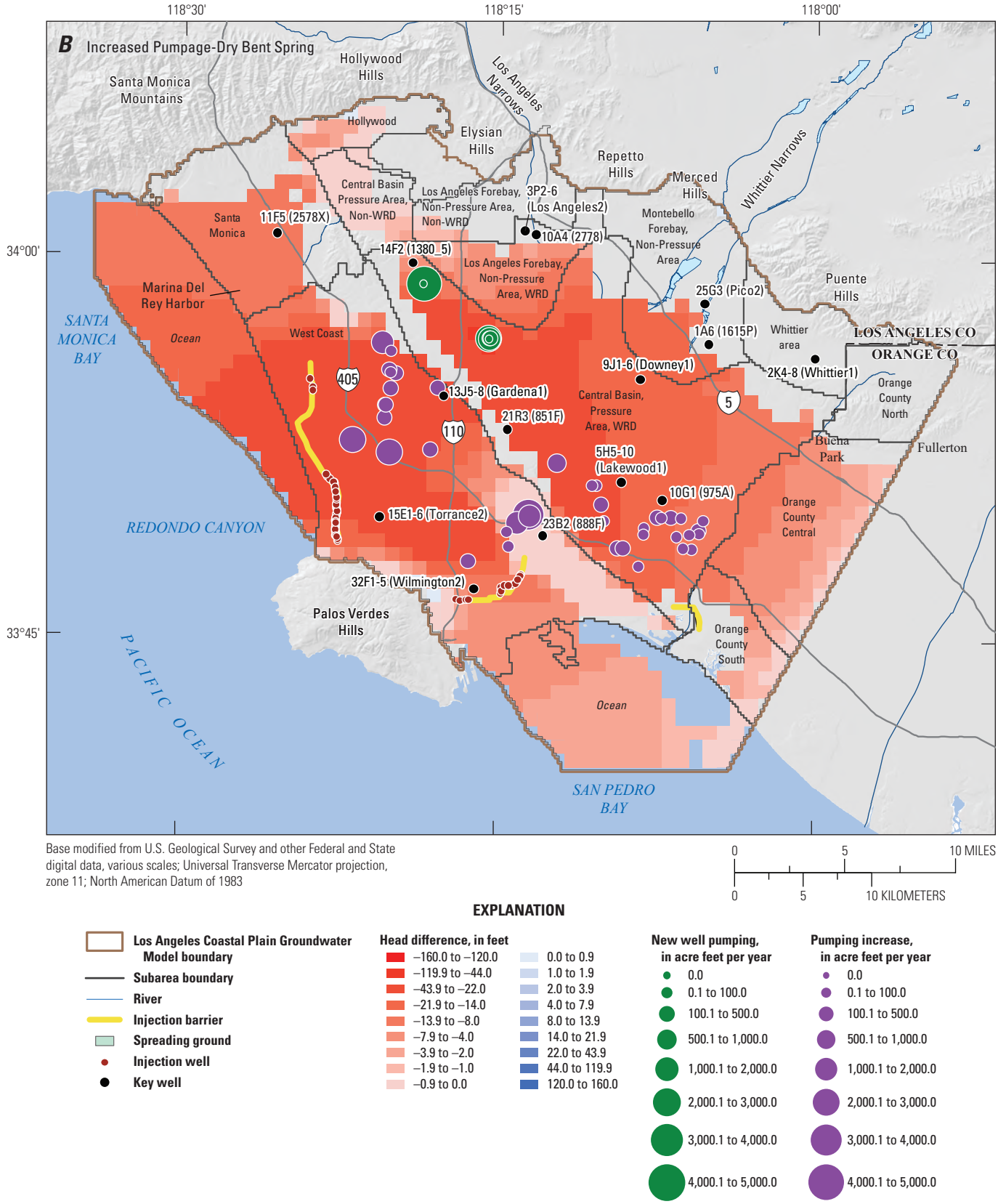


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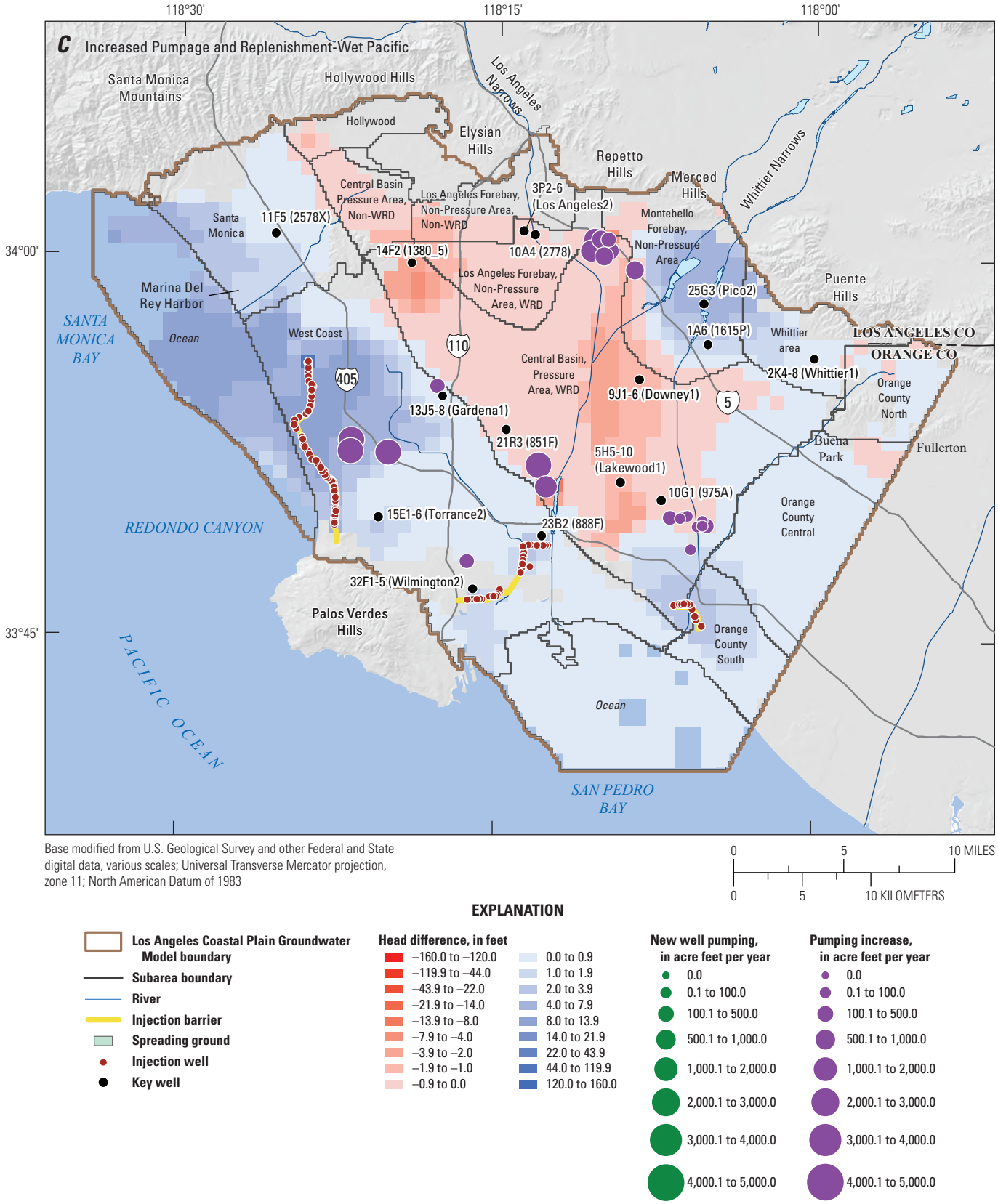


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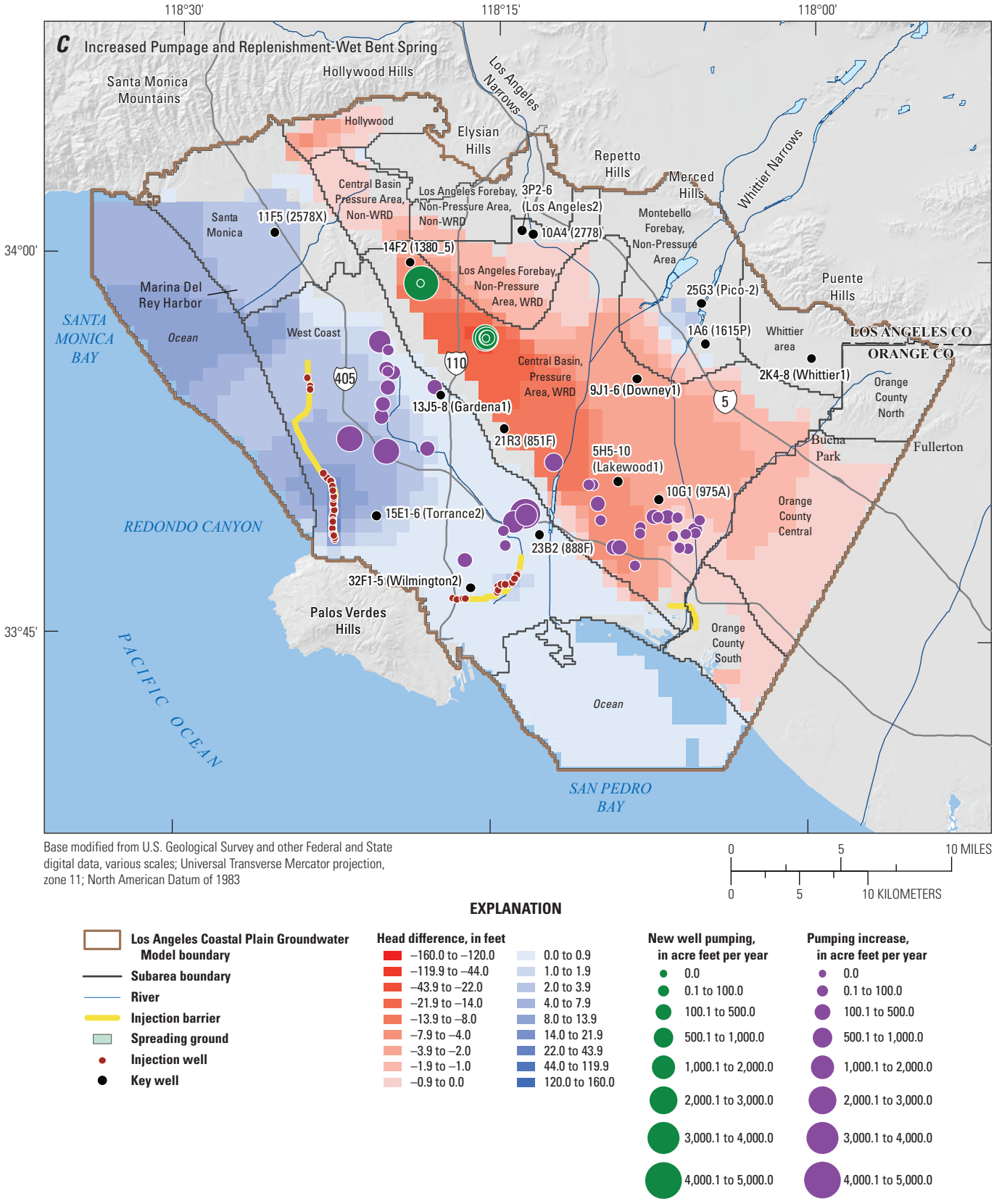


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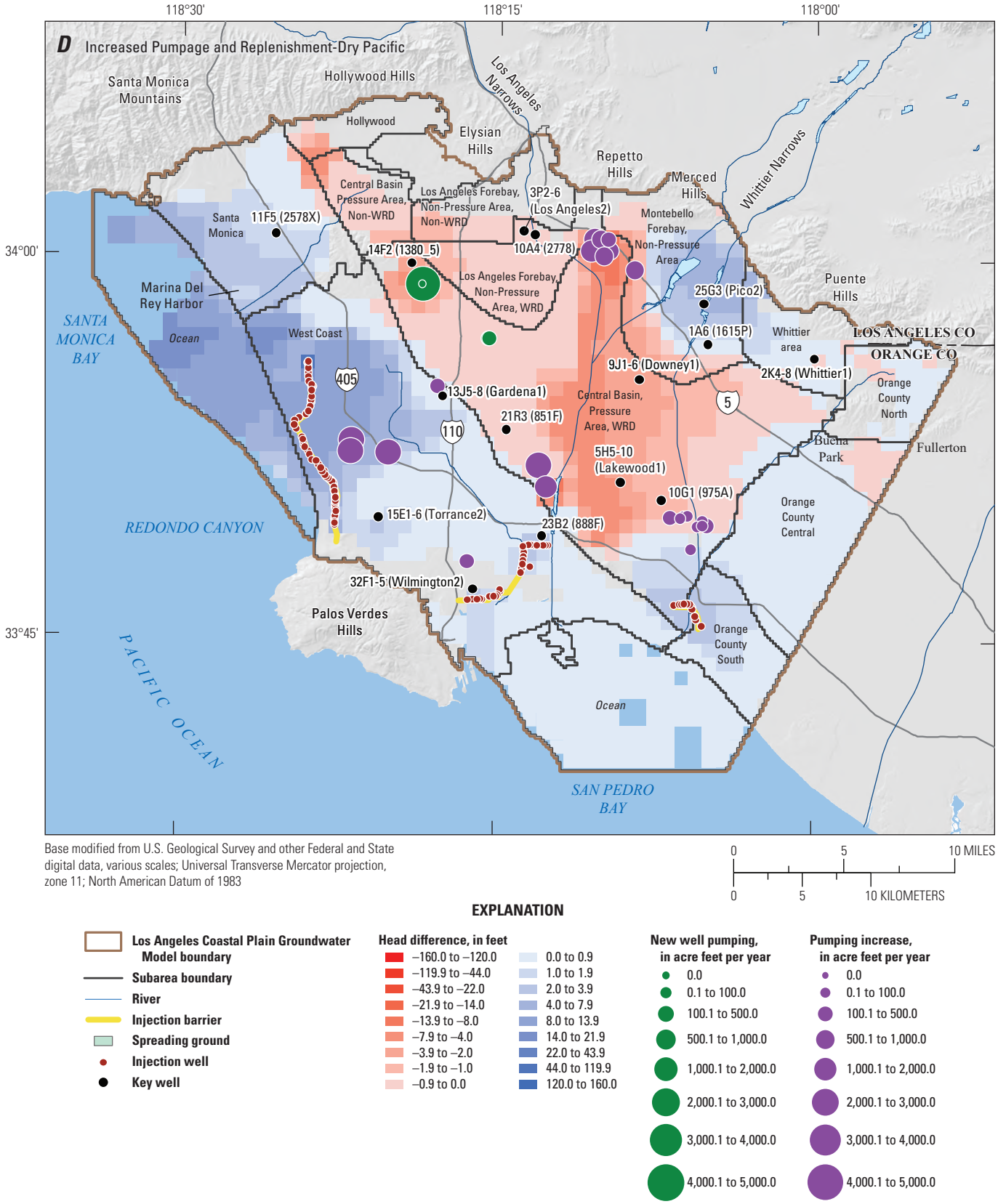


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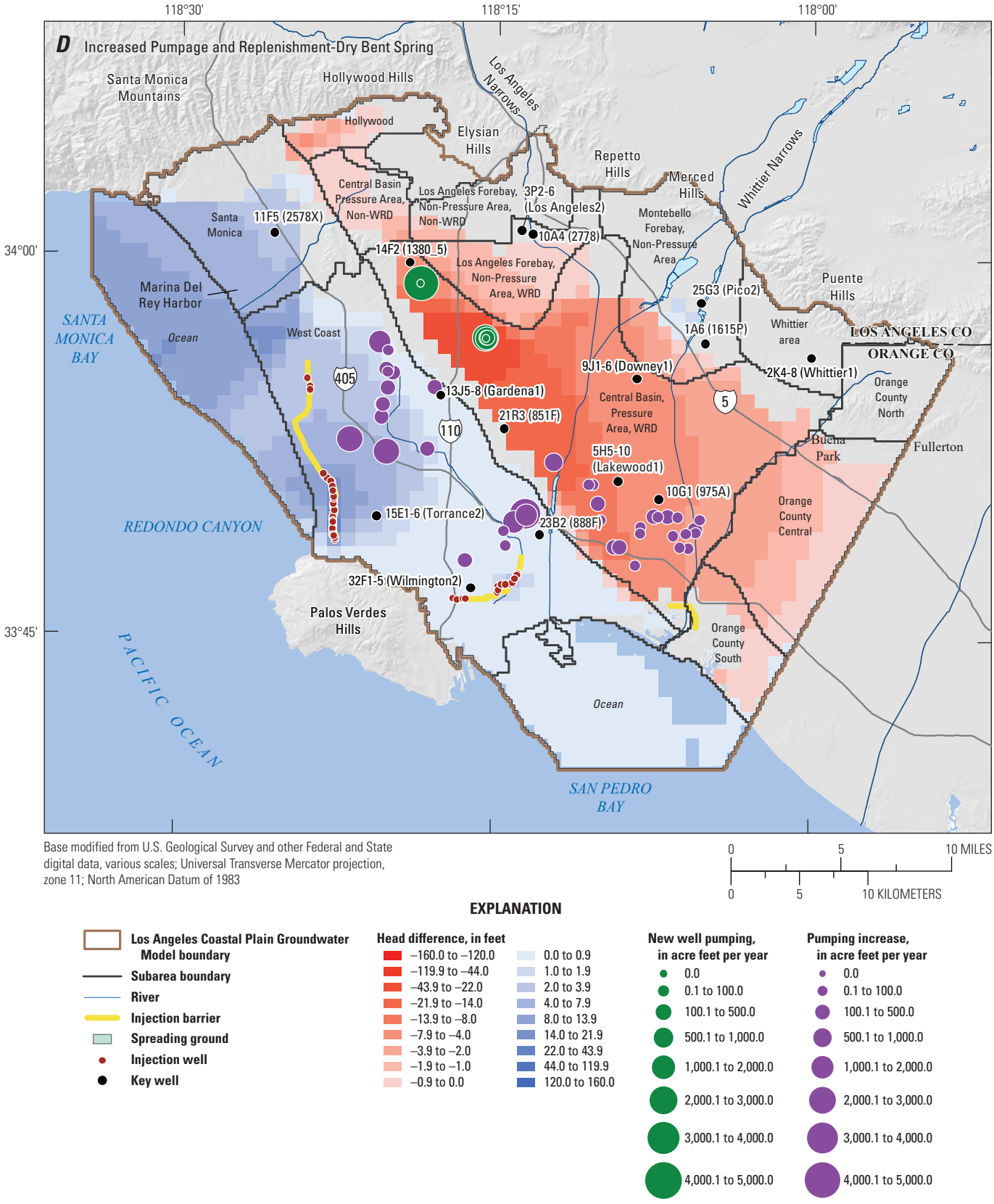


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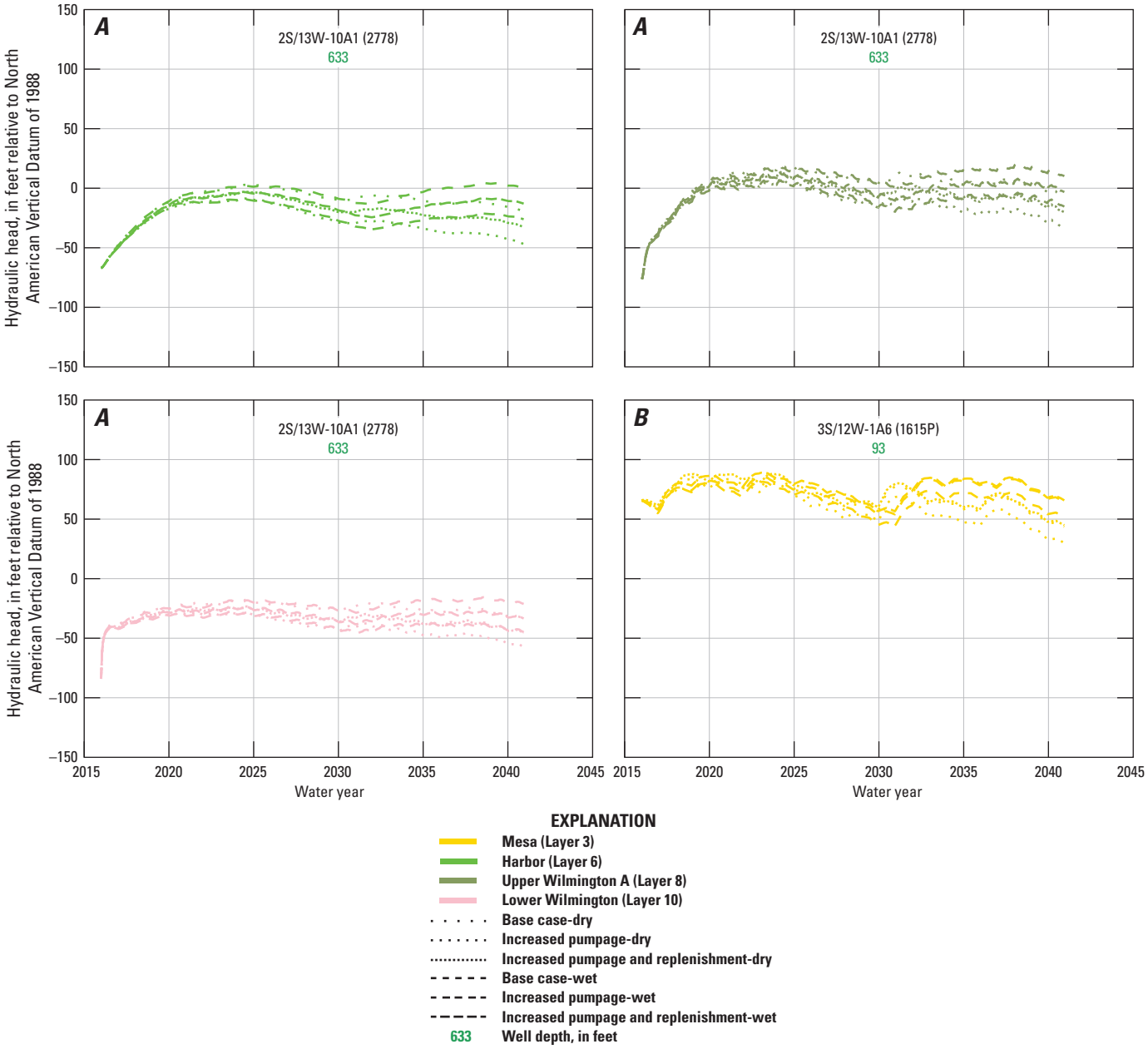


Figure D20. Simulated hydrographs for the Pacific and Bent Spring aquifer systems at selected calibration wells for future water-management scenarios, water years 2016–40: *A*, 2S/13W-10A1 (2778); *B*, 3S/12W-01A6 (1615P); *C*, 4S/12W-10G1 (975A); *D*, 3S/13W-21R1 (851F); *E*, 2S/14W-14F2 (1380); *F*, 4S/13W-23B2 (888F); and *G*, 2S/15W-11F5 (2578X), Los Angeles Coastal Plain Groundwater-flow Model.

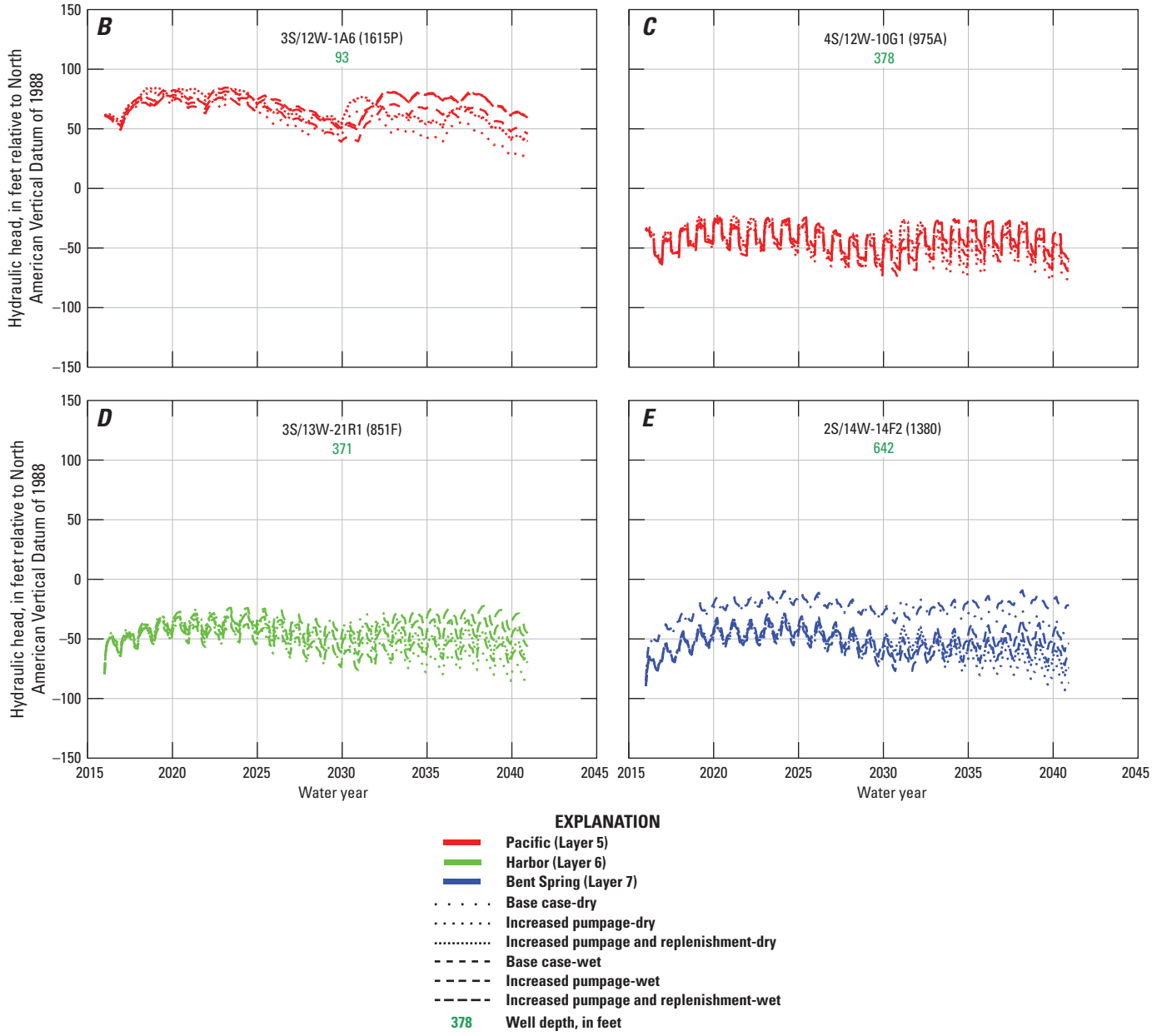


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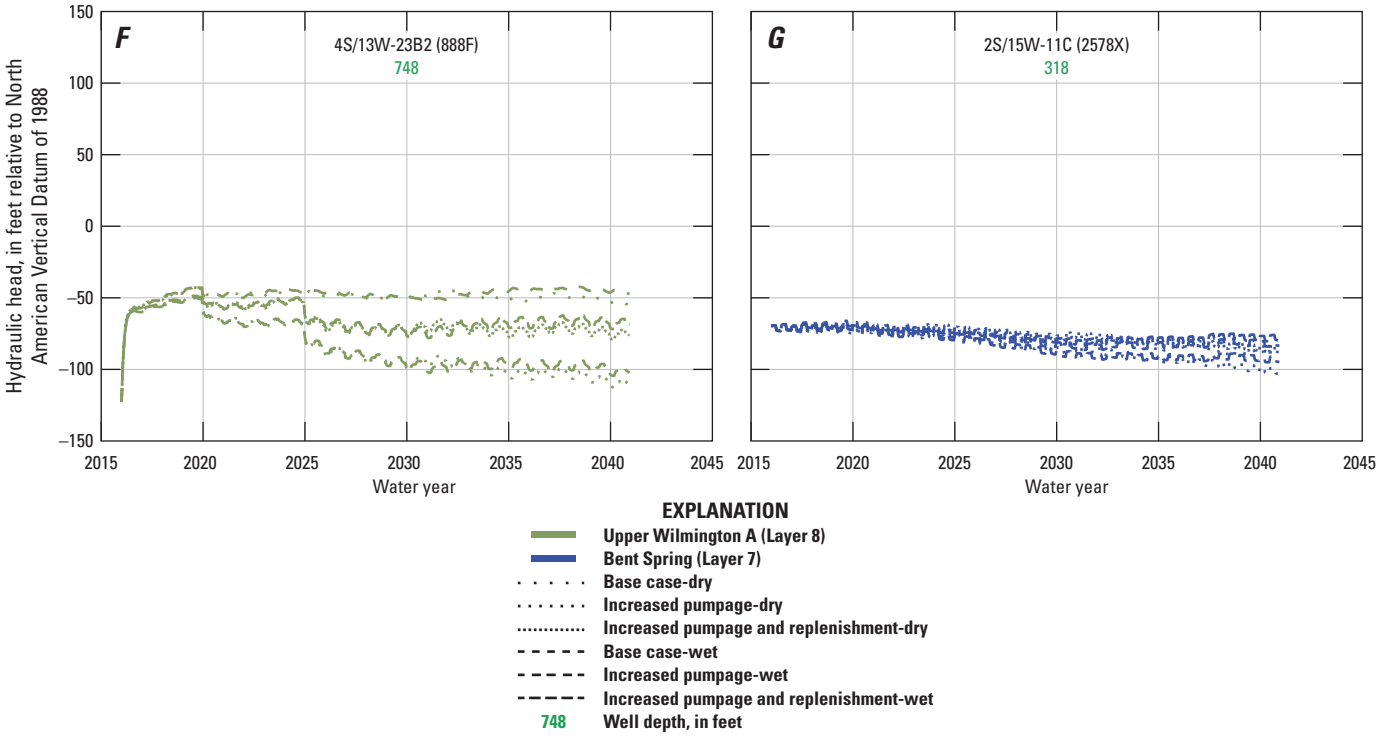


Figure D20.—Continued

Increased-Pumpage Scenario with Dry Conditions

The increased-pumpage scenario with dry conditions used the areal-recharge rates, runoff entering the spreading grounds, and heads along the specified-head and general-head boundaries simulated for water years 1991 to 2015, the same as for the base-case scenario with dry conditions (table D8). For this scenario, simulated average outflows also were greater than inflows, with about 830,000 acre-ft coming from storage (average of 33,000 acre-ft per year; fig. D18; appendix 4, table 4.17). Simulated hydraulic-head change maps for the Pacific aquifer system showed that the increased pumpage resulted in hydraulic-head declines throughout the aquifer system compared to the base-case scenario with dry conditions (fig. D19*B*). Hydraulic-head declines ranged from about 10 ft in the eastern Whittier Area to more than 100 ft in the West Coast Basin (figs. D1, D19*B*). Simulated hydraulic-head change maps for the Bent Spring aquifer system also showed that the increased pumpage resulted in hydraulic-head declines throughout the aquifer system compared to the base-case scenario with dry conditions (fig. D19*B*). Hydraulic-head declines ranged from about 10 ft in the southeastern West Coast Basin to over 50 ft in the northern part of West Coast Basin (fig. D19*B*). Increased-pumpage dry scenario hydraulic-head declines were more extreme than increased-pumpage wet scenario declines in most areas.

Comparison of Scenarios

The base case with dry conditions, the increased-pumpage with wet conditions, and the increased-pumpage with dry conditions scenarios all lost water from storage due to increased pumping, though the amount of water lost varied greatly between the increased-pumpage with wet conditions and the increased-pumpage scenario with dry conditions (fig. D18). The simulated hydraulic-head change maps and hydrographs showed that increasing pumping rates to adjudicated rates would result in water-level declines compared to the base case throughout the LACPGM, in all aquifer systems.

Simulation-Optimization Analysis

The comparison between results from the base case and the increased-pumpage scenarios indicated that increasing pumping rates to adjudication levels results in considerably lower simulated heads throughout most of the LACP in all aquifer systems. The recharge rates simulated for these management scenarios were not adequate to prevent hydraulic heads from declining during the simulation period. To evaluate possible effects of increased recharge, it was assumed that the WRD could increase groundwater replenishment by an additional 15,000 acre-ft/yr at the spreading grounds and about 33,400 acre-ft/yr into the injection wells to help offset the hydraulic-head declines caused from the increased pumpage. The additional 15,000 acre-ft/yr of recharge at the spreading grounds was in addition to any changes in runoff water due to wet or dry conditions. The increased recharge amounts were based on discussions with WRD and were derived from data from historical spreading and injection rates. The WRD could recharge this water at existing spreading grounds and injection wells at different times and at various rates, which results in multiple management decisions. The LACPGM was coupled with mathematical optimization algorithms to optimally identify the quantity and distribution of recharge that would minimize hydraulic-head declines. Optimization methodology was applied to the increased-pumpage scenarios with wet and dry conditions to determine if the simulated hydraulic-head declines could be mitigated by supplementing recharge at the existing spreading grounds and injection wells.

Optimization Methodology

The optimization of proposed management scenarios was done using PEST parameter estimation with recharge amounts as the estimated parameters. The optimization criteria for the increased-pumpage and replenishment scenarios with wet and dry conditions were set to minimize the amounts that simulated heads fall below the lowest simulated heads of the base case scenario and to not allow heads to rise above land surface. Recharge was added to the spreading grounds and barrier injection wells to meet the optimization criteria. The amounts of additional recharge water being added to the WND, SGRSG and RHSG spreading grounds and the WCBBP, DGBP, and ABP barrier wells each year remained fixed throughout each simulation run and were determined by optimization parameters. Total recharge at the spreading grounds was not allowed to exceed 250,000 acre-ft/yr for any given year based on historical maximums. Injections at the WCBBP, DGBP, and ABP were not allowed to exceed 45,000, 10,000, and 8,000 acre-ft/yr for any given year, respectively, based on historical maximums.

The minimum and maximum hydraulic heads allowed by the optimization criteria were set up as observations in PEST. The minimum hydraulic heads allowed were the lowest simulated heads of the base-case scenario while the maximum hydraulic heads allowed for the topmost model cells were land surfaces. While the minimum and maximum hydraulic heads allowed are not measured values, they were set up as observations in PEST to make them part of PEST's objective function and allow PEST to optimize parameters to achieve these criteria. Because simulated hydraulic heads above or equal to the minimum level are acceptable in the management scenarios, simulated heads greater than the optimization criteria were set equal to the optimization criteria using a postprocessing Python script. Similarly, for maximum heads (land surfaces), simulated heads less than the optimization criteria were set equal to the optimization criteria so that simulated heads greater than the minimum heads did not add to PEST's objective function. The optimization criteria averaged simulated hydraulic heads over areas of five by five model cells. This averaging was done to reduce the number of PEST observations required from over 400,000 to under 16,000 and to smooth out simulated drawdowns at production wells.

Six PEST parameters were used for the management scenarios. Each parameter defined the amount of additional recharge added to each spreading ground or injection barrier project. A python script was written to read the additional recharge amounts from a text file produced by PEST and update the MODFLOW-USG management-scenario well package (WEL) file to reflect the additional spreading and injection. This script was run as a pre-processing step prior to running the MODFLOW-USG management-scenario models. All six parameters were used as prior information with a preferred value of zero to favor solutions with minimum recharge added. The six parameters were weighted several orders of magnitude lower than the optimization criteria to ensure that the optimization criteria were met first. Favoring solutions with minimum recharge added had little effect on the results of the optimization scenarios because the optimization could not achieve the other objectives in all areas of the model, even when using the maximum amount of additional recharge.

Simulation-Optimization Results

The optimized increased-pumpage and replenishment scenarios with wet and dry conditions resulted in a simulated storage gain of about 340,000 acre-ft and a storage loss of 78,300 acre-ft of cumulative storage, respectively, by the end of the simulated period (fig. D18; appendix 4, tables 4.2*E*, 4.2*F*). The simulated average annual recharge rates at the spreading grounds and at the injection wells for the optimized increased-pumpage and replenishment scenario with wet conditions were about 148,000 acre-ft/yr (about 17,000 acre-ft/yr higher than the base-case; appendix 4, table 4.18) and 68,000 acre-ft/yr (about 33,400 acre-ft/yr higher than the base-case), respectively. The increases in average annual recharge rates at the spreading grounds were due to additional runoff water collected by the spreading grounds during wet conditions and additional water supplied by WRD. The simulated average annual recharge at the spreading grounds and at the injection wells for optimized increased-pumpage and replenishment scenario with dry conditions were about 140,000 acre-ft/yr (about 17,000 acre-ft/yr higher than the base-case and increased-pumpage scenarios with dry conditions; appendix 4, table 4.19) and about 68,000 acre-ft/yr (about 33,400 acre-ft/yr higher than the base-case and increased-pumpage scenarios with dry conditions), respectively.

Simulated hydraulic-head change maps for the Pacific aquifer system showed that the optimized increased-pumpage and replenishment scenario with wet conditions resulted in hydraulic-head rises in the Montebello Forebay, the eastern part of the Central Basin, and the entire West Coast Basin compared to the base-case scenario with wet conditions (figs. D1, D19*C*). However, simulated hydraulic-heads declined by as much as 20 ft in the Los Angeles Forebay and the northwestern part of the Central Basin compared to the base-case scenario (figs. D1, D19*C*). Simulated hydraulic-head change maps for the Bent Spring aquifer system showed that the optimized increased-pumpage and replenishment scenario with wet conditions resulted in hydraulic-head rises in the Montebello Forebay and the western part of the West Coast Basin compared to the base-case scenario with wet conditions; however, the model simulated hydraulic-head declines throughout most of the Central Basin (fig. D19*C*). Simulated hydraulic-head change maps for the optimized increased-pumpage scenario and replenishment with dry conditions contained more pronounced hydraulic head decreases than the simulated hydraulic-head change maps for the optimized increased-pumpage and replenishment scenario with wet conditions (fig. D19*D*).

These results of the optimized increased-pumping and replenishment scenarios indicated that the supplemental recharge can control hydraulic-head declines throughout most of the Pacific aquifer system; however, the Los Angeles Forebay and northwestern part of the Central Basin are too far away from existing spreading grounds and injection wells to prevent hydraulic-head declines caused by the increased pumpage. The deeper aquifer systems, as represented by the Bent Spring aquifer system, received less benefit from the spreading grounds in the Central Basin than the shallower aquifer systems, as represented by the Pacific aquifer system. Simulated hydraulic heads in the Bent Spring aquifer system rose in the western and southern parts of the West Coast Basin because multiple injection wells are screened in the aquifer system, which allowed increased injection to offset the increased pumpage (fig. D19*C*). The calibrated LACPGM could be used in the future to help identify new spreading ground locations and injection sites that could be used to minimize the hydraulic-head declines caused from the presumed increased pumpage in the LACP. In this study, the costs of recharge were not included in the simulation-optimization analysis. Future work could include developing a simulation-optimization model that could identify least-cost solutions for mitigating hydraulic-head declines from potential increased pumpage in the LACP.

Summary and Conclusions

The primary goal of this study was to improve the understanding of groundwater basins to inform management of groundwater in the Los Angeles Coastal Plain (LACP) area. Our understanding of groundwater in the study area is built on geologic and hydrologic data. This study, in cooperation with the Water Replenishment District of Southern California (WRD), compiled comprehensive geologic and hydrologic data, including construction data and geophysical logs for wells, water-level measurements, and data associated with groundwater recharge and discharge. This study has also built upon previous studies, including a previous groundwater-flow model (Reichard and others, 2003), a geologic framework model (Ponti and others, 2007), and a precipitation-runoff model (Hevesi and Johnson, 2016). Available information on groundwater hydrology was assembled, and a conceptual groundwater-flow model of the study area was developed.

The conceptual groundwater-flow model, previous studies, and data compiled were used to develop the Los Angeles Coastal Plain Groundwater Model (LACPGM) using MODFLOW-USG. The LACPGM model area included the Central, West Coast, Hollywood, Santa Monica, and partial Orange County Basins. The LACPGM is a 12-layer unstructured-grid model based upon a 13-layer chronostratigraphic hydrogeologic-framework model developed for this study (Chapter B), with the bottom two layers of the framework combined into a single model layer in the LACPGM. Chronostratigraphic-unit layering provides a more realistic representation of the geologic structure, the distribution of lithologic facies, and aquifer architecture, which improves our ability to simulate the movement of groundwater in a complex aquifer system.

The Reichard and others (2003) transient model runtime (1971 to 2000) was extended to 2015 in the LACPGM. Initial conditions were simulated using 1971 water levels interpolated across the study area. The LACPGM is a transient model with 180 quarterly stress periods. Areal recharge in LACPGM is based on the precipitation-runoff model from Hevesi and Johnson (2016). Geologic and geophysical logs from WRD/USGS monitoring sites were used to determine grain size of the chronostratigraphic units. Grain sizes were used to help determine initial horizontal hydraulic conductivity and were also used as part of the calibration process. Development of the LACPGM required compiling data to define boundary conditions, pumpage, injection, and water spreading. Water-level data were compiled from monitoring wells, including 57 WRD/USGS multiple-well monitoring sites, multi-completion monitoring sites from the Orange County Water District, and long-screened monitoring wells. The LACPGM was calibrated to monitoring-well water levels, mostly in the Central and West Coast Basins, using PEST parameter estimation software (Doherty, 2010).

The calibrated model was used to analyze groundwater budgets for subareas within the study area. The Montebello Forebay had the highest average inflows of any subarea within the study area, including 122,700 acre-ft/year from water spreading and 36,300 acre-ft/year of underflow through the Whittier Narrows from 1971 to 2015. Inflows also were high into the Orange County Central subarea, averaging 39,100 acre-ft/year from areas of Orange County Basin to the east of the General Head Boundary (GHB). The West Coast Basin had substantial recharge, with an average 27,300 acre-ft/year of injection and 12,100 acre-ft/year of areal recharge from 1971 to 2015. Subareas with high discharge (pumpage) include the Central Basin Pressure Area, West Coast Basin, Orange County Central, and the Montebello Forebay, averaged about 130,000, 50,000, 48,000, and 45,000 acre-ft/year from 1971 to 2015, respectively. Most of the flow between subareas occurred in northern subareas of the model area, with a north to south flow direction. Flow from the Montebello Forebay to the Central Basin Pressure Area averaged 115,800 acre-ft/year, and flow from the Los Angeles Forebay (non-WRD) to the Los Angeles Forebay (WRD) averaged about 9,200 acre-ft/year from 1971 to 2015. Only 4,500 acre-ft/year flowed from the Central Basin Pressure Area (WRD) into the West Coast Basin subarea, due to flow being partially restricted by the Newport-Inglewood fault zone and a smaller hydraulic gradient between the Central and West Coast Basins subareas.

The LACPGM was used to predict water levels resulting from six future water-management scenarios: base case wet and dry scenarios, increased pumpage wet and dry scenarios, and optimized replenishment wet and dry scenarios. Model scenarios used data from selected wet and dry periods during the LACPGM runtime of 1971 to 2015. The model scenarios simulated expected future pumping rates and estimated increases in water spreading and injection needed to maintain water levels. Results of model scenarios showed that additional water spreading and injection had a limited effect on reducing drawdowns at production wells that are far away from existing recharge facilities and was unable to curtail large drawdowns in the northeastern and eastern Central Basin and eastern West Coast Basin subareas. Large drawdowns generally occurred in the upper (aquifer systems above Bent Spring) and lower (aquifer systems below and including Bent Spring) aquifer systems in the Central Basin, with more drawdown occurring in the lower aquifer system. In the West Coast Basin subarea, large drawdowns generally occurred in the lower aquifer systems. To mitigate the impacts of these larger drawdowns that are distal to the existing recharge facilities, new recharge facilities closer to the pumping centers could be constructed, or other measures could be applied to reduce overall pumping, in these high-drawdown areas.

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Appendix 1. The Use of Water-Quality Data to Help Identify Chronostratigraphic Unit Boundaries, Sediment Sources, Sediment Facies, Water Sources, and Model Zones

By Peter Martin, Michael Land, and Roy A. Schroeder

Water-quality data were used in this study to help identify chronostratigraphic unit boundaries, sediment sources, sediment facies, water sources, and model zones. Background information on the water-quality data or parameters used for this study and how they were applied are discussed in the following sections.

Data Compilation

The water-quality data used for this study were compiled from historical data stored on the USGS National Water Information System (NWIS, U.S. Geological Survey, 2016). Most of these data were collected and analyzed as part of an ongoing cooperative study between the USGS and the Water Replenishment District of Southern California (WRD) to examine groundwater resources in the Central and West Coast Basins in Los Angeles County, California (Land and others, 2002; Reichard and others, 2003; Land and others, 2004). Most of these water-quality samples were collected from a network of multiple-well monitoring sites constructed in cooperation with WRD (fig. 1.1, tables 1.1, 1.2). These multiple-well monitoring sites were mostly in the Central and West Coast Basins, with one well, 5S/12W-1C3-9 (Seal Beach 1), in the Orange County Basin. Wells identified in figure 1.1 show only the section and sequence number from the State Well Number listed in table 1.1. These sites consist of two to nine nested wells isolated from one another in the borehole by a low-permeability grout. A detailed description of the construction of a typical USGS multiple-well monitoring site is presented in Land and others (2002). Additional data, from production wells in the Los Angeles and Orange County Basins (fig. 1.1, tables 1.1, 1.2), were collected for the Coastal Los Angeles Basin Study of the Statewide Basin Assessment Project of the Groundwater Ambient Monitoring and Assessment (GAMA) Program (Mathany and others, 2008). Data collection procedures, sample handling, preservation, analysis, and quality assurance are presented in Land and others (2002, 2004) for the multiple-well monitoring sites and in Mathany and others (2008) for the GAMA data. Water-quality data collected by the USGS and used for this study are stored in the NWIS and can be accessed by the public using the 15-digit USGS station identification (ID) numbers in table 1.1. Selected water-quality data were also compiled from the WRD (Water Replenishment District of Southern California, 2017).

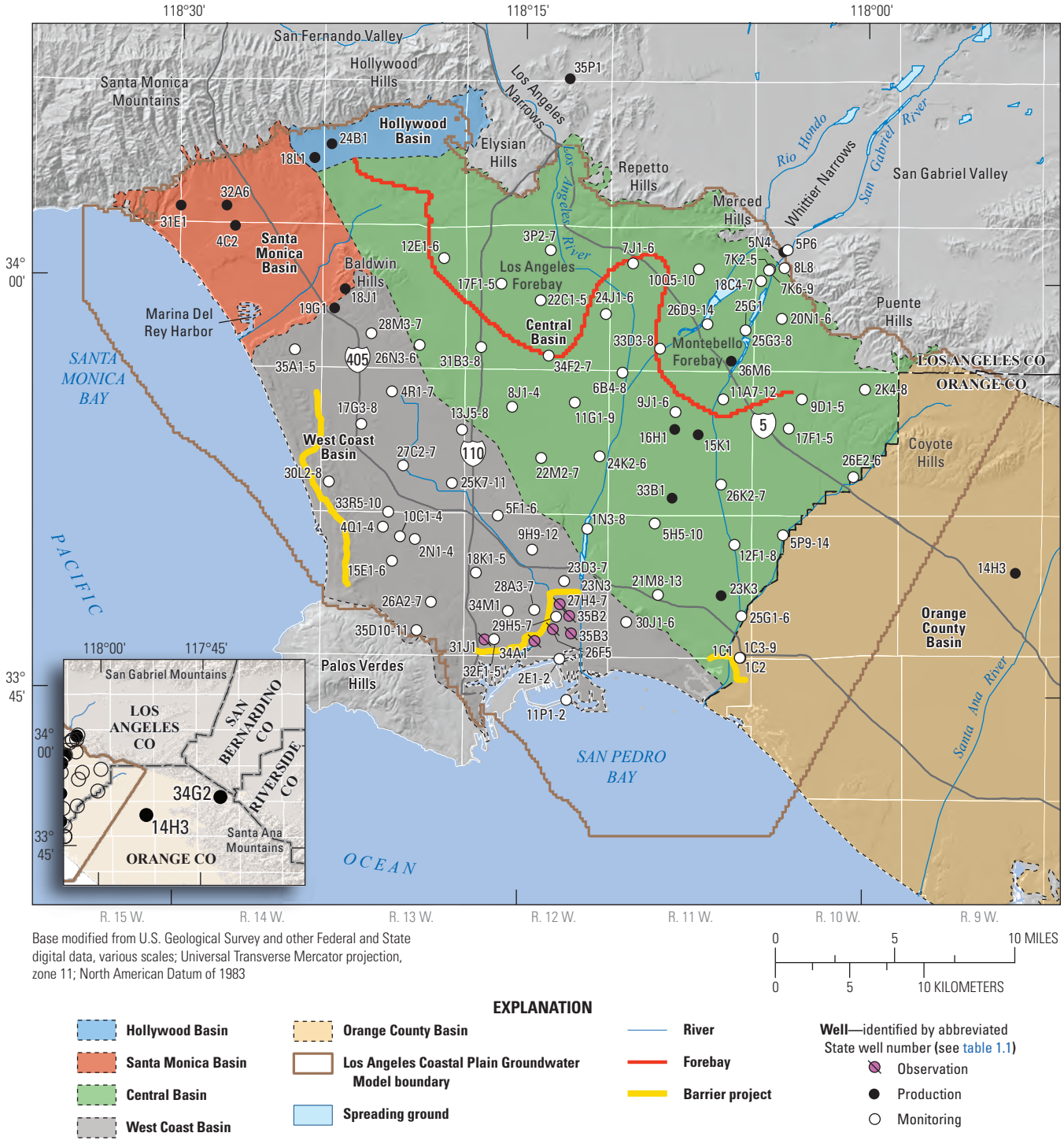


Figure 1.1. Locations of the multiple-well monitoring sites, observation wells, and production wells with water-quality data used for this study, Los Angeles and Orange Counties, California.

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a
Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
1N/13W-35P1	35P1	340700118130001	DS_WATERS	SFV	prod.	wq	494
1S/13W-15H1	15H1	n.a.	2771I	LAF	obs.	wl	352
1S/13W-15R2	15R2	n.a.	2772E	LAF	obs.	wl	321
1S/13W-22R1	22R1	n.a.	2773	LAF	prod.	wl	279
1S/13W-33A1	33A1	n.a.	2765	LAF	prod.	wl	260
1S/14W-14E1	14E1	n.a.	2671A	HB	prod.	wl	281
1S/14W-18L1	18L1	340400118230001	BH_2	HB	prod.	wq	235
1S/15W-24B1	24B1	340400118240001	BH_5	HB	prod.	wq	268
1S/15W-31E1	31E1	340235118295901	SM 1 (2505)	SMB	prod.	wl, wq	313
1S/15W-32A5	32A5	340238118272501	2535J	SMB	prod.	wl	239
1S/15W-32A6	32A6	340200118270001	SM Arcadia_5	SMB	prod.	wq	243
2S/11W-5N4	5N4	340112118033701	Whittier_14	MF	prod.	wq	202
2S/11W-5P6	5P6	340112118032601	Whittier Narrows1_1	SGV	multi.	wq	215
2S/11W-5P7	5P7	340112118032602	Whittier Narrows1_2	SGV	multi.	wq	215
2S/11W-5P8	5P8	340112118032603	Whittier Narrows1_3	SGV	multi.	wq	215
2S/11W-5P9	5P9	340112118032604	Whittier Narrows1_4	SGV	multi.	wq	215
2S/11W-5P10	5P10	340112118032605	Whittier Narrows1_5	SGV	multi.	wq	215
2S/11W-5P11	5P11	340112118032606	Whittier Narrows1_6	SGV	multi.	wq	215
2S/11W-5P12	5P12	340112118032607	Whittier Narrows1_7	SGV	multi.	wq	215
2S/11W-5P13	5P13	340112118032608	Whittier Narrows1_8	SGV	multi.	wq	215
2S/11W-5P14	5P14	340112118032609	Whittier Narrows1_9	SGV	multi.	wq	215
2S/11W-6G2	6G2	n.a.	2927A	SGV	prod.	wl	201
2S/11W-7K2	7K2	340030118041201	Pico Rivera3_1	MF	multi.	wq	191
2S/11W-7K3	7K3	340030118041202	Pico Rivera3_2	MF	multi.	wq	191
2S/11W-7K4	7K4	340030118041203	Pico Rivera3_3	MF	multi.	wq	191
2S/11W-7K5	7K5	340030118041204	Pico Rivera3_4	MF	multi.	wq	191
2S/11W-7K6	7K6	340027118041501	Pico Rivera4_1	MF	multi.	wq	192
2S/11W-7K7	7K7	340027118041502	Pico Rivera4_2	MF	multi.	wq	192
2S/11W-7K8	7K8	340027118041503	Pico Rivera4_3	MF	multi.	wq	192
2S/11W-7K9	7K9	340027118041504	Pico Rivera4_4	MF	multi.	wq	192
2S/11W-8L8	8L8	340033118033401	Whittier Narrows2_1	MF	multi.	wq	209
2S/11W-8L9	8L9	340033118033402	Whittier Narrows2_2	MF	multi.	wq	209
2S/11W-8L10	8L10	340033118033403	Whittier Narrows2_3	MF	multi.	wq	209
2S/11W-8L11	8L11	340033118033404	Whittier Narrows2_4	MF	multi.	wq	209
2S/11W-8L12	8L12	340033118033405	Whittier Narrows2_5	MF	multi.	wq	209
2S/11W-8L13	8L13	340033118033406	Whittier Narrows2_6	MF	multi.	wq	209
2S/11W-8L14	8L14	340033118033407	Whittier Narrows2_7	MF	multi.	wq	209
2S/11W-8L15	8L15	340033118033408	Whittier Narrows2_8	MF	multi.	wq	209
2S/11W-8L16	8L16	340033118033409	Whittier Narrows2_9	MF	multi.	wq	209
2S/11W-18C4	18C4	340005118043301	Pico Rivera1_1	MF	multi.	wq	183
2S/11W-18C5	18C5	340005118043302	Pico Rivera1_2	MF	multi.	wq	183

ange Counties, California.

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
300	62	300	1	—	—	n.a.
76	—	—	—	01/04/2010	298.2	Mesa
—	20	40	1	01/04/2010	288.6	Mesa
—	33	99	1	04/14/1978	263.5	Mesa
—	87	254	1	03/13/1979	149.9	Mesa
—	1	54	1	07/29/2009	263.4	Mesa
740	398	730	4	—	—	Upper Wilmington A
665	360	630	3	—	—	Pacific
282	151	250	1	04/27/2009	112.7	Pacific
218	85	218	1	04/27/2009	211.2	Mesa
250	120	220	1	—	—	Mesa
414	183	386	3	—	—	Mesa
808	749	769	1	09/17/2014	146.8	Long Beach BC
808	609	629	1	09/17/2014	149.5	Long Beach A
808	462	482	1	09/17/2014	153.0	Lower Wilmington
808	392	402	1	09/17/2014	160.8	Upper Wilmington B
808	334	344	1	09/17/2014	161.6	Upper Wilmington B
808	272	282	1	09/17/2014	163.2	Upper Wilmington A
808	233	243	1	09/17/2014	163.3	Upper Wilmington A
808	163	173	1	09/17/2014	163.5	Mesa
808	95	105	1	09/17/2014	165.3	Dominguez
—	15	44	1	10/24/2014	173.7	Mesa
735	680	735	1	06/27/2016	132.1	Long Beach C
620	530	620	1	06/27/2016	132.9	Long Beach C
330	270	330	1	06/27/2016	114.9	Long Beach A
130	100	130	1	06/27/2016	134.1	Mesa
780	750	780	1	07/12/2016	127.5	Long Beach C
680	590	680	1	07/12/2016	128.7	Long Beach C
310	260	310	1	07/12/2016	110.7	Long Beach A
130	110	130	1	07/12/2016	129.8	Mesa
718	659	678	1	09/18/2014	–18.4	“Repetto”
718	579	598	1	09/18/2014	–18.3	“Repetto”
718	469	488	1	09/18/2014	–17.7	“Repetto”
718	418	428	1	09/18/2014	–10.8	“Repetto”
718	328	338	1	09/18/2014	82.4	Long Beach C
718	263	273	1	09/18/2014	129.0	Long Beach B
718	213	223	1	09/18/2014	129.9	Pacific
718	135	145	1	09/18/2014	132.8	Mesa
718	90	100	1	09/18/2014	151.9	Mesa
900	860	900	1	09/17/2014	104.1	Long Beach C
480	460	480	1	09/17/2014	73.6	Long Beach B

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a
Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
2S/11W-18C6	18C6	340005118043303	Pico Rivera1_3	MF	multi.	wq	183
2S/11W-18C7	18C7	340005118043304	Pico Rivera1_4	MF	multi.	wq	183
2S/11W-20N1	20N1	335842118034101	Whittier2_1	MF	multi.	wq	169
2S/11W-20N2	20N2	335842118034102	Whittier2_2	MF	multi.	wq	169
2S/11W-20N3	20N3	335842118034103	Whittier2_3	MF	multi.	wq	169
2S/11W-20N4	20N4	335842118034104	Whittier2_4	MF	multi.	wq	169
2S/11W-20N5	20N5	335842118034105	Whittier2_5	MF	multi.	wq	169
2S/11W-20N6	20N6	335842118034106	Whittier2_6	MF	multi.	wq	169
2S/11W-33E2	33E2	n.a.	1654H	W	prod.	wl	151
2S/12W-7J1	7J1	340040118100901	Commerce1_1	CB	multi.	wq	164
2S/12W-7J2	7J2	340040118100902	Commerce1_2	CB	multi.	wq	164
2S/12W-7J3	7J3	340040118100903	Commerce1_3	CB	multi.	wq	164
2S/12W-7J4	7J4	340040118100904	Commerce1_4	CB	multi.	wq	164
2S/12W-7J5	7J5	340040118100905	Commerce1_5	CB	multi.	wq	164
2S/12W-7J6	7J6	340040118100906	Commerce1_6	CB	multi.	wq	164
2S/12W-10Q5	10Q5	340027118071901	Montebello1_1	MF	multi.	wq	192
2S/12W-10Q6	10Q6	340027118071902	Montebello1_2	MF	multi.	wq	192
2S/12W-10Q7	10Q7	340027118071903	Montebello1_3	MF	multi.	wq	192
2S/12W-10Q8	10Q8	340027118071904	Montebello1_4	MF	multi.	wq	192
2S/12W-10Q9	10Q9	340027118071905	Montebello1_5	MF	multi.	wq	192
2S/12W-10Q10	10Q10	340027118071906	Montebello1_6	MF	multi.	wq	192
2S/12W-24M3	24M3	n.a.	1601P	MF	prod.	wl	162
2S/12W-25G1	25G1	335817118051301	Pico Rivera W12	MF	prod.	wq	157
2S/12W-25G3	25G3	335818118051201	Pico Rivera2_1	MF	multi.	wq	152
2S/12W-25G4	25G4	335818118051202	Pico Rivera2_2	MF	multi.	wq	152
2S/12W-25G5	25G5	335818118051203	Pico Rivera2_3	MF	multi.	wq	152
2S/12W-25G6	25G6	335818118051204	Pico Rivera2_4	MF	multi.	wq	152
2S/12W-25G7	25G7	335818118051205	Pico Rivera2_5	MF	multi.	wq	152
2S/12W-25G8	25G8	335818118051206	Pico Rivera2_6	MF	multi.	wq	152
2S/12W-26D9	26D9	335829118065201	Rio Hondo1_1	MF	multi.	wq	147
2S/12W-26D10	26D10	335829118065202	Rio Hondo1_2	MF	multi.	wq	147
2S/12W-26D11	26D11	335829118065203	Rio Hondo1_3	MF	multi.	wq	147
2S/12W-26D12	26D12	335829118065204	Rio Hondo1_4	MF	multi.	wq	147
2S/12W-26D13	26D13	335829118065205	Rio Hondo1_5	MF	multi.	wq	147
2S/12W-26D14	26D14	335829118065206	Rio Hondo1_6	MF	multi.	wq	147
2S/12W-33D3	33D3	335735118085801	Bell Gardens1_1	MF	multi.	wq	120
2S/12W-33D4	33D4	335735118085802	Bell Gardens1_2	MF	multi.	wq	120
2S/12W-33D5	33D5	335735118085803	Bell Gardens1_3	MF	multi.	wq	120
2S/12W-33D6	33D6	335735118085804	Bell Gardens1_4	MF	multi.	wq	120
2S/12W-33D7	33D7	335735118085805	Bell Gardens1_5	MF	multi.	wq	120
2S/12W-33D8	33D8	335735118085806	Bell Gardens1_6	MF	multi.	wq	120

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
400	380	400	1	09/17/2014	72.3	Long Beach A
190	170	190	1	09/17/2014	81.4	Pacific
1,390	1,370	1,390	1	09/12/2014	69.3	Long Beach B
1,110	1,090	1,110	1	09/12/2014	69.6	Long Beach A
675	655	675	1	09/12/2014	55.0	Upper Wilmington A
445	425	445	1	09/12/2014	55.2	Harbor
335	315	335	1	09/12/2014	87.0	Pacific
170	150	170	1	09/12/2014	97.0	Mesa
—	15	296	1	04/20/2008	118.1	Pacific
1,390	1,330	1,390	1	09/22/2014	35.1	Long Beach C
960	940	960	1	09/23/2014	23.4	Long Beach A
780	760	780	1	09/23/2014	19.2	Upper Wilmington B
590	570	590	1	09/23/2014	–14.6	Upper Wilmington A
345	325	345	1	09/23/2014	–9.1	Pacific
225	205	225	1	09/23/2014	36.8	Mesa
980	900	960	1	09/22/2014	61.6	Long Beach C
710	690	710	1	09/22/2014	54.7	Long Beach B
520	500	520	1	09/22/2014	54.2	Upper Wilmington B
390	370	390	1	09/22/2014	51.9	Upper Wilmington A
230	210	230	1	09/22/2014	54.7	Pacific
110	90	110	1	09/19/2007	91.3	Mesa
—	154	174	1	10/04/1992	112.3	Mesa
520	242	446	3	—	—	Mesa
1,200	1,180	1,200	1	09/15/2014	40.6	Long Beach A
850	830	850	1	09/15/2014	40.2	Upper Wilmington B
580	560	580	1	09/15/2014	48.8	Upper Wilmington A
340	320	340	1	09/15/2014	68.1	Pacific
255	235	255	1	09/15/2014	67.7	Mesa
120	100	120	1	09/15/2014	74.0	Dominguez
1,150	1,110	1,130	1	09/17/2014	39.5	Long Beach A
930	910	930	1	09/17/2014	35.0	Lower Wilmington
730	710	730	1	09/17/2014	34.2	Upper Wilmington B
450	430	450	1	09/17/2014	29.2	Upper Wilmington A
300	280	300	1	09/17/2014	37.7	Pacific
160	140	160	1	09/17/2014	41.5	Mesa
1,795	1,775	1,795	1	09/16/2014	–11.5	Lower Wilmington
1,410	1,390	1,410	1	09/16/2014	–12.6	Upper Wilmington A
1,110	1,090	1,110	1	09/16/2014	–10.7	Bent Spring
875	855	875	1	09/16/2014	–3.0	Harbor
575	555	575	1	09/16/2014	1.3	Pacific
390	370	390	1	09/16/2014	1.0	Pacific_A

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
2S/12W-33L3	33L3	n.a.	1554F	MF	obs.	wl	118
2S/12W-36M6	36M6	335712118054901	Pico Rivera W8	MF	prod.	wq	140
2S/13W-3P2	3P2	340106118134801	Los Angeles2_1	LAF	multi.	wq	223
2S/13W-3P3	3P3	340106118134802	Los Angeles2_2	LAF	multi.	wq	223
2S/13W-3P4	3P4	340106118134803	Los Angeles2_3	LAF	multi.	wq	223
2S/13W-3P5	3P5	340106118134804	Los Angeles2_4	LAF	multi.	wq	223
2S/13W-3P6	3P6	340106118134805	Los Angeles2_5	LAF	multi.	wq	223
2S/13W-3P7	3P7	340106118134806	Los Angeles2_6	LAF	multi.	—	223
2S/13W-10A1	10A1	n.a.	2778	LAF	prod.	wl	221
2S/13W-17F1	17F1	335952118155601	Los Angeles1_1	LAF	multi.	wq	177
2S/13W-17F2	17F2	335952118155602	Los Angeles1_2	LAF	multi.	wq	177
2S/13W-17F3	17F3	335952118155603	Los Angeles1_3	LAF	multi.	wq	177
2S/13W-17F4	17F4	335952118155604	Los Angeles1_4	LAF	multi.	wq	177
2S/13W-17F5	17F5	335952118155605	Los Angeles1_5	LAF	multi.	wq	177
2S/13W-22C1	22C1	335917118141001	Huntington Park1_1	LAF	multi.	wq	180
2S/13W-22C2	22C2	335917118141002	Huntington Park1_2	LAF	multi.	wq	180
2S/13W-22C3	22C3	335917118141003	Huntington Park1_3	LAF	multi.	wq	180
2S/13W-22C4	22C4	335917118141004	Huntington Park1_4	LAF	multi.	wq	180
2S/13W-22C5	22C5	335917118141005	Huntington Park1_5	LAF	multi.	wq	180
2S/13W-24J1	24J1	335849118112201	Bell1_1	CB	multi.	wq	147
2S/13W-24J2	24J2	335849118112202	Bell1_2	CB	multi.	wq	147
2S/13W-24J3	24J3	335849118112203	Bell1_3	CB	multi.	wq	147
2S/13W-24J4	24J4	335849118112204	Bell1_4	CB	multi.	wq	147
2S/13W-24J5	24J5	335849118112205	Bell1_5	CB	multi.	wq	147
2S/13W-24J6	24J6	335849118112206	Bell1_6	CB	multi.	wq	147
2S/13W-31B3	31B3	335733118164701	Los Angeles4_1	CB	multi.	wq	141
2S/13W-31B4	31B4	335733118164702	Los Angeles4_2	CB	multi.	wq	141
2S/13W-31B5	31B5	335733118164703	Los Angeles4_3	CB	multi.	wq	141
2S/13W-31B6	31B6	335733118164704	Los Angeles4_4	CB	multi.	wq	141
2S/13W-31B7	31B7	335733118164705	Los Angeles4_5	CB	multi.	wq	141
2S/13W-31B8	31B8	335733118164706	Los Angeles4_6	CB	multi.	wq	141
2S/13W-32C4	32C4	n.a.	1434J	CB	prod.	wl	132
2S/13W-34F2	34F2	335716118135101	South Gate2_1	LAF	multi.	wq	122
2S/13W-34F3	34F3	335716118135102	South Gate2_2	LAF	multi.	wq	122
2S/13W-34F4	34F4	335716118135103	South Gate2_3	LAF	multi.	wq	122
2S/13W-34F5	34F5	335716118135104	South Gate2_4	LAF	multi.	wq	122
2S/13W-34F6	34F6	335716118135105	South Gate2_5	LAF	multi.	wq	122
2S/13W-34F7	34F7	335716118135106	South Gate2_6	LAF	multi.	wq	122
2S/13W-36F2	36F2	n.a.	1504C	CB	prod.	wl	124
2S/14W-5D8	5D8	n.a.	2626P	CB	prod.	wl	79
2S/14W-12E1	12E1	340046118182701	Los Angeles3_1	LAF	multi.	wq	147

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
—	130	140	1	10/16/2014	37.0	Mesa
627	277	584	2	—	—	Pacific
1,370	1,330	1,370	1	09/18/2014	46.4	Long Beach C
730	710	730	1	09/18/2014	–3.6	Upper Wilmington A
525	505	525	1	09/18/2014	–4.1	Upper Wilmington A
430	410	430	1	09/18/2014	–18.0	Harbor
265	245	265	1	09/18/2014	–26.1	Pacific
155	135	155	1	09/18/2014	dry	Mesa
770	160	645	1	10/16/2014	–22.4	Harbor
1,370	1,350	1,370	1	09/15/2014	–32.5	Upper Wilmington B
1,100	1,080	1,100	1	09/15/2014	–26.1	Upper Wilmington A
940	920	940	1	09/15/2014	–26.8	Bent Spring
660	640	660	1	09/15/2014	–28.5	Harbor
370	350	370	1	09/15/2014	–17.9	Pacific_A
910	890	910	1	09/18/2014	–34.6	Bent Spring
710	690	710	1	09/18/2014	–38.7	Harbor
440	420	440	1	09/18/2014	–25.4	Pacific_A
295	275	295	1	09/18/2014	11.5	Mesa
134	114	134	1	09/19/2007	48.3	Dominguez
1,750	1,730	1,750	1	09/17/2014	–33.7	Long Beach B
1,215	1,195	1,215	1	09/17/2014	–40.8	Lower Wilmington
985	965	985	1	09/17/2014	–29.1	Upper Wilmington A
635	615	635	1	09/17/2014	–27.7	Bent Spring
440	420	440	1	09/17/2014	–19.7	Pacific
270	250	270	1	09/17/2014	10.8	Pacific_A
1,780	1,740	1,780	1	09/18/2014	–29.3	Long Beach A
1,230	1,190	1,230	1	09/18/2014	–60.8	Lower Wilmington
740	720	740	1	09/18/2014	–50.2	Upper Wilmington A
510	490	510	1	09/18/2014	–34.6	Harbor
375	355	375	1	09/18/2014	–32.4	Harbor
255	235	255	1	09/18/2014	–17.8	Pacific
—	604	785	1	01/06/2010	–39.8	Upper Wilmington A
1,760	1,740	1,760	1	09/23/2014	–37.1	Harbor
1,430	1,410	1,430	1	09/23/2014	–36.5	Harbor
1,082	1,062	1,082	1	09/23/2014	–29.9	Pacific
690	670	690	1	09/23/2014	–20.4	Pacific_A
430	410	430	1	09/23/2014	42.6	Mesa
225	205	225	1	09/23/2014	48.5	Dominguez
1,400	978	1,266	1	10/01/1997	18.5	Harbor
—	70	370	1	09/15/2009	20.0	Mesa
1,570	1,210	1,230	1	09/18/2014	–19.4	Lower Wilmington

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a
Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
2S/14W-12E2	12E2	340046118182702	Los Angeles3_2	LAF	multi.	wq	147
2S/14W-12E3	12E3	340046118182703	Los Angeles3_3	LAF	multi.	wq	147
2S/14W-12E4	12E4	340046118182704	Los Angeles3_4	LAF	multi.	wq	147
2S/14W-12E5	12E5	340046118182705	Los Angeles3_5	LAF	multi.	wq	147
2S/14W-12E6	12E6	340046118182706	Los Angeles3_6	LAF	multi.	wq	147
2S/14W-14F2	14F2	345947118190401	1380	CB	prod.	wl	120
2S/14W-18J1	18J1	335900118220001	Holy_Cross_AA	WCB	prod.	wq	234
2S/14W-19G1	19G1	335800118230001	Hillside_Park_1	WCB	prod.	wq	76
2S/14W-22P4	22P4	n.a.	1362P	CB	prod.	wl	172
2S/14W-26N3	26N3	335737118192501	Inglewood2_1	CB	multi.	wq	217
2S/14W-26N4	26N4	335737118192502	Inglewood2_2	CB	multi.	wq	217
2S/14W-26N5	26N5	335737118192503	Inglewood2_3	CB	multi.	wq	117
2S/14W-26N6	26N6	335737118192504	Inglewood2_4	CB	multi.	wq	117
2S/14W-28M3	28M3	335801118213101	Inglewood1_1	WCB	multi.	wq	117
2S/14W-28M4	28M4	335801118213102	Inglewood1_2	WCB	multi.	wq	117
2S/14W-28M5	28M5	335801118213103	Inglewood1_3	WCB	multi.	wq	117
2S/14W-28M6	28M6	335801118213104	Inglewood1_4	WCB	multi.	wq	117
2S/14W-28M7	28M7	335801118213105	Inglewood1_5	WCB	multi.	wq	117
2S/14W-29H1	29H1	n.a.	1333C	WCB	prod.	wl	94
2S/14W-32C2	32C2	n.a.	1324H	WCB	prod.	wl	95
2S/15W-4C2	4C2	340152118273601	2546K	SMB	prod.	wl, wq	154
2S/15W-9N9	9N9	n.a.	2539L	SMB	obs.	wl	26
2S/15W-11F5	11F5	n.a.	2578X	SMB	prod.	wl	78
2S/15W-13P7	13P7	n.a.	1290P	SMB	obs.	wl	34
2S/15W-22E3	22E3	n.a.	1251T	SMB	obs.	wl	10
2S/15W-28Q1	28Q1	n.a.	1243B	SMB	—	wl	10
2S/15W-35A1	35A1	335723118245501	Westchester1_1	WCB	multi.	wq	127
2S/15W-35A2	35A2	335723118245502	Westchester1_2	WCB	multi.	wq	127
2S/15W-35A3	35A3	335723118245503	Westchester1_3	WCB	multi.	wq	127
2S/15W-35A4	35A4	335723118245504	Westchester1_4	WCB	multi.	wq	127
2S/15W-35A5	35A5	335723118245505	Westchester1_5	WCB	multi.	wq	127
3S/08W-34G2	34G2	335210117422801	Canyon_RV_1_ east	OCB	prod.	wq	383
3S/10W-8B00	8B00	n.a.	LH–FS142	OCB	prod.	wl	282
3S/10W-9G1	9G1	n.a.	LH–FS192	OCB	prod.	wl	307
3S/10W-21H2	21H2	n.a.	FM–6	OCB	obs.	wl	255
3S/11W-2K4	2K4	335609118000101	Whittier1_1	W	multi.	wq	212
3S/11W-2K5	2K5	335609118000102	Whittier1_2	W	multi.	wq	212
3S/11W-2K6	2K6	335609118000104	Whittier1_4	W	multi.	wq	212
3S/11W-2K7	2K7	335609118000105	Whittier1_5	W	multi.	wq	212
3S/11W-2K8	2K8	335609118000201	Whittier1_3	W	multi.	wq	212
3S/11W-9D2	9D2	335546118024302	Santa Fe Springs1_2	W	multi.	wq	167

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
895	875	895	1	09/18/2014	–6.6	Upper Wilmington A
725	705	725	1	09/18/2014	–12.2	Harbor
570	550	570	1	09/18/2014	–18.2	Pacific
350	330	350	1	09/18/2014	–14.1	Pacific_A
210	190	210	1	09/18/2014	7.5	Mesa
954	330	954	1	06/01/2010	–50.5	Bent Spring
440	260	430	1	—	—	Upper Wilmington B
620	200	600	3	—	—	Upper Wilmington A
—	285	324	1	11/03/1998	–11.3	Pacific
860	800	840	1	09/12/2014	–25.3	Long Beach A
470	450	470	1	09/12/2014	–17.2	Lower Wilmington
350	330	350	1	09/12/2014	–4.7	Harbor
245	225	245	1	09/12/2014	1.3	Pacific
1,400	1,380	1,400	1	09/12/2014	–31.4	Long Beach C
885	865	885	1	09/12/2014	–46.4	Long Beach A
450	430	450	1	09/12/2014	–33.4	Upper Wilmington B
300	280	300	1	09/12/2014	2.3	Harbor
170	150	170	1	09/12/2014	7.8	Pacific
—	246	432	1	04/12/1979	–19.6	Upper Wilmington A
400	163	342	1	04/11/1979	–13.6	Pacific
550	210	530	4	04/27/2009	–24.8	Pacific
—	135	145	1	04/27/2009	10.6	Pacific
460	180	456	1	11/29/1999	1.5	Bent Spring
—	230	240	1	04/17/2011	10.3	Bent Spring
—	120	185	1	10/18/2010	2.3	Pacific
—	84	132	1	04/20/2008	2.4	Mesa
860	740	760	1	09/13/2014	–2.8	Lower Wilmington
580	560	580	1	09/13/2014	7.3	Upper Wilmington B
475	455	475	1	09/13/2014	7.7	Upper Wilmington B
330	310	330	1	09/13/2014	7.8	Bent Spring
235	215	235	1	09/13/2014	7.9	Harbor
98	60	84	1	—	—	n.a.
1,180	600	1,160	—	06/25/2012	252.3	Lower Wilmington
—	300	500	—	09/12/2014	269.4	Lower Wilmington
—	150	310	1	09/09/2014	192.8	Long Beach A
1,280	1,180	1,200	1	09/15/2014	114.4	Long Beach C
940	920	940	1	09/15/2014	114.4	Long Beach BC
470	450	470	1	09/15/2014	103.7	Long Beach A
220	200	220	1	09/15/2014	197.2	Pacific
620	600	620	1	09/15/2014	105.9	Long Beach B
845	825	845	1	09/29/2002	83.2	Lower Wilmington

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a
Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
3S/11W-9D3	9D3	335546118024303	Santa Fe Springs1_3	W	multi.	wq	167
3S/11W-9D4	9D4	335546118024304	Santa Fe Springs1_4	W	multi.	wq	167
3S/11W-17F1	17F1	335443118031901	Norwalk1_1	CB	multi.	wq	97
3S/11W-17F2	17F2	335443118031902	Norwalk1_2	CB	multi.	wq	97
3S/11W-17F3	17F3	335443118031903	Norwalk1_3	CB	multi.	wq	97
3S/11W-17F4	17F4	335443118031904	Norwalk1_4	CB	multi.	wq	97
3S/11W-17F5	17F5	335443118031905	Norwalk1_5	CB	multi.	wq	97
3S/11W-26E2	26E2	335258118002401	La Mirada1_1	CB	multi.	wq	80
3S/11W-26E3	26E3	335258118002402	La Mirada1_2	CB	multi.	wq	80
3S/11W-26E4	26E4	335258118002403	La Mirada1_3	CB	multi.	wq	80
3S/11W-26E5	26E5	335258118002404	La Mirada1_4	CB	multi.	wq	80
3S/11W-26E6	26E6	335258118002405	La Mirada1_5	CB	multi.	wq	80
3S/11W-35J3	35J3	n.a.	BP–CIVC	OCB	prod.	wl	78
3S/12W-1A6	1A6	335647118050301	1615P	MF	prod.	wl	138
3S/12W-6B4	6B4	335642118103701	South Gate1_1	CB	multi.	wq	104
3S/12W-6B5	6B5	335642118103702	South Gate1_2	CB	multi.	wq	104
3S/12W-6B6	6B6	335642118103703	South Gate1_3	CB	multi.	wq	104
3S/12W-6B7	6B7	335642118103704	South Gate1_4	CB	multi.	wq	104
3S/12W-6B8	6B8	335642118103705	South Gate1_5	CB	multi.	wq	104
3S/12W-8L3	8L3	335314118063601	1537A	CB	prod.	wl	94
3S/12W-9J1	9J1	335517118081301	Downey1_1	CB	multi.	wq	100
3S/12W-9J2	9J2	335517118081302	Downey1_2	CB	multi.	wq	100
3S/12W-9J3	9J3	335517118081303	Downey1_3	CB	multi.	wq	100
3S/12W-9J4	9J4	335517118081304	Downey1_4	CB	multi.	wq	100
3S/12W-9J5	9J5	335517118081305	Downey1_5	CB	multi.	wq	100
3S/12W-9J6	9J6	335517118081306	Downey1_6	CB	multi.	wq	100
3S/12W-11A7	11A7	335545118061101	Norwalk2_1	MF	multi.	wq	117
3S/12W-11A8	11A8	335545118061102	Norwalk2_2	MF	multi.	wq	117
3S/12W-11A9	11A9	335545118061103	Norwalk2_3	MF	multi.	wq	117
3S/12W-11A10	11A10	335545118061104	Norwalk2_4	MF	multi.	wq	117
3S/12W-11A11	11A11	335545118061105	Norwalk2_5	MF	multi.	wq	117
3S/12W-11A12	11A12	335545118061106	Norwalk2_6	MF	multi.	wq	117
3S/12W-15K1	15K1	335400118070001	St. John Bosco	CB	prod.	wq	91
3S/12W-16H1	16H1	335440118081101	Park 40D	CB	prod.	wq	92
3S/12W-26C2	26C2	335314118063601	981C	CB	prod.	wl	76
3S/12W-26K2	26K2	335239118061501	Cerritos2_1	CB	multi.	wq	67
3S/12W-26K3	26K3	335239118061502	Cerritos2_2	CB	multi.	wq	67
3S/12W-26K4	26K4	335239118061503	Cerritos2_3	CB	multi.	wq	67
3S/12W-26K5	26K5	335239118061504	Cerritos2_4	CB	multi.	wq	67
3S/12W-26K6	26K6	335239118061505	Cerritos2_5	CB	multi.	wq	67
3S/12W-26K7	26K7	335239118061506	Cerritos2_6	CB	multi.	wq	67

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
560	540	560	1	09/29/2002	57.9	Harbor
285	265	285	1	09/29/2002	43.9	Pacific_A
1,420	1,400	1,420	1	09/15/2014	18.5	Lower Wilmington
1,010	990	1,010	1	09/15/2014	–30.7	Upper Wilmington A
740	720	740	1	09/15/2014	–4.7	Bent Spring
450	430	450	1	09/15/2014	–10.9	Pacific
240	220	240	1	09/15/2014	–7.2	Pacific_A
1,150	1,130	1,150	1	09/11/2014	–41.9	Upper Wilmington A
985	965	985	1	09/11/2014	–36.9	Bent Spring
710	690	710	1	09/11/2014	–52.0	Harbor
490	470	490	1	09/11/2014	–64.9	Pacific
245	225	245	1	09/11/2014	–29.9	Pacific_A
—	373	638	1	01/03/2001	–21.8	Pacific
216	91	192	1	09/26/2014	42.1	Pacific
1,460	1,140	1,460	1	09/29/2014	–18.9	Bent Spring
1,340	1,320	1,340	1	09/29/2014	–16.1	Harbor
930	910	930	1	09/29/2014	–11.6	Harbor
585	565	585	1	09/29/2014	–12.7	Pacific
250	220	240	1	09/29/2014	35.7	Mesa
—	50	285	1	11/12/1998	49.4	Dominguez
1,190	1,170	1,190	1	09/16/2014	–20.4	Bent Spring
960	940	960	1	09/16/2014	–16.2	Harbor
600	580	600	1	09/16/2014	–13.6	Pacific
390	370	390	1	09/16/2014	–9.1	Pacific_A
270	250	270	1	09/16/2014	27.4	Mesa
110	90	110	1	09/16/2014	33.4	Dominguez
1,480	1,460	1,480	1	09/11/2014	–3.2	Lower Wilmington
1,280	1,260	1,280	1	09/11/2014	–2.9	Lower Wilmington
980	960	980	1	09/11/2014	–12.2	Upper Wilmington A
820	800	820	1	09/11/2014	–9.9	Bent Spring
500	480	500	1	09/11/2014	1.4	Pacific
256	236	256	1	09/11/2014	11.9	Pacific_A
—	—	—	1	—	—	Dominguez
572	546	572	1	—	—	Pacific
590	568	590	1	03/12/2009	–14.0	Pacific_A
1,470	1,350	1,370	1	09/15/2014	–32.7	Harbor
935	915	935	1	09/15/2014	–46.8	Pacific
760	740	760	1	09/15/2014	–41.8	Pacific
510	490	510	1	09/15/2014	–14.6	Pacific_A
370	350	370	1	09/15/2014	17.1	Mesa
170	150	170	1	09/15/2014	26.4	Dominguez

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a
Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
3S/12W-31E3	31E3	n.a.	913E	CB	prod.	wl	55
3S/12W-33B1	33B1	335209118082001	BSMWC_615	CB	prod.	wq	65
3S/13W-8J1	8J1	335524118152001	Willowbrook1_1	CB	multi.	wq	99
3S/13W-8J2	8J2	335524118152002	Willowbrook1_2	CB	multi.	wq	99
3S/13W-8J3	8J3	335524118152003	Willowbrook1_3	CB	multi.	wq	99
3S/13W-8J4	8J4	335524118152004	Willowbrook1_4	CB	multi.	wq	99
3S/13W-11G1	11G1	335535118124001	Lynwood1_1	CB	multi.	wq	87
3S/13W-11G2	11G2	335535118124002	Lynwood1_2	CB	multi.	wq	87
3S/13W-11G3	11G3	335535118124003	Lynwood1_8	CB	multi.	wq	87
3S/13W-11G4	11G4	335535118123901	Lynwood1_3	CB	multi.	wq	87
3S/13W-11G5	11G5	335535118123902	Lynwood1_4	CB	multi.	wq	87
3S/13W-11G6	11G6	335535118123903	Lynwood1_5	CB	multi.	wq	87
3S/13W-11G7	11G7	335535118123904	Lynwood1_6	CB	multi.	wq	87
3S/13W-11G8	11G8	335535118123905	Lynwood1_7	CB	multi.	wq	87
3S/13W-11G9	11G9	335535118123906	Lynwood1_9	CB	multi.	wq	87
3S/13W-21R1	21R1	n.a.	851F	CB	prod.	wl	94
3S/13W-22M2	22M2	335333118140601	Compton2_1	CB	multi.	wq	77
3S/13W-22M3	22M3	335333118140602	Compton2_2	CB	multi.	wq	77
3S/13W-22M4	22M4	335333118140603	Compton2_3	CB	multi.	wq	77
3S/13W-22M5	22M5	335333118140604	Compton2_4	CB	multi.	wq	77
3S/13W-22M6	22M6	335333118140605	Compton2_5	CB	multi.	wq	77
3S/13W-22M7	22M7	335333118140606	Compton2_6	CB	multi.	wq	77
3S/13W-24K2	24K2	335337118113401	Compton1_1	CB	multi.	wq	68
3S/13W-24K3	24K3	335337118113402	Compton1_2	CB	multi.	wq	68
3S/13W-24K4	24K4	335337118113403	Compton1_3	CB	multi.	wq	68
3S/13W-24K5	24K5	335337118113404	Compton1_4	CB	multi.	wq	68
3S/13W-24K6	24K6	335337118113405	Compton1_5	CB	multi.	wq	68
3S/14W-4R1	4R1	335555118204001	Inglewood3_1	WCB	multi.	wq	72
3S/14W-4R2	4R2	335555118204002	Inglewood3_2	WCB	multi.	wq	72
3S/14W-4R3	4R3	335555118204003	Inglewood3_3	WCB	multi.	wq	72
3S/14W-4R4	4R4	335555118204004	Inglewood3_4	WCB	multi.	wq	72
3S/14W-4R5	4R5	335555118204005	Inglewood3_5	WCB	multi.	wq	72
3S/14W-4R6	4R6	335555118204006	Inglewood3_6	WCB	multi.	wq	72
3S/14W-4R7	4R7	335555118204007	Inglewood3_7	WCB	multi.	wq	72
3S/14W-13J5	13J5	335431118173101	Gardena1_1	WCB	multi.	wq	86
3S/14W-13J6	13J6	335431118173102	Gardena1_2	WCB	multi.	wq	86
3S/14W-13J7	13J7	335431118173103	Gardena1_3	WCB	multi.	wq	86
3S/14W-13J8	13J8	335431118173104	Gardena1_4	WCB	multi.	wq	86
3S/14W-17G3	17G3	335443118215501	Hawthorne1_1	WCB	multi.	wq	86
3S/14W-17G4	17G4	335443118215502	Hawthorne1_2	WCB	multi.	wq	86
3S/14W-17G5	17G5	335443118215503	Hawthorne1_3	WCB	multi.	wq	86

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
—	701	933	1	04/01/1999	–48.5	Upper Wilmington A
674	602	644	2	—	—	Pacific
905	885	905	1	09/17/2014	–71.7	Upper Wilmington B
520	500	520	1	09/17/2014	–45.6	Bent Spring
380	360	380	1	09/17/2014	–50.7	Harbor
220	200	220	1	09/17/2014	–49.1	Pacific
2,900	2,880	2,900	1	09/23/2014	–26.6	Long Beach A
2,450	2,430	2,450	1	09/23/2014	46.4	Lower Wilmington
335	315	335	1	09/23/2014	–30.0	Pacific_A
1,670	1,650	1,670	1	09/23/2014	–47.6	Upper Wilmington B
1,465	1,445	1,465	1	09/23/2014	–61.7	Upper Wilmington A
1,220	1,200	1,220	1	09/23/2014	–43.3	Bent Spring
900	880	900	1	09/23/2014	–37.1	Harbor
660	640	660	1	09/23/2014	–37.8	Harbor
180	160	180	1	09/23/2014	40.8	Dominguez
—	366	525	1	11/05/1996	–29.0	Harbor
1,495	1,475	1,495	1	09/12/2014	–33.6	Long Beach A
850	830	850	1	09/12/2014	–58.8	Upper Wilmington B
605	585	605	1	09/12/2014	–48.2	Harbor
400	380	400	1	09/12/2014	–46.8	Harbor
315	295	315	1	09/12/2014	–39.9	Pacific
170	150	170	1	09/12/2014	–33.4	Pacific_A
1,410	1,370	1,390	1	09/16/2014	–80.0	Upper Wilmington B
1,170	1,150	1,170	1	09/16/2014	–79.7	Upper Wilmington A
820	800	820	1	09/16/2014	–36.6	Harbor
480	460	480	1	09/16/2014	–35.0	Pacific
325	305	325	1	09/16/2014	–21.4	Pacific_A
1,940	1,900	1,940	1	09/12/2014	–27.6	Long Beach C
1,460	1,440	1,460	1	09/12/2014	–37.7	Long Beach BC
1,275	1,255	1,275	1	09/12/2014	–59.0	Long Beach B
910	890	910	1	09/12/2014	–81.4	Long Beach A
560	540	560	1	09/12/2014	–72.1	Upper Wilmington A
390	370	390	1	09/12/2014	–15.2	Harbor
265	245	265	1	09/12/2014	1.8	Pacific
990	970	990	1	09/15/2014	–56.9	Long Beach A
465	445	465	1	09/15/2014	–134.7	Upper Wilmington A
365	345	365	1	09/15/2014	–97.6	Bent Spring
140	120	140	1	09/15/2014	–12.6	Pacific
990	910	950	1	09/17/2014	–66.7	Lower Wilmington
730	710	730	1	09/17/2014	–18.3	Upper Wilmington B
540	520	540	1	09/17/2014	–17.2	Bent Spring

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a
Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
3S/14W-17G6	17G6	335443118215504	Hawthorne1_4	WCB	multi.	wq	86
3S/14W-17G7	17G7	335443118215505	Hawthorne1_5	WCB	multi.	wq	86
3S/14W-17G8	17G8	335443118215506	Hawthorne1_6	WCB	multi.	wq	86
3S/14W-22L1	22L1	335340118201801	760C	WCB	prod.	wl	53
3S/14W-25K7	25K7	335235118175901	Gardena2_1	WCB	multi.	wq	28
3S/14W-25K8	25K8	335235118175902	Gardena2_2	WCB	multi.	wq	28
3S/14W-25K9	25K9	335235118175903	Gardena2_3	WCB	multi.	wq	28
3S/14W-25K10	25K10	335235118175904	Gardena2_4	WCB	multi.	wq	28
3S/14W-25K11	25K11	335235118175905	Gardena2_5	WCB	multi.	wq	28
3S/14W-27C2	27C2	335312118200701	Lawndale1_1	WCB	multi.	wq	34
3S/14W-27C3	27C3	335312118200702	Lawndale1_2	WCB	multi.	wq	34
3S/14W-27C4	27C4	335312118200703	Lawndale1_3	WCB	multi.	wq	34
3S/14W-27C5	27C5	335312118200704	Lawndale1_4	WCB	multi.	wq	34
3S/14W-27C6	27C6	335312118200705	Lawndale1_5	WCB	multi.	wq	34
3S/14W-27C7	27C7	335312118200706	Lawndale1_6	WCB	multi.	wq	34
3S/14W-30L2	30L2	335236118232101	Manhattan Beach1_1	WCB	multi.	wq	136
3S/14W-30L3	30L3	335236118232102	Manhattan Beach1_2	WCB	multi.	wq	136
3S/14W-30L4	30L4	335236118232103	Manhattan Beach1_3	WCB	multi.	wq	136
3S/14W-30L5	30L5	335236118232104	Manhattan Beach1_4	WCB	multi.	wq	136
3S/14W-30L6	30L6	335236118232105	Manhattan Beach1_5	WCB	multi.	wq	136
3S/14W-30L7	30L7	335236118232106	Manhattan Beach1_6	WCB	multi.	wq	136
3S/14W-30L8	30L8	335236118232107	Manhattan Beach1_7	WCB	multi.	wq	136
3S/14W-30N1	30N1	n.a.	702E	WCB	obs.	wl	182
3S/14W-31D1	31D1	n.a.	702M	WCB	obs.	wl	170
3S/14W-31L3	31L3	n.a.	713D	WCB	obs.	wl	169
3S/14W-33R5	33R5	335131118204501	Torrance1_1	WCB	multi.	wq	81
3S/14W-33R6	33R6	335131118204502	Torrance1_2	WCB	multi.	wq	81
3S/14W-33R7	33R7	335131118204503	Torrance1_3	WCB	multi.	wq	81
3S/14W-33R8	33R8	335131118204504	Torrance1_4	WCB	multi.	wq	81
3S/14W-33R9	33R9	335131118204505	Torrance1_5	WCB	multi.	wq	81
3S/14W-33R10	33R10	335131118204506	Torrance1_6	WCB	multi.	wq	81
3S/15W-13H9	13H9	n.a.	1308T	WCB	obs.	wl	101
4S/10W-8F3	8F3	n.a.	CB–1	OCB	multi	wl	122
4S/10W-14H3	14H3	334932117532401	Anaheim_46	OCB	prod.	wq	180
4S/11W-3E1	3E1	n.a.	BPM–1	OCB	multi	wl	59
4S/11W-5P9	5P9	335049118032901	Cerritos1_1	CB	multi.	wq	40
4S/11W-5P10	5P10	335049118032902	Cerritos1_2	CB	multi.	wq	40
4S/11W-5P11	5P11	335049118032903	Cerritos1_3	CB	multi.	wq	40
4S/11W-5P12	5P12	335049118032904	Cerritos1_4	CB	multi.	wq	40
4S/11W-5P13	5P13	335049118032905	Cerritos1_5	CB	multi.	wq	40
4S/11W-5P14	5P14	335049118032906	Cerritos1_6	CB	multi.	wq	40

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
420	400	420	1	09/17/2014	–17.0	Bent Spring
260	240	260	1	09/17/2014	–11.3	Harbor
130	110	130	1	09/17/2014	0.6	Pacific
502	352	458	1	09/25/2014	–12.6	Bent Spring
1,375	1,275	1,335	2	09/23/2014	–42.0	Long Beach A
790	770	790	1	09/23/2014	–56.0	Upper Wilmington A
630	610	630	1	09/23/2014	–56.3	Upper Wilmington A
360	340	360	1	09/23/2014	–24.5	Harbor
255	235	255	1	09/23/2014	–12.0	Pacific
1,400	1,360	1,400	1	09/15/2014	–34.6	Long Beach A
905	885	905	1	09/15/2014	–61.5	Lower Wilmington
635	615	635	1	09/15/2014	–16.3	Upper Wilmington B
415	395	415	1	09/15/2014	–15.9	Harbor
310	290	310	1	09/15/2014	–13.2	Harbor
190	170	190	1	09/15/2014	–6.5	Pacific
1,990	1,950	1,990	1	09/16/2014	–0.5	Long Beach C
1,590	1,570	1,590	1	09/16/2014	–2.6	Long Beach BC
1,270	1,250	1,270	1	09/16/2014	–33.8	Long Beach A
885	865	885	1	09/16/2014	–5.8	Upper Wilmington B
660	640	660	1	09/16/2014	–3.4	Bent Spring
340	320	340	1	09/16/2014	6.4	Pacific
200	180	200	1	09/16/2014	10.0	Mesa
532	232	350	1	10/14/2013	7.7	Mesa
—	140	296	1	10/14/2013	7.7	Mesa
460	270	450	1	10/14/2013	9.6	Pacific
1,480	1,360	1,380	1	09/15/2014	–34.6	Long Beach B
960	940	960	1	09/15/2014	–44.6	Lower Wilmington
790	770	790	1	09/15/2014	–11.4	Upper Wilmington B
600	580	600	1	09/15/2014	–8.9	Bent Spring
340	320	340	1	09/15/2014	–2.5	Pacific
160	140	160	1	09/15/2014	–2.2	Mesa
235	190	225	1	10/23/2013	6.7	Harbor
1,510	76	1,470	9	09/16/2014	56.5	Multiple*
1,550	599	1,530	1	—	—	n.a.
2,155	128	2,115	14	09/03/2014	25.0	Multiple*
1,215	1,155	1,175	1	09/15/2014	–60.6	Harbor
1,020	1,000	1,020	1	09/15/2014	–66.3	Pacific
630	610	630	1	09/15/2014	–52.4	Pacific
290	270	290	1	09/15/2014	9.7	Mesa
200	180	200	1	09/15/2014	13.5	Dominguez
135	125	135	1	09/15/2014	13.5	Dominguez

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
4S/11W-13C4	13C4	n.a.	AMD–8	OCB	multi	wl	81
4S/11W-15Q2	15Q2	n.a.	BPM–2	OCB	multi	wl	58
4S/11W-19Q2	19Q2	n.a.	SCWC–LAC3	OCB	prod.	wl	25
4S/11W-25J4	25J4	n.a.	GGM-3	OCB	multi	wl	78
4S/11W-26N1	26N1	334719118003901	GG–22	OCB	prod.	wl	49
4S/11W-30H1	30H1	n.a.	LAM1	OCB	multi	wl	22
4S/11W-35H3	35H3	n.a.	SCWC–SBCH	OCB	prod.	wl	54
4S/11W-35N2	35N2	n.a.	GGM–2	OCB	multi	wl	46
4S/12W-5H5	5H5	335112118090401	Lakewood1_1	CB	multi.	wq	50
4S/12W-5H6	5H6	335112118090402	Lakewood1_2	CB	multi.	wq	50
4S/12W-5H7	5H7	335112118090403	Lakewood1_3	CB	multi.	wq	50
4S/12W-5H8	5H8	335112118090404	Lakewood1_4	CB	multi.	wq	50
4S/12W-5H9	5H9	335112118090405	Lakewood1_5	CB	multi.	wq	50
4S/12W-5H10	5H10	335112118090406	Lakewood1_6	CB	multi.	wq	50
4S/12W-10G1	10G1	335033118071401	975A	CB	prod.	wl	49
4S/12W-12F1	12F1	335028118053901	Lakewood2_1	CB	multi.	wq	37
4S/12W-12F2	12F2	335028118053902	Lakewood2_2	CB	multi.	wq	37
4S/12W-12F3	12F3	335028118053903	Lakewood2_3	CB	multi.	wq	37
4S/12W-12F4	12F4	335028118053904	Lakewood2_4	CB	multi.	wq	37
4S/12W-12F5	12F5	335028118053905	Lakewood2_5	CB	multi.	wq	37
4S/12W-12F6	12F6	335028118053906	Lakewood2_6	CB	multi.	wq	37
4S/12W-12F7	12F7	335028118053907	Lakewood2_7	CB	multi.	wq	37
4S/12W-12F8	12F8	335028118053908	Lakewood2_8	CB	multi.	wq	37
4S/12W-21M8	21M8	334837118085701	Long Beach6_1	CB	multi.	wq	37
4S/12W-21M9	21M9	334837118085702	Long Beach6_2	CB	multi.	wq	37
4S/12W-21M10	21M10	334837118085703	Long Beach6_3	CB	multi.	wq	37
4S/12W-21M11	21M11	334837118085704	Long Beach6_4	CB	multi.	wq	37
4S/12W-21M12	21M12	334837118085705	Long Beach6_5	CB	multi.	wq	37
4S/12W-21M13	21M13	334837118085706	Long Beach6_6	CB	multi.	wq	37
4S/12W-23K3	23K3	334836118061201	LB Annex 201	CB	prod.	wq	19
4S/12W-25E1	25E1	334747118055001	500D	CB	prod.	wl	18
4S/12W-25G1	25G1	334753118051901	Long Beach1_1	CB	multi.	wq	33
4S/12W-25G2	25G2	334753118051902	Long Beach1_2	CB	multi.	wq	33
4S/12W-25G3	25G3	334753118051903	Long Beach1_3	CB	multi.	wq	33
4S/12W-25G4	25G4	334753118051904	Long Beach1_4	CB	multi.	wq	33
4S/12W-25G5	25G5	334753118051905	Long Beach1_5	CB	multi.	wq	33
4S/12W-25G6	25G6	334753118051906	Long Beach1_6	CB	multi.	wq	33
4S/12W-28H9	28H9	334746118081601	460K	CB	prod.	wl	29
4S/12W-30J1	30J1	334737118101901	Long Beach8_1	WCB	multi.	wq	20
4S/12W-30J2	30J2	334737118101902	Long Beach8_2	WCB	multi.	wq	20
4S/12W-30J3	30J3	334737118101903	Long Beach8_3	WCB	multi.	wq	20

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
2,060	78	2,020	15	09/03/2014	55.0	Multiple*
2,220	180	2,180	15	09/03/2014	29.3	Multiple*
—	348	595	—	09/14/2014	–46.9	Pacific
2,000	195	2,180	—	—	—	Multiple*
—	416	1,020	1	08/28/2014	–34.3	Pacific
1,660	72	1,620	12	09/23/2014	10.5	Multiple*
—	200	570	1	09/21/2014	3.2	Pacific_A
2,050	212	2,000	13	09/23/2014	18.7	Multiple*
1,009	989	1,009	1	09/16/2014	–166.9	Upper Wilmington A
660	640	660	1	09/16/2014	–46.3	Harbor
470	450	470	1	09/16/2014	–50.7	Harbor
300	280	300	1	09/16/2014	–25.1	Pacific_A
160	140	160	1	09/16/2014	–6.9	Mesa
90	70	90	1	09/16/2014	23.3	Dominguez
—	367	388	1	11/05/2008	–65.0	Pacific
2,000	1,960	2,000	1	09/15/2014	–45.6	Upper Wilmington A
1,760	1,740	1,760	1	09/15/2014	–52.2	Bent Spring
1,320	1,300	1,320	1	09/15/2014	–61.2	Harbor
1,015	995	1,015	1	09/15/2014	–71.8	Pacific
710	690	710	1	09/15/2014	–55.5	Pacific
575	555	575	1	09/15/2014	–32.3	Pacific_A
275	255	275	1	09/15/2014	15.2	Mesa
120	110	120	1	09/15/2014	17.2	Dominguez
1,530	1,490	1,510	1	09/16/2014	–62.3	Long Beach A
950	930	950	1	09/16/2014	–78.7	Upper Wilmington B
760	740	760	1	09/16/2014	–80.0	Upper Wilmington B
500	480	500	1	09/16/2014	–126.3	Upper Wilmington A
400	380	400	1	09/16/2014	–126.3	Bent Spring
240	220	240	1	09/16/2014	–40.8	Pacific
838	507	838	1	—	—	Bent Spring
1,186	1,124	1,146	1	09/18/2009	–55.3	Pacific
1,470	1,430	1,450	1	09/16/2014	–47.0	Upper Wilmington B
1,250	1,230	1,250	1	09/16/2014	–49.7	Upper Wilmington B
990	970	990	1	09/16/2014	–88.0	Upper Wilmington A
619	599	619	1	09/16/2014	–47.1	Harbor
420	400	420	1	09/16/2014	–43.7	Pacific
175	155	175	1	09/16/2014	–18.5	Mesa
550	143	550	1	09/18/2014	–108.2	Harbor
1,495	1,435	1,455	1	09/19/2014	–15.7	Long Beach A
1,040	1,020	1,040	1	09/19/2014	–31.0	Lower Wilmington
800	780	800	1	09/19/2014	–38.3	Upper Wilmington B

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
4S/12W-30J4	30J4	334737118101904	Long Beach8_4	WCB	multi.	wq	20
4S/12W-30J5	30J5	334737118101905	Long Beach8_5	WCB	multi.	wq	20
4S/12W-30J6	30J6	334737118101906	Long Beach8_6	WCB	multi.	wq	20
4S/12W-32G1	32G1	n.a.	441	WCB	obs.	wl	41
4S/13W-1N3	1N3	335100118120401	Long Beach2_1	CB	multi.	wq	44
4S/13W-1N4	1N4	335100118120402	Long Beach2_2	CB	multi.	wq	44
4S/13W-1N5	1N5	335100118120403	Long Beach2_3	CB	multi.	wq	44
4S/13W-1N6	1N6	335100118120404	Long Beach2_4	CB	multi.	wq	44
4S/13W-1N7	1N7	335100118120405	Long Beach2_5	CB	multi.	wq	44
4S/13W-1N8	1N8	335100118120406	Long Beach2_6	CB	multi.	wq	44
4S/13W-5F1	5F1	335126118155801	Carson3_1	WCB	multi.	wq	22
4S/13W-5F2	5F2	335126118155802	Carson3_2	WCB	multi.	wq	22
4S/13W-5F3	5F3	335126118155803	Carson3_3	WCB	multi.	wq	22
4S/13W-5F4	5F4	335126118155804	Carson3_4	WCB	multi.	wq	22
4S/13W-5F5	5F5	335126118155805	Carson3_5	WCB	multi.	wq	22
4S/13W-5F6	5F6	335126118155806	Carson3_6	WCB	multi.	wq	22
4S/13W-9H9	9H9	335013118142501	Carson1_1	WCB	multi.	wq	27
4S/13W-9H10	9H10	335013118142502	Carson1_2	WCB	multi.	wq	27
4S/13W-9H11	9H11	335013118142503	Carson1_3	WCB	multi.	wq	27
4S/13W-9H12	9H12	335013118142504	Carson1_4	WCB	multi.	wq	27
4S/13W-12K1	12K1	n.a.	906D	CB	prod.	wl	91
4S/13W-18K1	18K1	334921118165301	Carson2_1	WCB	multi.	wq	42
4S/13W-18K2	18K2	334921118165302	Carson2_2	WCB	multi.	wq	42
4S/13W-18K3	18K3	334921118165303	Carson2_3	WCB	multi.	wq	42
4S/13W-18K4	18K4	334921118165304	Carson2_4	WCB	multi.	wq	42
4S/13W-18K5	18K5	334921118165305	Carson2_5	WCB	multi.	wq	42
4S/13W-21H5	21H5	n.a.	868H	WCB	prod.	wl	23
4S/13W-23B2	23B2	334905118124601	888F	WCB	prod.	wl	29
4S/13W-23D3	23D3	334904118130301	Long Beach3_1	WCB	multi.	wq	26
4S/13W-23D4	23D4	334904118130302	Long Beach3_2	WCB	multi.	wq	26
4S/13W-23D5	23D5	334904118130303	Long Beach3_3	WCB	multi.	wq	26
4S/13W-23D6	23D6	334904118130304	Long Beach3_4	WCB	multi.	wq	26
4S/13W-23D7	23D7	334904118130305	Long Beach3_5	WCB	multi.	wq	26
4S/13W-23N3	23N3	334814118131301	889P	WCB	obs.	wq	20
4S/13W-26F5	26F5	334749118124901	380P	WCB	obs.	wq	15
4S/13W-27H4	27H4	334747118132301	Long Beach7_1	WCB	multi.	wq	19
4S/13W-27H5	27H5	334747118132302	Long Beach7_2	WCB	multi.	wq	19
4S/13W-27H6	27H6	334747118132303	Long Beach7_3	WCB	multi.	wq	19
4S/13W-27H7	27H7	334747118132304	Long Beach7_4	WCB	multi.	wq	19
4S/13W-28A3	28A3	334802118141801	Wilmington1_1	WCB	multi.	wq	33
4S/13W-28A4	28A4	334802118141802	Wilmington1_2	WCB	multi.	wq	33

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
655	635	655	1	09/19/2014	–36.5	Upper Wilmington A
435	415	435	1	09/19/2014	–36.1	Bent Spring
185	165	185	1	09/19/2014	1.5	Mesa
130	110	130	1	10/01/2013	3.5	Mesa
1,090	970	990	1	09/15/2014	–102.7	Upper Wilmington A
740	720	740	1	09/15/2014	–56.0	Bent Spring
470	450	470	1	09/15/2014	–43.5	Pacific
300	280	300	1	09/15/2014	–15.1	Pacific_A
180	160	180	1	09/15/2014	–2.3	Mesa
115	95	115	1	09/15/2014	0.7	Dominguez
1,800	1,600	1,620	1	09/15/2014	–34.6	Long Beach A
1,240	1,220	1,240	1	09/15/2014	–39.9	Upper Wilmington B
1,100	1,080	1,100	1	09/15/2014	–42.5	Upper Wilmington B
890	870	890	1	09/15/2014	–42.7	Upper Wilmington A
640	620	640	1	09/15/2014	–42.8	Upper Wilmington A
380	360	380	1	09/15/2014	–18.1	Harbor
1,010	990	1,010	1	10/09/2014	–43.1	Upper Wilmington A
760	740	760	1	10/09/2014	–42.2	Upper Wilmington A
480	460	480	1	10/09/2014	–14.5	Harbor
270	250	270	1	10/09/2014	–13.2	Pacific
1,285	915	1,000	—	10/16/2014	–74.7	Upper Wilmington A
1,290	1,230	1,250	1	09/18/2014	–34.6	Lower Wilmington
870	850	870	1	09/18/2014	–30.6	Upper Wilmington A
620	600	620	1	09/18/2014	–30.3	Upper Wilmington A
470	450	470	1	09/18/2014	–27.1	Bent Spring
250	230	250	1	09/18/2014	–24.8	Pacific
721	440	709	1	10/26/1994	–59.7	Upper Wilmington A
—	650	900	1	10/22/2013	–43.3	Upper Wilmington A
1,390	1,350	1,390	1	09/15/2014	–32.3	Long Beach A
1,017	997	1,017	1	09/15/2014	–39.9	Upper Wilmington B
690	670	690	1	09/15/2014	–39.9	Upper Wilmington A
550	530	550	1	09/15/2014	–40.4	Bent Spring
430	410	430	1	09/15/2014	0.3	Harbor
471	460	470	1	05/05/2014	–39.5	Upper Wilmington A
500	483	493	1	02/12/2009	–9.8	Upper Wilmington A
1,400	1,180	1,200	1	09/22/2014	–30.8	Long Beach A
670	650	670	1	09/22/2014	–37.7	Upper Wilmington A
490	470	490	1	09/22/2014	–37.7	Upper Wilmington A
380	360	380	1	09/22/2014	–29.5	Bent Spring
1,035	915	935	1	09/15/2014	–35.8	Upper Wilmington B
800	780	800	1	09/15/2014	–36.5	Upper Wilmington B

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
4S/13W-28A5	28A5	334802118141803	Wilmington1_3	WCB	multi.	wq	33
4S/13W-28A6	28A6	334802118141804	Wilmington1_4	WCB	multi.	wq	33
4S/13W-28A7	28A7	334802118141805	Wilmington1_5	WCB	multi.	wq	33
4S/13W-29H5	29H5	334759118152801	340L	WCB	multi.	wq	43
4S/13W-29H6	29H6	334759118152802	340M	WCB	multi.	wq	43
4S/13W-29H7	29H7	334759118152803	340N	WCB	multi.	wq	43
4S/13W-30G1	30G1	n.a.	310C	WCB	prod.	wl	40
4S/13W-31J1	31J1	334656118162801	321A	WCB	obs.	wq	24
4S/13W-32F1	32F1	334657118160001	Wilmington2_1	WCB	multi.	wq	32
4S/13W-32F2	32F2	334657118160002	Wilmington2_2	WCB	multi.	wq	32
4S/13W-32F3	32F3	334657118160003	Wilmington2_3	WCB	multi.	wq	32
4S/13W-32F4	32F4	334657118160004	Wilmington2_4	WCB	multi.	wq	32
4S/13W-32F5	32F5	334657118160005	Wilmington2_5	WCB	multi.	wq	32
4S/13W-34A1	34A1	334720118133201	371D	WCB	obs.	wq	9
4S/13W-34M1	34M1	334654118141801	361H	WCB	obs.	wq	6
4S/13W-35B2	35B2	334712118124301	381J	WCB	obs.	wq	9
4S/13W-35B3	35B3	334712118124302	381K	WCB	obs.	wq	9
4S/14W-1F2	1F2	n.a.	794B	WCB	prod.	wl	53
4S/14W-2N1	2N1	335033118193101	PM–3 Madrid_1	WCB	multi.	wq	67
4S/14W-2N2	2N2	335033118193102	PM–3 Madrid_2	WCB	multi.	wq	67
4S/14W-2N3	2N3	335033118193103	PM–3 Madrid_3	WCB	multi.	wq	67
4S/14W-2N4	2N4	335033118193104	PM–3 Madrid_4	WCB	multi.	wq	67
4S/14W-4Q1	4Q1	335059118205801	PM–4 Mariner_1	WCB	multi.	wq	98
4S/14W-4Q2	4Q2	335059118205802	PM–4 Mariner_2	WCB	multi.	wq	98
4S/14W-4Q3	4Q3	335059118205803	PM–4 Mariner_3	WCB	multi.	wq	98
4S/14W-4Q4	4Q4	335059118205804	PM–4 Mariner_4	WCB	multi.	wq	98
4S/14W-7C3	7C3	n.a.	715D	WCB	obs.	wl	62
4S/14W-8E3	8E3	n.a.	725J	WCB	obs.	wl	136
4S/14W-8G1	8G1	n.a.	735	WCB	obs.	wl	97
4S/14W-9Q1	9Q1	n.a.	746	WCB	prod.	wl	103
4S/14W-10C1	10C1	335038118201301	PM–1 Columbia_1	WCB	multi.	wq	81
4S/14W-10C2	10C2	335038118201302	PM–1 Columbia_2	WCB	multi.	wq	81
4S/14W-15E1	15E1	334944118203301	Torrance2_1	WCB	multi.	wq	81
4S/14W-15E2	15E2	334944118203302	Torrance2_2	WCB	multi.	wq	81
4S/14W-15E3	15E3	334944118203303	Torrance2_3	WCB	multi.	wq	81
4S/14W-15E4	15E4	334944118203304	Torrance2_4	WCB	multi.	wq	81
4S/14W-15E5	15E5	334944118203305	Torrance2_5	WCB	multi.	wq	81
4S/14W-15E6	15E6	334944118203306	Torrance2_6	WCB	multi.	wq	81
4S/14W-15N1	15N1	334904118202401	758F	WCB	obs.	wl	78
4S/14W-17R3	17R3	n.a.	737H	WCB	obs.	wl	77
4S/14W-22Q1	22Q1	n.a.	769	WCB	—	wl	74

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
570	550	570	1	09/15/2014	–36.5	Upper Wilmington A
245	225	245	1	09/15/2014	–11.5	Pacific
140	120	140	1	09/15/2014	–8.4	Mesa
166	121	156	1	09/02/2014	–17.8	Pacific
391	201	381	1	09/02/2014	–25.8	Harbor
734	424	724	1	09/02/2014	–28.1	Upper Wilmington A
682	210	420	1	10/09/2013	–29.0	Harbor
670	659	669	1	09/02/2014	–25.6	Lower Wilmington
1,030	950	970	1	09/15/2014	–28.6	Long Beach B
775	755	775	1	09/15/2014	–25.7	Long Beach A
560	540	560	1	09/15/2014	–21.5	Lower Wilmington
410	390	410	1	09/15/2014	–20.4	Upper Wilmington B
140	120	140	1	09/15/2014	–5.1	Mesa
650	640	650	1	10/23/2014	–36.9	Long Beach A
735	724	734	1	10/22/2014	–29.6	Long Beach A
713	693	703	1	10/23/2014	–62.7	Lower Wilmington
398	378	388	1	10/23/2014	–2.4	Upper Wilmington B
600	477	540	1	04/22/1999	–51.7	Bent Spring
683	640	680	1	09/16/2014	–12.2	Bent Spring
518	480	520	1	09/16/2014	–9.6	Harbor
273	240	280	1	09/16/2014	–9.4	Pacific
188	145	185	1	09/16/2014	–9.4	Pacific
720	670	710	1	09/16/2014	–5.1	Bent Spring
550	500	540	1	09/16/2014	–2.5	Harbor
390	340	380	1	09/16/2014	0.7	Pacific
250	200	240	1	09/16/2014	0.8	Pacific
—	399	409	1	10/21/2013	4.1	Bent Spring
283	248	258	1	10/22/2013	16.6	Pacific
295	154	284	1	10/24/2013	3.0	Pacific
—	234	388	1	10/15/2013	–2.1	Harbor
600	555	595	1	09/16/2014	–8.8	Bent Spring
505	460	500	1	09/16/2014	–8.5	Harbor
1,235	1,195	1,235	1	09/16/2014	–33.5	Long Beach A
925	905	925	1	09/16/2014	–11.3	Upper Wilmington B
790	770	790	1	09/16/2014	–10.4	Upper Wilmington A
550	530	550	1	09/16/2014	–2.9	Bent Spring
410	390	410	1	09/16/2014	–1.9	Harbor
260	240	260	1	09/16/2014	–1.4	Pacific
380	360	370	1	04/23/2007	–4.9	Harbor
190	150	180	1	04/17/2011	4.2	Mesa
—	310	320	1	10/09/2013	–7.6	Harbor

Table 1.1. Site identification, well-construction, water-level, and chronostratigraphic unit information for wells used in this study, Los Angeles and Ora

[USGS, U.S. Geological Survey; ft, foot; LSD, land surface datum; mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988; n.a., not assigned; —, not a
Fernando Valley; SGV, San Gabriel Valley; SMB, Santa Monica Basin; W, Whittier area. **Well type**: multi., multiple well; obs., observation; prod., production. **Well data**: wl, wat

State well number	State well number (abbreviated)	USGS site number	Local well name	Well location	Well type	Well data	Altitude of LSD (ft above NAVD 88)
4S/14W-26A2	26A2	334815118184701	Lomita1_1	WCB	multi.	wq	77
4S/14W-26A3	26A3	334815118184702	Lomita1_2	WCB	multi.	wq	77
4S/14W-26A4	26A4	334815118184703	Lomita1_3	WCB	multi.	wq	77
4S/14W-26A5	26A5	334815118184704	Lomita1_4	WCB	multi.	wq	77
4S/14W-26A6	26A6	334815118184705	Lomita1_5	WCB	multi.	wq	77
4S/14W-26A7	26A7	334815118184706	Lomita1_6	WCB	multi.	wq	77
4S/14W-35D10	35D10	334714118192701	Chandler3_1	WCB	multi.	wq	156
4S/14W-35D11	35D11	334714118192702	Chandler3_2	WCB	multi.	wq	156
5S/11W-3N5	3N5	n.a.	WM–RES2	OCB	prod.	wl	31
5S/11W-7C1	7C1	334534118042001	NVLW–SB6	OCB	—	wl	12
5S/11W-8A1	8A1	n.a.	SBM–1	OCB	multi	wl	19
5S/11W-17D10	17D10	n.a.	NVLW–SB3	OCB	—	wl	9
5S/11W-21L5	21L5	334310118020001	PIRT–HB	OCB	prod.	wl	25
5S/11W-28M2	28M2	n.a.	OCWD–BSO2	OCB	—	wl	4
5S/12W-1A3	1A3	n.a.	SB–LEI	OCB	prod.	wl	13
5S/12W-1C1	1C1	334620118051802	512B	OCB	multi.	wq	11
5S/12W-1C2	1C2	334620118051801	512C	OCB	multi.	wq	11
5S/12W-1C3	1C3	334622118052001	Seal Beach1_1	OCB	multi.	wq	12
5S/12W-1C4	1C4	334622118052002	Seal Beach1_2	OCB	multi.	wq	12
5S/12W-1C5	1C5	334622118052003	Seal Beach1_3	OCB	multi.	wq	12
5S/12W-1C6	1C6	334622118052004	Seal Beach1_4	OCB	multi.	wq	12
5S/12W-1C7	1C7	334622118052005	Seal Beach1_5	OCB	multi.	wq	12
5S/12W-1C8	1C8	334622118052006	Seal Beach1_6	OCB	multi.	wq	12
5S/12W-1C9	1C9	334622118052007	Seal Beach1_7	OCB	multi.	wq	12
5S/13W-2E1	2E1	334615118131001	Long Beach4_1	WCB	multi.	wq	8
5S/13W-2E2	2E2	334615118131002	Long Beach4_2	WCB	multi.	wq	8
5S/13W-11P1	11P1	334445118125301	Long Beach5_1	WCB	multi.	wq	13
5S/13W-11P2	11P2	334445118125302	Long Beach5_2	WCB	multi.	wq	13

*Full screen depths and chronostratigraphic unit information is included in the model archive.

ange Counties, California.—Continued

available. **Well location**: CB, Central Basin Pressure Area; HB, Hollywood Basin; LAF, Los Angeles Forebay; MF, Montebello Forebay; OCB, Orange County Basin; SFV, San
er level; wq, water quality]

Well depth (ft below LSD)	Depth to top perforation (ft below LSD)	Depth to bottom perforation (ft below LSD)	Number of perforated intervals	Date, water level measured (mm/dd/yyyy)	Water-level elevation (ft above NAVD 88)	Chronostratigraphic unit
1,340	1,240	1,260	1	09/17/2014	–27.6	Long Beach A
720	700	720	1	09/17/2014	–17.9	Upper Wilmington B
570	550	570	1	09/17/2014	–16.6	Bent Spring
420	400	420	1	09/17/2014	–17.2	Harbor
240	220	240	1	09/17/2014	–15.8	Pacific
120	100	120	1	09/17/2014	–13.4	Mesa
363	341	363	1	09/17/2014	–18.6	Bent Spring
192	165	192	1	09/17/2014	–18.1	Harbor
—	340	937	1	09/19/2014	–46.7	Pacific
—	579	802	—	06/30/2016	–45.6	Harbor
1,300	74	1,260	8	09/23/2014	6.2	Dominguez
—	300	680	—	07/01/2014	–63.4	Harbor
—	50	156	1	06/26/2014	–13.8	Mesa
—	44	106	—	09/05/2014	–12.0	Harbor
—	420	840	1	09/29/2014	–68.2	Harbor
372	330	365	1	03/03/2016	–7.0	Pacific
470	425	465	1	03/03/2016	–12.8	Harbor
1,485	1,345	1,365	1	09/16/2014	–45.5	Lower Wilmington
1,180	1,160	1,180	1	09/16/2014	–45.7	Upper Wilmington B
1,040	1,020	1,040	1	09/16/2014	–45.6	Upper Wilmington B
795	775	795	1	09/16/2014	–79.0	Upper Wilmington A
625	605	625	1	09/16/2014	–51.2	Bent Spring
235	215	235	1	09/16/2014	–10.3	Mesa
70	60	70	1	09/16/2014	–1.7	Dominguez
1,380	1,200	1,220	1	09/17/2014	–31.3	Long Beach B
820	800	820	1	09/17/2014	–12.9	Long Beach A
1,110	1,090	1,110	1	09/16/2014	–17.1	Long Beach A
355	335	355	1	09/16/2014	5.5	Bent Spring

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Chronostratigraphic unit	Sample collection date (mm/dd/yyyy)	pH	Dissolved solids, filtered, sum of constituents (mg/L)	Calcium, filtered (mg/L)	Magnesium, filtered (mg/L)	Potassium, filtered (mg/L)	Sodium, filtered (mg/L)	Alkalinity, filtered (mg/L as $CaCO_3$)	Chloride, filtered (mg/L)
Central Basin											
Los Angeles Forebay											
2S/13W-3P2	Los Angeles2_1	Long Beach C	01/29/2013	7.7	17,000	210	240	59.0	5,700	560	10,000
2S/13W-3P3	Los Angeles2_2	Upper Wilmington A	06/09/2010	7.5	1,090	208	53.7	9.38	93.0	322	204
2S/13W-3P4	Los Angeles2_3	Upper Wilmington A	06/09/2010	7.4	1,080	216	52.3	6.76	95.5	330	236
2S/13W-3P5	Los Angeles2_4	Harbor	06/09/2010	7.3	1,150	221	54.6	7.45	114	371	283
2S/13W-3P6	Los Angeles2_5	Pacific	04/24/2013	7.6	1,400	190	62.0	11.0	160	300	170
2S/13W-17F1	Los Angeles1_1	Upper Wilmington B	04/25/2001	8.1	351	54.1	11.7	4.07	45.2	186	22.3
2S/13W-17F2	Los Angeles1_2	Upper Wilmington A	04/24/2001	7.6	373	59.6	14.3	3.58	47.2	193	23.3
2S/13W-17F3	Los Angeles1_3	Bent Spring	04/27/2001	7.6	377	57.6	14.7	3.62	49.1	194	23.5
2S/13W-17F4	Los Angeles1_4	Harbor	04/26/2001	7.6	462	78.6	19.7	4.30	50.3	212	42.0
2S/13W-17F5	Los Angeles1_5	Pacific_A	04/26/2001	7.3	641	113	28.6	4.48	57.6	243	83.2
2S/13W-22C1	Huntington Park1_1	Bent Spring	04/09/1997	7.8	341	58.6	13.9	3.43	38.7	185	21.1
2S/13W-22C2	Huntington Park1_2	Harbor	04/10/1997	8.0	353	59.1	14.1	3.42	39.7	189	22.5
2S/13W-22C3	Huntington Park1_3	Pacific_A	04/10/1997	8.0	466	79.1	18.8	3.91	49.0	202	42.6
2S/13W-22C4	Huntington Park1_4	Mesa	04/09/1997	7.8	658	122	29.3	4.62	55.6	262	59.9
2S/13W-34F2	South Gate2_1	Harbor	09/22/2014	8.0	350	59.3	12.8	3.19	40.5	181	20.7
2S/13W-34F3	South Gate2_2	Harbor	09/22/2014	8.0	351	57.4	12.7	3.68	46.0	188	20.7
2S/13W-34F4	South Gate2_3	Pacific	09/22/2014	8.0	340	53.7	11.2	2.98	48.6	184	21.1
2S/13W-34F5	South Gate2_4	Pacific_A	09/22/2014	7.9	397	62.3	16.2	3.98	52.1	186	34.5
2S/13W-34F6	South Gate2_5	Mesa	09/22/2014	8.0	349	54.7	12.2	3.52	48.6	181	23.1
2S/13W-34F7	South Gate2_6	Dominguez	09/22/2014	7.9	367	61.2	15.2	2.97	48.0	207	23.3
2S/14W-12E1	Los Angeles3_1	Lower Wilmington	04/03/2012	8.2	392	15.0	5.44	4.09	112	255	36.5
2S/14W-12E2	Los Angeles3_2	Upper Wilmington A	04/03/2012	8.0	350	51.2	13.2	3.80	48.6	185	23.1
2S/14W-12E3	Los Angeles3_3	Harbor	04/03/2012	7.8	361	58.2	14.0	4.11	46.7	194	21.8
2S/14W-12E4	Los Angeles3_4	Pacific	04/03/2012	7.8	397	69.1	15.4	4.26	44.5	204	38.7
2S/14W-12E5	Los Angeles3_5	Pacific_A	04/03/2012	7.7	551	94.2	22.9	4.43	59.2	220	54.1
2S/14W-12E6	Los Angeles3_6	Mesa	04/03/2012	7.7	697	129	29.7	4.33	63.2	235	114

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Chronostratigraphic unit	Sample collection date (mm/dd/yyyy)	pH	Dissolved solids, filtered, sum of constituents (mg/L)	Calcium, filtered (mg/L)	Magnesium, filtered (mg/L)	Potassium, filtered (mg/L)	Sodium, filtered (mg/L)	Alkalinity, filtered (mg/L as $CaCO_3$)	Chloride, filtered (mg/L)
					Montebello Forebay						
2S/11W-5N4	Whittier_14	Mesa	09/13/2006	7.7	519	88.2	15.2	4.48	56.7	178	81.1
2S/11W-7K2	Pico Rivera3_1	Long Beach C	07/19/2016	7.7	379	84.6	13.4	3.10	23.5	149	30.8
2S/11W-7K3	Pico Rivera3_2	Long Beach C	07/19/2016	8.0	317	66.5	11.6	3.31	25.6	164	17.4
2S/11W-7K4	Pico Rivera3_3	Long Beach A	07/19/2016	8.0	485	112	18.0	3.97	27.8	189	47.8
2S/11W-7K5	Pico Rivera3_4	Mesa	07/19/2016	7.8	531	71.0	15.3	4.80	95.5	159	97.9
2S/11W-7K6	Pico Rivera4_1	Long Beach C	07/20/2016	7.8	426	90.4	14.6	3.59	30.9	171	33.4
2S/11W-7K7	Pico Rivera4_2	Long Beach C	07/20/2016	7.9	296	55.9	8.64	3.13	32.8	159	13.1
2S/11W-7K8	Pico Rivera4_3	Long Beach A	07/20/2016	7.9	527	121	18.6	4.44	32.7	200	58.7
2S/11W-7K9	Pico Rivera4_4	Mesa	07/20/2016	7.7	528	73.1	14.7	4.71	92.8	164	96.0
2S/11W-8L8	Whittier Narrows2_1	Tertiary	09/18/2014	7.9	240	6.4	1.90	1.40	78.0	150	14.0
2S/11W-8L9	Whittier Narrows2_2	Tertiary	09/18/2014	7.9	210	12	3.40	<1.0	59.0	140	8.60
2S/11W-8L10	Whittier Narrows2_3	Tertiary	09/18/2014	7.8	210	9.4	2.60	1.60	57.0	120	6.00
2S/11W-8L11	Whittier Narrows2_4	Tertiary	09/18/2014	7.9	200	12	2.80	2.30	50.0	110	4.30
2S/11W-8L12	Whittier Narrows2_5	Long Beach C	09/18/2014	7.9	330	68	9.90	2.50	26.0	150	21.0
2S/11W-8L13	Whittier Narrows2_6	Long Beach B	09/18/2014	8.0	200	34	3.90	2.00	27.0	120	4.00
2S/11W-8L14	Whittier Narrows2_7	Pacific	09/18/2014	8.1	220	38	5.30	2.30	24.0	110	9.80
2S/11W-8L15	Whittier Narrows2_8	Mesa	09/18/2014	7.9	1,900	230	77.0	5.00	240	400	220
2S/11W-8L16	Whittier Narrows2_9	Mesa	09/18/2014	7.8	2,000	230	110	4.90	240	430	230
2S/11W-18C4	Pico Rivera1_1	Long Beach C	05/09/1997	7.8	356	8.21	2.88	4.70	119	291	4.02
2S/11W-18C5	Pico Rivera1_2	Long Beach B	04/30/1997	7.6	307	67.7	11.7	3.13	20.7	171	19.0
2S/11W-18C6	Pico Rivera1_3	Long Beach A	04/30/1997	7.0	649	119	22.8	4.69	63.3	206	84.0
2S/11W-18C7	Pico Rivera1_4	Pacific	04/30/1997	7.3	577	98.3	17.3	4.70	71.5	208	68.8
2S/11W-20N1	Whittier2_1	Long Beach B	09/22/2008	7.5	850	91.6	22.4	5.35	184	240	238
2S/11W-20N2	Whittier2_2	Long Beach A	09/22/2008	8.0	253	22.0	3.97	2.55	61.3	173	11.4
2S/11W-20N3	Whittier2_3	Upper Wilmington A	09/22/2008	7.8	727	86.1	33.4	4.26	116	210	119
2S/11W-20N4	Whittier2_4	Harbor	09/22/2008	7.3	1,690	138	82.1	4.31	321	400	235
2S/11W-20N5	Whittier2_5	Pacific	09/22/2008	7.7	701	131	24.7	4.93	74.8	222	116
2S/11W-20N6	Whittier2_6	Mesa	09/22/2008	7.4	1,030	173	39.9	4.95	126	370	89.6

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Chronostratigraphic unit	Sample collection date (mm/dd/yyyy)	pH	Dissolved solids, filtered, sum of constituents (mg/L)	Calcium, filtered (mg/L)	Magnesium, filtered (mg/L)	Potassium, filtered (mg/L)	Sodium, filtered (mg/L)	Alkalinity, filtered (mg/L as $CaCO_3$)	Chloride, filtered (mg/L)
Montebello Forebay—Continued											
2S/12W-10Q5	Montebello1_1	Long Beach C	05/01/2002	8.1	2,050	13.3	5.75	7.72	780	922	658
2S/12W-10Q6	Montebello1_2	Long Beach B	04/30/2002	8.0	888	18.8	7.57	5.86	331	598	126
2S/12W-10Q7	Montebello1_3	Upper Wilmington B	04/30/2002	7.7	607	88.5	15.5	4.37	99.6	213	83.7
2S/12W-10Q8	Montebello1_4	Upper Wilmington A	05/01/2002	7.8	539	107	17.3	3.72	51.7	198	75.2
2S/12W-10Q9	Montebello1_5	Pacific	05/02/2002	7.6	488	80.2	15.4	3.24	66.0	175	63.4
2S/12W-10Q10	Montebello1_6	Mesa	05/02/2002	7.3	833	131	30.1	4.81	117	283	189
2S/12W-25G1	Pico Rivera W12	Mesa	08/16/2006	7.4	451	58.4	13.8	3.81	70.8	144	83.3
2S/12W-25G3	Pico Rivera2_1	Long Beach A	03/31/1999	7.6	455	70.5	20.8	6.35	52.1	181	58.9
2S/12W-25G4	Pico Rivera2_2	Upper Wilmington B	03/30/1999	7.8	523	117	23.1	3.66	29.6	242	54.1
2S/12W-25G5	Pico Rivera2_3	Upper Wilmington A	04/01/1999	7.7	494	101	19.9	3.97	34.2	201	58.6
2S/12W-25G6	Pico Rivera2_4	Pacific	03/30/1999	7.6	547	81.5	17.3	4.41	79.1	176	94.1
2S/12W-25G7	Pico Rivera2_5	Mesa	04/01/1999	7.5	503	71.5	16.7	4.37	73.5	168	88.1
2S/12W-25G8	Pico Rivera2_6	Dominguez	03/31/1999	7.5	524	72.2	21.3	7.22	73.0	140	93.1
2S/12W-26D9	Rio Hondo1_1	Long Beach A	01/28/1998	8.0	280	39.9	7.89	2.94	41.9	150	18.8
2S/12W-26D10	Rio Hondo1_2	Lower Wilmington	01/28/1998	7.8	446	95.1	16.5	3.67	28.5	172	50.2
2S/12W-26D11	Rio Hondo1_3	Upper Wilmington B	01/29/1998	7.7	450	79.6	14.5	4.04	49.0	159	59.2
2S/12W-26D12	Rio Hondo1_4	Upper Wilmington A	01/30/1998	7.6	467	74.8	14.1	3.96	61.6	154	68.7
2S/12W-26D13	Rio Hondo1_5	Pacific	01/30/1998	7.5	355	50.5	10.1	3.71	52.5	129	48.5
2S/12W-26D14	Rio Hondo1_6	Mesa	01/29/1998	7.3	341	46.0	12.4	4.19	49.7	105	58.3
2S/12W-33D3	Bell Gardens1_1	Lower Wilmington	09/25/2008	8.0	438	97.5	13.5	2.42	31.0	172	47.3
2S/12W-33D4	Bell Gardens1_2	Upper Wilmington A	09/25/2008	8.1	291	37.5	7.20	2.75	55.4	167	28.3
2S/12W-33D5	Bell Gardens1_3	Bent Spring	09/25/2008	7.8	439	78.1	12.8	3.73	52.6	152	59.3
2S/12W-33D6	Bell Gardens1_4	Harbor	09/25/2008	7.8	376	60.2	10.5	3.54	52.1	136	50.5
2S/12W-33D7	Bell Gardens1_5	Pacific	09/25/2008	7.6	354	58.1	10.8	3.15	46.3	148	36.6
2S/12W-33D8	Bell Gardens1_6	Pacific_A	09/25/2008	7.7	389	67.5	12.2	3.56	47.6	164	43.2
2S/12W-36M6	Pico Rivera W8	Pacific	08/25/2010	7.6	514	109	21.4	3.53	32.0	225	56.4
3S/12W-11A7	Norwalk2_1	Lower Wilmington	09/18/2008	8.0	438	61.5	11.7	4.15	77.3	184	66.5
3S/12W-11A8	Norwalk2_2	Lower Wilmington	09/18/2008	8.3	293	11.5	2.15	2.61	96.0	188	30.1

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Chronostratigraphic unit	Sample collection date (mm/dd/yyyy)	pH	Dissolved solids, filtered, sum of constituents (mg/L)	Calcium, filtered (mg/L)	Magnesium, filtered (mg/L)	Potassium, filtered (mg/L)	Sodium, filtered (mg/L)	Alkalinity, filtered (mg/L as $CaCO_3$)	Chloride, filtered (mg/L)
Montebello Forebay—Continued											
3S/12W-11A9	Norwalk2_3	Upper Wilmington A	09/18/2008	8.2	248	43.7	4.97	2.83	37.4	156	12.7
3S/12W-11A10	Norwalk2_4	Bent Spring	09/18/2008	8.0	321	65.3	10.5	3.43	30.6	171	20.1
3S/12W-11A11	Norwalk2_5	Pacific	09/18/2008	7.9	450	85.3	16.0	4.22	45.2	162	65.6
3S/12W-11A12	Norwalk2_6	Pacific_A	09/18/2008	7.7	517	89.8	17.7	4.24	61.3	193	71.9
Whittier area											
3S/11W-2K4	Whittier1_1	Long Beach C	03/17/2000	7.5	2,540	201	129	10.0	421	276	279
3S/11W-2K5	Whittier1_2	Long Beach BC	03/16/2000	7.5	2,390	199	124	10.1	396	297	239
3S/11W-2K6	Whittier1_4	Long Beach A	03/16/2000	7.6	679	80.9	33.3	3.83	97.9	265	79.6
3S/11W-2K7	Whittier1_5	Pacific	03/15/2000	7.6	670	83.1	38.1	3.28	85.5	245	80.2
3S/11W-2K8	Whittier1_3	Long Beach B	03/16/2000	7.6	1,490	141	77.3	7.51	236	305	173
3S/11W-9D2	Santa Fe Springs1_2	Lower Wilmington	04/23/1999	8.2	781	5.50	2.25	2.57	280	325	167
3S/11W-9D3	Santa Fe Springs1_3	Harbor	04/23/1999	8.2	826	36.0	27.9	5.23	220	491	119
3S/11W-9D4	Santa Fe Springs1_4	Pacific_A	04/23/1999	7.7	771	19.1	9.60	3.41	243	326	158
Pressure area											
2S/12W-7J1	Commerce1_1	Long Beach C	04/06/2001	7.5	12,200	183	144	45.4	4,280	508	7,070
2S/12W-7J2	Commerce1_2	Long Beach A	08/18/1999	7.7	486	71.8	13.6	3.16	40.0	151	46.1
2S/12W-7J3	Commerce1_3	Upper Wilmington B	08/18/1999	7.8	457	55.4	17.9	3.41	75.2	215	73.5
2S/12W-7J4	Commerce1_4	Upper Wilmington A	08/19/1999	7.7	504	46.1	18.0	3.49	106	208	123
2S/12W-7J5	Commerce1_5	Pacific	08/17/1999	7.6	556	91.7	24.3	2.47	57.7	202	88.3
2S/12W-7J6	Commerce1_6	Mesa	08/17/1999	7.7	384	53.6	16.4	1.80	50.5	172	60.8
2S/13W-24J1	Bell1_1	Long Beach B	05/20/2010	8.0	948	12.6	5.08	5.31	342	653	144
2S/13W-24J2	Bell1_2	Lower Wilmington	05/20/2010	8.0	342	52.0	10.1	2.74	51.0	174	21.5
2S/13W-24J3	Bell1_3	Upper Wilmington A	05/20/2010	8.0	312	46.1	10.3	3.31	47.0	164	27.3
2S/13W-24J4	Bell1_4	Bent Spring	05/20/2010	7.6	354	57.3	13.2	3.20	45.9	184	25.5
2S/13W-24J5	Bell1_5	Pacific	05/20/2010	7.8	446	75.5	17.8	2.75	51.3	185	47.3
2S/13W-24J6	Bell1_6	Pacific_A	05/20/2010	7.6	648	120	30.0	2.81	60.0	252	110
2S/13W-31B3	Los Angeles4_1	Long Beach A	05/03/2013	8.1	1,880	11.8	6.18	14.1	753	1650	36.0
2S/13W-31B4	Los Angeles4_2	Lower Wilmington	05/03/2013	7.9	584	15.8	6.58	10.6	193	485	10.0

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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Pressure area—Continued											
2S/13W-31B5	Los Angeles4_3	Upper Wilmington A	05/03/2013	8.1	348	56.0	11.6	3.06	46.3	181	20.4
2S/13W-31B6	Los Angeles4_4	Harbor	05/03/2013	7.9	354	52.4	12.3	3.99	48.9	188	20.8
2S/13W-31B7	Los Angeles4_5	Harbor	05/03/2013	8.1	378	48.2	10.4	3.93	66.1	194	21.9
2S/13W-31B8	Los Angeles4_6	Pacific	05/03/2013	7.8	389	61.6	14.9	3.74	46.5	191	28.5
2S/14W-26N3	Inglewood2_1	Long Beach A	04/28/1999	7.9	1,640	18.5	17.4	0.71	605	1,450	73.5
2S/14W-26N4	Inglewood2_2	Lower Wilmington	04/28/1999	7.9	1,480	11.5	9.00	18.8	566	1,340	21.9
2S/14W-26N5	Inglewood2_3	Harbor	04/26/1999	7.7	293	27.0	9.51	6.45	55.9	219	20.7
3S/11W-17F1	Norwalk1_1	Lower Wilmington	05/19/2004	7.8	470	13.1	5.84	2.49	164	307	68.7
3S/11W-17F2	Norwalk1_2	Upper Wilmington A	05/19/2004	8.1	301	7.88	1.05	1.60	110	181	57.5
3S/11W-17F3	Norwalk1_3	Bent Spring	05/19/2004	8.2	262	18.7	2.44	2.25	76.8	141	50.2
3S/11W-17F4	Norwalk1_4	Pacific	12/20/2004	7.9	207	22.8	4.73	2.34	45.5	137	17.5
3S/11W-17F5	Norwalk1_5	Pacific_A	12/20/2004	7.6	424	69.2	15.6	3.61	68.2	210	113
3S/11W-26E2	La Mirada1_1	Upper Wilmington A	08/04/1999	8.2	359	16.3	3.51	2.09	108	159	26.1
3S/11W-26E3	La Mirada1_2	Bent Spring	08/04/1999	8.1	264	36.5	5.86	2.23	47.2	142	15.8
3S/11W-26E4	La Mirada1_3	Harbor	08/05/1999	8.1	326	22.0	6.96	2.59	84.1	228	15.8
3S/11W-26E5	La Mirada1_4	Pacific	08/05/1999	7.8	429	42.8	13.8	3.20	83.0	203	27.0
3S/11W-26E6	La Mirada1_5	Pacific_A	08/05/1999	7.9	492	60.6	18.0	3.04	83.0	204	61.8
3S/12W-6B4	South Gate1_1	Bent Spring	08/06/1999	8.0	308	48.9	7.94	2.37	46.5	170	21.0
3S/12W-6B5	South Gate1_2	Harbor	08/16/1999	7.7	556	53.6	23.3	6.04	143	301	183
3S/12W-6B6	South Gate1_3	Harbor	08/16/1999	7.8	447	83.1	16.2	2.95	42.2	169	50.1
3S/12W-6B7	South Gate1_4	Pacific	08/06/1999	7.8	477	86.3	16.5	3.04	49.2	183	56.0
3S/12W-6B8	South Gate1_5	Mesa	08/06/1999	7.7	413	65.2	17.1	2.79	60.0	200	33.8
3S/12W-9J1	Downey1_1	Bent Spring	12/30/1997	7.9	208	39.4	5.56	3.04	25.5	160	5.84
3S/12W-9J2	Downey1_2	Harbor	12/29/1997	7.8	348	72.4	11.6	3.65	26.3	179	26.0
3S/12W-9J3	Downey1_3	Pacific	12/31/1997	7.6	488	103	19.2	3.49	28.5	172	66.3
3S/12W-9J4	Downey1_4	Pacific_A	12/29/1997	7.5	529	92.8	19.0	4.64	54.4	202	74.1
3S/12W-9J5	Downey1_5	Mesa	12/30/1997	7.6	531	118	22.5	4.42	29.5	260	62.6
3S/12W-9J6	Downey1_6	Dominguez	12/31/1997	7.3	812	151	31.0	5.88	73.0	302	93.8

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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Pressure area—Continued											
3S/12W-15K1	St. John Bosco	Dominguez	11/16/2006	7.3	938	180	33.6	5.36	95.8	336	116
3S/12W-16H1	Park 40D	Pacific	08/14/2006	7.5	531	106	20.6	4.45	47.0	219	64.2
3S/12W-26K2	Cerritos2_1	Harbor	05/29/2002	8.0	215	41.0	5.16	2.82	24.8	158	6.49
3S/12W-26K3	Cerritos2_2	Pacific	05/30/2002	7.7	475	98.2	17.0	3.98	34.5	179	63.6
3S/12W-26K4	Cerritos2_3	Pacific	05/31/2002	8.1	228	41.0	5.40	2.60	29.3	168	6.76
3S/12W-26K5	Cerritos2_4	Pacific_A	05/31/2002	7.9	254	49.2	8.07	2.82	27.7	194	7.65
3S/12W-26K6	Cerritos2_5	Mesa	05/30/2002	7.9	243	48.5	7.02	2.99	25.4	190	7.17
3S/12W-26K7	Cerritos2_6	Dominguez	05/29/2002	7.5	644	140	26.5	3.83	43.2	323	59.2
3S/12W-33B1	BSMWC_615	Pacific	08/15/2006	7.5	376	81.2	14.4	3.33	27.7	198	30.9
3S/13W-8J1	Willowbrook1_1	Upper Wilmington B	01/07/1998	7.9	311	27.0	5.45	5.66	79.3	255	17.5
3S/13W-8J2	Willowbrook1_2	Bent Spring	01/07/1998	8.0	319	52.4	9.26	2.97	43.6	168	20.6
3S/13W-8J3	Willowbrook1_3	Harbor	01/08/1998	7.8	332	56.4	11.6	3.35	41.0	183	20.3
3S/13W-8J4	Willowbrook1_4	Pacific	01/08/1998	7.9	347	52.6	9.55	3.42	53.2	185	24.8
3S/13W-11G1	Lynwood1_1	Long Beach A	10/16/2014	8.2	665	9.56	2.11	2.96	262	587	12.0
3S/13W-11G2	Lynwood1_2	Lower Wilmington	10/16/2014	8.7	299	4.89	0.31	1.02	105	165	22.6
3S/13W-11G3	Lynwood1_8	Pacific_A	10/16/2014	7.8	444	81.1	17.9	3.34	42.6	184	48.6
3S/13W-11G4	Lynwood1_3	Upper Wilmington B	10/17/2014	8.2	286	38.2	5.55	1.56	51.2	123	21.8
3S/13W-11G5	Lynwood1_4	Upper Wilmington A	10/17/2014	8.2	319	45.0	6.12	2.	54.5	146	22.3
3S/13W-11G6	Lynwood1_5	Bent Spring	10/16/2014	8.2	289	39.7	2.80	2.48	58.6	164	22.4
3S/13W-11G7	Lynwood1_6	Harbor	10/16/2014	8.1	334	45.8	10.6	4.16	53.4	178	21.5
3S/13W-11G8	Lynwood1_7	Harbor	10/16/2014	8.1	348	52.6	11.1	3.18	51.1	189	22.4
3S/13W-11G9	Lynwood1_9	Dominguez	10/16/2014	7.5	975	201	42.8	4.99	73.2	310	145
3S/13W-22M2	Compton2_1	Long Beach A	05/21/2009	8.3	526	12.1	2.06	2.81	200	488	15.0
3S/13W-22M3	Compton2_2	Upper Wilmington B	05/21/2009	8.1	330	28.1	5.08	4.25	95.8	290	14.3
3S/13W-22M4	Compton2_3	Harbor	05/21/2009	8.2	295	44.6	6.07	2.72	50.5	164	19.3
3S/13W-22M5	Compton2_4	Harbor	05/21/2009	8.0	348	64.1	10.5	2.61	43.8	189	26.4
3S/13W-22M6	Compton2_5	Pacific	05/21/2009	8.1	381	61.6	13.2	4.42	54.0	195	33.8
3S/13W-22M7	Compton2_6	Pacific_A	05/21/2009	7.8	430	78.0	17.2	3.94	46.4	185	65.3

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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Pressure area—Continued											
3S/13W-24K2	Compton1_1	Upper Wilmington B	05/19/2004	8.0	215	19.1	1.47	1.60	62.5	169	14.7
3S/13W-24K3	Compton1_2	Upper Wilmington A	05/19/2004	8.0	293	41.2	3.19	1.79	57.6	148	22.9
3S/13W-24K4	Compton1_3	Harbor	05/19/2004	7.9	312	47.9	7.70	2.93	48.4	165	24.8
3S/13W-24K5	Compton1_4	Pacific	05/19/2004	7.9	330	60.7	5.62	2.71	48.1	173	22.0
3S/13W-24K6	Compton1_5	Pacific_A	05/19/2004	7.8	329	57.5	9.08	2.83	45.1	187	20.5
4S/11W-5P9	Cerritos1_1	Harbor	08/03/1999	8.2	282	35.4	4.98	2.50	59.5	166	15.2
4S/11W-5P10	Cerritos1_2	Pacific	08/03/1999	8.3	263	9.60	1.74	1.94	83.2	157	13.6
4S/11W-5P11	Cerritos1_3	Pacific	08/03/1999	8.0	308	42.5	5.55	1.95	58.6	171	19.7
4S/11W-5P12	Cerritos1_4	Mesa	08/02/1999	8.0	278	46.5	10.7	1.94	36.9	181	12.5
4S/11W-5P13	Cerritos1_5	Dominguez	08/03/1999	7.9	274	39.3	9.53	2.10	43.8	183	10.8
4S/11W-5P14	Cerritos1_6	Dominguez	08/04/1999	7.9	278	48.2	9.66	2.12	33.8	192	11.3
4S/12W-5H5	Lakewood1_1	Upper Wilmington A	04/25/1997	8.7	181	10.5	0.35	0.85	54.2	98	19.2
4S/12W-5H6	Lakewood1_2	Harbor	04/23/1997	8.2	206	31.4	3.70	2.04	35.0	145	17.3
4S/12W-5H7	Lakewood1_3	Harbor	04/23/1997	8.1	247	39.3	4.52	2.38	30.8	158	9.13
4S/12W-5H8	Lakewood1_4	Pacific_A	04/24/1997	7.9	278	55.7	6.93	2.97	32.0	172	27.3
4S/12W-5H9	Lakewood1_5	Mesa	04/24/1997	7.9	256	50.3	8.82	2.52	25.2	185	9.84
4S/12W-5H10	Lakewood1_6	Dominguez	04/24/1997	7.5	610	142	13.5	4.59	52.4	199	208
4S/12W-12F1	Lakewood2_1	Upper Wilmington A	05/29/2014	8.7	219	10.2	0.39	1.	68.0	106	13.3
4S/12W-12F2	Lakewood2_2	Bent Spring	05/29/2014	8.3	188	23.1	3.05	2.18	38.5	140	5.73
4S/12W-12F3	Lakewood2_3	Harbor	05/29/2014	8.4	181	26	2.26	1.65	35.7	137	6.
4S/12W-12F4	Lakewood2_4	Pacific	05/29/2014	8.0	289	62.1	8.75	3.11	23.2	187	13.2
4S/12W-12F5	Lakewood2_5	Pacific	05/19/2015	8.1	245	46.1	4.44	2.55	35.5	179	6.16
4S/12W-12F6	Lakewood2_6	Pacific_A	05/29/2014	8.2	248	31.2	4.60	2.51	52.7	202	5.76
4S/12W-12F7	Lakewood2_7	Mesa	05/29/2014	8.1	233	52.8	3.42	2.31	24.6	182	5.78
4S/12W-12F8	Lakewood2_8	Dominguez	05/29/2014	8.1	258	43.9	5.53	2.56	40.9	216	6.73
4S/12W-21M8	Long Beach6_1	Long Beach A	07/16/2002	8.3	645	7.66	1.58	1.92	258	563	19.6
4S/12W-21M9	Long Beach6_2	Upper Wilmington B	07/16/2002	8.4	283	3.79	0.52	1.04	106	215	19.3
4S/12W-21M10	Long Beach6_3	Upper Wilmington B	07/17/2002	8.4	225	3.21	0.44	1.19	84.4	168	16.7

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Pressure area—Continued											
4S/12W-21M11	Long Beach6_4	Upper Wilmington A	08/21/2002	8.3	226	3.54	0.48	1.39	77.0	149	15.4
4S/12W-21M12	Long Beach6_5	Bent Spring	08/22/2002	8.5	192	11.9	1.	1.13	55.4	125	17.6
4S/12W-21M13	Long Beach6_6	Pacific	07/17/2002	8.0	248	35.0	3.42	2.20	45.9	139	32.9
4S/12W-23K3	LB Annex 201	Bent Spring	08/17/2006	8.8	205	9.10	0.38	0.74	62.7	128	12.0
4S/12W-25G1	Long Beach1_1	Upper Wilmington B	03/14/2000	8.6	202	2.24	0.24	0.80	79.0	166	15.2
4S/12W-25G2	Long Beach1_2	Upper Wilmington B	03/15/2000	8.6	208	2.58	0.15	0.57	78.5	162	15.0
4S/12W-25G3	Long Beach1_3	Upper Wilmington A	03/10/2000	8.5	196	4.45	0.31	0.74	65.9	126	12.4
4S/12W-25G4	Long Beach1_4	Harbor	03/15/2000	8.1	232	19.6	1.96	1.42	58.7	138	12.3
4S/12W-25G5	Long Beach1_5	Pacific	03/14/2000	7.6	1,630	282	39.7	5.53	246	164	647
4S/12W-25G6	Long Beach1_6	Mesa	03/14/2000	7.8	742	146	22.8	3.44	72.6	210	132
4S/13W-1N3	Long Beach2_1	Upper Wilmington A	03/09/2000	7.9	391	6.75	1.47	2.42	143	328	20.9
4S/13W-1N4	Long Beach2_2	Bent Spring	03/30/2001	7.9	280	12.9	1.62	2.13	89.7	212	19.8
4S/13W-1N5	Long Beach2_3	Pacific	03/09/2000	8.0	248	12.4	1.27	1.56	73.5	144	22.3
4S/13W-1N6	Long Beach2_4	Pacific_A	03/08/2000	8.0	294	35.1	3.99	2.97	60.1	154	28.8
4S/13W-1N7	Long Beach2_5	Mesa	03/07/2000	7.7	840	149	21.4	5.05	107	302	97.1
4S/13W-1N8	Long Beach2_6	Dominguez	03/08/2000	7.6	1,190	209	34.5	6.85	138	322	153
Orange County Basin											
3S/8W-34G2	Canyon_RV_1_ EAST	n.a.	09/13/2006	7.6	634	93.4	21.6	6.10	86.0	218	96.1
4S/10W-14H3	Anaheim_46	n.a.	06/07/2006	7.8	575	96.9	17.3	4.23	67.5	210	91.4
5S/12W-1C1	512B	Pacific	05/12/2011	8.2	434	56.7	11.3	1.78	62.6	98	74.6
5S/12W-1C2	512C	Harbor	05/12/2011	8.3	401	57.9	4.64	2.02	68.7	106	69.4
5S/12W-1C3	Seal Beach1_1	Lower Wilmington	05/12/2011	8.4	289	4.59	0.83	1.08	110	226	18.3
5S/12W-1C4	Seal Beach1_2	Upper Wilmington B	05/12/2011	8.7	219	2.97	0.36	0.71	79.3	167	16.5
5S/12W-1C5	Seal Beach1_3	Upper Wilmington B	05/12/2011	8.8	212	2.73	0.49	0.89	77.1	161	15.3
5S/12W-1C6	Seal Beach1_4	Upper Wilmington A	05/12/2011	7.9	250	4.56	0.64	1.03	84.7	196	19.1
5S/12W-1C7	Seal Beach1_5	Bent Spring	04/24/2014	8.4	215	7.03	1.49	1.61	71.8	127	14.9
5S/12W-1C8	Seal Beach1_6	Mesa	05/12/2011	8.2	501	65.0	11.8	2.74	84.2	130	86.1
5S/12W-1C9	Seal Beach1_7	Dominguez	05/12/2011	7.8	1,620	268	59.1	7.34	225	180	764

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Chronostratigraphic unit	Sample collection date (mm/dd/yyyy)	pH	Dissolved solids, filtered, sum of constituents (mg/L)	Calcium, filtered (mg/L)	Magnesium, filtered (mg/L)	Potassium, filtered (mg/L)	Sodium, filtered (mg/L)	Alkalinity, filtered (mg/L as $CaCO_3$)	Chloride, filtered (mg/L)
West Coast Basin											
2S/14W-18J1	Holy_Cross_AA	Upper Wilmington B	11/15/2006	7.4	2,360	252	110	14.8	438	485	640
2S/14W-19G1	Hillside_Park_1	Upper Wilmington A	09/12/2006	7.8	743	62.4	28.4	13.4	160	456	106
2S/14W-28M3	Inglewood1_1	Long Beach C	04/27/1999	7.8	4,350	38.2	29.5	36.0	1,600	1,560	1,620
2S/14W-28M4	Inglewood1_2	Long Beach A	09/29/2014	7.4	1,350	197	68.2	10.2	184	390	399
2S/14W-28M5	Inglewood1_3	Upper Wilmington B	04/26/1999	7.6	861	85.5	35.8	6.71	156	318	228
2S/14W-28M6	Inglewood1_4	Harbor	04/27/1999	7.6	624	77.9	34.2	8.43	82.7	226	170
2S/14W-28M7	Inglewood1_5	Pacific	04/26/1999	7.3	921	145	45.6	6.12	104	253	300
2S/15W-35A1	Westchester1_1	Lower Wilmington	05/22/2002	7.9	1,290	15.8	13.8	17.7	468	997	129
2S/15W-35A2	Westchester1_2	Upper Wilmington B	05/22/2002	7.9	781	24.1	14.1	14.9	258	597	72.1
2S/15W-35A3	Westchester1_3	Upper Wilmington B	05/20/2002	7.8	631	40.0	18.6	12.9	168	466	65.8
2S/15W-35A4	Westchester1_4	Bent Spring	05/21/2002	7.8	603	68.3	26.8	9.82	103	361	63.5
2S/15W-35A5	Westchester1_5	Harbor	05/21/2002	7.8	586	65.1	25.3	8.50	106	339	66.6
3S/14W-4R1	Inglewood3_1	Long Beach C	05/17/2013	7.9	2,440	22.2	11.3	17.1	862	684	1,040
3S/14W-4R2	Inglewood3_2	Long Beach BC	05/17/2013	8.1	1,370	10.7	5.86	13.7	530	1160	55.1
3S/14W-4R3	Inglewood3_3	Long Beach B	05/17/2013	8.1	712	5.71	2.85	7.67	264	589	17.7
3S/14W-4R4	Inglewood3_4	Long Beach A	05/17/2013	8.0	989	13.3	8.48	16.8	354	840	29.1
3S/14W-4R5	Inglewood3_5	Upper Wilmington A	05/17/2013	7.7	589	65.5	21.7	9.24	111	392	98.8
3S/14W-4R6	Inglewood3_6	Harbor	05/17/2013	8.0	464	62.1	21.5	7.53	64.2	208	136
3S/14W-4R7	Inglewood3_7	Pacific	05/17/2013	7.8	910	146	44.9	7.38	109	254	380
3S/14W-13J5	Gardena1_1	Long Beach A	06/06/1996	7.7	369	14.0	7.20	12.0	96.0	295	17.0
3S/14W-13J6	Gardena1_2	Upper Wilmington A	06/07/1996	7.7	324	53.0	11.0	3.50	38.0	188	21.0
3S/14W-13J7	Gardena1_3	Bent Spring	06/07/1996	7.8	325	53.0	10.0	3.30	39.0	175	22.0
3S/14W-13J8	Gardena1_4	Pacific	06/06/1996	7.2	842	150	37.0	5.40	87.0	163	370
3S/14W-17G3	Hawthorne1_1	Lower Wilmington	08/17/1999	7.8	886	14.8	12.0	21.2	292	725	47.9
3S/14W-17G4	Hawthorne1_2	Upper Wilmington B	08/07/1999	7.9	765	11.2	7.85	15.2	277	632	42.6
3S/14W-17G5	Hawthorne1_3	Bent Spring	08/07/1999	7.8	564	33.6	20.9	14.2	143	441	50.0
3S/14W-17G6	Hawthorne1_4	Bent Spring	08/07/1999	7.6	484	37.2	17.7	10.2	112	355	52.5
3S/14W-17G7	Hawthorne1_5	Harbor	08/07/1999	7.6	558	79.0	27.4	5.94	78.7	209	187

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Chronostratigraphic unit	Sample collection date (mm/dd/yyyy)	pH	Dissolved solids, filtered, sum of constituents (mg/L)	Calcium, filtered (mg/L)	Magnesium, filtered (mg/L)	Potassium, filtered (mg/L)	Sodium, filtered (mg/L)	Alkalinity, filtered (mg/L as $CaCO_3$)	Chloride, filtered (mg/L)
West Coast Basin—Continued											
3S/14W-17G8	Hawthorne1_6	Pacific	08/17/1999	7.4	2,060	304	88.7	8.45	273	285	577
3S/14W-25K7	Gardena2_1	Long Beach A	09/26/2004	8.1	346	15.4	5.93	5.67	107	295	13.7
3S/14W-25K8	Gardena2_2	Upper Wilmington A	09/26/2004	7.8	326	36.3	11.1	5.86	55.0	188	22.1
3S/14W-25K9	Gardena2_3	Upper Wilmington A	09/26/2004	7.9	322	48.9	11.7	3.81	41.5	183	22.6
3S/14W-25K10	Gardena2_4	Harbor	09/26/2004	7.7	239	31.4	8.60	3.29	40.0	180	21.1
3S/14W-25K11	Gardena2_5	Pacific	09/26/2004	8.0	313	47.6	10.6	3.26	48.4	198	35.7
3S/14W-27C2	Lawndale1_1	Long Beach A	09/08/2014	8.1	576	10.2	3.56	6.04	209	490	17.5
3S/14W-27C3	Lawndale1_2	Lower Wilmington	09/08/2014	8.0	759	4.59	3.58	9.12	290	644	33.3
3S/14W-27C4	Lawndale1_3	Upper Wilmington B	09/08/2014	8.0	358	16.4	9.79	9.80	100	266	26.9
3S/14W-27C5	Lawndale1_4	Harbor	09/08/2014	8.0	395	43.8	16.2	5.49	71.6	203	58.3
3S/14W-27C6	Lawndale1_5	Harbor	09/08/2014	8.0	393	52.9	17.7	5.34	58.9	198	55.8
3S/14W-27C7	Lawndale1_6	Pacific	09/08/2014	7.6	1,380	201	56.1	8.84	220	264	544
3S/14W-30L2	Manhattan Beach1_1	Long Beach C	08/28/2013	7.9	6,910	47.6	35.7	20.3	2,410	594	3,940
3S/14W-30L3	Manhattan Beach1_2	Long Beach BC	08/28/2013	8.0	2,610	31.2	12.9	16.6	885	463	1,320
3S/14W-30L4	Manhattan Beach1_3	Long Beach A	08/28/2013	8.1	1,230	15.3	10.8	25.6	404	958	126
3S/14W-30L5	Manhattan Beach1_4	Upper Wilmington B	08/28/2013	8.1	899	25.5	9.44	9.84	181	503	36.5
3S/14W-30L6	Manhattan Beach1_5	Bent Spring	08/28/2013	7.2	20,900	1,990	939	106	4,160	130	12,100
3S/14W-30L7	Manhattan Beach1_6	Pacific	08/28/2013	7.5	7,250	1,010	273	38.1	1,250	166	4,010
3S/14W-30L8	Manhattan Beach1_7	Mesa	08/28/2013	8.0	675	57.5	15.8	5.38	136	140	139
3S/14W-33R5	Torrance1_1	Long Beach B	06/17/2010	8.0	967	13.8	5.86	12.6	353	700	96.4
3S/14W-33R6	Torrance1_2	Lower Wilmington	06/17/2010	8.1	1,070	7.21	4.86	10.2	427	925	16.6
3S/14W-33R7	Torrance1_3	Upper Wilmington B	06/17/2010	7.9	512	13.2	6.61	14.3	173	426	29.1
3S/14W-33R8	Torrance1_4	Bent Spring	06/17/2010	8.0	384	23.2	10.8	10.6	103	294	29.9
3S/14W-33R9	Torrance1_5	Pacific	06/17/2010	7.5	3,040	474	112	15.2	433	174	1,560
3S/14W-33R10	Torrance1_6	Mesa	06/17/2010	7.9	805	104	23.3	6.25	139	227	183
4S/12W-30J1	Long Beach8_1	Long Beach A	09/29/2004	7.9	638	6.14	1.89	2.56	253	544	23.6
4S/12W-30J2	Long Beach8_2	Lower Wilmington	09/29/2004	7.9	609	7.81	2.73	4.38	228	500	35.9
4S/12W-30J3	Long Beach8_3	Upper Wilmington B	09/30/2004	7.9	851	9.81	4.71	7.72	329	636	88.9

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

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West Coast Basin—Continued											
4S/12W-30J4	Long Beach8_4	Upper Wilmington A	09/30/2004	7.7	1,390	49.6	34.7	12.8	435	408	585
4S/12W-30J5	Long Beach8_5	Bent Spring	09/30/2004	7.4	1,030	61.4	26.3	10.3	294	313	419
4S/12W-30J6	Long Beach8_6	Mesa	09/30/2004	7.5	938	107	31.8	6.75	200	212	418
4S/13W-5F1	Carson3_1	Long Beach A	04/02/2012	8.1	456	8.07	2.33	2.87	163	369	13.6
4S/13W-5F2	Carson3_2	Upper Wilmington B	04/02/2012	8.3	236	19.0	3.84	3.26	60.0	159	20.1
4S/13W-5F3	Carson3_3	Upper Wilmington B	04/02/2012	7.9	247	15.2	2.93	3.31	71.2	177	21.2
4S/13W-5F4	Carson3_4	Upper Wilmington A	04/02/2012	7.8	235	21.6	5.93	3.78	54.6	175	20.6
4S/13W-5F5	Carson3_5	Upper Wilmington A	04/02/2012	7.8	245	31.9	8.52	3.06	44.5	184	20.6
4S/13W-5F6	Carson3_6	Harbor	04/02/2012	8.1	323	44.6	11.4	3.79	51.5	186	21.0
4S/13W-9H9	Carson1_1	Upper Wilmington A	01/06/1998	8.2	202	18.8	3.77	3.09	50.7	150	20.1
4S/13W-9H10	Carson1_2	Upper Wilmington A	01/05/1998	8.1	228	31.9	6.71	2.37	42.3	177	20.5
4S/13W-9H11	Carson1_3	Harbor	01/06/1998	8.0	311	43.5	11.9	3.14	46.6	171	22.6
4S/13W-9H12	Carson1_4	Pacific	01/06/1998	7.8	553	86.5	20.8	4.45	74.4	215	112
4S/13W-18K1	Carson2_1	Lower Wilmington	08/07/2002	8.1	224	4.74	1.11	3.14	80.6	169	19.7
4S/13W-18K2	Carson2_2	Upper Wilmington A	08/08/2002	8.3	266	12.4	4.29	4.27	81.0	197	21.2
4S/13W-18K3	Carson2_3	Upper Wilmington A	08/09/2002	8.2	263	21.9	7.56	4.57	60.4	192	21.3
4S/13W-18K4	Carson2_4	Bent Spring	08/08/2002	7.8	277	34.3	11.7	4.27	51.0	219	21.3
4S/13W-18K5	Carson2_5	Pacific	08/07/2002	8.0	270	37.4	8.61	3.28	47.0	190	21.3
4S/13W-23D3	Long Beach3_1	Long Beach A	03/29/2001	8.0	448	11.0	3.47	3.81	156	392	18.5
4S/13W-23D4	Long Beach3_2	Upper Wilmington B	03/29/2001	8.2	235	15.9	2.73	2.50	61.5	144	18.8
4S/13W-23D5	Long Beach3_3	Upper Wilmington A	03/28/2001	7.9	221	17.9	3.24	2.71	55.8	159	24.8
4S/13W-23D6	Long Beach3_4	Bent Spring	03/27/2001	7.8	577	88.8	24.0	6.24	72.9	139	213
4S/13W-23D7	Long Beach3_5	Harbor	03/26/2001	7.8	1,210	238	57.3	7.84	98.6	148	619
4S/13W-23N3	889P	Upper Wilmington A	02/11/1999	7.7	394	29.2	5.59	3.53	109	194	107
4S/13W-26F5	380P	Upper Wilmington A	02/04/1999	8.3	261	9.37	2.	2.91	86.2	177	36.9
4S/13W-27H4	Long Beach7_1	Long Beach A	08/27/2003	8.3	573	6.2	3.03	4.77	206	503	22.9
4S/13W-27H5	Long Beach7_2	Upper Wilmington A	08/26/2003	8.0	329	13.5	4.08	3.46	107	181	74.4
4S/13W-27H6	Long Beach7_3	Upper Wilmington A	08/26/2003	7.9	313	12.8	4.43	3.21	97.1	177	67.6

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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West Coast Basin—Continued											
4S/13W-27H7	Long Beach7_4	Bent Spring	08/25/2003	7.5	3,770	463	174	20.9	615	145	2,100
4S/13W-28A3	Wilmington1_1	Upper Wilmington B	04/24/1999	7.9	498	50.0	16.1	7.14	106	138	213
4S/13W-28A4	Wilmington1_2	Upper Wilmington B	04/25/1999	7.8	787	124	26.9	5.61	130	138	337
4S/13W-28A5	Wilmington1_3	Upper Wilmington A	04/25/1999	7.3	1,720	214	46.5	9.42	346	153	907
4S/13W-28A6	Wilmington1_4	Pacific	04/25/1999	7.6	2,470	282	95.9	12.9	457	148	1,210
4S/13W-28A7	Wilmington1_5	Mesa	04/24/1999	7.6	789	85.2	30.6	7.37	145	204	233
4S/13W-29H5	340L	Pacific	02/03/1999	7.5	1,260	180	61.0	13.0	614	260	1,300
4S/13W-29H6	340M	Harbor	02/03/1999	7.4	2,500	170	53.0	7.80	231	220	570
4S/13W-29H7	340N	Upper Wilmington A	02/03/1999	8.0	2,560	57.0	16.0	3.40	81.0	180	140
4S/13W-31J1	321A	Lower Wilmington	02/06/1999	7.6	3,660	202	155	20.1	957	306	2,110
4S/13W-32F1	Wilmington2_1	Long Beach B	04/21/1999	8.2	515	3.31	2.24	5.46	195	391	56.5
4S/13W-32F2	Wilmington2_2	Long Beach A	02/18/1999	8.0	1,310	29.8	21.6	12.7	437	472	513
4S/13W-32F3	Wilmington2_3	Lower Wilmington	02/18/1999	7.6	336	19.8	7.47	4.34	102	187	72.3
4S/13W-32F4	Wilmington2_4	Upper Wilmington B	04/21/1999	7.5	1,990	143	66.7	16.4	492	290	1,010
4S/13W-32F5	Wilmington2_5	Mesa	02/18/1999	7.5	9,580	640	310	30.9	2,600	206	5,230
4S/13W-34A1	371D	Long Beach A	02/11/1999	8.4	257	6.42	1.41	3.41	89.3	165	41.9
4S/13W-34M1	361H	Long Beach A	02/10/1999	7.8	319	17.6	4.38	3.03	95.3	175	71.2
4S/13W-35B2	381J	Lower Wilmington	03/18/1999	8.1	812	12.1	8.16	1.68	298	687	75.7
4S/13W-35B3	381K	Upper Wilmington B	03/19/1999	8.0	5,450	293	251	42.2	1,410	203	3,050
4S/14W-2N1	PM-3 Madrid_1	Bent Spring	08/29/1995	7.7	390	16.0	10.0	—	130	320	28.0
4S/14W-2N2	PM-3 Madrid_2	Harbor	08/28/1995	7.9	710	32.0	10.0	—	57.0	190	35.0
4S/14W-2N3	PM-3 Madrid_3	Pacific	08/29/1995	7.7	700	70.0	22.0	—	81.0	180	180
4S/14W-2N4	PM-3 Madrid_4	Pacific	08/28/1995	7.8	1,100	70.0	20.0	—	120	190	210
4S/14W-4Q1	PM-4 Mariner_1	Bent Spring	04/27/2014	8.4	340	26	11.0	6.80	78.0	240	27.0
4S/14W-4Q2	PM-4 Mariner_2	Harbor	09/07/2014	7.5	16,000	1,400	450	52.0	2,100	150	6,500
4S/14W-4Q3	PM-4 Mariner_3	Pacific	09/07/2014	8.2	670	65	18.0	6.20	120	160	100
4S/14W-4Q4	PM-4 Mariner_4	Pacific	09/07/2014	8.1	630	69	19.0	6.00	110	190	110
4S/14W-10C1	PM-1 Columbia_1	Bent Spring	08/21/2014	8.3	280	26	15.0	9.20	66.0	200	22.0

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West Coast Basin—Continued											
4S/14W-10C2	PM-1 Columbia_2	Harbor	08/21/2014	7.9	2,400	300	100	14.0	210	140	880
4S/14W-15E1	Torrance2_1	Long Beach A	03/30/2011	7.8	1,590	104	80.7	15.4	372	493	672
4S/14W-15E2	Torrance2_2	Upper Wilmington B	03/30/2011	7.3	4,220	183	89.1	42.8	1,230	136	2,540
4S/14W-15E3	Torrance2_3	Upper Wilmington A	03/30/2011	7.3	10,200	1,080	787	88.5	1,470	104	6,570
4S/14W-15E4	Torrance2_4	Bent Spring	03/30/2011	7.7	386	18.8	10.7	5.76	107	249	49.8
4S/14W-15E5	Torrance2_5	Harbor	03/30/2011	7.4	3,230	486	143	19.7	458	192	1,720
4S/14W-15E6	Torrance2_6	Pacific	03/30/2011	7.8	874	117	33.0	7.04	141	205	286
4S/14W-26A2	Lomita1_1	Long Beach A	04/20/1999	7.7	1,300	99.9	28.7	15.7	323	245	580
4S/14W-26A3	Lomita1_2	Upper Wilmington B	04/20/1999	7.6	845	81.8	23.1	10.7	187	239	341
4S/14W-26A4	Lomita1_3	Bent Spring	04/22/1999	7.7	715	63.0	20.1	9.59	165	308	233
4S/14W-26A5	Lomita1_4	Harbor	04/19/1999	7.6	686	58.9	16.4	9.	164	246	247
4S/14W-26A6	Lomita1_5	Pacific	04/19/1999	7.7	1,110	113	30.2	12.6	245	232	509
4S/14W-35D10	Chandler3_1	Bent Spring	09/25/2014	7.4	620	100	28.0	4.00	130	400	160
4S/14W-35D11	Chandler3_2	Harbor	09/25/2014	7.2	1,000	170	47.0	3.50	140	350	200
5S/13W-02E1	Long Beach4_1	Long Beach B	04/03/2001	7.8	630	9.57	4.63	5.78	259	492	21.4
5S/13W-02E2	Long Beach4_2	Long Beach A	04/04/2001	8.0	1,180	6.55	7.18	10.8	422	614	337
5S/13W-11P1	Long Beach5_1	Long Beach A	04/24/2002	7.9	4,010	17.8	30.5	25.8	1,500	1,230	1,650
5S/13W-11P2	Long Beach5_2	Bent Spring	04/24/2002	6.9	35,600	519	1,220	272	10,800	289	19,900
Santa Monica Basin											
1S/15W-31E1	SM 1 (2505)	Pacific	08/10/2006	7.0	623	112	55.0	3.08	88.6	335	102
1S/15W-33A1	SM Arcadia_5	Mesa	08/07/2006	6.8	593	115	53.2	3.04	72.9	272	111
2S/15W-4C2	SM 3 (2646K)	Pacific	08/24/2010	7.1	835	126	55.2	2.09	70.6	327	84.0
Hollywood Basin											
1S/14W-18L1	BH_2	Upper Wilmington A	11/14/2006	8.0	811	23.8	21.5	6.03	254	410	220
1S/15W-24B1	BH_5	Pacific	08/09/2006	7.7	381	59.5	32.3	4.68	85.6	308	36.9
San Fernando Valley											
1N/13W-35P1	DS_WATERS	n.a.	11/16/2006	7.3	841	136	61.4	1.62	59.4	290	105

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Chronostratigraphic unit	Sample collection date (mm/dd/yyyy)	pH	Dissolved solids, filtered, sum of constituents (mg/L)	Calcium, filtered (mg/L)	Magnesium, filtered (mg/L)	Potassium, filtered (mg/L)	Sodium, filtered (mg/L)	Alkalinity, filtered (mg/L as $CaCO_3$)	Chloride, filtered (mg/L)
San Gabriel Valley											
2S/11W-5P6	Whittier Narrows1_1	Long Beach BC	09/17/2014	7.3	1,200	57.0	12.0	3.40	330	92	520
2S/11W-5P7	Whittier Narrows1_2	Long Beach A	09/17/2014	8.0	200	11	0.42	1.70	62.0	110	26.0
2S/11W-5P8	Whittier Narrows1_3	Lower Wilmington	09/17/2014	7.9	460	100	9.80	2.90	32.0	140	75.0
2S/11W-5P9	Whittier Narrows1_4	Upper Wilmington B	09/17/2014	8.0	510	110	13.0	4.40	40.0	150	92.0
2S/11W-5P10	Whittier Narrows1_5	Upper Wilmington B	09/17/2014	8.0	270	55	9.	3.50	22.0	120	28.0
2S/11W-5P11	Whittier Narrows1_6	Upper Wilmington A	09/17/2014	8.1	600	93	14.0	5.10	79.0	160	100
2S/11W-5P12	Whittier Narrows1_7	Upper Wilmington A	09/17/2014	8.0	610	84	14.0	5.20	96.0	160	100
2S/11W-5P13	Whittier Narrows1_8	Mesa	09/17/2014	8.1	610	84	15.0	5.50	96.0	170	100
2S/11W-5P14	Whittier Narrows1_9	Dominguez	09/17/2014	8.0	640	80	20.0	6.10	100	180	110

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
Central Basin													
Los Angeles Forebay													
2S/13W-3P2	Los Angeles2_1	0.16	—	11.0	—	<0.20	—	6,200	1,613	—	—	—	—
2S/13W-3P3	Los Angeles2_2	0.27	30.1	293	0.87	<0.039	1,400	242	843	0.11	<0.1	–19.	57.4
2S/13W-3P4	Los Angeles2_3	0.33	25.6	242	0.095	<0.039	1,420	224	1,054	0.083	0.9	–20.51	49.4
2S/13W-3P5	Los Angeles2_4	0.35	25.4	220	0.10	<0.039	1,440	276	1,025	0.082	2.3	—	—
2S/13W-3P6	Los Angeles2_5	0.28	—	540	—	<0.20	—	430	395	—	—	—	—
2S/13W-17F1	Los Angeles1_1	0.33	33.5	68.8	0.45	<0.044	386	144	155	0.032	<0.1	–11.75	52.8
2S/13W-17F2	Los Angeles1_2	0.50	24.5	83.6	0.030	<0.047	440	139	168	0.026	<0.1	–13.05	82.1
2S/13W-17F3	Los Angeles1_3	0.42	24.4	83.5	<0.04	0.04	441	154	153	0.007	0.2	—	—
2S/13W-17F4	Los Angeles1_4	0.48	21.5	111	<0.04	1.4	578	162	259	0.026	<0.1	–14.39	76.5
2S/13W-17F5	Los Angeles1_5	0.43	24.6	135	<0.04	11.3	840	195	427	0.009	0.1	—	—
2S/13W-22C1	Huntington Park1_1	0.54	22.8	80.0	0.010	<0.050	451	132	160	0.025	<0.1	–13.62	83.7
2S/13W-22C2	Huntington Park1_2	0.47	22.4	82.3	<0.01	0.11	470	133	169	0.004	<0.1	–13.45	83.5
2S/13W-22C3	Huntington Park1_3	0.40	24.0	120	<0.01	3.4	628	150	284	0.008	1.2	—	—

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
Los Angeles Forebay													
2S/13W-22C4	Huntington Park1_4	0.40	25.3	196	<0.01	5.0	919	168	357	0.006	0.6	—	—
2S/13W-34F2	South Gate2_1	0.45	25.3	77.7	0.13	<0.040	406	123	168	0.027	<0.1	–13.23	72.9
2S/13W-34F3	South Gate2_2	0.39	21.5	75.0	0.030	<0.040	480	119	174	0.021	<0.1	–13.14	75.0
2S/13W-34F4	South Gate2_3	0.38	19.0	72.0	0.020	<0.040	472	111	190	0.022	<0.1	–13.56	68.8
2S/13W-34F5	South Gate2_4	0.44	21.3	91.6	0.020	0.39	482	127	272	0.005	<0.1	–13.45	77.4
2S/13W-34F6	South Gate2_5	0.43	18.6	78.0	0.030	<0.040	510	126	183	0.017	<0.1	–13.26	75.1
2S/13W-34F7	South Gate2_6	0.50	22.5	75.9	0.048	<0.040	491	130	179	0.017	0.1	–13.59	74.1
2S/14W-12E1	Los Angeles3_1	0.38	39.1	23.3	1.66	<0.040	56	332	110	0.098	0.3	–16.	17.5
2S/14W-12E2	Los Angeles3_2	0.38	25.4	72.0	0.15	<0.040	334	133	174	0.038	<0.1	–13.23	72.0
2S/14W-12E3	Los Angeles3_3	0.51	22.7	75.6	0.042	<0.040	440	137	159	0.040	<0.1	–13.70	80.2
2S/14W-12E4	Los Angeles3_4	0.48	24.3	76.4	0.031	<0.040	492	140	276	0.057	0.2	–14.02	74.9
2S/14W-12E5	Los Angeles3_5	0.38	23.3	116	0.010	9.7	728	168	322	0.003	2.3	–15.82	85.5
2S/14W-12E6	Los Angeles3_6	0.39	23.2	162	<0.010	6.4	894	187	610	0.003	0.7	–15.48	80.0
Montebello Forebay													
2S/11W-5N4	Whittier_14	0.26	19.6	135	<0.010	2.5	587	87	932	0.013	7.9	–13.80	92.7
2S/11W-7K2	Pico Rivera3_1	0.30	20.7	114	<0.01	<0.040	626	47	655	0.003	3.4	–11.19	86.1
2S/11W-7K3	Pico Rivera3_2	0.32	20.4	66.8	0.020	1.3	484	56	311	0.001	1.3	–10.95	84.5
2S/11W-7K4	Pico Rivera3_3	0.28	21.7	128	<0.01	2.6	766	61	784	0.003	4.2	–12.99	90.1
2S/11W-7K5	Pico Rivera3_4	0.37	20.2	118	0.020	2.6	445	230	426	0.012	9.1	–15.65	97.2
2S/11W-7K6	Pico Rivera4_1	0.26	24.3	125	0.040	<0.040	697	59	566	0.003	3.0	–11.49	86.3
2S/11W-7K7	Pico Rivera4_2	0.33	23.1	62.6	0.030	<0.040	414	57	230	0.004	0.7	–10.65	80.3
2S/11W-7K8	Pico Rivera4_3	0.25	21.3	134	0.010	3.2	833	82	716	0.004	4.2	–13.88	91.5
2S/11W-7K9	Pico Rivera4_4	0.32	20.9	112	0.010	3.1	444	234	410	0.009	9.0	–16.22	95.8
2S/11W-8L8	Whittier Narrows2_1	0.56	—	7.90	—	<0.20	—	240	56	0.036	—	—	—
2S/11W-8L9	Whittier Narrows2_2	0.41	—	4.	—	<0.20	—	190	67	0.021	—	—	—
2S/11W-8L10	Whittier Narrows2_3	0.44	—	21.0	—	<0.20	—	85	65	0.014	—	—	—
2S/11W-8L11	Whittier Narrows2_4	0.34	—	24.0	—	<0.20	—	80	50	0.006	—	—	—
2S/11W-8L12	Whittier Narrows2_5	0.27	—	80.0	—	<0.20	—	58	225	<0.001	—	—	—

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
Montebello Forebay—Continued													
2S/11W-8L13	Whittier Narrows2_6	0.21	—	20.0	—	2.0	—	52	59	<0.001	—	—	—
2S/11W-8L14	Whittier Narrows2_7	0.23	—	32.0	—	0.98	—	54	99	<0.001	—	—	—
2S/11W-8L15	Whittier Narrows2_8	0.21	—	690	—	2.6	—	510	433	0.002	—	—	—
2S/11W-8L16	Whittier Narrows2_9	0.20	—	730	—	3.6	—	620	343	0.005	—	—	—
2S/11W-18C4	Pico Rivera1_1	0.31	29.7	4.99	2.01	<0.050	122	603	7	0.005	0.2	–3.86	1.6
2S/11W-18C5	Pico Rivera1_2	0.36	23.0	65.2	0.18	<0.050	509	69	275	0.004	4.5	–11.52	89.8
2S/11W-18C6	Pico Rivera1_3	0.21	22.2	217	<0.01	<0.050	665	194	433	0.012	12.2	—	—
2S/11W-18C7	Pico Rivera1_4	0.38	20.9	171	<0.01	1.7	609	215	320	0.012	14.7	—	—
2S/11W-20N1	Whittier2_1	0.30	26.8	134	0.16	0.03	514	518	459	0.41	1.1	–10.88	57.6
2S/11W-20N2	Whittier2_2	0.30	28.6	17.8	0.10	<0.040	211	224	51	0.018	<0.1	–11.29	38.3
2S/11W-20N3	Whittier2_3	0.35	25.4	212	<0.020	0.58	686	218	546	0.025	1.1	–13.11	51.8
2S/11W-20N4	Whittier2_4	0.51	44.5	613	0.015	2.5	1,310	804	292	0.25	0.2	—	—
2S/11W-20N5	Whittier2_5	0.28	23.0	170	<0.020	4.7	812	173	671	0.004	7.5	—	—
2S/11W-20N6	Whittier2_6	0.30	27.6	308	0.010	8.0	873	319	281	0.006	3.9	—	—
2S/12W-10Q5	Montebello1_1	0.45	25.7	0.34	4.24	<0.041	176	6,430	102	1.32	<0.1	–4.42	0.12
2S/12W-10Q6	Montebello1_2	0.29	31.6	0.70	2.57	<0.045	187	2,380	53	0.19	<0.1	–5.30	1.2
2S/12W-10Q7	Montebello1_3	0.20	24.9	146	0.51	<0.050	696	345	243	0.095	19.0	–12.12	130.1
2S/12W-10Q8	Montebello1_4	0.17	23.3	143	0.18	<0.050	769	186	404	0.069	19.6	—	—
2S/12W-10Q9	Montebello1_5	0.38	22.6	116	<0.04	4.7	534	231	274	0.006	6.3	—	—
2S/12W-10Q10	Montebello1_6	0.30	25.1	117	0.23	9.8	1,020	425	445	0.046	6.0	—	—
2S/12W-25G1	Pico Rivera W12	0.35	20.1	99.6	0.010	3.3	451	228	365	0.012	9.8	–12.91	95.6
2S/12W-25G3	Pico Rivera2_1	0.41	17.0	120	<0.02	2.7	584	162	364	0.007	8.4	–12.34	93.2
2S/12W-25G4	Pico Rivera2_2	0.31	22.0	130	<0.02	2.8	747	97	558	0.001	16.8	–13.59	111.2
2S/12W-25G5	Pico Rivera2_3	0.36	21.4	129	<0.02	3.2	715	124	473	0.002	18.3	—	—
2S/12W-25G6	Pico Rivera2_4	0.46	20.6	135	<0.02	3.2	532	284	331	0.017	8.4	—	—
2S/12W-25G7	Pico Rivera2_5	0.33	19.3	130	<0.02	1.6	491	233	378	0.022	9.0	—	—
2S/12W-25G8	Pico Rivera2_6	0.47	17.3	139	<0.02	2.7	—	263	354	0.018	8.4	—	—
2S/12W-26D9	Rio Hondo1_1	0.29	25.6	51.7	0.16	<0.050	287	61	308	0.029	0.2	–12.95	35.5

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
Montebello Forebay—Continued													
2S/12W-26D10	Rio Hondo1_2	0.24	25.2	125	0.060	<0.050	657	53	947	0.005	18.5	–12.20	82.9
2S/12W-26D11	Rio Hondo1_3	0.35	21.8	117	<0.02	2.7	567	148	400	0.005	12.1	—	—
2S/12W-26D12	Rio Hondo1_4	0.45	21.5	121	<0.02	2.9	476	202	340	0.020	8.1	–11.68	96.4
2S/12W-26D13	Rio Hondo1_5	0.41	19.3	87.3	<0.02	1.3	330	151	321	0.014	9.0	—	—
2S/12W-26D14	Rio Hondo1_6	0.34	15.9	85.9	<0.02	1.3	455	133	438	0.012	8.8	—	—
2S/12W-33D3	Bell Gardens1_1	0.21	24.5	117	0.24	<0.040	854	58	816	0.006	9.9	–12.	88.2
2S/12W-33D4	Bell Gardens1_2	0.31	21.4	37.1	0.18	<0.040	356	125	226	0.016	2.5	–13.37	70.3
2S/12W-33D5	Bell Gardens1_3	0.32	21.1	107	<0.020	2.6	565	165	359	0.005	5.4	–12.24	109.5
2S/12W-33D6	Bell Gardens1_4	0.41	21.6	84.1	<0.020	2.3	388	159	318	0.002	5.6	—	—
2S/12W-33D7	Bell Gardens1_5	0.24	24.7	75.0	<0.020	2.1	377	184	199	0.002	5.7	—	—
2S/12W-33D8	Bell Gardens1_6	0.37	23.3	82.4	<0.020	2.1	425	160	270	0.002	5.7	—	—
2S/12W-36M6	Pico Rivera W8	0.31	21.3	122	<0.020	2.8	772	74	762	0.002	5.6	–13.96	103.7
3S/12W-11A7	Norwalk2_1	0.34	20.3	85.0	<0.020	0.06	533	206	323	0.060	4.4	–15.95	62.3
3S/12W-11A8	Norwalk2_2	0.50	23.9	12.1	0.20	<0.040	105	247	122	0.050	<0.1	—	—
3S/12W-11A9	Norwalk2_3	0.22	19.0	32.7	0.030	<0.040	368	40	318	0.010	<0.1	–13.25	70.2
3S/12W-11A10	Norwalk2_4	0.30	22.0	60.2	<0.020	1.1	600	57	353	<0.002	1.4	—	—
3S/12W-11A11	Norwalk2_5	0.26	20.9	102	<0.020	2.7	753	130	505	0.009	9.1	—	—
3S/12W-11A12	Norwalk2_6	0.40	23.7	118	<0.020	3.0	519	173	416	0.010	6.4	—	—
Whittier area													
3S/11W-2K4	Whittier1_1	0.31	33.3	1,300	2.84	<0.050	2,270	850	328	0.25	<0.1	–14.92	15.5
3S/11W-2K5	Whittier1_2	0.32	33.5	1,240	2.18	<0.050	2,060	922	259	0.23	<0.1	–15.01	14.9
3S/11W-2K6	Whittier1_4	0.22	39.4	168	<0.02	4.5	741	183	435	0.091	<0.1	—	—
3S/11W-2K7	Whittier1_5	0.32	43.4	169	<0.02	5.2	743	153	524	0.022	<0.1	—	—
3S/11W-2K8	Whittier1_3	0.55	33.3	645	0.63	<0.050	1,290	567	305	0.15	0.1	–15.01	15.3
3S/11W-9D2	Santa Fe Springs1_2	0.68	17.9	92.7	2.19	<0.050	97.8	1,110	150	0.18	<0.1	—	—
3S/11W-9D3	Santa Fe Springs1_3	0.41	37.3	40.7	1.56	<0.050	681	488	244	0.15	0.4	—	—
3S/11W-9D4	Santa Fe Springs1_4	0.58	26.6	90.5	1.26	<0.050	334	895	177	0.19	<0.1	—	—

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
Pressure area													
2S/12W-7J1	Commerce1_1	0.19	31.3	4.47	27.3	0.02	4,230	6,530	1,083	9.44	<0.1	–5.97	2.5
2S/12W-7J2	Commerce1_2	0.31	24.4	100	1.93	<0.050	575	125	369	0.002	<0.1	–16.77	28.5
2S/12W-7J3	Commerce1_3	0.40	31.0	67.7	0.71	<0.050	499	209	352	0.13	0.2	–15.01	56.7
2S/12W-7J4	Commerce1_4	0.44	33.4	49.1	0.64	<0.040	444	246	500	0.17	2.4	–14.99	100.1
2S/12W-7J5	Commerce1_5	0.33	29.9	115	<0.02	4.7	807	141	626	0.013	19.1	—	—
2S/12W-7J6	Commerce1_6	0.48	29.6	40.1	<0.02	6.1	380	135	450	0.017	<0.1	—	—
2S/13W-24J1	Bell1_1	0.52	38.5	0.24	3.20	<0.033	129	1,600	90	0.25	<0.1	–4.82	0.46
2S/13W-24J2	Bell1_2	0.29	24.5	74.2	0.51	<0.040	376	137	157	0.030	<0.1	–13.31	65.6
2S/13W-24J3	Bell1_3	0.47	23.8	54.3	0.14	<0.040	313	128	213	0.044	<0.1	–14.64	46.0
2S/13W-24J4	Bell1_4	0.48	25.6	70.5	0.069	<0.040	432	155	165	0.039	0.2	–13.47	69.1
2S/13W-24J5	Bell1_5	0.41	24.3	108	<0.020	1.5	642	143	331	0.011	3.6	—	—
2S/13W-24J6	Bell1_6	0.43	25.1	135	<0.020	2.5	887	155	710	0.007	<0.1	–14.57	79.7
2S/13W-31B3	Los Angeles4_1	<1.00	39.2	<9.00	6.72	<0.040	158	5,300	7	0.061	<0.1	–4.32	0.28
2S/13W-31B4	Los Angeles4_2	0.29	36.0	9.57	5.43	<0.040	196	502	20	0.013	<0.1	–3.69	3.6
2S/13W-31B5	Los Angeles4_3	0.33	23.8	76.4	0.12	<0.040	452	126	162	0.029	<0.1	–13.49	74.0
2S/13W-31B6	Los Angeles4_4	0.43	24.3	76.3	0.085	<0.040	408	132	158	0.040	<0.1	–13.53	74.3
2S/13W-31B7	Los Angeles4_5	0.43	25.2	82.8	0.080	<0.040	404	144	152	0.034	<0.1	–13.19	73.3
2S/13W-31B8	Los Angeles4_6	0.47	24.9	87.1	<0.010	1.3	488	150	190	0.006	<0.1	–13.16	83.2
2S/14W-26N3	Inglewood2_1	0.65	32.8	10.9	12.4	<0.040	276	3,750	20	0.040	<0.1	23.28	0.02
2S/14W-26N4	Inglewood2_2	0.39	34.8	3.03	12.2	<0.050	209	3,400	6	0.025	<0.1	16.10	3.4
2S/14W-26N5	Inglewood2_3	0.28	36.2	7.70	1.60	<0.050	306	211	98	0.027	<0.1	–7.59	30.6
3S/11W-17F1	Norwalk1_1	0.47	23.0	19.6	—	—	241	395	174	0.12	<0.1	–15.65	6.8
3S/11W-17F2	Norwalk1_2	0.61	18.5	0.15	—	—	78.1	201	286	0.14	<0.1	–10.59	0.92
3S/11W-17F3	Norwalk1_3	0.28	18.1	13.6	—	—	356	81	620	0.13	<0.1	–17.41	14.4
3S/11W-17F4	Norwalk1_4	0.33	19.8	10.7	—	—	438	53	330	0.029	<0.1	–13.96	39.4
3S/11W-17F5	Norwalk1_5	0.35	23.4	2.66	—	—	722	84	1,345	0.089	0.1	–18.39	43.4
3S/11W-26E2	La Mirada1_1	0.79	16.1	92.8	0.080	<0.050	278	164	159	0.039	<0.1	–13.59	20.0
3S/11W-26E3	La Mirada1_2	0.59	15.7	52.9	0.070	<0.050	470	72	219	0.013	<0.1	–11.88	52.7

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
Pressure area—Continued													
3S/11W-26E4	La Mirada1_3	0.74	21.2	57.8	0.13	<0.050	270	155	102	0.027	<0.1	–12.77	22.1
3S/11W-26E5	La Mirada1_4	0.59	25.9	94.5	0.15	<0.050	525	144	188	0.044	<0.1	–12.	53.2
3S/11W-26E6	La Mirada1_5	0.52	26.1	105	<0.02	1.9	659	158	391	0.013	<0.1	—	—
3S/12W-6B4	South Gate1_1	0.30	23.5	58.8	0.090	<0.050	431	105	200	0.031	<0.1	–13.87	48.3
3S/12W-6B5	South Gate1_2	0.39	41.7	3.82	<0.02	2.4	559	481	380	0.36	16.5	–11.83	93.7
3S/12W-6B6	South Gate1_3	0.37	26.1	110	<0.02	2.6	683	123	407	0.003	24.8	—	—
3S/12W-6B7	South Gate1_4	0.36	23.5	125	<0.02	1.7	641	158	354	0.003	13.5	—	—
3S/12W-6B8	South Gate1_5	0.46	28.1	79.0	0.030	<0.050	564	132	256	0.082	<0.1	—	—
3S/12W-9J1	Downey1_1	0.39	20.2	16.2	<0.02	0.07	363	55	106	<0.001	0.7	–12.14	74.0
3S/12W-9J2	Downey1_2	0.36	20.4	73.8	<0.02	2.0	621	61	426	<0.001	6.0	–12.34	85.8
3S/12W-9J3	Downey1_3	0.41	21.6	133	<0.02	2.9	811	78	850	0.001	34.5	–11.18	123.5
3S/12W-9J4	Downey1_4	0.47	20.9	133	<0.02	2.7	603	179	414	0.014	19.9	—	—
3S/12W-9J5	Downey1_5	0.38	22.4	124	<0.02	<0.050	837	94	666	0.011	6.9	—	—
3S/12W-9J6	Downey1_6	0.36	24.5	259	<0.02	<0.050	788	204	460	0.005	18.2	—	—
3S/12W-15K1	St. John Bosco	0.34	24.9	279	<0.020	<0.060	856	232	500	0.013	8.6	–13.91	106.4
3S/12W-16H1	Park 40D	0.42	20.6	133	0.008	1.2	745	155	414	0.009	22	—	—
3S/12W-26K2	Cerritos2_1	0.29	20.1	18.9	<0.04	0.03	416	56	116	0.002	<0.1	–12.29	75.6
3S/12W-26K3	Cerritos2_2	0.35	20.2	117	<0.04	2.9	682	94	677	0.002	16.0	–11.79	143.9
3S/12W-26K4	Cerritos2_3	0.32	20.2	17.7	0.040	<0.050	365	63	107	0.005	<0.1	–12.38	64.8
3S/12W-26K5	Cerritos2_4	0.43	22.0	17.6	0.060	<0.050	344	77	99	0.005	<0.1	–12.44	78.1
3S/12W-26K6	Cerritos2_5	0.34	21.6	17.0	0.090	<0.050	390	72	100	0.005	<0.1	–12.42	73.0
3S/12W-26K7	Cerritos2_6	0.36	23.8	156	<0.04	<0.050	917	87	680	0.015	3.2	—	—
3S/12W-33B1	BSMWC_615	0.48	22.6	73.2	0.012	0.58	595	75	412	0.002	6.6	–12.34	93.4
3S/13W-8J1	Willowbrook1_1	0.34	26.0	0.70	2.	<0.032	279	166	105	0.025	<0.1	–11.41	15.9
3S/13W-8J2	Willowbrook1_2	0.37	22.4	70.8	0.29	<0.035	448	113	182	0.028	<0.1	–13.54	67.8
3S/13W-8J3	Willowbrook1_3	0.47	21.7	70.7	0.080	<0.036	442	118	172	0.028	<0.1	–12.97	71.5
3S/13W-8J4	Willowbrook1_4	0.46	20.3	76.2	0.10	<0.031	458	129	192	0.034	0.1	—	—
3S/13W-11G1	Lynwood1_1	0.55	22.4	3.17	1.69	<0.040	139	1,380	9	0.023	<0.1	–5.26	0.49

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
Pressure area—Continued													
3S/13W-11G2	Lynwood1_2	0.47	17.2	49.1	0.23	<0.040	17.6	180	126	0.030	<0.1	–14.52	13.3
3S/13W-11G3	Lynwood1_8	0.43	22.2	112	<0.01	1.7	616	131	371	0.002	4.6	–13.39	98.8
3S/13W-11G4	Lynwood1_3	0.32	15.8	78.4	0.27	<0.040	135	101	216	0.025	<0.1	–13.95	55.2
3S/13W-11G5	Lynwood1_4	0.29	20.2	82.9	0.19	<0.040	529	90	248	0.027	<0.1	–13.26	41.1
3S/13W-11G6	Lynwood1_5	0.30	17.4	52.0	0.16	<0.037	454	91	246	0.031	<0.1	–13.66	52.4
3S/13W-11G7	Lynwood1_6	0.41	23.1	73.4	0.19	<0.040	378	124	173	0.027	<0.1	–13.38	61.9
3S/13W-11G8	Lynwood1_7	0.37	22.1	75.0	0.080	<0.039	441	120	187	0.027	<0.1	–13.47	62.6
3S/13W-11G9	Lynwood1_9	0.29	21.9	304	0.20	<0.040	1,660	165	879	0.23	0.3	–14.15	84.2
3S/13W-22M2	Compton2_1	0.45	25.6	0.74	2.24	<0.038	144	680	22	0.018	<0.1	–4.28	0.13
3S/13W-22M3	Compton2_2	0.30	24.4	0.43	1.41	<0.040	307	193	74	0.019	<0.1	–5.38	3.8
3S/13W-22M4	Compton2_3	0.24	24.8	55.1	0.58	<0.040	357	109	177	0.028	<0.1	–13.48	46.4
3S/13W-22M5	Compton2_4	0.25	25.8	73.7	0.48	<0.040	520	121	218	0.030	0.2	–13.41	72.5
3S/13W-22M6	Compton2_5	0.33	23.6	80.4	0.28	<0.040	520	127	266	0.037	0.1	—	—
3S/13W-22M7	Compton2_6	0.41	24.1	95.4	0.017	0.29	628	160	408	0.003	0.4	—	—
3S/13W-24K2	Compton1_1	0.36	18.1	2.55	—	—	59.9	144	102	0.035	<0.1	–17.85	9.6
3S/13W-24K3	Compton1_2	0.37	20.5	59.0	—	—	236	101	227	0.037	<0.1	–14.35	29.1
3S/13W-24K4	Compton1_3	0.32	26.2	57.2	—	—	426	112	221	0.060	<0.1	–3.50	44.4
3S/13W-24K5	Compton1_4	0.31	22.5	71.2	—	—	574	91	242	0.038	<0.1	—	—
3S/13W-24K6	Compton1_5	0.41	23.6	64.3	—	—	536	127	161	0.036	0.1	—	—
4S/11W-5P9	Cerritos1_1	0.27	16.5	48.8	0.32	<0.050	401	98	155	0.013	<0.1	–12.21	56.2
4S/11W-5P10	Cerritos1_2	0.34	21.4	40.4	0.11	<0.050	150	110	124	0.020	<0.1	–11.73	46.0
4S/11W-5P11	Cerritos1_3	0.35	23.3	57.7	0.25	<0.050	537	88	224	0.034	<0.1	–12.19	33.9
4S/11W-5P12	Cerritos1_4	0.54	23.5	37.2	0.11	<0.050	409	95	132	0.019	<0.1	–12.40	57.0
4S/11W-5P13	Cerritos1_5	0.47	26.1	29.1	0.18	<0.050	393	98	110	0.023	<0.1	–12.88	58.7
4S/11W-5P14	Cerritos1_6	0.31	29.5	24.2	0.29	<0.050	467	86	131	0.067	<0.1	—	—
4S/12W-5H5	Lakewood1_1	0.50	16.9	15.4	0.37	<0.050	139	61	315	0.050	<0.1	–12.46	7.6
4S/12W-5H6	Lakewood1_2	0.44	23.4	15.9	0.090	<0.050	247	63	275	0.050	0.3	–12.50	54.2
4S/12W-5H7	Lakewood1_3	0.32	24.8	15.0	0.20	<0.050	339	64	143	0.019	<0.1	–12.93	61.4

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
Pressure area—Continued													
4S/12W-5H8	Lakewood1_4	0.35	23.1	15.2	0.28	<0.050	617	72	379	0.043	0.5	–13.67	59.1
4S/12W-5H9	Lakewood1_5	0.52	24.7	15.2	0.080	<0.050	385	90	109	0.017	<0.1	–12.49	71.7
4S/12W-5H10	Lakewood1_6	0.19	23.6	42.2	0.43	<0.050	1,330	94	2,213	0.10	2.0	—	—
4S/12W-12F1	Lakewood2_1	0.45	13.6	50.6	0.18	<0.040	123	61	218	0.036	<0.1	–12.54	23.0
4S/12W-12F2	Lakewood2_2	0.35	19.9	13.6	0.16	<0.040	204	55	104	0.015	<0.1	–12.60	45.3
4S/12W-12F3	Lakewood2_3	0.29	19.3	11.1	0.32	<0.036	257	46	130	0.023	0.1	–13.35	34.9
4S/12W-12F4	Lakewood2_4	0.44	20.3	42.4	<0.010	0.50	449	71	186	0.001	0.5	–11.31	86.6
4S/12W-12F5	Lakewood2_5	0.32	24.3	16.8	0.14	<0.040	378	63	98	0.008	<0.1	–12.73	61.7
4S/12W-12F6	Lakewood2_6	0.39	22.2	11.2	0.19	<0.038	266	64	90	0.011	<0.1	–12.30	66.6
4S/12W-12F7	Lakewood2_7	0.24	22.6	14.9	0.26	<0.040	501	65	89	0.015	<0.1	–12.78	64.1
4S/12W-12F8	Lakewood2_8	0.39	24.6	6.88	0.23	<0.040	360	78	86	0.035	<0.1	–13.10	69.7
4S/12W-21M8	Long Beach6_1	0.55	20.7	2.72	1.71	<0.044	81.4	1,130	17	0.061	<0.1	–5.21	1.8
4S/12W-21M9	Long Beach6_2	0.61	19.0	1.52	0.49	<0.045	48.1	338	57	0.028	<0.1	–10.59	9.8
4S/12W-21M10	Long Beach6_3	0.57	17.8	1.17	0.21	<0.050	34.5	242	69	0.019	<0.1	–15.86	22.5
4S/12W-21M11	Long Beach6_4	0.67	17.2	9.81	0.22	<0.050	49.9	133	116	0.015	<0.1	—	—
4S/12W-21M12	Long Beach6_5	0.54	17.0	11.4	0.31	<0.050	78.4	86	205	0.030	<0.1	—	—
4S/12W-21M13	Long Beach6_6	0.23	22.7	16.8	0.28	<0.050	274	50	658	0.067	<0.1	–13.14	44.4
4S/12W-23K3	LB Annex 201	0.62	16.1	27.2	0.23	<0.060	28.5	70	171	0.010	<0.1	–13.64	28.1
4S/12W-25G1	Long Beach1_1	0.72	20.5	1.59	0.60	<0.050	23.6	186	82	0.019	<0.1	–15.30	30.5
4S/12W-25G2	Long Beach1_2	0.73	20.2	0.31	0.34	<0.050	26.8	197	76	0.019	<0.1	–15.24	30.1
4S/12W-25G3	Long Beach1_3	0.66	19.8	15.2	0.17	<0.050	25.3	88	141	0.009	<0.1	–14.90	23.7
4S/12W-25G4	Long Beach1_4	0.39	18.8	32.9	0.27	<0.050	191	64	192	0.006	0.1	–12.24	52.9
4S/12W-25G5	Long Beach1_5	0.21	22.0	282	0.68	<0.050	2,660	87	7,437	0.031	26.0	–12.47	61.4
4S/12W-25G6	Long Beach1_6	0.33	24.7	214	0.39	<0.050	1,390	90	1,467	0.046	0.3	—	—
4S/13W-1N3	Long Beach2_1	0.69	22.6	0.27	1.41	<0.040	66.8	546	38	0.018	<0.1	–8.31	1.3
4S/13W-1N4	Long Beach2_2	0.38	23.6	2.22	0.74	<0.047	129	200	99	0.027	<0.1	–10.68	4.3
4S/13W-1N5	Long Beach2_3	0.58	21.2	27.2	0.38	<0.050	74.3	141	158	0.036	<0.1	–16.68	22.3
4S/13W-1N6	Long Beach2_4	0.37	23.8	46.3	0.20	<0.050	318	96	300	0.043	<0.1	–15.75	40.8

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
Pressure area—Continued													
4S/13W-1N7	Long Beach2_5	0.18	27.4	257	0.22	<0.050	1,120	254	382	0.035	5.1	—	—
4S/13W-1N8	Long Beach2_6	0.32	28.1	430	0.36	<0.050	1,600	332	461	0.038	3.6	—	—
Orange County Basin													
3S/8W-34G2	Canyon_RV_1_ EAST	0.50	21.0	166	0.006	2.0	648	261	368	0.022	6.9	–14.27	98.8
4S/10W-14H3	Anaheim_46	0.49	21.4	133	<0.010	4.1	669	184	497	0.010	4.3	–12.31	105.0
5S/12W-1C1	512B	0.24	14.6	152	0.16	<0.020	578	128	583	0.016	4.4	–7.94	83.9
5S/12W-1C2	512C	0.22	14.6	118	0.091	<0.020	565	127	546	0.021	3.6	–8.42	88.2
5S/12W-1C3	Seal Beach1_1	0.44	17.3	0.25	0.23	<0.014	50.7	218	84	0.012	<0.1	–9.72	4.1
5S/12W-1C4	Seal Beach1_2	0.52	17.3	0.67	0.22	<0.017	27.7	131	126	0.011	<0.1	–14.93	23.6
5S/12W-1C5	Seal Beach1_3	0.59	16.9	0.39	0.20	<0.017	28.6	192	80	0.012	<0.1	–15.38	26.7
5S/12W-1C6	Seal Beach1_4	0.80	19.0	1.02	0.12	<0.015	43.1	228	84	0.012	0.2	–11.22	8.0
5S/12W-1C7	Seal Beach1_5	0.62	14.4	30.7	0.091	<0.040	67.5	81	184	0.022	0.4	–13.58	38.7
5S/12W-1C8	Seal Beach1_6	0.35	17.1	155	0.17	<0.020	662	127	678	0.020	5.1	–7.38	83.7
5S/12W-1C9	Seal Beach1_7	0.40	19.8	164	0.35	<0.020	2,210	144	5,306	0.15	1.3	–13.29	69.3
West Coast Basin													
2S/14W-18J1	Holy_Cross_AA	0.26	39.2	561	2.07	<0.060	1,950	1,260	508	1.12	5.1	—	—
2S/14W-19G1	Hillside_Park_1	0.36	37.2	54.2	2.93	<0.060	482	492	215	0.20	<0.1	–13.50	35.7
2S/14W-28M3	Inglewood1_1	0.38	34.5	3.57	25.8	<0.035	652	10,700	151	12.8	<0.1	–0.50	2.2
2S/14W-28M4	Inglewood1_2	0.18	25.8	215	0.35	0.11	1,250	414	964	0.12	1.3	–17.42	61.7
2S/14W-28M5	Inglewood1_3	0.57	43.2	116	0.69	<0.050	654	391	583	0.47	<0.1	–13.62	53.5
2S/14W-28M6	Inglewood1_4	0.44	34.2	79.2	1.34	<0.050	518	192	885	0.091	0.3	—	—
2S/14W-28M7	Inglewood1_5	0.27	34.4	101	0.050	8.1	1,110	217	1,382	0.033	1.6	—	—
2S/15W-35A1	Westchester1_1	0.30	39.7	1.22	4.15	<0.036	249	2,330	55	0.16	<0.1	–6.36	2.2
2S/15W-35A2	Westchester1_2	0.32	36.4	2.72	3.01	<0.050	305	949	76	0.15	<0.1	–12.27	6.4
2S/15W-35A3	Westchester1_3	0.34	39.0	13.2	1.79	<0.050	406	481	137	0.13	0.2	—	—
2S/15W-35A4	Westchester1_4	0.29	38.0	75.8	0.90	<0.050	575	234	271	0.10	<0.1	–17.41	30.2
2S/15W-35A5	Westchester1_5	0.26	33.3	79.0	0.58	<0.050	506	234	285	0.10	<0.1	—	—
3S/14W-4R1	Inglewood3_1	0.48	39.0	14.6	11.3	<0.040	318	3,370	309	2.42	0.2	–5.07	2.2

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
West Coast Basin—Continued													
3S/14W-4R2	Inglewood3_2	0.51	40.5	4.03	9.06	<0.040	162	4,680	12	0.34	<0.1	2.91	0.48
3S/14W-4R3	Inglewood3_3	0.28	42.5	9.57	3.70	<0.040	75.8	1,040	17	0.006	<0.1	–0.41	3.1
3S/14W-4R4	Inglewood3_4	0.23	42.3	7.45	5.70	<0.040	200	2,020	14	0.009	0.2	–5.52	1.3
3S/14W-4R5	Inglewood3_5	0.17	42.4	0.49	1.60	<0.040	735	326	303	0.19	<0.1	–18.78	24.1
3S/14W-4R6	Inglewood3_6	0.33	33.5	11.1	0.93	<0.040	526	112	1,214	0.040	0.3	–20.13	45.7
3S/14W-4R7	Inglewood3_7	0.36	28.8	37.6	0.37	<0.040	1,210	98	3,878	0.084	1.0	–28.33	35.1
3S/14W-13J5	Gardena1_1	0.30	40.0	1.30	5.60	0.08	160	355	48	0.029	0.3	–2.94	8.7
3S/14W-13J6	Gardena1_2	0.50	30.0	56.0	0.14	0.07	440	132	159	0.026	0.3	–14.47	65.4
3S/14W-13J7	Gardena1_3	0.40	26.0	66.0	0.30	0.10	470	117	188	0.028	0.1	—	—
3S/14W-13J8	Gardena1_4	0.30	29.0	53.0	0.090	2.0	1,200	117	3,162	0.009	1.0	—	—
3S/14W-17G3	Hawthorne1_1	0.16	46.1	<0.10	5.63	<0.050	248	1,380	35	0.026	<0.1	–13.47	2.8
3S/14W-17G4	Hawthorne1_2	0.27	28.7	0.65	2.54	<0.050	153	1,020	42	0.040	<0.1	–11.37	7.6
3S/14W-17G5	Hawthorne1_3	0.24	34.4	1.08	2.40	<0.050	415	486	103	0.077	<0.1	–15.89	9.6
3S/14W-17G6	Hawthorne1_4	0.39	37.4	0.65	2.	<0.050	420	396	133	0.063	<0.1	–16.54	15.6
3S/14W-17G7	Hawthorne1_5	0.34	32.7	18.8	0.74	<0.050	808	142	1,317	0.046	1.0	—	—
3S/14W-17G8	Hawthorne1_6	0.23	19.7	602	0.13	0.64	2,780	262	2,202	0.21	17.6	—	—
3S/14W-25K7	Gardena2_1	0.29	20.4	0.25	—	—	221	311	44	0.025	<0.1	11.55	4.6
3S/14W-25K8	Gardena2_2	0.32	28.6	53.0	—	—	377	165	134	0.026	<0.1	–14.56	53.9
3S/14W-25K9	Gardena2_3	0.41	31.1	51.5	—	—	429	127	178	0.026	<0.1	–14.30	58.3
3S/14W-25K10	Gardena2_4	0.34	25.8	<0.18	—	—	417	93	227	0.025	<0.1	–10.30	38.5
3S/14W-25K11	Gardena2_5	0.37	27.8	19.5	—	—	490	122	293	0.028	0.1	–16.72	64.3
3S/14W-27C2	Lawndale1_1	0.46	26.8	2.34	4.22	<0.040	122	796	22	0.068	0.4	6.56	1.0
3S/14W-27C3	Lawndale1_2	0.34	28.0	0.41	2.81	<0.040	62.7	1,070	31	0.035	<0.1	–12.27	3.5
3S/14W-27C4	Lawndale1_3	0.33	23.8	9.84	0.92	<0.040	201	180	149	0.039	<0.1	–19.	18.6
3S/14W-27C5	Lawndale1_4	0.39	26.7	50.2	0.45	<0.040	443	107	545	0.030	0.2	–16.37	48.7
3S/14W-27C6	Lawndale1_5	0.45	22.9	60.3	0.40	<0.040	562	91	613	0.028	0.2	–15.22	47.4
3S/14W-27C7	Lawndale1_6	0.26	23.4	150	0.070	3.0	1,550	320	1,700	0.026	1.2	–17.58	64.6
3S/14W-30L2	Manhattan Beach1_1	0.51	27.2	<0.45	20.7	<0.039	1,170	14,200	277	6.72	<0.1	–3.22	0.24

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
West Coast Basin—Continued													
3S/14W-30L3	Manhattan Beach1_2	0.62	29.8	1.50	13.5	<0.040	422	6,500	203	2.63	<0.1	3.60	0.52
3S/14W-30L4	Manhattan Beach1_3	0.38	43.7	4.16	16.3	<0.037	244	3,560	35	0.70	<0.1	4.29	0.36
3S/14W-30L5	Manhattan Beach1_4	0.22	26.3	<0.45	1.33	<0.040	295	401	91	0.11	0.2	–11.85	3.5
3S/14W-30L6	Manhattan Beach1_5	<1.00	28.0	1,410	12.5	<0.038	20,000	570	21,228	0.26	<0.1	–18.14	8.2
3S/14W-30L7	Manhattan Beach1_6	<1.00	30.7	504	1.15	<0.039	9,760	122	32,869	0.044	0.2	–17.24	37.2
3S/14W-30L8	Manhattan Beach1_7	0.33	22.5	188	0.12	4.9	454	177	785	0.062	7.5	–12.98	76.2
3S/14W-33R5	Torrance1_1	0.68	43.4	4.95	7.97	<0.032	166	2,470	39	0.59	<0.1	2.34	0.34
3S/14W-33R6	Torrance1_2	0.43	32.4	3.40	3.09	<0.022	101	1,940	9	—	<0.1	–5.01	0.21
3S/14W-33R7	Torrance1_3	0.35	15.9	1.49	1.30	<0.038	151	375	78	0.099	<0.1	–9.41	3.3
3S/14W-33R8	Torrance1_4	0.37	23.0	3.56	0.58	<0.039	285	186	161	0.065	<0.1	–17.56	7.8
3S/14W-33R9	Torrance1_5	0.18	28.6	305	1.07	<0.039	3,940	204	7,647	0.076	16.1	—	—
3S/14W-33R10	Torrance1_6	0.36	27.7	182	0.46	<0.038	991	196	934	0.091	10.9	—	—
4S/12W-30J1	Long Beach8_1	0.89	22.1	0.48	1.45	<0.040	81.2	395	60	0.061	<0.1	—	—
4S/12W-30J2	Long Beach8_2	1.05	26.5	1.66	—	—	106	248	145	0.11	<0.1	–0.45	1.7
4S/12W-30J3	Long Beach8_3	0.78	26.3	1.69	—	—	173	417	213	0.11	<0.1	2.12	1.0
4S/12W-30J4	Long Beach8_4	0.30	20.1	<0.90	—	—	789	1,070	547	1.38	<0.1	1.42	0.98
4S/12W-30J5	Long Beach8_5	0.24	22.4	0.81	1.65	<0.040	710	185	2,265	0.95	<0.1	1.05	1.0
4S/12W-30J6	Long Beach8_6	0.60	27.8	16.9	—	—	660	210	1,990	0.083	<0.1	–19.89	28.4
4S/13W-5F1	Carson3_1	0.63	38.7	2.04	1.56	<0.040	52.2	612	22	0.12	<0.1	–0.99	0.70
4S/13W-5F2	Carson3_2	0.30	18.1	14.3	1.02	<0.040	239	101	199	0.034	<0.1	–15.75	37.0
4S/13W-5F3	Carson3_3	0.39	20.9	3.51	0.89	<0.040	170	103	206	0.030	<0.1	–15.27	28.7
4S/13W-5F4	Carson3_4	0.32	20.1	1.97	0.58	<0.040	257	90	229	0.029	<0.1	–9.59	31.6
4S/13W-5F5	Carson3_5	0.29	24.3	<0.09	0.35	<0.040	393	110	187	0.030	<0.1	–13.29	45.0
4S/13W-5F6	Carson3_6	0.43	24.9	52.2	0.071	<0.040	417	126	167	0.032	0.3	–14.70	68.0
4S/13W-9H9	Carson1_1	0.33	18.8	0.34	0.52	<0.025	185	96	209	0.028	0.1	–12.36	27.6
4S/13W-9H10	Carson1_2	0.26	21.6	0.12	0.37	<0.033	369	102	201	0.027	<0.1	–12.34	43.6
4S/13W-9H11	Carson1_3	0.35	22.9	60.7	0.23	<0.033	398	105	215	0.032	<0.1	–14.22	56.1
4S/13W-9H12	Carson1_4	0.47	21.5	108	0.23	<0.032	835	117	957	0.051	0.1	—	—

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
West Coast Basin—Continued													
4S/13W-18K1	Carson2_1	0.35	16.6	2.78	0.58	<0.050	40.1	131	150	0.031	<0.1	–9.65	18.4
4S/13W-18K2	Carson2_2	0.23	17.3	8.16	0.57	<0.050	146	132	161	0.028	<0.1	–17.43	37.2
4S/13W-18K3	Carson2_3	0.30	22.9	6.35	0.56	<0.050	252	117	182	0.029	<0.1	–17.12	43.6
4S/13W-18K4	Carson2_4	0.29	24.5	0.81	0.56	<0.050	401	115	185	0.033	<0.1	—	—
4S/13W-18K5	Carson2_5	0.36	25.1	13.9	0.18	<0.050	392	113	188	0.029	<0.1	–17.03	53.8
4S/13W-23D3	Long Beach3_1	0.51	20.2	1.04	2.47	<0.047	120	372	50	0.032	<0.1	6.28	1.8
4S/13W-23D4	Long Beach3_2	0.38	22.6	25.3	0.32	<0.047	191	138	136	0.030	0.1	–15.84	24.1
4S/13W-23D5	Long Beach3_3	0.38	23.8	0.17	0.36	<0.047	226	132	188	0.047	<0.1	–18.92	14.1
4S/13W-23D6	Long Beach3_4	0.30	28.6	57.9	0.41	<0.047	962	109	1,954	0.59	<0.1	–14.33	42.8
4S/13W-23D7	Long Beach3_5	0.21	23.7	62.7	0.56	<0.047	2,530	110	5,627	1.66	<0.1	–13.85	55.1
4S/13W-23N3	889P	0.32	23.3	0.16	—	—	310	312	343	0.22	—	—	—
4S/13W-26F5	380P	0.53	21.3	<0.10	—	—	142	203	182	0.072	<0.1	—	—
4S/13W-27H4	Long Beach7_1	0.63	35.6	2.98	2.84	<0.052	77.2	785	29	0.15	<0.1	4.20	3.5
4S/13W-27H5	Long Beach7_2	0.42	20.6	1.16	0.31	<0.060	171	238	313	0.16	0.1	–14.42	8.8
4S/13W-27H6	Long Beach7_3	0.47	20.2	4.	0.29	<0.060	185	223	303	0.12	<0.1	–14.93	9.8
4S/13W-27H7	Long Beach7_4	<0.17	23.6	278	2.25	<0.060	4,860	419	5,012	1.22	1.8	–15.94	61.4
4S/13W-28A3	Wilmington1_1	0.18	21.8	<0.10	0.62	0.09	371	123	1,732	0.87	<0.1	–15.82	29.6
4S/13W-28A4	Wilmington1_2	0.11	21.3	58.6	0.76	0.08	1,150	175	1,926	0.15	<0.1	–18.36	44.5
4S/13W-28A5	Wilmington1_3	<0.10	24.0	49.5	1.59	0.09	2,130	240	3,779	0.39	1.6	—	—
4S/13W-28A6	Wilmington1_4	<0.10	26.1	288	2.24	0.12	3,690	221	5,475	0.79	18.9	—	—
4S/13W-28A7	Wilmington1_5	0.13	26.2	140	0.88	0.08	1,090	203	1,148	0.17	11.8	—	—
4S/13W-29H5	340L	—	—	98.0	—	—	2,200	1,400	929	—	3.1	—	—
4S/13W-29H6	340M	—	—	150	—	—	2,000	470	1,213	—	1.0	—	—
4S/13W-29H7	340N	—	—	18.0	—	—	600	130	1,077	—	0.1	—	—
4S/13W-31J1	321A	0.23	23.8	<0.10			2,240	853	2,474	0.45	<0.1	—	—
4S/13W-32F1	Wilmington2_1	1.	24.2	<0.10	1.57	0.07	39.1	653	87	0.033	<0.1	–0.27	2.5
4S/13W-32F2	Wilmington2_2	0.38	20.3	<0.10	2.31	0.09	360	1,350	380	1.07	<0.1	–0.32	5.2
4S/13W-32F3	Wilmington2_3	0.33	20.8	<0.10	0.96	0.08	177	266	272	0.14	<0.1	–15.04	14.4

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
West Coast Basin—Continued													
4S/13W-32F4	Wilmington2_4	0.24	29.0	29.4	4.29	0.09	1,270	557	1,813	0.32	1.4	—	—
4S/13W-32F5	Wilmington2_5	0.11	24.3	595	2.48	0.09	5,990	621	8,422	0.10	16.8	—	—
4S/13W-34A1	371D	0.33	14.5	<0.10	—	—	53.2	149	281	0.099	<0.1	—	—
4S/13W-34M1	361H	0.41	20.5	<0.10	—	—	129	251	284	0.18	<0.1	—	—
4S/13W-35B2	381J	0.62	16.3	0.52	—	—	184	1,320	57	0.022	0.1	—	—
4S/13W-35B3	381K	<0.10	19.3	259	—	—	3,760	370	8,243	0.31	<0.1	—	—
4S/14W-2N1	PM-3 Madrid_1	0.40	19.0	17.0	—	—	—	360	78	0.029	0.8	–13.18	9.8
4S/14W-2N2	PM-3 Madrid_2	0.40	27.0	3.30	—	—	—	120	292	0.040	<0.1	–17.27	38.5
4S/14W-2N3	PM-3 Madrid_3	0.40	29.0	13.0	—	—	—	130	1,385	0.22	0.9	–19.73	37.8
4S/14W-2N4	PM-3 Madrid_4	0.40	23.0	31.0	—	—	—	230	913	0.24	4.3	–19.29	39.7
4S/14W-4Q1	PM-4 Mariner_1	0.35	—	<2.0	—	<0.20	—	150	175	—	—	—	—
4S/14W-4Q2	PM-4 Mariner_2	0.11	—	830	—	<0.20	—	240	27,083	0.086	—	—	—
4S/14W-4Q3	PM-4 Mariner_3	0.43	—	190	—	<0.20	—	250	462	0.023	—	—	—
4S/14W-4Q4	PM-4 Mariner_4	0.27	—	140	—	<0.20	—	230	500	0.067	—	—	—
4S/14W-10C1	PM-1 Columbia_1	0.34	—	<2.0	—	<0.20	—	130	169	0.057	—	—	—
4S/14W-10C2	PM-1 Columbia_2	0.16	—	110	—	<0.20	—	270	3,259	0.11	—	—	—
4S/14W-15E1	Torrance2_1	0.57	28.6	10.0	3.20	<0.015	1,540	777	865	0.15	0.1	–1.73	0.60
4S/14W-15E2	Torrance2_2	0.11	31.2	<0.90	6.94	<0.020	2,170	539	4,712	0.59	<0.1	–9.56	1.4
4S/14W-15E3	Torrance2_3	0.06	29.5	76.8	7.89	<0.020	16,900	281	23,381	0.27	<0.1	–23.78	1.5
4S/14W-15E4	Torrance2_4	0.58	41.7	<0.09	0.41	<0.020	228	252	198	0.072	<0.1	–10.46	12.5
4S/14W-15E5	Torrance2_5	0.19	34.6	240	0.48	<0.019	4,110	209	8,230	0.18	24.8	–19.32	30.8
4S/14W-15E6	Torrance2_6	0.28	32.4	132	0.17	<0.020	912	173	1,653	0.15	9.8	–17.	66.9
4S/14W-26A2	Lomita1_1	0.12	30.2	72.8	0.40	<0.040	730	877	661	1.57	<0.1	–17.47	25.7
4S/14W-26A3	Lomita1_2	0.18	30.9	26.9	0.34	<0.040	546	480	710	1.27	<0.1	–16.51	25.8
4S/14W-26A4	Lomita1_3	0.18	28.9	13.5	—	—	448	376	620	0.70	0.3	—	—
4S/14W-26A5	Lomita1_4	0.23	30.7	13.9	0.28	<0.040	400	415	595	0.68	<0.1	–7.79	9.4
4S/14W-26A6	Lomita1_5	0.12	32.8	26.1	—	—	748	674	755	1.63	0.2	—	—
4S/14W-35D10	Chandler3_1	0.24	—	30.0	—	<0.20	—	200	800	0.094	—	—	—

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	Fluoride, filtered (mg/L)	Silica, filtered (mg/L as SiO_2)	Sulfate, filtered (mg/L)	Ammonia, filtered (mg/L as nitrogen)	Nitrate, filtered (mg/L as nitrogen)	Strontium, filtered (ug/L)	Boron, filtered (ug/L)	Chloride / Boron ratio (mg/mg)	Iodide, filtered (mg/L)	Tritium, unfiltered (tritium units)	δ^{13}Carbon, filtered (per mil)	Carbon-14, filtered (percent modern)
West Coast Basin—Continued													
4S/14W-35D11	Chandler3_2	0.20	—	100	—	13.0	—	360	462	<0.001	—	—	—
5S/13W-2E1	Long Beach4_1	1.14	28.1	3.62	2.38	<0.044	134	1,100	19	0.11	0.2	3.08	2.5
5S/13W-2E2	Long Beach4_2	0.50	35.3	1.36	2.83	<0.044	97.5	1,150	293	0.98	<0.1	–12.72	4.3
5S/13W-11P1	Long Beach5_1	0.40	40.7	0.66	10.5	<0.044	734	8,400	196	1.40	<0.1	–6.37	0.79
5S/13W-11P2	Long Beach5_2	0.44	14.5	2,640	7.86	<0.050	8,500	4,130	4,818	0.16	<0.1	–12.33	48.5
Santa Monica Basin													
1S/15W-31E1	SM 1 (2505)	0.36	27.5	215	0.012	4.2	557	149	685	0.002	4.3	–16.12	93.9
1S/15W-33A1	SM Arcadia_5	0.34	35.0	188	0.036	2.9	514	127	874	0.018	3.7	–15.65	89.0
2S/15W-4C2	SM 3 (2646K)	0.38	32.0	237	<0.020	6.5	592	105	800	0.005	2.7	–15.88	78.5
Hollywood Basin													
1S/14W-18L1	BH_2	1.50	37.6	7.05	1.10	<0.060	284	1,190	185	0.23	0.1	–10.	20.9
1S/15W-24B1	BH_5	0.53	40.0	121	0.29	<0.060	432	239	154	0.037	<0.1	–15.45	41.2
San Fernando Valley													
1N013W-35P1	DS_WATERS	0.57	37.6	233	<0.020	7.1	708	71	1,479	0.005	6.8	–16.41	88.7
San Gabriel Valley													
2S/11W-5P6	Whittier Narrows1_1	0.78	—	<2.0	—	<0.20	—	1,100	650	1.30	—	—	—
2S/11W-5P7	Whittier Narrows1_2	0.41	—	12.0	—	<0.20	—	150	188	0.039	—	—	—
2S/11W-5P8	Whittier Narrows1_3	0.25	—	110	—	1.3	—	70	943	<0.001	—	—	—
2S/11W-5P9	Whittier Narrows1_4	0.26	—	120	—	1.5	—	110	989	0.007	—	—	—
2S/11W-5P10	Whittier Narrows1_5	0.30	—	50.0	—	0.83	—	54	730	<0.001	—	—	—
2S/11W-5P11	Whittier Narrows1_6	0.27	—	130	—	2.1	—	240	417	0.012	—	—	—
2S/11W-5P12	Whittier Narrows1_7	0.28	—	140	—	2.8	—	260	358	0.008	—	—	—
2S/11W-5P13	Whittier Narrows1_8	0.29	—	120	—	4.2	—	250	429	0.009	—	—	—
2S/11W-5P14	Whittier Narrows1_9	0.39	—	140	—	2.3	—	240	400	0.011	—	—	—

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
Central Basin									
Los Angeles Forebay									
2S/13W-3P2	Los Angeles2_1	—	—	—	—	Highly saline	n.a.	*	n.a.
2S/13W-3P3	Los Angeles2_2	–46.8	–6.94	—	Ca/Na-mixed	Slightly saline	n.a.	n.a.	Los Angeles (slightly saline)
2S/13W-3P4	Los Angeles2_3	–46.2	–6.88	—	Ca/Na-mixed	Slightly saline	n.a.	n.a.	Los Angeles (slightly saline)
2S/13W-3P5	Los Angeles2_4	–46.5	–6.83	—	Ca/Na-mixed	Slightly saline	n.a.	n.a.	Los Angeles (slightly saline)
2S/13W-3P6	Los Angeles2_5	–46.5	–6.83	—	Ca/Na-SO_4/HCO_3	Slightly saline	n.a.	non-marine	Los Angeles (slightly saline)
2S/13W-17F1	Los Angeles1_1	–49.0	–7.29	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
2S/13W-17F2	Los Angeles1_2	–46.6	–7.32	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
2S/13W-17F3	Los Angeles1_3	–47.8	–7.24	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
2S/13W-17F4	Los Angeles1_4	–47.2	–7.19	—	Ca-HCO_3/SO_4	Fresh	n.a.	shallow marine	Los Angeles
2S/13W-17F5	Los Angeles1_5	–47.6	–7.24	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Los Angeles
2S/13W-22C1	Huntington Park1_1	–47.5	–7.32	0.7085	Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-22C2	Huntington Park1_2	–47.3	–7.23	0.7085	Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-22C3	Huntington Park1_3	–48.7	–7.09	0.7085	Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-22C4	Huntington Park1_4	–44.2	–6.78	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Mixed
2S/13W-34F2	South Gate2_1	–47.1	–7.44	0.7083	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-34F3	South Gate2_2	–47.2	–7.38	0.7083	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-34F4	South Gate2_3	–47.6	–7.32	0.7084	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-34F5	South Gate2_4	–46.6	–7.15	0.7085	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-34F6	South Gate2_5	–47.7	–7.26	0.7083	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-34F7	South Gate2_6	–47.1	–7.15	0.7085	Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/14W-12E1	Los Angeles3_1	–49.8	–7.58	0.7084	Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/14W-12E2	Los Angeles3_2	–47.3	–7.33	0.7082	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/14W-12E3	Los Angeles3_3	–48.4	–7.38	0.7084	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/14W-12E4	Los Angeles3_4	–47.3	–7.25	0.7084	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/14W-12E5	Los Angeles3_5	–56.2	–7.99	0.7084	Ca/Na-HCO_3/SO_4	Fresh	LAR	non-marine	Los Angeles/artificial
2S/14W-12E6	Los Angeles3_6	–51.9	–7.56	0.7085	Ca/Na-HCO_3/Cl	Fresh	LAR	non-marine	Los Angeles/artificial

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
				Montebello Forebay					
2S/11W-5N4	Whittier_14	–57.6	–7.97	0.7102	Ca/Na-mixed	Fresh	SGR	non-marine	Montebello/spreading
2S/11W-7K2	Pico Rivera3_1	–57.4	–8.34	0.0071	Ca-HCO_3/SO_4	Fresh	SGR	non-marine	Montebello
2S/11W-7K3	Pico Rivera3_2	–56.5	–8.36	0.0071	Ca-HCO_3	Fresh	SGR	non-marine	Montebello
2S/11W-7K4	Pico Rivera3_3	–59.8	–8.29	0.7101	Ca-HCO_3/SO_4	Fresh	SGR	non-marine	Montebello/spreading
2S/11W-7K5	Pico Rivera3_4	–59.0	–8.02	0.7102	Na/Ca-mixed	Fresh	SGR	non-marine	Montebello/spreading
2S/11W-7K6	Pico Rivera4_1	–56.1	–8.26	0.7098	Ca-HCO_3/SO_4	Fresh	SGR	non-marine	Montebello
2S/11W-7K7	Pico Rivera4_2	–56.1	–8.56	0.7098	Ca/Na-HCO_3	Fresh	SGR	shallow marine	Montebello
2S/11W-7K8	Pico Rivera4_3	–57.9	–8.08	0.7101	Ca-HCO_3/SO_4	Fresh	SGR	non-marine	Montebello/spreading
2S/11W-7K9	Pico Rivera4_4	–60.2	–8.12	0.7103	Na/Ca-mixed	Fresh	SGR	non-marine	Montebello/spreading
2S/11W-8L8	Whittier Narrows2_1	–57.6	–8.60	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello
2S/11W-8L9	Whittier Narrows2_2	–57.5	–8.57	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello
2S/11W-8L10	Whittier Narrows2_3	–59.4	–8.67	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello
2S/11W-8L11	Whittier Narrows2_4	–58.9	–8.74	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello
2S/11W-8L12	Whittier Narrows2_5	–60.7	–8.87	—	Ca-HCO_3/SO_4	Fresh	n.a.	shallow marine	Montebello
2S/11W-8L13	Whittier Narrows2_6	–58.2	–8.78	—	Ca/Na-HCO_3	Fresh	n.a.	deep marine	Montebello
2S/11W-8L14	Whittier Narrows2_7	–58.2	–8.68	—	Ca/Na-HCO_3	Fresh	n.a.	deep marine	Montebello
2S/11W-8L15	Whittier Narrows2_8	–46.3	–6.69	—	Ca/Na-SO_4/HCO_3	Slightly saline	n.a.	n.a.	Local (slightly saline)
2S/11W-8L16	Whittier Narrows2_9	–46.0	–6.64	—	mixed-SO_4/HCO_3	Slightly saline	n.a.	n.a.	Local (slightly saline)
2S/11W-18C4	Pico Rivera1_1	–65.8	–9.56	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello paleowater
2S/11W-18C5	Pico Rivera1_2	–57.0	–8.47	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
2S/11W-18C6	Pico Rivera1_3	–59.0	–8.09	—	Ca-mixed	Fresh	n.a.	non-marine	Montebello/spreading

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
Montebello Forebay—Continued									
2S/11W-18C7	Pico Rivera1_4	–60.1	–8.23	—	Ca-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/11W-20N1	Whittier2_1	–55.2	–8.19	—	Na-Cl/HCO_3	Fresh	n.a.	n.a.	Montebello
2S/11W-20N2	Whittier2_2	–57.2	–8.71	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello
2S/11W-20N3	Whittier2_3	–56.4	–8.34	—	Na/Ca-mixed	Fresh	n.a.	non-marine	Montebello
2S/11W-20N4	Whittier2_4	–44.2	–6.55	—	Na-SO_4	Slightly saline	n.a.	n.a.	Local (slightly saline)
2S/11W-20N5	Whittier2_5	–59.5	–8.32	—	Ca-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/11W-20N6	Whittier2_6	–52.9	–7.61	—	Ca/Na-HCO_3/Cl	Slightly saline	n.a.	shallow marine	Montebello/spreading (slightly saline)
2S/12W-10Q5	Montebello1_1	–55.2	–8.29	0.7095	Na-Cl/HCO_3	Slightly saline	LAR, SGR	n.a.	Montebello paleowater (slightly saline)
2S/12W-10Q6	Montebello1_2	–63.3	–9.36	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello paleowater
2S/12W-10Q7	Montebello1_3	–62.2	–8.62	0.7097	Ca/Na-HCO_3/SO_4	Fresh	SGR	shallow marine	Montebello/spreading
2S/12W-10Q8	Montebello1_4	–63.1	–8.83	—	Ca-HCO_3	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-10Q9	Montebello1_5	–56.6	–7.74	—	Ca/Na-HCO_3/SO_4	Fresh	n.a.	shallow marine	Montebello/spreading
2S/12W-10Q10	Montebello1_6	—	—	—	Ca/Na-HCO_3/Cl	Fresh	n.a.	non-marine	n.a.
2S/12W-25G1	Pico Rivera W12	–57.0	–8.08	0.7103	Na/Ca-mixed	Fresh	SGR	non-marine	Montebello/spreading
2S/12W-25G3	Pico Rivera2_1	–53.6	–7.66	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-25G4	Pico Rivera2_2	–59.4	–8.32	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-25G5	Pico Rivera2_3	–63.3	–8.61	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-25G6	Pico Rivera2_4	–57.1	–8.08	—	Ca/Na-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-25G7	Pico Rivera2_5	–54.8	–7.62	—	Na/Ca-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-25G8	Pico Rivera2_6	–50.1	–7.06	—	mixed-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-26D9	Rio Hondo1_1	–55.3	–8.39	—	Ca/Na-HCO_3	Fresh	n.a.	non-marine	Montebello
2S/12W-26D10	Rio Hondo1_2	–62.4	–8.92	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-26D11	Rio Hondo1_3	–64.9	–8.88	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-26D12	Rio Hondo1_4	–59.8	–8.38	—	Ca/Na-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-26D13	Rio Hondo1_5	–54.2	–7.48	—	Ca/Na-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-26D14	Rio Hondo1_6	–52.6	–7.46	—	Ca/Na-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-33D3	Bell Gardens1_1	–65.7	–9.14	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
Montebello Forebay—Continued									
2S/12W-33D4	Bell Gardens1_2	–55.4	–8.23	—	Na/Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
2S/12W-33D5	Bell Gardens1_3	–60.3	–8.35	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-33D6	Bell Gardens1_4	–53.8	–7.78	—	Ca/Na-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/12W-33D7	Bell Gardens1_5	–52.0	–7.55	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Montebello/spreading
2S/12W-33D8	Bell Gardens1_6	–51.9	–7.59	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello/spreading
2S/12W-36M6	Pico Rivera W8	–60.6	–8.39	0.7101	Ca-HCO_3/SO_4	Fresh	SGR	non-marine	Montebello/spreading
3S/12W-11A7	Norwalk2_1	–55.9	–7.92	—	Na/Ca-HCO_3	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-11A8	Norwalk2_2	–52.8	–7.90	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
3S/12W-11A9	Norwalk2_3	–54.9	–8.39	—	Ca-HCO_3	Fresh	n.a.	non-marine	Montebello
3S/12W-11A10	Norwalk2_4	–56.5	–8.56	—	Ca-HCO_3	Fresh	n.a.	non-marine	Montebello
3S/12W-11A11	Norwalk2_5	–62.7	–8.65	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-11A12	Norwalk2_6	–54.8	–7.64	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
Whitter area									
3S/11W-2K4	Whittier1_1	–42.5	–6.63	—	Na-SO_4	Slightly saline	n.a.	n.a.	Local (slightly saline)
3S/11W-2K5	Whittier1_2	–41.0	–6.42	—	Na-SO_4	Slightly saline	n.a.	n.a.	Local (slightly saline)
3S/11W-2K6	Whittier1_4	–37.0	–5.78	—	Na/Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Local
3S/11W-2K7	Whittier1_5	–37.0	–5.85	—	mixed-HCO_3/SO_4	Fresh	n.a.	non-marine	Local
3S/11W-2K8	Whittier1_3	–40.7	–6.32	—	Na/Ca-SO_4	Slightly saline	n.a.	non-marine	Local (slightly saline)
3S/11W-9D2	Santa Fe Springs1_2	–49.3	–7.66	—	Na-HCO_3/Cl	Fresh	n.a.	shallow marine	Local
3S/11W-9D3	Santa Fe Springs1_3	–44.0	–6.73	—	Na-HCO_3	Fresh	n.a.	shallow marine	Local
3S/11W-9D4	Santa Fe Springs1_4	–49.4	–7.51	—	Na-HCO_3/Cl	Fresh	n.a.	shallow marine	Local
Pressure area									
2S/12W-7J1	Commerce1_1	–31.9	–5.72	0.7094	Na-Cl	Highly saline	LAR, SGR	*	Los Angeles paleowater (highly saline)
2S/12W-7J2	Commerce1_2	–45.1	–7.04	—	Na-HCO_3/Cl	Fresh	n.a.	non-marine	Los Angeles
2S/12W-7J3	Commerce1_3	–43.7	–6.93	—	Na/Ca-HCO_3	Fresh	n.a.	non-marine	Mixed
2S/12W-7J4	Commerce1_4	–50.0	–7.55	0.7091	Na-HCO_3/Cl	Fresh	LAR, SGR	non-marine	Los Angeles
2S/12W-7J5	Commerce1_5	–56.9	–8.14	—	Ca/Na-mixed	Fresh	n.a.	non-marine	Montebello/spreading

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
Pressure area—Continued									
2S/12W-7J6	Commerce1_6	–39.8	–6.29	—	Ca/Na-HCO_3	Fresh	n.a.	non-marine	Local
2S/13W-24J1	Bell1_1	–62.1	–9.01	0.7091	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
2S/13W-24J2	Bell1_2	–47.8	–7.29	0.7086	Na/Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-24J3	Bell1_3	–48.4	–7.31	0.7085	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-24J4	Bell1_4	–46.9	–7.33	0.7086	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-24J5	Bell1_5	–53.3	–7.76	0.7092	Ca/Na-HCO_3	Fresh	LAR, SGR	non-marine	Montebello/spreading
2S/13W-24J6	Bell1_6	–42.9	–6.74	0.7088	Ca-HCO_3	Fresh	LAR	non-marine	Local
2S/13W-31B3	Los Angeles4_1	–60.3	–9.01	0.7094	Na-HCO_3	Slightly saline	LAR, SGR	deep marine	Montebello paleowater (slightly saline)
2S/13W-31B4	Los Angeles4_2	–62.5	–9.07	0.7090	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
2S/13W-31B5	Los Angeles4_3	–48.5	–7.30	0.7080	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-31B6	Los Angeles4_4	–48.0	–7.31	0.7083	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-31B7	Los Angeles4_5	–47.2	–7.39	0.7082	Na/Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/13W-31B8	Los Angeles4_6	–48.0	–7.21	0.7085	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
2S/14W-26N3	Inglewood2_1	–60.8	–8.98	0.7096	Na-HCO_3	Slightly saline	LAR, SGR	deep marine	Montebello paleowater (slightly saline)
2S/14W-26N4	Inglewood2_2	–56.3	–8.30	0.7086	Na-HCO_3	Slightly saline	LAR	deep marine	Montebello paleowater (slightly saline)
2S/14W-26N5	Inglewood2_3	–38.4	–6.18	0.7084	Na-HCO_3	Fresh	LAR	deep marine	Local
3S/11W-17F1	Norwalk1_1	–48.4	–7.22	0.7086	Na-HCO_3	Fresh	Local	shallow marine	Local paleowater
3S/11W-17F2	Norwalk1_2	–63.8	–9.20	0.7092	Na-HCO_3	Fresh	SGR, Local	shallow marine	Montebello paleowater
3S/11W-17F3	Norwalk1_3	–56.1	–8.33	0.7091	Na-HCO_3	Fresh	SGR, Local	non-marine	Montebello
3S/11W-17F4	Norwalk1_4	–55.1	–8.36	0.7093	Na/Ca-HCO_3	Fresh	SGR, Local	non-marine	Montebello
3S/11W-17F5	Norwalk1_5	–48.7	–7.55	0.7096	Ca/Na-HCO_3	Fresh	SGR, Local	non-marine	Local
3S/11W-26E2	La Mirada1_1	–52.5	–7.89	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
3S/11W-26E3	La Mirada1_2	–55.3	–8.23	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
3S/11W-26E4	La Mirada1_3	–54.8	–8.20	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
3S/11W-26E5	La Mirada1_4	–53.7	–7.98	—	Na/Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
3S/11W-26E6	La Mirada1_5	–51.7	–7.79	—	Na/Ca-Cl/HCO_3	Fresh	n.a.	non-marine	Mixed

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
Pressure area—Continued									
3S/12W-6B4	South Gate1_1	–48.0	–7.38	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/12W-6B5	South Gate1_2	–59.0	–8.30	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-6B6	South Gate1_3	–61.3	–8.72	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-6B7	South Gate1_4	–59.3	–8.38	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-6B8	South Gate1_5	–47.8	–7.36	—	Ca-HCO_3/Cl	Fresh	n.a.	shallow marine	Los Angeles
3S/12W-9J1	Downey1_1	–55.2	–8.40	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
3S/12W-9J2	Downey1_2	–58.9	–8.60	—	Ca-HCO_3	Fresh	n.a.	non-marine	Montebello
3S/12W-9J3	Downey1_3	–69.1	–9.39	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-9J4	Downey1_4	–59.3	–8.18	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-9J5	Downey1_5	–53.8	–7.95	—	Ca-HCO_3	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-9J6	Downey1_6	–54.5	–7.74	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-15K1	St. John Bosco	–55.6	–7.89	0.7102	Ca/Na-mixed	Fresh	SGR	non-marine	Montebello/spreading
3S/12W-16H1	Park 40D	–57.3	–8.27	0.7103	Ca/Na-mixed	Fresh	SGR	non-marine	Montebello/spreading
3S/12W-26K2	Cerritos2_1	–56.2	–8.37	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
3S/12W-26K3	Cerritos2_2	–64.6	–8.65	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
3S/12W-26K4	Cerritos2_3	–53.9	–8.12	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
3S/12W-26K5	Cerritos2_4	–54.9	–8.14	—	Ca-HCO_3	Fresh	n.a.	deep marine	Montebello
3S/12W-26K6	Cerritos2_5	–55.0	–8.11	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
3S/12W-26K7	Cerritos2_6	–48.4	–7.34	—	Ca-mixed	Fresh	n.a.	non-marine	Local
3S/12W-33B1	BSMWC_615	–57.0	–8.34	0.7102	Ca-HCO_3	Fresh	SGR	non-marine	Montebello
3S/13W-8J1	Willowbrook1_1	–50.2	–7.93	0.7085	Na/Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
3S/13W-8J2	Willowbrook1_2	–46.5	–7.37	0.7085	Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
3S/13W-8J3	Willowbrook1_3	–47.1	–7.35	0.7084	Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
3S/13W-8J4	Willowbrook1_4	–49.7	–7.47	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/13W-11G1	Lynwood1_1	–62.2	–9.27	0.7090	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
3S/13W-11G2	Lynwood1_2	–50.6	–7.80	0.7090	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Mixed
3S/13W-11G3	Lynwood1_8	–57.2	–8.12	0.7085	Ca-mixed	Fresh	LAR	non-marine	Montebello/spreading
3S/13W-11G4	Lynwood1_3	–46.2	–7.27	0.7087	Na/Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
Pressure area—Continued									
3S/13W-11G5	Lynwood1_4	–45.9	–7.28	0.7094	Na/Ca-HCO_3	Fresh	LAR, SGR	shallow marine	Los Angeles
3S/13W-11G6	Lynwood1_5	–48.0	–7.45	0.7096	Na/Ca-HCO_3	Fresh	LAR, SGR	shallow marine	Los Angeles
3S/13W-11G7	Lynwood1_6	–47.5	–7.25	0.7084	Na/Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
3S/13W-11G8	Lynwood1_7	–46.2	–7.22	0.7085	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
3S/13W-11G9	Lynwood1_9	–43.9	–6.76	0.7084	Ca-mixed	Fresh	LAR	non-marine	Local
3S/13W-22M2	Compton2_1	–62.6	–9.06	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello paleowater
3S/13W-22M3	Compton2_2	–56.4	–8.34	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello paleowater
3S/13W-22M4	Compton2_3	–48.8	–7.39	—	Na/Ca-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/13W-22M5	Compton2_4	–48.4	–7.26	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/13W-22M6	Compton2_5	–49.1	–7.43	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/13W-22M7	Compton2_6	–47.1	–7.07	—	Ca-HCO_3	Fresh	n.a.	non-marine	Los Angeles
3S/13W-24K2	Compton1_1	–54.0	–8.14	—	Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles paleowater
3S/13W-24K3	Compton1_2	–47.2	–7.17	—	Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/13W-24K4	Compton1_3	–48.0	–7.23	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/13W-24K5	Compton1_4	–48.8	–7.26	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/13W-24K6	Compton1_5	–47.8	–7.41	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
4S/11W-5P9	Cerritos1_1	–56.3	–8.26	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/11W-5P10	Cerritos1_2	–53.3	–8.13	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/11W-5P11	Cerritos1_3	–53.1	–8.14	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/11W-5P12	Cerritos1_4	–54.7	–8.19	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/11W-5P13	Cerritos1_5	–52.3	–8.13	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/11W-5P14	Cerritos1_6	–53.0	–8.08	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/12W-5H5	Lakewood1_1	–58.6	–8.91	—	Na-HCO_3	Fresh	n.a.	non-marine	Montebello Paleowater
4S/12W-5H6	Lakewood1_2	–53.1	–8.18	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/12W-5H7	Lakewood1_3	–52.7	–8.07	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/12W-5H8	Lakewood1_4	–50.8	–7.85	—	Ca-HCO_3	Fresh	n.a.	non-marine	Mixed
4S/12W-5H9	Lakewood1_5	–53.6	–8.12	—	Ca-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/12W-5H10	Lakewood1_6	–52.0	–7.79	—	Ca-HCO_3	Fresh	n.a.	n.a.	Mixed

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
Pressure area—Continued									
4S/12W-12F1	Lakewood2_1	–56.9	–8.32	0.7104	Na-HCO_3	Fresh	SGR, SAR	shallow marine	Montebello
4S/12W-12F2	Lakewood2_2	–56.0	–8.38	0.7096	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Montebello
4S/12W-12F3	Lakewood2_3	–54.5	–8.30	0.7097	Na-HCO_3	Fresh	SGR	shallow marine	Montebello
4S/12W-12F4	Lakewood2_4	–55.1	–8.20	0.7102	Ca-HCO_3	Fresh	SGR	shallow marine	Montebello
4S/12W-12F5	Lakewood2_5	–52.6	–8.09	0.7098	Na/Ca-HCO_3	Fresh	SGR	deep marine	Montebello
4S/12W-12F6	Lakewood2_6	–53.9	–8.18	0.7106	Na-HCO_3	Fresh	SGR, SAR	deep marine	Montebello
4S/12W-12F7	Lakewood2_7	–53.8	–8.18	0.7100	Ca-HCO_3	Fresh	SGR	deep marine	Montebello
4S/12W-12F8	Lakewood2_8	–54.2	–8.14	0.7101	Ca/Na-HCO_3	Fresh	SGR	deep marine	Montebello
4S/12W-21M8	Long Beach6_1	–65.7	–9.30	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello paleowater
4S/12W-21M9	Long Beach6_2	–60.2	–8.73	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello paleowater
4S/12W-21M10	Long Beach6_3	–58.1	–8.54	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello
4S/12W-21M11	Long Beach6_4	–58.4	–8.51	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/12W-21M12	Long Beach6_5	–58.6	–8.57	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/12W-21M13	Long Beach6_6	–55.2	–8.10	—	Ca/Na-HCO_3	Fresh	n.a.	non-marine	Montebello
4S/12W-23K3	LB Annex 201	–56.6	–8.39	0.7100	Na-HCO_3	Fresh	SGR	shallow marine	Montebello
4S/12W-25G1	Long Beach1_1	–57.5	–8.64	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello
4S/12W-25G2	Long Beach1_2	–57.0	–8.56	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello
4S/12W-25G3	Long Beach1_3	–56.9	–8.55	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/12W-25G4	Long Beach1_4	–57.0	–8.39	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
4S/12W-25G5	Long Beach1_5	–65.2	–9.08	—	Na-Cl/SO_4	Slightly saline	n.a.	*	Injection/seawater (3%)
4S/12W-25G6	Long Beach1_6	–53.0	–7.77	—	Ca-mixed	Fresh	n.a.	non-marine	Montebello
4S/13W-1N3	Long Beach2_1	–63.6	–9.17	0.7085	Na-HCO_3	Fresh	LAR	deep marine	Montebello paleowater
4S/13W-1N4	Long Beach2_2	–60.7	–8.84	0.7096	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
4S/13W-1N5	Long Beach2_3	–51.1	–7.87	0.7090	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Montebello
4S/13W-1N6	Long Beach2_4	–49.0	–7.55	0.7096	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Los Angeles
4S/13W-1N7	Long Beach2_5	–41.7	–6.44	0.7099	Ca-SO_4/HCO_3	Fresh	SGR	non-marine	Local
4S/13W-1N8	Long Beach2_6	–41.8	–6.20	0.7098	Ca-SO_4/HCO_3	Slightly saline	SGR	non-marine	Local (slightly saline)

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
Orange County Basin									
3S/08W34G2	Canyon_RV_1_EAST	–54.2	–7.50	0.7106	Ca/Na-mixed	Fresh	SAR, Local	non-marine	n.a.
4S/10W14H3	Anaheim_46	–56.3	–7.85	0.7116	Ca/Na-mixed	Fresh	SAR	non-marine	n.a.
5S/12W-1C1	512B	–75.8	–9.76	0.7110	Ca/Na-mixed	Fresh	SGR, SAR	non-marine	Injection
5S/12W-1C2	512C	–75.1	–9.85	0.7109	Na/Ca-mixed	Fresh	SGR, SAR	non-marine	Injection
5S/12W-1C3	Seal Beach1_1	–62.3	–9.15	0.7104	Na-HCO_3	Fresh	SGR	deep marine	Montebello paleowater
5S/12W-1C4	Seal Beach1_2	–58.9	–8.69	0.7105	Na-HCO_3	Fresh	SGR, SAR	shallow marine	Montebello
5S/12W-1C5	Seal Beach1_3	–58.0	–8.63	0.7103	Na-HCO_3	Fresh	SGR	deep marine	Montebello
5S/12W-1C6	Seal Beach1_4	–61.2	–9.03	0.7101	Na-HCO_3	Fresh	SGR	deep marine	Montebello paleowater
5S/12W-1C7	Seal Beach1_5	–57.4	–8.42	0.7103	Na-HCO_3	Fresh	SGR	shallow marine	Montebello
5S/12W-1C8	Seal Beach1_6	–79.8	–10.28	0.7106	Na/Ca-mixed	Fresh	SGR, SAR	non-marine	Montebello/Injection
5S/12W-1C9	Seal Beach1_7	–53.1	–7.81	0.7106	Ca/Na-Cl	Slightly saline	SGR, SAR	*	Montebello/seawater (4%)
West Coast Basin									
2S/14W-18J1	Holy_Cross_AA	–45.6	–6.63	0.7084	mixed-mixed	Slightly saline	LAR	n.a.	Local (slightly saline)
2S/14W-19G1	Hillside_Park_1	–42.2	–6.54	0.7085	Na/Ca-HCO_3	Fresh	LAR	shallow marine	Local
2S/14W-28M3	Inglewood1_1	–49.9	–7.98	0.7089	Na-Cl	Moderately saline	LAR, SGR	n.a.	Los Angeles paleowater (moderately saline)
2S/14W-28M4	Inglewood1_2	–41.0	–6.18	0.7083	mixed-Cl/HCO_3	Slightly saline	LAR	n.a.	Local (slightly saline)
2S/14W-28M5	Inglewood1_3	–41.1	–6.09	0.7084	Na/Ca-Cl	Fresh	LAR	n.a.	Local
2S/14W-28M6	Inglewood1_4	–39.4	–6.14	—	Ca/Na-Cl	Fresh	n.a.	non-marine	Local
2S/14W-28M7	Inglewood1_5	–40.5	–6.16	—	Ca/Na-Cl	Fresh	n.a.	n.a.	Local
2S/15W-35A1	Westchester1_1	–50.4	–7.54	—	Na-HCO_3	Slightly saline	n.a.	deep marine	Los Angeles paleowater (slightly saline)
2S/15W-35A2	Westchester1_2	–45.0	–6.83	—	Na-HCO_3	Fresh	n.a.	deep marine	Local paleowater
2S/15W-35A3	Westchester1_3	–44.5	–6.69	—	Na-HCO_3	Fresh	n.a.	shallow marine	Local
2S/15W-35A4	Westchester1_4	–40.1	–6.18	—	Na/Ca-HCO_3	Fresh	n.a.	shallow marine	Local
2S/15W-35A5	Westchester1_5	–40.8	–6.18	—	Na/Ca-HCO_3	Fresh	n.a.	shallow marine	Local
3S/14W-4R1	Inglewood3_1	–55.4	–8.30	0.7090	Na-Cl	Slightly saline	LAR, SGR	n.a.	Montebello paleowater (slightly saline)

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
West Coast Basin—Continued									
3S/14W-4R2	Inglewood3_2	–60.0	–9.11	0.7095	Na-HCO_3	Slightly saline	LAR, SGR	deep marine	Montebello paleowater (slightly saline)
3S/14W-4R3	Inglewood3_3	–58.4	–8.59	0.7089	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
3S/14W-4R4	Inglewood3_4	–54.4	–8.31	0.7090	Na-HCO_3	Fresh	LAR, SGR	deep marine	Los Angeles paleowater
3S/14W-4R5	Inglewood3_5	–40.8	–6.45	0.7082	Na/Ca-HCO_3	Fresh	LAR	non-marine	Local
3S/14W-4R6	Inglewood3_6	–44.4	–7.03	0.7084	Ca/Na-HCO_3/Cl	Fresh	LAR	non-marine	Mixed
3S/14W-4R7	Inglewood3_7	–40.3	–6.44	0.7082	mixed-Cl	Fresh	LAR	n.a.	Local
3S/14W-13J5	Gardena1_1	–53.3	–7.75	—	Na-HCO_3	Fresh	n.a.	deep marine	Los Angeles paleowater
3S/14W-13J6	Gardena1_2	–49.0	–7.29	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/14W-13J7	Gardena1_3	–48.0	–7.29	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/14W-13J8	Gardena1_4	–42.4	–6.49	—	Ca-Cl	Fresh	n.a.	n.a.	Local
3S/14W-17G3	Hawthorne1_1	–50.5	–7.70	—	Na-HCO_3	Fresh	n.a.	deep marine	Los Angeles paleowater
3S/14W-17G4	Hawthorne1_2	–49.3	–7.59	—	Na-HCO_3	Fresh	n.a.	deep marine	Los Angeles paleowater
3S/14W-17G5	Hawthorne1_3	–46.1	–7.06	—	Na-HCO_3	Fresh	n.a.	shallow marine	Local paleowater
3S/14W-17G6	Hawthorne1_4	–45.6	–7.03	—	Na-HCO_3	Fresh	n.a.	shallow marine	Mixed
3S/14W-17G7	Hawthorne1_5	–45.5	–6.92	—	Ca/Na-Cl	Fresh	n.a.	non-marine	Mixed
3S/14W-17G8	Hawthorne1_6	–50.6	–6.85	—	Ca/Na-mixed	Slightly saline	n.a.	*	Los Angeles/injection/ seawater (3%)
3S/14W-25K7	Gardena2_1	–55.6	–8.18	—	Na-HCO_3	Fresh	n.a.	deep marine	Los Angeles paleowater
3S/14W-25K8	Gardena2_2	–48.6	–7.34	0.7084	Na/Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
3S/14W-25K9	Gardena2_3	–47.6	–7.32	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/14W-25K10	Gardena2_4	–46.8	–7.22	—	Na/Ca-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
3S/14W-25K11	Gardena2_5	–47.1	–7.30	0.7084	Ca/Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
3S/14W-27C2	Lawndale1_1	–60.9	–8.99	0.7090	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
3S/14W-27C3	Lawndale1_2	–53.2	–7.96	0.7091	Na-HCO_3	Fresh	LAR, SGR	deep marine	Los Angeles paleowater
3S/14W-27C4	Lawndale1_3	–48.0	–7.45	0.7088	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Los Angeles
3S/14W-27C5	Lawndale1_4	–45.2	–7.10	0.7084	Ca/Na-HCO_3	Fresh	LAR	non-marine	Mixed
3S/14W-27C6	Lawndale1_5	–45.5	–7.03	0.7084	Ca/Na-HCO_3	Fresh	LAR	non-marine	Mixed
3S/14W-27C7	Lawndale1_6	–41.9	–6.28	0.7084	Ca/Na-Cl	Slightly saline	LAR	*	Local (slightly saline)

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
West Coast Basin—Continued									
3S/14W-30L2	Manhattan Beach1_1	–42.3	–6.72	0.7099	Na-Cl	Moderately saline	SGR	n.a.	Los Angeles paleowater (moderately saline)
3S/14W-30L3	Manhattan Beach1_2	–56.5	–8.49	0.7102	Na-Cl	Slightly saline	SGR	n.a.	Montebello paleowater (slightly saline)
3S/14W-30L4	Manhattan Beach1_3	–61.9	–9.05	0.7091	Na-HCO_3	Slightly saline	LAR, SGR	deep marine	Montebello paleowater (slightly saline)
3S/14W-30L5	Manhattan Beach1_4	–51.9	–7.86	0.7085	Na-HCO_3	Fresh	LAR	deep marine	Los Angeles paleowater
3S/14W-30L6	Manhattan Beach1_5	–23.3	–3.79	0.7087	Na-Cl	Highly saline	LAR	*	Montebello paleowater (highly saline)
3S/14W-30L7	Manhattan Beach1_6	–37.8	–5.81	0.7084	Na/Ca-Cl	Moderately saline	LAR	*	Los Angeles/seawater (21%)
3S/14W-30L8	Manhattan Beach1_7	–63.3	–8.61	0.7085	Na-mixed	Fresh	LAR	non-marine	Injection
3S/14W-33R5	Torrance1_1	–61.4	–8.96	0.7093	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
3S/14W-33R6	Torrance1_2	–62.8	–9.01	0.7092	Na-HCO_3	Slightly saline	LAR, SGR	deep marine	Montebello paleowater (slightly saline)
3S/14W-33R7	Torrance1_3	–57.5	–8.39	0.7092	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
3S/14W-33R8	Torrance1_4	–50.2	–7.80	0.7085	Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles paleowater
3S/14W-33R9	Torrance1_5	–64.0	–8.62	0.7084	Ca/Na-Cl	Moderately saline	LAR	*	Injection/seawater (8%)
3S/14W-33R10	Torrance1_6	–58.6	–7.94	0.7085	Na/Ca-mixed	Fresh	LAR	non-marine	Injection
4S/12W-30J1	Long Beach8_1	–61.9	–9.19	—	Na-HCO_3	Fresh	n.a.	deep marine	Montebello paleowater
4S/12W-30J2	Long Beach8_2	–62.3	–9.17	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello paleowater
4S/12W-30J3	Long Beach8_3	–63.6	–9.29	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello paleowater
4S/12W-30J4	Long Beach8_4	–60.9	–9.04	—	Na-Cl	Slightly saline	n.a.	n.a.	Montebello paleowater (slightly saline)
4S/12W-30J5	Long Beach8_5	–60.5	–8.99	—	Na-Cl	Slightly saline	n.a.	n.a.	Montebello paleowater (slightly saline)
4S/12W-30J6	Long Beach8_6	–56.1	–8.39	—	Na-Cl	Fresh	n.a.	n.a.	Montebello
4S/13W-5F1	Carson3_1	–62.4	–9.17	0.7090	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
West Coast Basin—Continued									
4S/13W-5F2	Carson3_2	–48.5	–7.44	0.7090	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Los Angeles
4S/13W-5F3	Carson3_3	–48.3	–7.32	0.7089	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Los Angeles
4S/13W-5F4	Carson3_4	–48.5	–7.23	0.7087	Na-HCO_3	Fresh	LAR	shallow marine	Los Angeles
4S/13W-5F5	Carson3_5	–47.3	–7.29	0.7086	Na/Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
4S/13W-5F6	Carson3_6	–47.1	–7.27	0.7085	Na/Ca-HCO_3	Fresh	LAR	shallow marine	Los Angeles
4S/13W-9H9	Carson1_1	–48.4	–7.33	0.7090	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Los Angeles
4S/13W-9H10	Carson1_2	–46.6	–7.27	0.7090	Na/Ca-HCO_3	Fresh	LAR, SGR	shallow marine	Los Angeles
4S/13W-9H11	Carson1_3	–47.3	–7.30	0.7089	Ca/Na-HCO_3	Fresh	LAR, SGR	shallow marine	Los Angeles
4S/13W-9H12	Carson1_4	–47.0	–7.12	0.7094	Ca/Na-HCO_3	Fresh	LAR, SGR	non-marine	Los Angeles
4S/13W-18K1	Carson2_1	–50.4	–7.51	—	Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
4S/13W-18K2	Carson2_2	–49.5	–7.33	—	Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
4S/13W-18K3	Carson2_3	–48.2	–7.27	—	Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
4S/13W-18K4	Carson2_4	–49.5	–7.54	—	Na/Ca-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
4S/13W-18K5	Carson2_5	–48.3	–7.24	—	Ca/Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
4S/13W-23D3	Long Beach3_1	–62.7	–9.17	0.7089	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
4S/13W-23D4	Long Beach3_2	–51.1	–7.72	0.7095	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Mixed
4S/13W-23D5	Long Beach3_3	–53.2	–8.07	0.7094	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Montebello
4S/13W-23D6	Long Beach3_4	–48.4	–7.32	0.7093	Ca-Cl	Fresh	LAR, SGR	n.a.	Los Angeles
4S/13W-23D7	Long Beach3_5	–47.4	–7.10	0.7092	Ca-Cl	Slightly saline	LAR, SGR	*	Los Angeles/seawater (3%)
4S/13W-23N3	889P	–56.6	–8.48	0.7094	Na-HCO_3/Cl	Fresh	LAR, SGR	non-marine	Montebello
4S/13W-26F5	380P	–53.3	–7.85	0.7094	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Montebello
4S/13W-27H4	Long Beach7_1	–64.0	–9.39	0.7092	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
4S/13W-27H5	Long Beach7_2	–55.1	–8.37	0.7090	Na-HCO_3	Fresh	LAR, SGR	non-marine	Montebello paleowater
4S/13W-27H6	Long Beach7_3	–53.6	–8.15	0.7089	Na-HCO_3	Fresh	LAR, SGR	non-marine	Los Angeles paleowater
4S/13W-27H7	Long Beach7_4	–45.9	–6.86	0.7092	Na/Ca-Cl	Moderately saline	LAR, SGR	*	Montebello/seawater (11%)
4S/13W-28A3	Wilmington1_1	–46.8	–7.29	0.7091	Na-Cl	Fresh	LAR, SGR	n.a.	Los Angeles
4S/13W-28A4	Wilmington1_2	–46.0	–7.13	0.7093	Ca/Na-Cl	Fresh	LAR, SGR	n.a.	Los Angeles

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

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State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
West Coast Basin—Continued									
4S/13W-28A5	Wilmington1_3	–49.4	–7.34	0.7093	Na/Ca-Cl	Slightly saline	LAR, SGR	*	Mixed/seawater (5%)
4S/13W-28A6	Wilmington1_4	–77.5	–9.77	0.7088	Na-Cl	Slightly saline	LAR, SGR	*	Injection/seawater (6%)
4S/13W-28A7	Wilmington1_5	–73.3	–9.58	0.7088	Ca/Na-Cl	Fresh	LAR	n.a.	Injection
4S/13W-29H5	340L	–42.3	–6.46	0.7089	Na-Cl	Slightly saline	LAR, SGR	n.a.	Local/seawater (7%)
4S/13W-29H6	340M	–45.9	–6.84	0.7089	Na/Ca-Cl	Slightly saline	LAR, SGR	*	Los Angeles/seawater (3%)
4S/13W-29H7	340N	–46.3	–7.21	0.7090	Na/Ca-Cl/HCO_3	Slightly saline	LAR, SGR	non-marine	Los Angeles
4S/13W-31J1	321A	–50.5	–7.88	0.7090	Na-Cl	Moderately saline	LAR, SGR	*	Montebello/seawater (11%)
4S/13W-32F1	Wilmington2_1	–59.7	–8.73	0.7093	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
4S/13W-32F2	Wilmington2_2	–55.8	–8.63	0.7091	Na-Cl	Slightly saline	LAR, SGR	n.a.	Montebello paleowater (slightly saline)
4S/13W-32F3	Wilmington2_3	–50.6	–7.84	0.7090	Na-Cl/HCO_3	Fresh	LAR, SGR	shallow marine	Mixed
4S/13W-32F4	Wilmington2_4	–51.3	–7.96	0.7090	Na-Cl	Slightly saline	LAR, SGR	*	Mixed/seawater (5%)
4S/13W-32F5	Wilmington2_5	–57.7	–7.57	0.7091	Na-Cl	Moderately saline	LAR, SGR	*	Injection/seawater (28%)
4S/13W-34A1	371D	–61.2	–8.76	0.7095	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Montebello
4S/13W-34M1	361H	–54.6	–8.27	0.7092	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Montebello
4S/13W-35B2	381J	–61.5	–9.05	0.7096	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello
4S/13W-35B3	381K	–44.9	–6.64	0.7097	Na-Cl	Moderately saline	SGR	*	Montebello/seawater (16%)
4S/14W-2N1	PM-3 Madrid_1	–48.4	–7.76	—	Na-HCO_3	Fresh	n.a.	deep marine	Los Angeles paleowater
4S/14W-2N2	PM-3 Madrid_2	–48.5	–6.88	—	Na/Ca-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
4S/14W-2N3	PM-3 Madrid_3	–44.3	–6.88	—	mixed-Cl/HCO_3	Fresh	n.a.	non-marine	Los Angeles
4S/14W-2N4	PM-3 Madrid_4	–47.1	–6.91	—	Na/Ca-Cl/HCO_3	Slightly saline	n.a.	n.a.	Los Angeles (slightly saline)
4S/14W-4Q1	PM-4 Mariner_1	–50.7	–7.79	—	Na-HCO_3	Fresh	n.a.	shallow marine	Los Angeles paleowater
4S/14W-4Q2	PM-4 Mariner_2	–33.7	–5.12	—	Na/Ca-Cl	Highly saline	n.a.	*	Los Angeles/seawater (35%)
4S/14W-4Q3	PM-4 Mariner_3	–83.1	–10.54	—	Na-SO_4/Cl	Fresh	n.a.	non-marine	Injection
4S/14W-4Q4	PM-4 Mariner_4	–65.9	–8.65	—	Na/Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Los Angeles/injection

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
West Coast Basin—Continued									
4S/14W-10C1	PM-1 Columbia_1	–49.2	–7.46	—	Na/Ca-HCO_3	Fresh	n.a.	shallow marine	Los Angeles
4S/14W-10C2	PM-1 Columbia_2	–59.6	–8.40	—	Ca/Na-Cl	Slightly saline	n.a.	*	Los Angeles/injection/ seawater (5%)
4S/14W-15E1	Torrance2_1	–60.2	–8.86	0.7089	Na-HCO_3	Slightly saline	LAR, SGR	n.a.	Montebello paleowater (slightly saline)
4S/14W-15E2	Torrance2_2	–56.1	–8.18	0.7090	Na-Cl	Moderately saline	LAR, SGR	*	Montebello paleowater (moderately saline)
4S/14W-15E3	Torrance2_3	–43.2	–6.49	0.7089	mixed-Cl	Highly saline	LAR, SGR	*	Montebello paleowater (highly saline)
4S/14W-15E4	Torrance2_4	–50.7	–7.66	0.7089	Na-HCO_3	Fresh	LAR, SGR	shallow marine	Mixed
4S/14W-15E5	Torrance2_5	–69.0	–9.23	0.7083	Ca/Na-Cl	Moderately saline	LAR	*	Injection/seawater (9%)
4S/14W-15E6	Torrance2_6	–56.7	–7.97	0.7084	Na/Ca-Cl	Fresh	LAR	n.a.	Los Angeles/Injection
4S/14W-26A2	Lomita1_1	–41.7	–6.37	0.7086	Na/Ca-Cl	Slightly saline	Local	n.a.	Local (slightly saline)
4S/14W-26A3	Lomita1_2	–43.3	–6.57	0.7086	Na-Cl	Fresh	Local	n.a.	Local
4S/14W-26A4	Lomita1_3	–50.3	–7.73	0.7087	Na-Cl	Fresh	LAR	n.a.	Los Angeles
4S/14W-26A5	Lomita1_4	–52.6	–7.75	0.7087	Na-Cl	Fresh	Local	n.a.	Local paleowater
4S/14W-26A6	Lomita1_5	–41.1	–6.22	0.7086	Na/Ca-Cl	Slightly saline	Local	n.a.	Local (slightly saline)
4S/14W-35D10	Chandler3_1	–37.0	–5.90	—	Na/Ca-HCO_3	Fresh	n.a.	non-marine	Local
4S/14W-35D11	Chandler3_2	–39.0	–6.20	—	Ca/Na-HCO_3/Cl	Slightly saline	n.a.	non-marine	Local
5S/13W-2E1	Long Beach4_1	–61.1	–9.23	0.7094	Na-HCO_3	Fresh	LAR, SGR	deep marine	Montebello paleowater
5S/13W-2E2	Long Beach4_2	–49.2	–7.54	0.7096	Na-HCO_3/Cl	Slightly saline	LAR, SGR	n.a.	Los Angeles paleowater (slightly saline)
5S/13W-11P1	Long Beach5_1	–47.1	–7.47	0.7096	Na-Cl	Moderately saline	LAR, SGR	n.a.	Los Angeles paleowater (moderately saline)
5S/13W-11P2	Long Beach5_2	–3.7	–0.42	0.7092	Na-Cl	Brine	LAR, SGR	*	Seawater
Santa Monica Basin									
1S/15W-31E1	SM 1 (2505)	–57.0	–8.03	0.7088	mixed-SO_4/Cl	Fresh	Local	non-marine	Los Angeles/artificial
1S/15W-33A1	SM Arcadia_5	–54.5	–7.80	0.7088	mixed-mixed	Fresh	Local	non-marine	Los Angeles/artificial
2S/15W-4C2	SM 3 (2646K)	–49.8	–7.26	0.7087	mixed-HCO_3/SO_4	Fresh	LAR, Local	non-marine	Los Angeles

Table 1.2. Groundwater-quality data used for this study from multiple-well monitoring sites, and selected production and observation wells, Los Angeles and Orange Counties, California.—Continued

[See appendix 1 for explanation. **Abbreviations**: ft, foot; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; ug/L, micrograms per liter; $CaCO_3$, calcium carbonate; %, percent; <, less than; —, no data. Sediment source/facies: LAR, Los Angeles River; n.a., not assigned; SGR, San Gabriel River; SAR, Santa Ana River, *, potentially affected by mixing with anthropogenic sources of water or seawater]

State well number	Local well name	δ^2Hydrogen, unfiltered (per mil)	δ^{18}Oxygen, unfiltered (per mil)	Strontium-87 / Strontium-86, filtered (atom ratio)	Chemical facies	Dissolved-solids classification	Sediment source	Sediment facies	Groundwater recharge source
Hollywood Basin									
1S/14W-18L1	BH_2	–39.4	–6.31	0.7080	Na-HCO_3/Cl	Fresh	Local	n.a.	Local
1S/15W-24B1	BH_5	–36.8	–5.96	0.7081	mixed-HCO_3/SO_4	Fresh	Local	shallow marine	Local
San Fernando Valley									
1N/13W-35P1	DS_WATERS	–54.5	–7.72	0.7094	Ca/Mg-mixed	Fresh	LAR, SGR	non-marine	n.a.
San Gabriel Valley									
2S/11W-5P6	Whittier Narrows1_1	–48.6	–7.35	—	Na-Cl	Slightly saline	n.a.	n.a.	Local (slightly saline)
2S/11W-5P7	Whittier Narrows1_2	–54.4	–8.29	—	Na-HCO_3	Fresh	n.a.	shallow marine	Montebello
2S/11W-5P8	Whittier Narrows1_3	–60.6	–8.48	—	Ca-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/11W-5P9	Whittier Narrows1_4	–60.3	–8.14	—	Ca-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/11W-5P10	Whittier Narrows1_5	–59.9	–8.53	—	Ca-HCO_3/SO_4	Fresh	n.a.	non-marine	Montebello/spreading
2S/11W-5P11	Whittier Narrows1_6	–58.5	–7.93	—	Ca/Na-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/11W-5P12	Whittier Narrows1_7	–56.5	–7.79	—	Na/Ca-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/11W-5P13	Whittier Narrows1_8	–57.7	–7.88	—	Na/Ca-mixed	Fresh	n.a.	non-marine	Montebello/spreading
2S/11W-5P14	Whittier Narrows1_9	–57.7	–7.92	—	Na/Ca-mixed	Fresh	n.a.	non-marine	Montebello/spreading

Background on Water-Quality Data Analyzed

Water-quality data analyzed for this report include major-ion compositions; dissolved-solids, chloride (Cl), and boron (B) concentations; stable-isotope ratios for hydrogen (H), oxygen (O), strontium (Sr), and carbon ($^{13}C/^{12}C$); and the radioactive isotopes, tritium (^{3}H) and carbon-14 (^{14}C). A brief description of each of these constituents and how they were used in this study is included below.

Major-Ion Composition and Dissolved-Solids Concentration

The major-ion compositions and dissolved-solids concentrations of groundwater samples from multiple-well monitoring sites were used to help define chronostratigraphic unit boundaries and model zones. The major-ion composition of groundwater is controlled by the natural chemistry of the recharge water and geochemical reactions, primarily dissolution and precipitation of minerals, in the subsurface (Hem, 1985). Reactions that affect major-ion concentrations include aluminosilicate dissolution, calcite dissolution and precipitation, cation exchange on clays, and microbial sulfate reduction. The aqueous concentration of major ions is controlled by kinetics (rate of dissolution of minerals) and equilibrium (saturation with respect to minerals). The major-ion composition was characterized for this report by using trilinear Piper diagrams (Piper, 1944). Dissolved-solids concentrations of the samples also were used to help characterize the water quality.

Piper diagrams (Piper, 1944) can be used to display the relative contribution of major cations and anions, on a charge-equivalent basis, to the total ionic content of the water. Piper diagram percentage scales show cation concentrations on a triangle to the left and anion concentrations on a triangle to the right, while a central diamond integrates the data (fig. 1.2). Piper diagrams provide a useful visual depiction for comparing or contrasting differences in major-ion composition at multiple locations and can be related to causal geochemical reactions and mixing of groundwater from multiple sources where sufficient data exist. In this report, the dominant cation and anion species are used to describe the water type (chemical facies) of a water sample when a single cation or anion composes more than 60 percent of the total cations or anions, respectively (table 1.2). When a single cation or anion does not exceed 60 percent, the sample is described as mixed, and the first and second most abundant cations or anions are given for description purposes.

Total dissolved solids (or dissolved solids) are a measure of the quantity of all dissolved chemicals in water (Hem, 1985). Dissolved solids can be measured or calculated in several ways; most commonly, a summation of dissolved ions is used if a complete analysis is available, or the residue that remains after evaporation at a specific temperature is weighed (residue-on-evaporation, or ROE). The computed dissolved solids can differ from the ROE value by 10–20 mg/L in either the positive or negative direction when the solids concentration is 100–500 mg/L (Hem, 1985); thus, a direct comparison of dissolved-solids concentrations from different labs is difficult unless the method used by the analyzing laboratory is known. For this report, the total dissolved-solids concentrations were calculated as the summation of the reported major cations (calcium, magnesium, sodium, and potassium) and anions (chloride, sulfate, bicarbonate, fluoride, silica, and nitrate, if available).

Dissolved solids are commonly used to classify waters. For the purposes of this report, water containing less than 1,000 mg/L is classified as fresh; 1,000 to 3,000 mg/L is classified as slightly saline; 3,000 to 10,000 mg/L is classified as moderately saline; 10,000 to 35,000 is classified as highly saline; and more than 35,000 is classified as brine. Samples from 301 wells were classified as fresh, 46 as slightly saline, 11 as moderately saline, 5 as highly saline, and 1 as brine (table 1.2).

Dissolved Chloride and Boron

Chloride (Cl) and boron (B) were used in this study to help determine chronostratigraphic unit boundaries and sediment facies. Chloride a negatively charged ion and is considered a conservative (unreactive) element. Sources of Cl include both natural and anthropogenic processes. Chloride is present in all natural waters, but the concentrations usually are low (Hem, 1985). Chloride concentrations in chemical analyses compiled for this study range from about 4 mg/L in well 8L14 (2S/11W-8L14; Whittier Narrows2_6) to 19,900 mg/L in well 11P2 (5S/13W-11P2; Long Beach5_2; table 1.2). Sources of high Cl concentrations in the LACP include seawater, which contains Cl concentrations of about 19,000 mg/L, and oil-field brine water, which is reported to contain Cl concentrations ranging from 6,000 to 23,400 mg/L in the Long Beach-Santa Ana area (Piper and Garrett, 1953). Another source of high Cl concentrations in the study area is the dissolution of soluble salts found in fine-grained marine deposits. When porous rocks are submerged by the sea at any time after their formation, they become intruded with soluble salts, in which Cl is the major constituent (Hem, 1985). Fine-grained marine sediments may retain this chloride for a very long time (Hem, 1985).

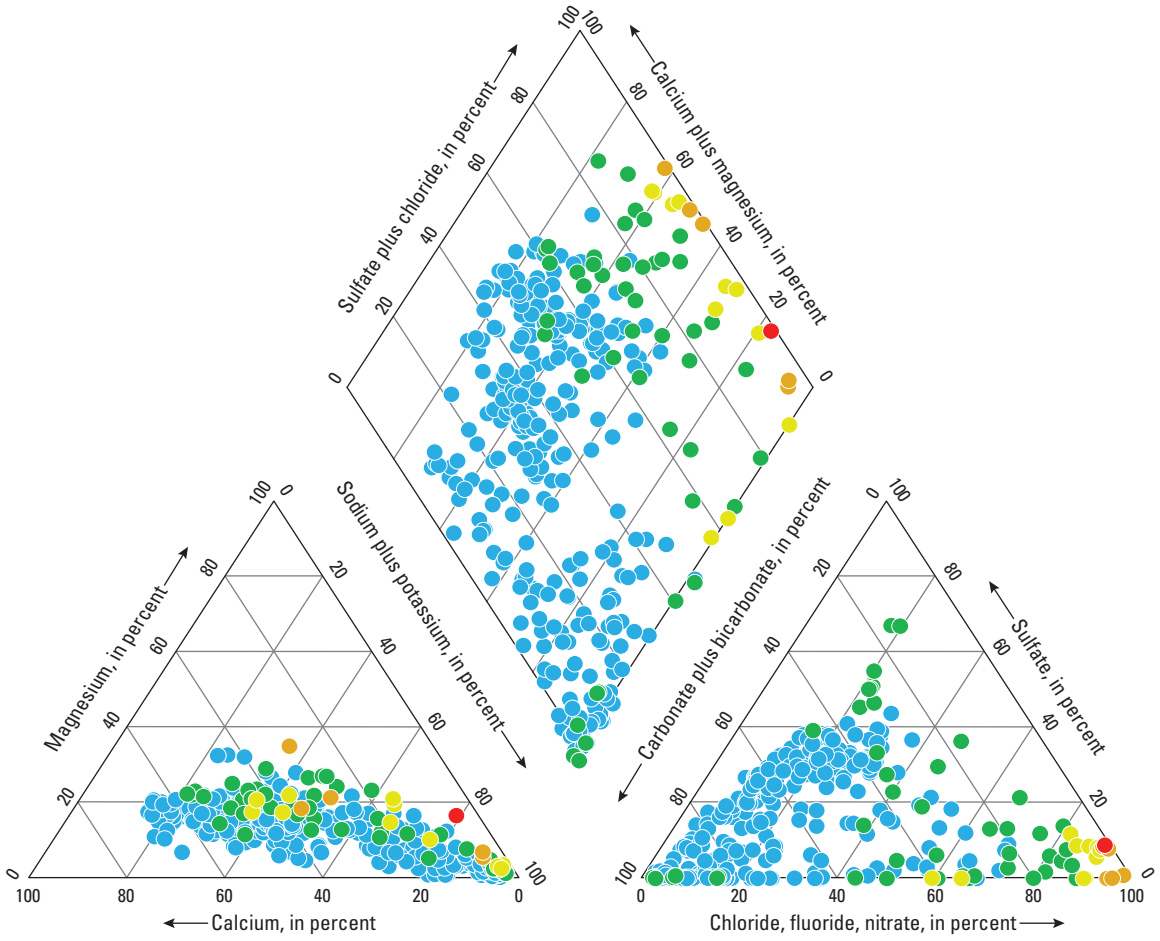


Figure 1.2. Major-ion composition in samples from monitoring wells in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California.

Boron generally is soluble and unaffected by evaporation, oxidation/reduction reactions, and precipitation or dissolution reactions (Bassett and others, 1995). Dissolved B may be affected by adsorption onto the surface of minerals, especially clay, in the aquifer system (Hem, 1985). This process is dependent on the concentration of B, pH, and salinity, as well as on aquifer mineralogy. Water analyses normally report boron concentrations in terms of elemental B, and the uncharged ion is the most likely form in most natural water (Hem, 1985). Boron concentrations in chemical analyses compiled for this study range from 40 µg/L in well 11A9 (3S/12W-11A9; Norwalk2_3) to 14,200 µg/L in well 30L2 (3S/14W-30L2; Manhattan Beach1_1; table 1.2). Sources of high B concentrations in the LACP include seawater, which contains boron concentrations of about 4,500 µg/L, and oil-field brine water, which is reported to contain B concentrations of as high as 70,000 µg/L in coastal oil fields (Piper and Garrett, 1953). Similar to Cl, another source of elevated B concentrations is the dissolution of B from fine-grained marine deposits. Water sampled from these deposits often contains B concentrations higher than what would be inferred from the Cl concentration if seawater was the source. Data from the literature indicate that B is concentrated by algae (Manley, 1983; Carrano and others, 2009; Miller and others, 2016). Manley (1983) reported that the concentration of B in the sieve tube sap from the brown algae *Macrocystis* was about 75-times the concentration of B in seawater. Boron concentrations in marine algae are typically in the range of 100,000 µg/L (Carrano and others, 2009), more than 20 times its concentration in seawater. Fine-grained organic sediments associated with deep marine deposits would be expected to have higher B concentrations than non-marine and shallow marine deposits because deep marine deposits often contain high concentrations of algae and other plankton.

Because Cl and B are relatively unreactive in groundwater, chloride-to-boron ratios have been used to help determine the source of high Cl and/or B concentrations in groundwater (Piper and Garrett, 1953; Martin, 1984; Dotsika and others, 2006). The Cl/B mass ratio in seawater is 4,222, whereas it is much lower in oil-field brines (Piper and Garrett, 1953). Piper and Garrett (1953) stated that high-chloride water with a Cl/B ratio less than 140 may be evidence for mixing with a brine source. The Cl/B ratios in rainwater range from 200 to 5,000 (Dotsika and others, 2006). The Cl/B ratios of a single rain event are highly variable, with a scatter of about 2 orders of magnitude (Rose and others, 2000). Rose and others (2000) determined that Cl and B data collected from lichens can be used to approximate atmospheric deposition of Cl and B at a particular location. A study in Quebec found that lichens had Cl/B ratios ranging from 88 to 545, with an average of 270 (n = 6). The highest Cl/B ratios were analyzed in lichens sampled closest to the coast (Rose and others, 2000). Native groundwater in non-marine sediments derived primarily from granitic rocks will have Cl/B ratios higher than present in local precipitation because Cl is more common in granitic rocks than B (Hem, 1985). Native groundwater in marine sediments would be expected to have lower Cl/B ratios than non-marine sediments as a result of the enriched B concentrations, relative to Cl concentrations, in the marine sediments.

Stable Isotopes

Elements exist as multiple isotopes (same number of protons but differing numbers of neutrons), and many elements have more than one stable (nonradioactive) isotope. In this study, the stable-isotope ratios for hydrogen (H), oxygen (O), and strontium (Sr) were used to help define chronostratigraphic unit boundaries, sediment source, water source, and model zones. The stable-isotope ratio for carbon ($^{13}C/^{12}C$) was used in conjunction with radiogenic carbon-14 (^{14}C) to make inferences about the extent to which this exchange has caused the calculated ^{14}C age to overestimate the actual time elapsed since recharge (Mazor, 1991).

The isotopic composition for H, O, and C are expressed in the standard delta (δ) notation (Gonfiantini, 1978), in units of per mil (parts per thousand), as differences relative to a standard, by:

$$(\delta E) = [(R_{sample} - R_{standard})/R_{standard}] \times 10^3 \qquad (1)$$

where

R is the ratio of the heavier to the lighter isotope for a given element (E).

Deuterium (D or ^2H) and protium (^1H) are naturally occurring stable isotopes of H, and oxygen-18 (^{18}O) and oxygen-16 (^{16}O) are naturally occurring stable isotopes of O. The standards for these isotopes ($^2H/^1H$ and $^{18}O/^{16}O$) are Vienna Standard Mean Ocean Water (VSMOW) and Standard Light Antarctic Precipitation (SLAP); by convention, the VSMOW value for δ is 0 per mil for both elements (Craig, 1961b), and the SLAP value is –428 per mil for deuterium ratios (δD). Analytical precision is plus or minus (±) 1.5 per mil for δD, and about ±0.5 per mil for $^{18}O/^{16}O$ ratios ($\delta^{18}O$; Coplen, 1994; Izbicki, 1996).

The δD and $\delta^{18}O$ composition of a groundwater sample can provide a record of the source water and its evaporative history. The isotopic composition of coastal precipitation throughout the world is correlated linearly and plots along a line known as the global meteoric water line (MWL; Craig, 1961a). Differences in the isotopic composition of precipitation occur along this line in response to trends dictated by latitude, altitude, and the temperature of condensation (Dansgaard, 1964). More negative values (depletion in the heavier relative to the lighter isotope) result when condensation takes place at colder temperatures and higher altitudes. The temperature effect, based on measurements in North America and Europe, is –0.7 per mil/°C for $\delta^{18}O$, which is equivalent to –5.6 per mil/°C for δD (Dansgaard, 1964). The altitude effect, based on measurements made on the western flank of the Sierra Nevada (not shown), is –2.3 per mil/km for $\delta^{18}O$ (Ingraham and Taylor, 1991; Rose and others, 1996). This is equivalent to –18.4 per mil/km for δD if isotope data fall on the global MWL or on a local MWL that is parallel to the global MWL. Water that has been partly evaporated is enriched in heavier isotopes relative to its original composition (Mazor, 1991); these values plot to the right of the MWL (for δD as the vertical and $\delta^{18}O$ as the horizontal axis). If the isotopic compositions of two sources are known, mixtures between these two sources will plot on a line connecting the two sources. The isotopic composition of groundwater in the study area commonly is the result of mixing processes between multiple sources.

Carbon-13 (^{13}C) and carbon-12 (^{12}C) are naturally occurring stable isotopes of C. The ratio of these isotopes is expressed as differences relative to the standard Vienna Pee Dee Belemnite (VPDB; Friedman and O'Neil, 1977; Coplen, 1994). Analytical precision is about ±0.5 per mil for the carbon-13/carbon-12 ratio ($\delta^{13}C$). Some representative $\delta^{13}C$ values are about 0 per mil in carbonates, about −8 per mil in atmospheric CO_2 at present (2018), and about −25 per mil for organic carbon in freshwater sediments (Degens, 1969) and aquifer materials (Clark and Fritz, 1999), for which the range is about ±2–3 per mil. The isotopic composition of dissolved inorganic carbon (DIC), carbonate, and bicarbonate in groundwater is usually derived from a mixture of atmospheric CO_2, oxidation (degradation or mineralization) of organic carbon, and dissolution of carbonate minerals. Because an exchange of C isotopes (equilibration) between carbonate minerals and DIC occurs, albeit slowly, groundwater could acquire less negative $\delta^{13}C$ values as it moves along a flow path from infiltration to where it is sampled in a well.

Strontium has two stable isotopes (strontium-87 [^{87}Sr] and strontium-86 [^{86}Sr]) that are measured and reported directly as atom ratios ($^{87}Sr/^{86}Sr$) to 4 or 5 significant digits. Strontium-87 in rocks and minerals is produced by decay of the radioactive isotope of rubidium (rubidium-87; ^{87}Rb), which has a half-life of 5×10^{10} years (Aldrich and others, 1956). Ratios of Sr depend on age and ^{87}Rb content of rocks and minerals; therefore, there can be large differences related to composition and age (Turekian and Wedepohl, 1961). The decay of ^{87}Rb isotope has increased the $^{87}Sr/^{86}Sr$ ratios of the Earth's crust from the initial value of 0.6989 (Wierzbowski, 2013). Because the continental crust is enriched in rubidium, its $^{87}Sr/^{86}Sr$ ratios become increasingly higher and more dissimilar from the ratios of the oceanic crust and mantle (Wierzbowski, 2013). The modern seawater $^{87}Sr/^{86}Sr$ ratio is 0.7092, but this value has ranged from 0.7068 to 0.7092 during the Phanerozoic, owing to changing inputs of strontium (Wierzbowski, 2013). Sediments from the continental crust, such as granites, will have high $^{87}Sr/^{86}Sr$ ratios (> 0.7100), whereas sediments from marine sedimentary deposits will have low $^{87}Sr/^{86}Sr$ ratios (0.708; Wierzbowski, 2013). The dissolution and exchange of strontium between solid and aqueous phases is fairly rapid, so groundwater commonly acquires a Sr isotopic signature that matches the rock type with which it was most recently in contact (Turekian and Wedepohl, 1961).

Radioactive Isotopes

Tritium (^{3}H) and ^{14}C were the two radioactive isotopes used in this study to determine water age; that is, the time needed for recharging (infiltrating) water to move through the subsurface until it is sampled at a well. The water age was used in this report to help define chronostratigraphic unit boundaries, water source, and model zones. For the simplest case (plug flow and no mixing), water age can be calculated from the radioactive decay equation:

$$A = A_0{}^{-\lambda t}, \text{ or its equivalent}$$

$$2.303(\mathrm{Log}[A] - \mathrm{Log}[A_0]) = -\lambda t \qquad (2)$$

where

A is the current activity,
A_o is the activity in the water at its time of recharge,
λ is the decay constant, and
t is time, in years.

The half-life (time for activity of the nuclide to decay by half) is given by $t_{½}=0.693/\lambda$. The half-life is 12.32 years for ^{3}H (Lucas and Unterweger, 2000) and 5,730 years for ^{14}C (Godwin, 1962).

Tritium is a naturally occurring radioactive isotope produced by the interaction of high-energy cosmic rays with the upper atmosphere (Mazor, 1991). For this study, tritium activity in samples was measured and reported in tritium units (TUs); 1 TU is equivalent to 1 ^{3}H atom per 10^{18} hydrogen atoms (Taylor and Roether, 1982). Activity also is commonly reported in units of picocuries per liter (pCi/L); 1 TU is approximately 3.19 pCi/L. Relatively high amounts of ^{3}H were introduced into the environment during the atmospheric detonation of thermonuclear bombs beginning in the early 1950s. This raised the ^{3}H concentration in precipitation several-hundredfold by the time testing was halted in 1963; however, ^{3}H concentrations in precipitation subsequently declined and are currently (2018) near natural background levels in many locations. Harms and others (2016) reported an activity of 2.5 TU in a rainfall sample collected near downtown Los Angeles in 2014. Activities ranging from 1.3 to 2.6 TU were measured in 7 of 8 rainfall samples collected during 2006 at an author's residence (R.A. Schroeder) on the coast in San Diego County. Activities in the Sierra Nevada snowpack were 3–4 TU during the winter of 2006–07 (R.L. Michel, USGS, written commun., 2007).

Absence of ^{3}H indicates water that recharged the aquifer earlier than about 1950; very high activity indicates water that infiltrated near the time of the "bomb peak" in the early 1960s; and low activity indicates either very recent recharge or a mixture of water with different ages if the simplifying assumptions are not valid (Mazor, 1991). For this study, water with a tritium content less than 1 TU is interpreted as "older" water recharged prior to 1952, while water with tritium content greater than or equal to 1 TU is interpreted as "modern" water recharged after 1952.

A naturally occurring radioactive isotope of carbon, ^{14}C, is produced by cosmic-ray spallation from nitrogen in the atmosphere (Mazor, 1991). Because of its long half-life, ^{14}C can be used to date water that is much older than is possible with ^{3}H. Carbon-14 is measured from the DIC in water and reported as percent modern carbon (pmc) by comparing ^{14}C activities to the specific activity of National Bureau of Standards oxalic acid; 12.88 disintegrations per minute per gram (g) of C in the year 1950 equals 100 pmc (Mazor, 1991). Activity of ^{14}C has varied in the past in response to fluctuations in its natural production rate; activity has been decreased by injection of CO_2 containing no ^{14}C into the atmosphere from burning of fossil fuel since the beginning of the Industrial Age approximately 200 years ago, and activity recently has increased with the nuclear era (Mazor, 1991). These factors are not important in the calculation of ^{14}C water ages for old water in this study as any effect is much less notable than is the exchange of aqueous DIC with carbonate minerals. The carbonate minerals have little or no ^{14}C resulting in a decrease in activity and corresponding increase in calculated "apparent" age of the DIC (Brinkmann and others, 1959; Vogel and Ehhalt, 1963).

Application of Water-Quality Data

Major-ion composition, boron concentrations, chloride-to-boron ratios, age of the water, and the stable-isotope ratios for H, O, and Sr were used in this study to help define the chronostratigraphic unit boundaries, sediment source, sediment facies, water source, and model zones. The following sections of the report describe how these different water-quality data or parameters were applied in this study.

Chronostratigraphic Boundaries

Following the initial identification of chronostratigraphic unit boundaries (see Chapter B), the boundary locations were refined using water-quality data from samples from the multiple-well monitoring sites (table 1.2). The principal water-quality data used were major-ion composition, dissolved-solids concentration, Cl/B ratio, stable isotopes of water, Sr isotope ratio, and water age. Samples from wells screened in the same chronostratigraphic unit along a flow path were compared to determine if they had similar water-quality characteristics. If the characteristics were similar, no adjustment was made; however, if the characteristics differed, then the boundary locations were re-evaluated. Maps were prepared showing selected water-quality parameters to help identify where differences occur in a selected parameter in each chronostratigraphic unit (figs. 1.3–1.8). These maps often show spatial patterns of gradual change in the values of water-quality parameters across the LACP within individual chronostratigraphic units, but local deviations from the regional spatial trends were carefully evaluated as supporting evidence to assign chronostratigraphic units to the wells in question (figs. 1.3–1.8).

Sediment Source

In this study, strontium isotope ratios were used as geochemical tracers of sediment source. As stated in the "Stable Isotopes" section of this appendix, the dissolution and exchange of strontium between solid and aqueous phases is fairly rapid, so groundwater commonly acquires a Sr isotopic signature that matches the rock type with which it was most recently in contact (Turekian and Wedepohl, 1961). In this context, it was assumed that the $^{87}Sr/^{86}Sr$ ratio of a groundwater sample can be used to determine the origin of the sediment. The $^{87}Sr/^{86}Sr$ ratios in samples collected from wells within and adjacent to the LACP ranged from 0.7080 to 0.7116 (n=184; table 1.2). Major sources of sediment to LACP include the Los Angeles River, San Gabriel River, Santa Ana River, and the low-lying hills that border the LACP (fig. 1.1).

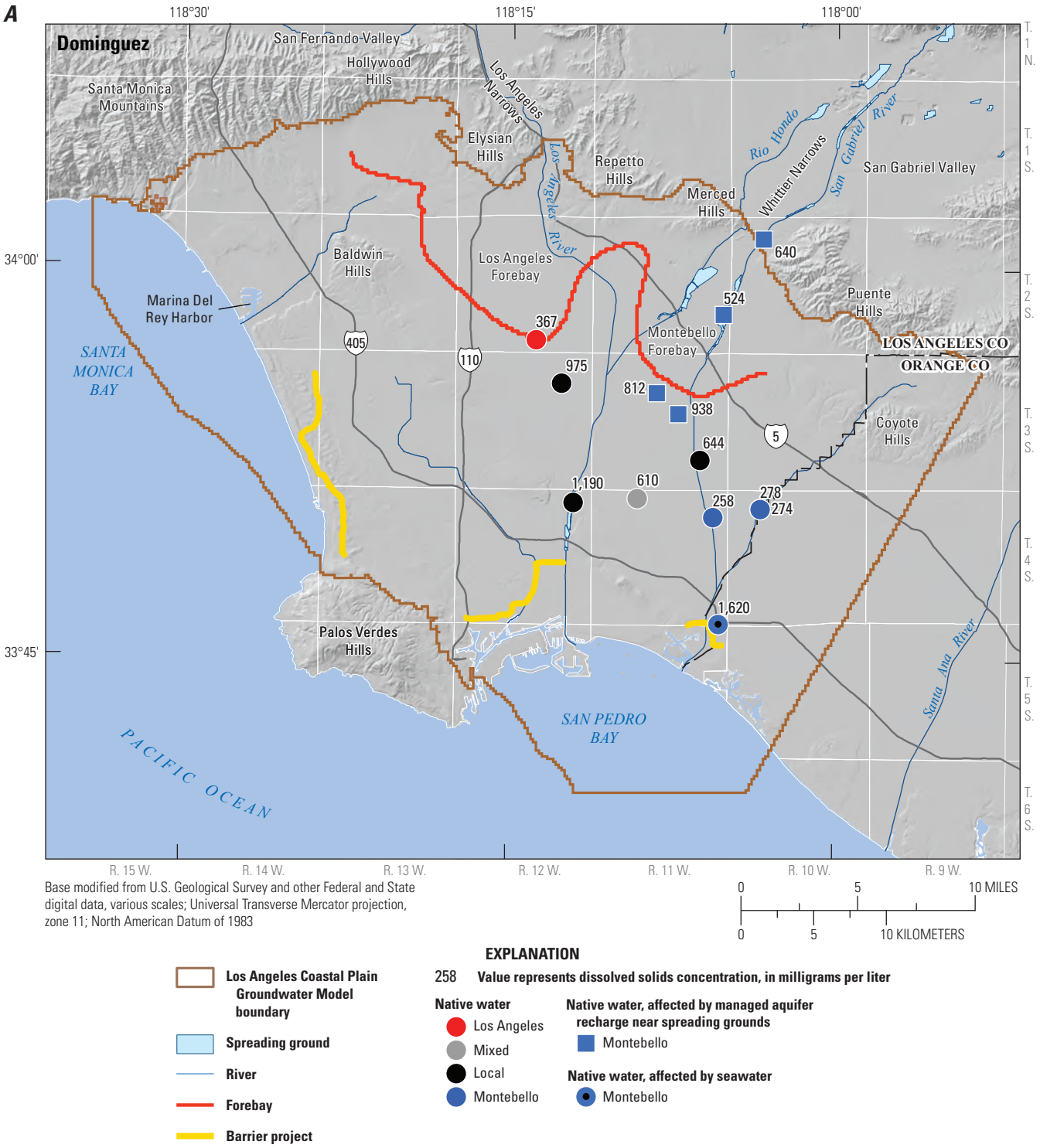
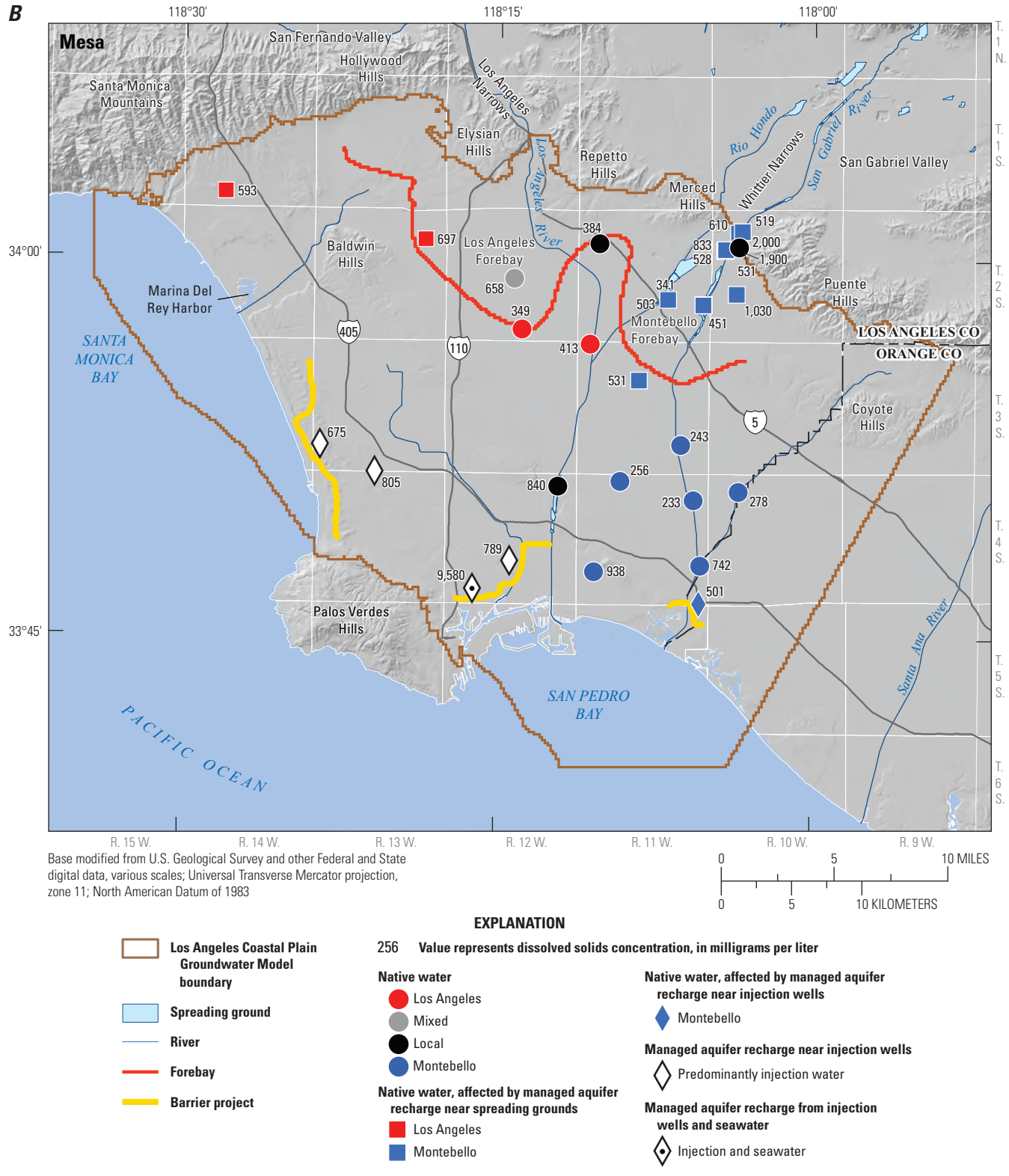


Figure 1.3. Dissolved-solids concentrations in samples from monitoring wells screened in chronostratigraphic units in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California: *A*, Dominguez; *B*, Mesa; *C*, Pacific A; *D*, Pacific; *E*, Harbor; *F*, Bent Spring; *G*, Upper Wilmington A; *H*, Upper Wilmington B; *I*, Lower Wilmington; *J*, Long Beach A; *K*, Long Beach B; *L*, Long Beach BC; *M*, Long Beach C; and *N*, Tertiary.



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

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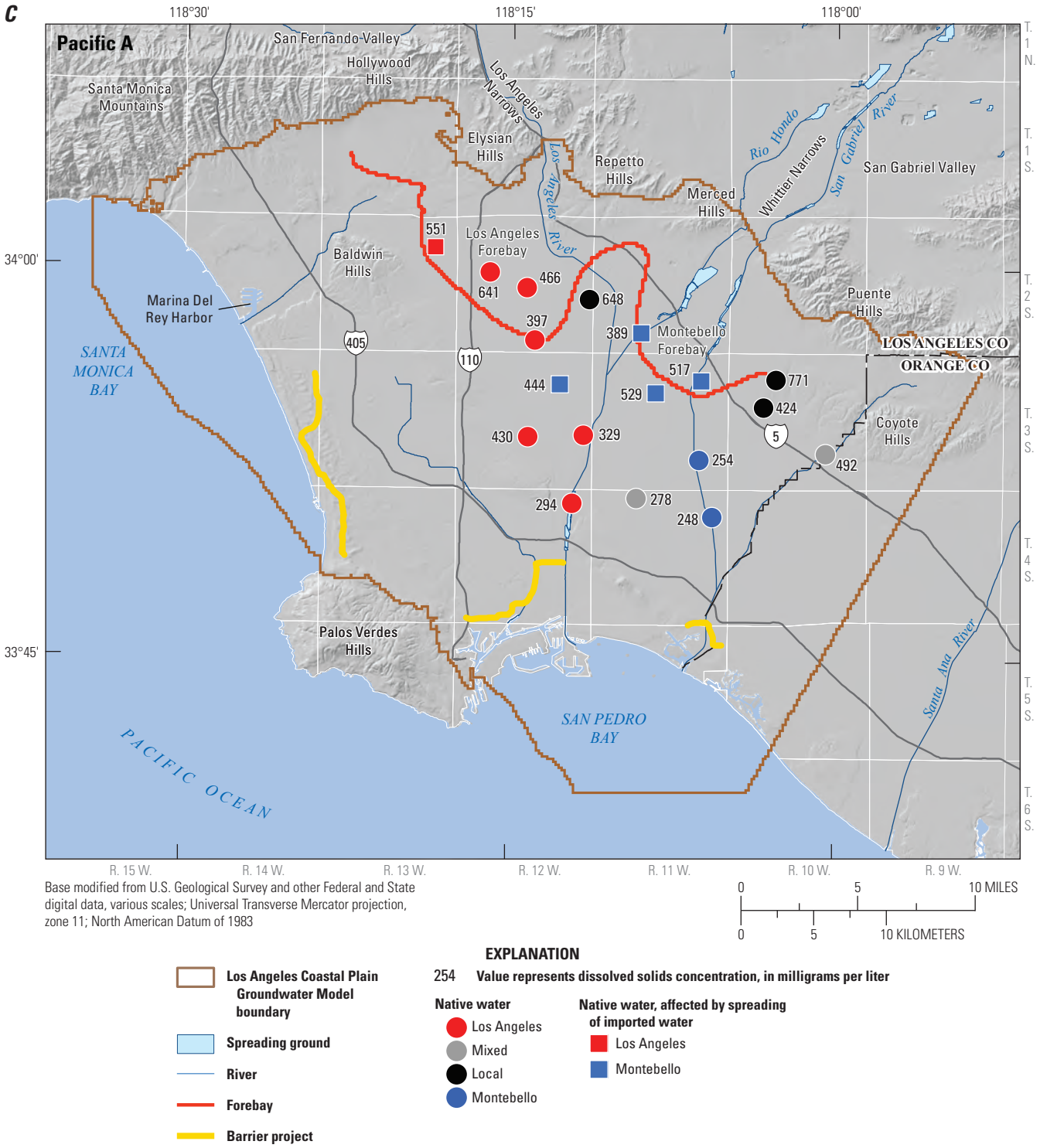
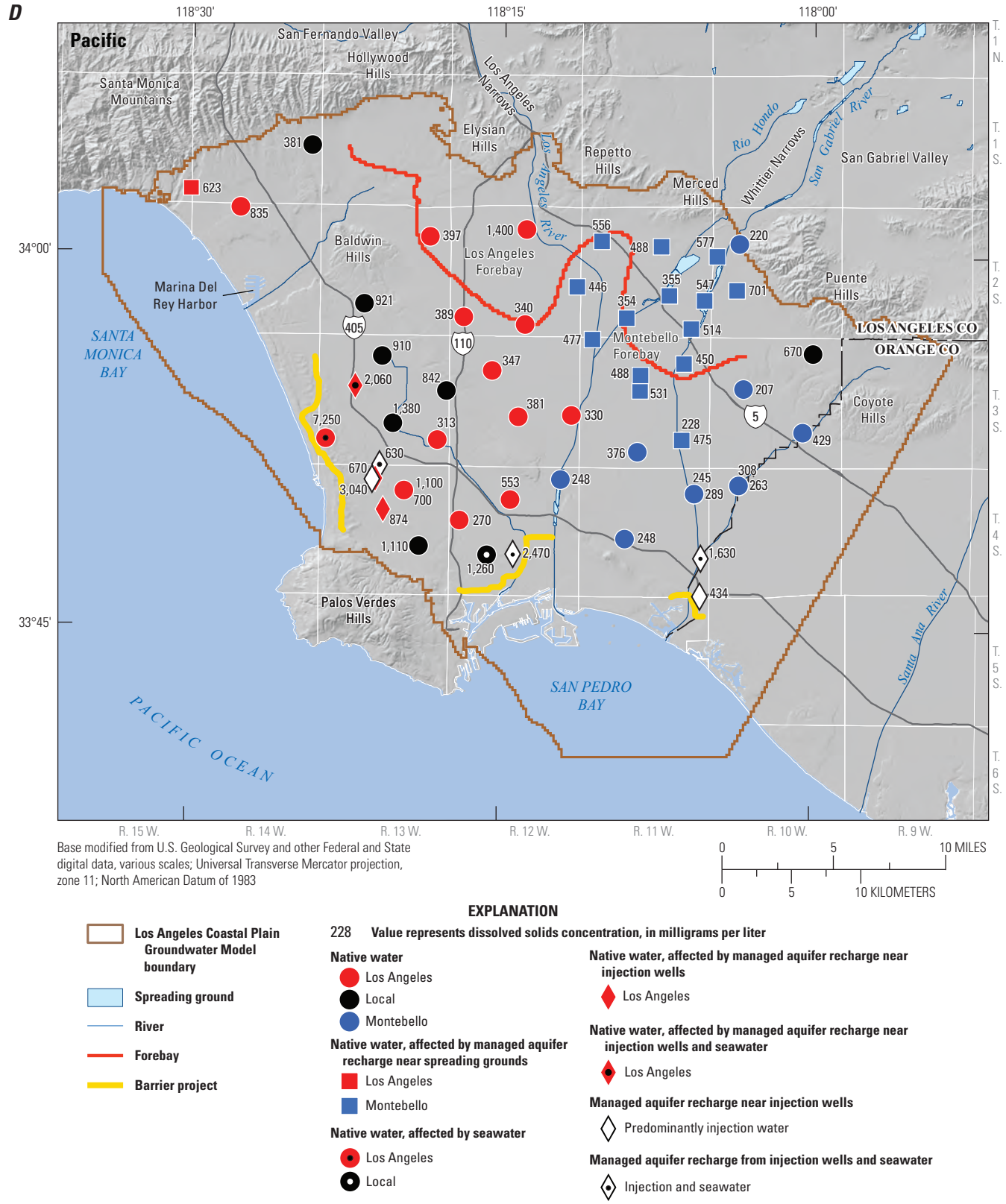


Figure 1.3.—Continued



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

EXPLANATION

- **Los Angeles Coastal Plain Groundwater Model boundary**
- **Spreading ground**
- **River**
- **Forebay**
- **Barrier project**

228 **Value represents dissolved solids concentration, in milligrams per liter**

Native water
- Los Angeles
- Local
- Montebello

Native water, affected by managed aquifer recharge near spreading grounds
- Los Angeles
- Montebello

Native water, affected by seawater
- Los Angeles
- Local

Native water, affected by managed aquifer recharge near injection wells
- Los Angeles

Native water, affected by managed aquifer recharge near injection wells and seawater
- Los Angeles

Managed aquifer recharge near injection wells
- Predominantly injection water

Managed aquifer recharge from injection wells and seawater
- Injection and seawater

Figure 1.3.—Continued

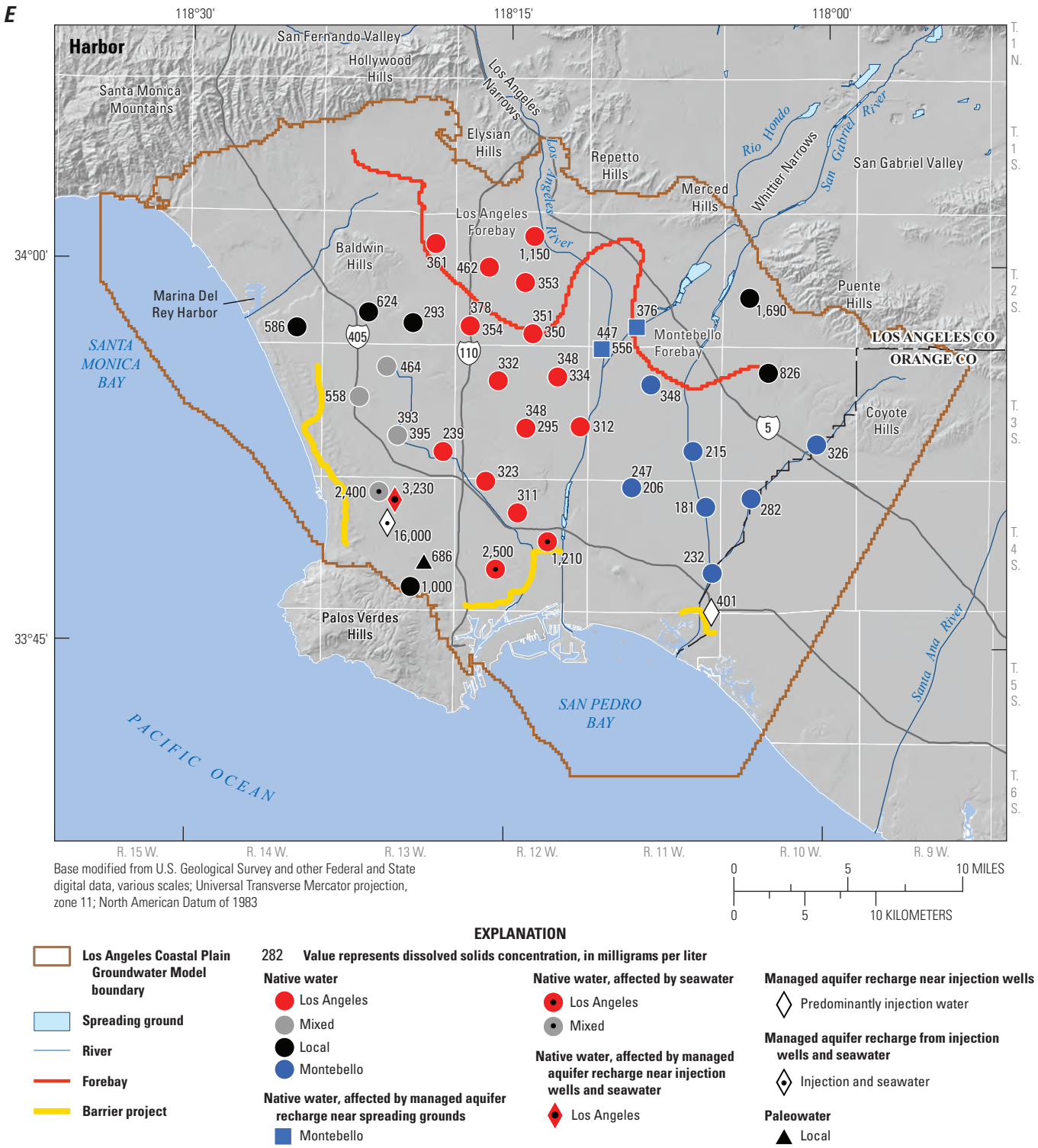


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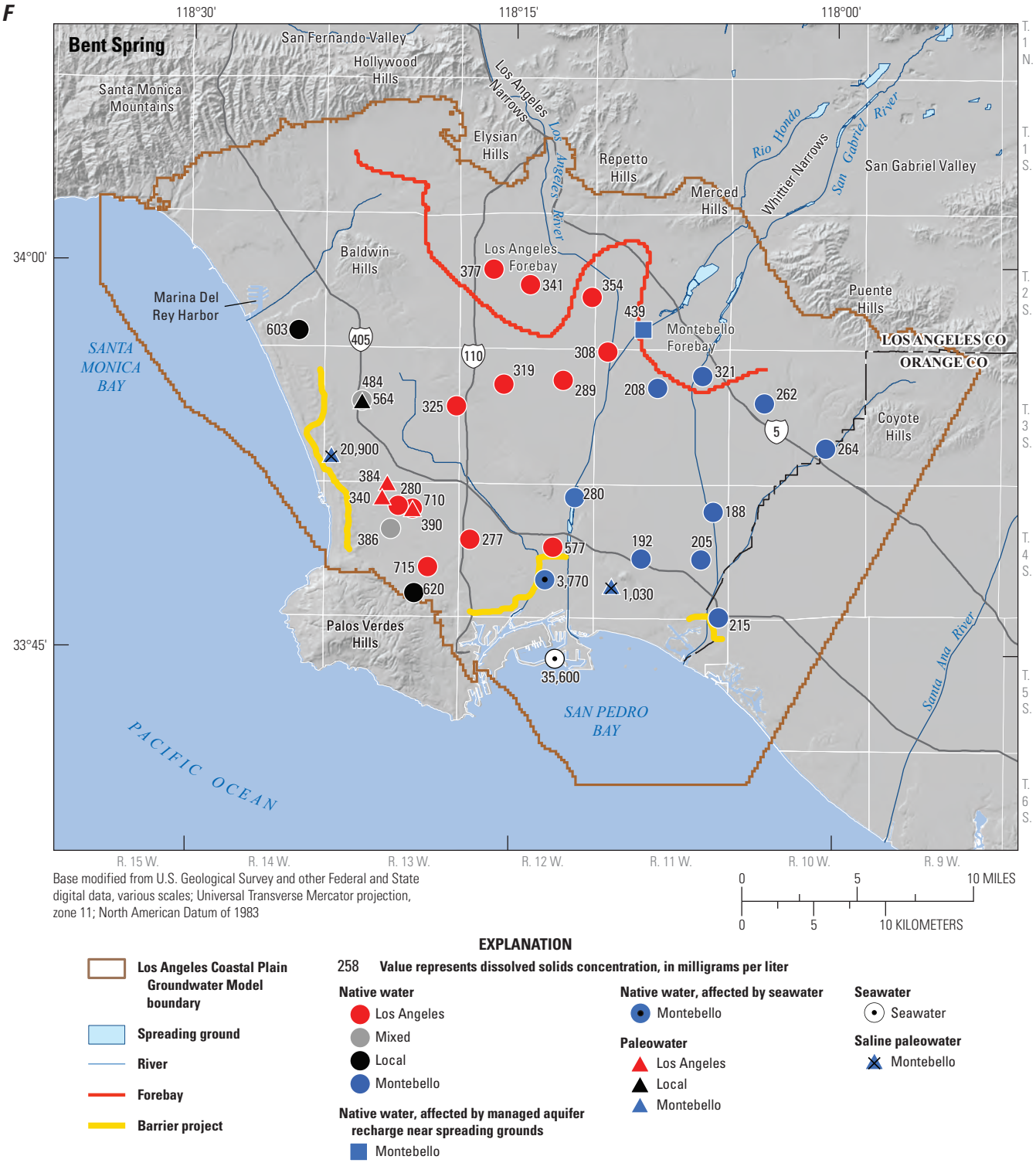


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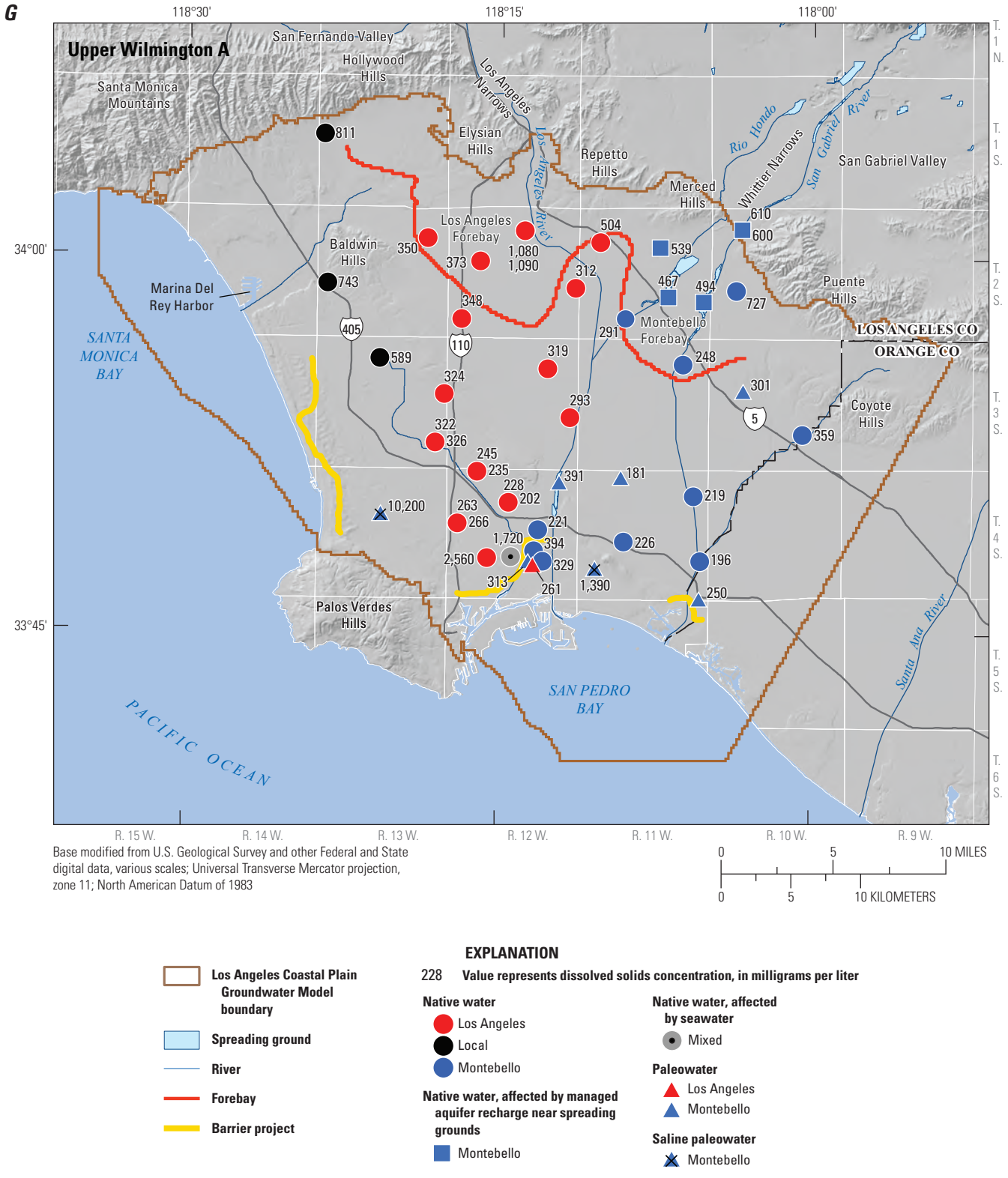


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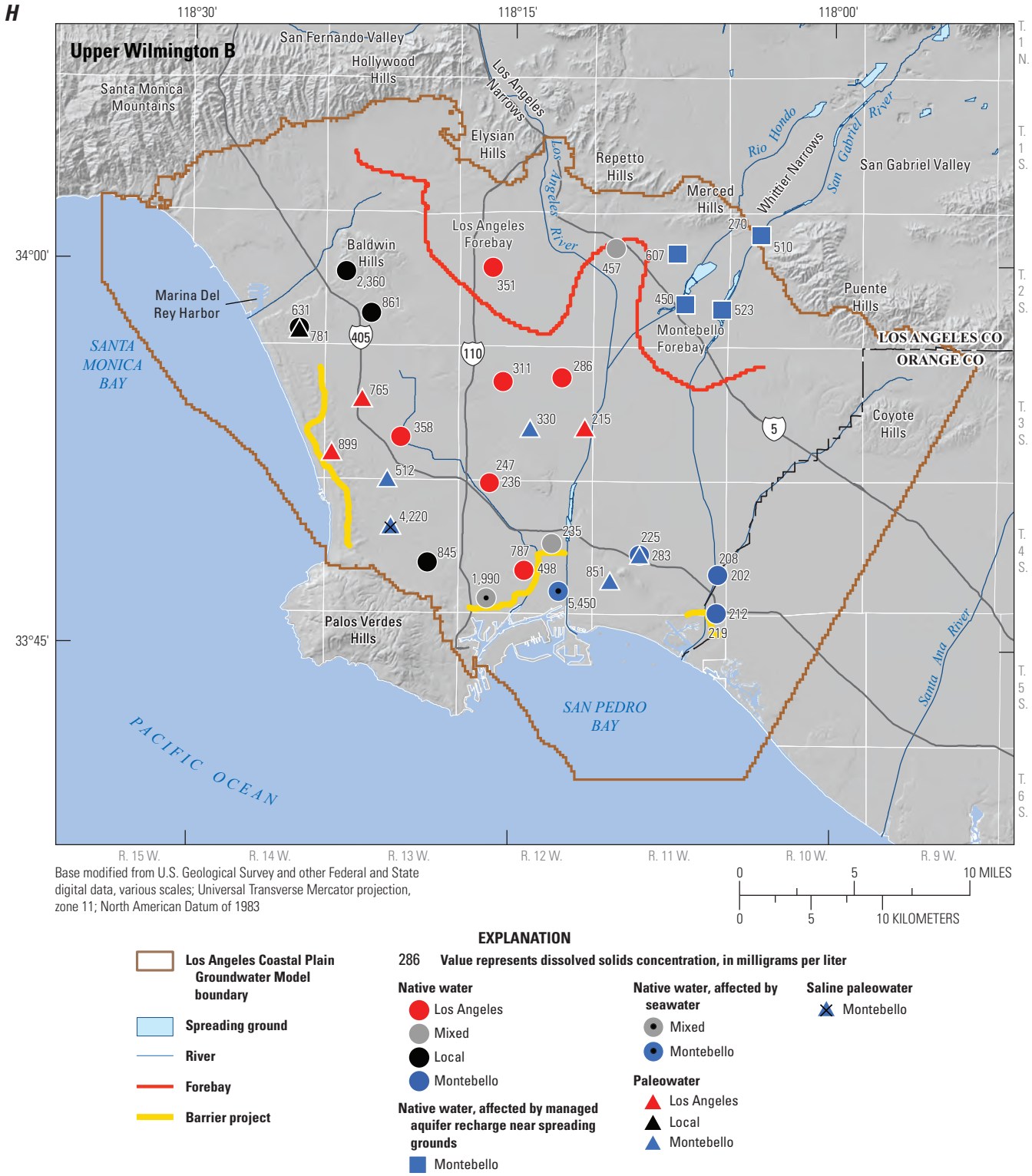


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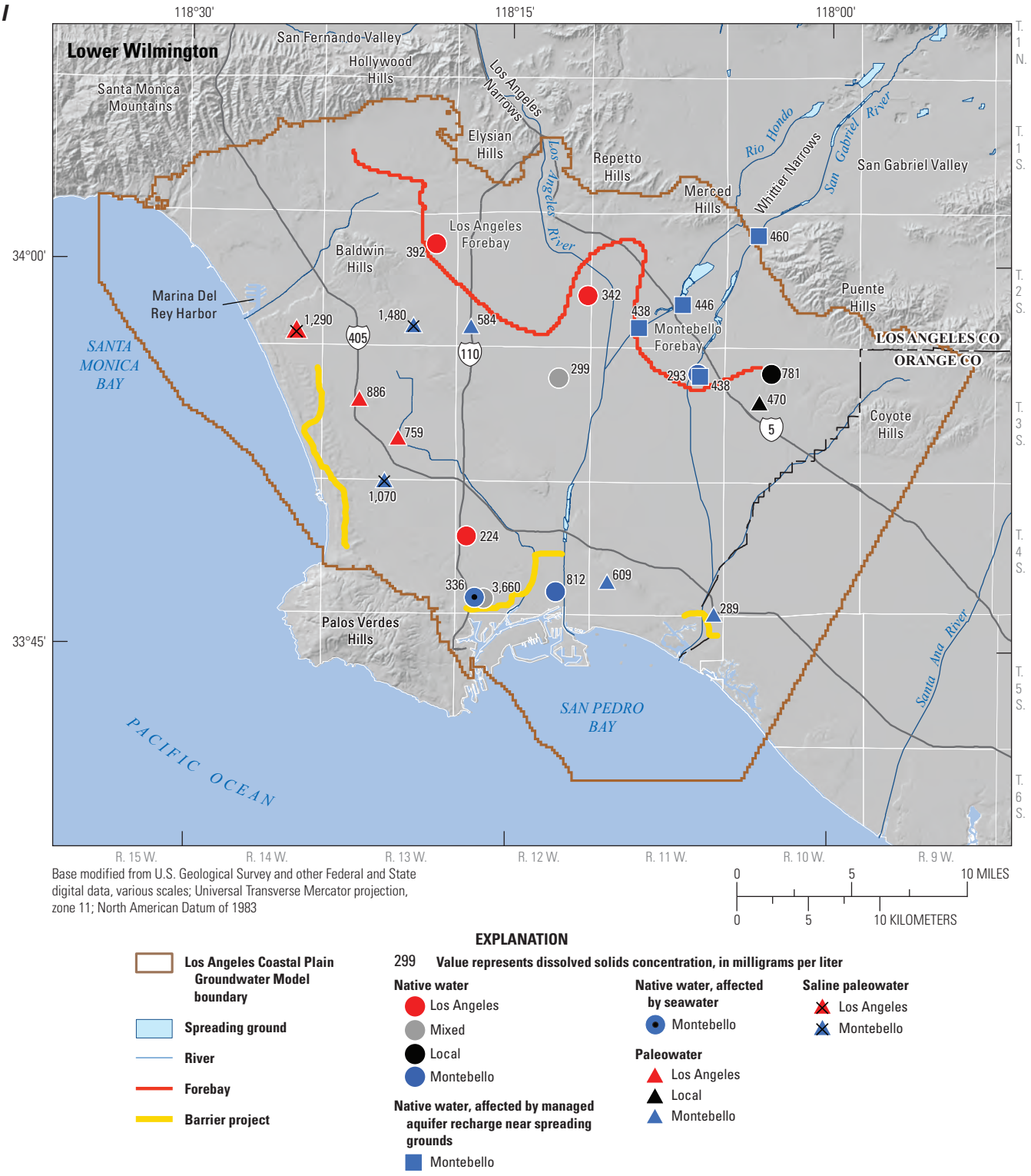
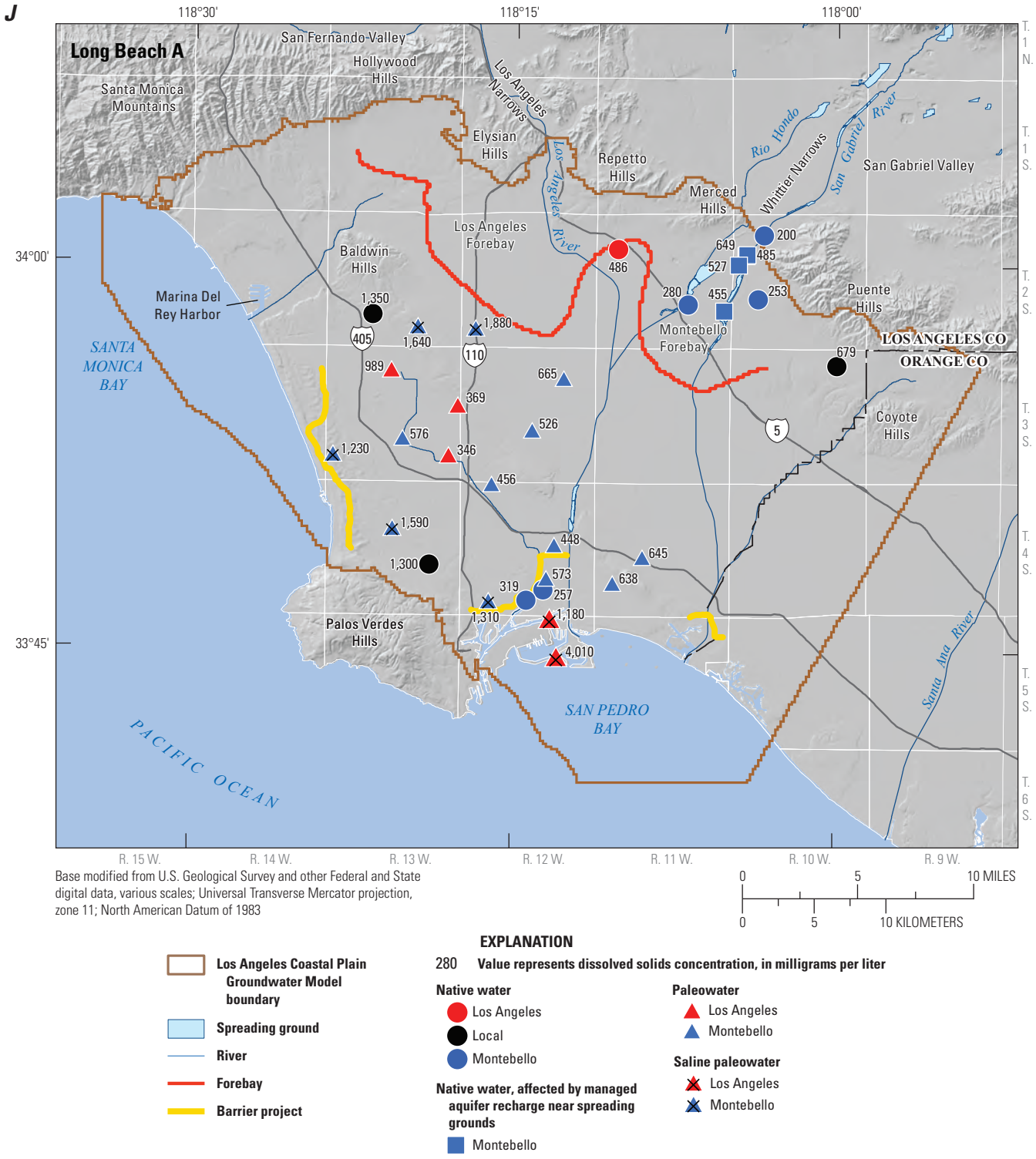


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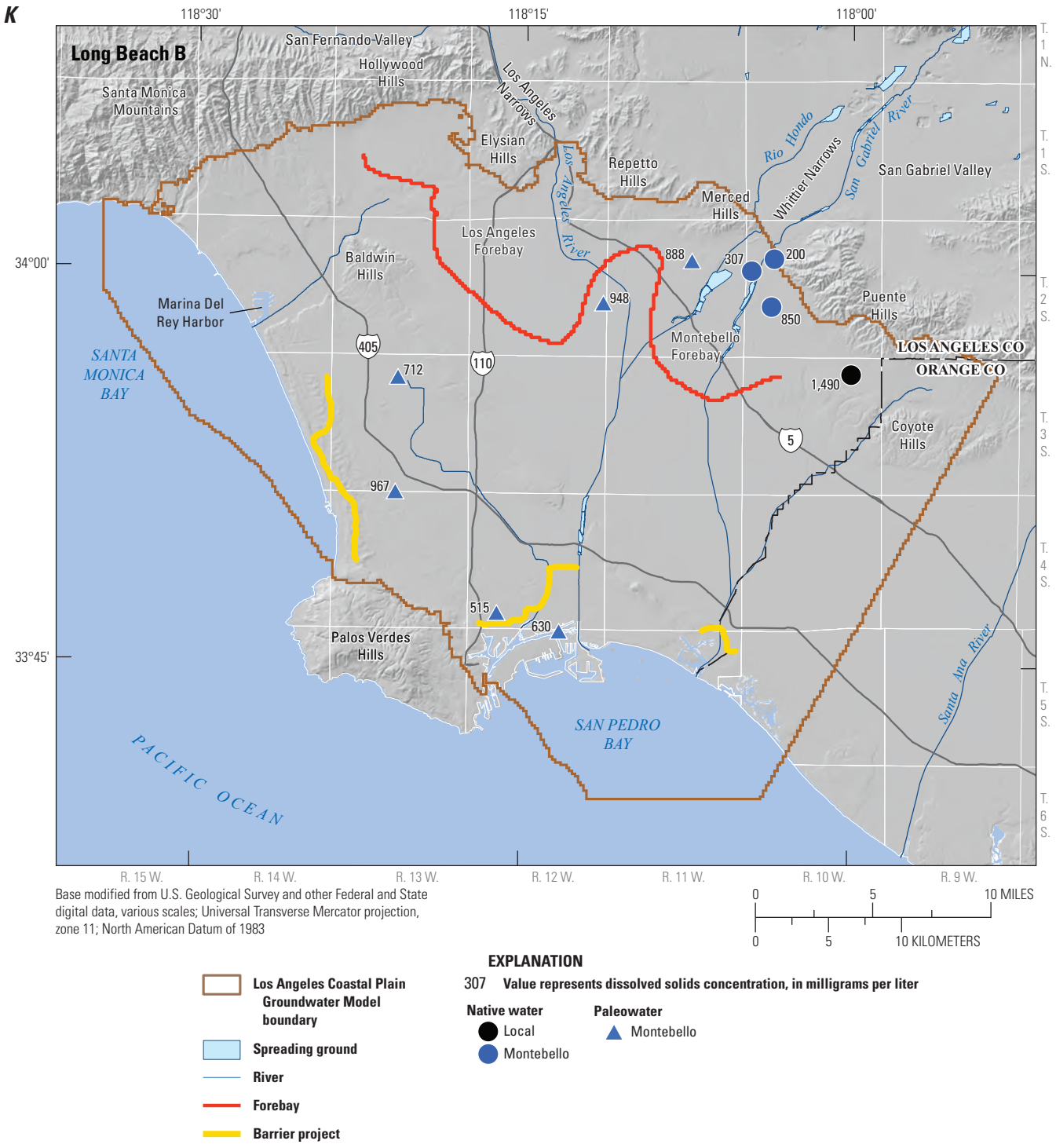


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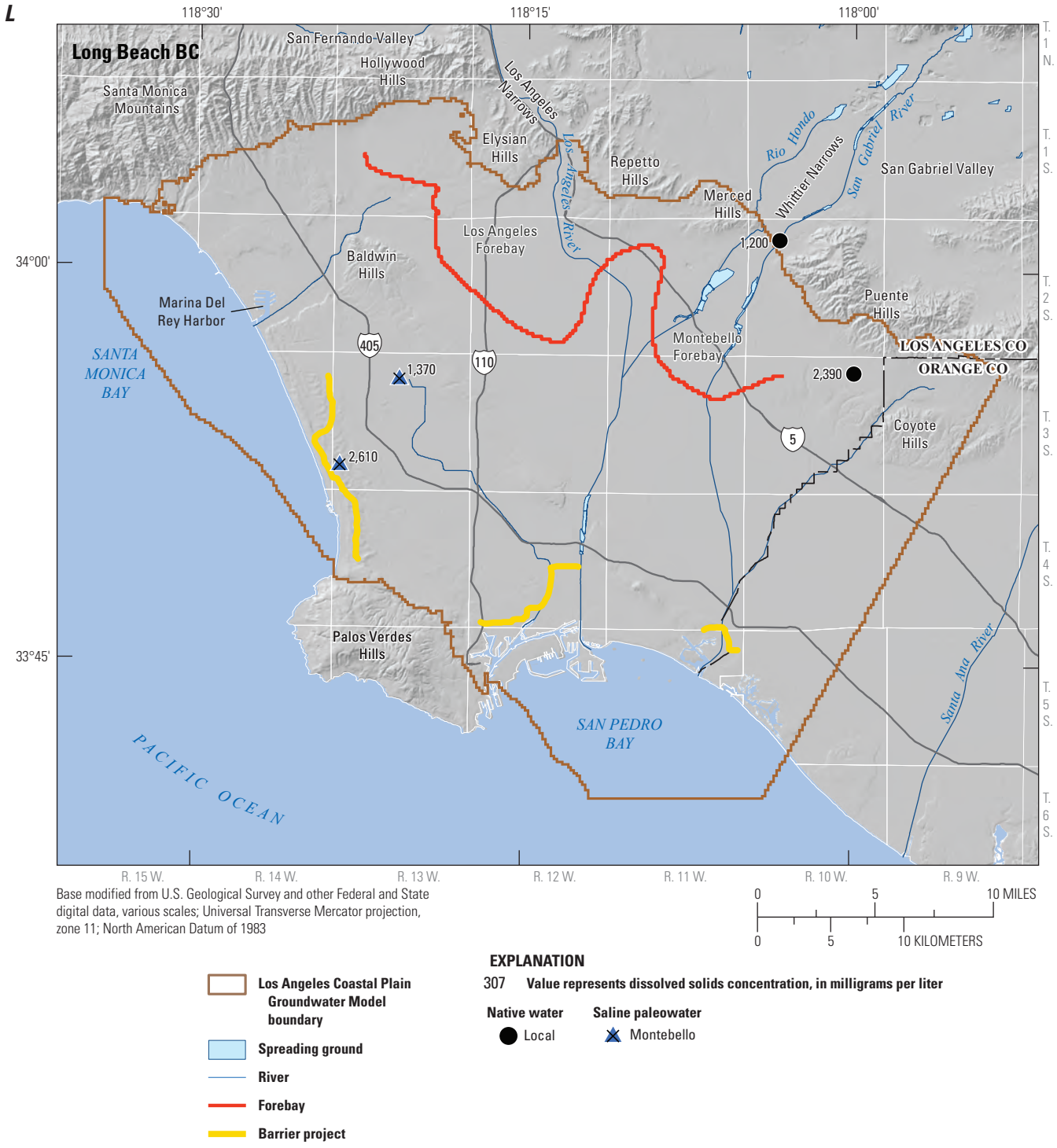


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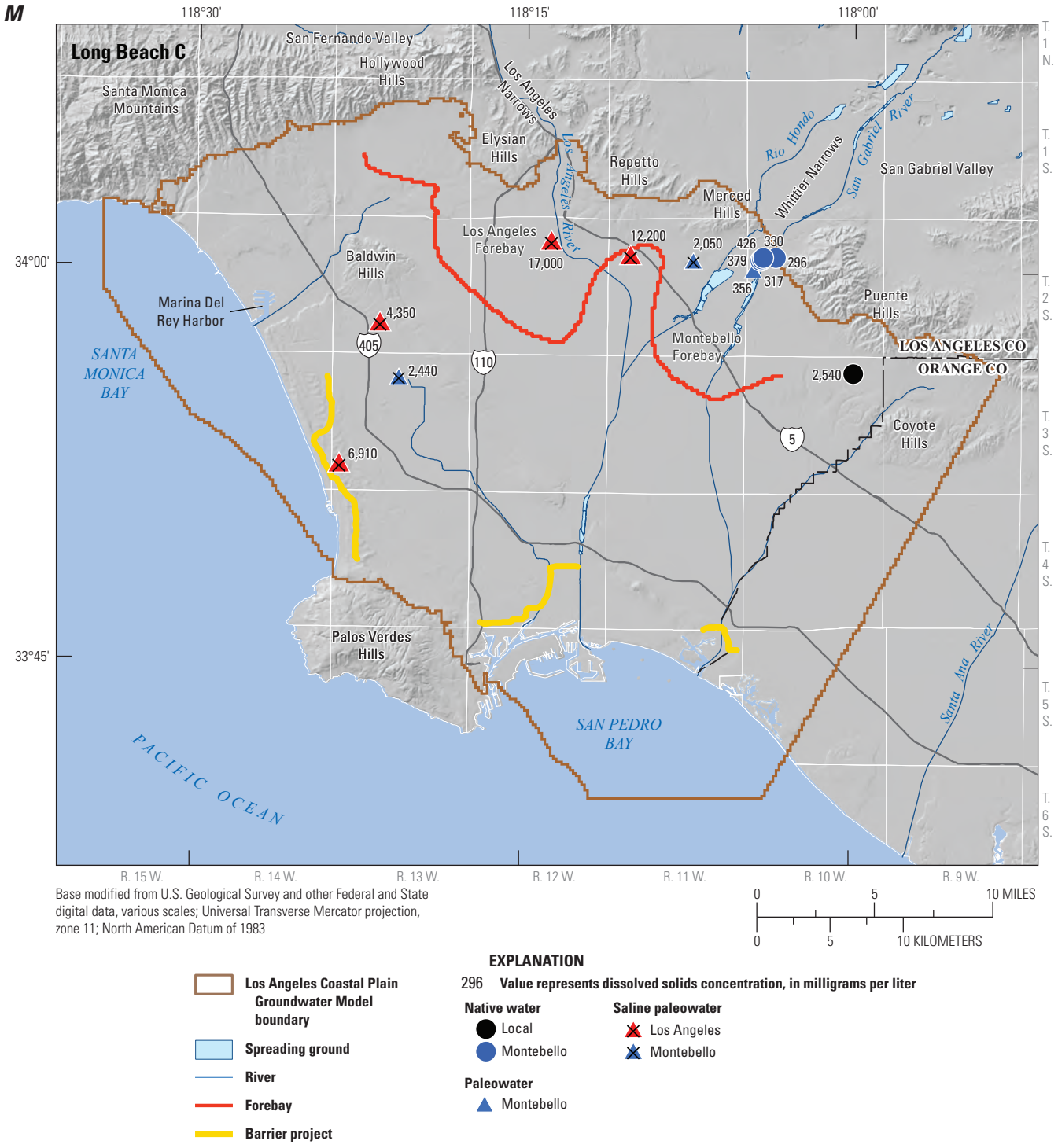


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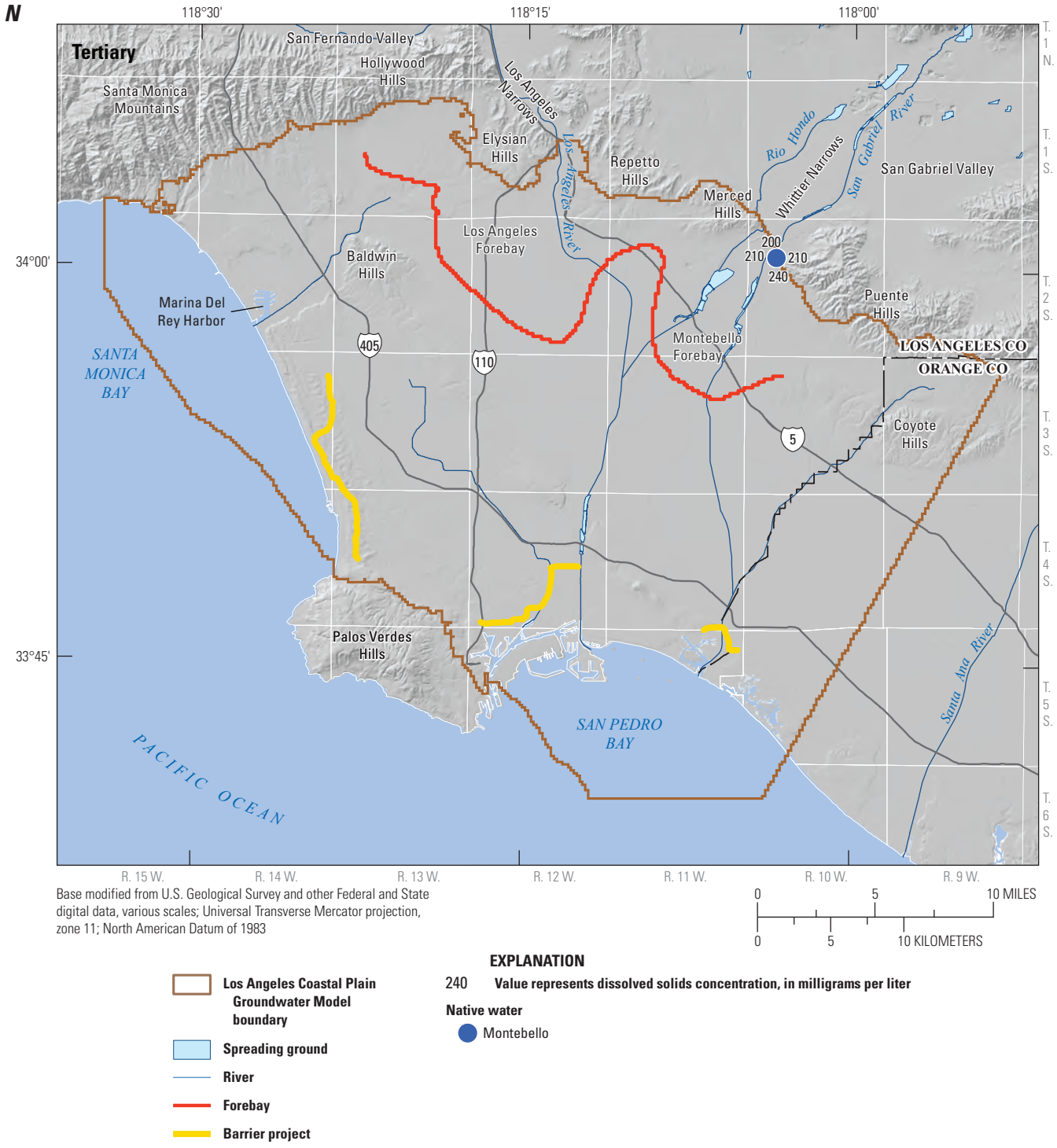


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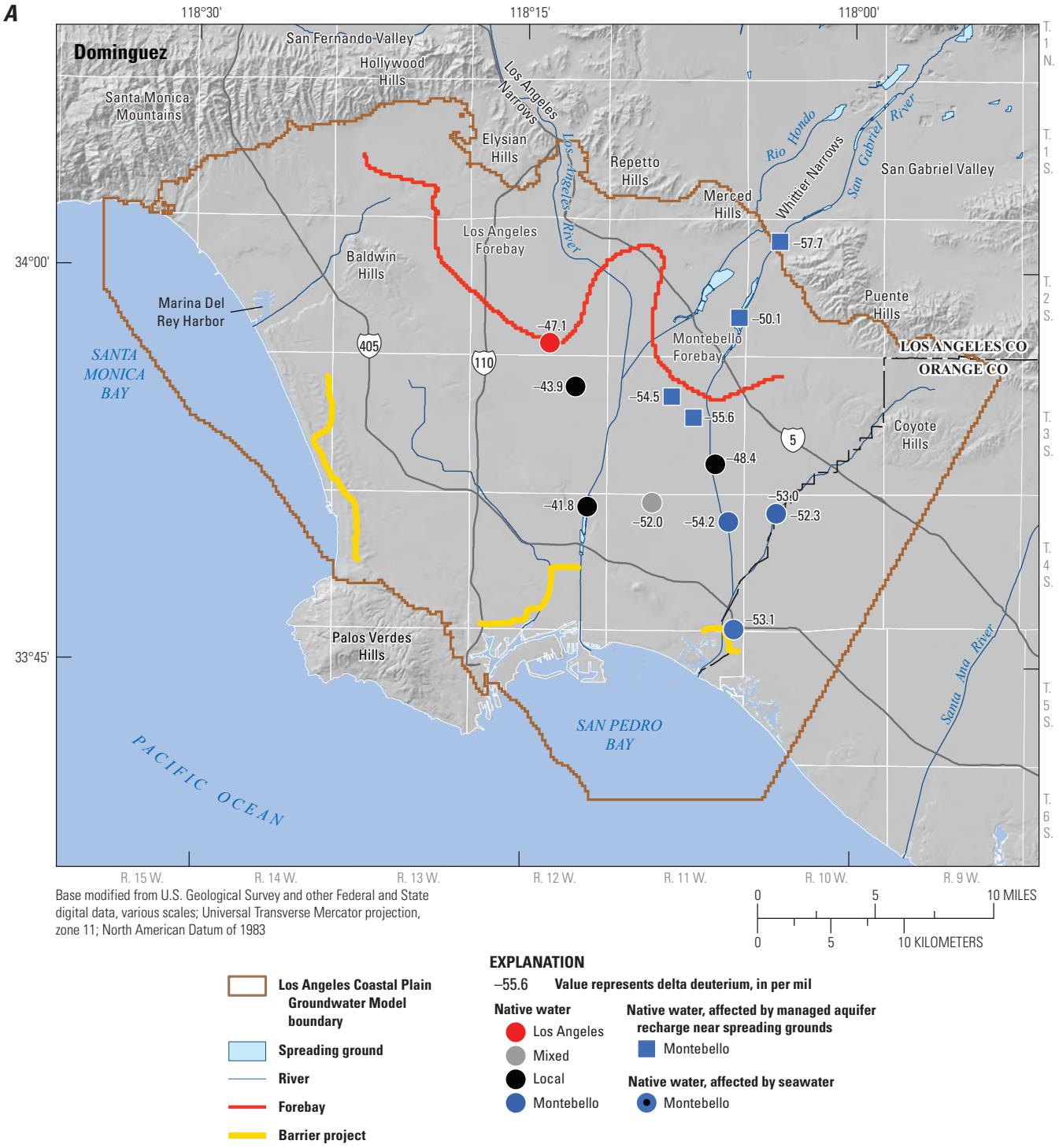


Figure 1.4. Delta deuterium values in samples from monitoring wells screened in chronostratigraphic units in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California: *A*, Dominguez; *B*, Mesa; *C*, Pacific A; *D*, Pacific; *E*, Harbor; *F*, Bent Spring; *G*, Upper Wilmington A; *H*, Upper Wilmington B; *I*, Lower Wilmington; *J*, Long Beach A; *K*, Long Beach B; *L*, Long Beach BC; *M*, Long Beach C; and *N*, Tertiary.

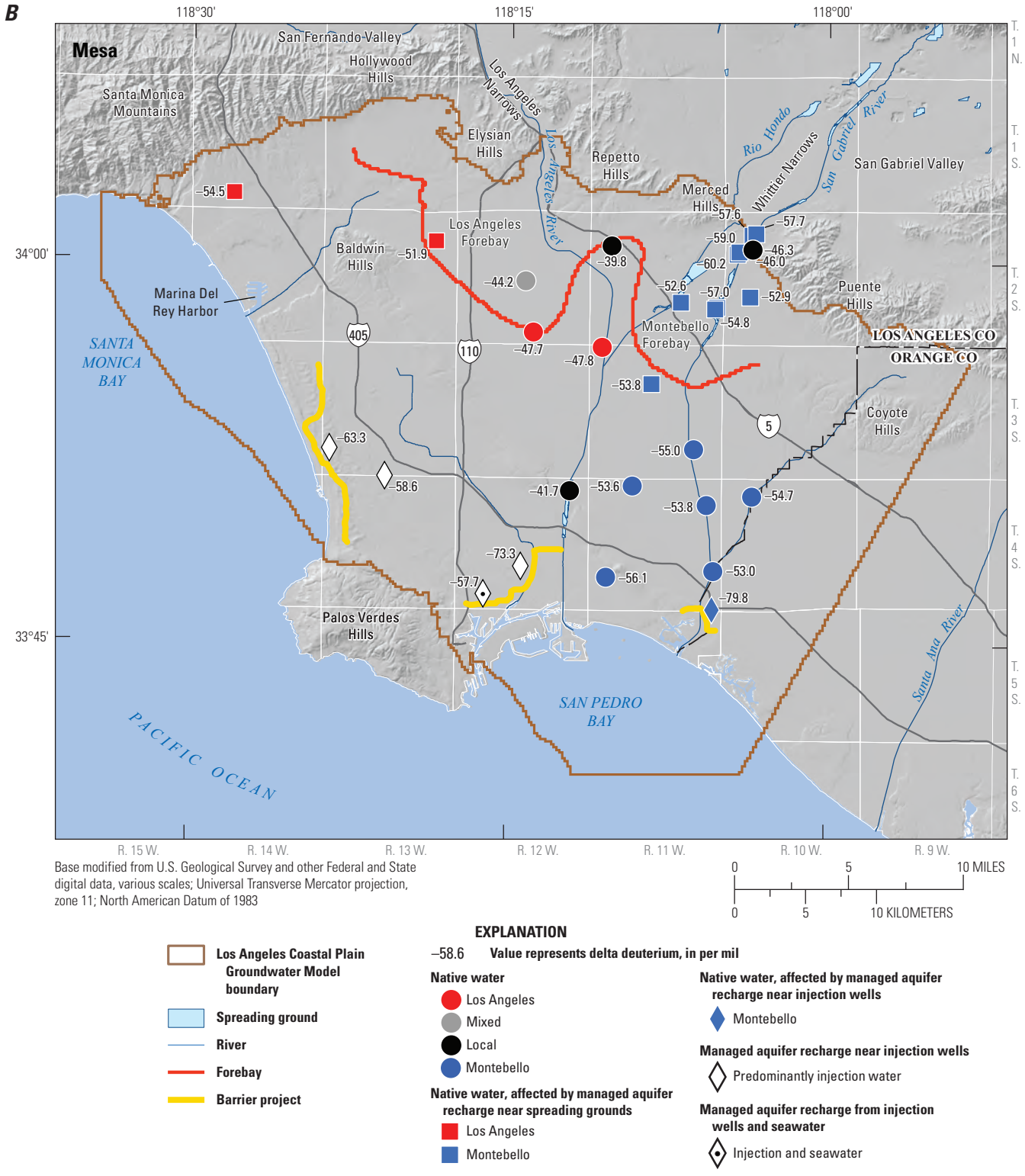


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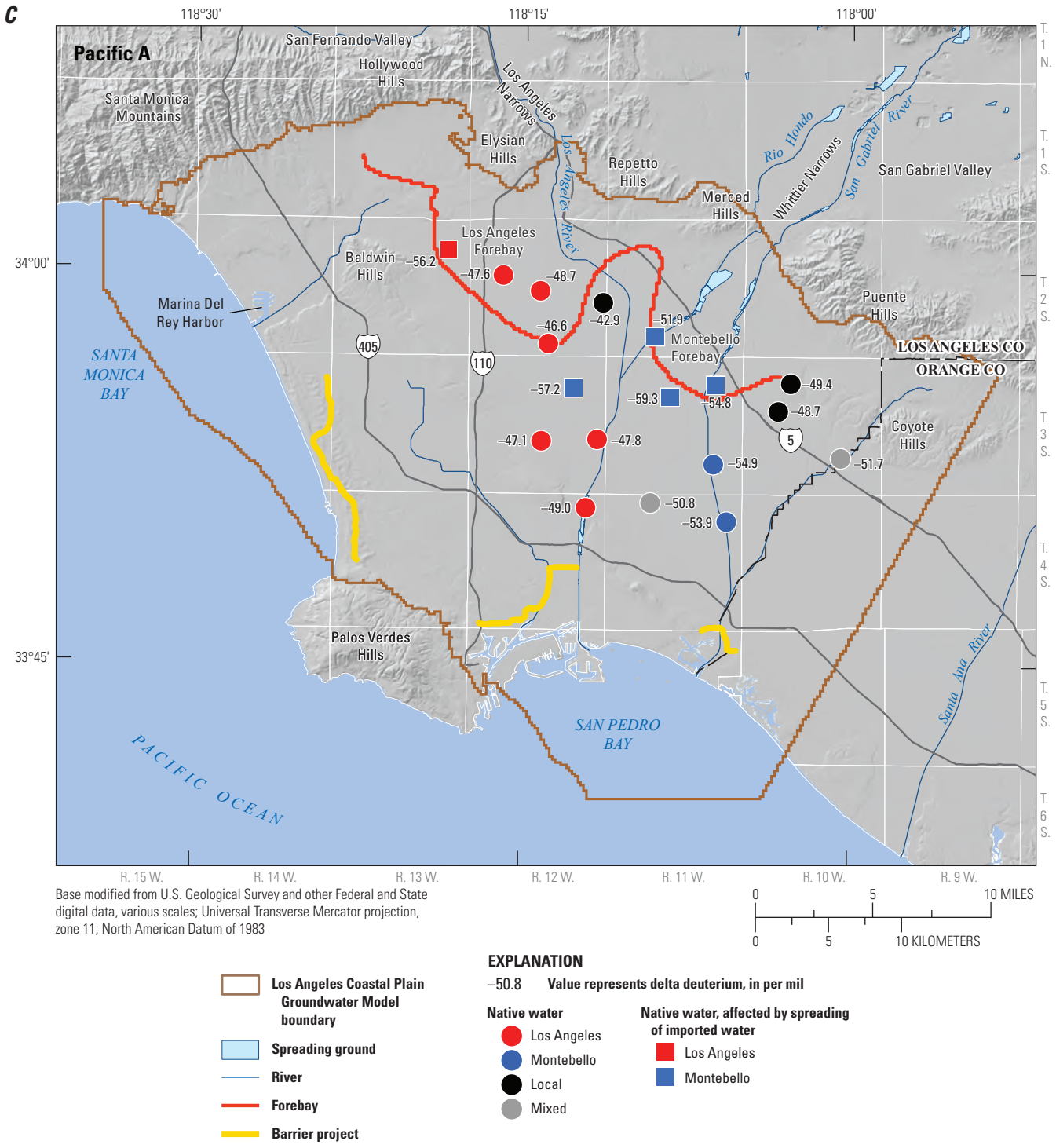


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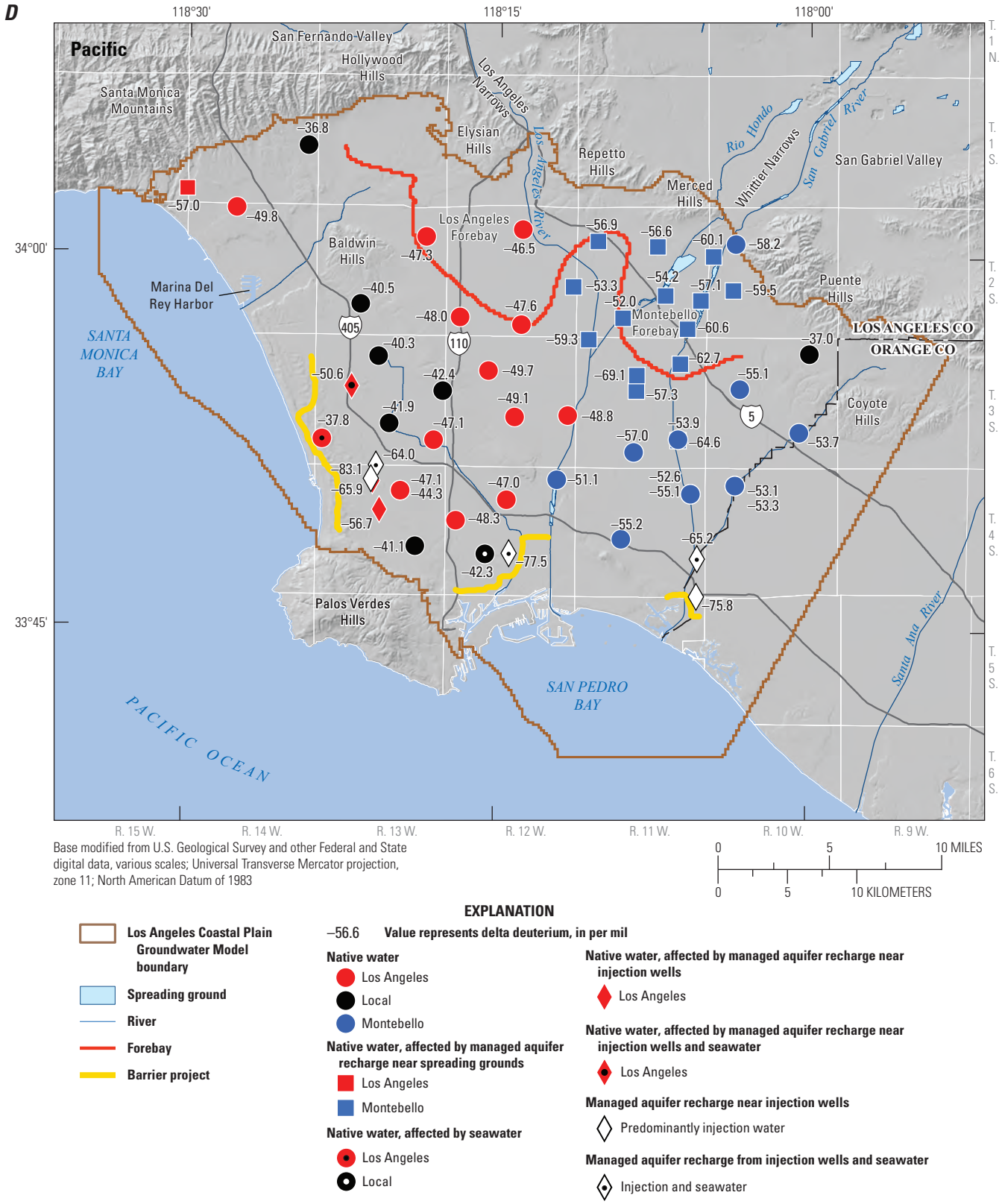


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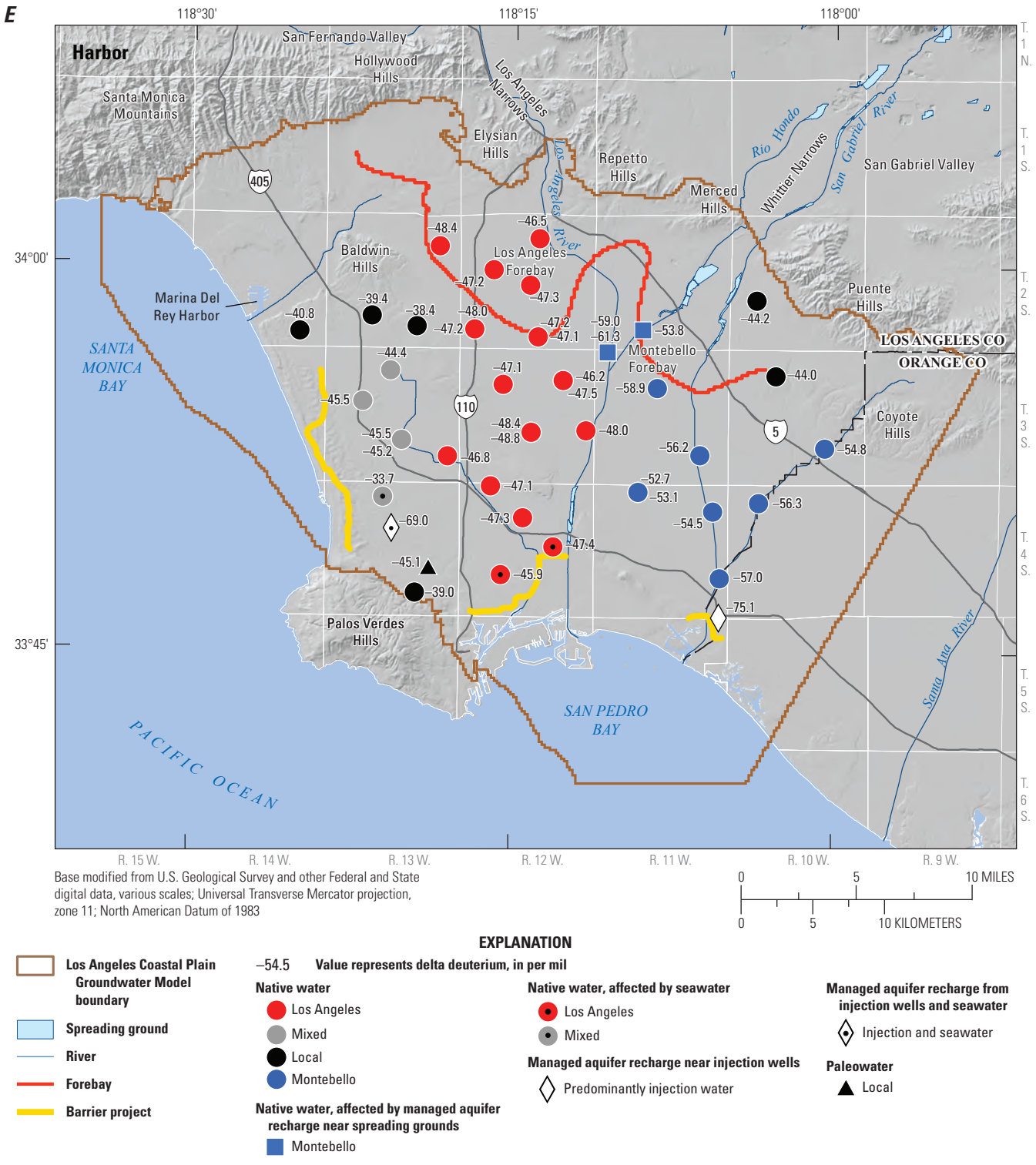


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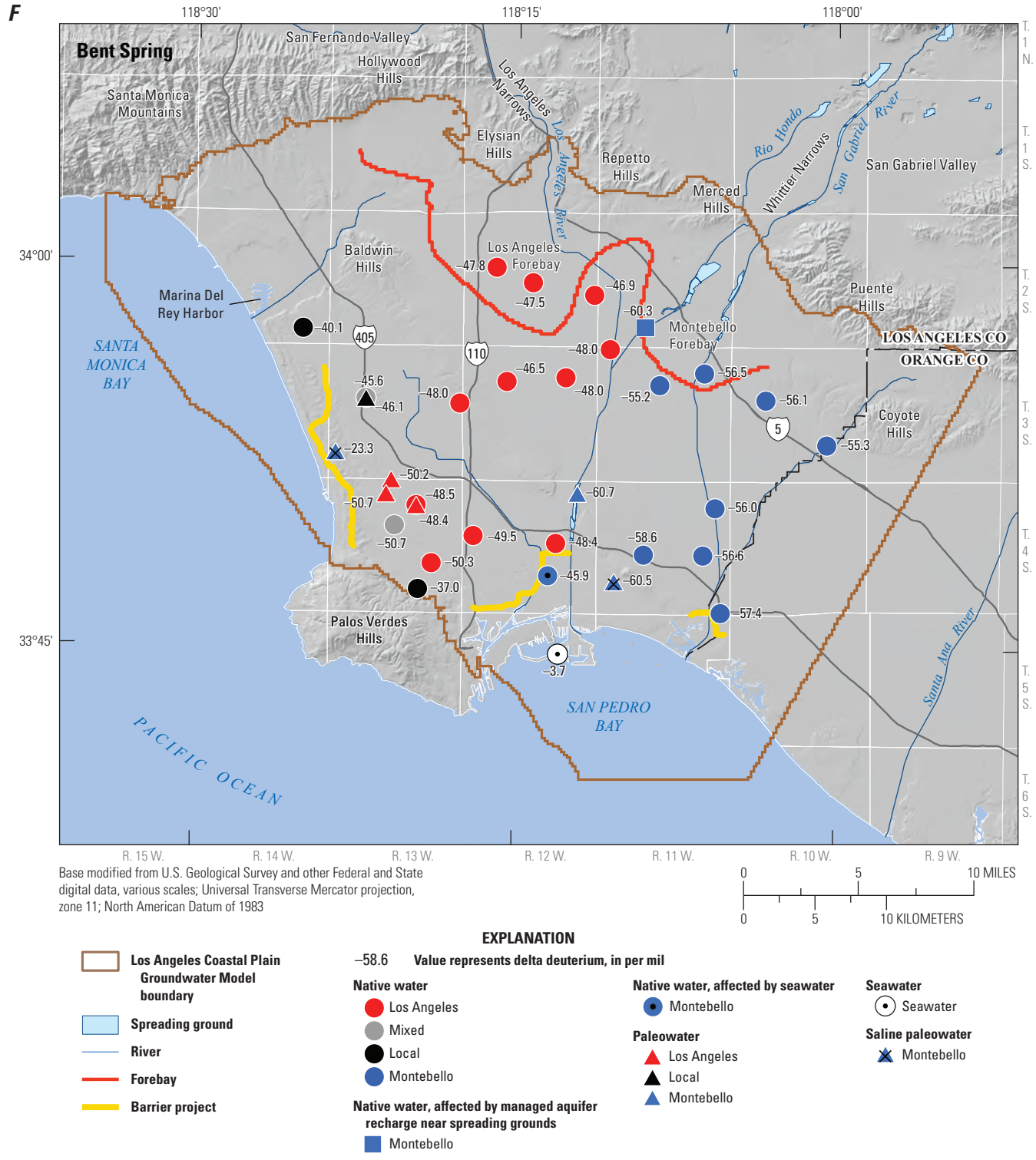


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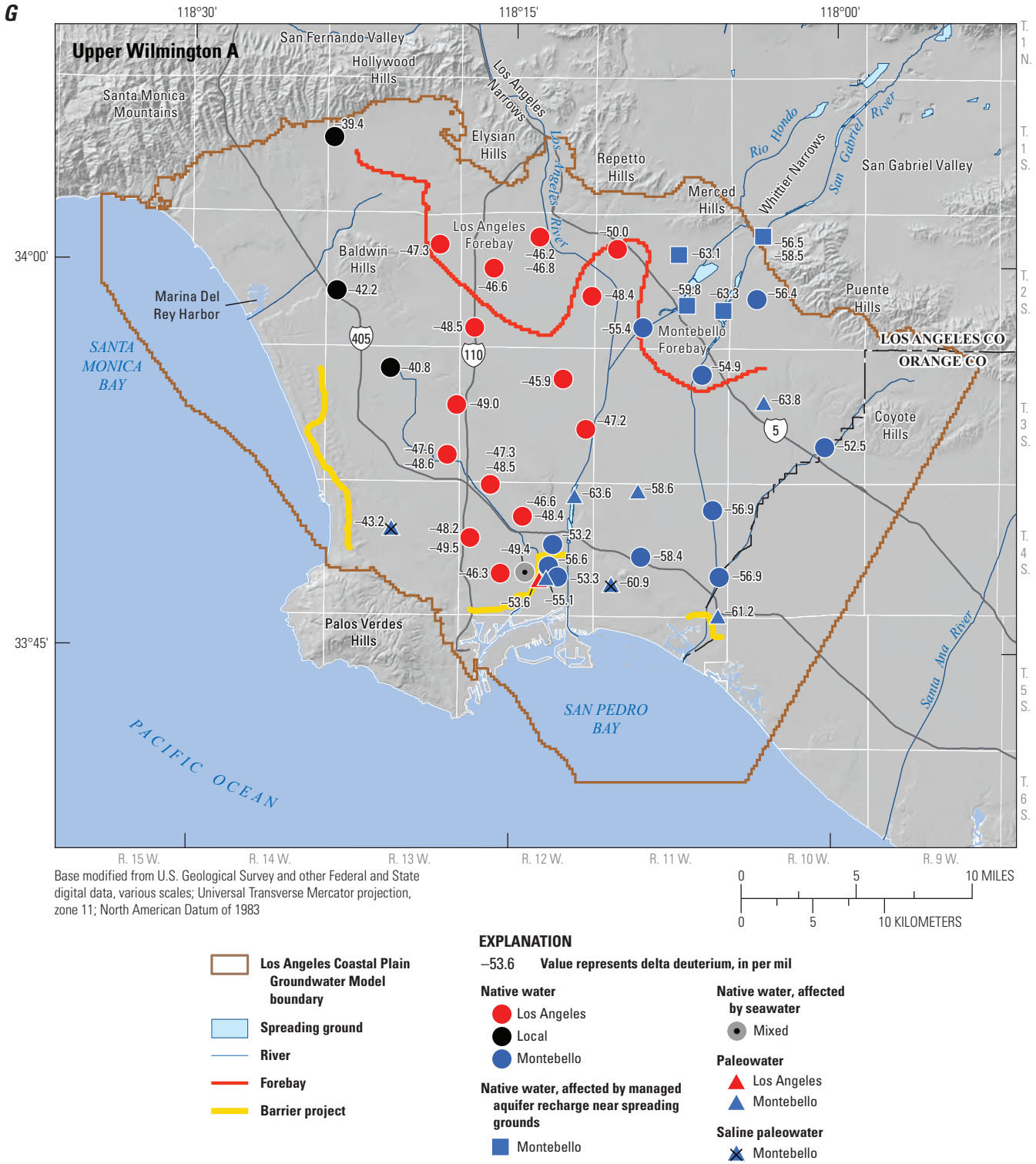


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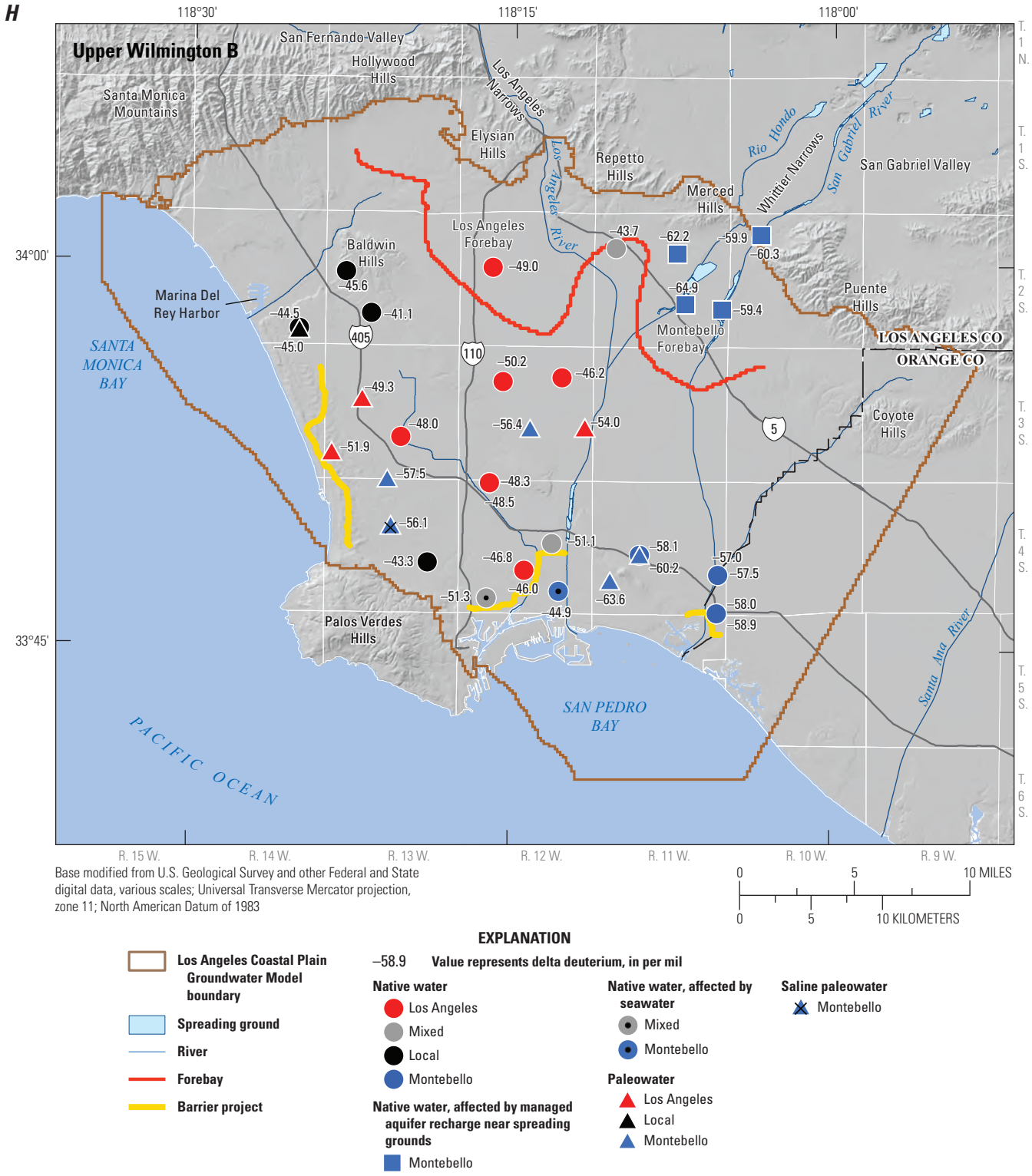


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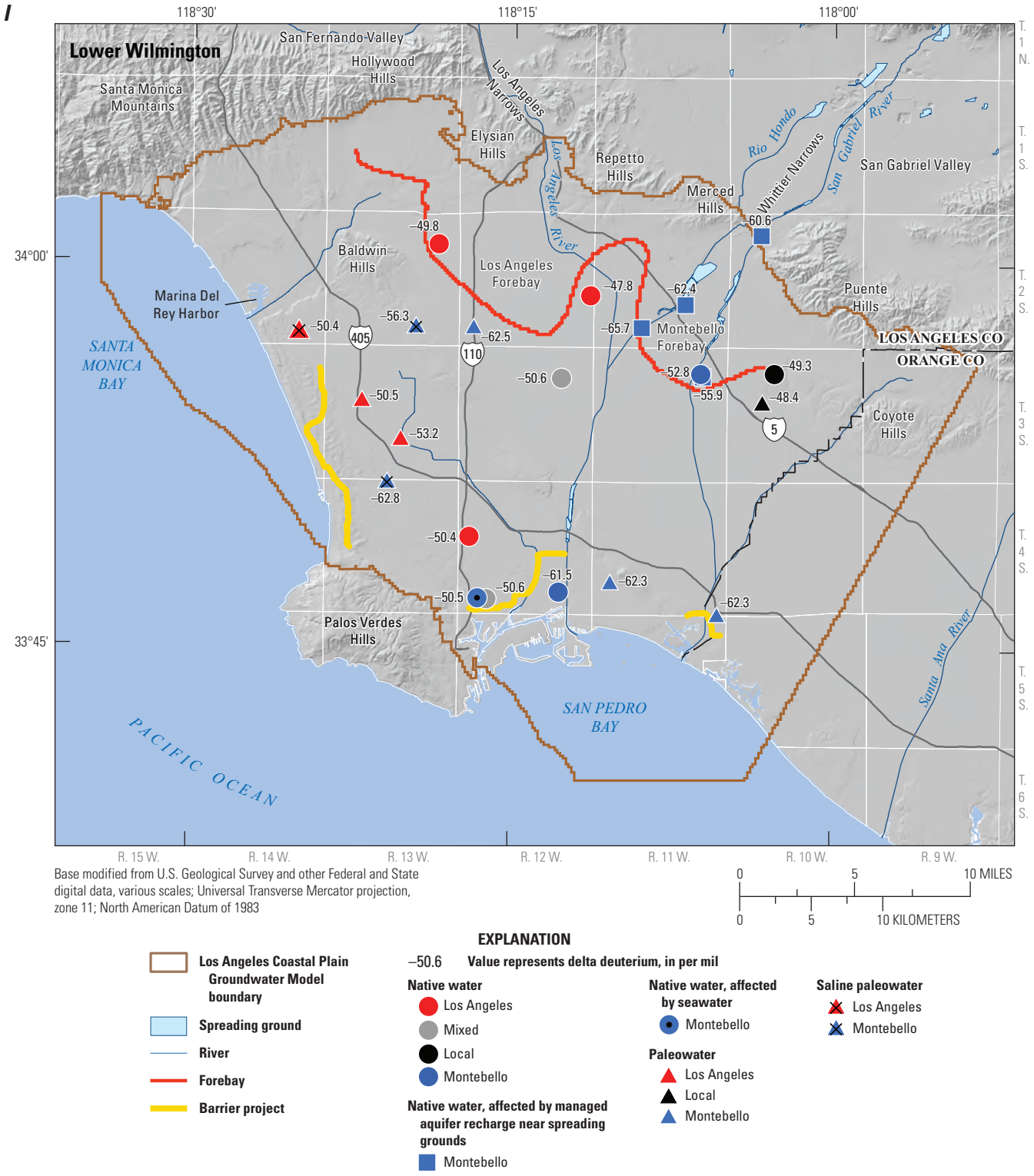


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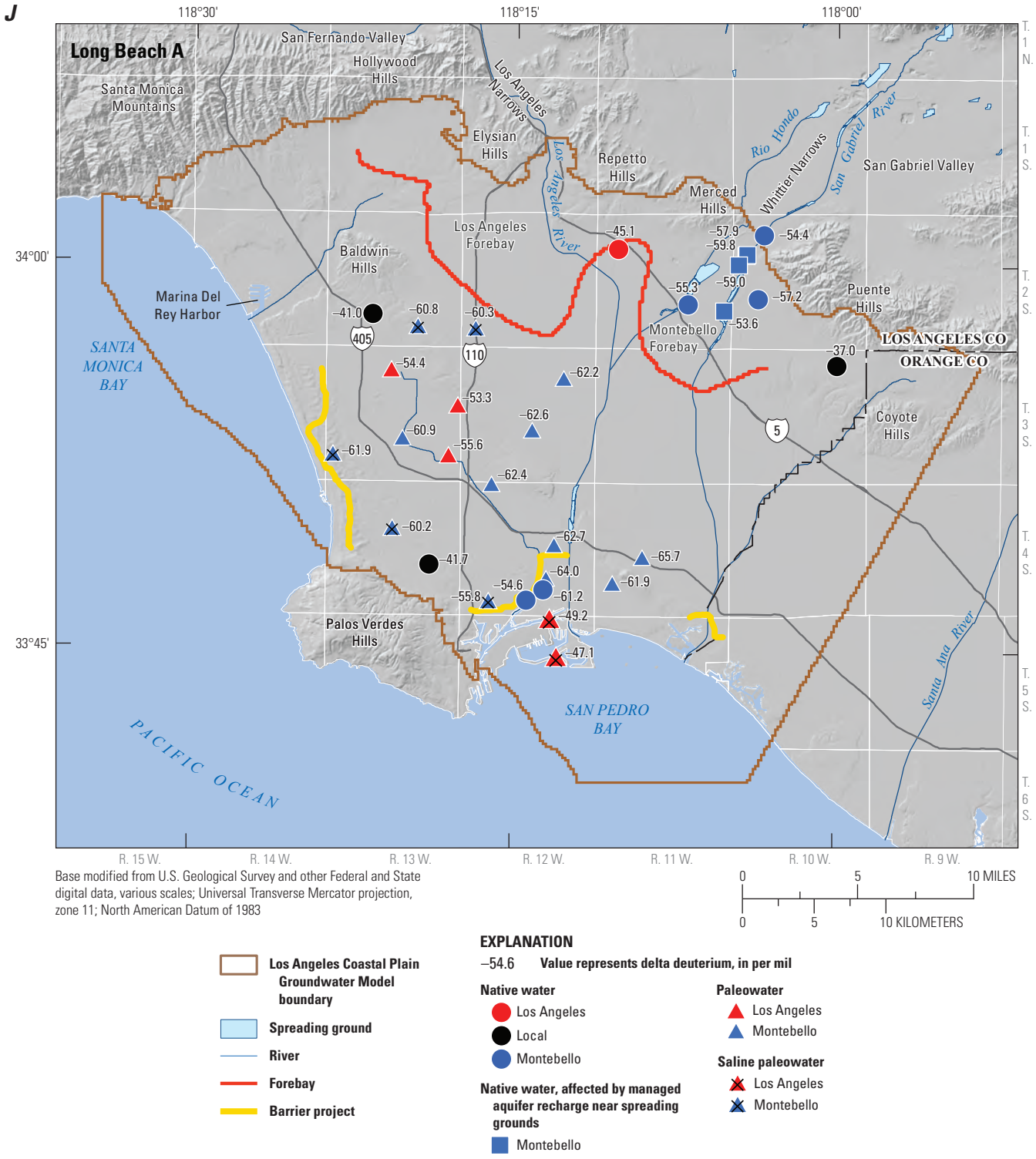


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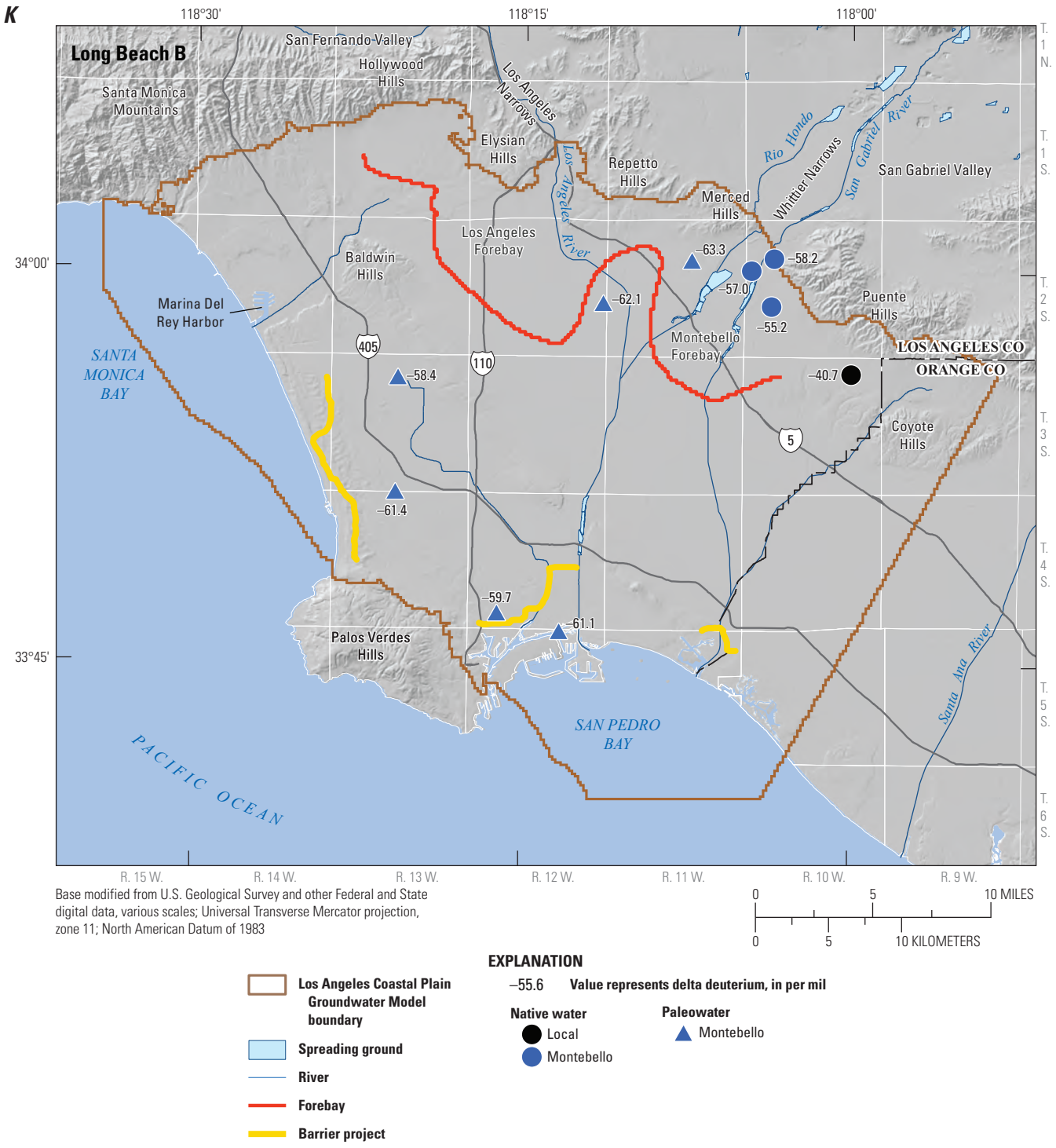


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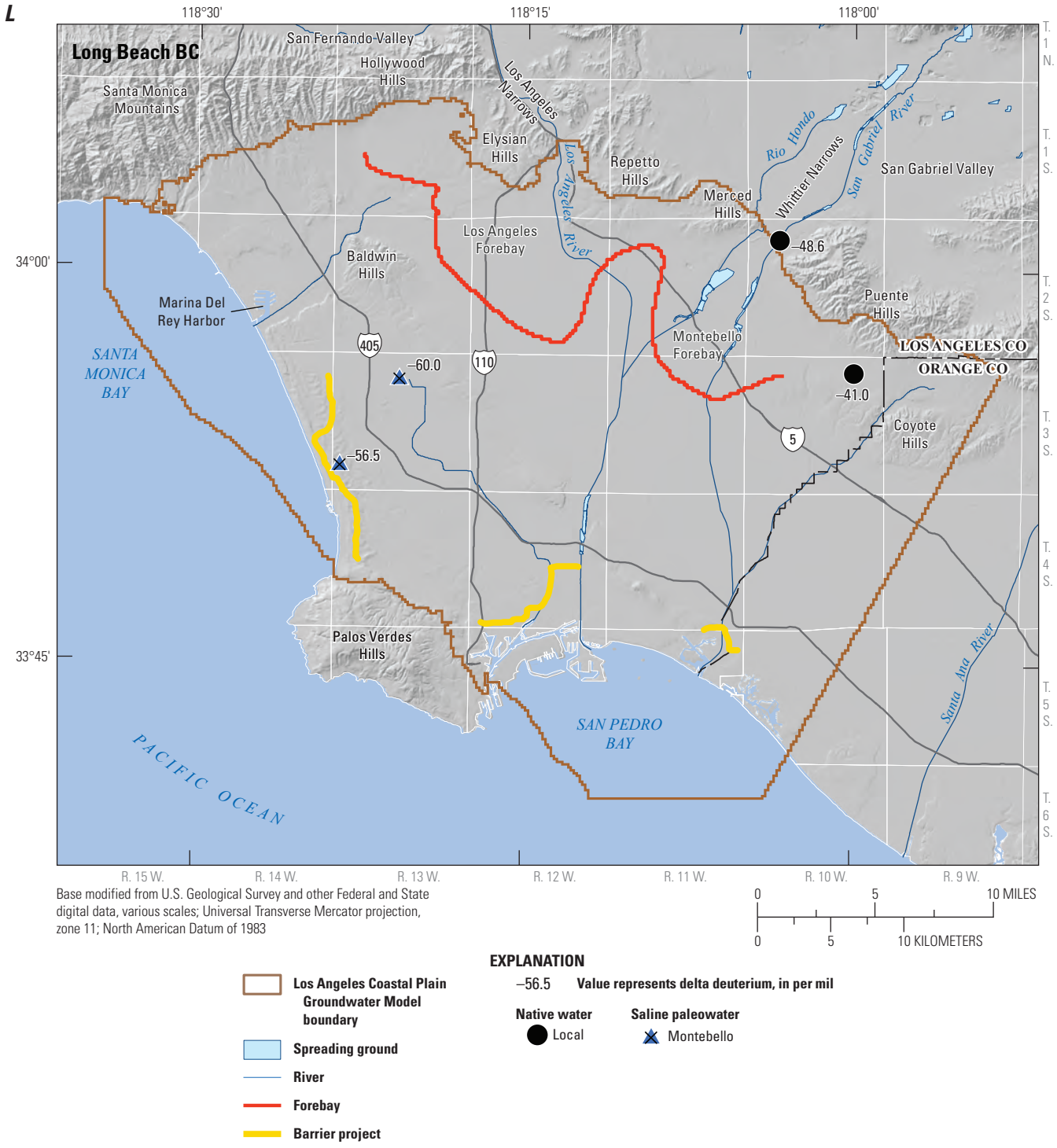


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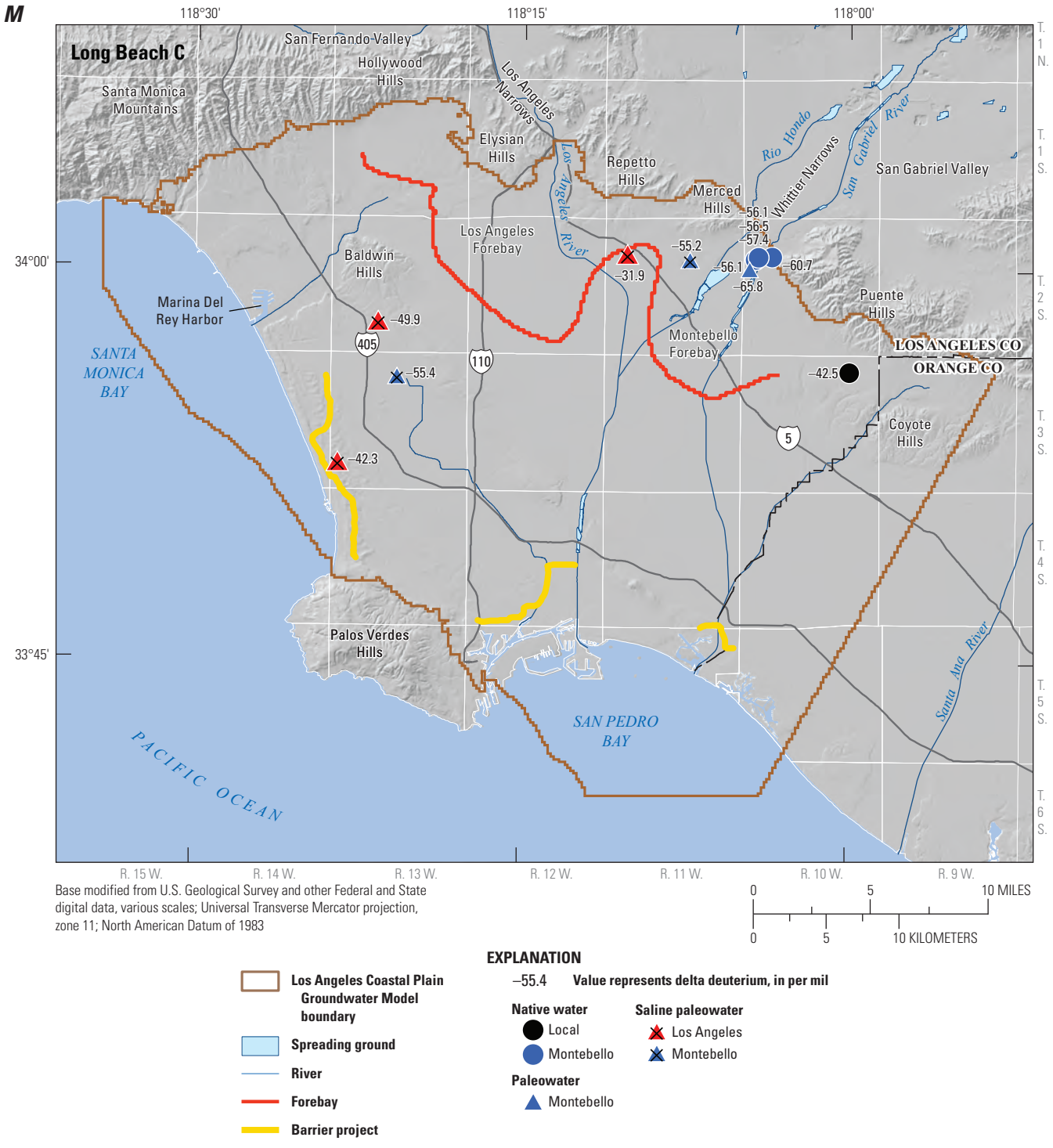


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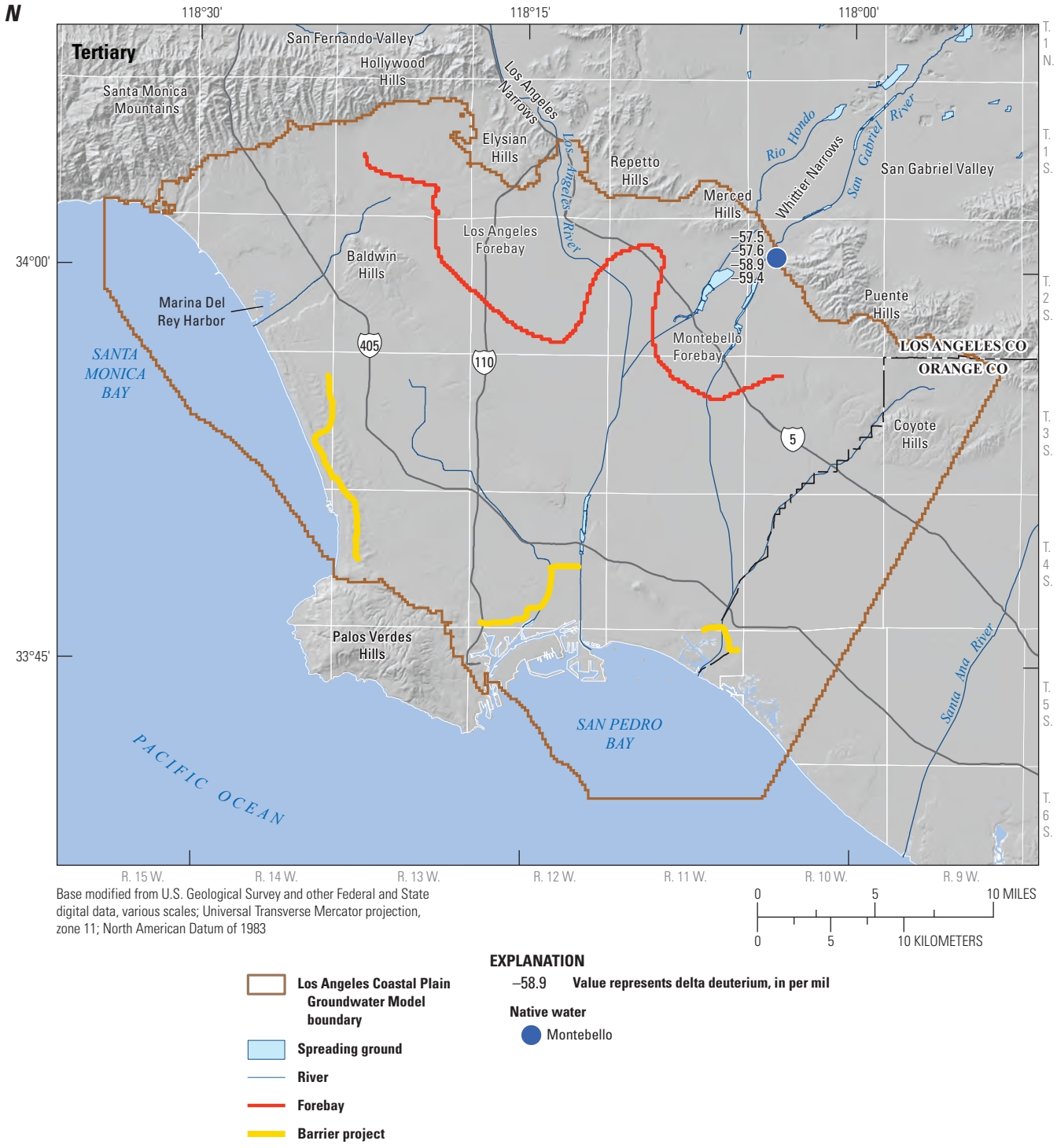


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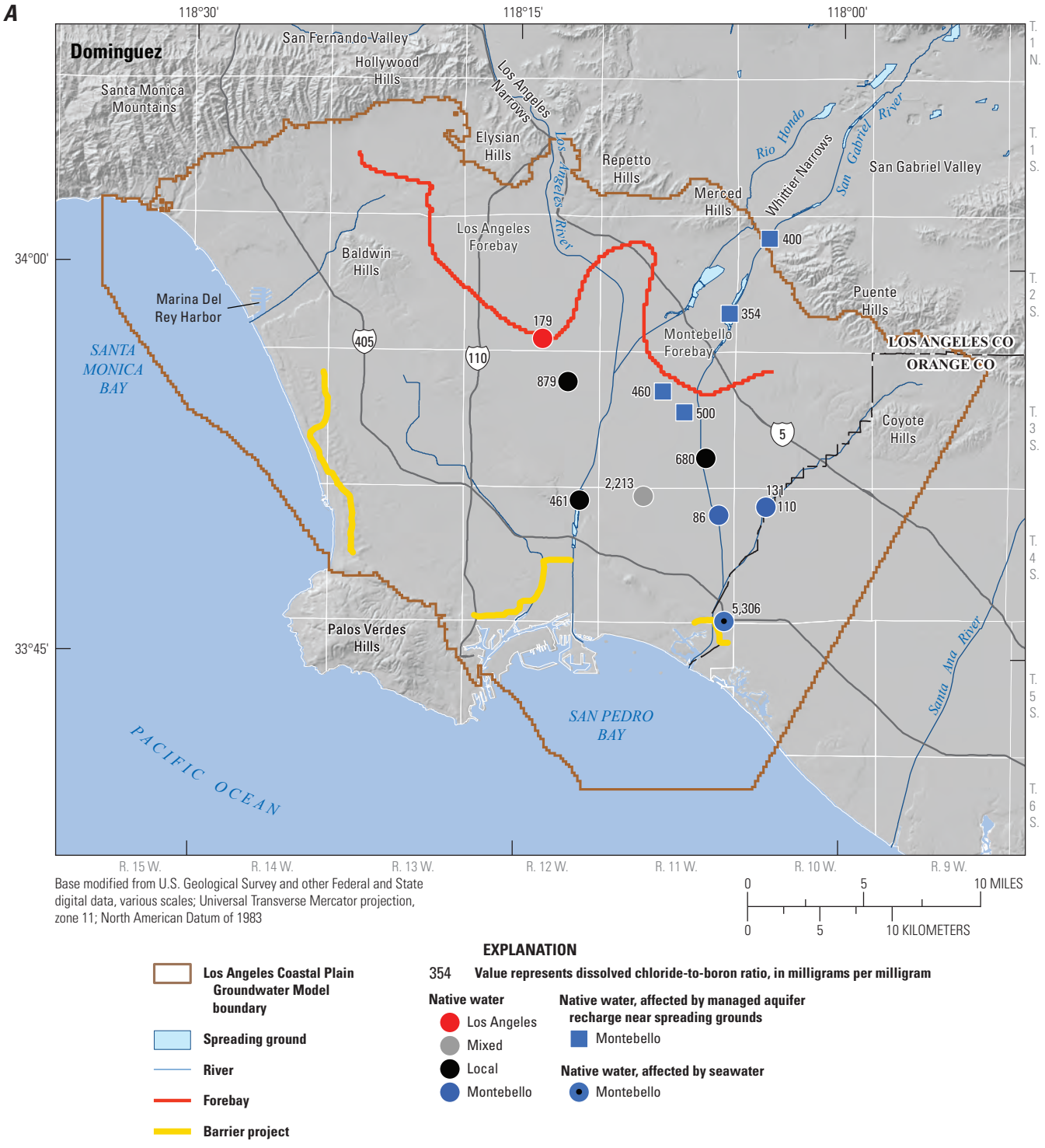


Figure 1.5. Chloride-to-boron ratios in samples from monitoring wells screened in chronostratigraphic units in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California: *A*, Dominguez; *B*, Mesa; *C*, Pacific A; *D*, Pacific; *E*, Harbor; *F*, Bent Spring; *G*, Upper Wilmington A; *H*, Upper Wilmington B; *I*, Lower Wilmington; *J*, Long Beach A; *K*, Long Beach B; *L*, Long Beach BC; *M*, Long Beach C; and *N*, Tertiary.

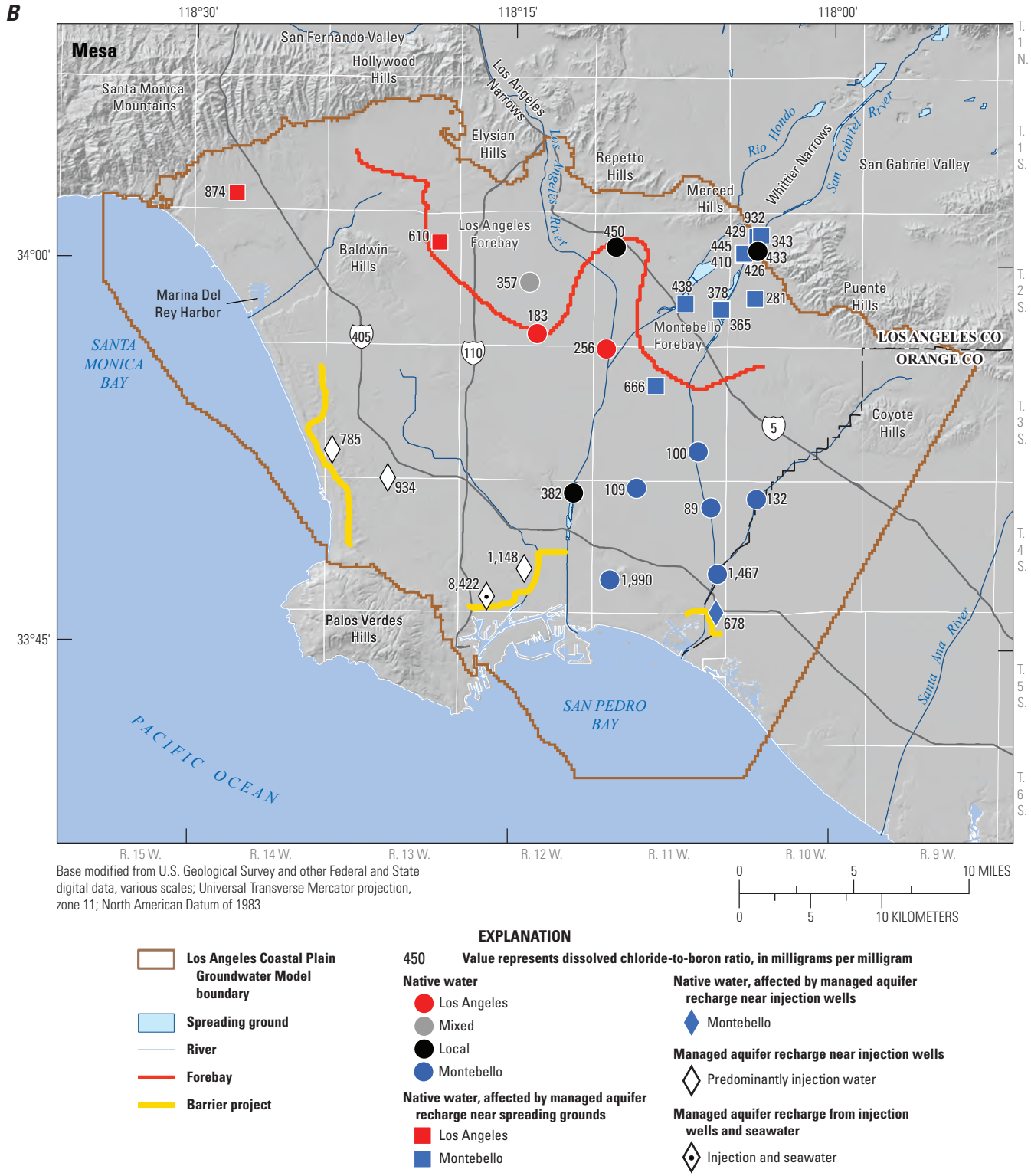


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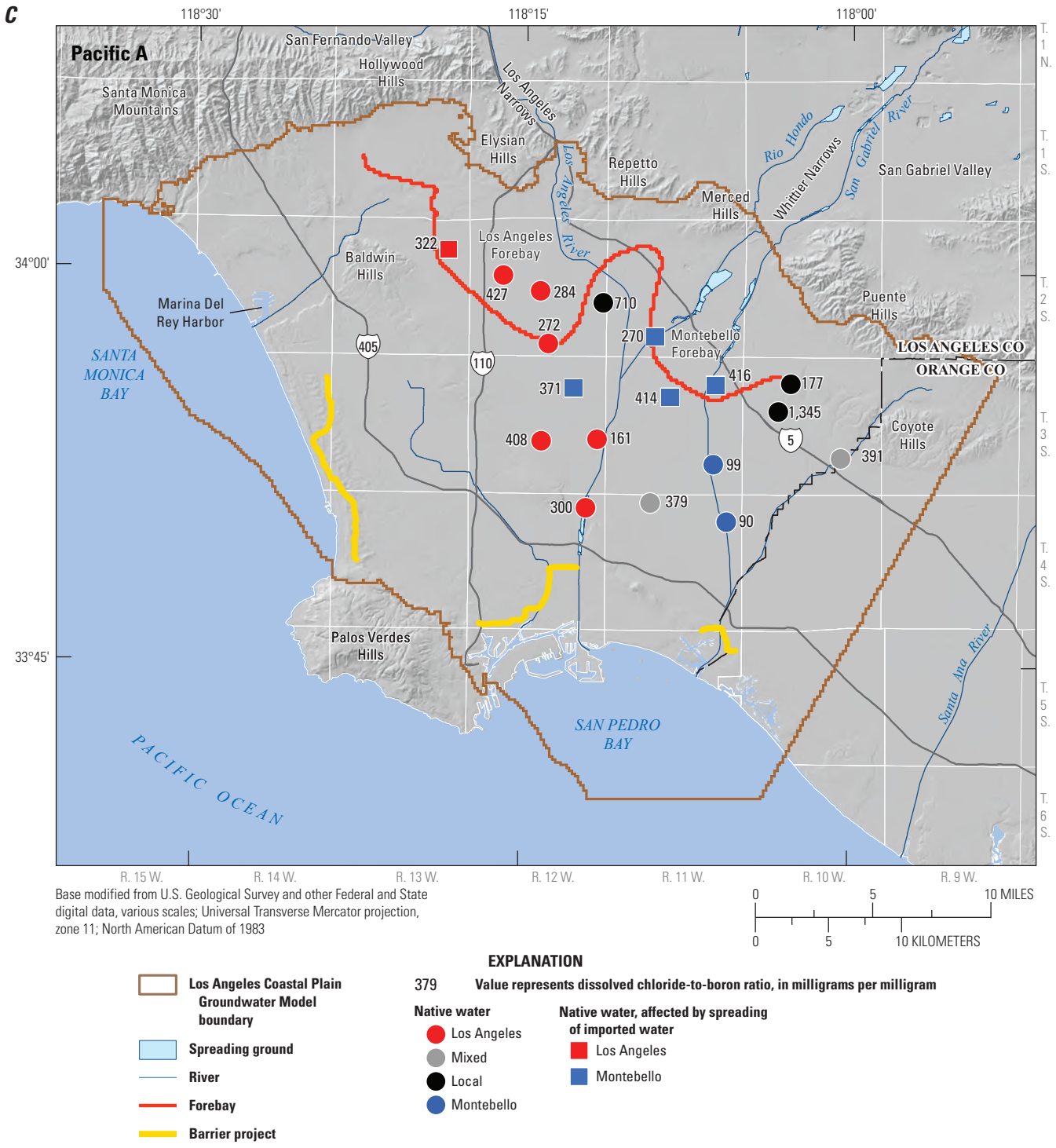


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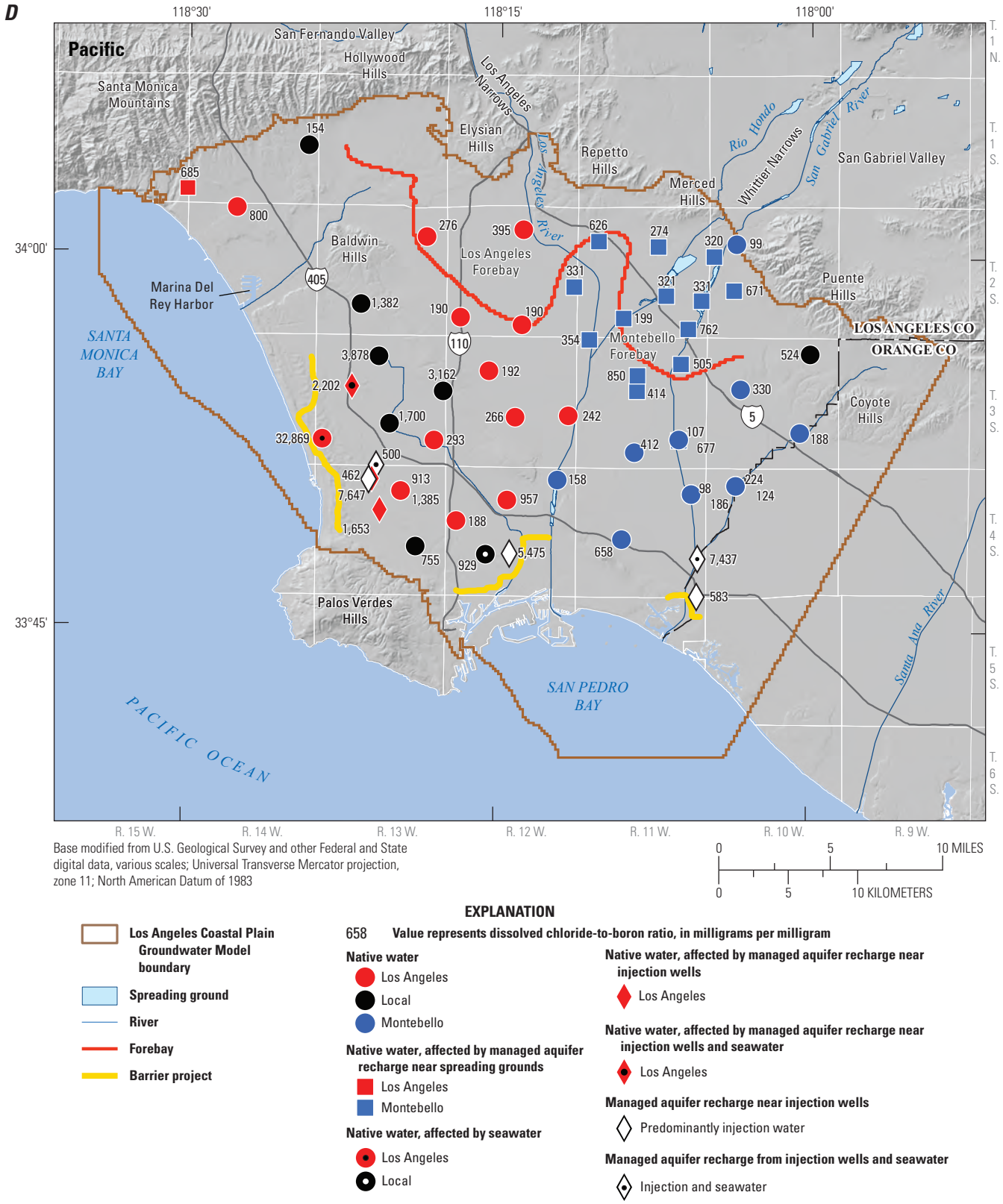


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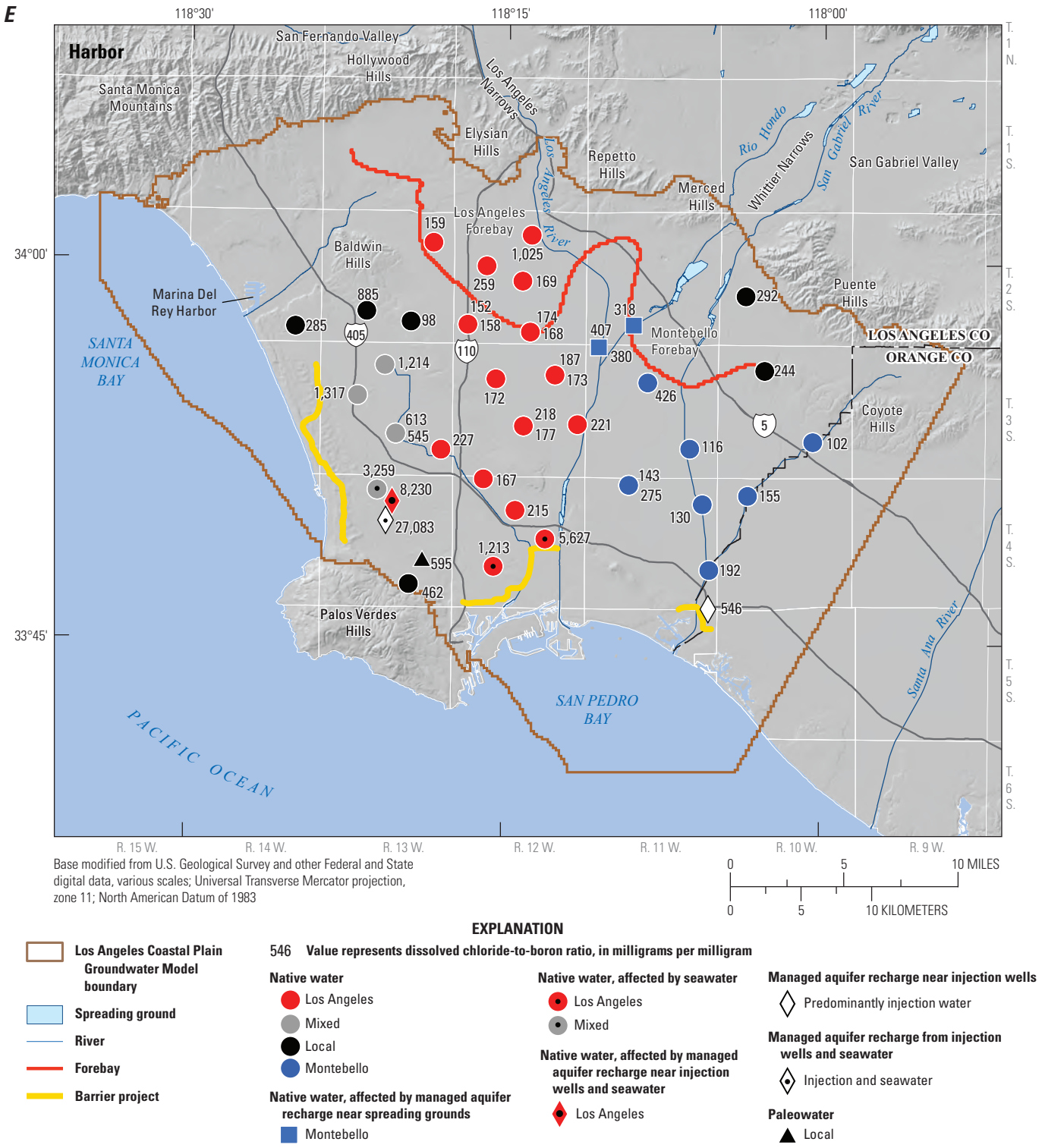
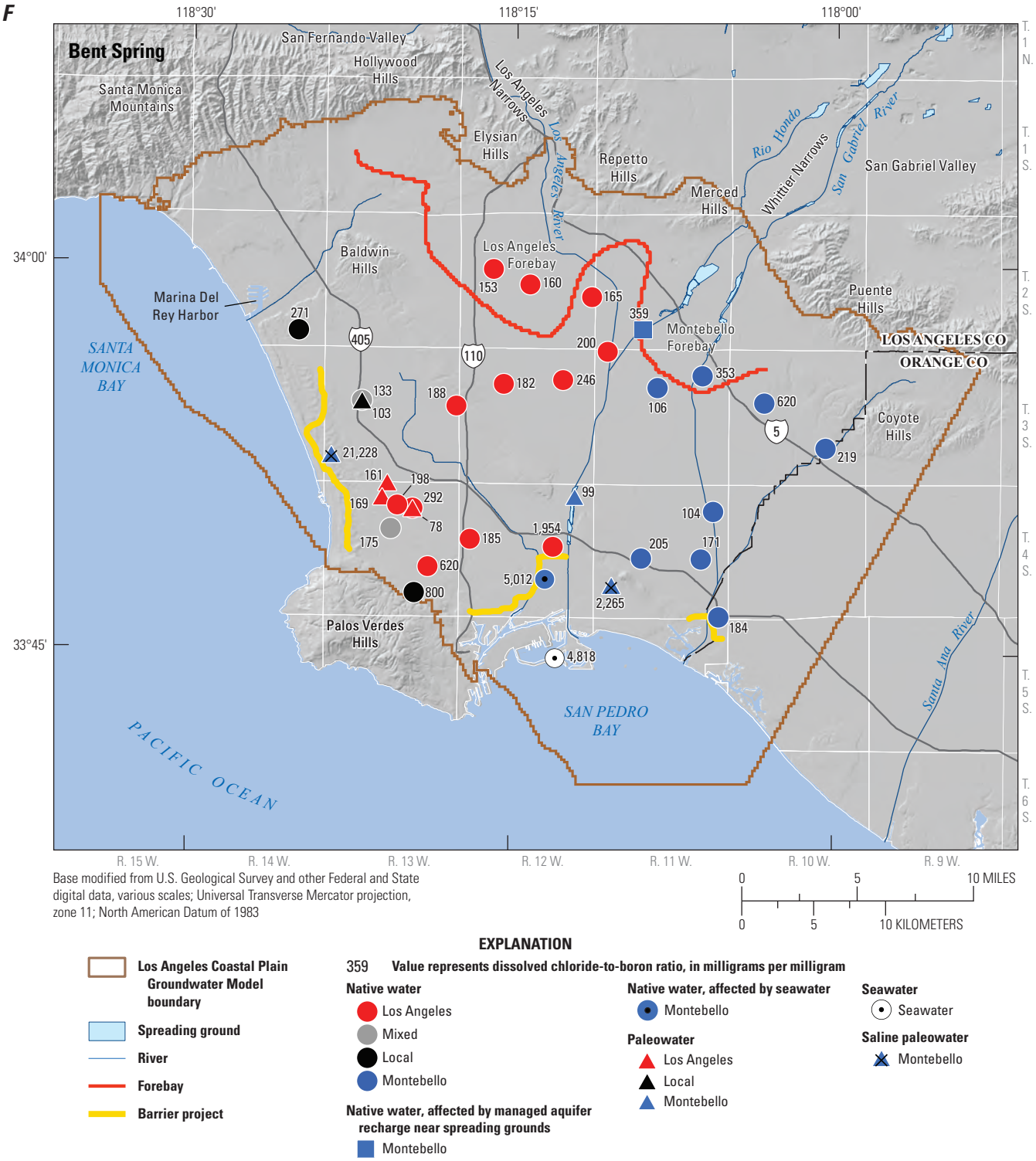


Figure 1.5.—Continued

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Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

EXPLANATION

- **Los Angeles Coastal Plain Groundwater Model boundary**
- **Spreading ground**
- **River**
- **Forebay**
- **Barrier project**

359 **Value represents dissolved chloride-to-boron ratio, in milligrams per milligram**

Native water
- Los Angeles
- Mixed
- Local
- Montebello

Native water, affected by managed aquifer recharge near spreading grounds
- Montebello

Native water, affected by seawater
- Montebello

Paleowater
- Los Angeles
- Local
- Montebello

Seawater
- Seawater

Saline paleowater
- Montebello

Figure 1.5.—Continued

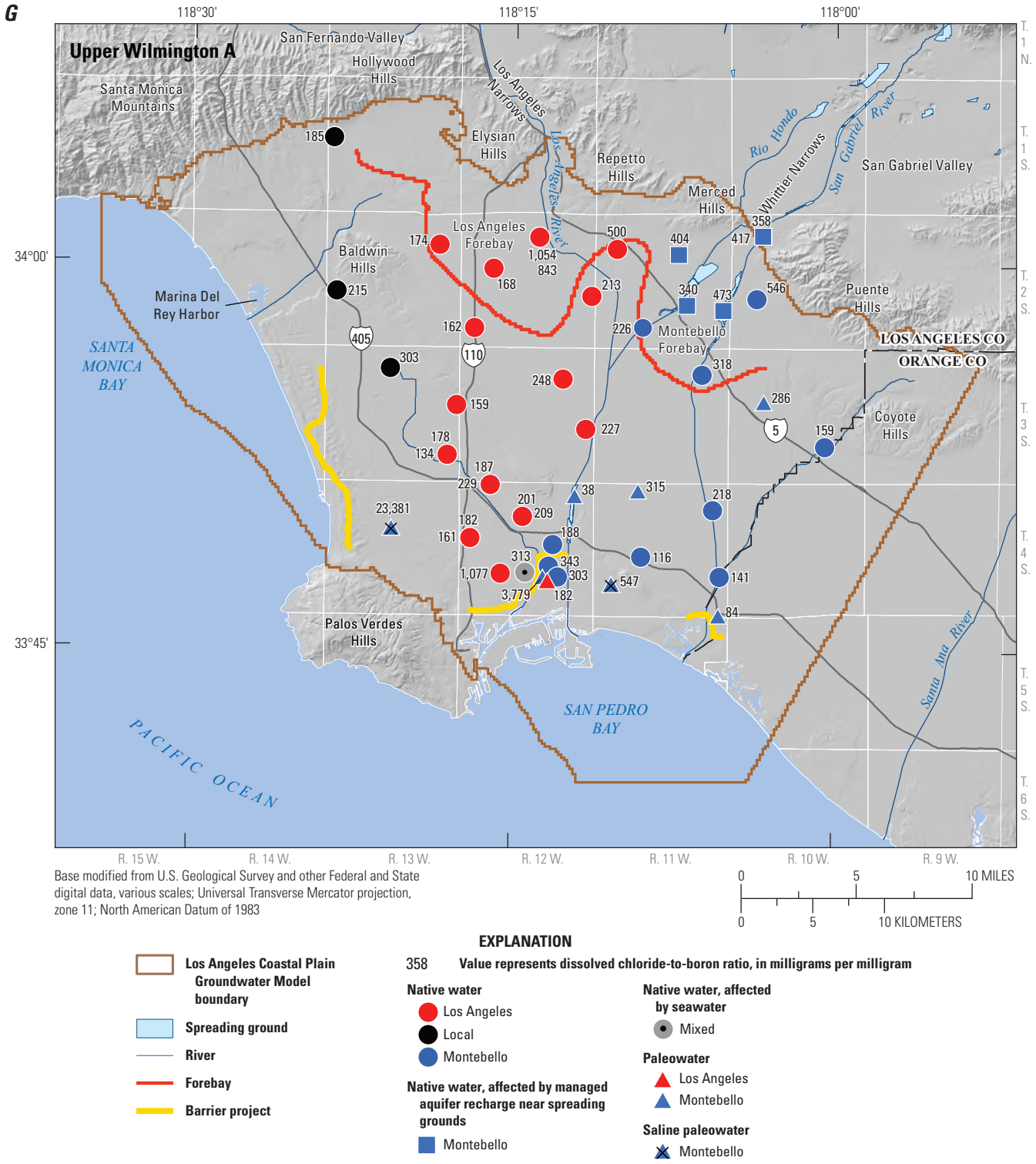


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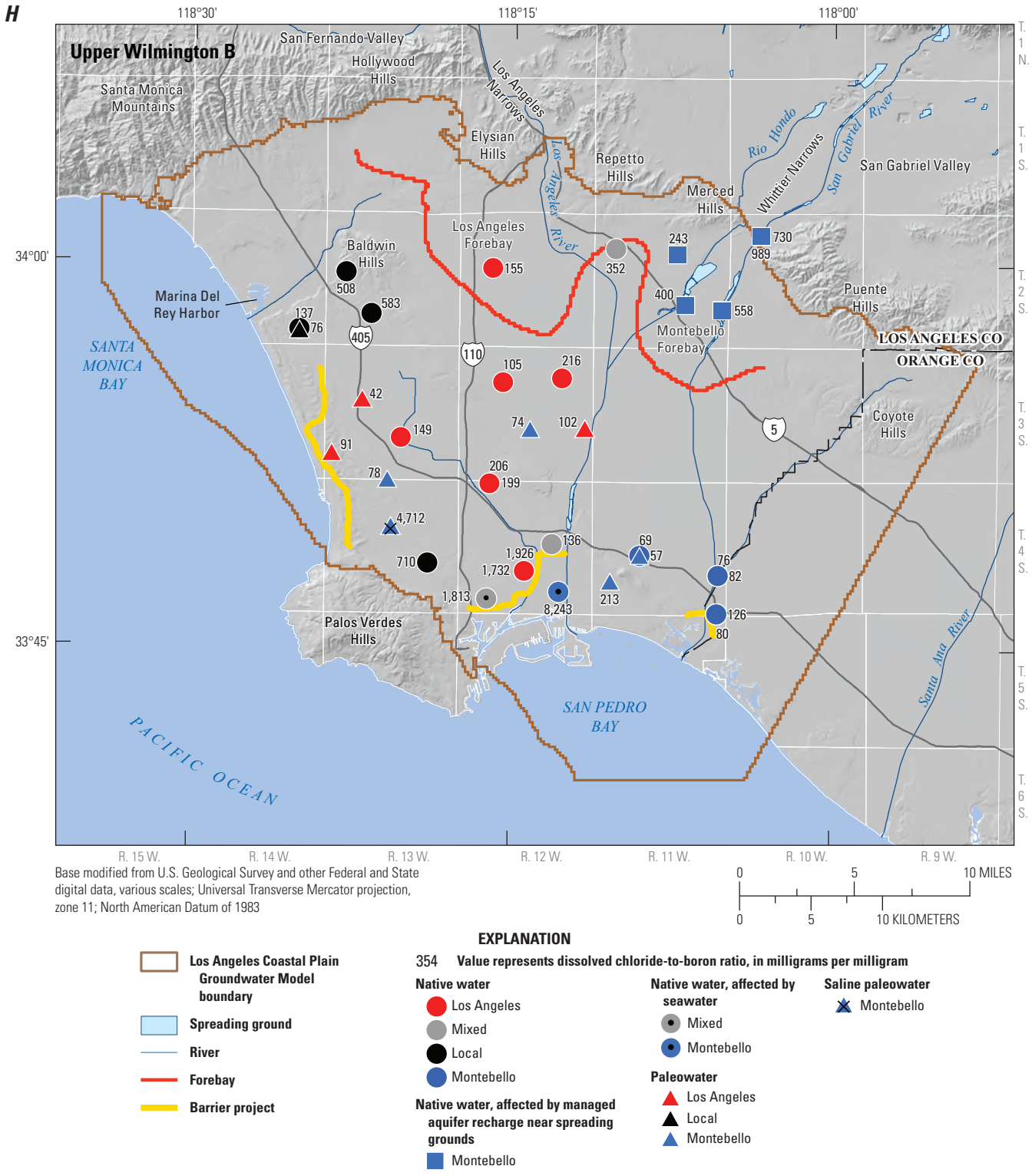


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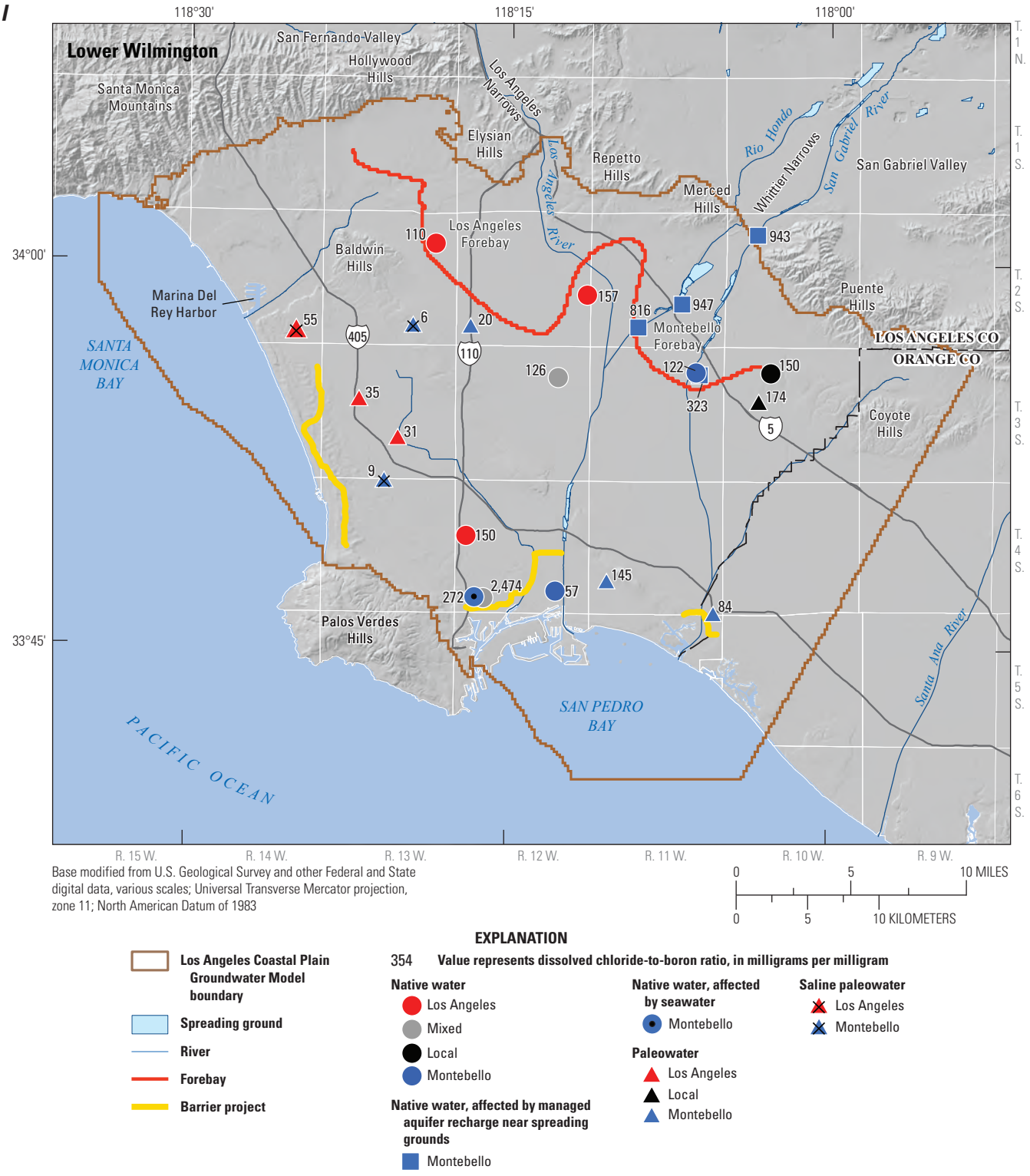


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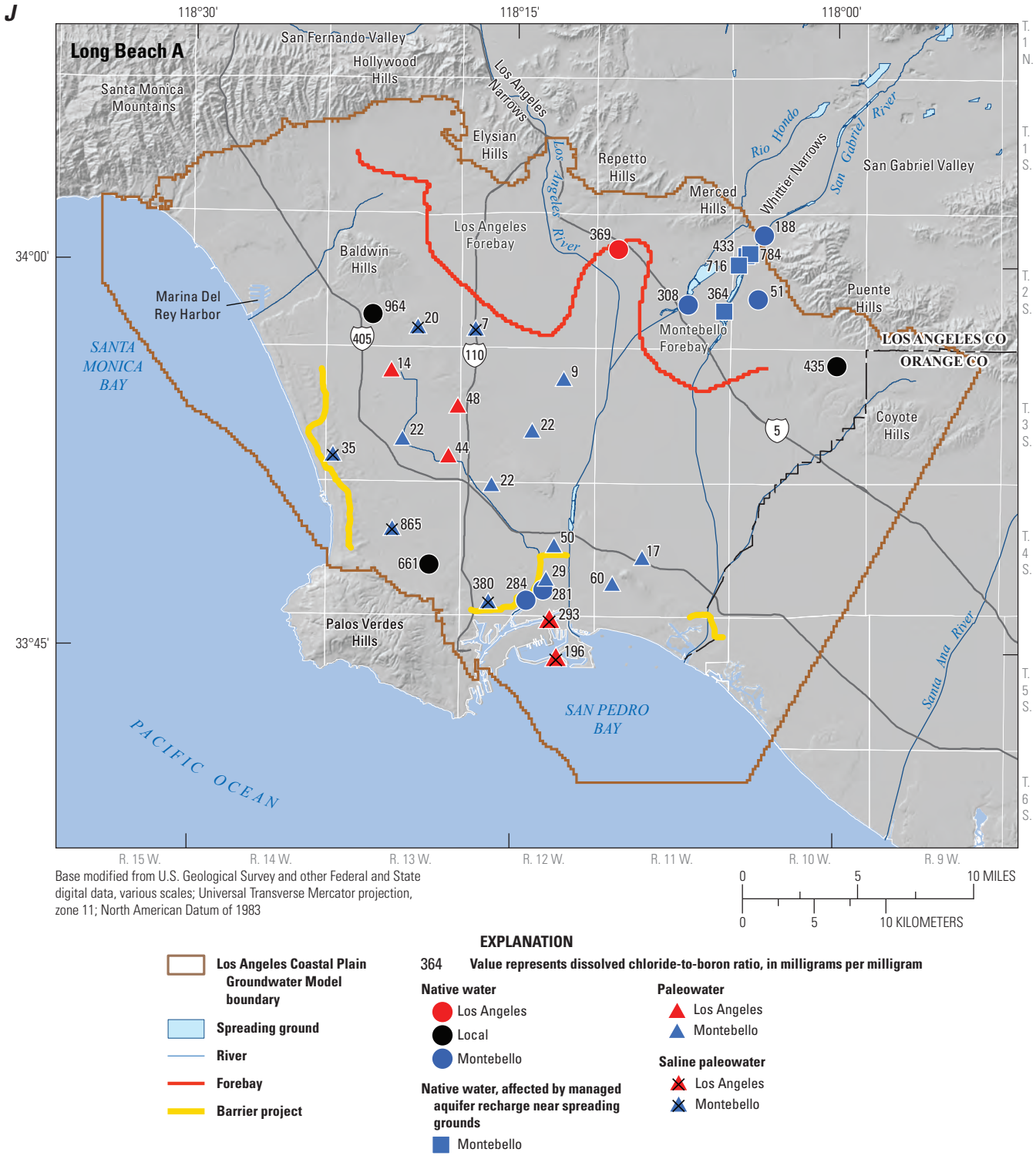


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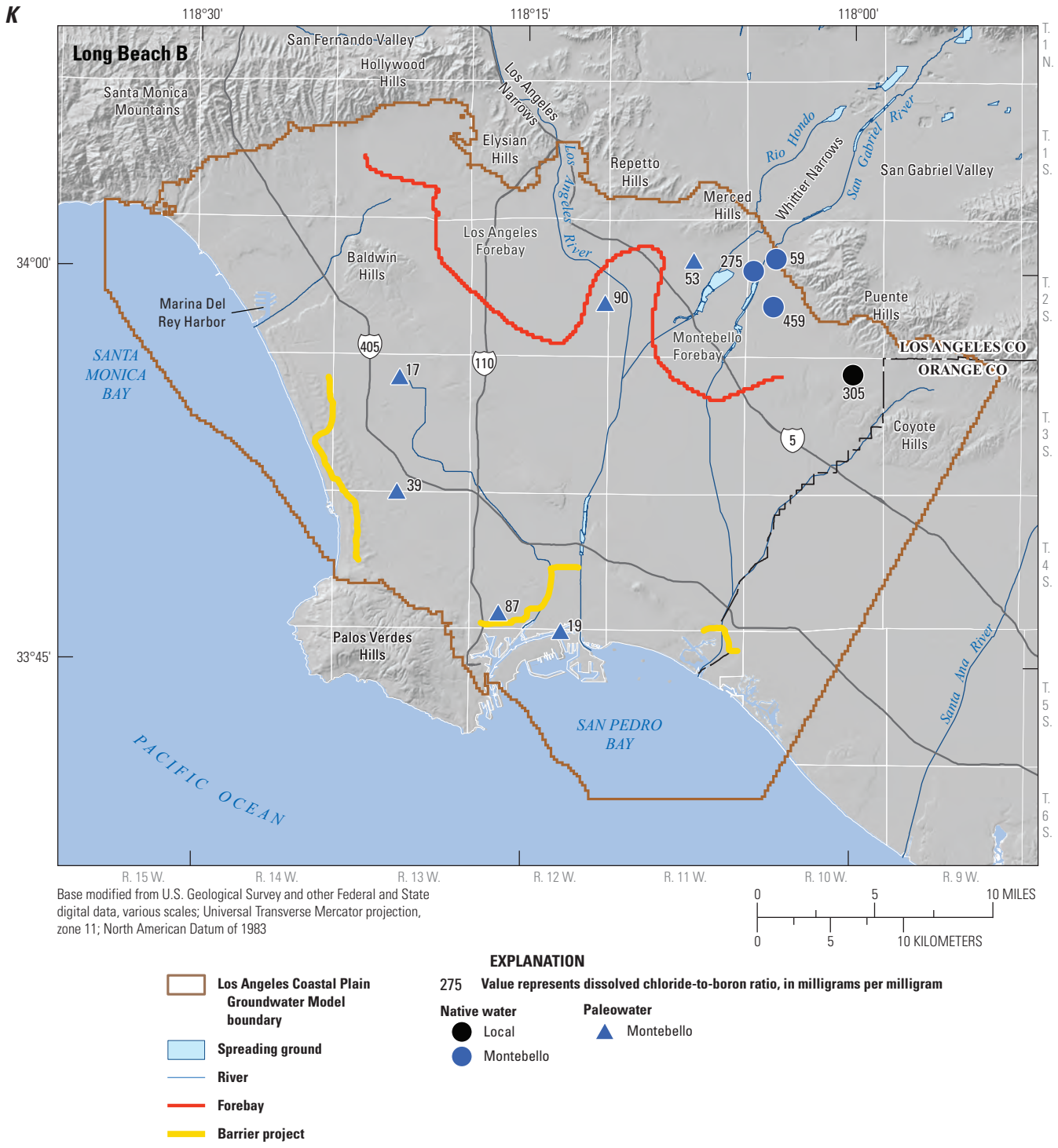


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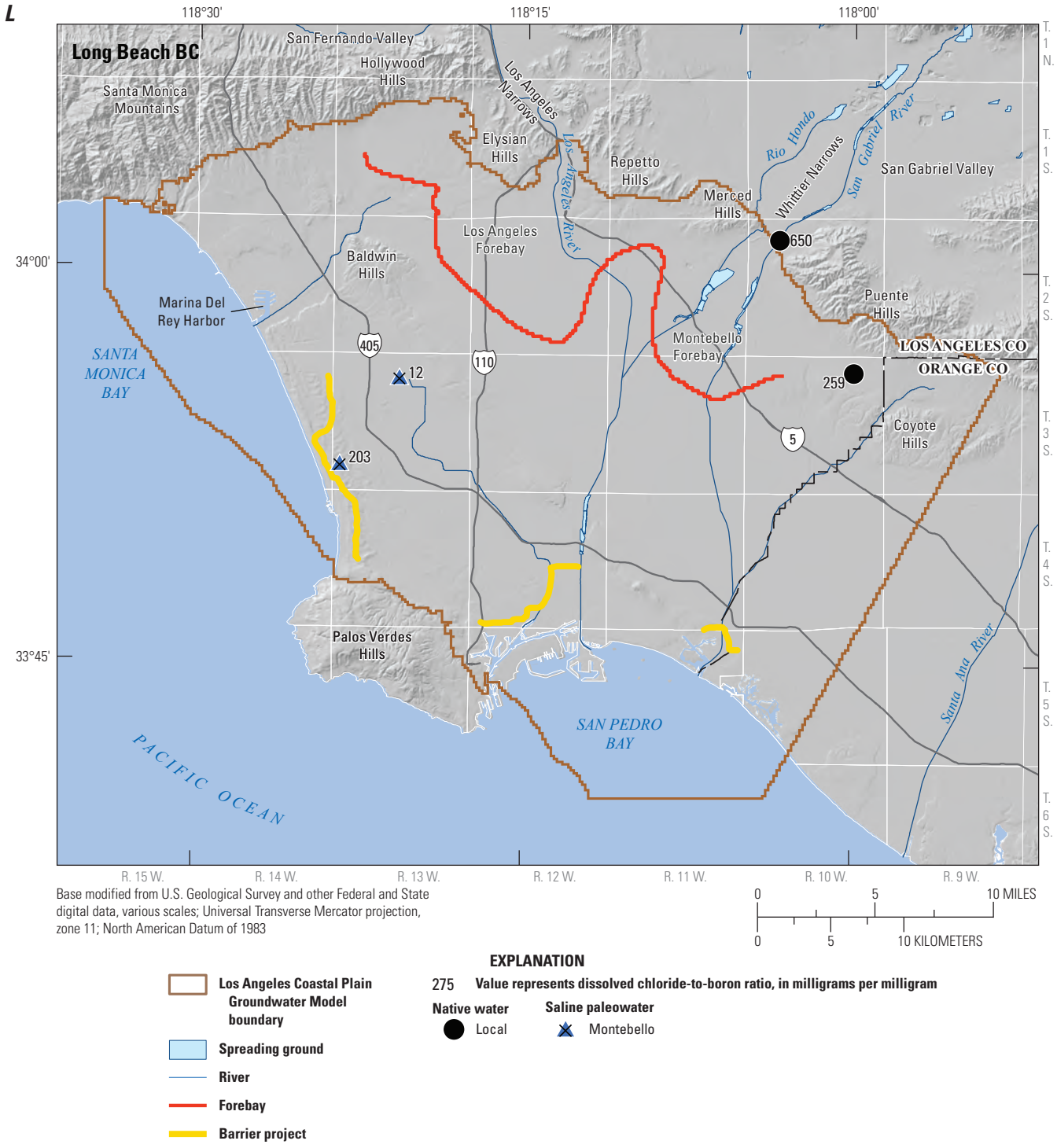


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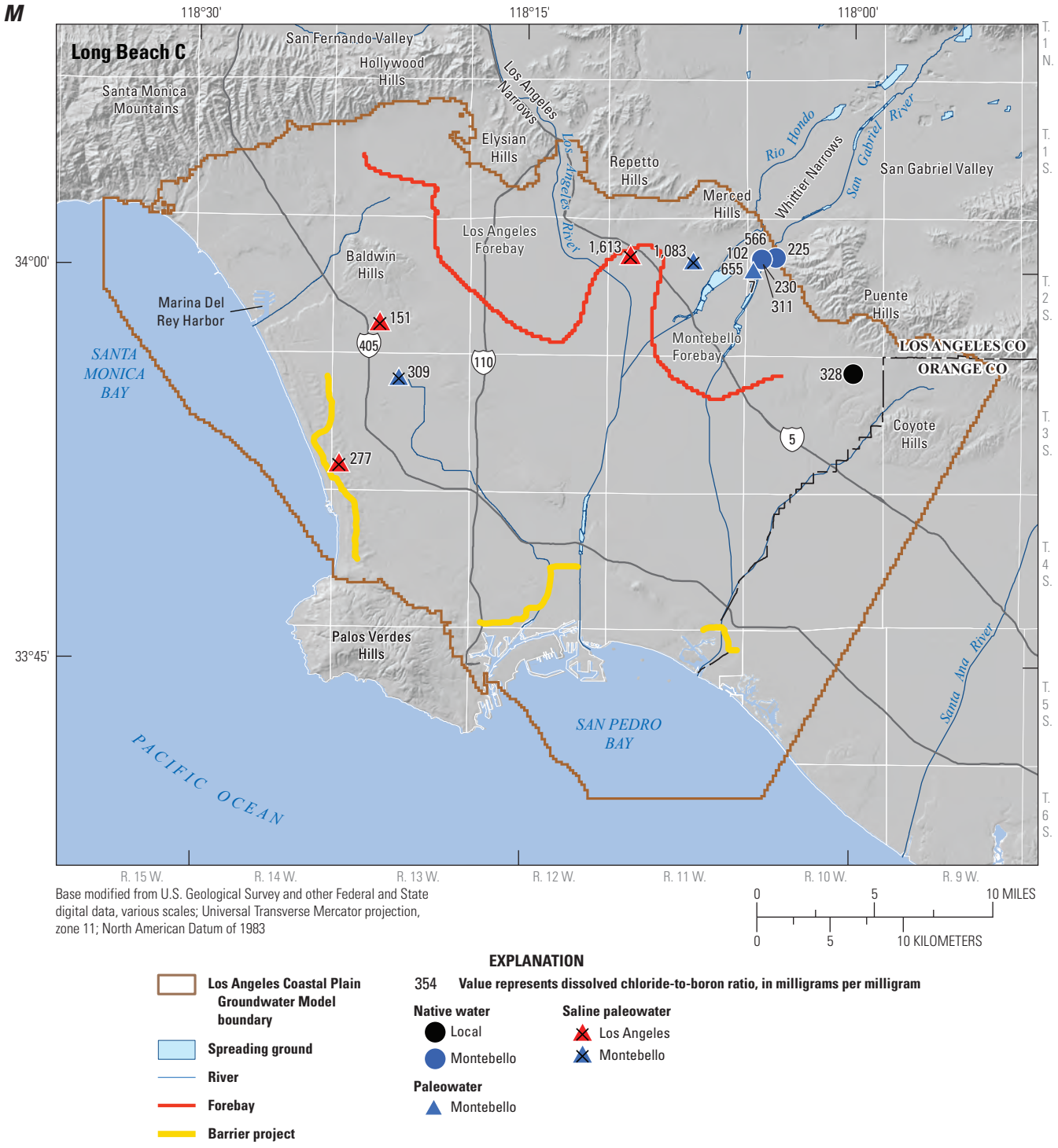


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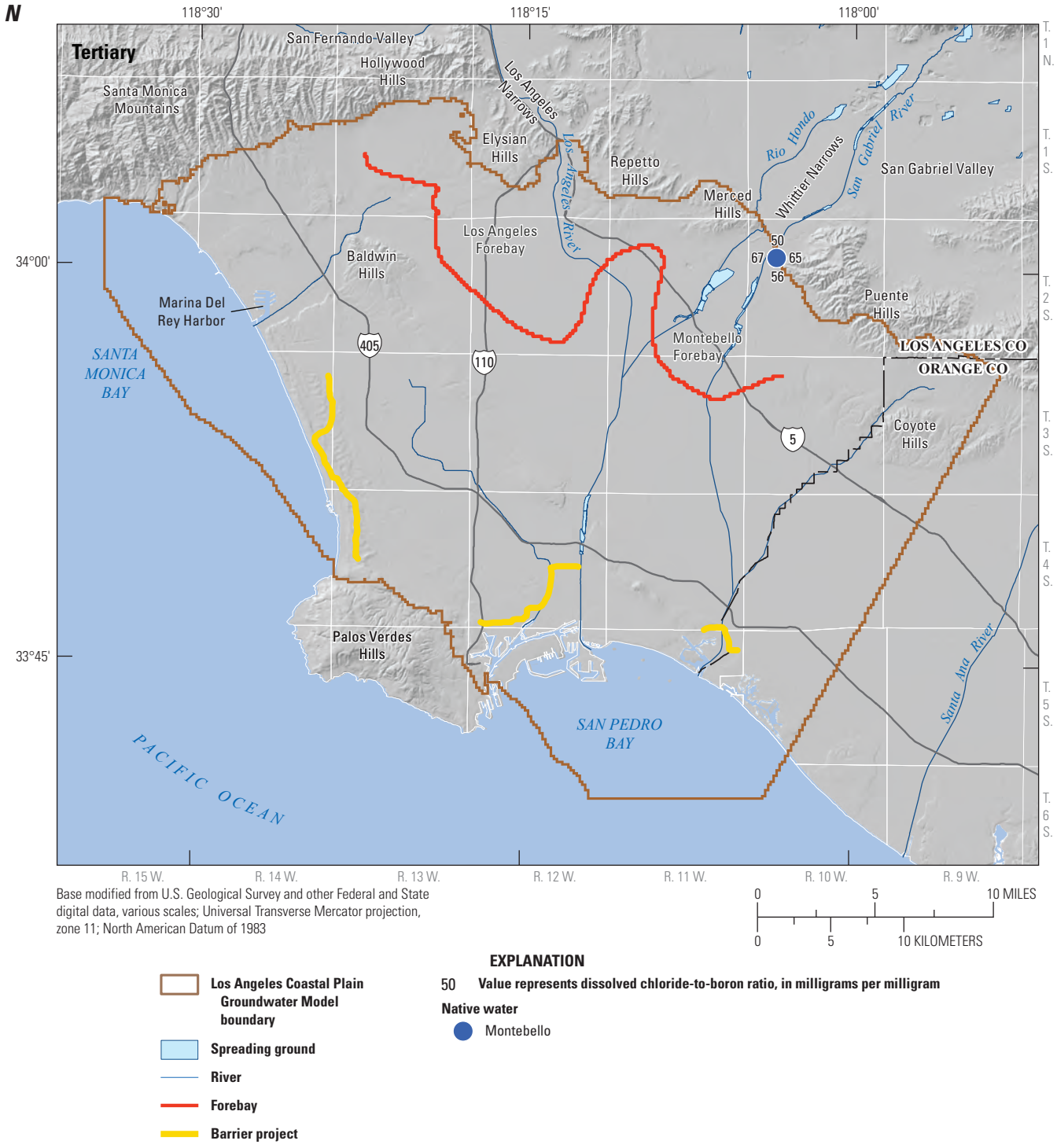


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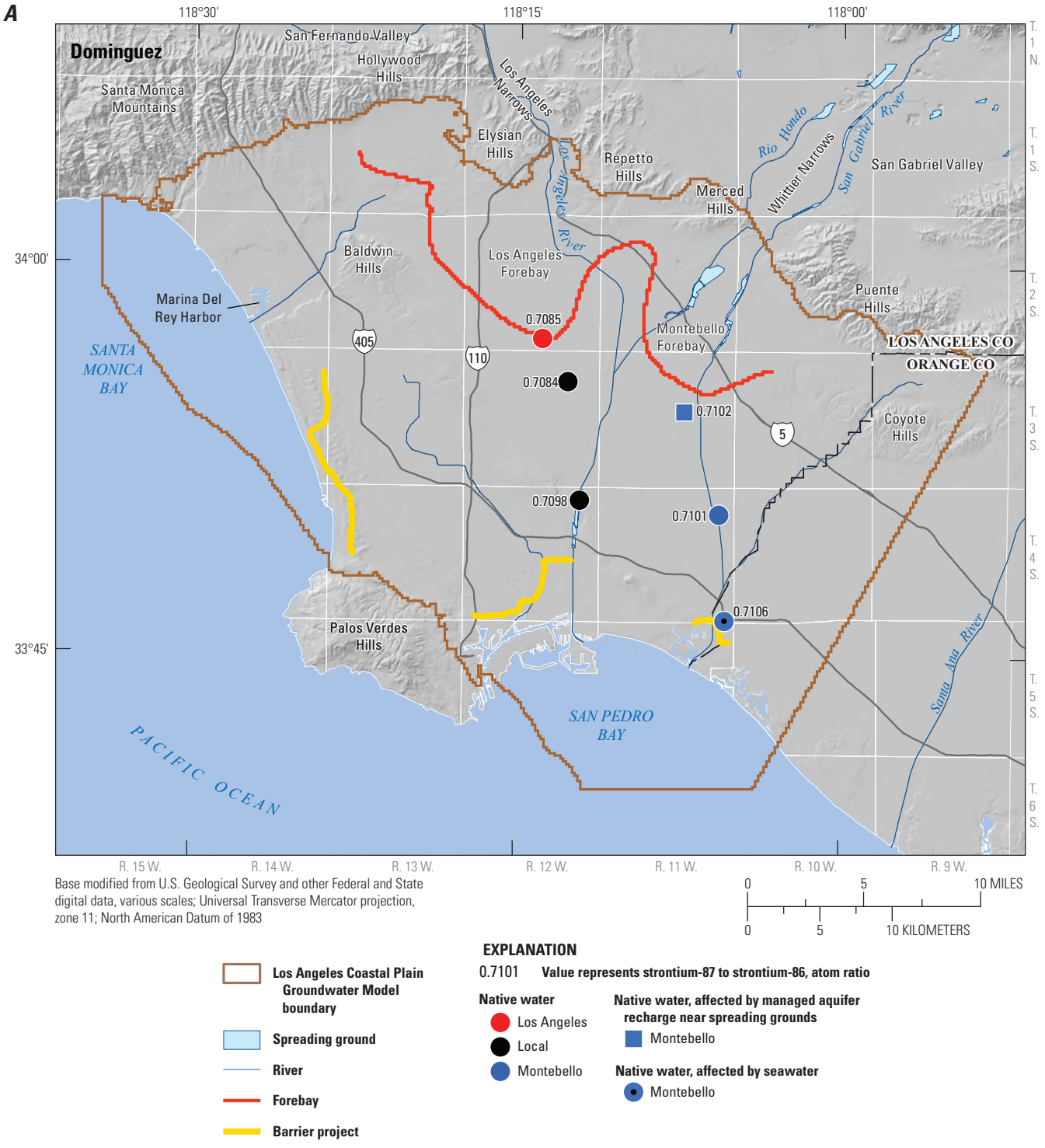


Figure 1.6. Strontium-isotope ratios in samples from monitoring wells screened in chronostratigraphic units in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California: *A*, Dominguez; *B*, Mesa; *C*, Pacific A; *D*, Pacific; *E*, Harbor; *F*, Bent Spring; *G*, Upper Wilmington A; *H*, Upper Wilmington B; *I*, Lower Wilmington; *J*, Long Beach A; *K*, Long Beach B; *L*, Long Beach BC; and *M*, Long Beach C.

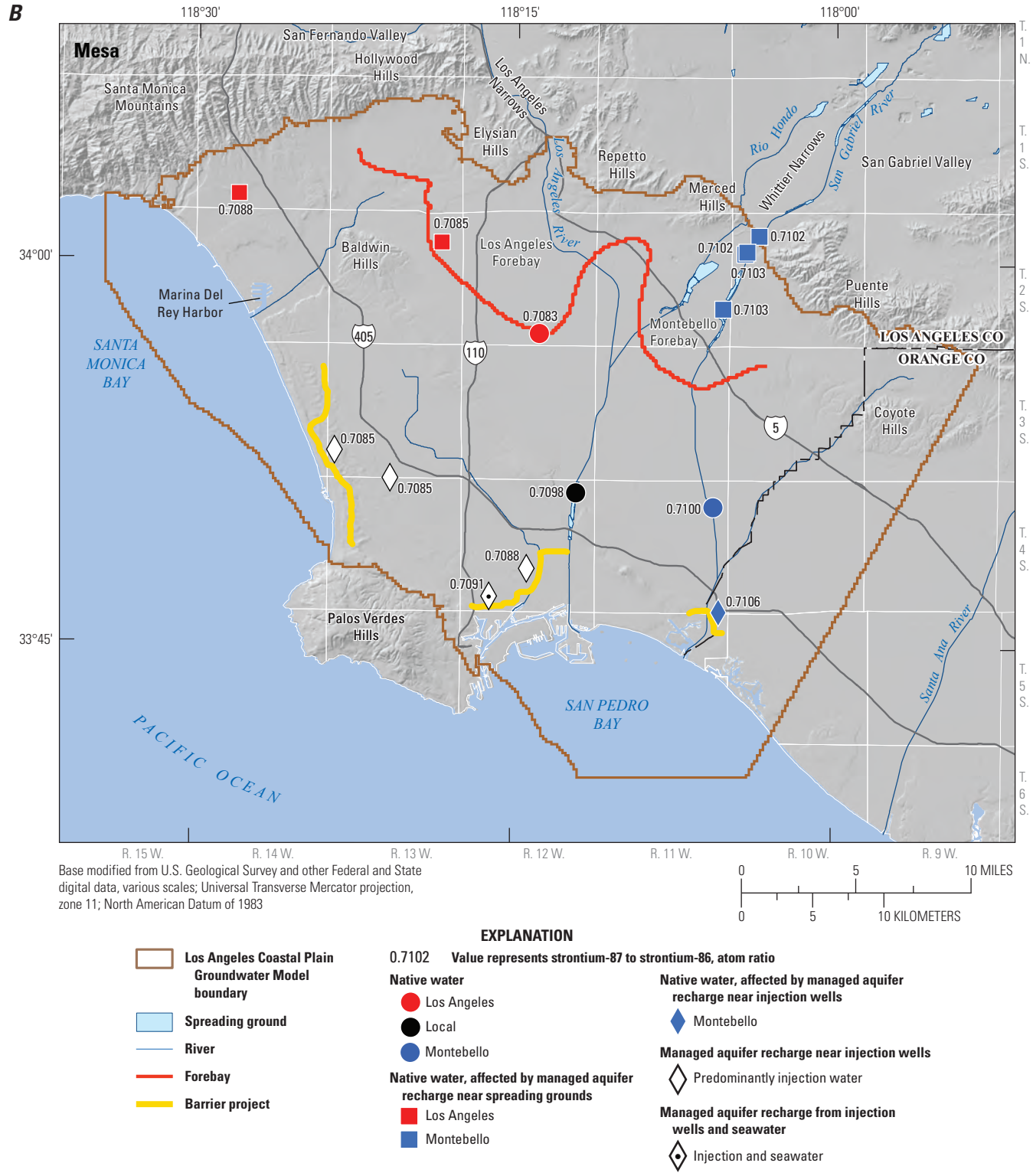


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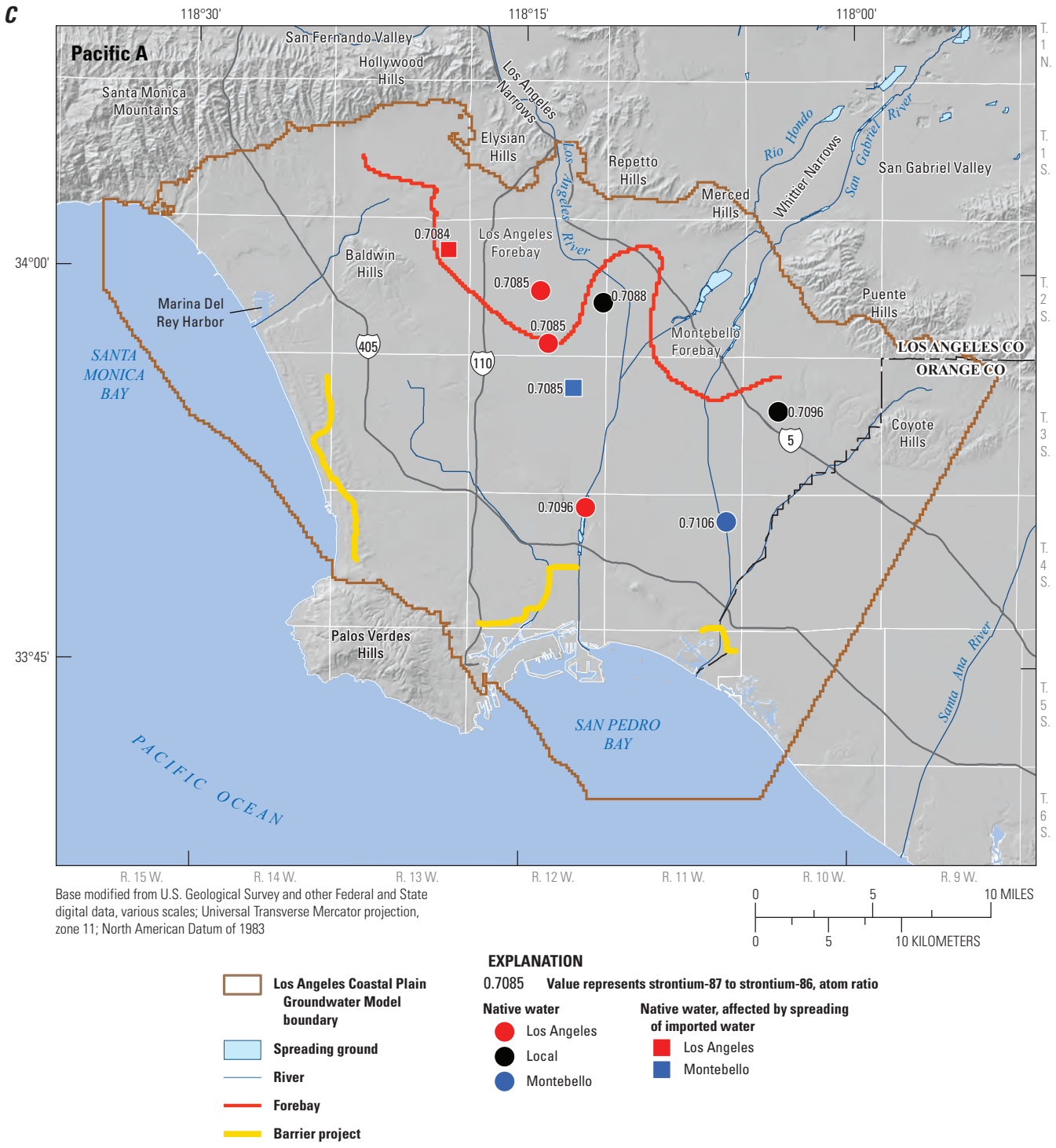


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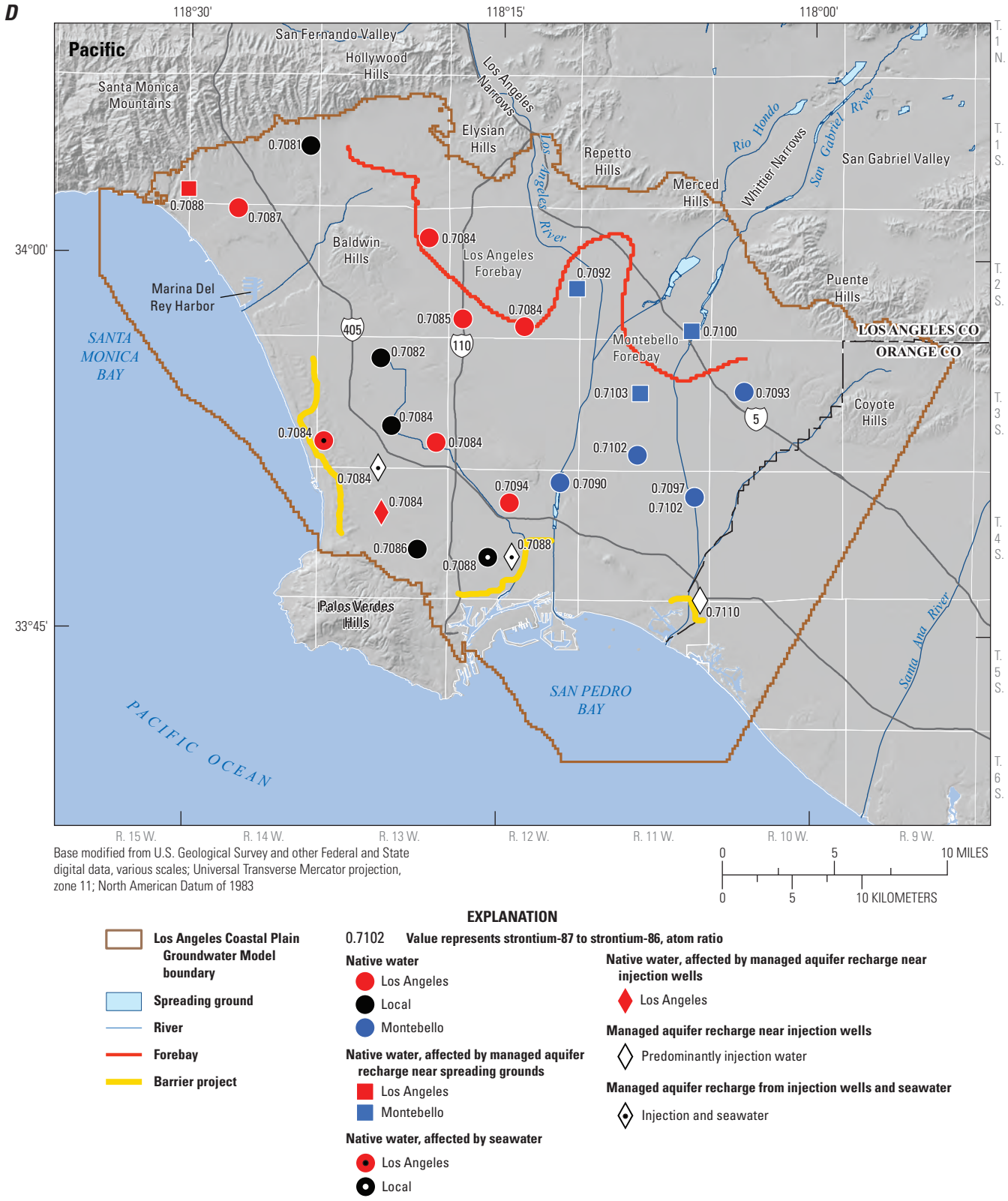


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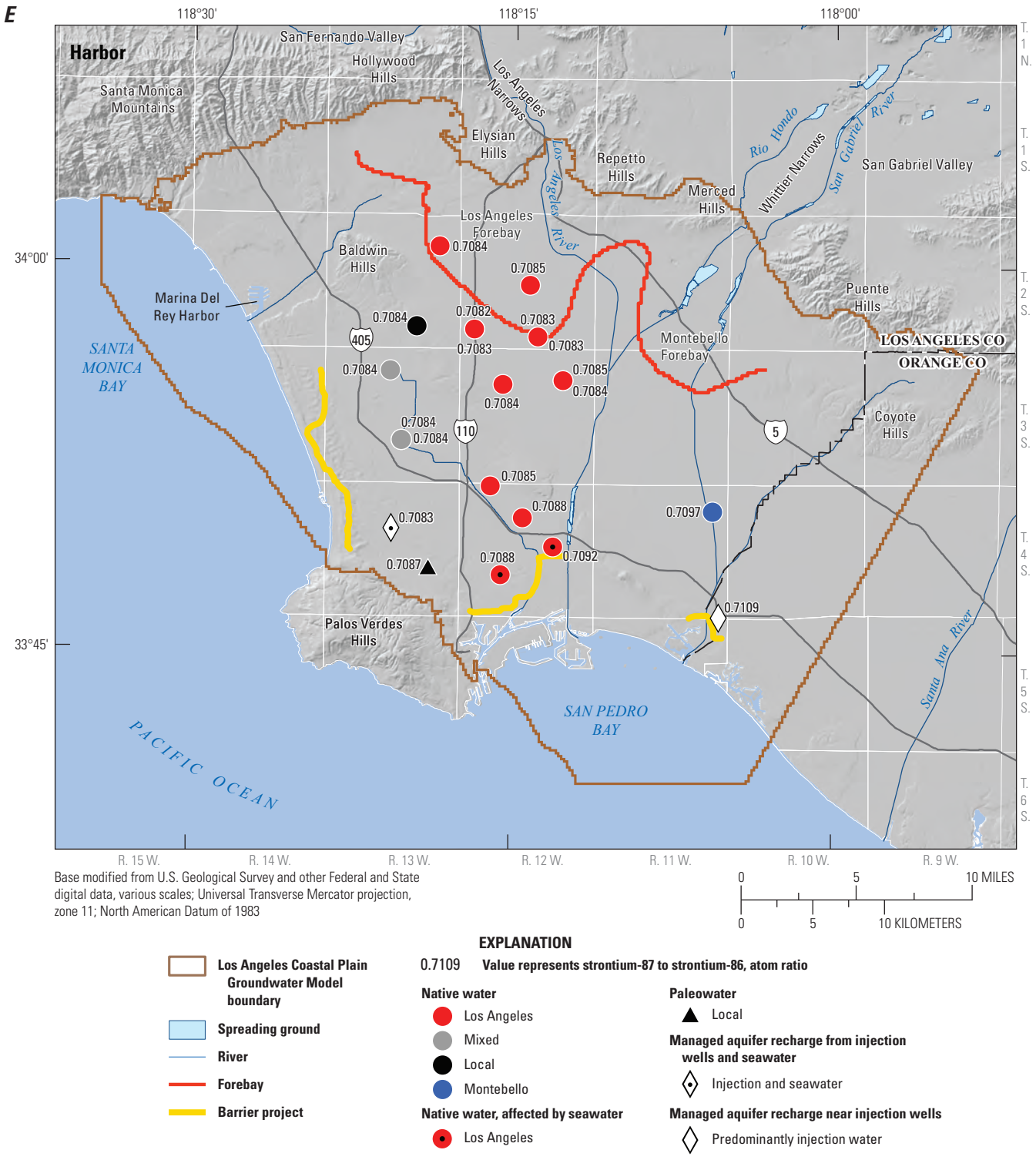


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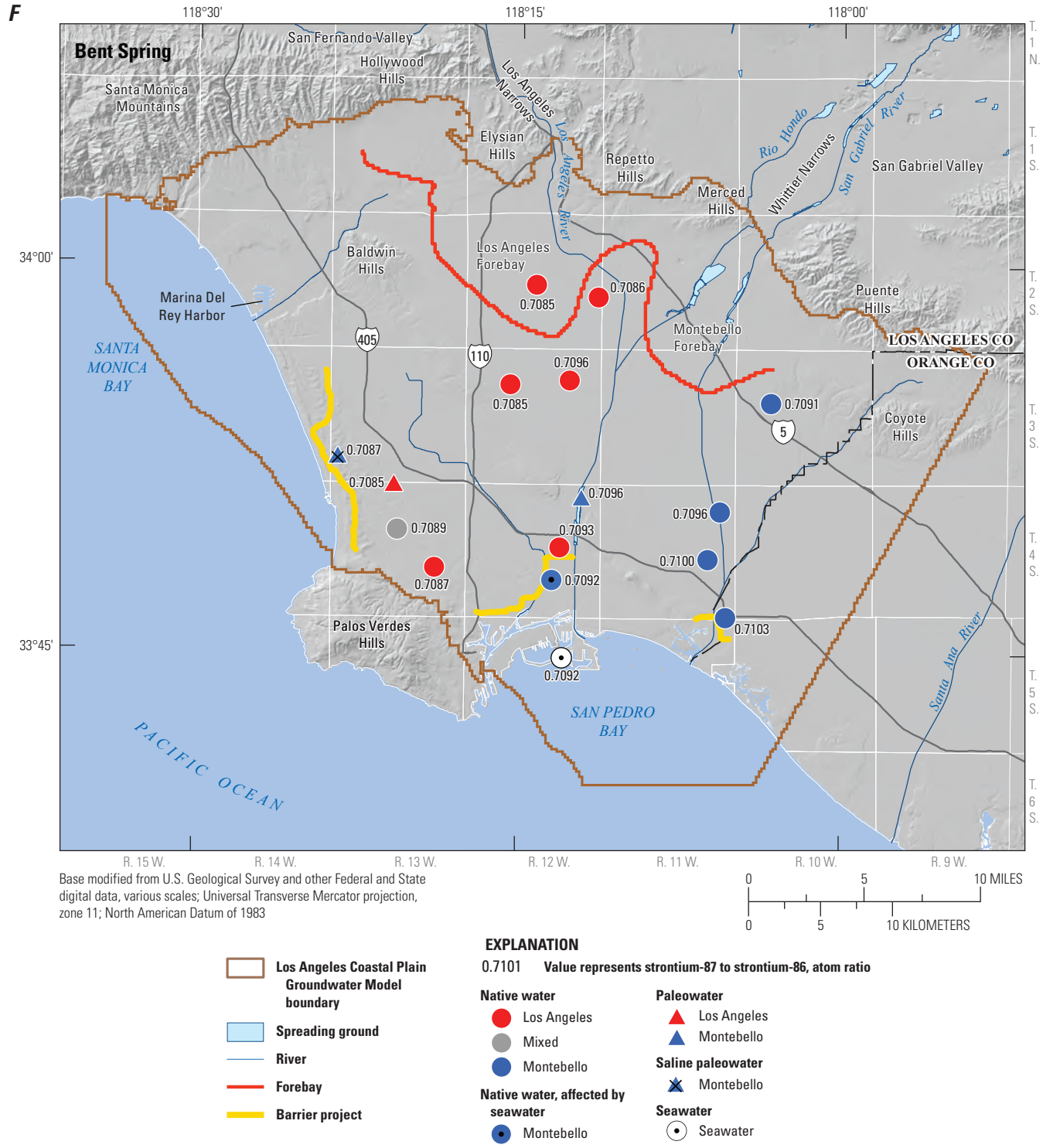


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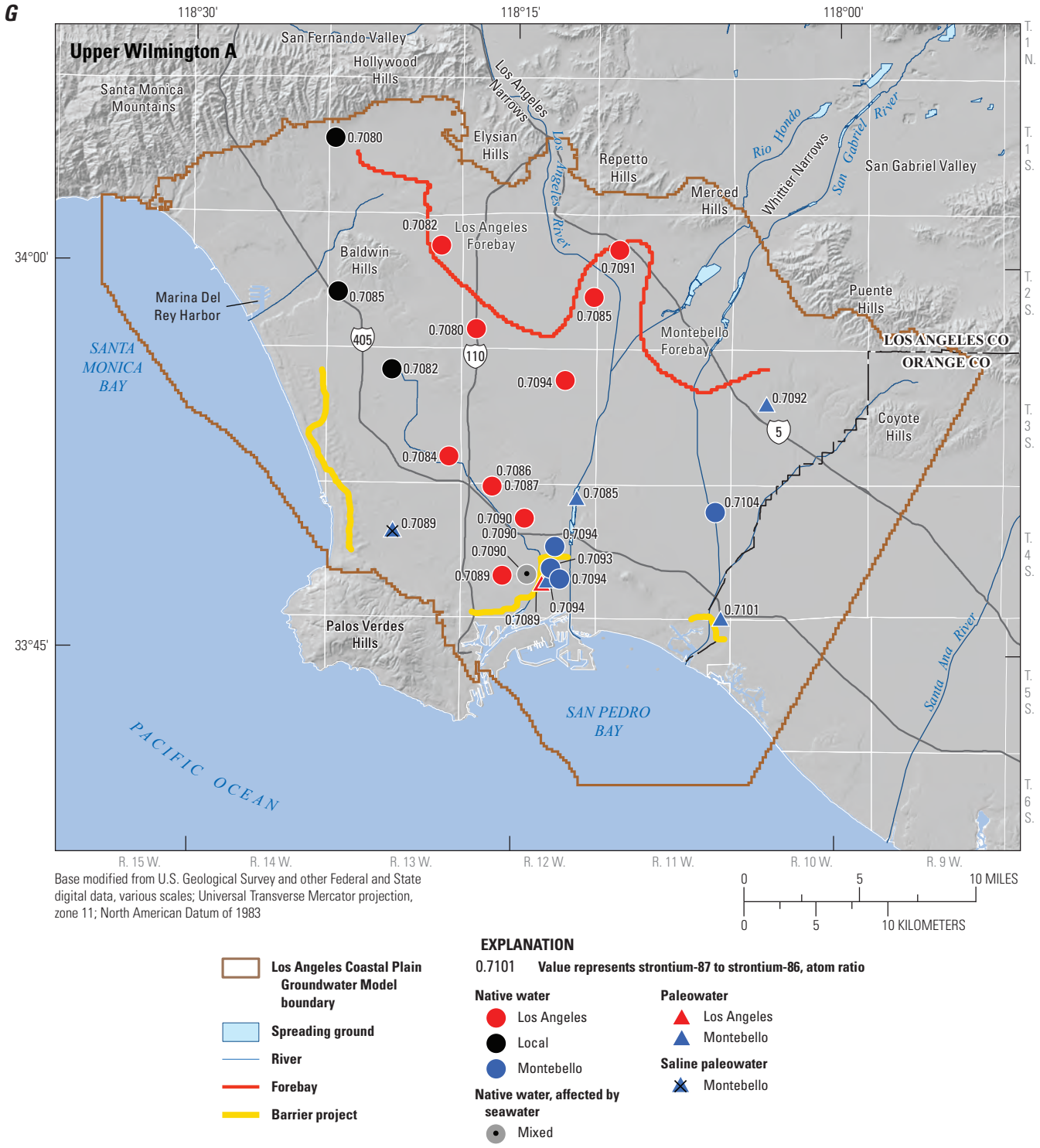


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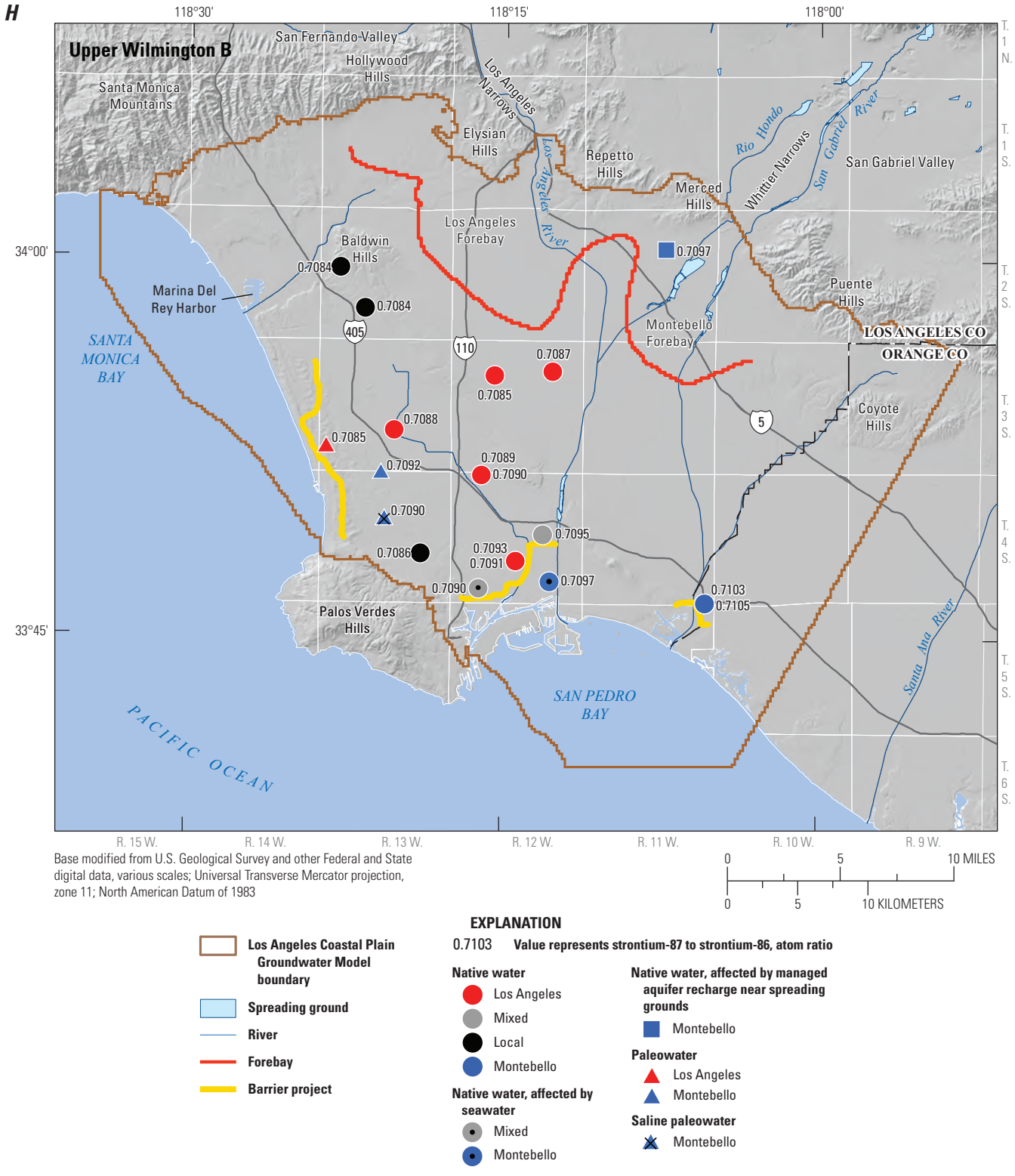


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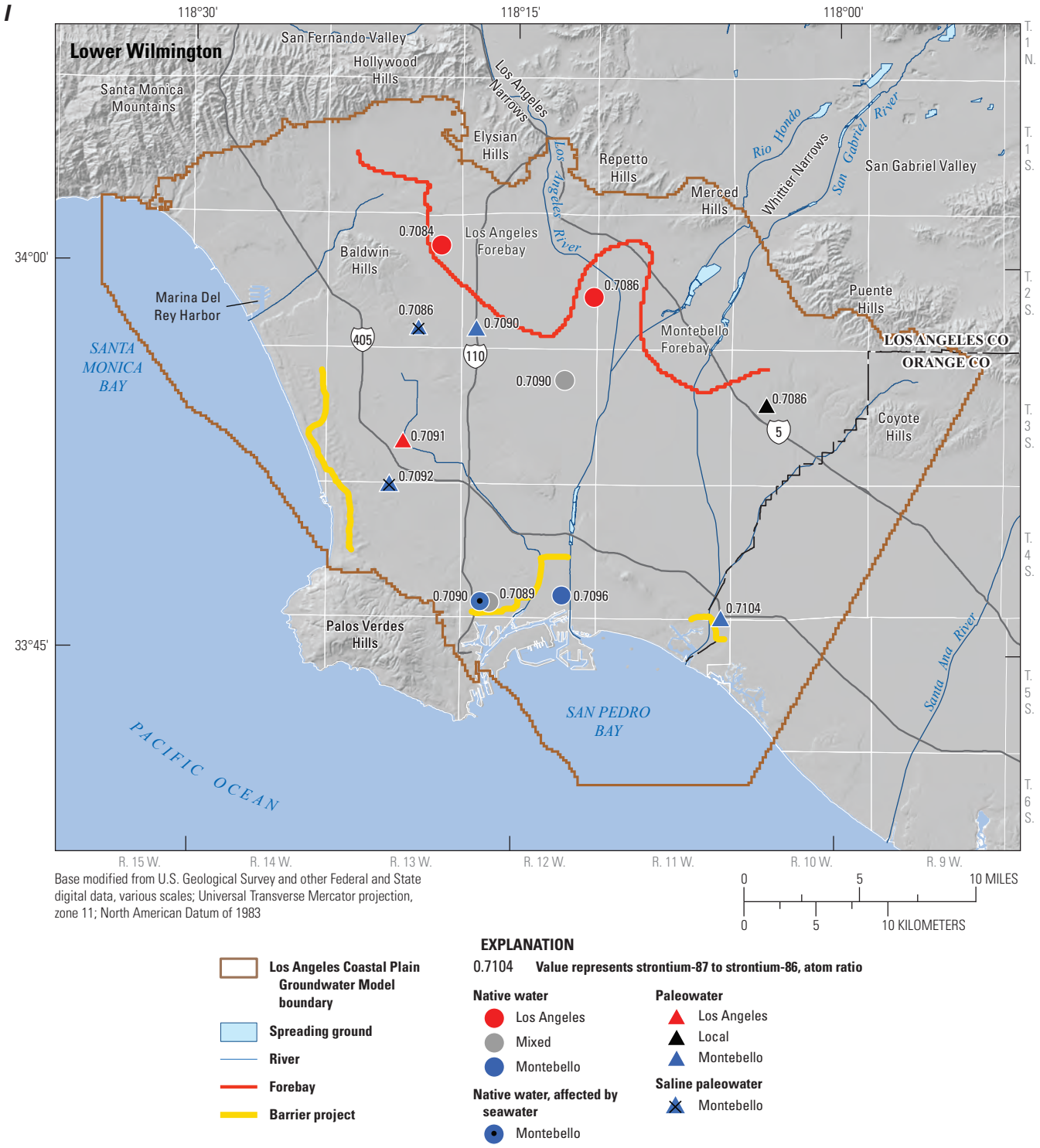


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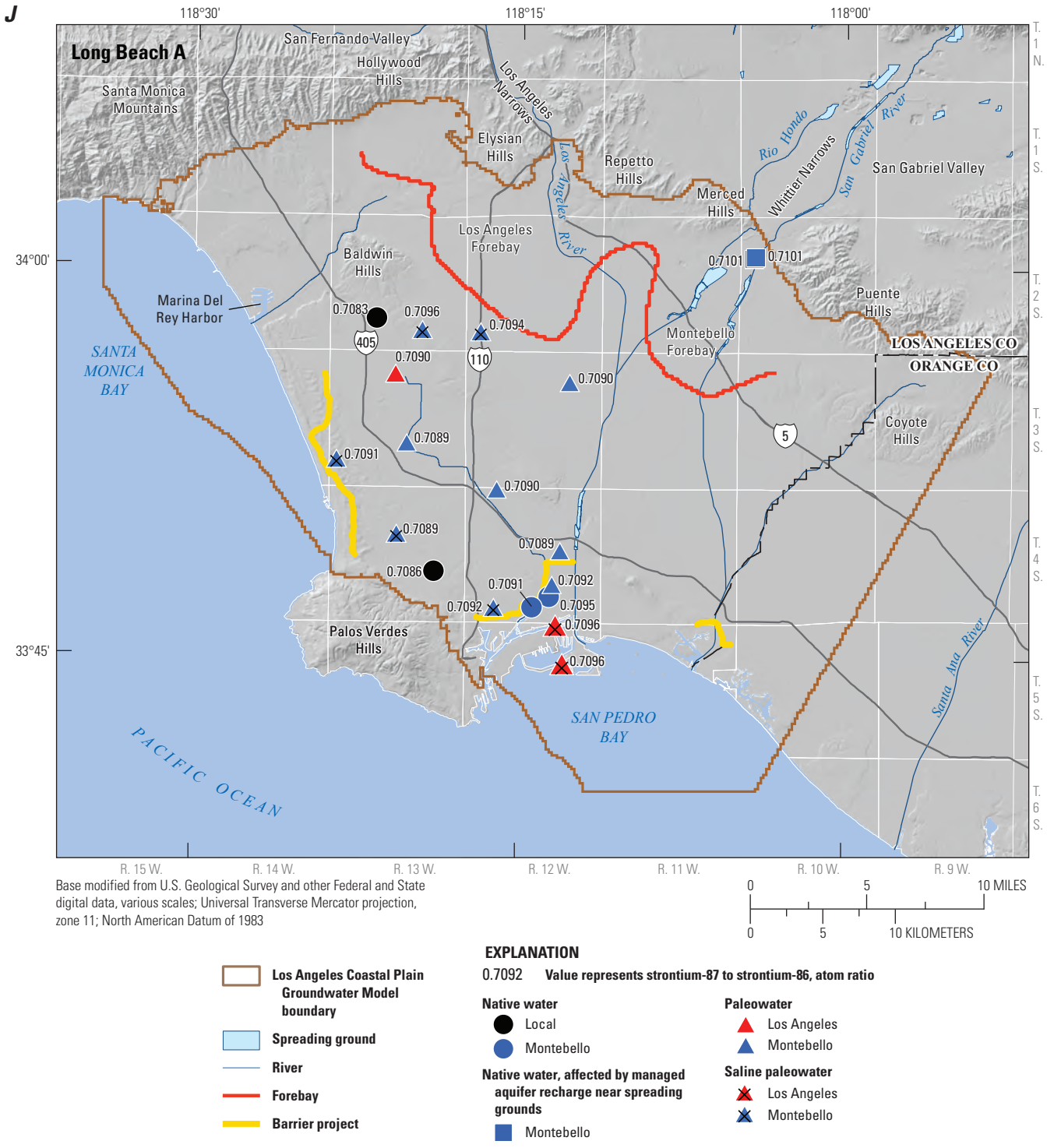


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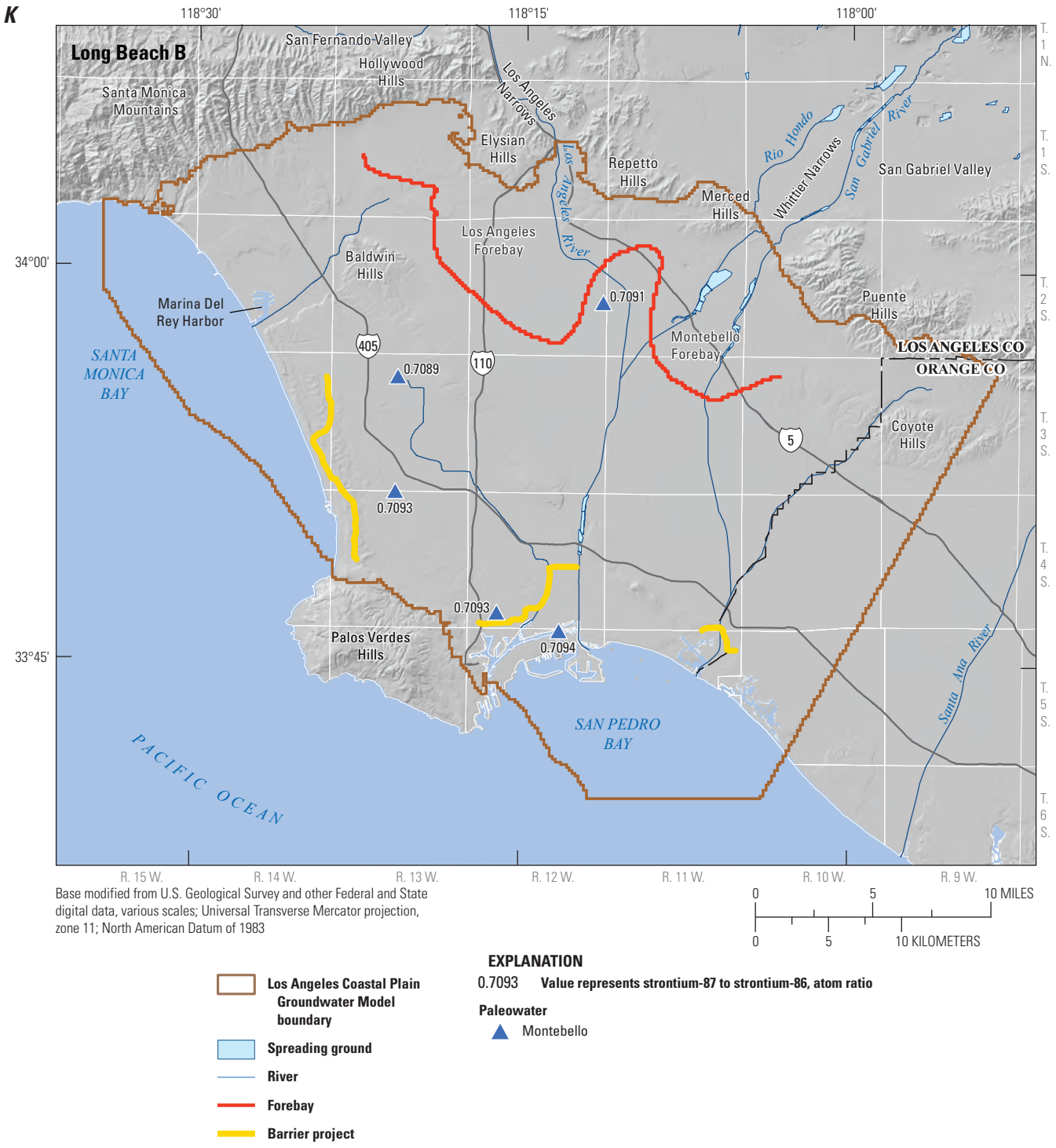


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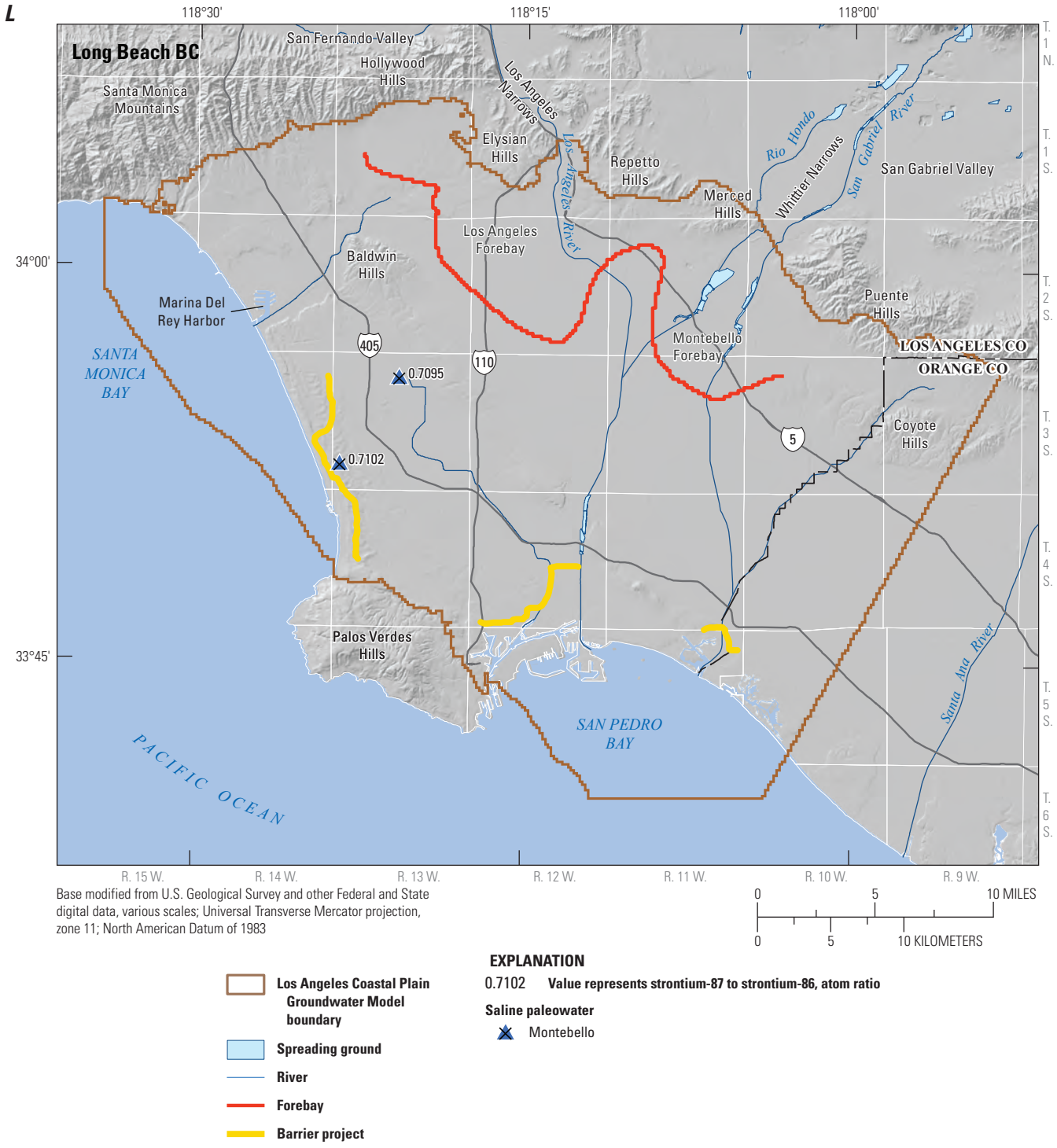


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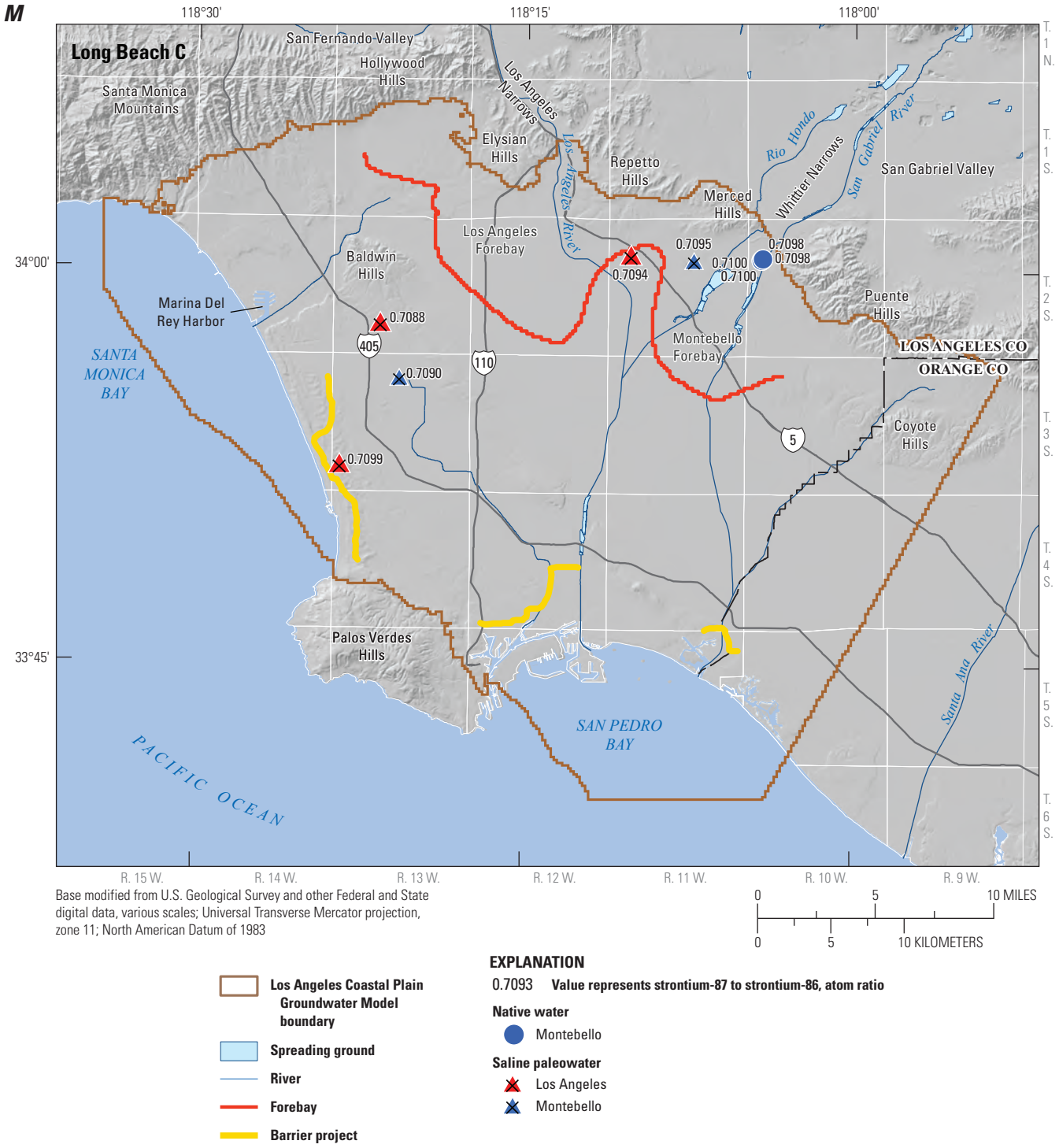


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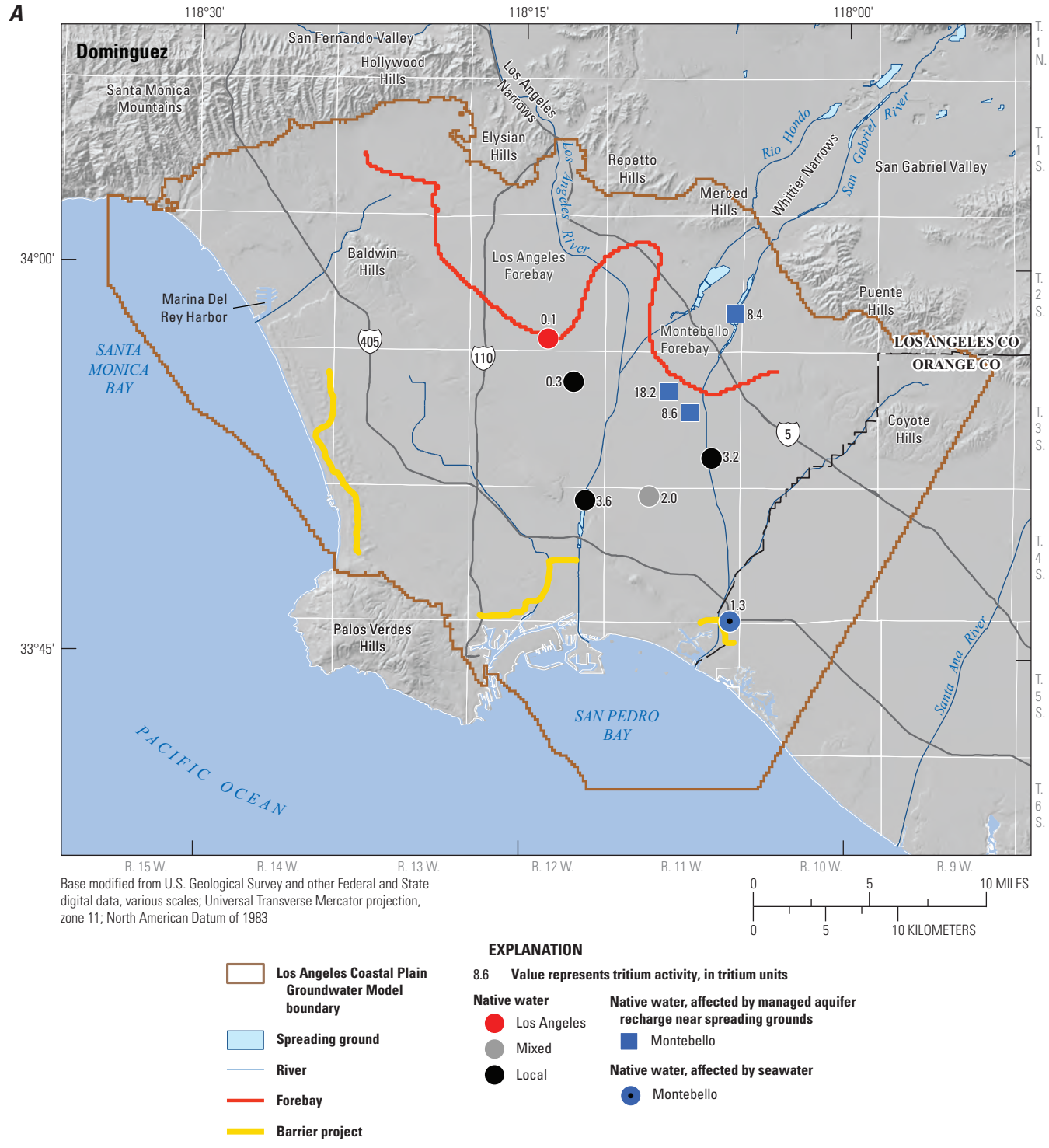


Figure 1.7. Tritium activity in samples from monitoring wells screened in chronostratigraphic units in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California: *A*, Dominguez; *B*, Mesa; *C*, Pacific A; *D*, Pacific; *E*, Harbor; *F*, Bent Spring; *G*, Upper Wilmington A; *H*, Upper Wilmington B; *I*, Lower Wilmington; *J*, Long Beach A; *K*, Long Beach B; and *L*, Long Beach C.

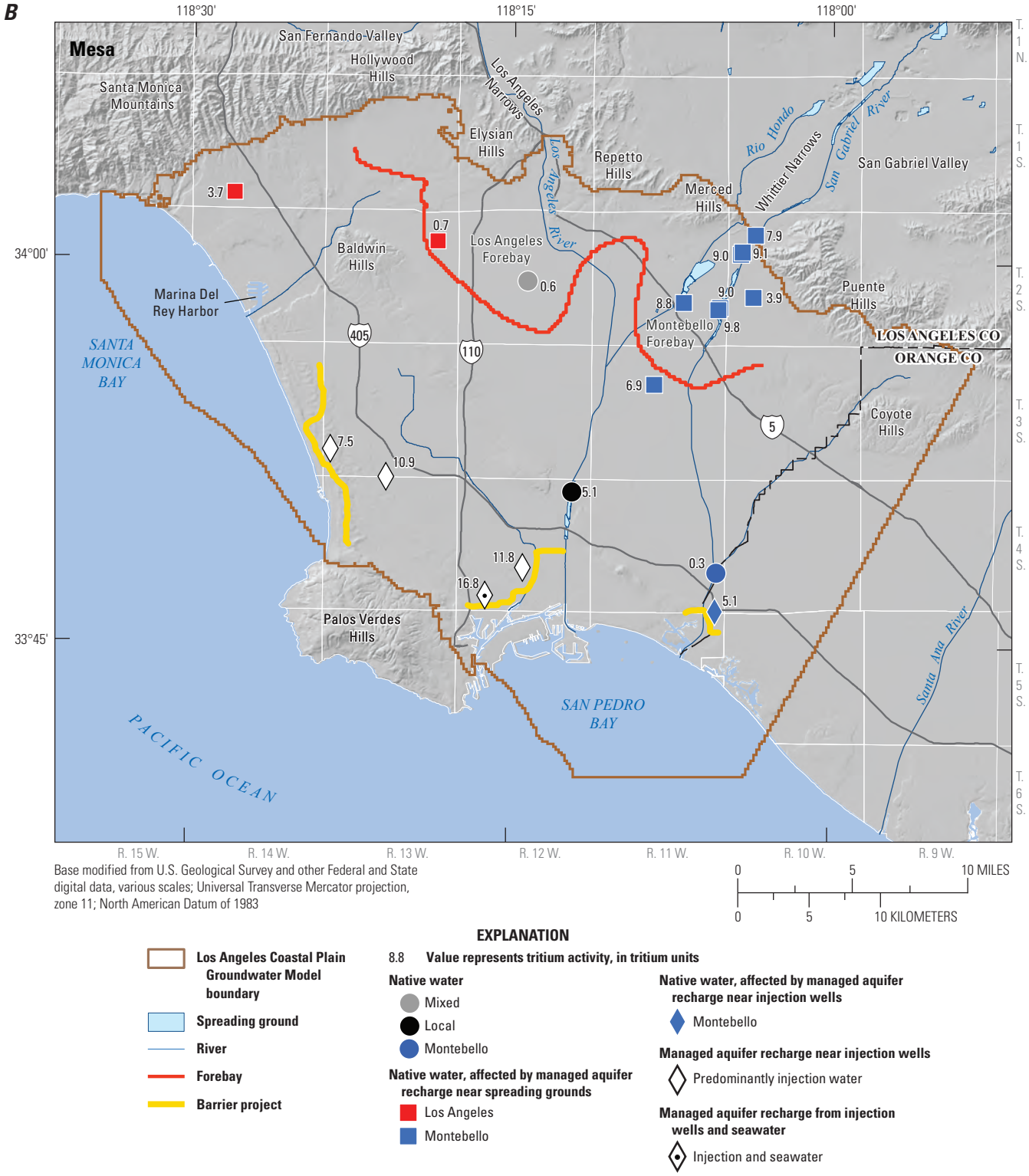


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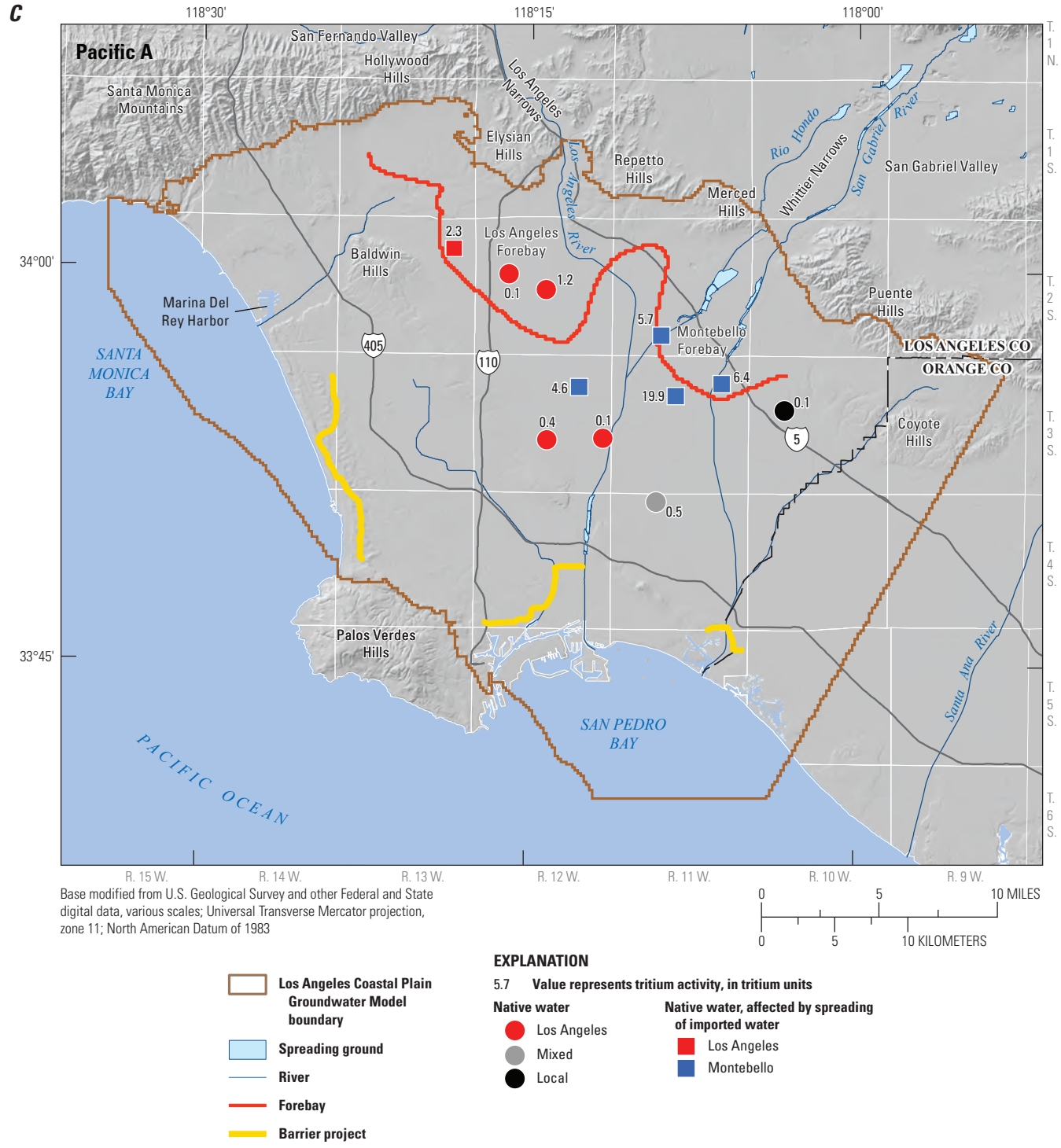


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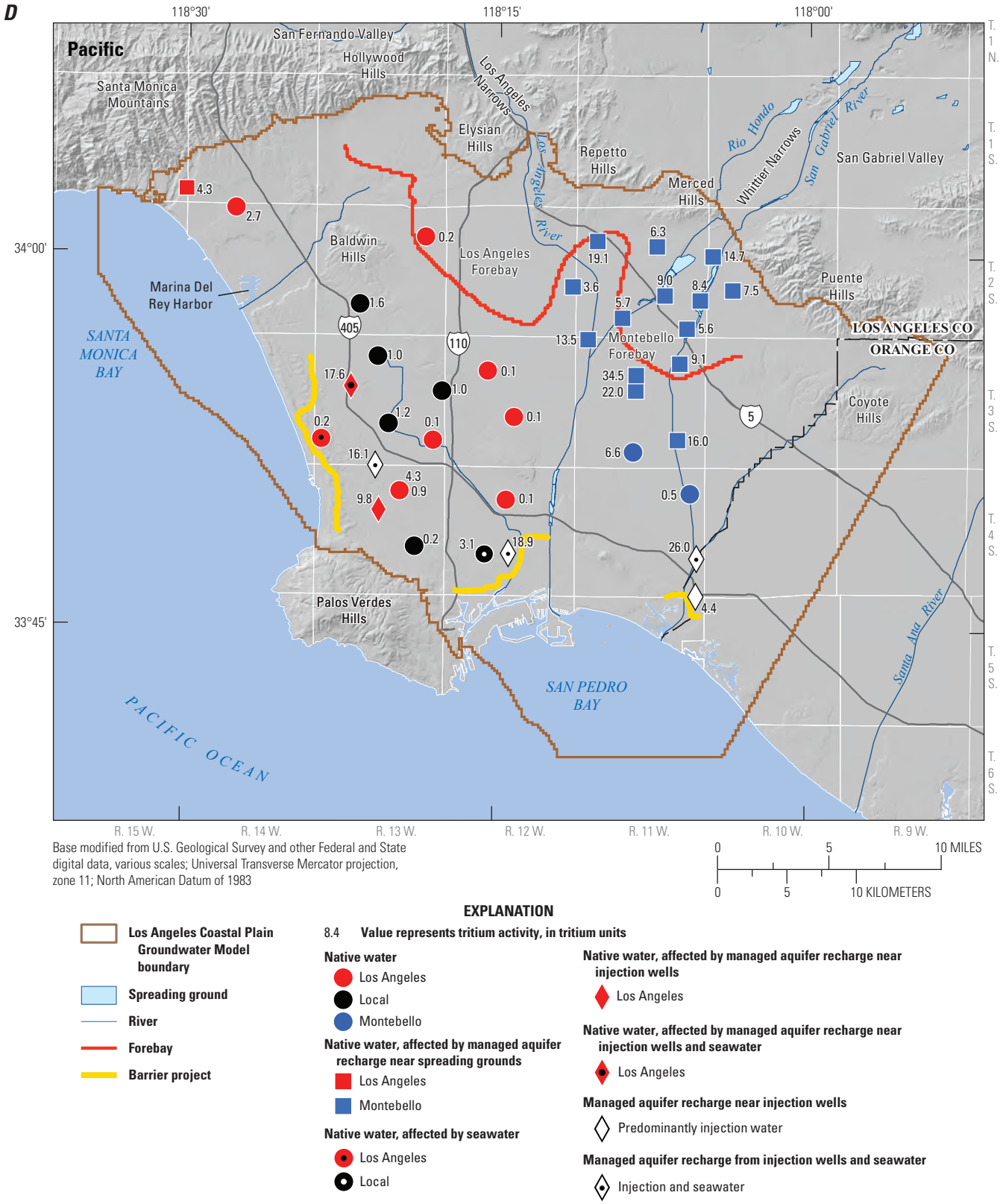
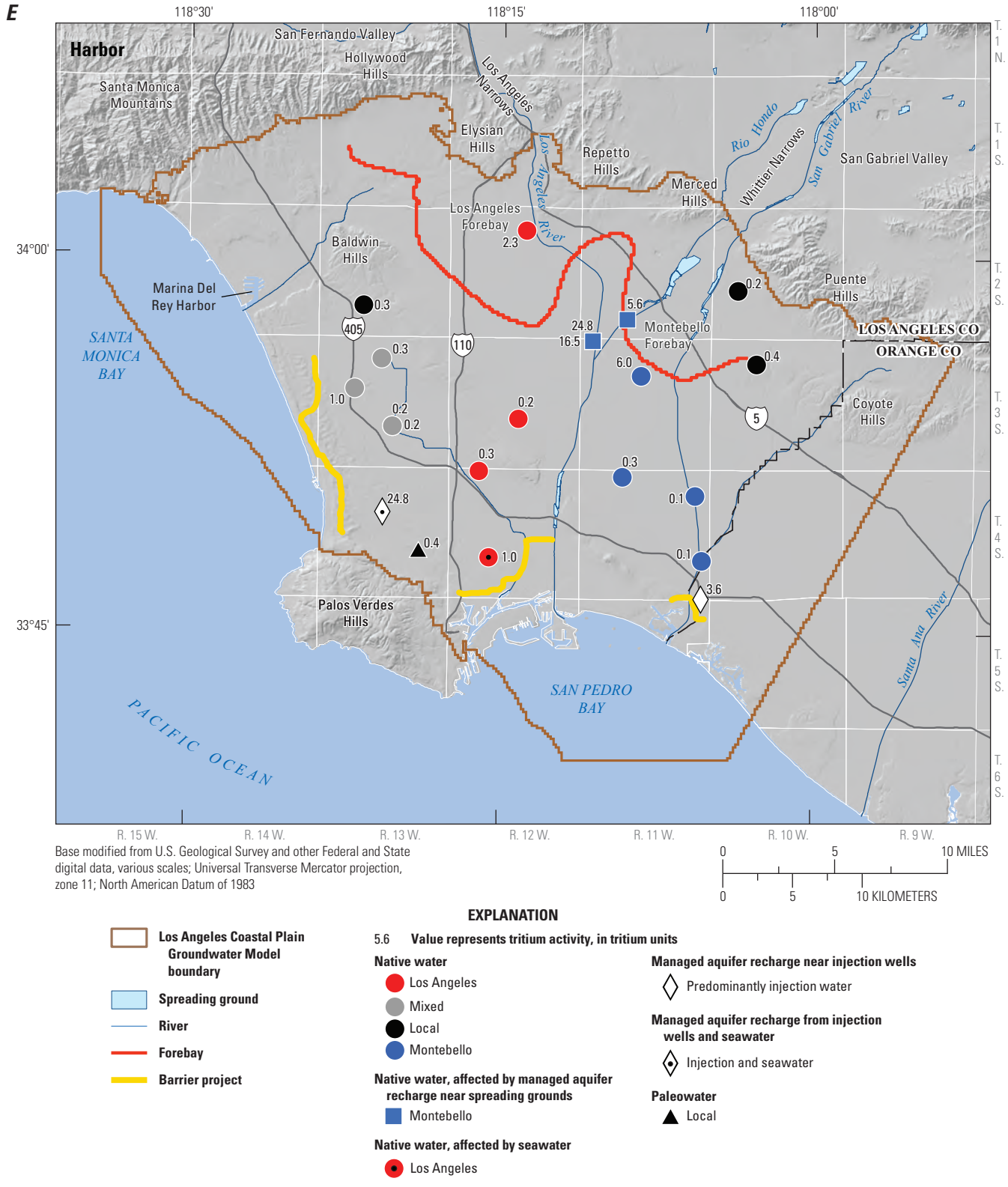


Figure 1.7.—Continued



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

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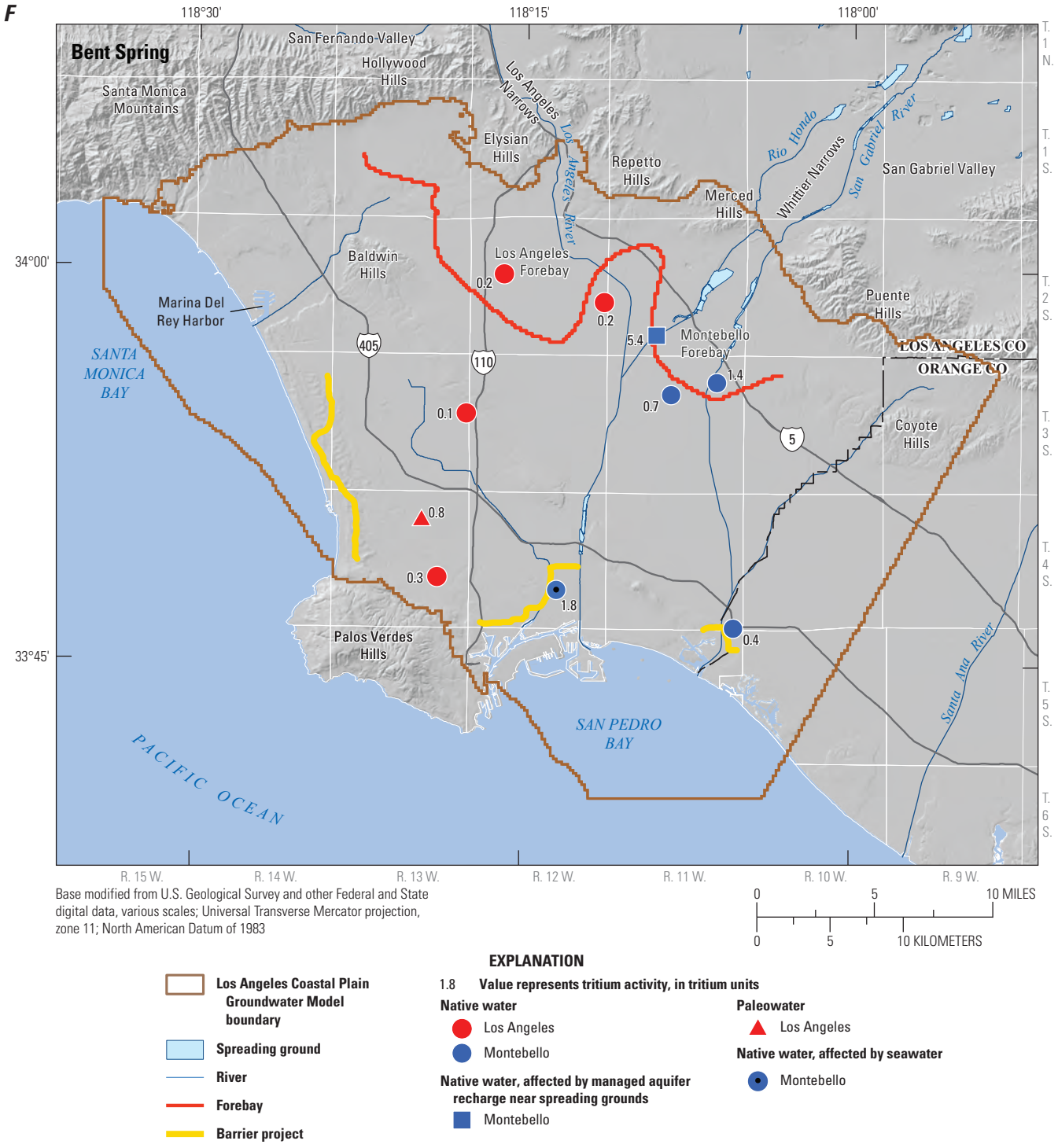


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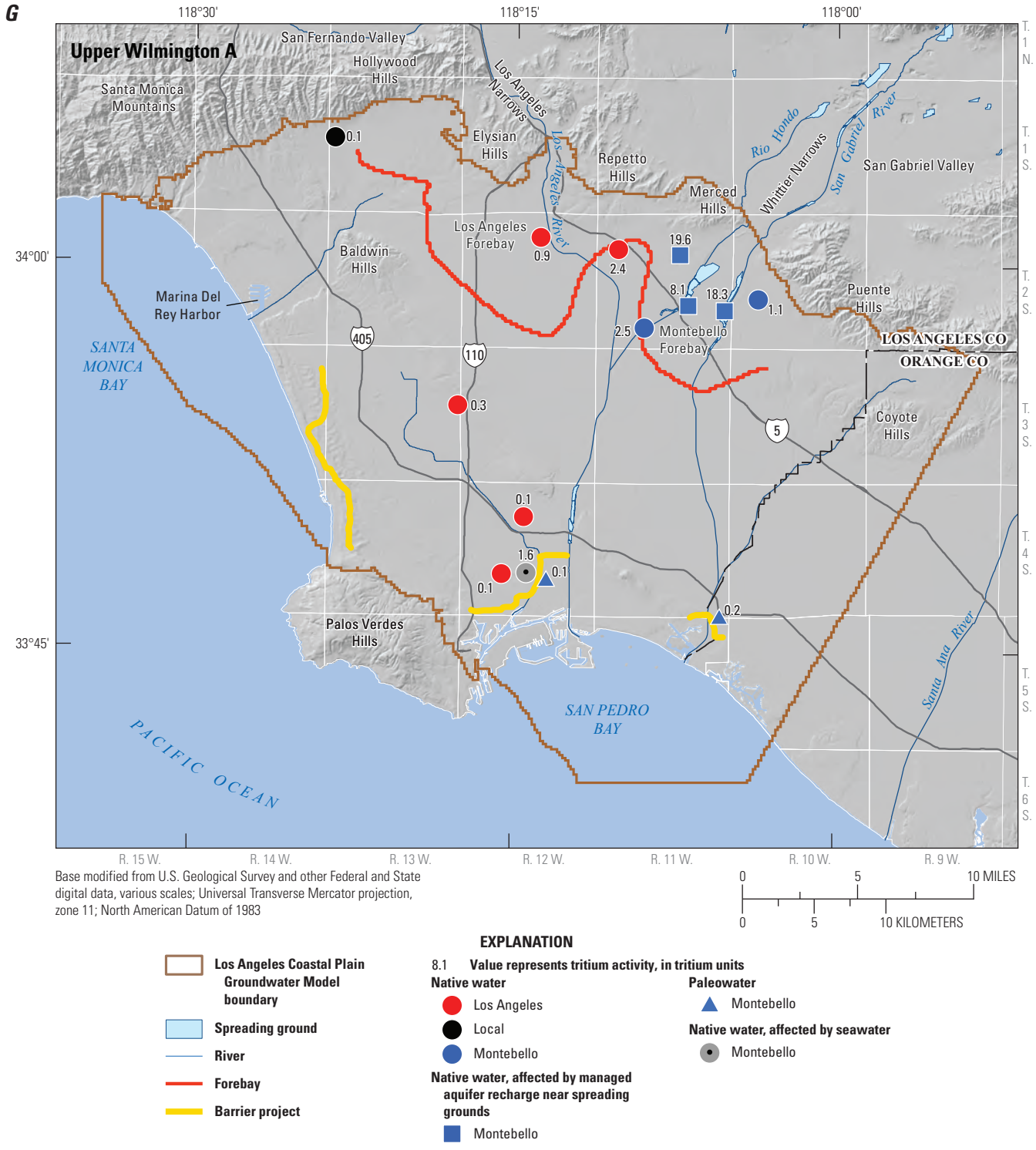


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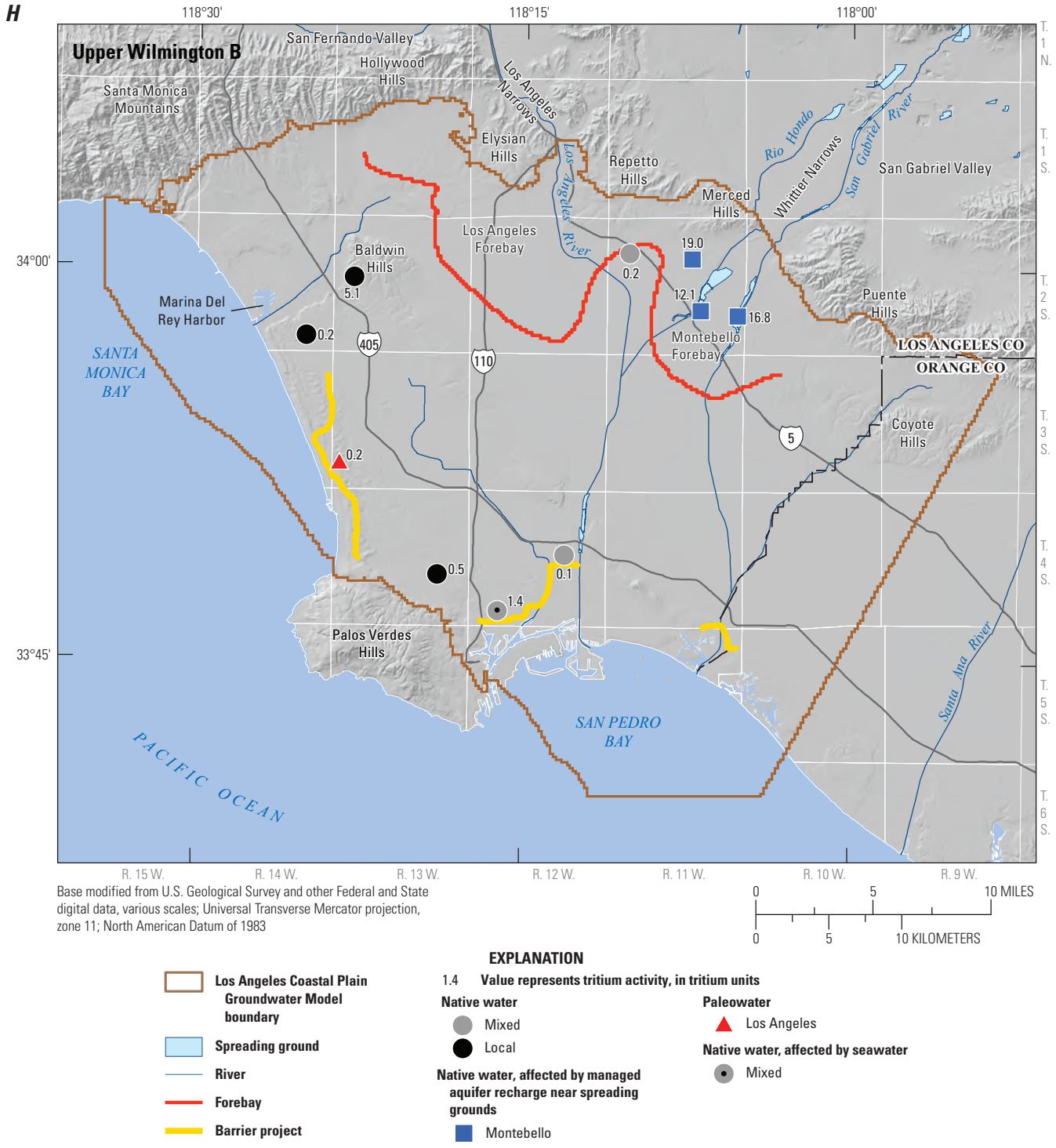


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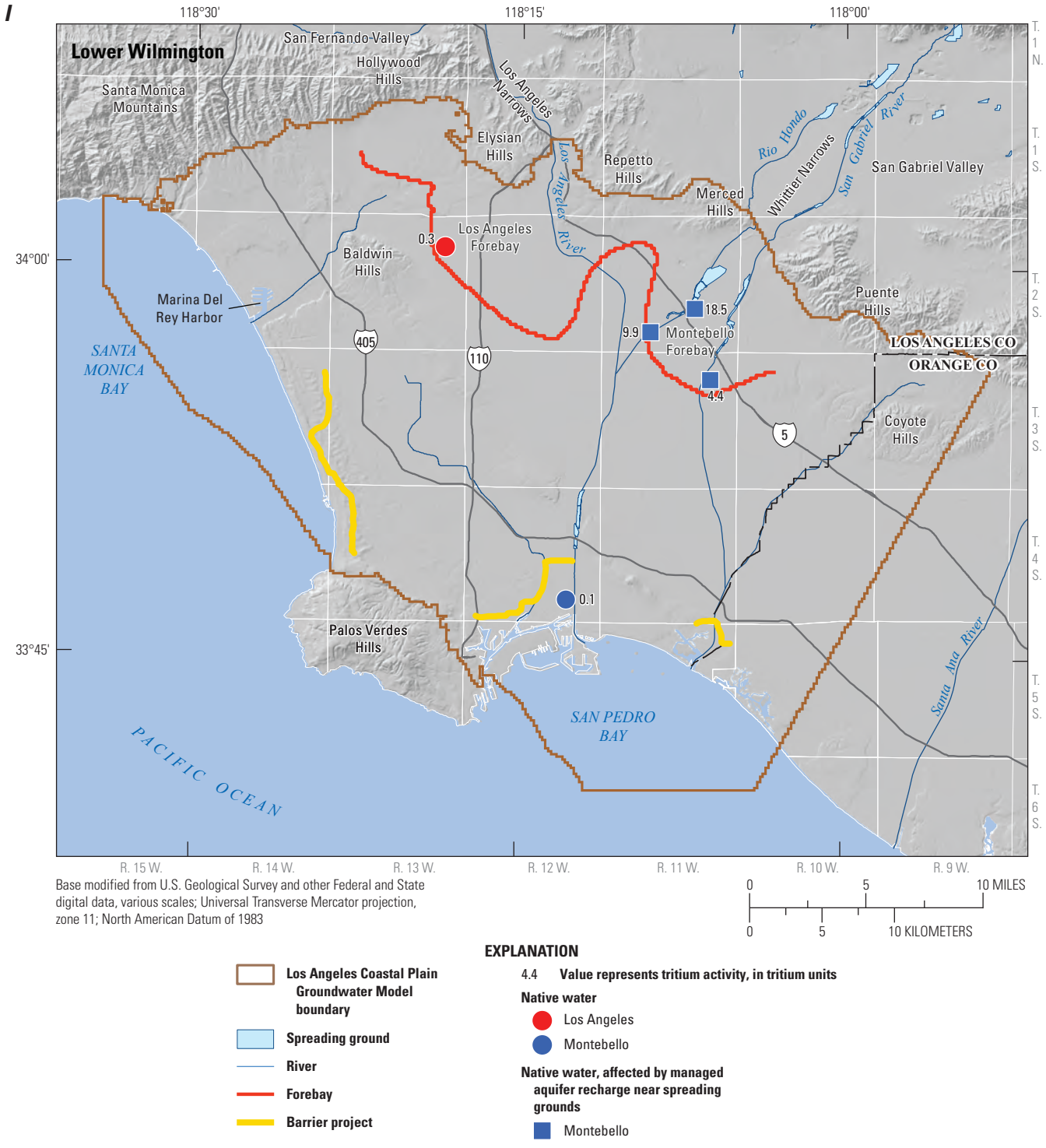


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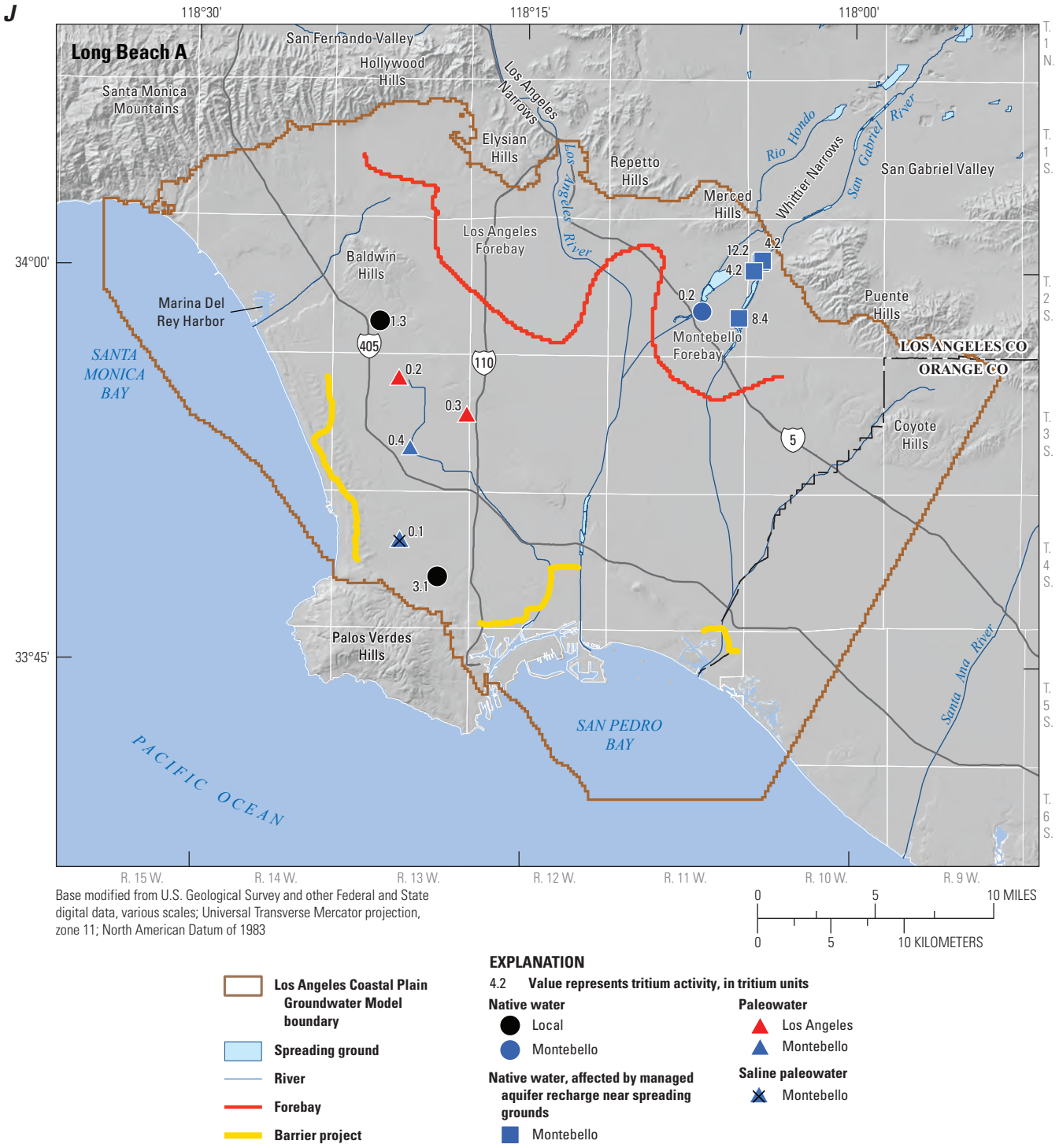


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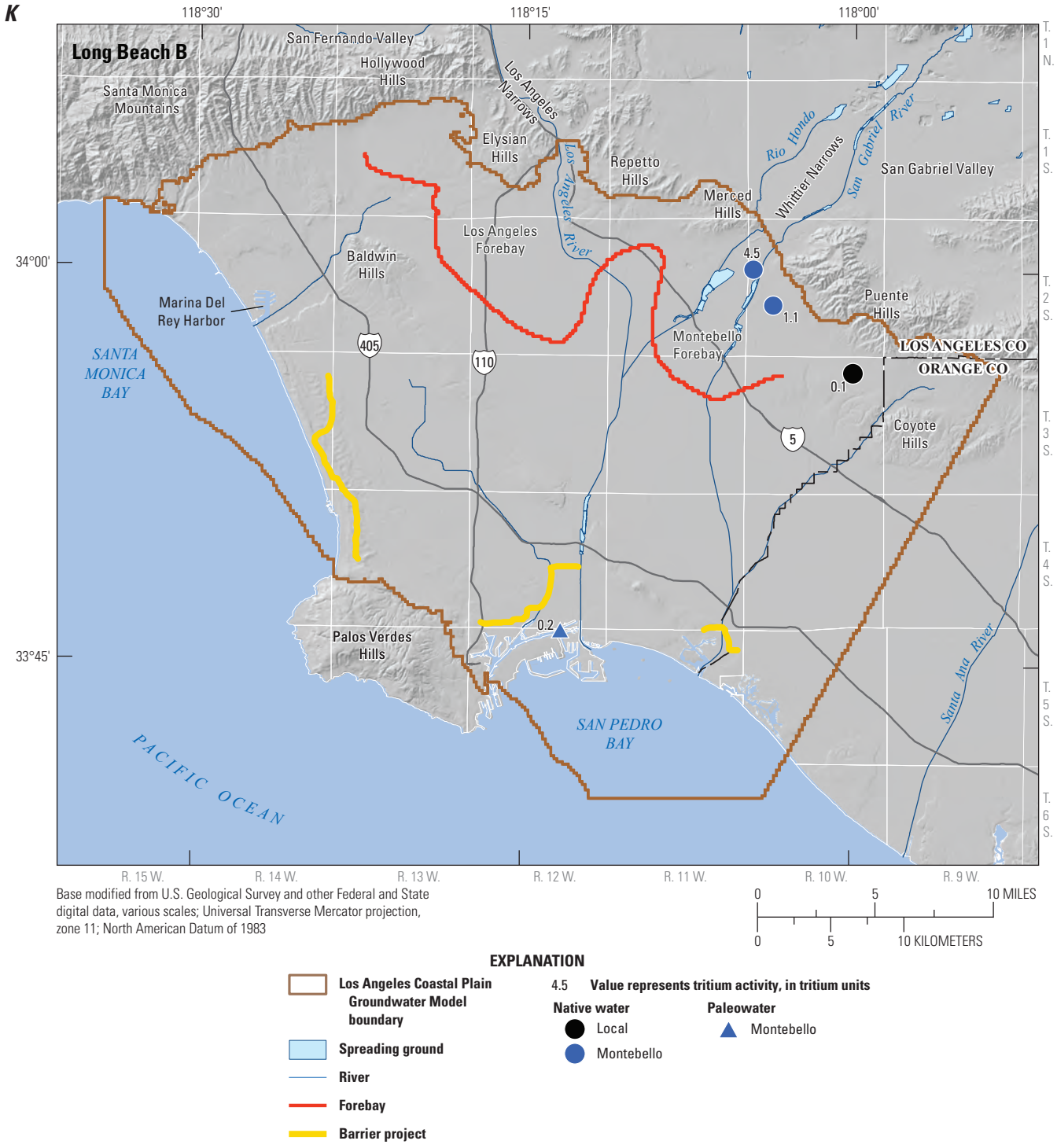


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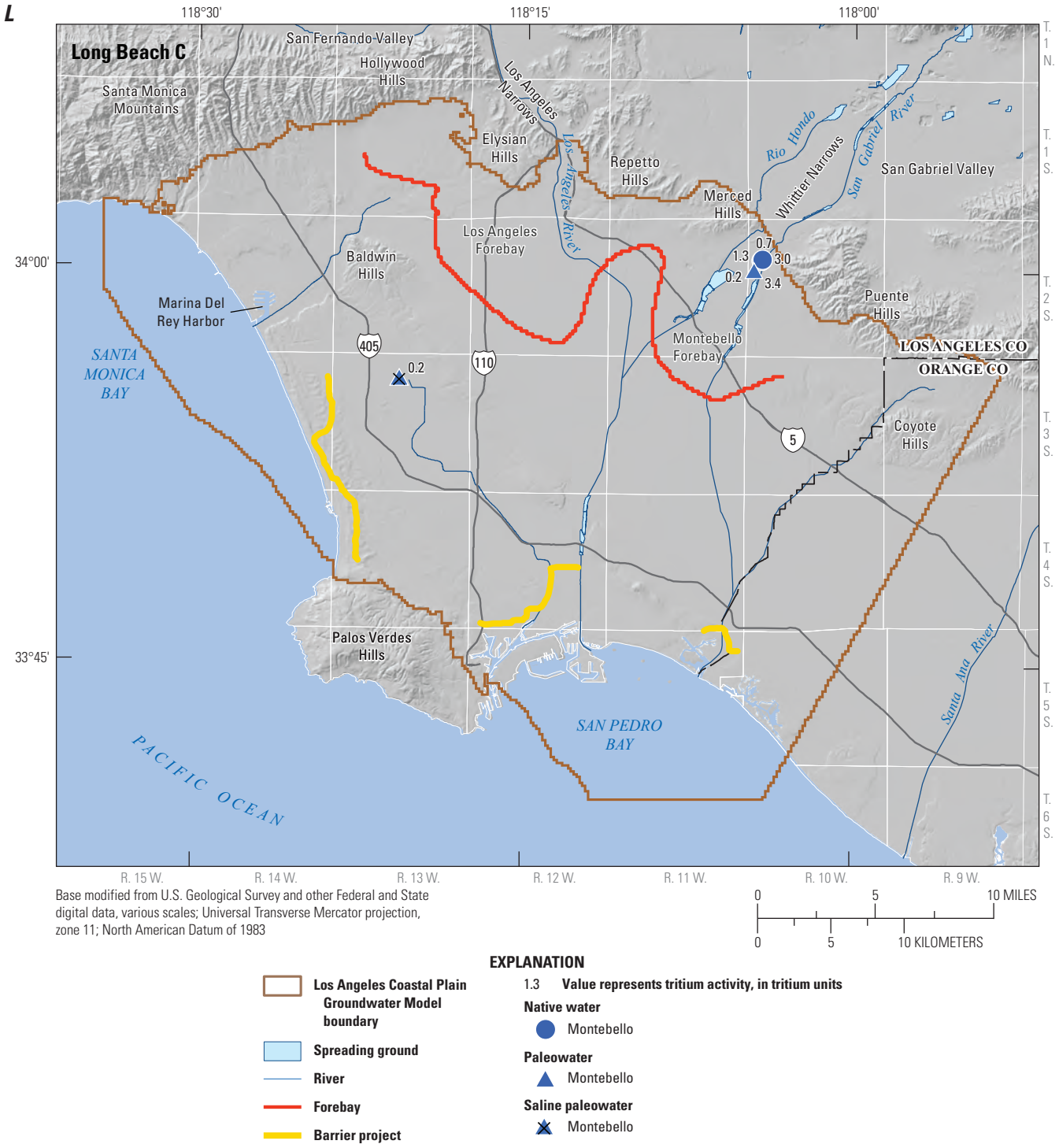


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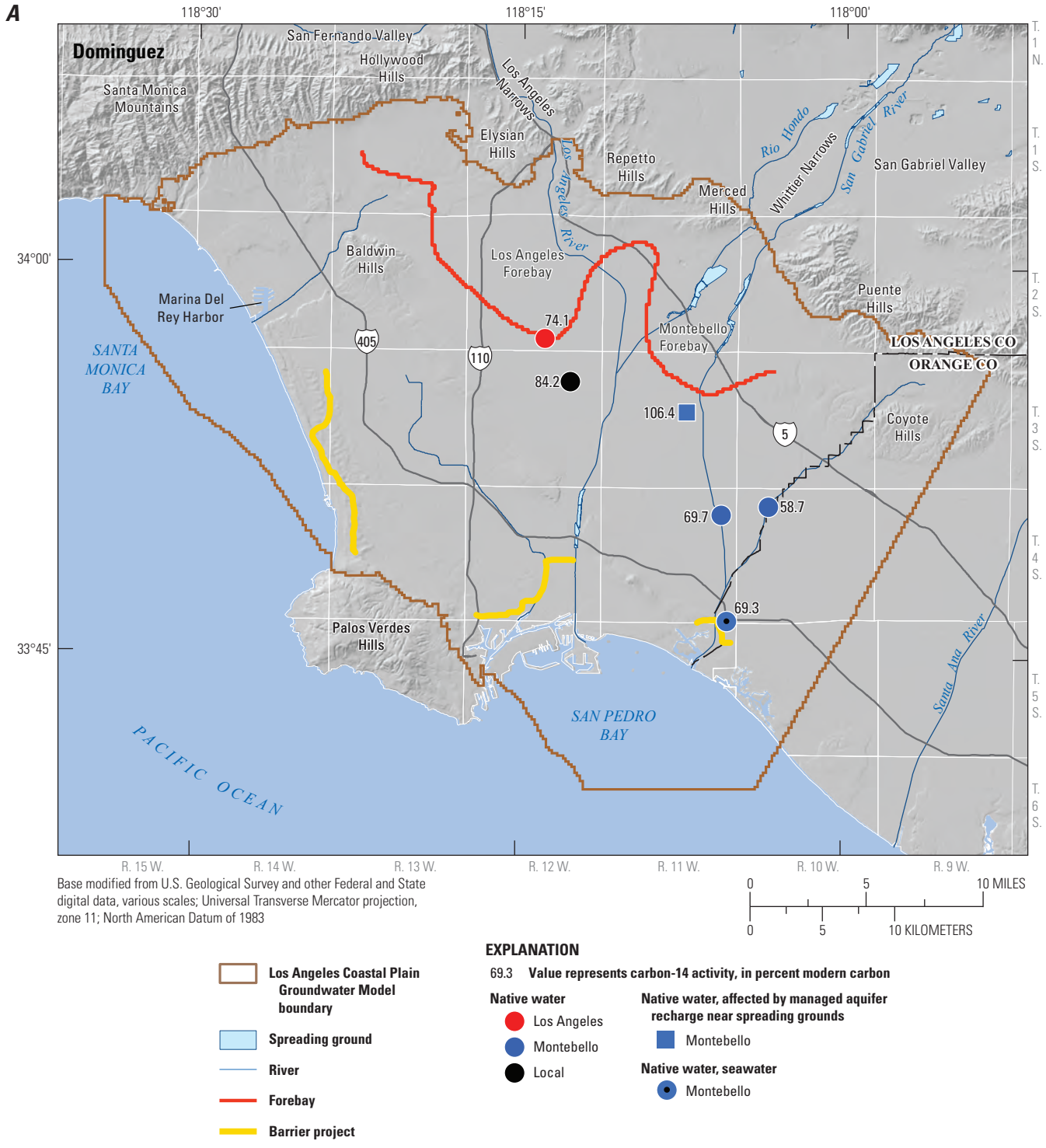


Figure 1.8. Carbon-14 activity in samples from monitoring wells screened in chronostratigraphic units in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California: *A*, Dominguez; *B*, Mesa; *C*, Pacific A; *D*, Pacific; *E*, Harbor; *F*, Bent Spring; *G*, Upper Wilmington A; *H*, Upper Wilmington B; *I*, Lower Wilmington; *J*, Long Beach A; *K*, Long Beach B; *L*, Long Beach BC; and *M*, Long Beach C.

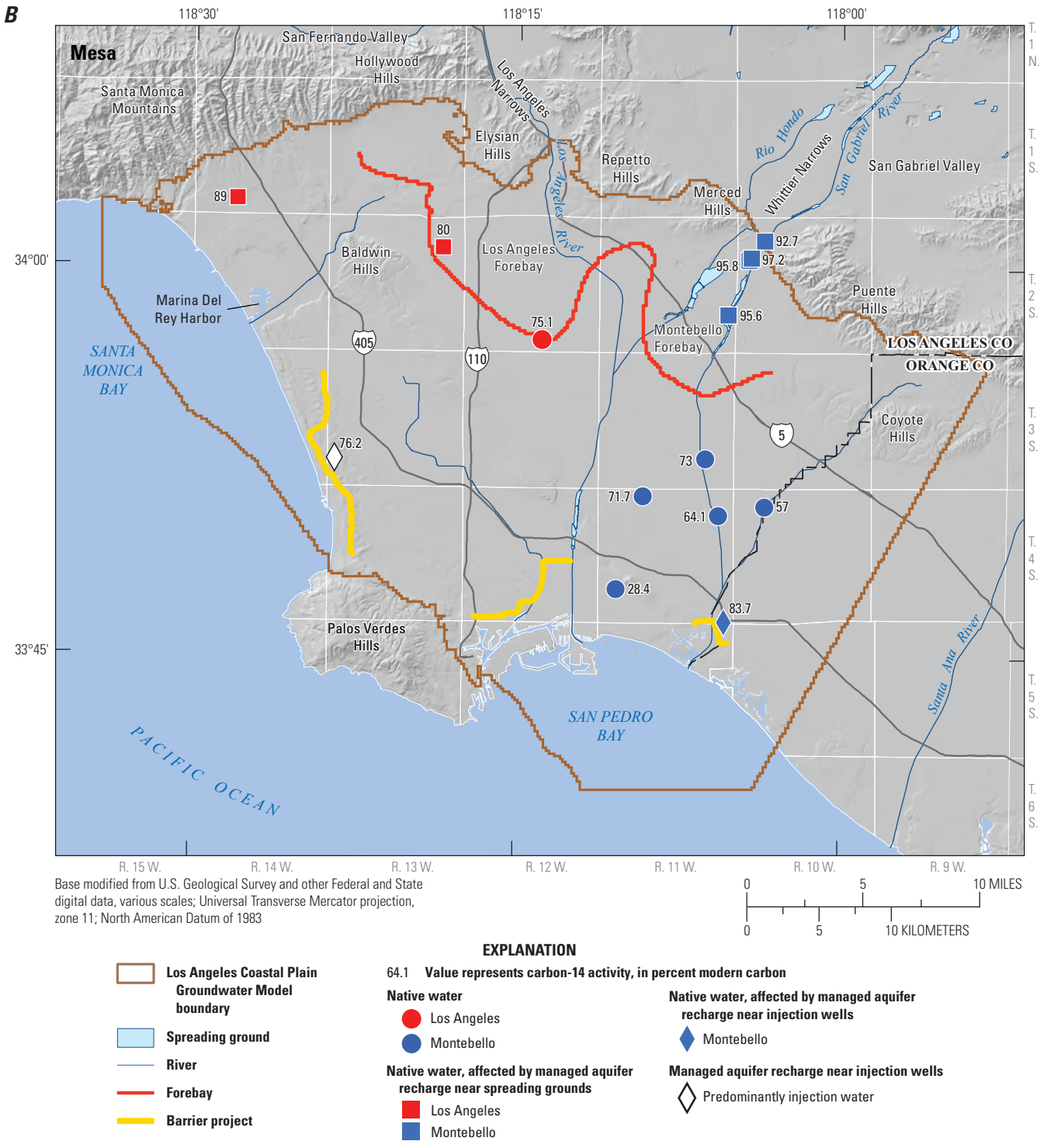
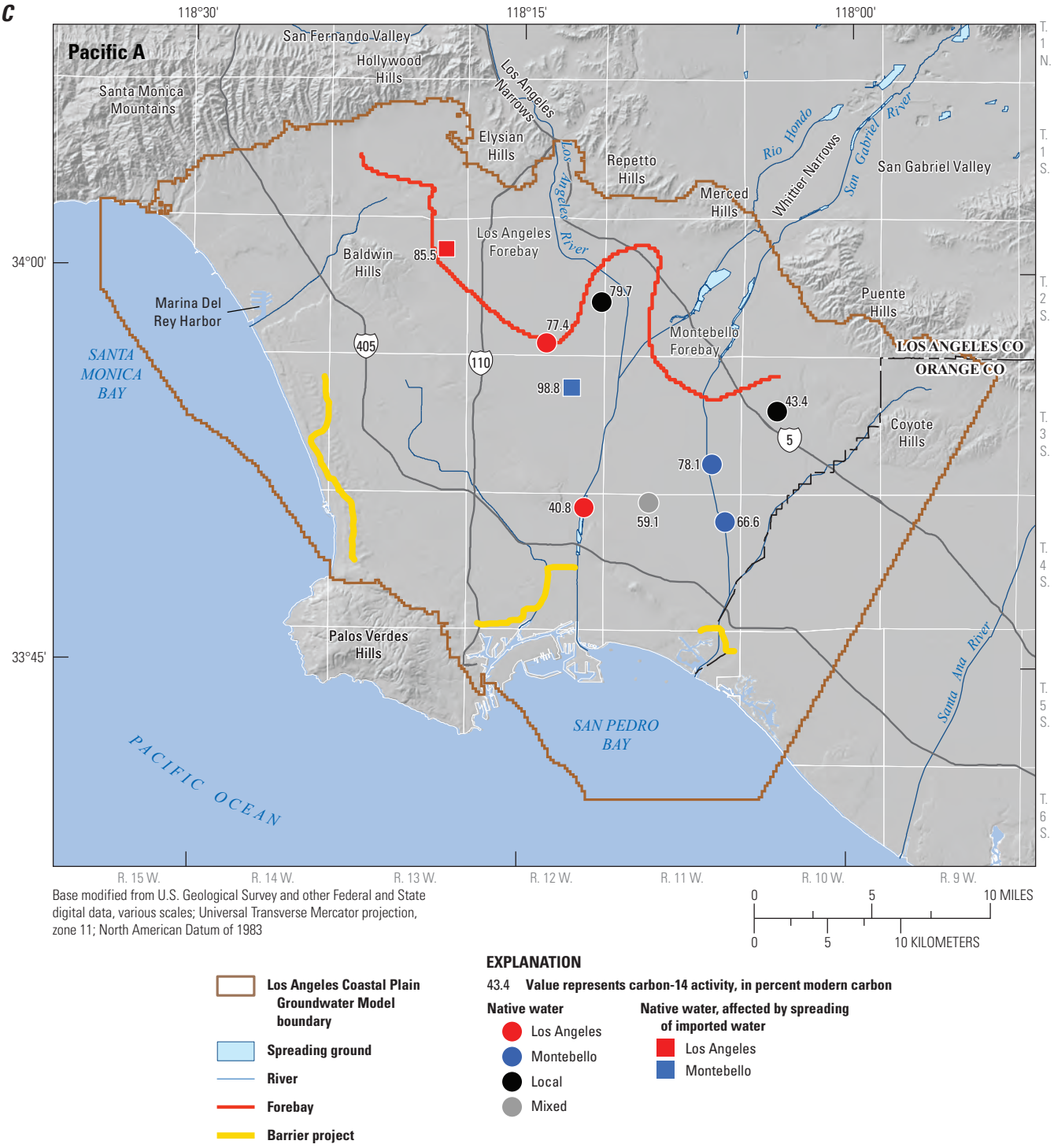


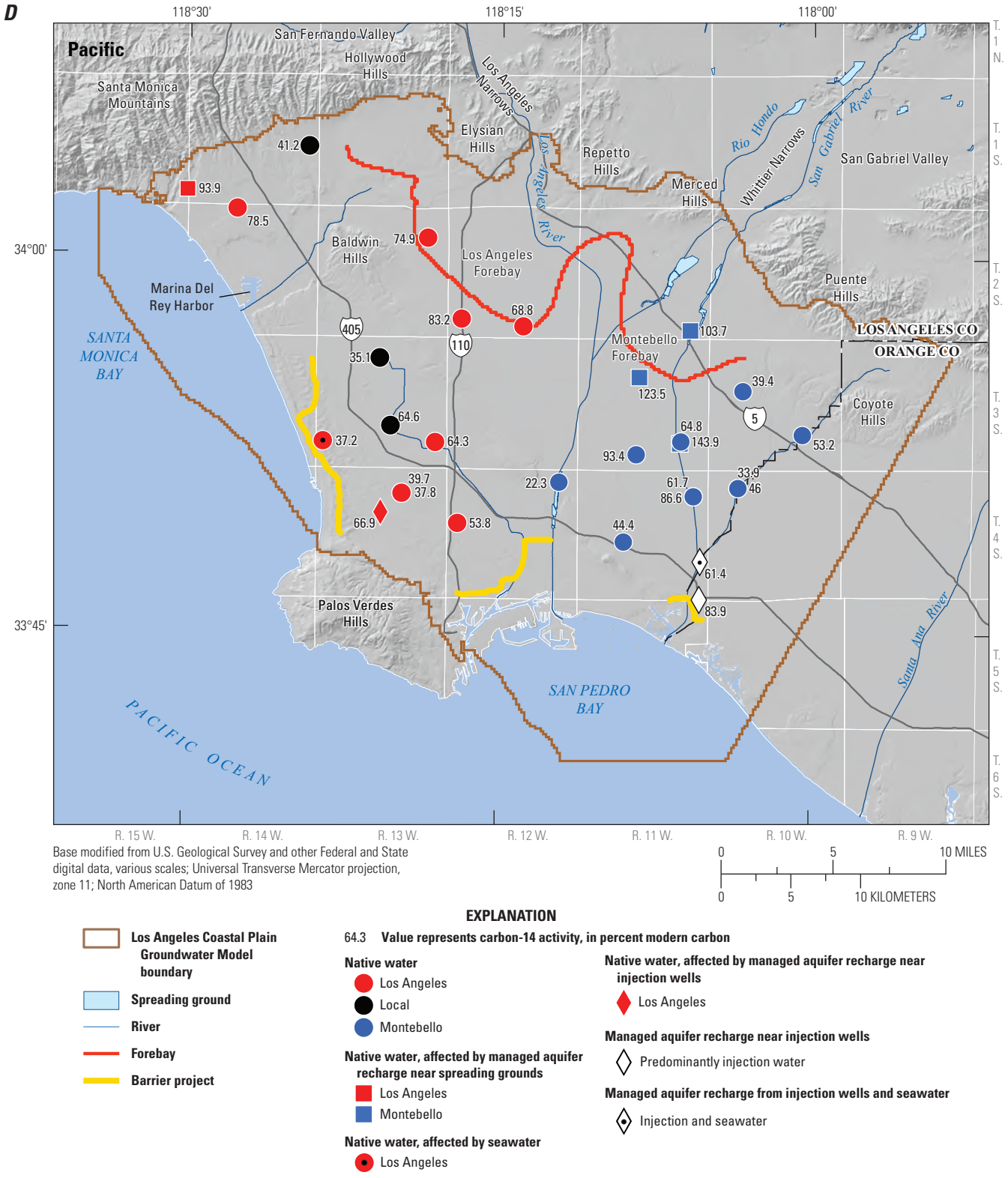
Figure 1.8.—Continued

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Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

Figure 1.8.—Continued



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Universal Transverse Mercator projection, zone 11; North American Datum of 1983

EXPLANATION

- **Los Angeles Coastal Plain Groundwater Model boundary**
- **Spreading ground**
- **River**
- **Forebay**
- **Barrier project**

64.3 **Value represents carbon-14 activity, in percent modern carbon**

Native water
- Los Angeles
- Local
- Montebello

Native water, affected by managed aquifer recharge near spreading grounds
- Los Angeles
- Montebello

Native water, affected by seawater
- Los Angeles

Native water, affected by managed aquifer recharge near injection wells
- Los Angeles

Managed aquifer recharge near injection wells
- Predominantly injection water

Managed aquifer recharge from injection wells and seawater
- Injection and seawater

Figure 1.8.—Continued

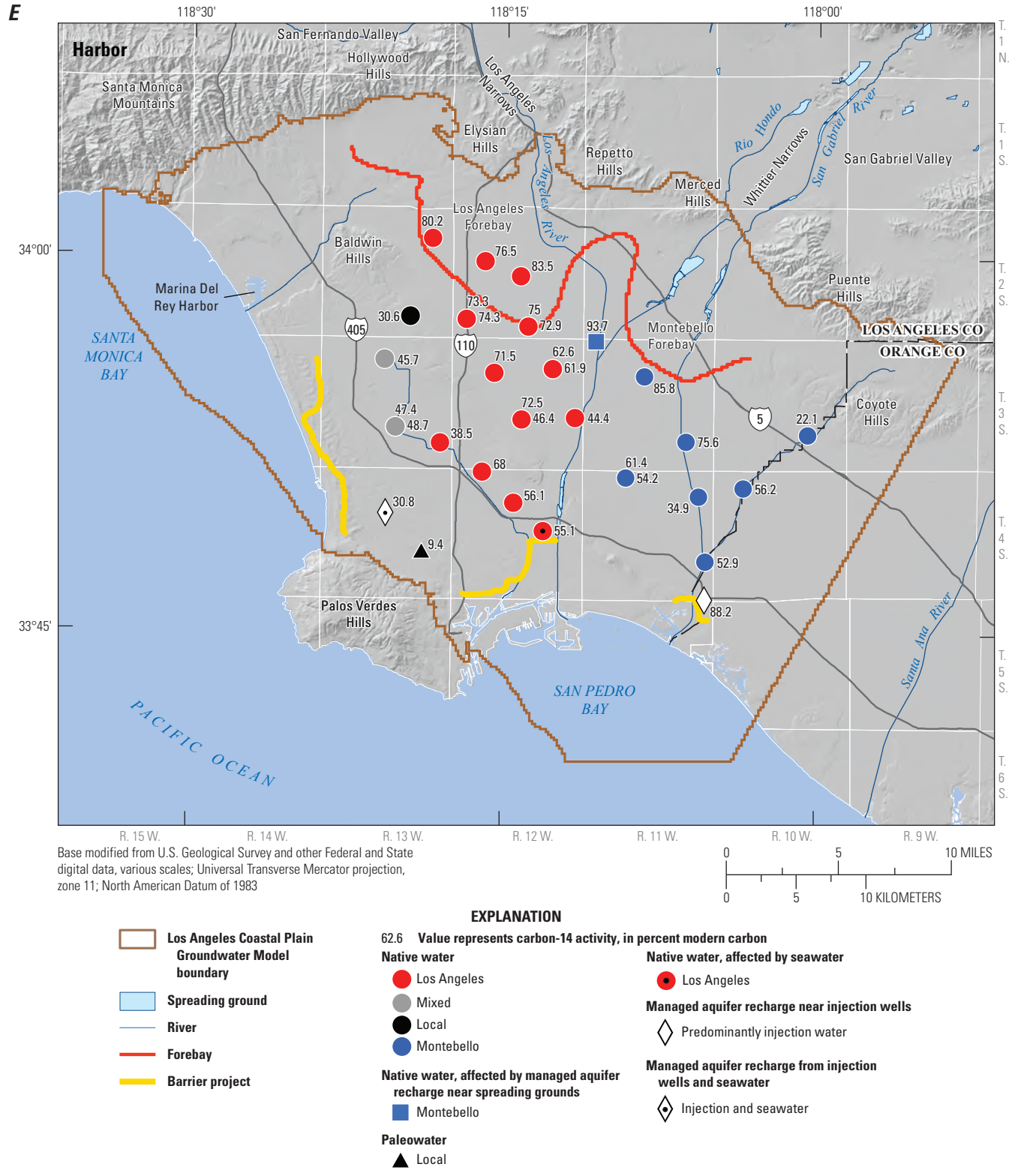


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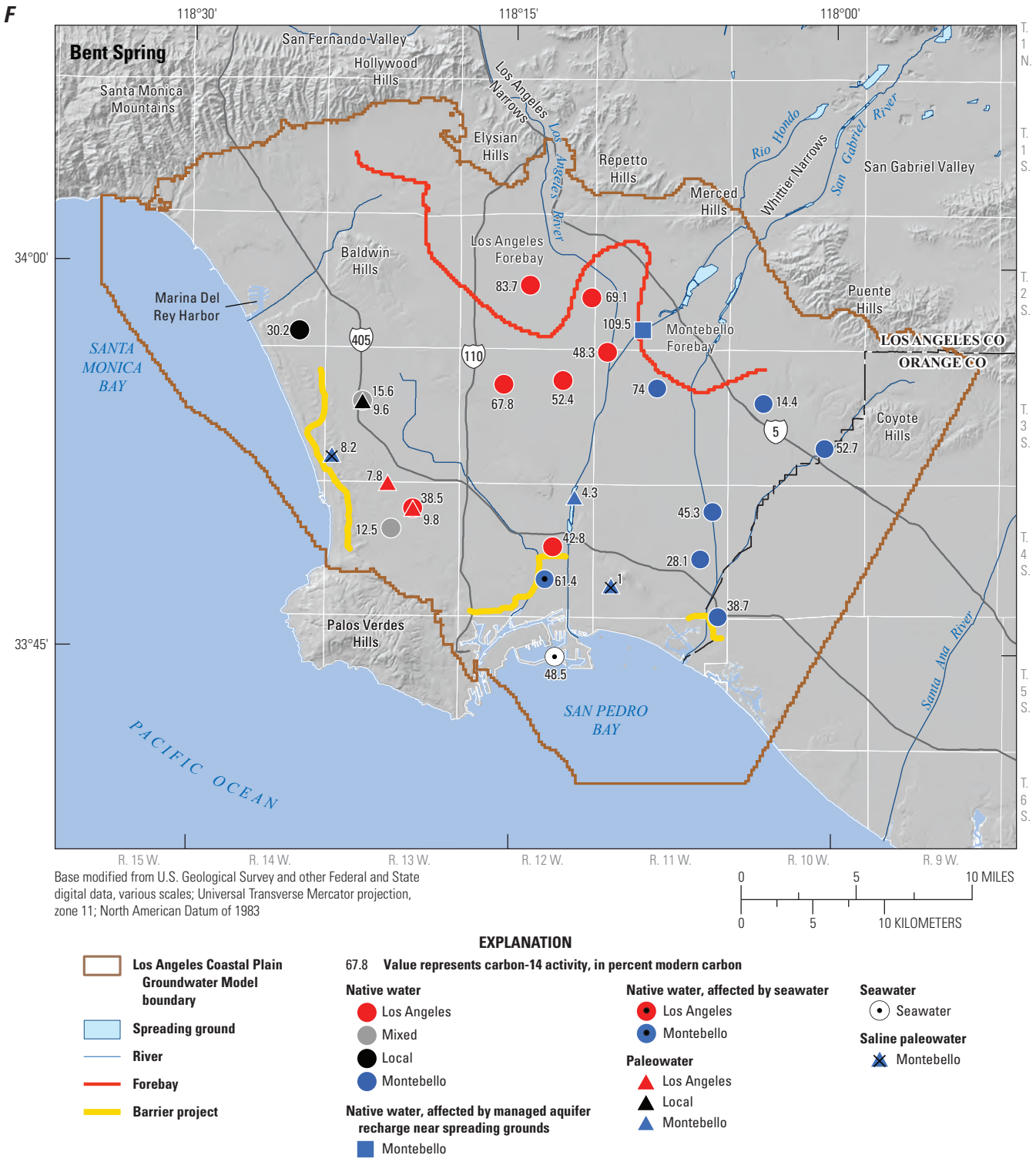


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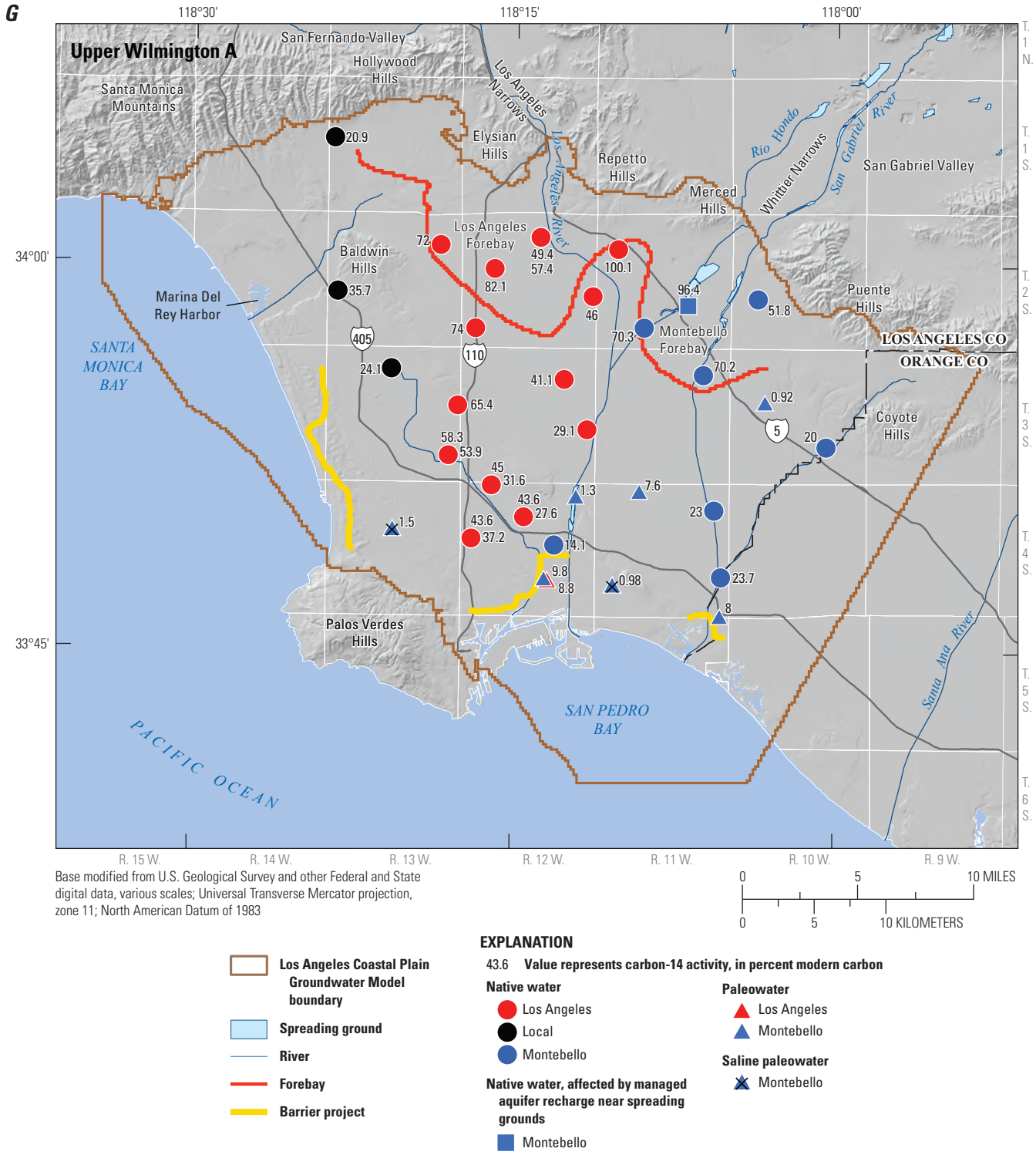


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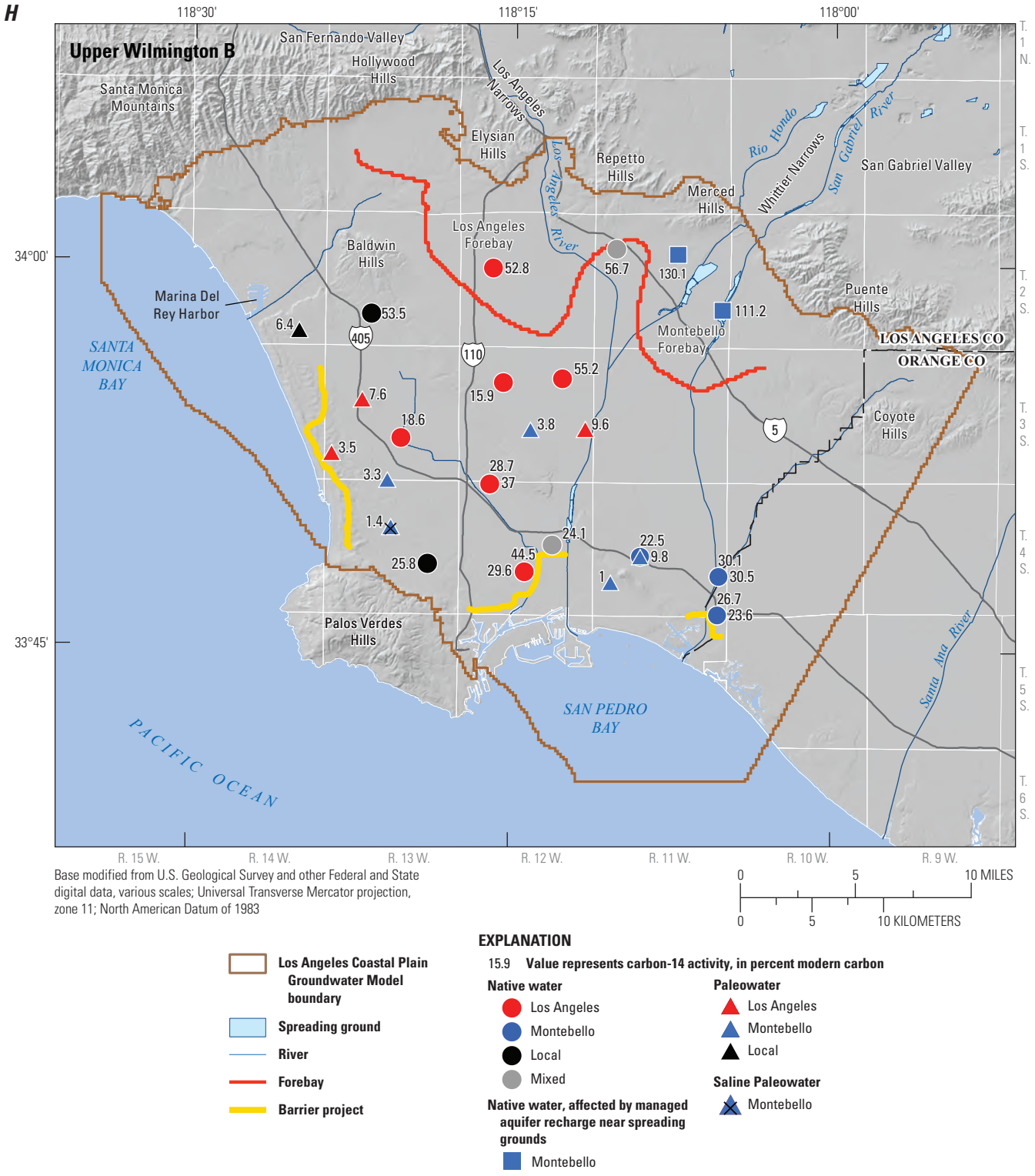
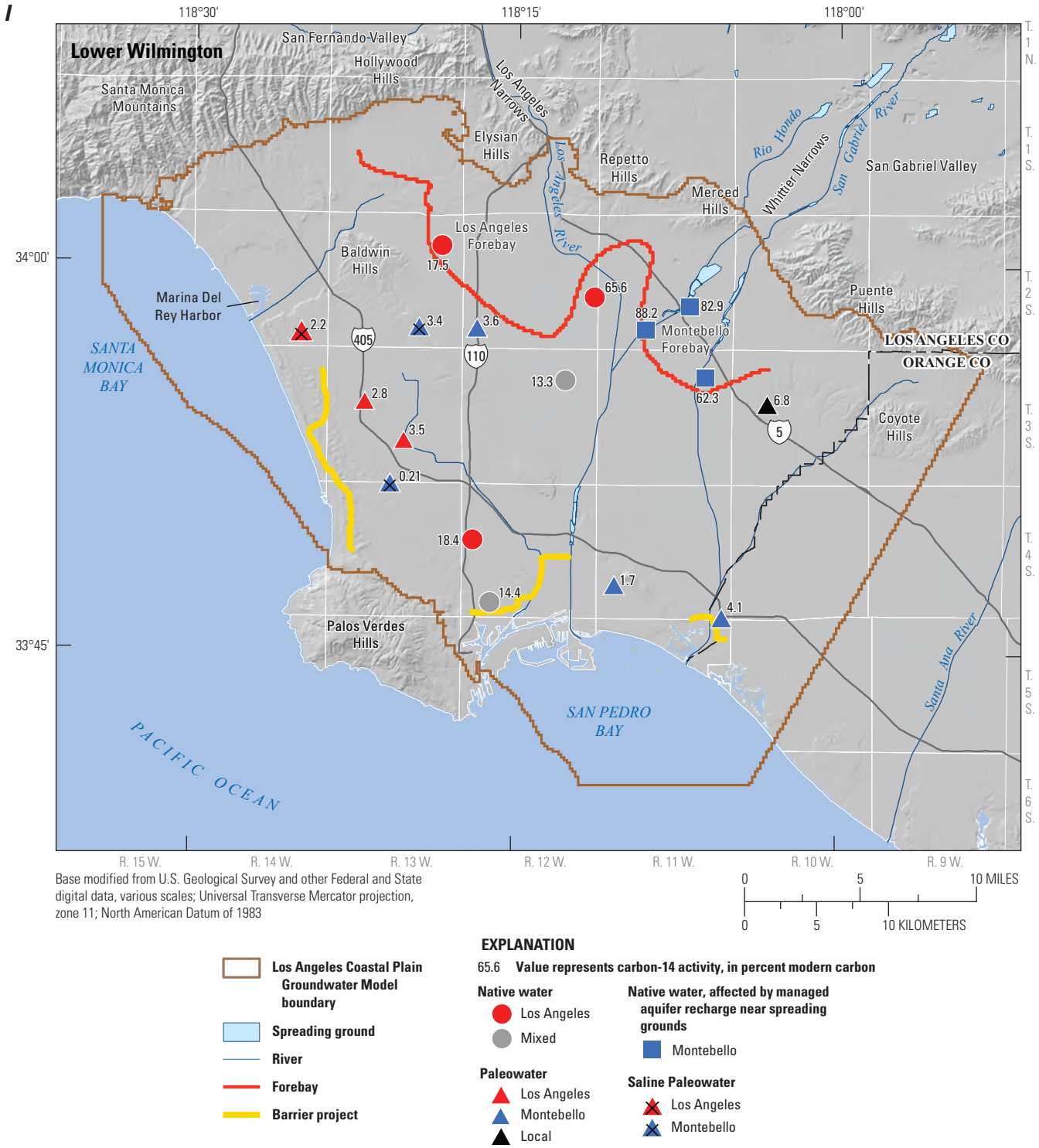


Figure 1.8.—Continued



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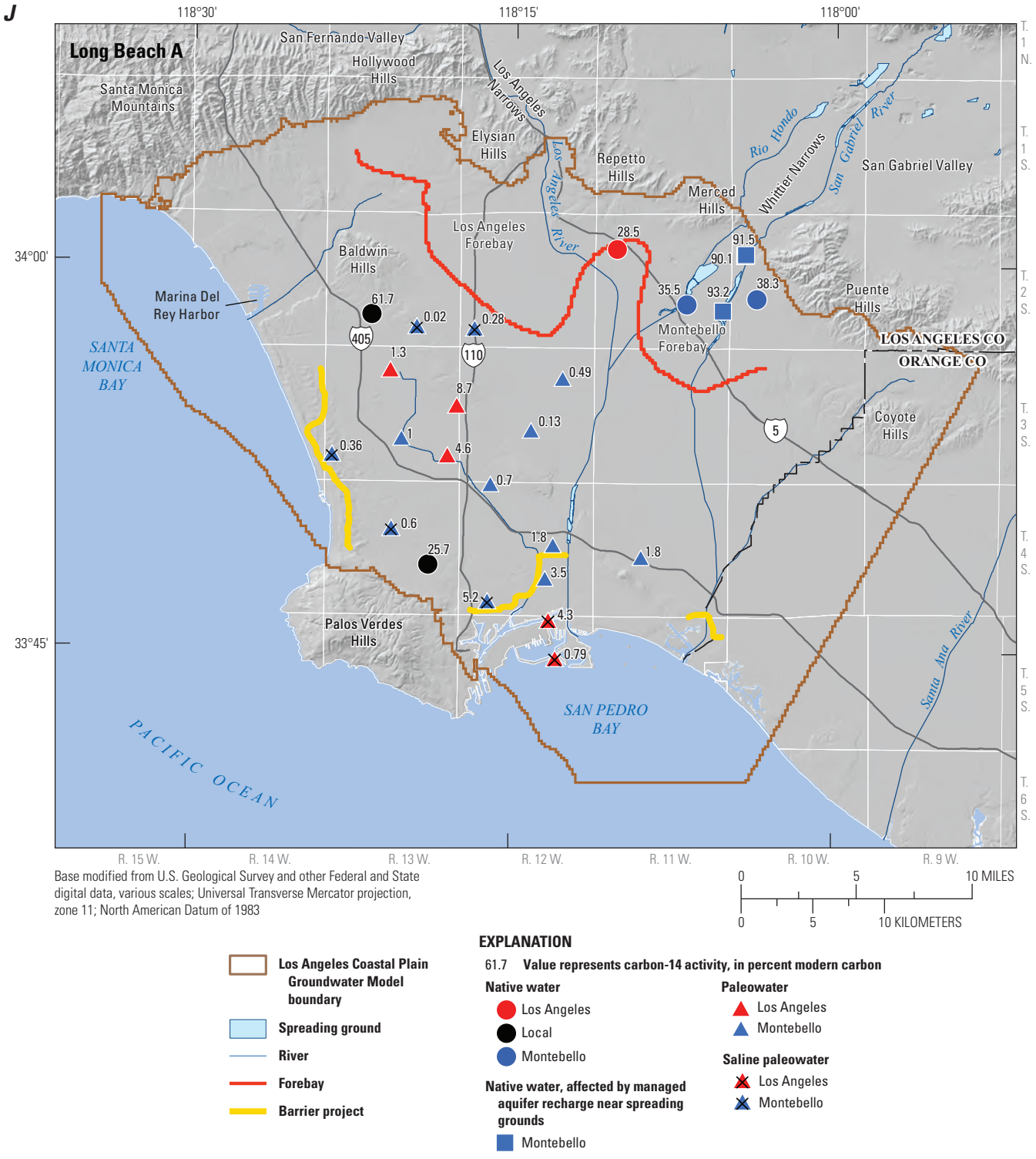


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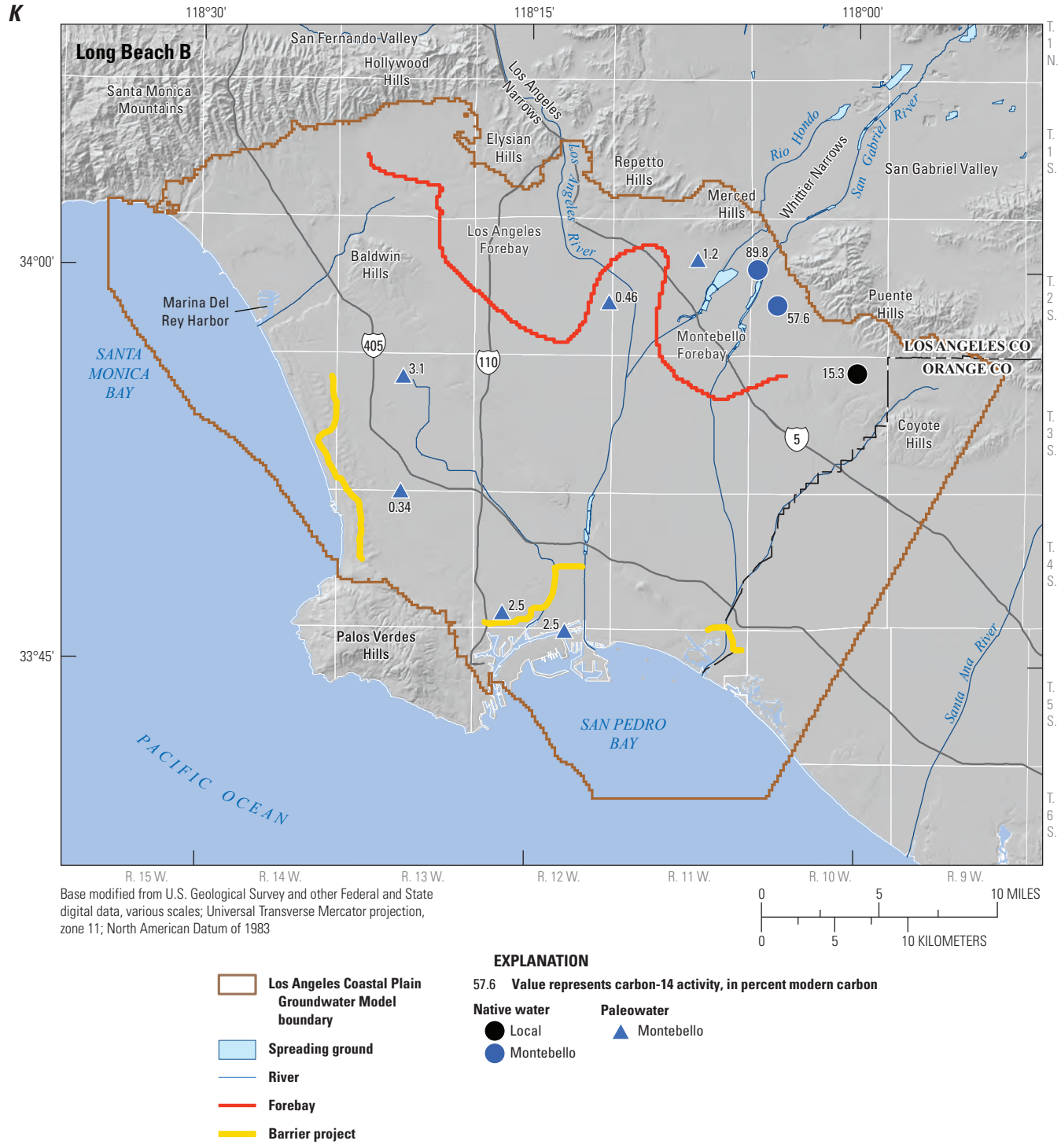


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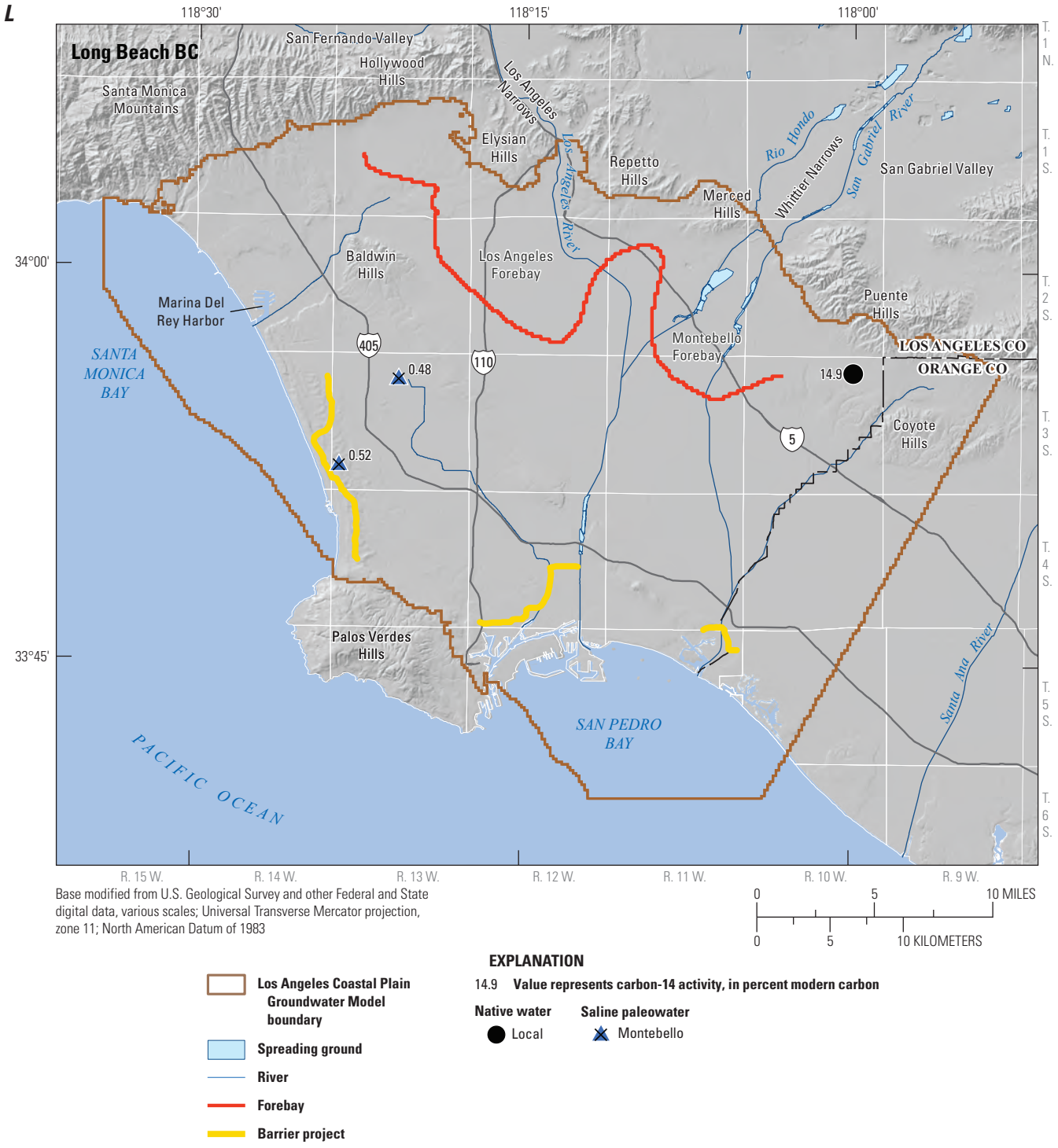


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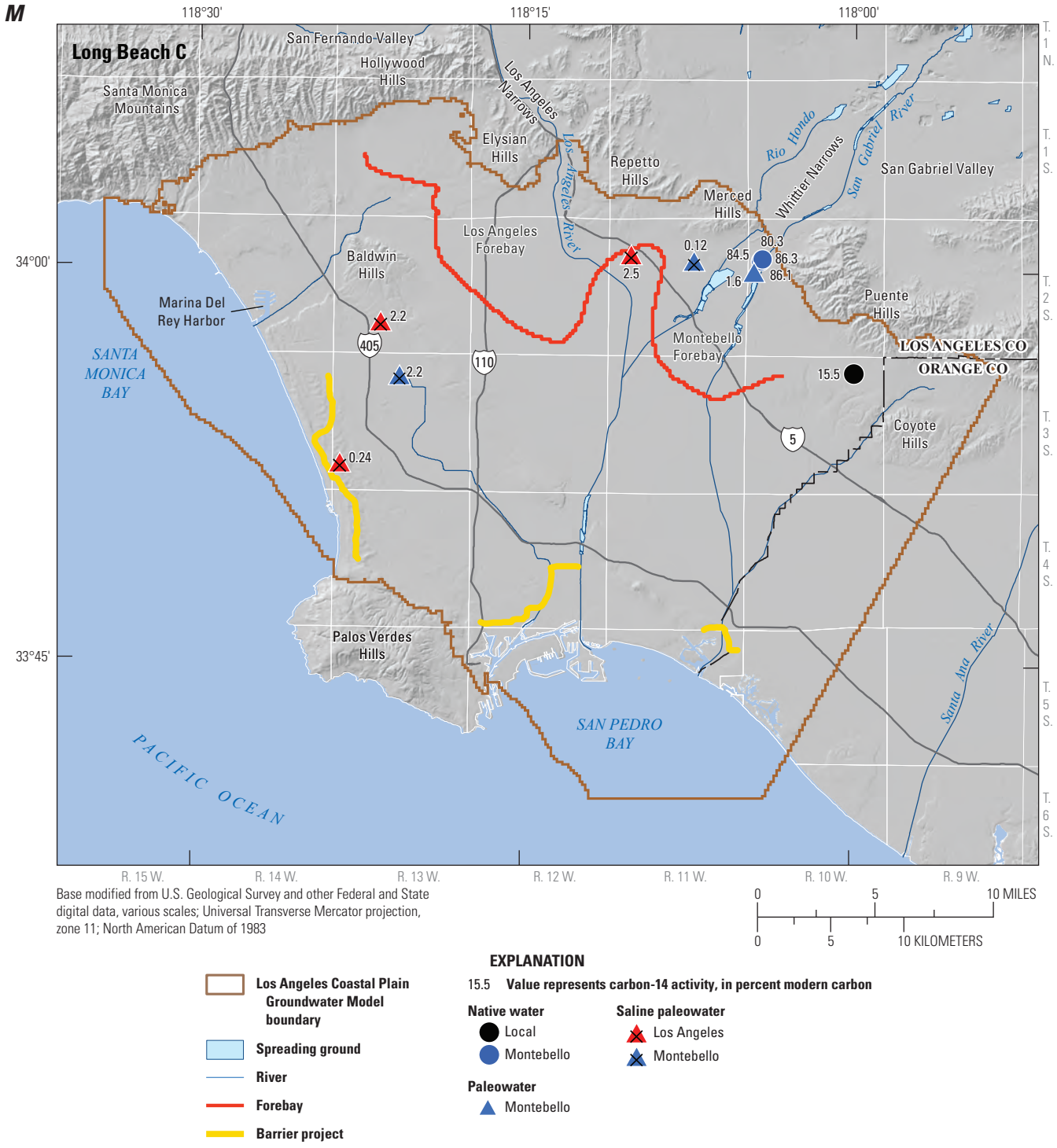


Figure 1.8.—Continued

The lowest $^{87}Sr/^{86}Sr$ value was observed in a sample from a monitoring well in the northwestern part of the Central Basin, near the Los Angeles Forebay (2S/13W-31B5; Los Angeles4_3; fig. 1.1, table 1.2). The Los Angeles Forebay receives sediment from the Los Angeles River, which drains the San Fernando Valley, which is surrounded predominantly by marine sedimentary rocks (Jennings, 1977). Marine sedimentary rocks have $^{87}Sr/^{86}Sr$ ratios as low as 0.708 (Wierzbowski, 2013). Strontium-isotope ratios of samples from wells in the Los Angeles Forebay range from 0.7082 to 0.7085 (n=15; figs. 1.6, 1.9, table 1.2). The samples in the Los Angeles Forebay were collected from wells screened solely in 8 of the 13 identified chronostratigraphic units in the LACP, and there is no substantial difference in isotopic values between units (table 1.2). For this study, $^{87}Sr/^{86}Sr$ ratios in the range of 0.7080 to 0.7088 indicated predominantly Los Angeles River sediment, unless affected by local sediment, as described below (fig. 1.9, table 1.2).

The San Gabriel River is another major source of sediment to the LACP (fig. 1.1). The headwaters of the San Gabriel River are in the San Gabriel Mountains (not shown), which are dominated by granitic rocks (Jennings, 1977). Sediments derived from the granitic rocks would be expected to have $^{87}Sr/^{86}Sr$ ratios greater than 0.7100 (Wierzbowski, 2013). The San Gabriel River enters the LACP through Whitter Narrows and then is a major source of sediment to the Montebello Forebay (fig. 1.1). Strontium-isotope ratios of samples from wells in the Montebello Forebay range from 0.7095 to 0.7103 (n=13; table 1.2, figs. 1.6, 1.9). The samples in the Montebello Forebay were collected from wells screened in 5 of the 13 chronostratigraphic units identified for this study, with samples from older chronostratigraphic units having slightly lower $^{87}Sr/^{86}Sr$ ratios than samples from the younger units (table 1.2). However, even the lowest $^{87}Sr/^{86}Sr$ ratios sampled from wells in the Montebello Forebay are considerably higher than values sampled from wells in the Los Angeles Forebay (figs. 1.6, 1.9, table 1.2). The greater range of $^{87}Sr/^{86}Sr$ ratios in samples from the Montebello Forebay compared to the Los Angeles Forebay probably is the result of mixing of granitic sediments from the upper part of the San Gabriel watershed (Jennings, 1977) with sediments originating from the marine sedimentary rocks in the hills surrounding the lower San Gabriel Valley (fig. B2). For this study, $^{87}Sr/^{86}Sr$ ratios in the range of 0.7097 to 0.7104 indicated predominantly San Gabriel River sediment (fig. 1.9, table 1.2).

The lowest $^{87}Sr/^{86}Sr$ ratio measured in the Montebello Forebay (0.7095; well 2S/12W-10Q5; table 1.2) was not used to define the range of $^{87}Sr/^{86}Sr$ ratios in San Gabriel River sediment (fig. 1.9). The water from well 2S/12W-10Q5 was slightly saline and had a ^{14}C value indicating that it was paleowater (table 1.2). The slightly saline water sampled by this well probably is the result of old seawater that has not been completely flushed from the sediments. The $^{87}Sr/^{86}Sr$ ratio of Pleistocene age seawater is less than the $^{87}Sr/^{86}Sr$ ratio in present day seawater (0.7092; Wierzbowski, 2013). Consequently, recent exchange with old seawater would cause the $^{87}Sr/^{86}Sr$ ratio of native water in contact with San Gabriel River sediment to be lower than expected. Therefore, the $^{87}Sr/^{86}Sr$ ratio from well 10Q5 was not included in the San Gabriel River $^{87}Sr/^{86}Sr$ ratio range (0.7097 to 0.7104; fig. 1.9).

The highest $^{87}Sr/^{86}Sr$ ratio (0.7116) was analyzed in a sample from a production well along the Santa Ana River in Orange County (4S/10W-14H3; Anaheim_46; fig. 1.1, table 1.2). The Santa Ana River has its headwaters in the San Bernardino Mountains (not shown), which are dominated by granitic rocks (Matti and others, 1992) and would be expected to have $^{87}Sr/^{86}Sr$ ratios greater than 0.7100 (Wierzbowski, 2013). Production well 3S/8W-34G2 (Canyon_RV_1_EAST) also is near the Santa Ana River, but the $^{87}Sr/^{86}Sr$ ratio (0.7106) in the sample from this well was substantially lower than the $^{87}Sr/^{86}Sr$ ratio in the sample from well 4S/10W-14H3 (0.7116; table 1.2). Well 3S/8W-34G2 is adjacent to the Santa Ana Mountains (fig. 1.1), where marine sedimentary rocks are exposed (Morton and Miller, 2006). The lower $^{87}Sr/^{86}Sr$ ratio in the sample from this well could be the result of mixing of sediment from the marine sedimentary rocks in the Santa Ana Mountains with granitic sediments from the San Bernardino Mountains. More strontium-isotope ratios along the Santa Ana River would better define the isotopic range of this source of sediment. For this study, 0.7114 indicated Santa Ana River sediments and $^{87}Sr/^{86}Sr$ ratios in the range of 0.7105 to 0.7114 indicated a mixture of San Gabriel River and Santa Ana River sediments (fig. 1.9, table 1.2).

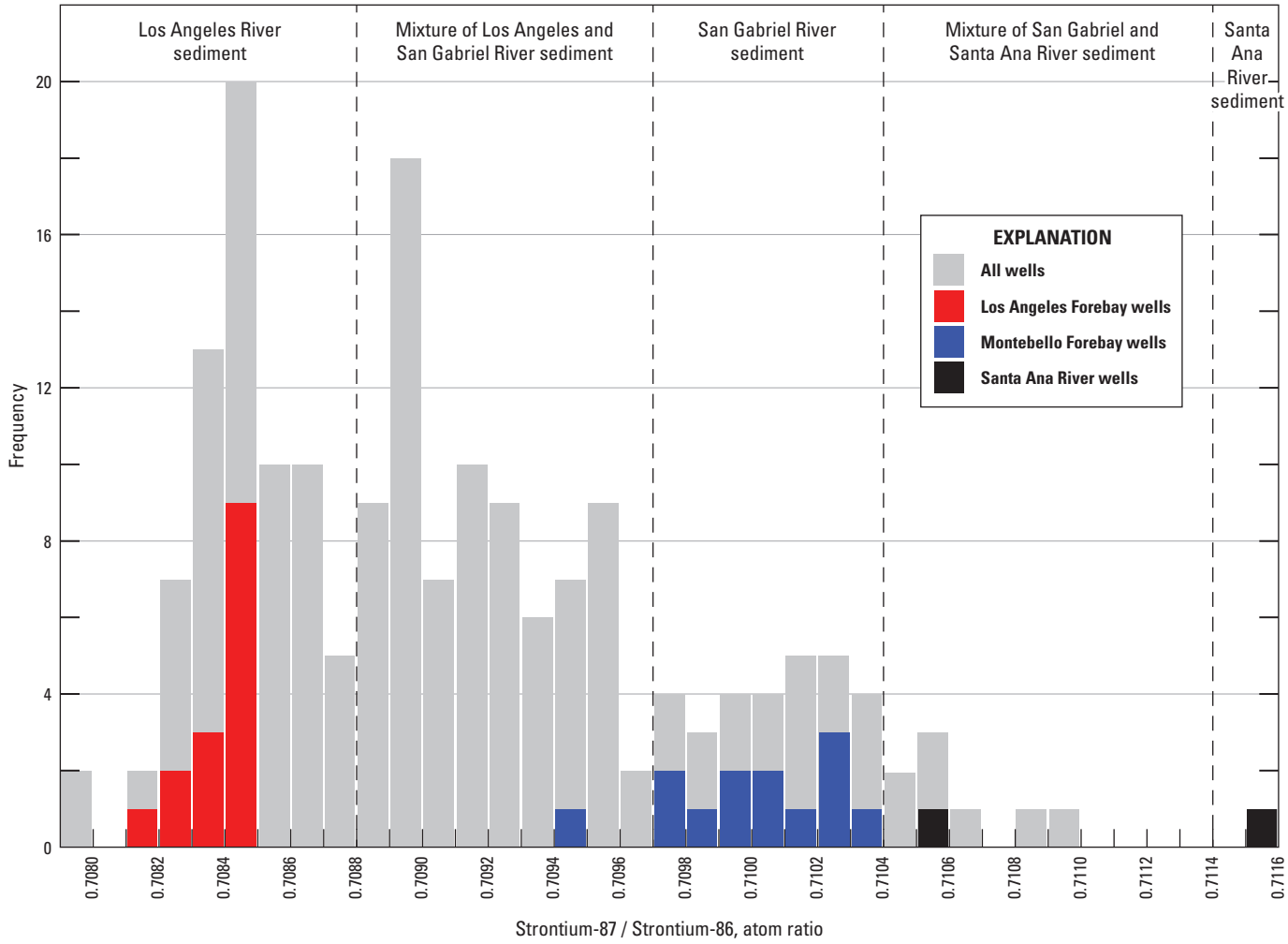


Figure 1.9. Strontium-isotope ratios in samples from monitoring wells and selected production wells in the Los Angeles Coastal Plain and surrounding area, Los Angeles and Orange Counties, California.

Another source of sediment to the LACP is erosion from the low-lying hills that border the LACP, referred to as local sediment in this report. These hills are predominantly marine sedimentary rocks (fig. B2); therefore, the $^{87}Sr/^{86}Sr$ ratios would be expected to be similar to those of Los Angeles River sediment. The $^{87}Sr/^{86}Sr$ ratios in samples from two wells adjacent to the Hollywood Hills (1S/14W-18L1, BH_2; and 1S/15W-24B1, BH_5) were 0.7080 and 0.7081 and three wells adjacent to the Santa Monica Mountains (1S/15W-31E1, SM 1; 1S/15W-33A1, SM Arcadia_5; and 2S/15W-4C2, SM 3) ranged from 0.7087 to 0.7088 (fig. 1.6, table 1.2). The $^{87}Sr/^{86}Sr$ ratios of these samples are within the range of Los Angeles River sediment; however, these wells are not in the Los Angeles River drainage basin and likely do not encounter sediment from the Los Angeles River. Rather, these wells probably are encountering sediment from the Santa Monica Mountains and Hollywood Hills. Likewise, the $^{87}Sr/^{86}Sr$ ratio in a sample from well 3S/11W-17F1 (17F1; Norwalk1_1), in the southeastern part of the Central Basin, was 0.7086 (fig. 1.6, table 1.2). The $^{87}Sr/^{86}Sr$ ratio of this sample is within the range of Los Angeles River sediment; however, this well is not in the Los Angeles River drainage basin and likely does not encounter sediment from the Los Angeles River. Well 17F1 is near the Montebello Forebay (fig. 1.1); however, the $^{87}Sr/^{86}Sr$ ratio for well 17F1 is noticeably different than $^{87}Sr/^{86}Sr$ ratios measured in samples from wells in the Montebello Forebay (fig. 1.6, table 1.2). This well probably encounters sediment from the Puente Hills. For this study, $^{87}Sr/^{86}Sr$ ratios in the range assigned to Los Angeles River sediment (0.7080 to 0.7088), but outside of the Los Angeles River drainage area, were considered to be predominantly local sediment (table 1.2).

Some of the samples compiled for this study have isotopic values that do not fall into any of the groups identified for this study. These samples probably are a mixture of two or more sources of sediment. Strontium isotope ratios in the range of 0.7089 to 0.7096 were considered to be a mixture between Los Angeles River and San Gabriel River sediments (fig. 1.9, table 1.2). The $^{87}Sr/^{86}Sr$ ratios of samples from wells 3S/11W-17F3-5 (Norwalk1_3-5) fall within this range (table 1.2). However, these wells are near the Puente Hills and not within the Los Angeles River drainage area (fig. 1.1). Therefore, these wells probably encounter a mixture of San Gabriel River and local sediments (table 1.2).

Some of the samples analyzed for $^{87}Sr/^{86}Sr$ ratios were characterized as being affected by seawater (* in Sediment facies column; table 1.2). The isotopic values of these samples could be affected by mixing with seawater. The $^{87}Sr/^{86}Sr$ ratio of modern seawater is 0.7092 (Wierzbowski, 2013); consequently, recent exchange with modern seawater would cause the $^{87}Sr/^{86}Sr$ ratio of native water in contact with Los Angeles River sediment to be higher than expected and the $^{87}Sr/^{86}Sr$ ratio of native water in contact with San Gabriel River sediment to be lower than expected.

Sediment Facies

Sediment facies were inferred for each chronostratigraphic unit by inspecting the grain size on available geologic logs, geophysical log signatures, microfossil data, and water-quality data (Cl/B ratios) compiled from multiple-well monitoring sites. The facies were generalized into non-marine sediments (alluvium and colluvium), shallow marine sediments (paralic and neritic deposits), and deep marine, or bathyal, sediments (slope and basin deposits; figs. B7–B19).

Chloride-to-boron ratios can be used to help differentiate non-marine from marine sediments because groundwater interacting with marine facies has lower Cl/B ratios than groundwater interacting with non-marine sediments as a result of the enrichment of B by algae, as discussed in the "Dissolved Chloride and Boron" section of this appendix.

The Cl/B ratio for water in non-marine sediments will vary depending on the native source water, the type of sediment or rocks the water is flowing through, and anthropogenic sources of Cl and B (for example irrigation return flows, wastewater, artificial recharge, and seawater intrusion). Chloride concentrations in native water range from 10 to 65 mg/L in the LACP (Poland and others, 1959; Reichard and others, 2003, Land and others 2004). In this report, samples with Cl concentrations greater than 200 mg/L were assumed to be affected by mixing with anthropogenic sources of water or seawater and were not used to delineate the sediment facies. Granitic rocks in the San Gabriel Mountains are a major source of sediment to the LACP. As presented in the "Dissolved Chloride and Boron" section of this appendix, native groundwater in non-marine sediments derived primarily from granitic rocks will have Cl/B ratios higher than local precipitation because Cl is more common than B in granitic rocks.

Long-term Cl/B ratios in precipitation are not available for the LACP; however, annual means for Cl and B analyzed from the San Gabriel River from 1995 through 2005 indicate that the Cl/B ratio of the San Gabriel River ranged from 185 to 517, with an average of 337 (Weston Solutions, Inc., 2005). Although the San Gabriel River drainage includes some marine rocks in lower altitude portions of the drainage, the river Cl/B ratio is likely to be dominated by larger water fluxes from higher altitude granitic rock areas. For the purposes of this report, water samples with Cl/ B ratios greater than 300 indicated non-marine sediments if the samples are not affected by anthropogenic sources (fig. 1.10, table 1.2). For the purposes of this report, samples with Cl/B ratios from 300 to 100 indicated shallow marine sediments, and ratios less than 100 indicated deep marine deposits (fig. 1.10, table 1.2). The threshold Cl/B ratio used to distinguish shallow from deep marine sediments was determined by checking the ratio from wells that had microfossil or other collaborating data, indicating that the wells were sampling deep marine sediments. Because the categorization of Cl/B ratios is somewhat subjective, these ratios were used as a secondary method of inferring sediment facies. Microfossils and interpretations from core samples were the primary datasets used to determine the final sediment facies (figs. B7–B19).

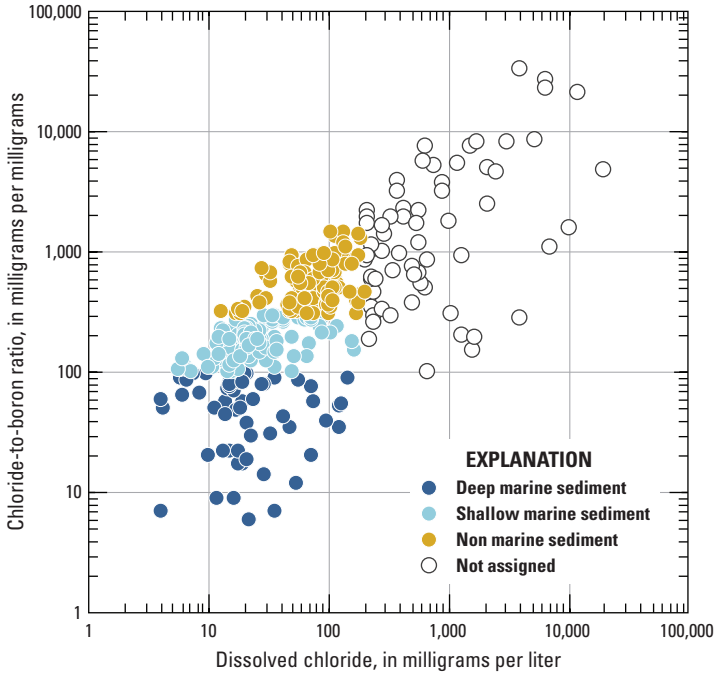


Figure 1.10. Chloride-to-boron ratio as a function of chloride in water from monitoring wells in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California.

Water Source

Previous work by the USGS (Reichard and others, 2003, Land and others, 2004) indicated that the stable isotopes of water (D and ^{18}O) could be used to help determine the source of groundwater in the LACP. Seven main isotopic groups correspond with sources of water or activities/processes affecting groundwater: (1) native Los Angeles Forebay water, (2) native Montebello Forebay water, (3) water originating from local precipitation falling on the LACP and surrounding low lying hills, referred to as local water, (4) water that was recharged during the Pleistocene, referred to as paleowater, (5) water affected by managed aquifer recharge in spreading grounds, (6) water affected by seawater intrusion, and (7) water affected by managed aquifer recharge near injection wells. These isotopic groups were reviewed and refined for this study using the data compiled from multiple-well monitoring sites in the LACP (table 1.2).

Los Angeles Forebay Water

Previous studies by the USGS in the LACP found that native water in the Los Angeles Forebay plotted along or above the meteoric water line with a δD range of –44 to –50 per mil and $\delta^{18}O$ range of –6.7 to –7.5 per mil (Reichard and others, 2003, Land and others, 2004). Infiltration of the Los Angeles River is the major source of recharge in the Los Angeles Forebay. Natural flow in the Los Angeles River originates as precipitation falling on the San Fernando Valley and surrounding mountains and hills (fig. 1.1). The elevation of the San Fernando Valley ranges from about 6,000 ft in the San Gabriel Mountains to the northeast to about 650 ft on the valley floor.

In this study, only stable-isotope data compiled from monitoring wells in the Los Angeles Forebay were used to define the isotopic range of native Los Angeles Forebay water (fig. 1.1). Stable-isotope data for this study were compiled from 25 wells in the Los Angeles Forebay, and had a δD ranged of –44.2 to –56.2 per mil and a $\delta^{18}O$ range of –6.78 to –7.99 per mil (table 1.2), which is larger than δD ranges presented by previous investigators (Reichard and others, 2003; Land and others, 2004). Anthropogenic sources of runoff to the Los Angeles River that infiltrate the Los Angeles Forebay, including wastewater recharge and irrigation return flows, affect the isotopic signature of samples receiving modern recharge. Samples with tritium activity greater than or equal to 0.1 TU were assumed to be affected by some anthropogenic sources of water. When samples believed to be affected with anthropogenic sources of water were removed, the remaining 13 samples had a δD range of –46.6 to –49.0 per mil and a $\delta^{18}O$ range of –6.94 to –7.44 per mil (see 'older water', fig. 1.11*A*). Samples from wells in the LACP with isotopic ratios within or close to this range that plotted near the MWL probably originated as recharge by the Los Angeles River in the Los Angeles Forebay prior to anthropogenic runoff and are referred to as "Los Angeles Forebay water" for the purposes of this report (fig. 1.11*A*, table 1.2).

Montebello Forebay Water

Previous studies by the USGS in the LACP indicated that native groundwater in the Montebello Forebay was isotopically lighter than native Los Angeles Forebay water (Reichard and others, 2003, Land and others, 2004). These previous studies found that native water in the Montebello Forebay plotted along or above the meteoric water line with a δD range of –54.0 to –66.0 per mil (and a $\delta^{18}O$ range of –8.0 to –9.5 per mil). Infiltration of the San Gabriel River and Rio Hondo are the major sources of recharge in the Montebello Forebay. Natural flow in the San Gabriel River and Rio Hondo originates as precipitation falling on the San Gabriel Valley and the San Gabriel Mountains to the northeast (fig. 1.1). Elevation of the San Gabriel Valley and Mountains ranges from about 10,000 ft in the peaks of the San Gabriel Mountains to about 200 ft at Whittier Narrows. Overall, the elevations of the mountains surrounding the San Gabriel Valley are considerably higher than the low mountains and hills surrounding the San Fernando Valley.

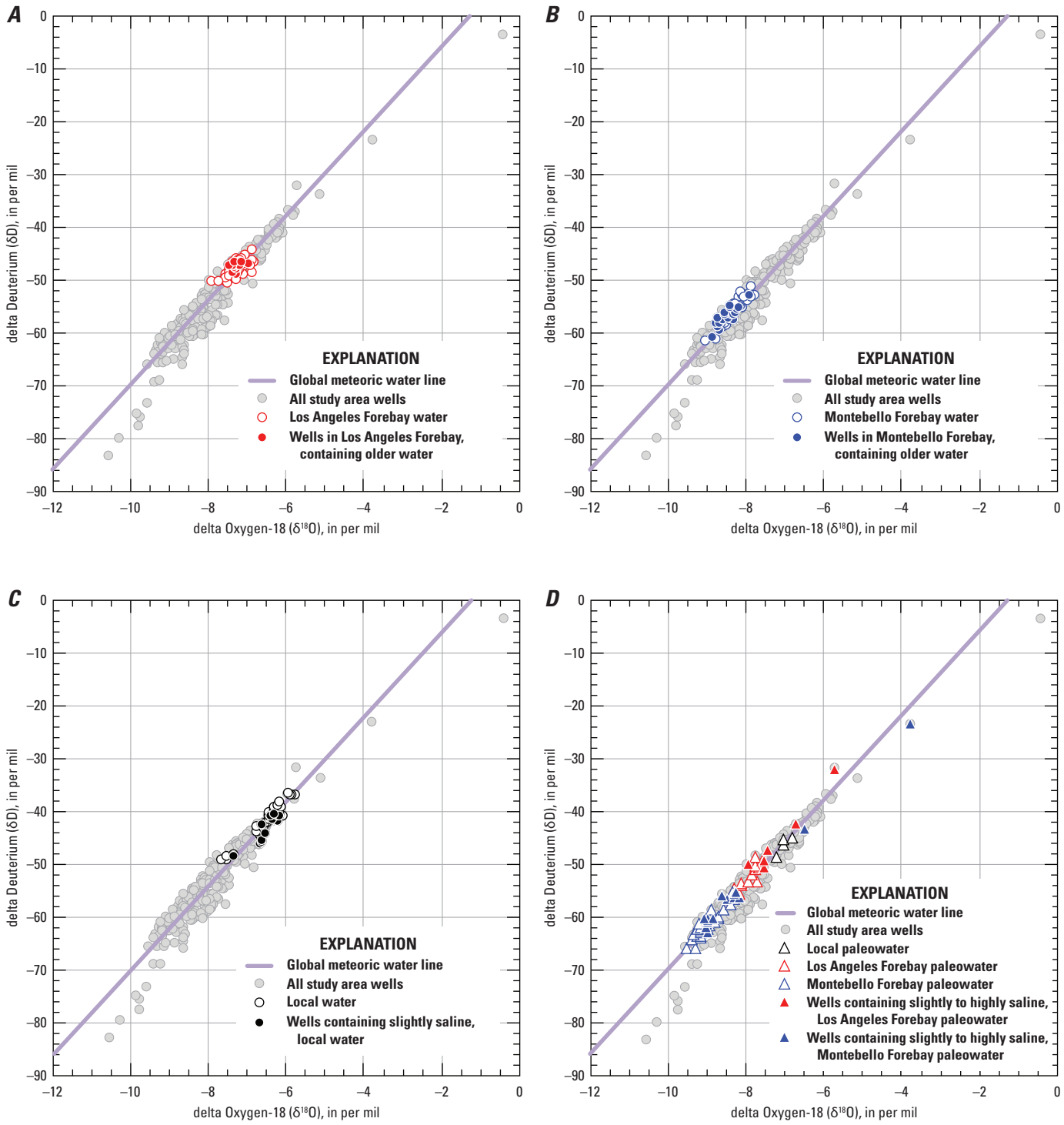


Figure 1.11. Relation between deuterium and oxygen-18 isotopic ratios for water samples from multiple-well monitoring sites in the Los Angeles Coastal Plain, Los Angeles and Orange Counties, California: *A*, Los Angeles Forebay water; *B*, Montebello Forebay water; *C*, local water; *D*, paleowater; *E*, water affected by managed aquifer recharge in spreading grounds or urban recharge; *F*, water affected by seawater intrusion; *G*, water affected by managed aquifer recharge near injection wells; and *H*, mixed water.

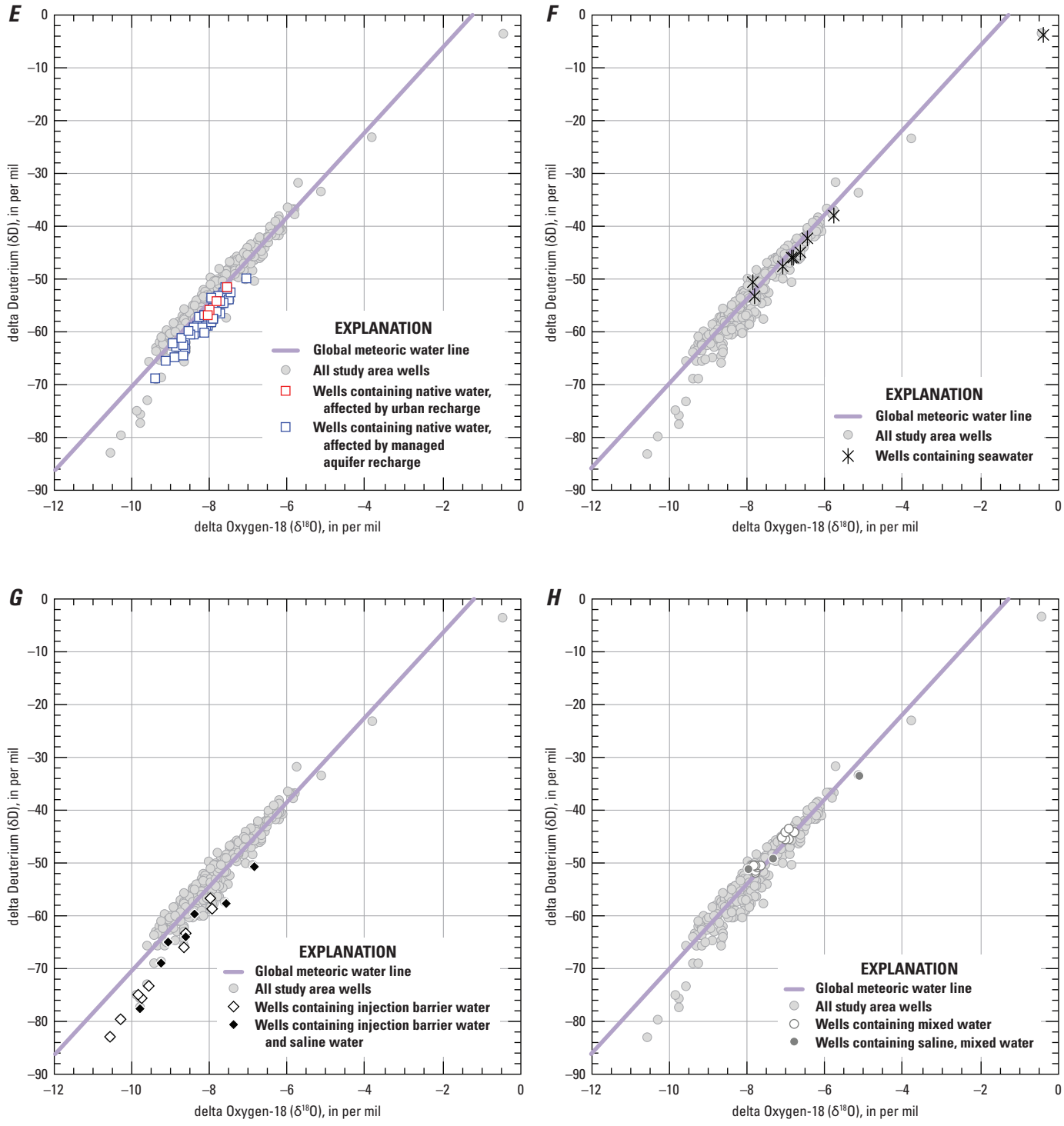


Figure 1.11.—Continued

Stable-isotope data for this study were compiled from 58 monitoring wells located in the Montebello Forebay and had a δD range of –44.2 to –65.8 per mil (and a $\delta^{18}O$ range of –6.55 to –9.56 per mil; table 1.2), which is larger than δD and $\delta^{18}O$ ranges presented by previous investigators (Reichard and others, 2003, Land and others, 2004). Spreading of imported water (Colorado River or California State Water Project [SWP]) in the Montebello Forebay has occurred since the 1950s to supplement natural recharge. Colorado River and SWP water is isotopically lighter than native groundwater in the Montebello Forebay and plots below the MWL due to extensive evaporation (Reichard and others, 2003; Williams and Rodini, 1997; fig. 1.11). Samples affected by mixing with the imported water (managed aquifer recharge in spreading grounds or injection barriers) had isotopic compositions that plotted below the MWL (fig. 1.11). To more accurately estimate the isotopic range of native groundwater in the Montebello Forebay, 33 samples that plotted below the MWL, indicating that they were affected by mixing with imported water, were excluded (table 1.2). Of the remaining 25 samples, the isotopically heaviest (less negative) samples in the Montebello Forebay were from wells 2S/11W-20N4 (Whittier2_4; δD = –44.2), 2S/11W-8L16 (Whittier Narrows2_9; δD = –46.0), and 2S/11W-8L15 (Whittier Narrows2_8; δD = –46.3; table 1.2). These wells are adjacent to the Puente Hills (fig. 1.1), and runoff from the Puente Hills probably is the source of recharge to these wells (see "Local Water" section). The isotopically lightest (more negative) samples in the Montebello Forebay, not affected by mixing with imported water, are from wells 2S/11W-18C4 (Pico Rivera1_1; δD = –65.8) and 2S/12W-10Q6 (Montebello1_2; δD = –63.3). These samples had ^{14}C activities of 1.6 pmc or less (table 1.2), which corresponded to uncorrected ages (residence time) of more than 34,000 years before present. These lighter isotopic values were consistent with recharge during cooler conditions during the late Pleistocene (Clark and Fritz, 1997) and were classified as paleowaters (see "Paleowater" section).

After removing samples classified as local or paleowater, the remaining 20 samples in the Montebello Forebay had a δD range of –52.8 to –60.7 per mil and a $\delta^{18}O$ range of –7.9 to –8.87 per mil (see "older water," fig. 1.11*B*). Samples from wells in the LACP with isotopic ratios within or close to this range that plotted near the MWL probably originated as recharge in the Montebello Forebay prior to the initiation of spreading of imported water and are referred to as "Montebello Forebay water" in this report (fig. 1.11*B*; table 1.2). The isotopic range of the Montebello Forebay water was lighter than Los Angeles Forebay water due to the higher elevation of the San Gabriel Mountains in the San Gabriel River watershed relative to the crest of the Los Angeles watershed. The isotopic range of the Montebello Forebay water was larger than the range of Los Angeles Forebay water because the Montebello Forebay receives natural recharge from the higher elevations of the San Gabriel Mountains and the lower hills that border the San Gabriel Valley.

Local Water

Isotopic data compiled for this study included multiple samples with δD and $\delta^{18}O$ values heavier (less negative) than the range of Los Angeles Forebay water (table 1.2). Previous studies by the USGS in the LACP identified water with a δD range of –36 to –43 per mil and a $\delta^{18}O$ range of –5.8 to –6.6 per mil as "local water" (Reichard and others, 2003; Land and others, 2004). Isotopically heavier water was attributed to local precipitation falling on the LACP and surrounding low lying hills, which are considerably lower in elevation than the hills and mountains that surround the San Fernando and San Gabriel Valleys. Samples within this range that plot on or near the MWL and are not affected by seawater intrusion are referred to as "local water" in this report (fig. 1.11*C*; table 1.2).

Samples from seven wells in or near the Whitter area [3S/11W-17F5 (17F5), 2S/11W-5P6 (5P6; Whittier Narrows1_1), 2S/11W-8L15-16 (8L15-16; Whittier Narrows2_8 and 9), 3S/11W-9D2, -9D4 (9D2, 9D4), and 3S/12W-26K7 (26K7); fig. 1.1] had δD values ranging from –46.0 to –49.4 per mil, which were isotopically lighter than the range previously reported for local water (table 1.2). The lighter samples were within the range of Los Angeles Forebay water; however, these wells are not in the Los Angeles River drainage basin and likely are not receiving water from the Los Angeles Forebay. These wells are near the Montebello Forebay; however, their isotopic ranges were substantially heavier than isotopic ranges measured in Montebello Forebay water (table 1.2). Therefore, these wells probably are receiving local runoff from the Puente Hills, and samples from these wells were classified as "local water," for the purposes of this report (fig. 1.11*C*; table 1.2).

Paleowater

In this report, samples with ^{14}C activity of 10 pmc or less were designated as paleowater (64 of the 249 samples with ^{14}C activity data compiled for this study; table 1.2). Samples with ^{14}C activities of 10 pmc or less correspond to uncorrected groundwater ages (residence times) of more than 18,000 years before present (table 1.2). These uncorrected ^{14}C ages indicated recharge occurred near the end of the last North American glaciation, when it likely was colder, wetter, or both in the surrounding mountains (Clark and Fritz, 1997). However, a recent (2017) study of beetle remains in the La Brea Tar Pits indicated that the climate in the Los Angeles Basin has been relatively stable over the past 50,000 years and was warmer and drier than inferred in previous studies (Holden and others, 2017). Consequently, paleowater that originated in the San Gabriel Mountains should be isotopically lighter than modern native Montebello Forebay water, but paleowater that originated in the Los Angeles Basins and surrounding low lying hills should be isotopically similar to native Los Angeles Forebay water. For this study, samples of paleowater with δD values lighter (more negative) than –55 per mil were considered to be "Montebello Forebay paleowater," values between –49 to –55 per mil were considered to be "Los Angeles Forebay paleowater," and values greater (less negative) than –49 per mil were generally considered to be "local paleowater" (fig. 1.11*D*; table 1.2).

Water Affected by Managed Aquifer Recharge in Spreading Grounds

Isotopic data compiled for this study showed that samples from many wells in the Montebello Forebay plotted below the MWL (fig. 1.11), indicating that the samples had been affected by evaporation. As stated previously, imported Colorado River and (later) SWP water has been spread in the Montebello Forebay since the 1950s to supplement local recharge, and isotopic values from these sources plotted below the MWL due to extensive evaporation (Reichard and others, 2003). Samples from wells in or near the Montebello Forebay with isotopic values that plotted below the MWL line and had δD values of less than –50 per mil probably were affected by the spreading of imported Colorado River or SWP water and are referred to as "water affected by managed aquifer recharge in spreading grounds" (or "spreading" [in table 1.2]) in this report (fig. 1.11*E*, table 1.2). Samples from two wells (2S/14W-12E5, -12E6 (12E5-6); fig. 1.1) had δD values (–51.9 to –56.2; table 1.2) that also plotted within this range; however, these wells are not located near the Montebello Forebay and likely are not receiving imported water from spreading grounds. These wells are probably receiving some imported water from applied irrigation or leaking underground pipes (Hevesi and Johnson, 2016). Samples from these wells are distinguished as "urban recharge" in fig. 1.11*E* for the purposes of this report.

Water Affected by Seawater Intrusion

Comprehensive monitoring in the West Coast Basin indicated that seawater intrusion was affecting the water quality of the West Coast Basin in the early 1930s (Piper and Garrett, 1953). Seawater intrusion has affected samples from 19 of the wells compiled for this report, as evidenced by higher than background Cl concentrations (greater than 500 mg/L) and high Cl/B ratios (greater than 1,000; fig. 1.10, table 1.2). The occurrence of older seawater also affected samples from seven wells with moderate to high salinity identified as paleowater (fig. 1.11*D*, table 1.2). The δD and $\delta^{18}O$ of seawater are both equal to 0.0 per mil and would plot below the MWL (fig. 1.11).

The isotopic composition of samples affected by seawater intrusion will plot along a mixing line between seawater and native water. If a simple two-member mixing is assumed, the chloride concentration of a sample can be used to estimate the isotopic composition of the sample prior to seawater intrusion because the isotopic composition and chloride concentration of seawater are known. In this study, Cl concentrations were used to estimate the δD of the native water prior to mixing with seawater to infer the source of the native water (table 1.2). Samples inferred to be affected by seawater intrusion are referred to as "water affected by seawater intrusion (seawater)" for the purposes of this report (fig. 1.11*F*, table 1.2).

Water Affected by Managed Aquifer Recharge near Injection Wells

Injection of water along the West Coast Basin and Dominguez Gap Barrier Project is an important source of recharge to the West Coast Basin (Reichard and others, 2003). Samples affected by the injection of imported water[2] are isotopically light, plot below and nearly parallel to the meteoric water line, and trend toward the isotopic composition of imported water (fig. 1.11*G*). The isotopic signature of imported water that has been spread in the Montebello Forebay or injected in the West Coast Basin are the same; therefore, the differentiation between the two sources was determined by location of the isotopic sample in the LACP. As of 2018, imported water spread at the Montebello Forebay had not yet reached the interior of the West Coast Basin; therefore, samples with isotopic signatures similar to imported water in the West Coast Basin were assumed to be the result of injection of imported water along the seawater barrier projects. Many of the samples affected by water from the injection barriers were also affected by seawater intrusion, which resulted in the samples being isotopically heavier than a simple mixture of native and imported water. Samples that were inferred to be affected by water from the seawater barrier projects are referred to as "managed aquifer recharge near injection wells" (or "injection" [in table 1.2]) for the purposes of this report (fig. 1.11*G*; table 1.2).

Mixed Water

Some of the samples compiled for this study have chemical compositions and isotopic values that do not classify predominantly into any of the other groups identified for this study. These samples probably are a mixture of two or more sources of water and are referred to as "mixed water" for the purposes of this report (fig. 1.11*H*; table 1.2).

Model Zones

Model parameters (horizontal and vertical hydraulic conductivity, specific storage, and specific yield) were initially estimated by dividing each layer into zones and estimating each zone's value based on an analysis of well log data, regional depositional patterns, and local variations of groundwater basin sediments reported in previous investigations (see "Calibration Results" section in Chapter D). Water-quality data collected from multiple-well monitoring sites (table 1.2) were used to help refine the model zones during model calibration. Major changes in water quality in samples from monitoring wells in the same model zone of a particular chronostratigraphic unit indicate that model zone is receiving water from multiple sources or includes sediment from different sources. Model zones were refined such that monitoring wells in the same chronostratigraphic unit and model zone had similar water quality. In general, each model zone had similar major-ion composition and dissolved-solids concentrations, the same sediment source (similar $^{87}Sr/^{86}Sr$ ratios), the same sediment facies (similar Cl/B ratios), similar water age as indicated by tritium and ^{14}C activities, and the same water source (similar δD and $\delta^{18}O$ isotopic ratios). Model zone maps with final calibrated values are shown and discussed in the "Model Calibration" section of this report (figs. D7, D8).

[2]Since 1994 and 2005, increasing proportions of tertiary-treated recycled water are utilized for injection into the West Coast Basin Barrier Project and Dominguez Gap Barrier Project, respectively, with the goal of providing the barriers with 100 percent recycled water (Water Replenishment District of Southern California, 2013). Detailed isotopic characterization of this water is beyond the scope of this study

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Appendix 2. Utilization of Downhole Geophysical Logs to Determine Sediment Grain Size

By Rhett Everett, Nicole Fenton, Whitney Seymour, and Scott Paulinski

The grain sizes of the sediments encountered at each of the multiple-well monitoring sites constructed by the USGS were estimated for this study by analysis of nuclear magnetic resonance (NMR), array induction 2-foot resistivity (AIT), long-normal resistivity, short-normal resistivity, and gamma log data collected during the drilling of the sites. The sites were constructed using the direct mud-rotary technique; therefore, the drill cuttings often were a mixture of different depths, making the task of determining the thickness and grain size of the sediment layers difficult from visual observations alone. Analysis of the downhole geophysical logs was used to delineate the thickness of sediment layers and infer the grain sizes of the sediments (fig. 2.1).

Natural gamma logs were collected at all (57) of the USGS multiple-well monitoring sites. Natural gamma logs measure the intensities of gamma-ray emissions resulting from the natural decay of potassium-40 and the daughter products of uranium and thorium (Schlumberger Limited, 1972). Gamma logs are used primarily to define lithology indicators and for geologic correlation. Clay, feldspar-rich gravel, and granite generally emit high-intensity gamma rays.

Digital NMR logs were collected at 24 sites. NMR logs can be used to make assessments of porosity, water content, mobile and immobile water fractions, and estimates of permeability (Coates and others, 1999). Low NMR values were interpreted as fine-grained sediments (silt and clay), intermediate NMR values were interpreted as medium-grained sediments (fine to medium sand), and high NMR values were interpreted as coarse-grained sediments (coarse sand and gravel). The thresholds between low, intermediate, and high NMR values were determined for each log based on an analysis of the NMR log values with respect to the geology, resistivity, and gamma logs. Thresholds were determined for the NMR and AIT logs to maximize the correlation between these logs so that high resistivity values and reported coarse-grained lithologies on the geologic log (coarse sand and gravel) corresponded to coarse-grained NMR log interpretations, while low resistivity values and reported fine-grained lithologies (silt and clay) corresponded to fine-grained NMR log interpretations.

Digital AIT resistivity logs were collected at 24 multiple-well monitoring sites. AIT logs measure formation conductivity as a function of borehole depth and distance from the borehole that can be converted to resistivity. The AIT logs were analyzed in conjunction with gamma logs collected at each site to estimate the bulk grain size. In general, low-resistivity values were interpreted as fine-grained sediment, intermediate-resistivity values were interpreted as medium-grained sediment, and high-resistivity values were interpreted as coarse-grained sediment. Gamma values were interpreted in a similar fashion, with low-gamma values interpreted as coarse-grained sediment and high-gamma values interpreted as fine-grained sediment. The thresholds between the low-, intermediate-, and high-resistivity and gamma values were determined separately for each layer in each borehole to reduce the error associated with changes in water quality (Keys and MacCary, 1983).

Digital short-normal and long-normal resistivity logs were collected at 30 multiple-well monitoring sites. The depth of penetration of a resistivity logging tool is related to the distance between the current electrode and the potential electrode on the resistivity sonde (Keys and MacCary, 1983). The short-normal or 16-inch resistivity curve may be influenced by invasion of the drilling fluid into the formation (Keys and MacCary, 1983). The long-normal or 64-inch resistivity curve shows the resistivity of the same area as the short-normal (16-inch resistivity) curve but farther away from the borehole and beyond the invaded zone. In permeable soil or rock, porosity affects the depth of invasion, and the dissolved ion content of water in the pores determines the resistivity of the material. For this analysis, if the resistivity of the short-normal log was greater than the long-normal log in an interval, the interval's dissolved ion content was assumed to not be from the local sediment. Where available, total dissolved solids (TDS) measurements were used to verify poor water quality, defined as greater than 900 mg/L. Poor-quality water reduces resistivity, which, if unrecognized, can lead to the potentially incorrect interpretation that low-resistivity values indicated fine-grained sediments. Spontaneous-potential logs also can be used to determine changes in water quality; however, natural variations in water type and quality compounded by the movement of water resulting from widespread pumping and induced recharge in the Los Angeles Basin do not allow for a straightforward interpretation of spontaneous-potential logs. For the intervals with poor water quality, the next best available log for interpreting grain size is the gamma log. Therefore, for zones with poor water quality, the gamma ray log was used to estimate grain size.

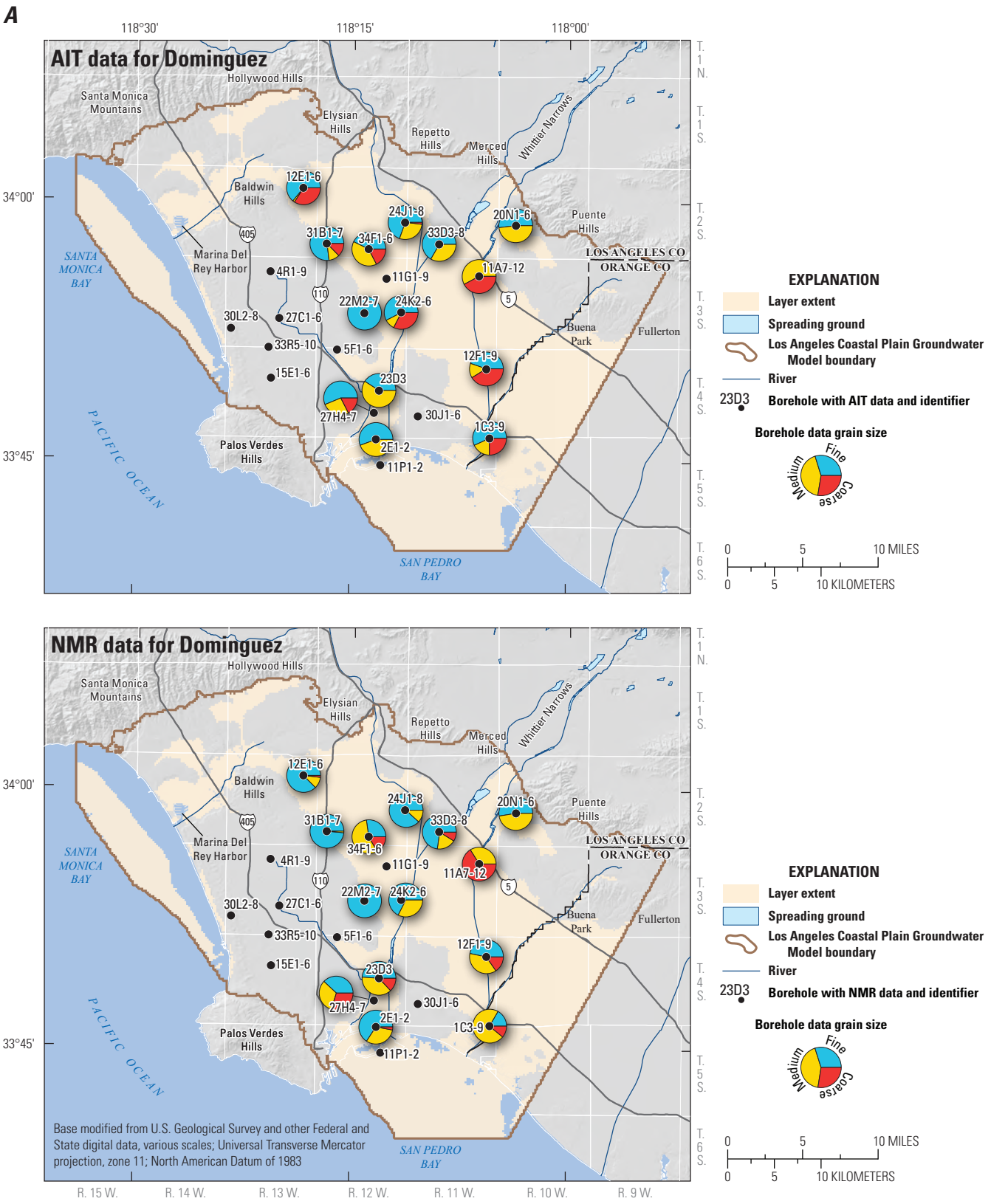


Figure 2.1. Results of grain-size analysis using array induction 2-foot resistivity (AIT), gamma, lithology, and nuclear magnetic resonance (NMR) logs for the *A,* Dominguez; *B*, Mesa; *C*, Pacific A; *D*, Pacific; *E*, Harbor; *F*, Bent Spring; *G*, Upper Wilmington A; *H*, Upper Wilmington B; *I*, Lower Wilmington; *J*, Long Beach A; *K*, Long Beach B; and *L*, Long Beach C aquifer systems in the Los Angeles Coastal Plain, California.

B

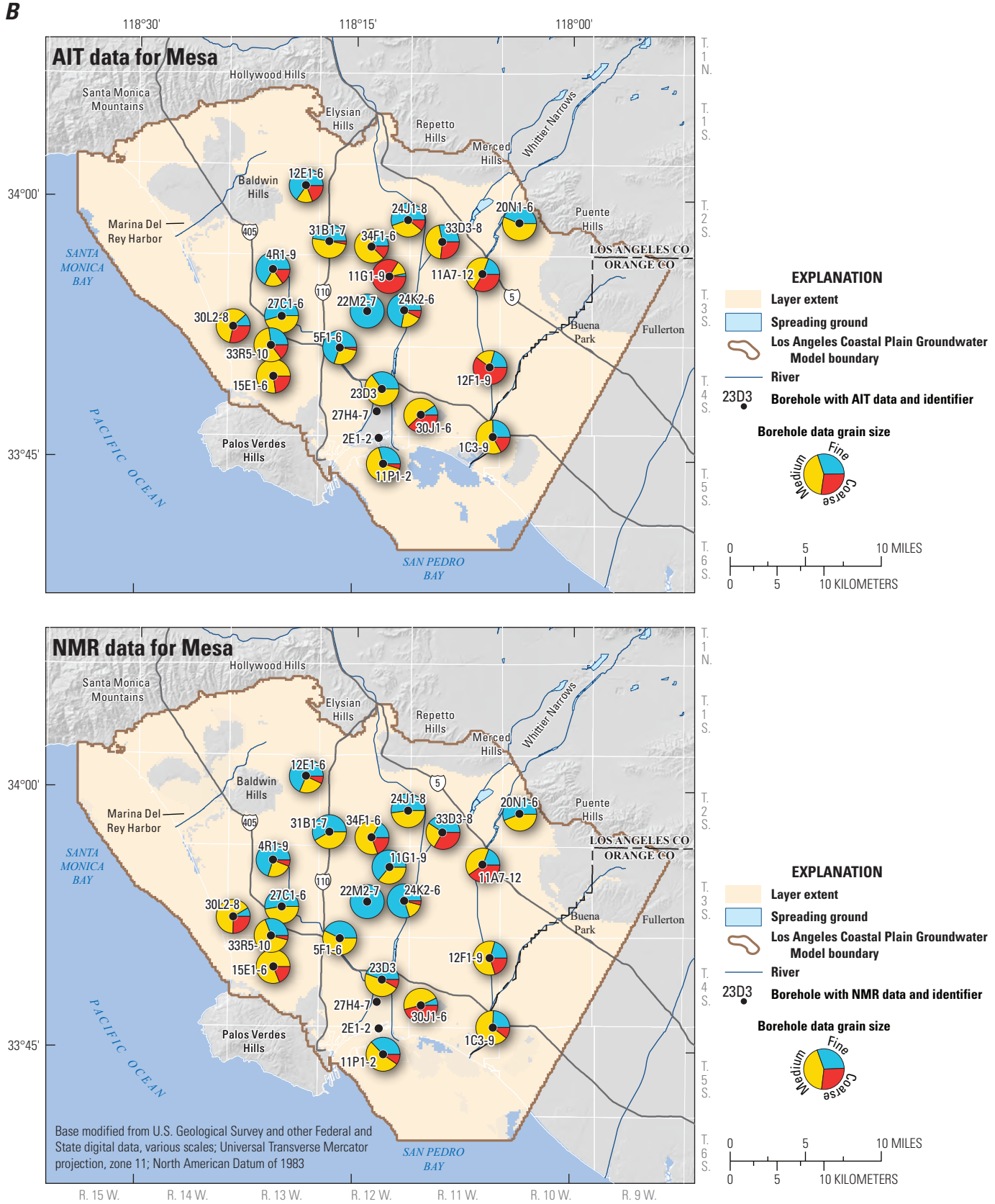


Figure 2.1.—Continued

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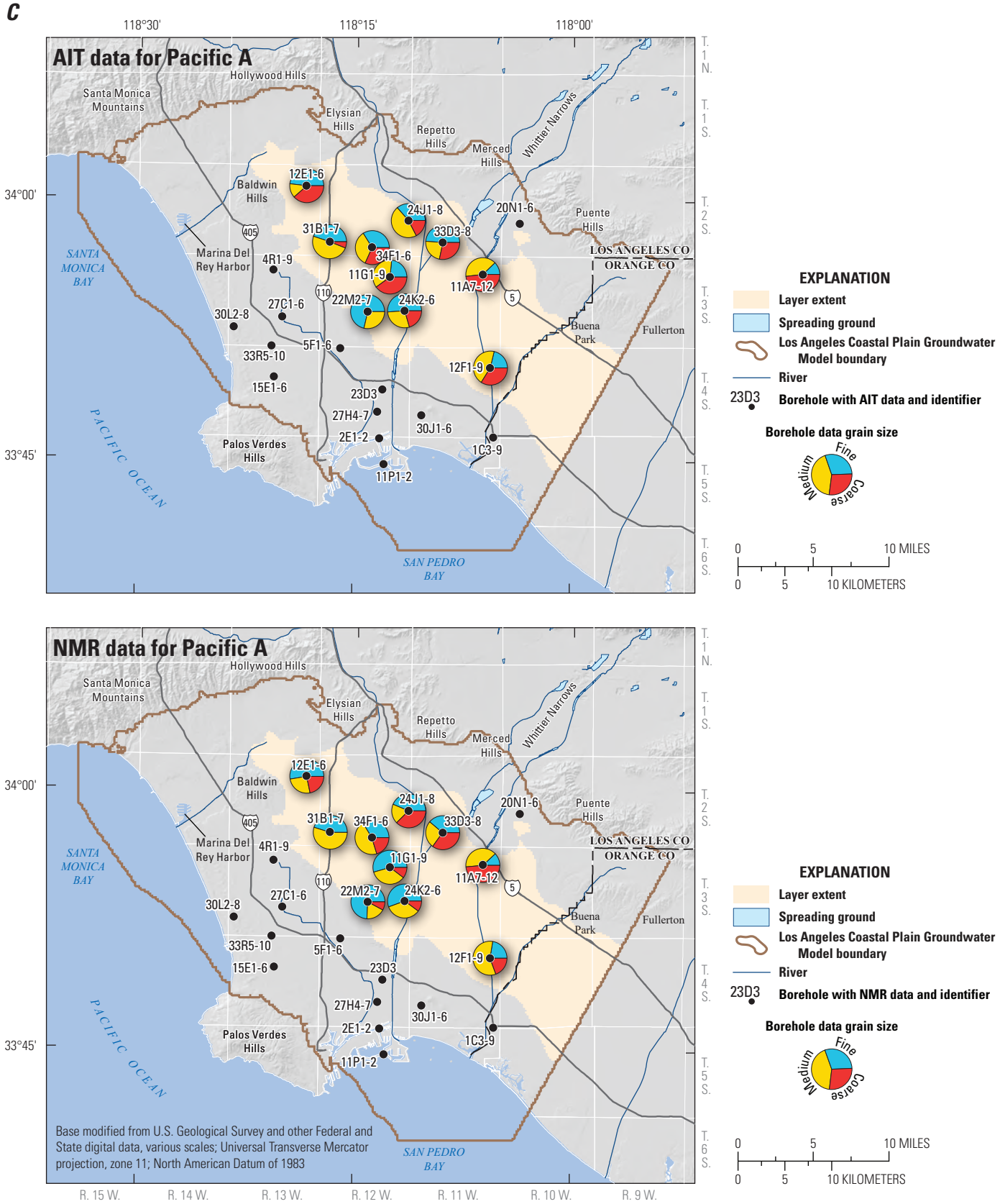


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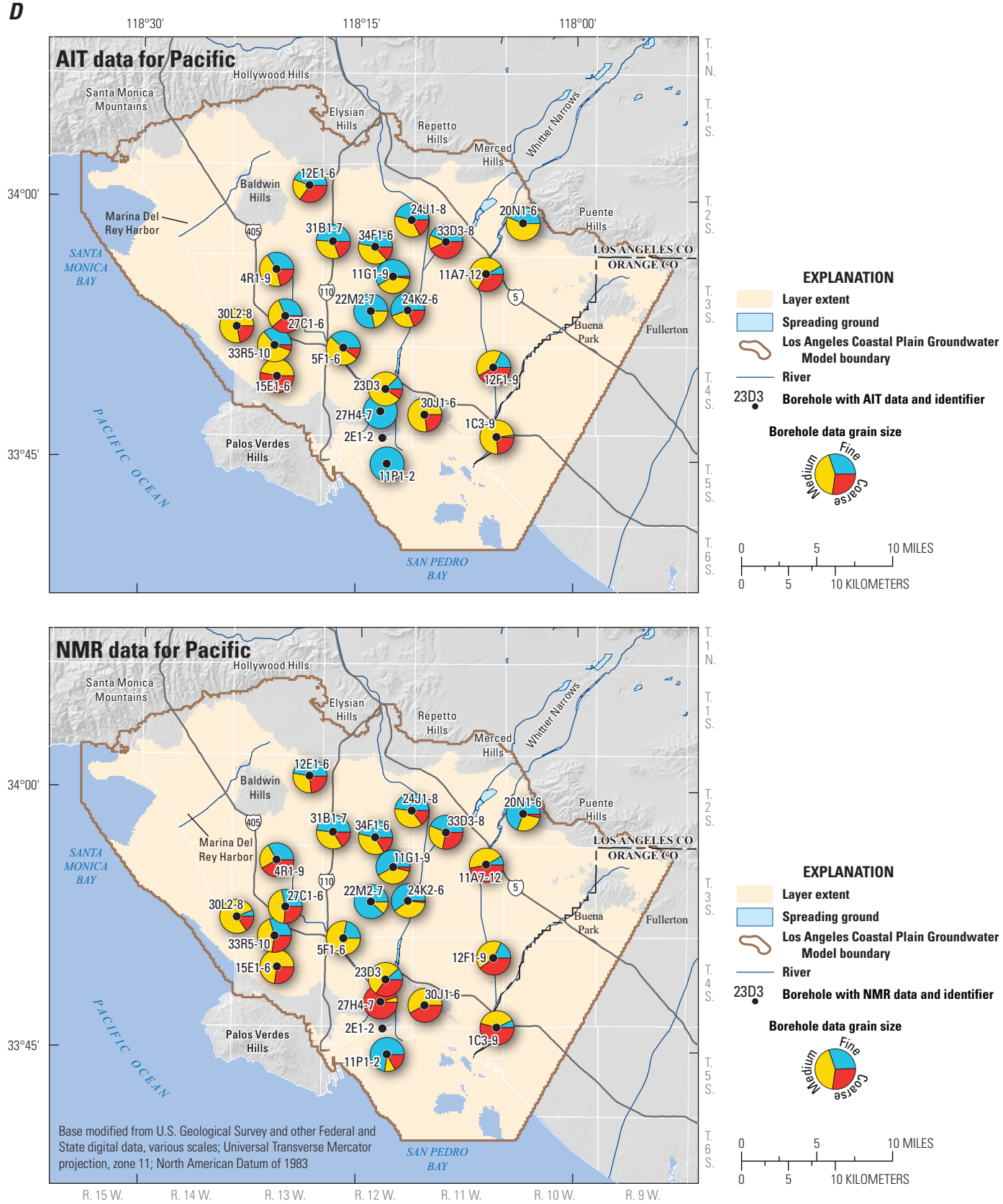


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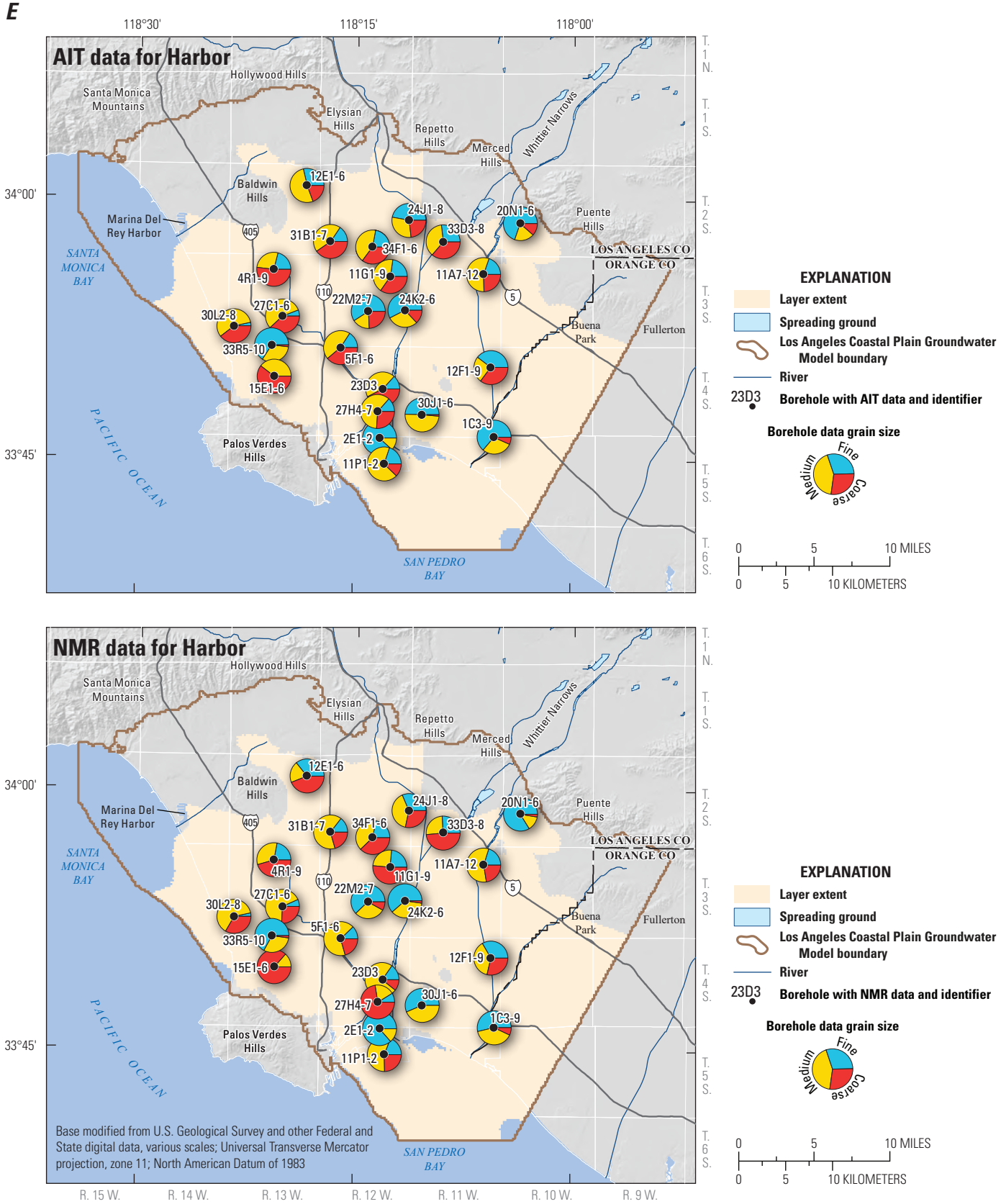


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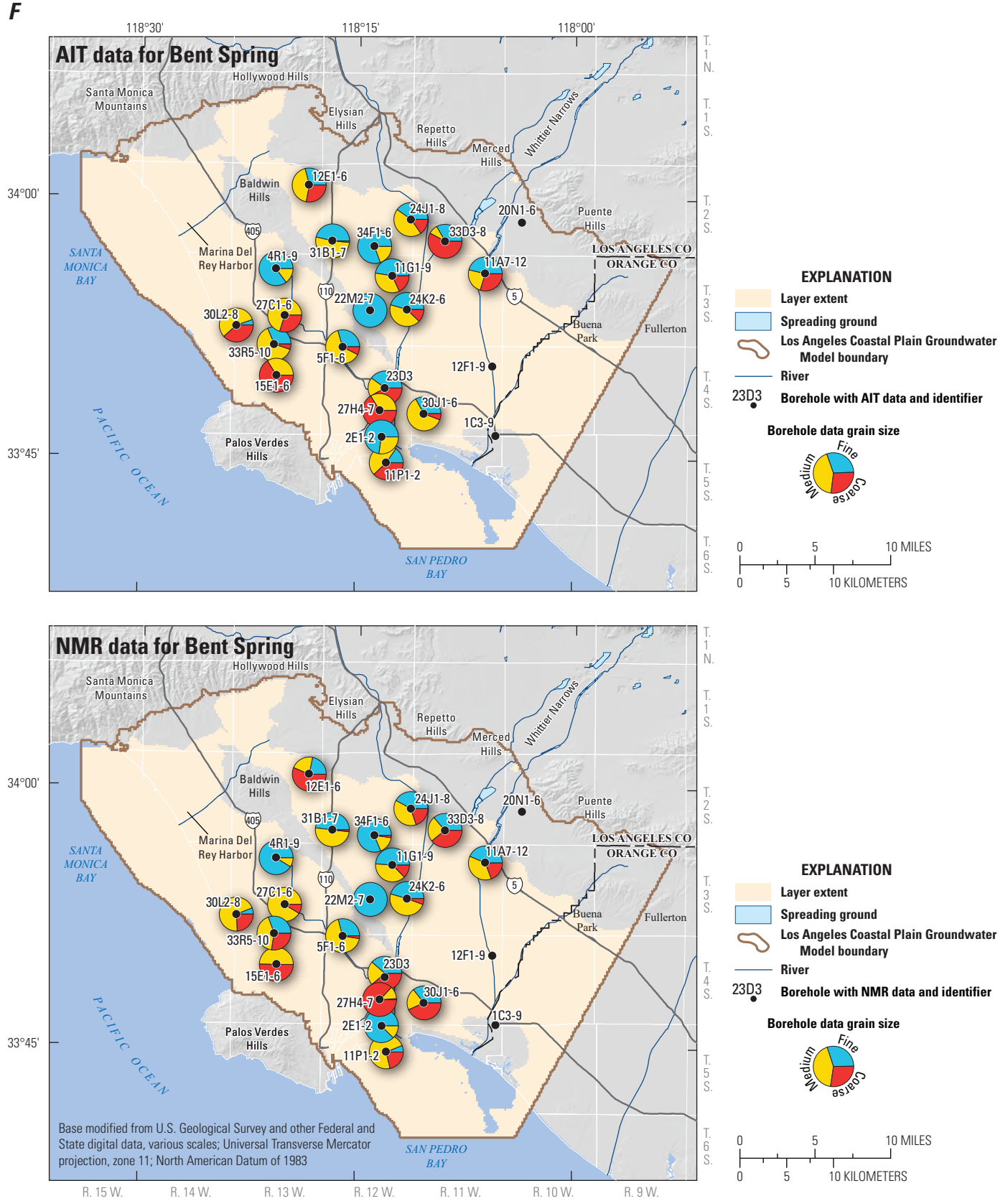


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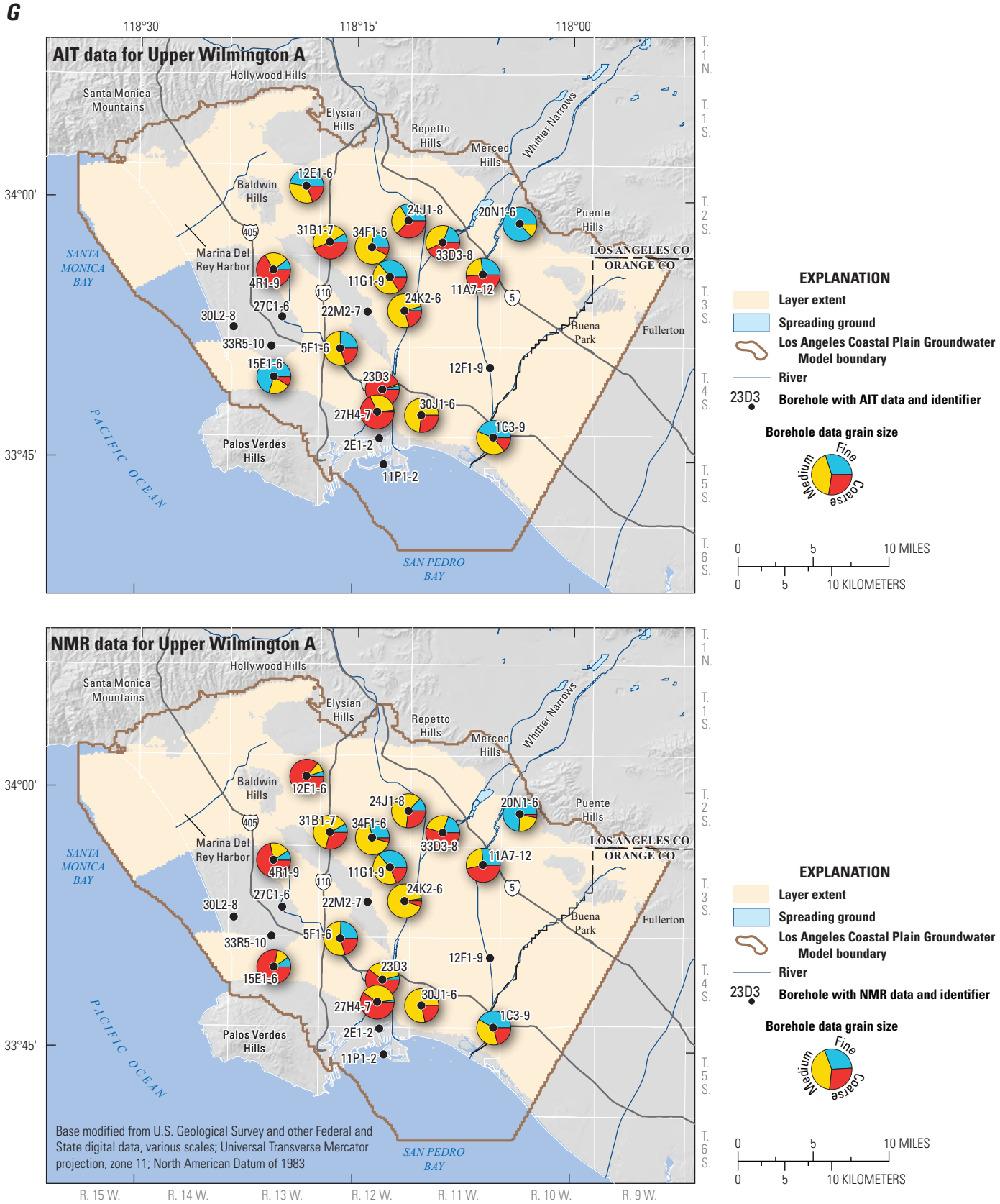


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H

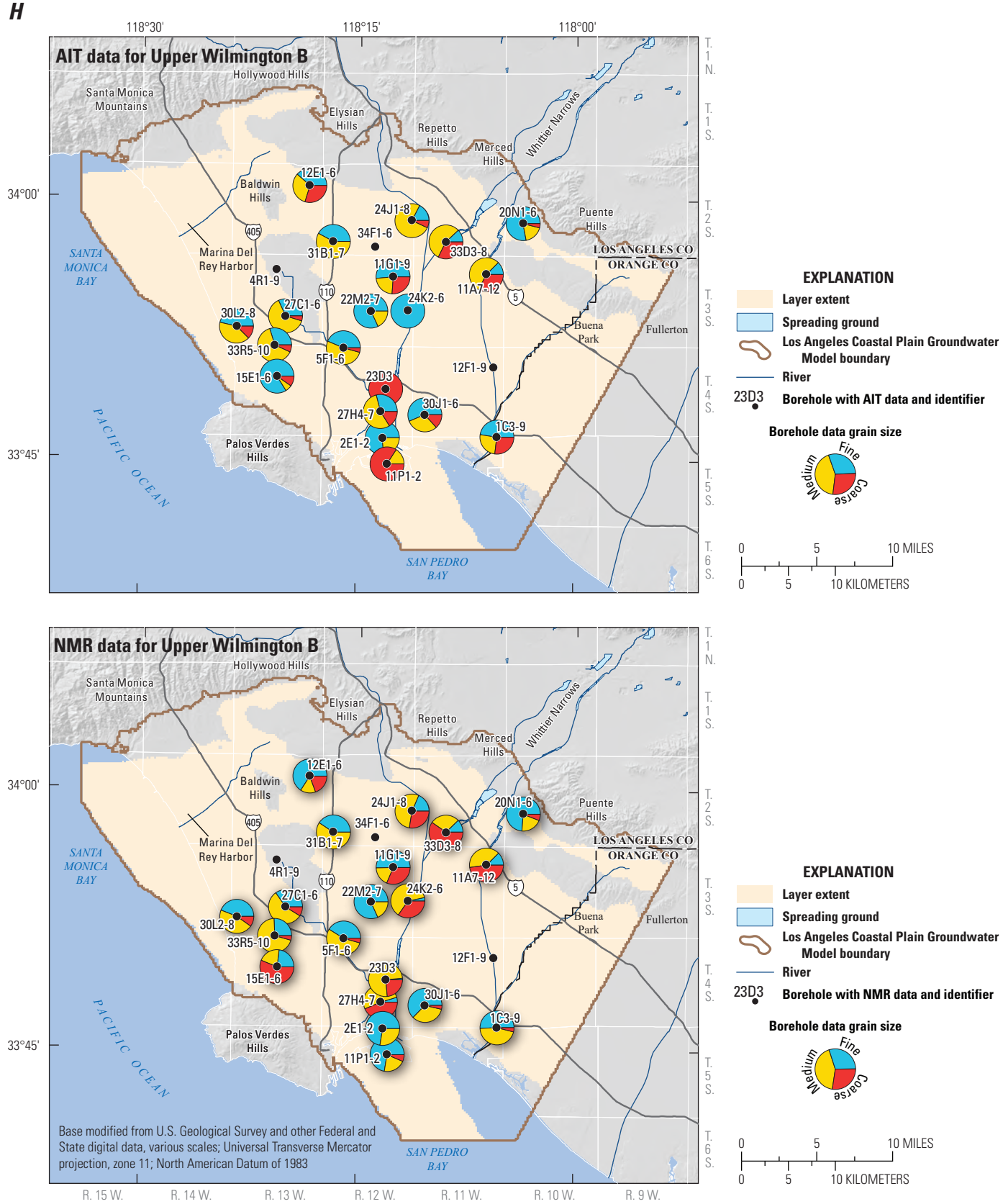


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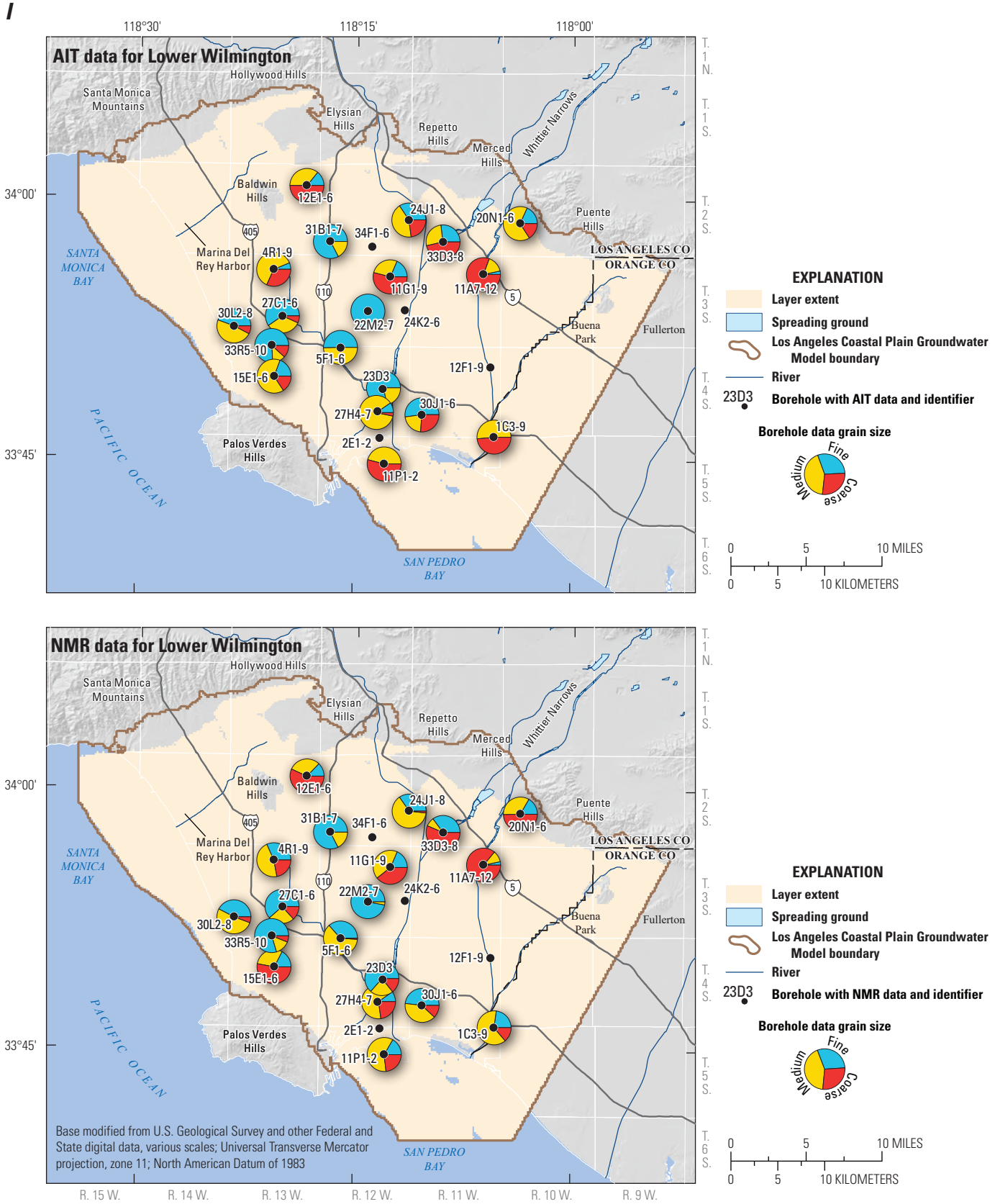


Figure 2.1.—Continued

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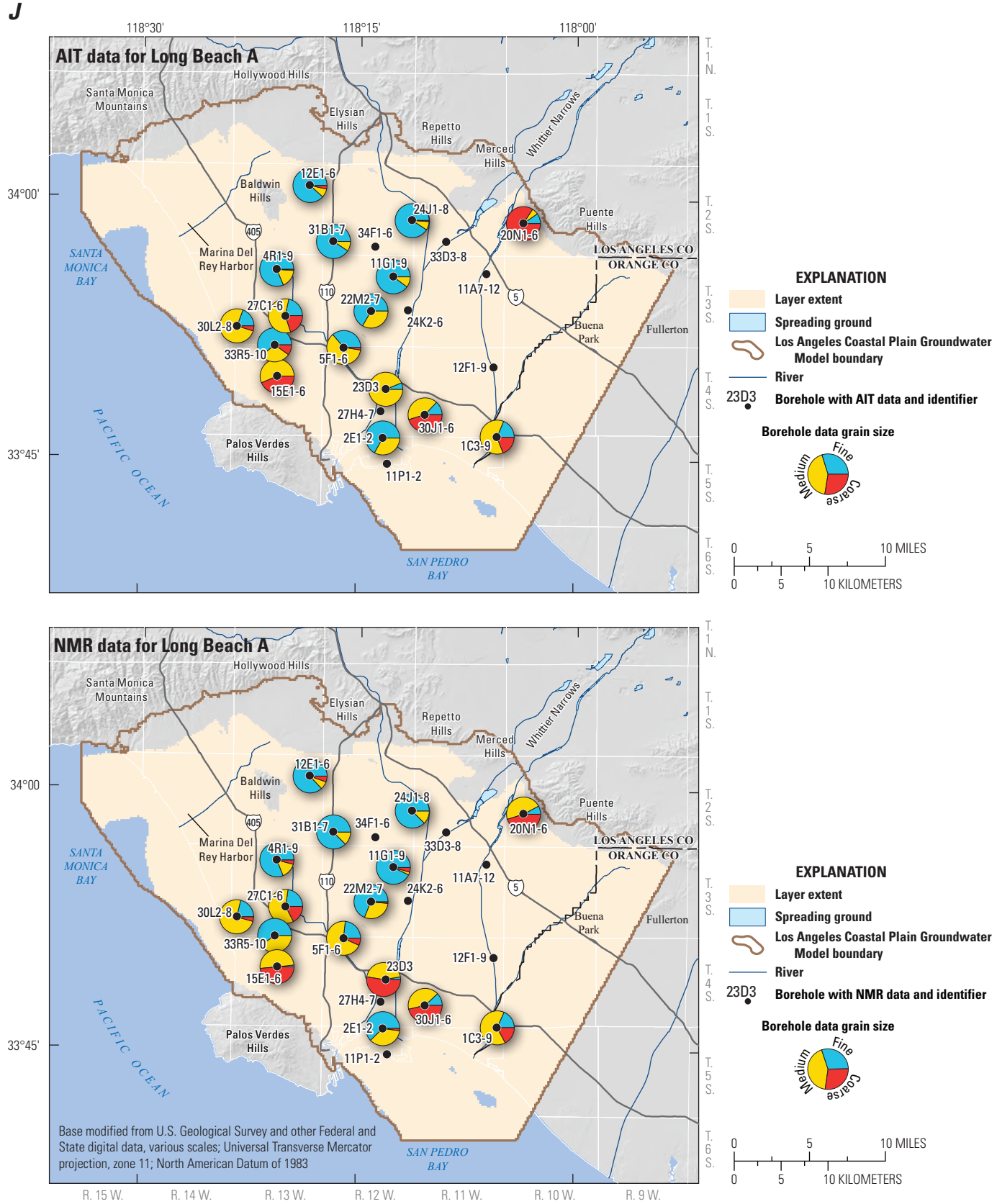


Figure 2.1.—Continued

K

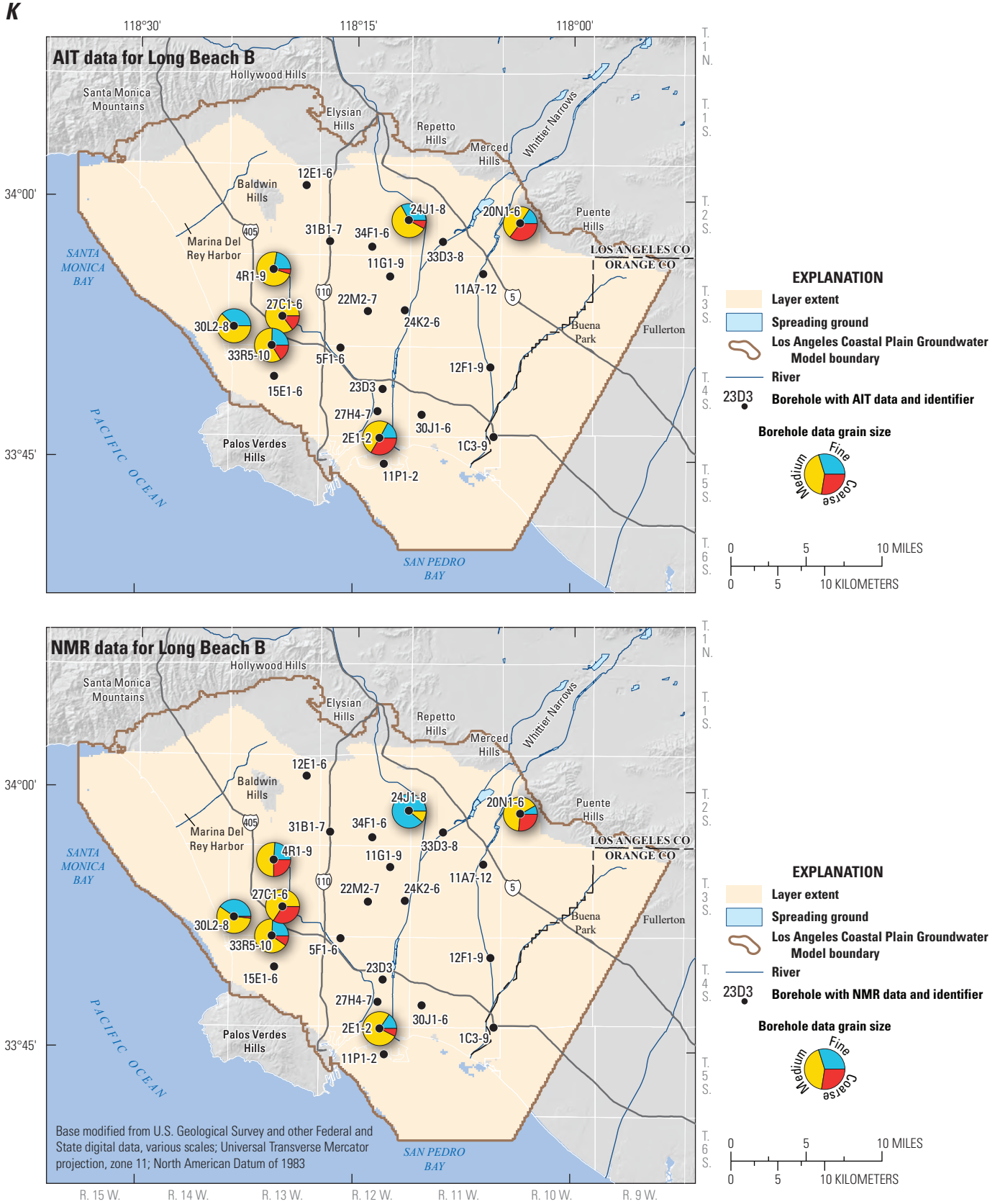


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L

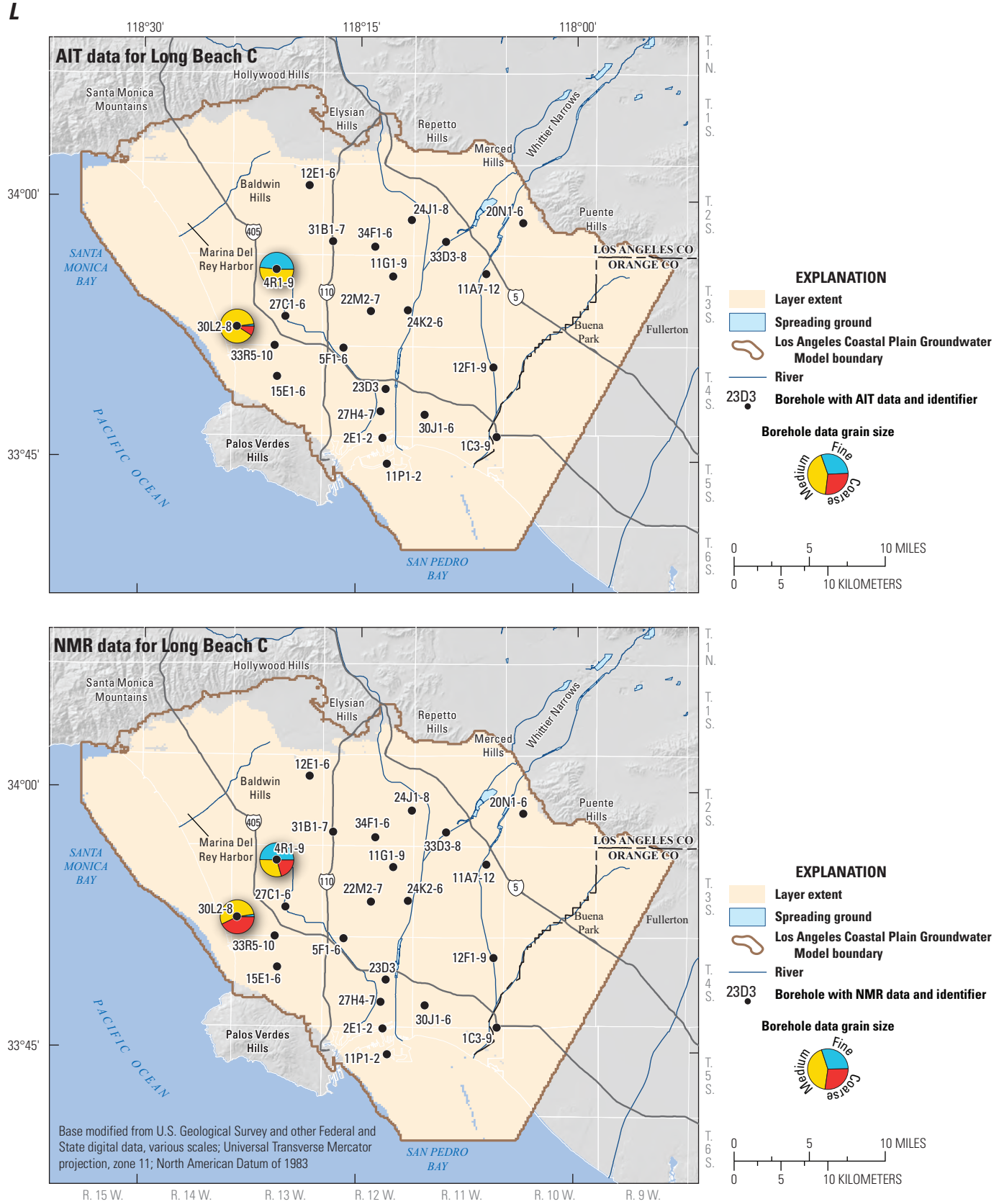


Figure 2.1.—Continued

Tool calibration changes over time, and borehole and formation-fluid properties greatly vary between sites; therefore, interpretations of the resistivity and gamma logs were done on a site by site basis. Thresholds for the logs were manually adjusted for each chronostratigraphic unit in each borehole based on several criteria. First, all available logs were reviewed for quality, and a simple interpretation was performed to understand the general depositional setting. Anomalies and sections that would not be suitable for interpretation were noted during this process. Second, the descriptions of the geologic logs were reviewed along with the site hydrologist's field notes. During this process, any abrupt changes in lithology, intervals of well sorted material, and thick sequences of identical lithology were noted. The third and final step involved selecting the threshold values while comparing the logs to the noted lithology.

The process of setting the threshold values was completed in three steps. These steps were done visually, simultaneously using plots of the resistivity and gamma ray logs alongside the graphic of the lithology summary, with vertical bars representing the threshold values and a graphic of the interpreted grain size. First, starting at the top and working down the log, the abrupt changes in lithology noted in the review process were identified. At these depths, the thresholds for each chronostratigraphic unit were adjusted until the log values were bracketed by the appropriate thresholds. For example, in the case of gravel overlying clay, the thresholds were set for resistivity logs so the log values for the gravel were above the high threshold and the log values for the clay were below the low threshold. For accuracy, the graph of the interpreted lithology was compared to the graphic of the lithology summary throughout the process. After the abrupt lithology changes were addressed, the intervals of well-sorted material were examined. During this step, the threshold values were slightly adjusted as needed to ensure that log values of a given material were bracketed by the appropriate threshold. If large changes in the thresholds (approximately 10 percent of the log scale) were made during this step in the process, the abrupt changes in lithology were reviewed. Again, the graph of the interpreted lithology was compared to the graphic of the lithology summary for accuracy. The third step in setting the thresholds was completed as a check to ensure that subtle changes in lithology were interpreted properly. For this step, the hydrologist's notes were reviewed for thin beds of varying lithology that may not have been included in the lithology summary; for example, a 3-foot thick coarse sand layer in the middle of a 50-foot thick clayey sand or a noted change in sand percentage. If the lithology at these depths was not interpreted correctly, all data were re-examined to determine a possible cause for the discrepancy. If the thresholds needed to be adjusted for proper interpretation, the entire process was repeated. Thresholds were fine tuned to increase agreement between the NMR and resistivity (AIT and long-normal resistivity) interpretations. The final interpreted lithology was then compared to the summary lithology and hydrologist's notes to ensure a reasonable match.

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Appendix 3. Los Angeles Coastal Plain Groundwater-flow Model Setup Including Wells Used to Constrain Boundary Conditions

By Daniel Culling and Scott Paulinski

Groundwater underflow (inflows and outflows) at the eastern boundary of the Los Angeles Coastal Plain Groundwater-flow Model (LACPGM) was simulated for all layers using the General Head Boundary Package (GHB) of MODFLOW-USG (Panday and others, 2013). Monthly water-level data were provided by Orange County Water District (OCWD) and the Water Replenishment District of Southern California (WRD) from selected wells on both sides of the boundary (fig. 3.1) and were used to estimate the temporally and spatially varying water levels along the Orange County General Head Boundary (GHB). Wells were chosen based on proximity to eastern boundary GHB model cells, temporal data coverage, and proximity to pumping. Production well water-level data were used only if the data were collected during static (non-pumping) conditions. Monthly water-level data from wells near the LACPGM's eastern boundary were averaged quarterly to match the modeled stress periods and used to estimate water levels at the nearest eastern boundary model cell of the LACPGM. GHB model cells based directly on water-level data from nearby wells are referred to as primary data GHB cells. Water-level data were interpolated between two primary data GHB cells if the long-term estimated water-levels of the two cells had a moderately strong linear correlation (coefficient of determination (R^2) > 0.50). This process filled in most (approximately 80 percent) data gaps within the GHB.

Due to sparse water-level data near the northern and southern end of the Orange County GHB, a few wells farther from the Orange County GHB were used to help estimate water levels along the GHB for some layers. These more distant wells include 12P2, 8A1, 18C1, and 9G1 (fig. 3.1). Although gaps in data do also exist along the middle section of the Orange County GHB, these gaps are generally smaller, and GHB water-levels in these gaps can be interpolated from nearby data. The data gaps along the northern and southern end of the Orange County GHB are generally larger and lack data to the north or south of the GHB. Data from more distant wells around the north and south ends of the GHB were used to limit extrapolation error. Many of the primary data GHB cells are based on water-level data that are not continuous for the entire model period (1971–2015). The OCWD has installed a series of multi-completion wells in the Orange County Basin to monitor water levels and water quality, including several wells near the eastern boundary of the LACPGM. These wells were not constructed until the early 1990s; consequently, many of the water-level periods of record in this area generally start around 1992. Few wells have water-level measurements extending back to the model start date (1971).

Water levels for wells missing earlier water-level data were extrapolated back in time using temporally overlapping water-level data from nearby wells with more complete records. To do this, a linear correlation plot was produced between the temporally overlapping data from the two wells, and a best-fit line was defined. Where a moderately strong linear correlation was found (R^2 > 0.50), the equation of the line relating the water levels of the primary data GHB cell to the water levels of the well with complete water-level data was used to compute estimated values for missing periods. The most critical well used for this purpose is well 8C2 (A-9), which has water-level data that span the model period. Small temporal gaps (< 3 stress periods) in data from a single well were filled by linearly interpolating between existing data points. Water-table slopes approaching the northern and southern boundary were linearly extrapolated to the boundary. In some rare cases, the calculated water level of a GHB cell was lower than the elevation of the bottom of the layer for that cell; in these instances, the water level was changed to match the bottom elevation of the layer.

In some cases, GHB water-levels were estimated based on data from other layers. Before doing this, a linear correlation plot was produced between hydrographs of different layers, and a best-fit line was defined. The equation of the best-fit line was then used to estimate the water-levels of an undefined GHB cell in one layer from the known water-levels of a GHB cell in another layer. Generally, the highest correlations were between adjacent layers, and correlations were lower for layers that were farther apart. The hydraulic heads in four groups of model layers were found that tended to be highly correlated: Dominguez and Mesa; Pacific A, Pacific, and Harbor; Bent Spring, Upper Wilmington A, Upper Wilmington B, and Lower Wilmington; and Long Beach A, Long Beach B, and Long Beach C. Where data were unavailable for estimates based on correlation, water levels were copied from the nearest model cell with a comparable value (for example, heads were copied between the Long Beach B and C aquifer systems, and so forth).

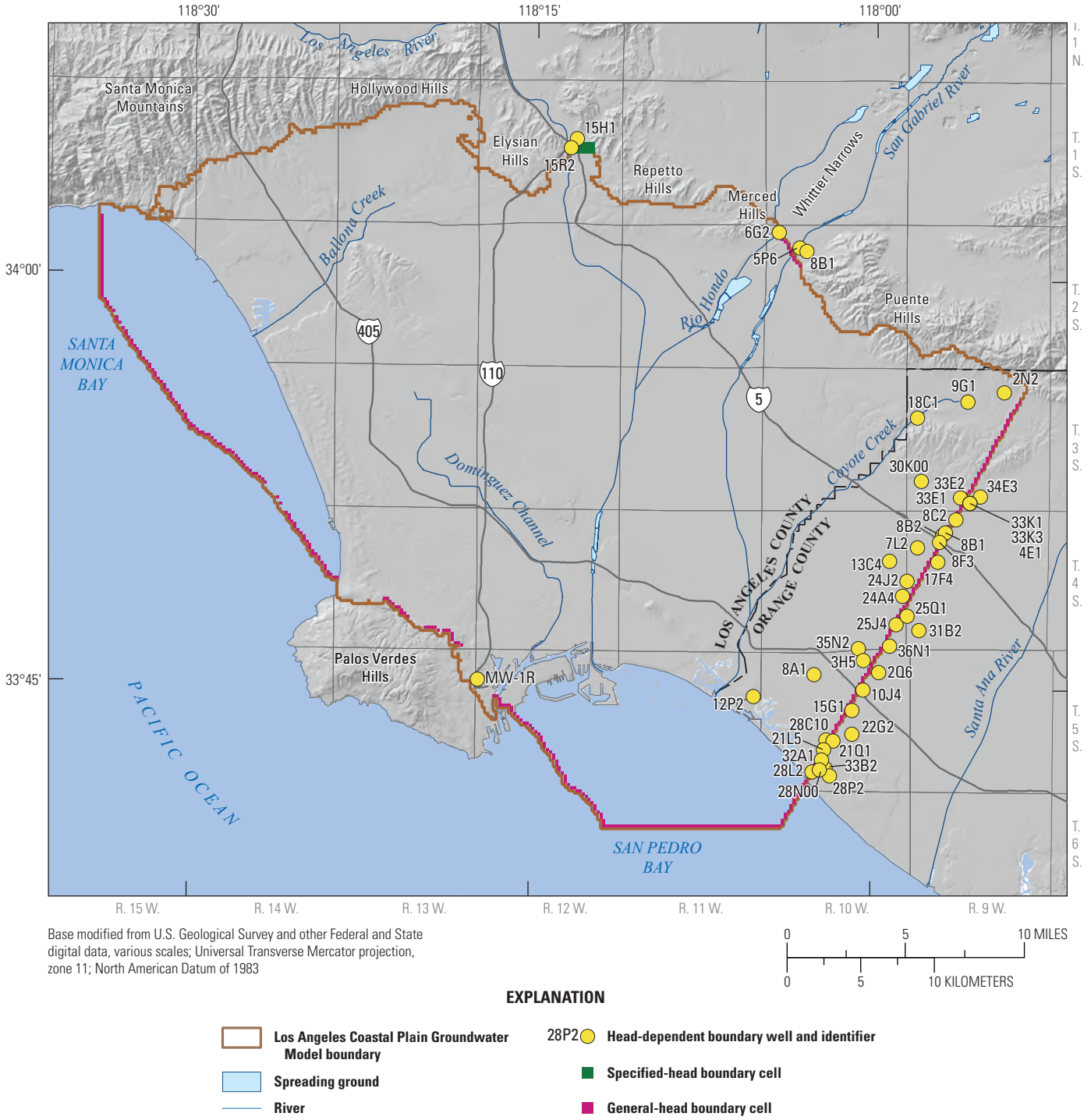


Figure 3.1. Wells used to constrain boundary conditions of the Los Angeles Coastal Plain Groundwater-flow Model. Common names are listed in table 3.1.

Figure 3.1 shows and labels the wells used to estimate GHB water-levels by state well number. For readers more familiar with common names, a lookup table is provided (table 3.1). Observed heads for wells used to estimate the Los Angeles Narrows time-variant specified head along with estimated boundary heads are shown in table 3.2.

Table 3.1. Wells used to constrain boundary conditions.

State well number	Common name
1S/13W-15H1	2771I
1S/13W-15R2	2772E
2S/11W-6G2	2927A
2S/11W-8B1	2948C
4S/10W-7L2	A-48
4S/11W-24A4	A-53
4S/10W-8C2	A-9
4S/10W-8B1	AM-30
4S/11W-13C4	AMD-8
4S/10W-8F3	CB-1
3S/10W-2N2	CREST-BR
3S/10W-33E1	FM-18
3S/10W-33K1	FM-19A
3S/10W-34E3	FM-20
3S/10W-21H2	FM-6
4S/11W-35N2	GGM-2
4S/11W-25J4	GGM-3
3S/10W-9G1	LH-FS192
—	MW-1R
5S/11W-32A1	OCWD-BSO4
5S/11W-22G2	OCWD-BS106
5S/11W-15G1	OCWD-BS107
5S/11W-28P2	OCWD-BS19
5S/11W-28C10	OCWD-BS20B
5S/11W-21L5	PRT-HB
3S/10W-30K	RAY-MW31
5S/12W-1C3	SB-1
5S/11W-8A1	SBM-1
4S/11W-25Q1	SCWC-SDAL
4S/11W-36N1	SCWC-SSYC
5S/11W-28P	SLC-P6
2S/11W-5P6	Whittier Narrows1_1
2S/11W-5P13	Whittier Narrows1_8
4S/10W-31B2	W-7040
5S/11W-3H5	WM-75A
5S/11W-10J4	WM-99
5S/11W-2Q6	WM-OC2

Table 3.2. Observed heads used to simulate boundary conditions at the Los Angeles Narrows.

[mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988]

Date (mm/dd/yyyy)	Well used	Common name	Observed water level, in feet relative to NAVD 88	Los Angeles Narrows boundary head, in feet relative to NAVD 88
01/27/1971	1S/13W-15R2	2772E	289.5	289.5
02/24/1971	1S/13W-15R2	2772E	289.4	289.4
03/24/1971	1S/13W-15R2	2772E	289.4	289.4
04/29/1971	1S/13W-15R2	2772E	289.6	289.6
05/26/1971	1S/13W-15R2	2772E	289.6	289.6
06/30/1971	1S/13W-15R2	2772E	289.6	289.6
07/29/1971	1S/13W-15R2	2772E	289.5	289.5
08/26/1971	1S/13W-15R2	2772E	289.6	289.6
09/22/1971	1S/13W-15R2	2772E	289.6	289.6
10/27/1971	1S/13W-15R2	2772E	289.6	289.6
11/04/1971	1S/13W-15R2	2772E	289.6	289.6
12/30/1971	1S/13W-15R2	2772E	289.8	289.8
01/26/1972	1S/13W-15R2	2772E	289.6	289.6
02/25/1972	1S/13W-15R2	2772E	289.6	289.6
03/29/1972	1S/13W-15R2	2772E	289.5	289.5
04/26/1972	1S/13W-15R2	2772E	289.5	289.5
05/26/1972	1S/13W-15R2	2772E	289.4	289.4
06/28/1972	1S/13W-15R2	2772E	289.4	289.4
07/26/1972	1S/13W-15R2	2772E	289.4	289.4
08/29/1972	1S/13W-15R2	2772E	289.3	289.3
09/28/1972	1S/13W-15R2	2772E	289.2	289.2
10/26/1972	1S/13W-15R2	2772E	289.1	289.1
11/28/1972	1S/13W-15R2	2772E	289.1	289.1
12/27/1972	1S/13W-15R2	2772E	290	290
01/31/1973	1S/13W-15R2	2772E	289.5	289.5
02/21/1973	1S/13W-15R2	2772E	289.8	289.8
03/29/1973	1S/13W-15R2	2772E	290	290
04/27/1973	1S/13W-15R2	2772E	290.1	290.1
05/24/1973	1S/13W-15R2	2772E	290	290
05/30/1974	1S/13W-15R2	2772E	289	289
06/26/1974	1S/13W-15R2	2772E	288.8	288.8
07/24/1974	1S/13W-15R2	2772E	290	290
08/30/1974	1S/13W-15R2	2772E	290.1	290.1
09/27/1974	1S/13W-15R2	2772E	289.9	289.9
10/30/1974	1S/13W-15R2	2772E	289.9	289.9
11/21/1974	1S/13W-15R2	2772E	289.9	289.9
12/26/1974	1S/13W-15R2	2772E	289.8	289.8
04/24/1975	1S/13W-15R2	2772E	290	290

Table 3.2. Observed heads used to simulate boundary conditions at the Los Angeles Narrows.—Continued

[mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988]

Date (mm/dd/yyyy)	Well used	Common name	Observed water level, in feet relative to NAVD 88	Los Angeles Narrows boundary head, in feet relative to NAVD 88
06/25/1975	1S/13W-15R2	2772E	290.1	290.1
07/23/1975	1S/13W-15R2	2772E	290	290
08/27/1975	1S/13W-15R2	2772E	289.1	289.1
09/24/1975	1S/13W-15R2	2772E	289.1	289.1
10/23/1975	1S/13W-15R2	2772E	285.8	285.8
11/25/1975	1S/13W-15R2	2772E	289.4	289.4
12/17/1975	1S/13W-15R2	2772E	289.2	289.2
01/22/1976	1S/13W-15R2	2772E	289	289
02/19/1976	1S/13W-15R2	2772E	289.1	289.1
03/18/1976	1S/13W-15R2	2772E	289	289
04/21/1976	1S/13W-15R2	2772E	289	289
05/19/1976	1S/13W-15R2	2772E	289	289
06/23/1976	1S/13W-15R2	2772E	288.9	288.9
07/22/1976	1S/13W-15R2	2772E	288.9	288.9
08/25/1976	1S/13W-15R2	2772E	288.9	288.9
09/23/1976	1S/13W-15R2	2772E	290.4	290.4
10/20/1976	1S/13W-15R2	2772E	288.9	288.9
11/17/1976	1S/13W-15R2	2772E	289	289
12/16/1976	1S/13W-15R2	2772E	289	289
01/20/1977	1S/13W-15R2	2772E	288.9	288.9
02/23/1977	1S/13W-15R2	2772E	288.9	288.9
03/24/1977	1S/13W-15R2	2772E	288.7	288.7
04/21/1977	1S/13W-15R2	2772E	288.4	288.4
05/25/1977	1S/13W-15R2	2772E	288.8	288.8
06/16/1977	1S/13W-15R2	2772E	288.1	288.1
07/29/1977	1S/13W-15R2	2772E	288.7	288.7
08/30/1977	1S/13W-15R2	2772E	288.7	288.7
09/22/1977	1S/13W-15R2	2772E	288.6	288.6
10/27/1977	1S/13W-15R2	2772E	288.7	288.7
11/18/1977	1S/13W-15R2	2772E	288.7	288.7
12/29/1977	1S/13W-15R2	2772E	289.1	289.1
01/26/1978	1S/13W-15R2	2772E	288.9	288.9
02/23/1978	1S/13W-15R2	2772E	289.2	289.2
03/24/1978	1S/13W-15R2	2772E	289.7	289.7
04/20/1978	1S/13W-15R2	2772E	288.9	288.9
05/25/1978	1S/13W-15R2	2772E	289.4	289.4
06/22/1978	1S/13W-15R2	2772E	289.3	289.3
07/26/1978	1S/13W-15R2	2772E	289.4	289.4
08/30/1978	1S/13W-15R2	2772E	289.3	289.3
09/21/1978	1S/13W-15R2	2772E	289.2	289.2
10/19/1978	1S/13W-15R2	2772E	289.1	289.1
11/16/1978	1S/13W-15R2	2772E	289.2	289.2
12/27/1978	1S/13W-15R2	2772E	289.1	289.1
01/18/1979	1S/13W-15R2	2772E	288.8	288.8
03/22/1979	1S/13W-15R2	2772E	289	289
04/19/1979	1S/13W-15R2	2772E	289.4	289.4
05/30/1979	1S/13W-15R2	2772E	289.3	289.3
11/29/1979	1S/13W-15R2	2772E	289.2	289.2
11/19/1980	1S/13W-15R2	2772E	289.3	289.3
11/24/1981	1S/13W-15R2	2772E	288.7	288.7
04/21/1982	1S/13W-15R2	2772E	289.1	289.1
11/18/1982	1S/13W-15R2	2772E	288.8	288.8
04/21/1983	1S/13W-15R2	2772E	287.9	287.9
10/19/1983	1S/13W-15R2	2772E	288.5	288.5
04/27/1984	1S/13W-15R2	2772E	289.7	289.7
10/18/1984	1S/13W-15R2	2772E	289.3	289.3
04/18/1985	1S/13W-15R2	2772E	289.3	289.3
10/31/1985	1S/13W-15R2	2772E	281.3	281.3
01/31/1986	1S/13W-15R2	2772E	289.2	289.2
03/27/1986	1S/13W-15R2	2772E	289.5	289.5
04/24/1986	1S/13W-15R2	2772E	289.5	289.5
05/23/1986	1S/13W-15R2	2772E	289.5	289.5
10/27/1986	1S/13W-15R2	2772E	289.7	289.7
11/25/1986	1S/13W-15R2	2772E	289.7	289.7
01/30/1987	1S/13W-15R2	2772E	289.7	289.7
04/29/1987	1S/13W-15R2	2772E	289.4	289.4
05/20/1987	1S/13W-15R2	2772E	289.3	289.3
06/23/1987	1S/13W-15R2	2772E	289.3	289.3
07/23/1987	1S/13W-15R2	2772E	289.2	289.2
08/28/1987	1S/13W-15R2	2772E	289.2	289.2
09/30/1987	1S/13W-15R2	2772E	289.2	289.2
10/27/1987	1S/13W-15R2	2772E	289.4	289.4
11/23/1987	1S/13W-15R2	2772E	289.2	289.2
12/21/1987	1S/13W-15R2	2772E	289.4	289.4
01/29/1988	1S/13W-15R2	2772E	290.2	290.2
02/18/1988	1S/13W-15R2	2772E	289.4	289.4
03/29/1988	1S/13W-15R2	2772E	289.3	289.3
04/22/1988	1S/13W-15R2	2772E	289.5	289.5

Table 3.2. Observed heads used to simulate boundary conditions at the Los Angeles Narrows.—Continued

[mm/dd/yyyy, month/day/year; NAVD 88, North American Vertical Datum of 1988]

Date (mm/dd/yyyy)	Well used	Common name	Observed water level, in feet relative to NAVD 88	Los Angeles Narrows boundary head, in feet relative to NAVD 88
05/24/1988	1S/13W-15R2	2772E	289.5	289.5
06/28/1988	1S/13W-15R2	2772E	289.5	289.5
07/28/1988	1S/13W-15R2	2772E	289.5	289.5
08/19/1988	1S/13W-15R2	2772E	289.6	289.6
09/16/1988	1S/13W-15R2	2772E	289.7	289.7
10/21/1988	1S/13W-15R2	2772E	289.7	289.7
11/23/1988	1S/13W-15R2	2772E	289.7	289.7
12/15/1988	1S/13W-15R2	2772E	289.6	289.6
02/28/1989	1S/13W-15R2	2772E	289.5	289.5
03/24/1989	1S/13W-15R2	2772E	289.4	289.4
04/24/1989	1S/13W-15R2	2772E	289.3	289.3
09/22/1989	1S/13W-15R2	2772E	289.5	289.5
10/25/1989	1S/13W-15R2	2772E	289.5	289.5
11/29/1989	1S/13W-15R2	2772E	268	268
12/18/1989	1S/13W-15R2	2772E	289.2	289.2
01/18/1990	1S/13W-15R2	2772E	289.3	289.3
02/28/1990	1S/13W-15R2	2772E	289.5	289.5
03/17/1990	1S/13W-15R2	2772E	289.5	289.5
04/21/1990	1S/13W-15R2	2772E	289.6	289.6
05/17/1990	1S/13W-15R2	2772E	289.3	289.3
07/27/1990	1S/13W-15R2	2772E	289.4	289.4
10/11/1990	1S/13W-15R2	2772E	289.2	289.2
11/02/1990	1S/13W-15R2	2772E	289.2	289.2
01/10/1991	1S/13W-15R2	2772E	289.4	289.4
02/06/1991	1S/13W-15R2	2772E	289.1	289.1
03/08/1991	1S/13W-15R2	2772E	289.2	289.2
04/09/1991	1S/13W-15R2	2772E	289.2	289.2
05/03/1991	1S/13W-15R2	2772E	289.2	289.2
06/07/1991	1S/13W-15R2	2772E	289.2	289.2
07/02/1991	1S/13W-15R2	2772E	289.2	289.2
08/08/1991	1S/13W-15R2	2772E	289.3	289.3
10/04/1991	1S/13W-15R2	2772E	289.5	289.5
11/05/1991	1S/13W-15R2	2772E	290	290
12/17/1991	1S/13W-15R2	2772E	289.4	289.4
01/14/1992	1S/13W-15R2	2772E	289.5	289.5
02/14/1992	1S/13W-15R2	2772E	289.7	289.7
03/06/1992	1S/13W-15R2	2772E	289.7	289.7
05/13/2000	1S/13W-15R2	2772E	289.7	289.7
10/17/2000	1S/13W-15R2	2772E	289.5	289.5
04/06/2001	1S/13W-15R2	2772E	289.5	289.5
01/20/2007	1S/13W-15R2	2772E	288.5	288.5
04/07/2007	1S/13W-15R2	2772E	288.5	288.5
09/15/2007	1S/13W-15R2	2772E	288.5	288.5
11/29/2007	1S/13W-15R2	2772E	288.2	288.2
12/21/2007	1S/13W-15R2	2772E	288.6	288.6
03/17/2008	1S/13W-15R2	2772E	288.3	288.3
06/02/2008	1S/13W-15R2	2772E	288.3	288.3
07/07/2008	1S/13W-15R2	2772E	288.3	288.3
08/11/2008	1S/13W-15R2	2772E	288	288
09/08/2008	1S/13W-15R2	2772E	287.5	287.5
12/02/2008	1S/13W-15R2	2772E	289	289
07/06/2009	1S/13W-15R2	2772E	288.9	288.9
08/03/2009	1S/13W-15R2	2772E	288.8	288.8
09/14/2009	1S/13W-15R2	2772E	288.7	288.7
12/10/2009	1S/13W-15R2	2772E	288.7	288.7
01/04/2010	1S/13W-15R2	2772E	288.6	288.6
10/15/2011	1S/13W-15H1	2771I	299.7	290.5
08/10/2012	1S/13W-15H1	2771I	299	289.3
10/15/2012	1S/13W-15H1	2771I	298.5	288.4
09/11/2013	1S/13W-15H1	2771I	297.55	286.7
03/12/2014	1S/13W-15H1	2771I	298.03	287.6
10/16/2014	1S/13W-15H1	2771I	297.08	285.9
03/18/2015	1S/13W-15H1	2771I	297	285.7
10/08/2015	1S/13W-15H1	2771I	295.65	283.4

References Cited

Panday, S., Langevin, C.D., Niswonger, R.G., Ibaraki, M., and Hughes, J.D., 2013, MODFLOW-USG version 1—An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods 6–A45, 66 p., https://doi.org/10.3133/tm6A45.

Appendix 4. Results for Los Angeles Coastal Plain Groundwater-flow Model and Management Scenario Simulations

Appendix 4 figures contain detailed groundwater-flow budgets by subarea and groundwater-flow maps by layer of the Los Angeles Coastal Plain Groundwater Model (LACPGM).

Appendix 4 tables contain detailed groundwater-flow budgets by subarea of the LACPGM and detailed groundwater-flow budgets of the future water-management scenarios.

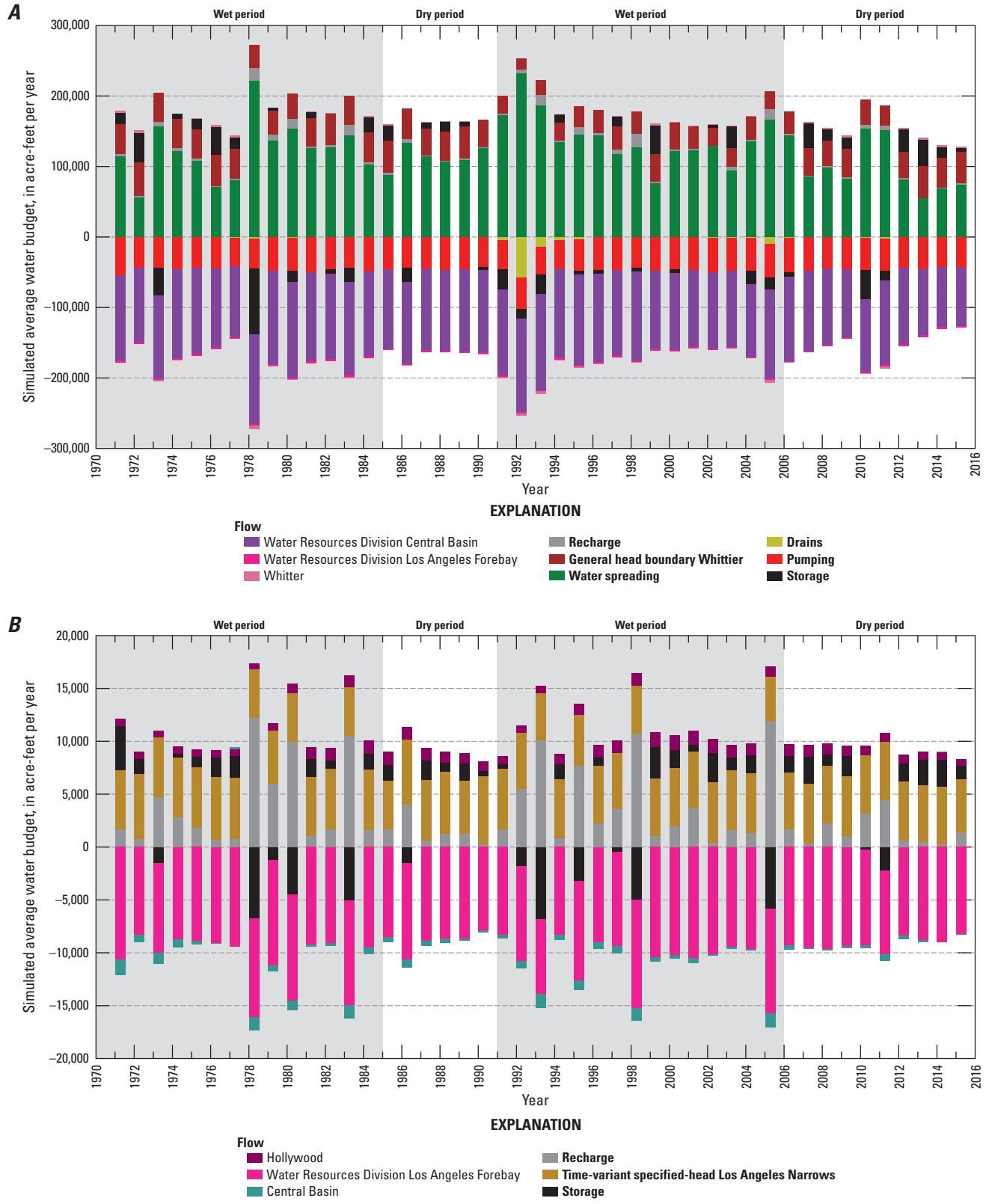
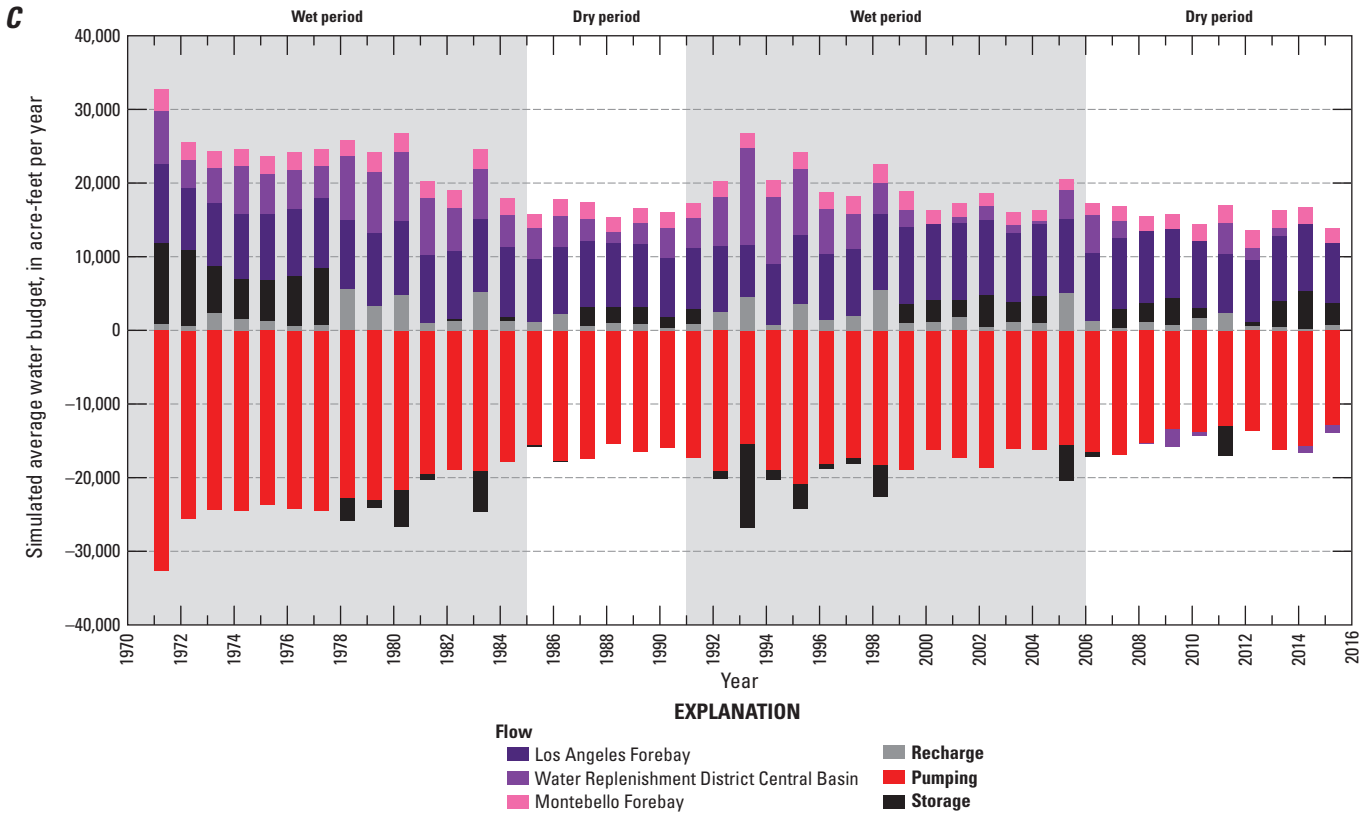


Figure 4.1. Simulated average annual groundwater-flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California, 1971 to 2015: *A*, Montebello Forebay; *B*, Los Angeles Forebay, non-Water Replenishment District of Southern California (WRD); *C*, Los Angeles Forebay, WRD; *D*, Hollywood Basin; *E*, Central Basin Pressure Area, non-WRD; *F*, Central Basin Pressure Area, WRD; *G*, Orange County, North; *H*, Orange County, Central; *I*, Orange County, South; *J*, Santa Monica Basin; *K*, Whittier area; and *L*, West Coast Basin.



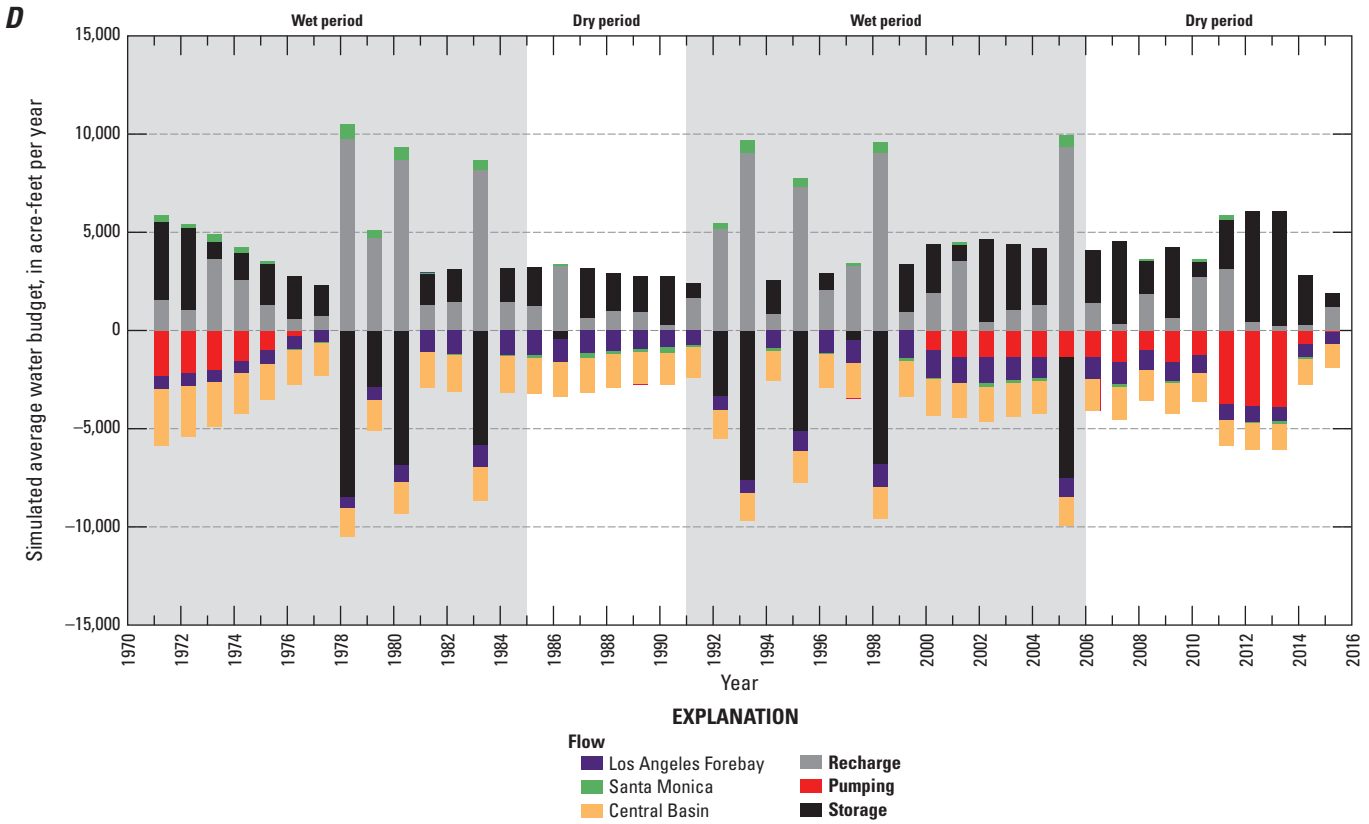


Figure 4.1.—Continued

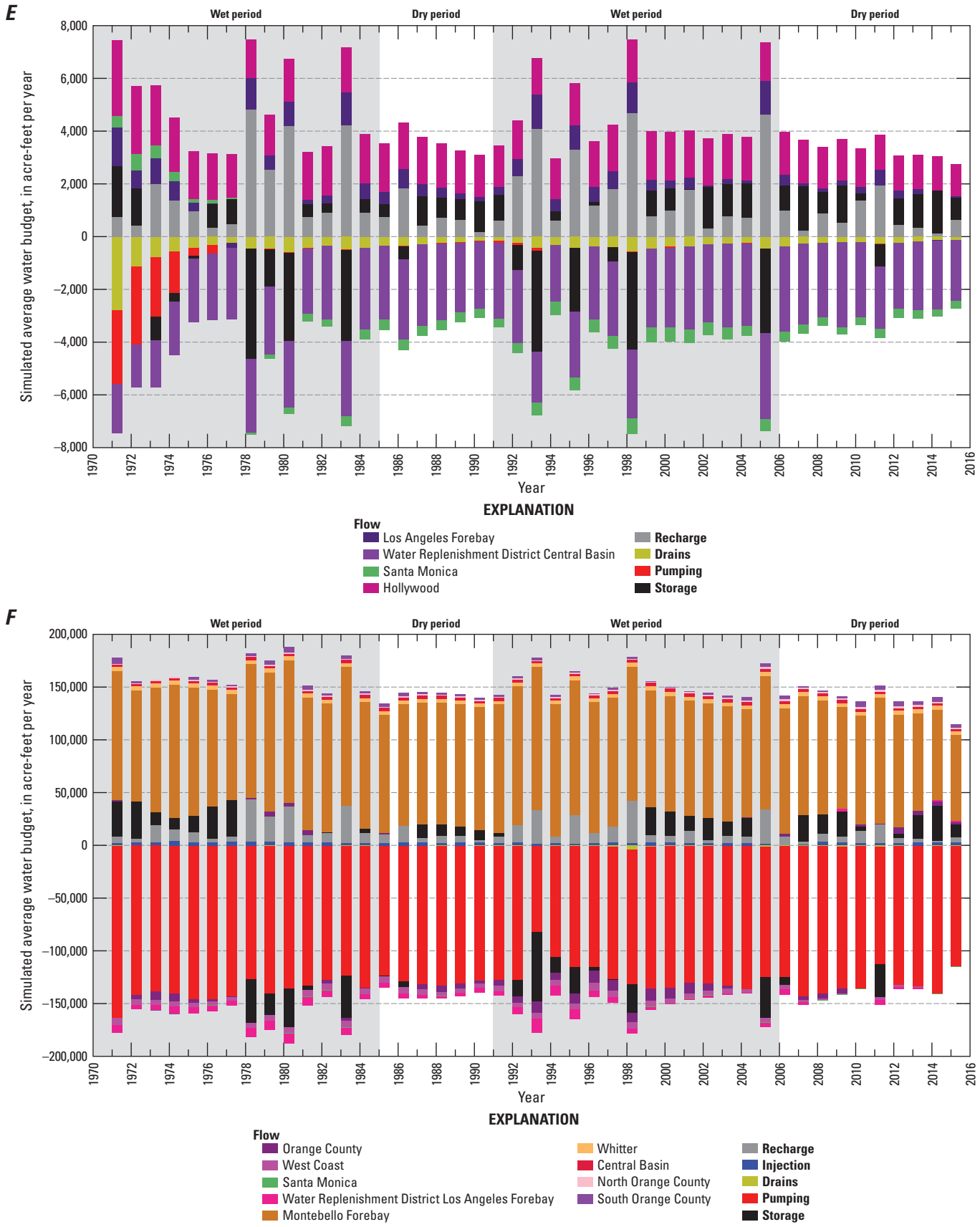
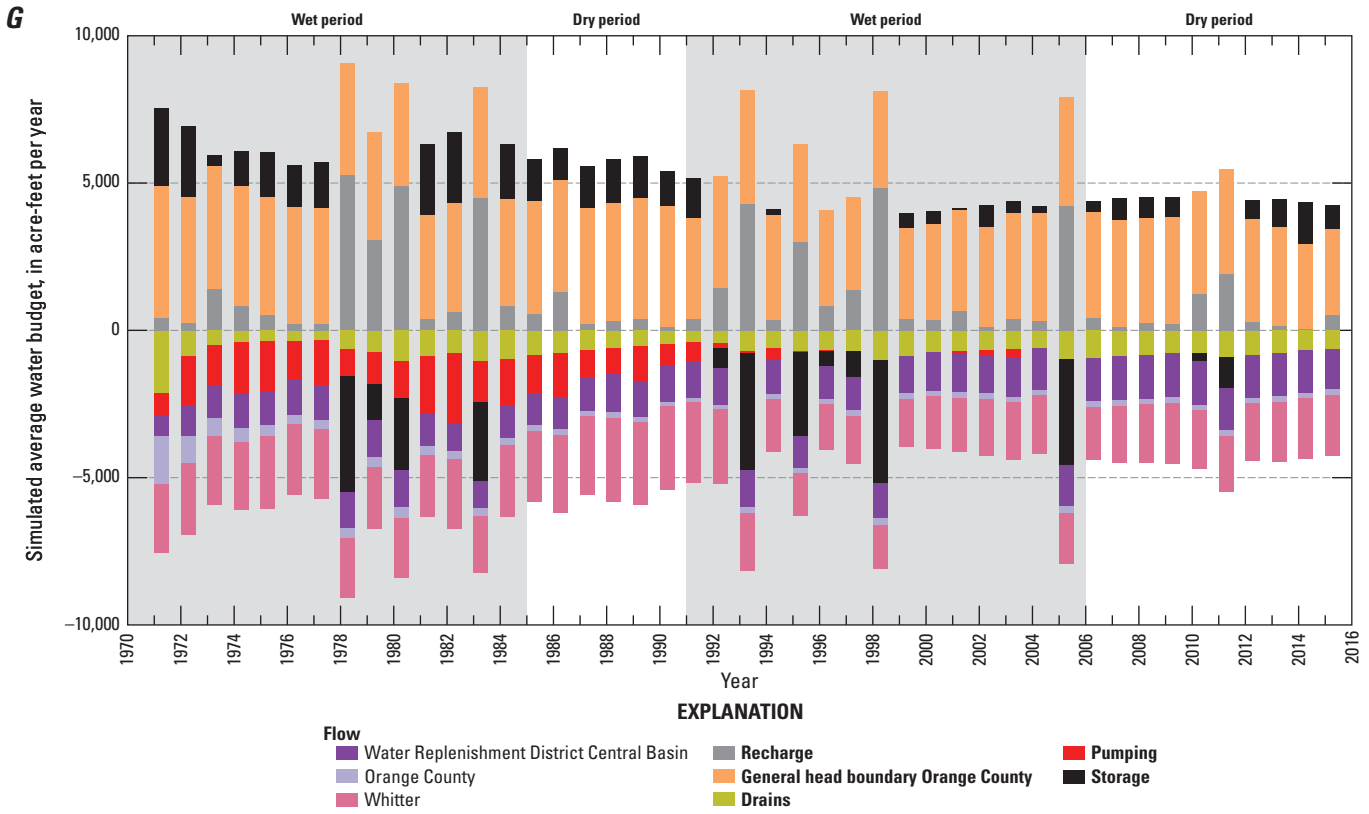


Figure 4.1.—Continued



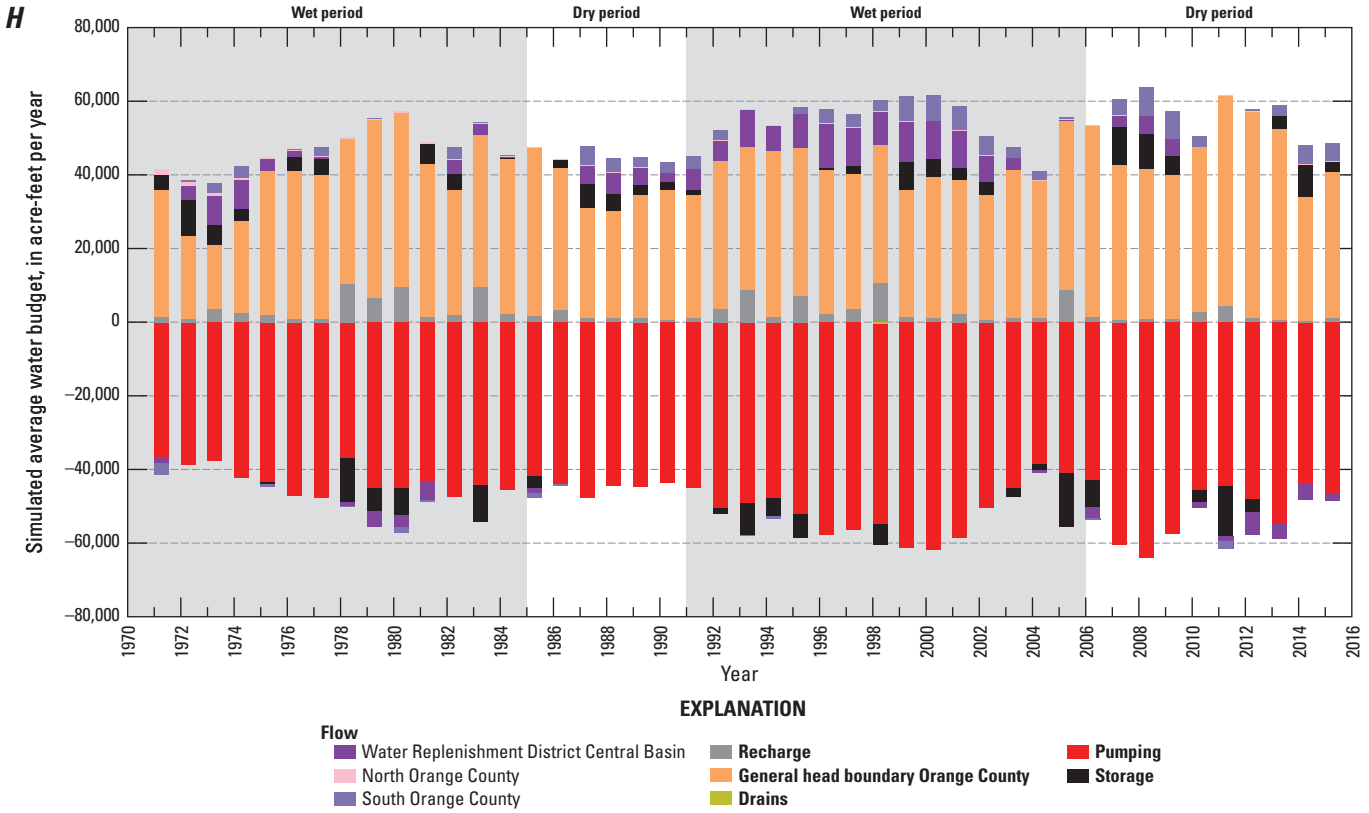


Figure 4.1.—Continued

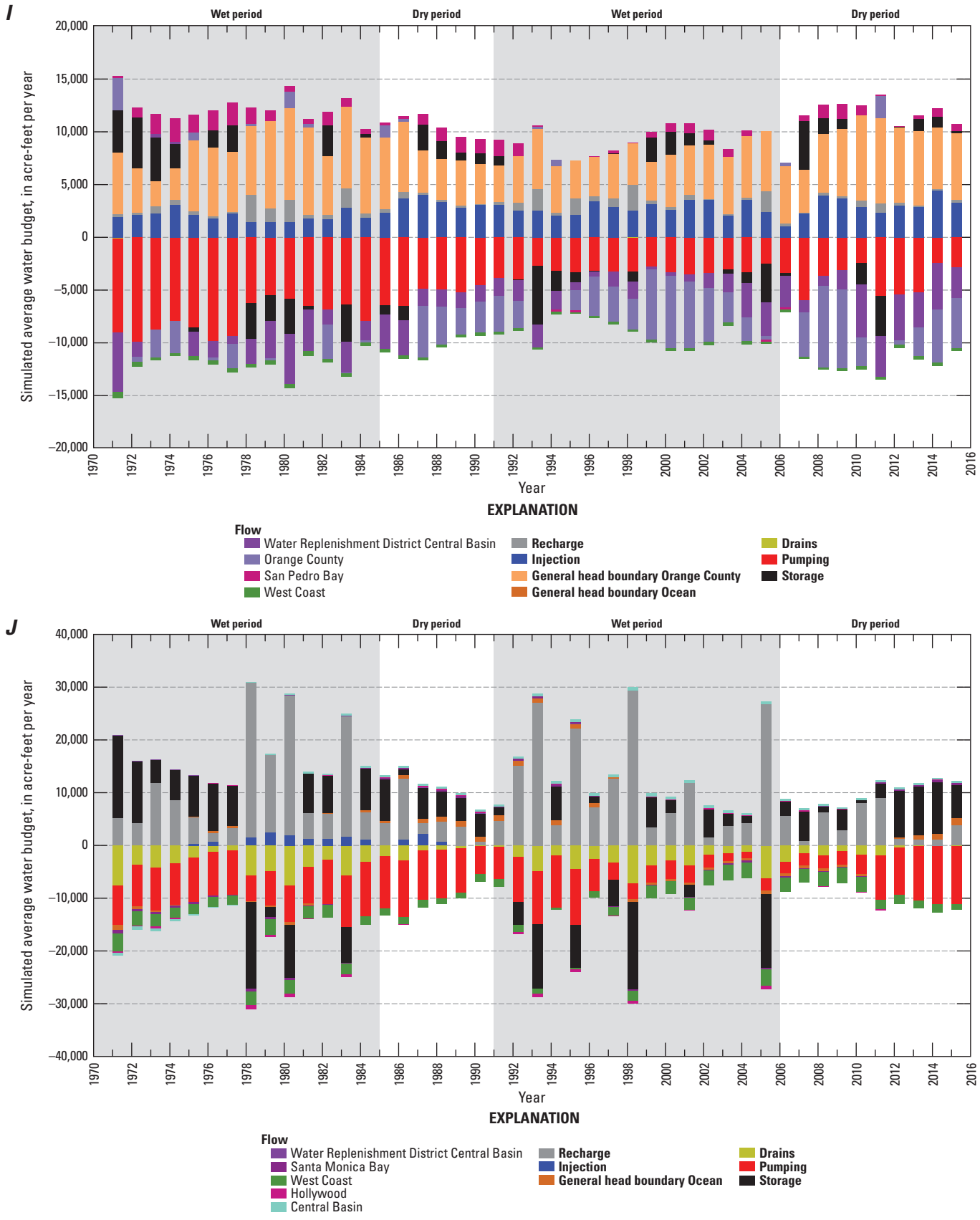
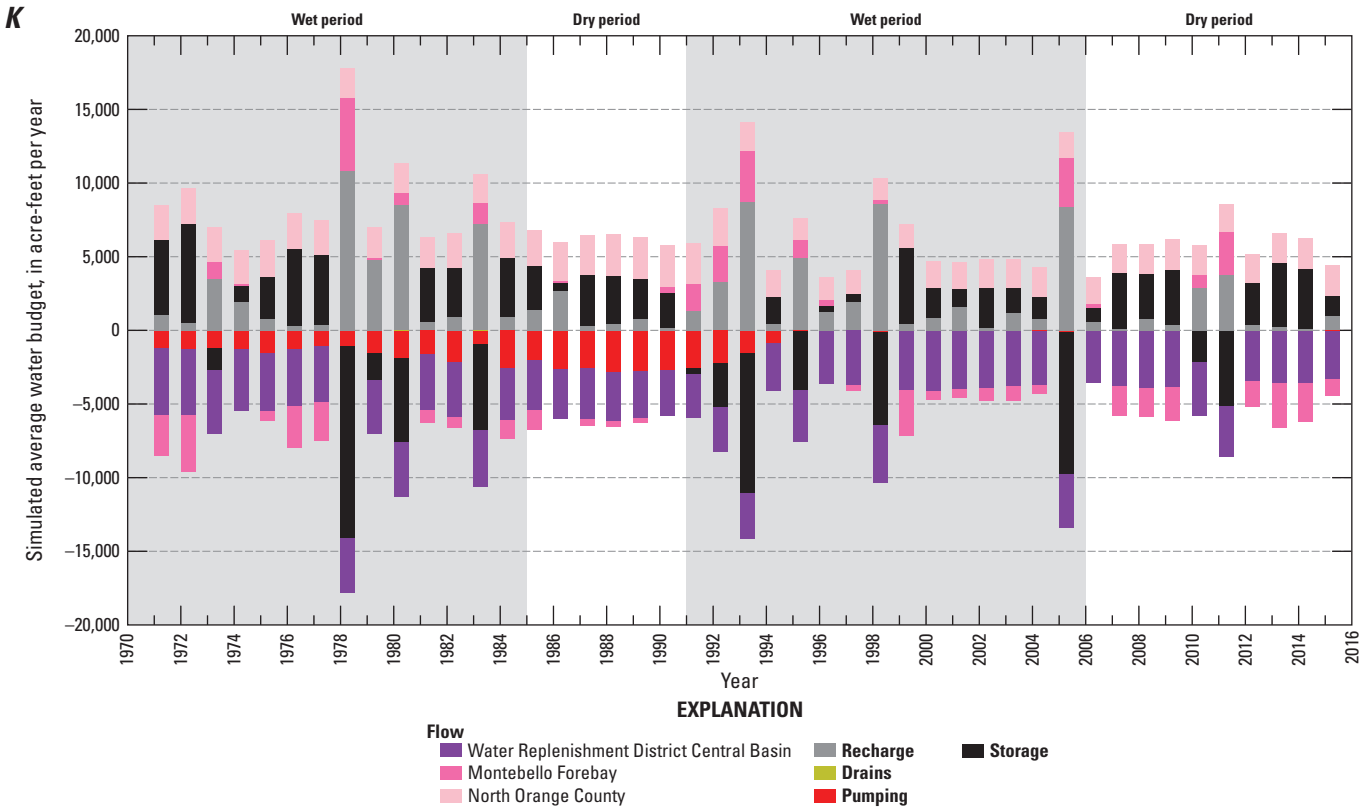


Figure 4.1.—Continued



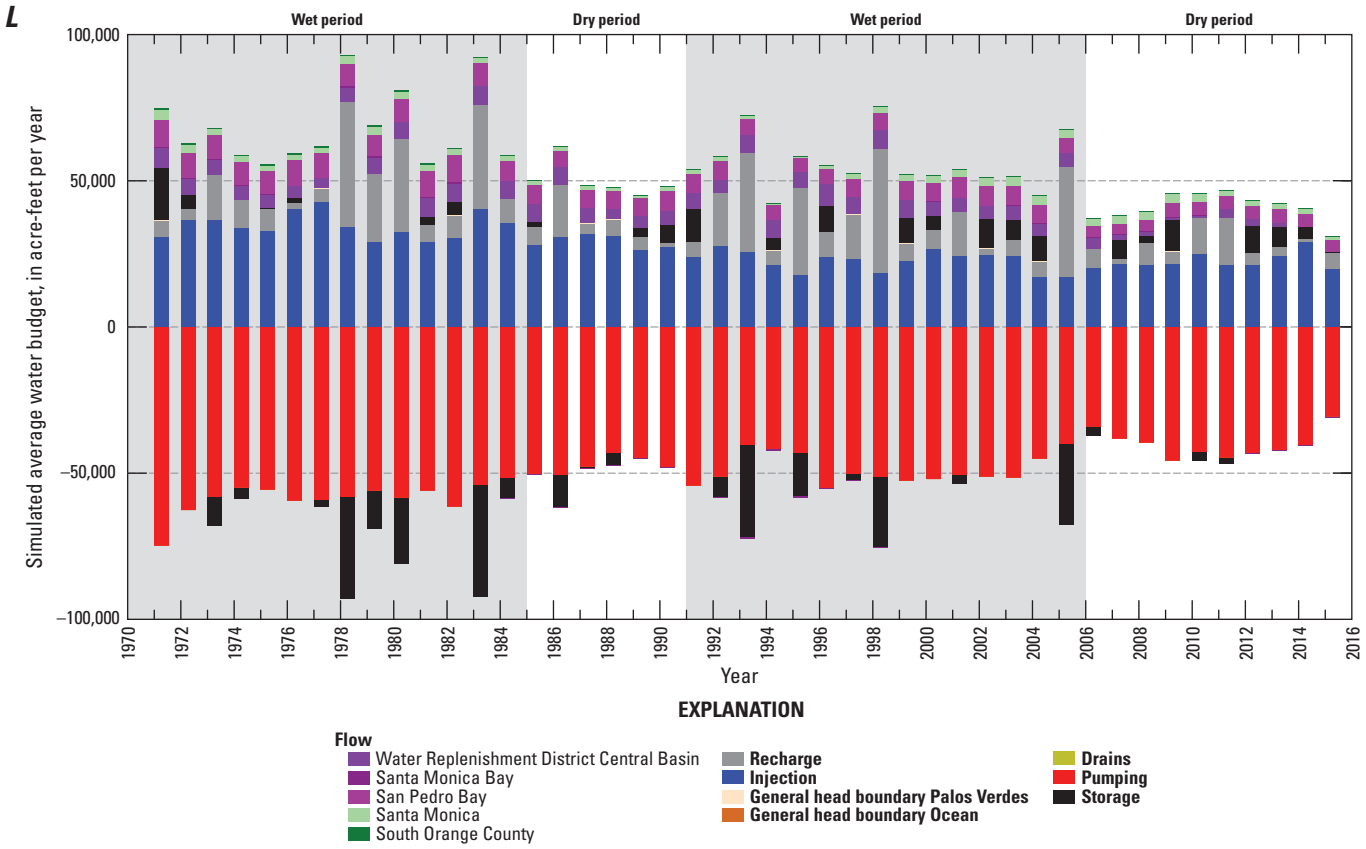


Figure 4.1.—Continued

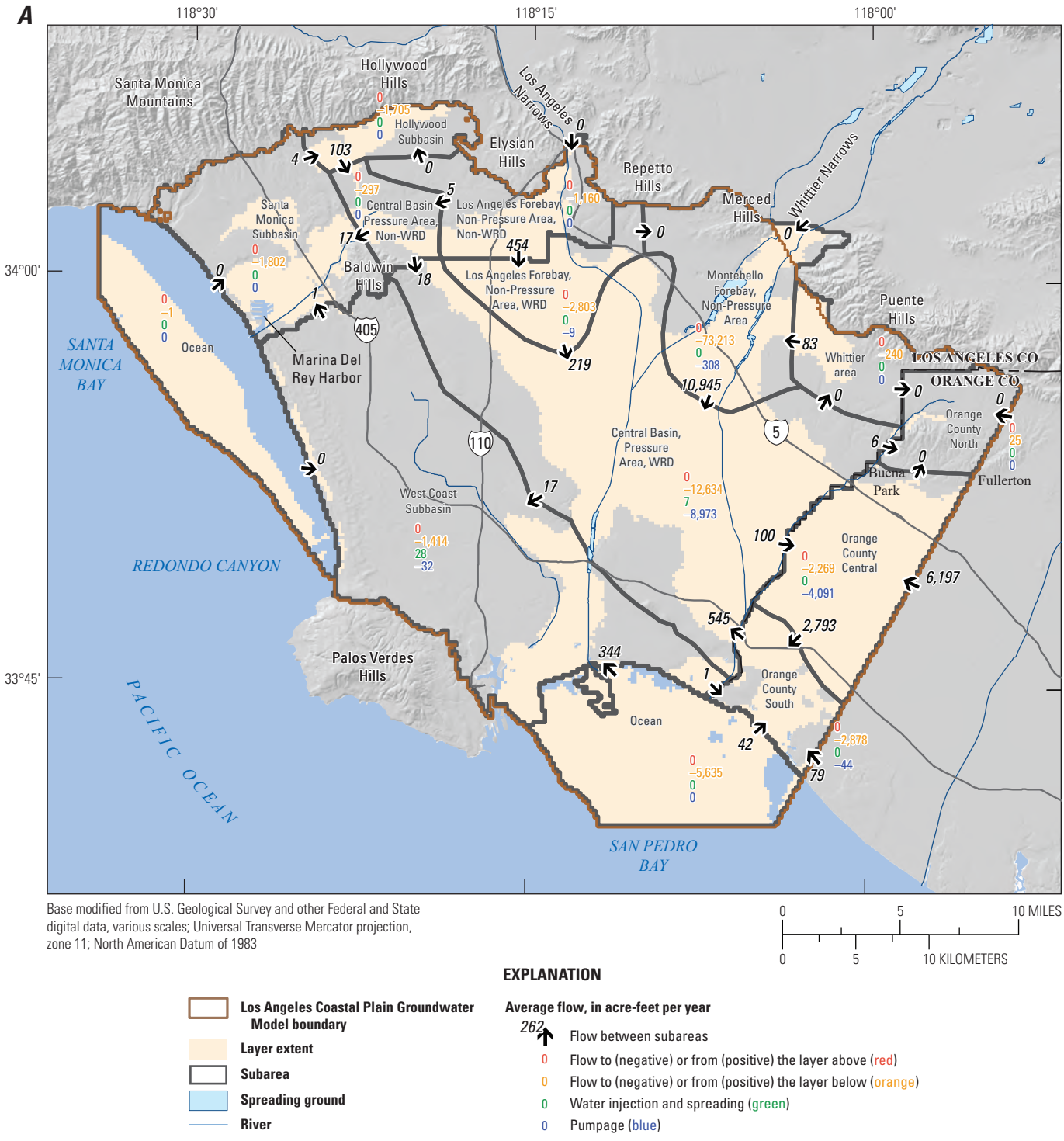


Figure 4.2. Average groundwater flow between subareas, underflow, recharge, spreading, injection, and pumping for *A*, Dominguez; *B*, Mesa; *C*, Pacific A; *D*, Pacific; *E*, Harbor; *F*, Bent Spring; *G*, Upper Wilmington A; *H*, Upper Wilmington B; *I*, Lower Wilmington; *J*, Long Beach A; *K*, Long Beach B; and *L*, Long Beach C layers of the Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California,1971 to 2015. All flows are in acre-feet/year.

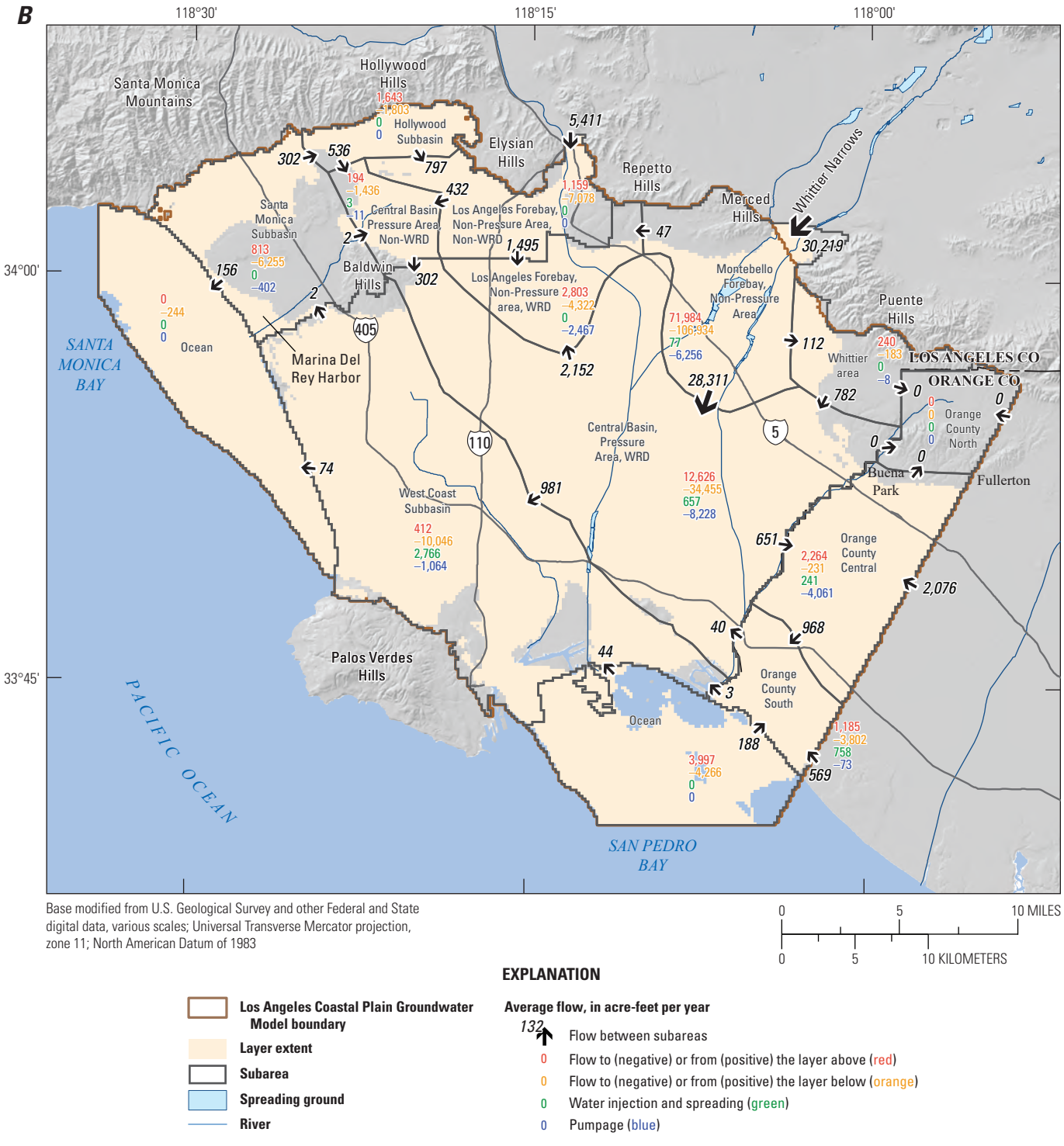


Figure 4.2.—Continued

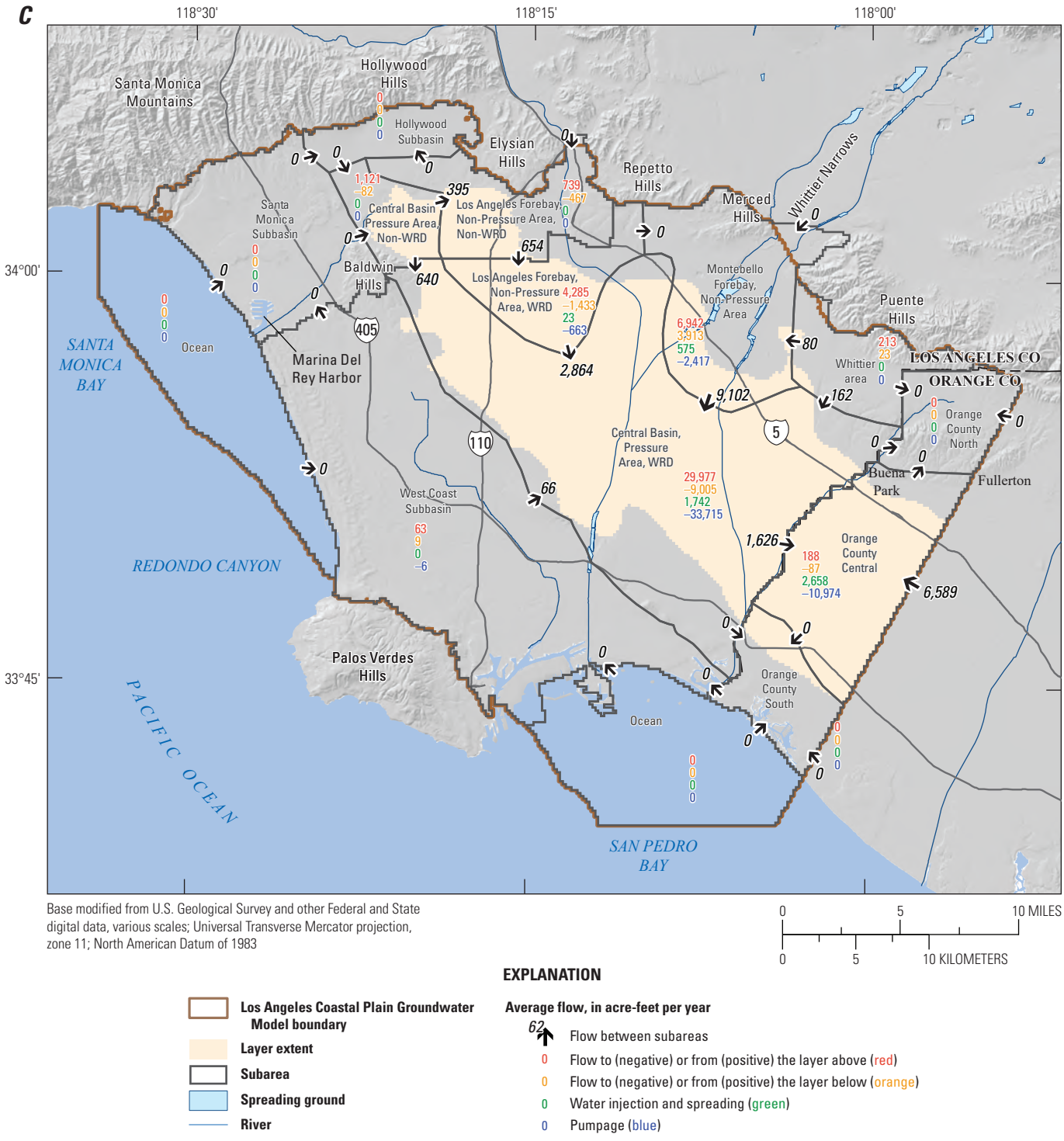


Figure 4.2.—Continued

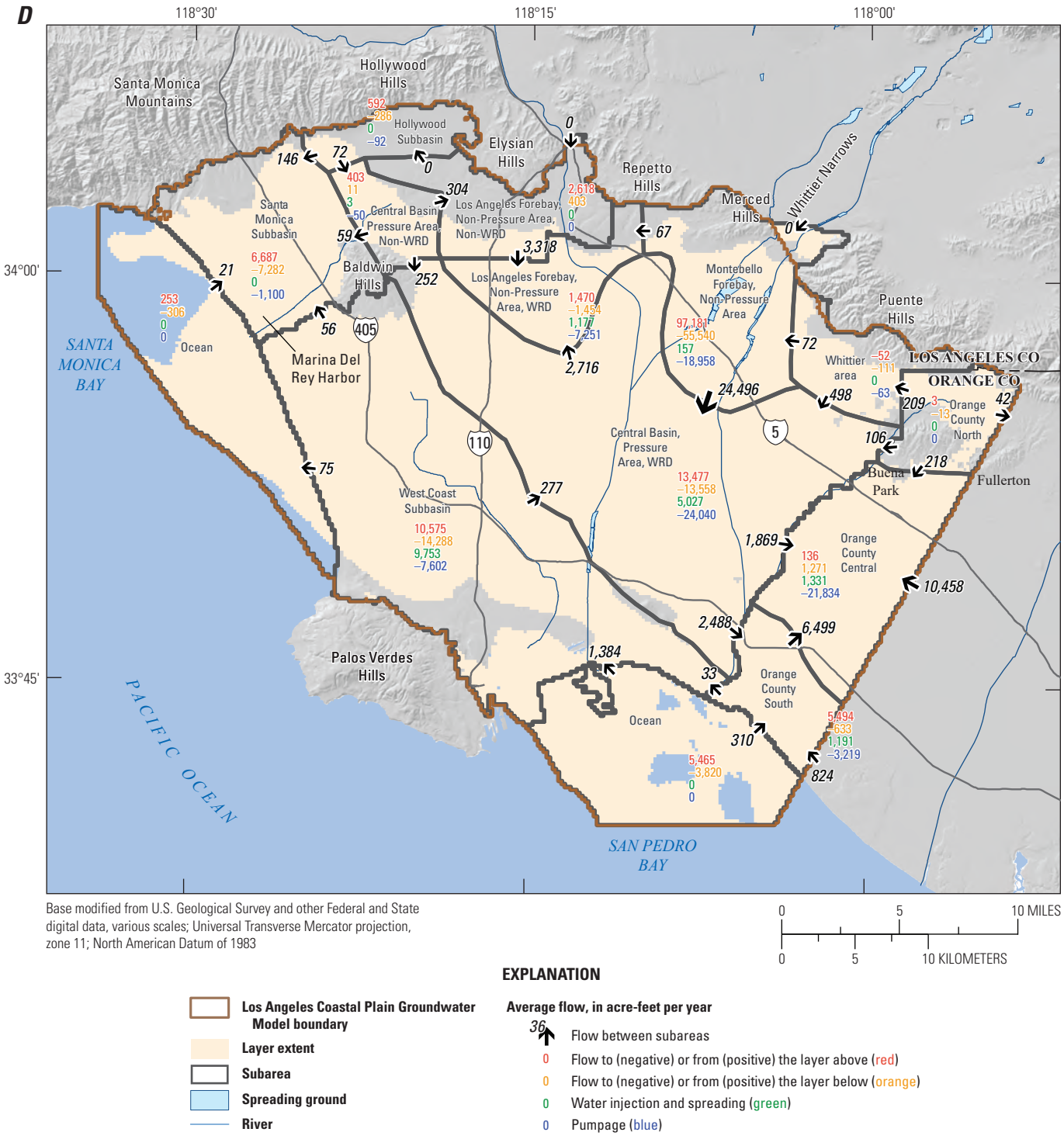


Figure 4.2.—Continued

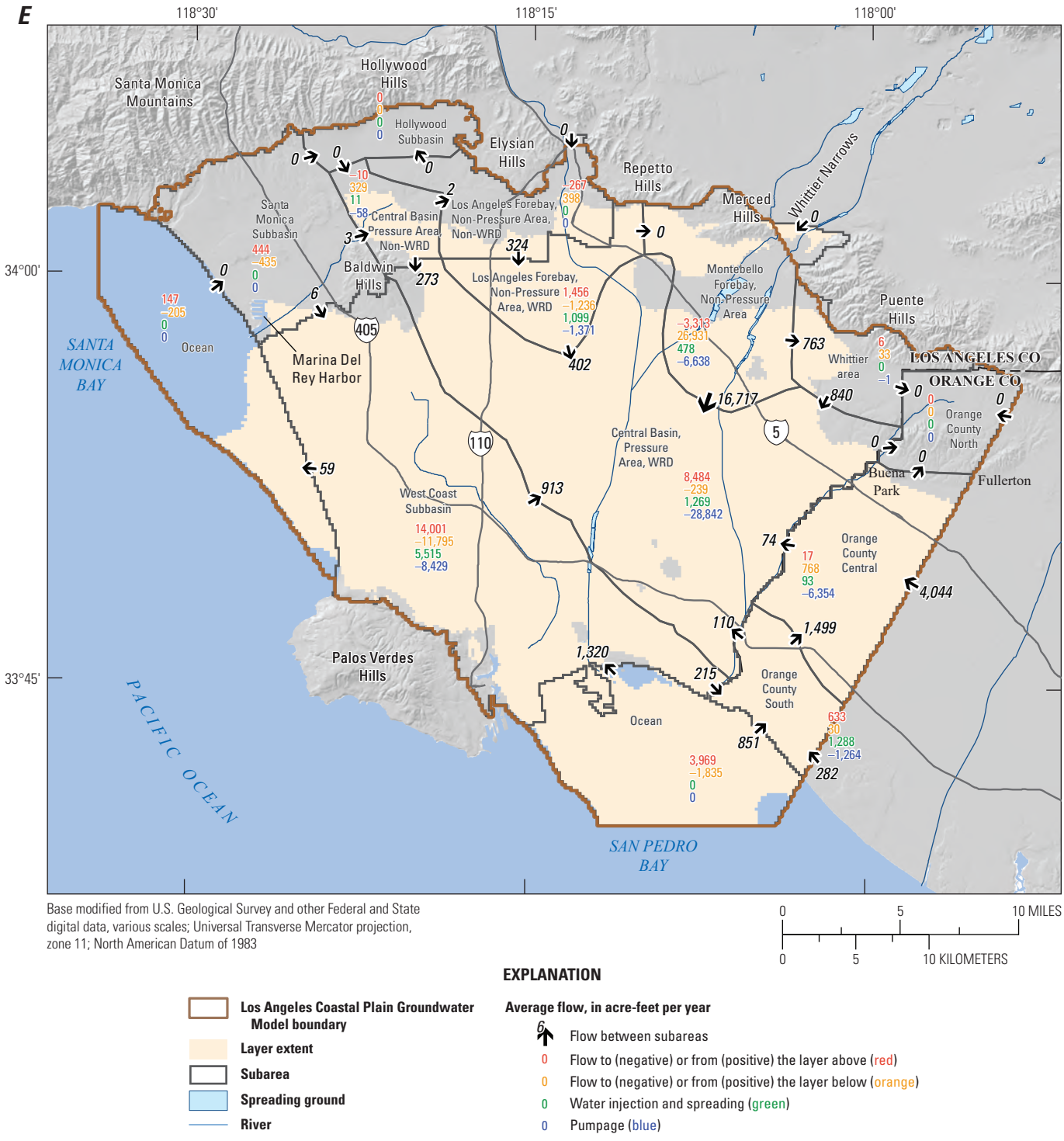


Figure 4.2.—Continued

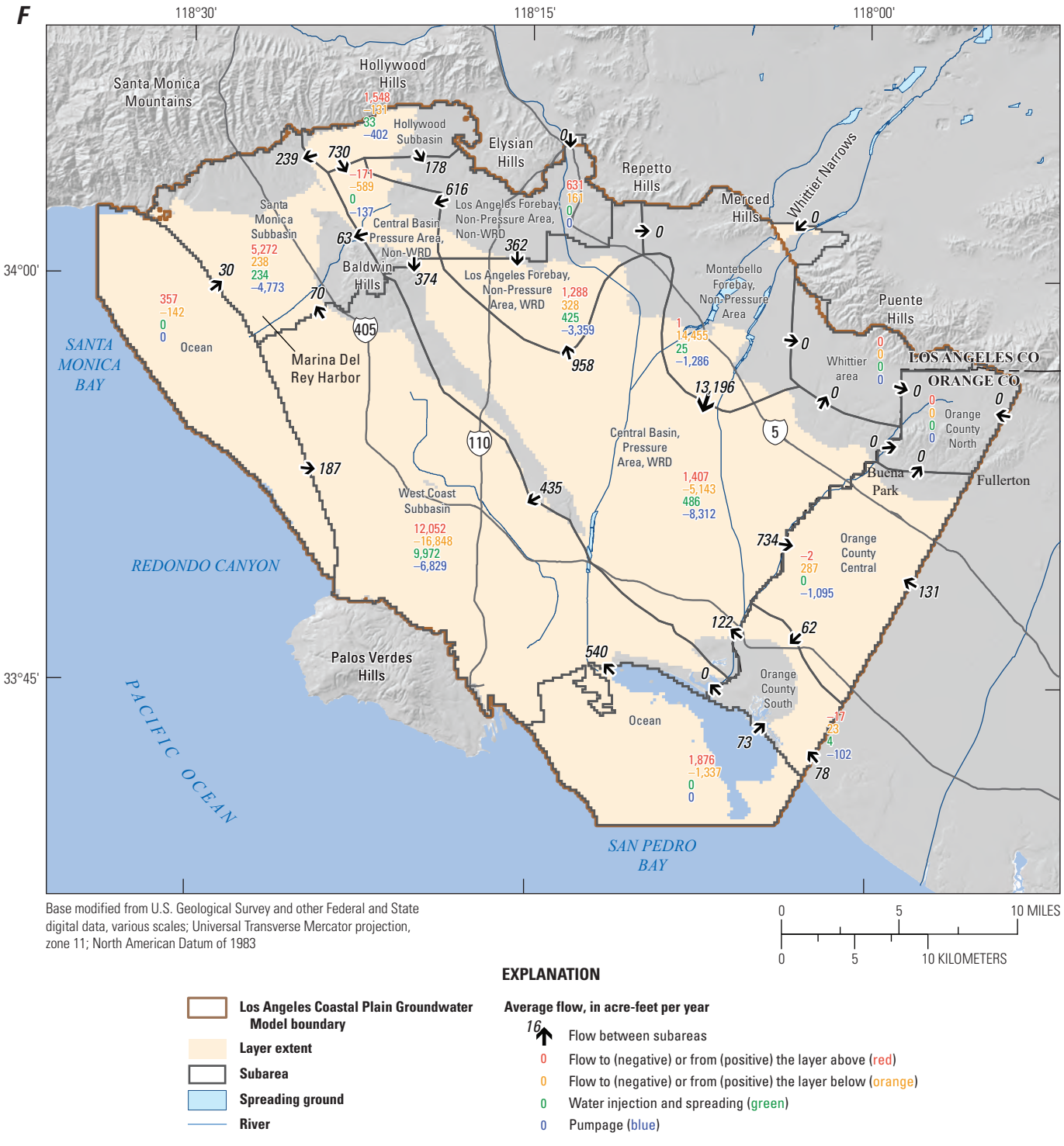


Figure 4.2.—Continued

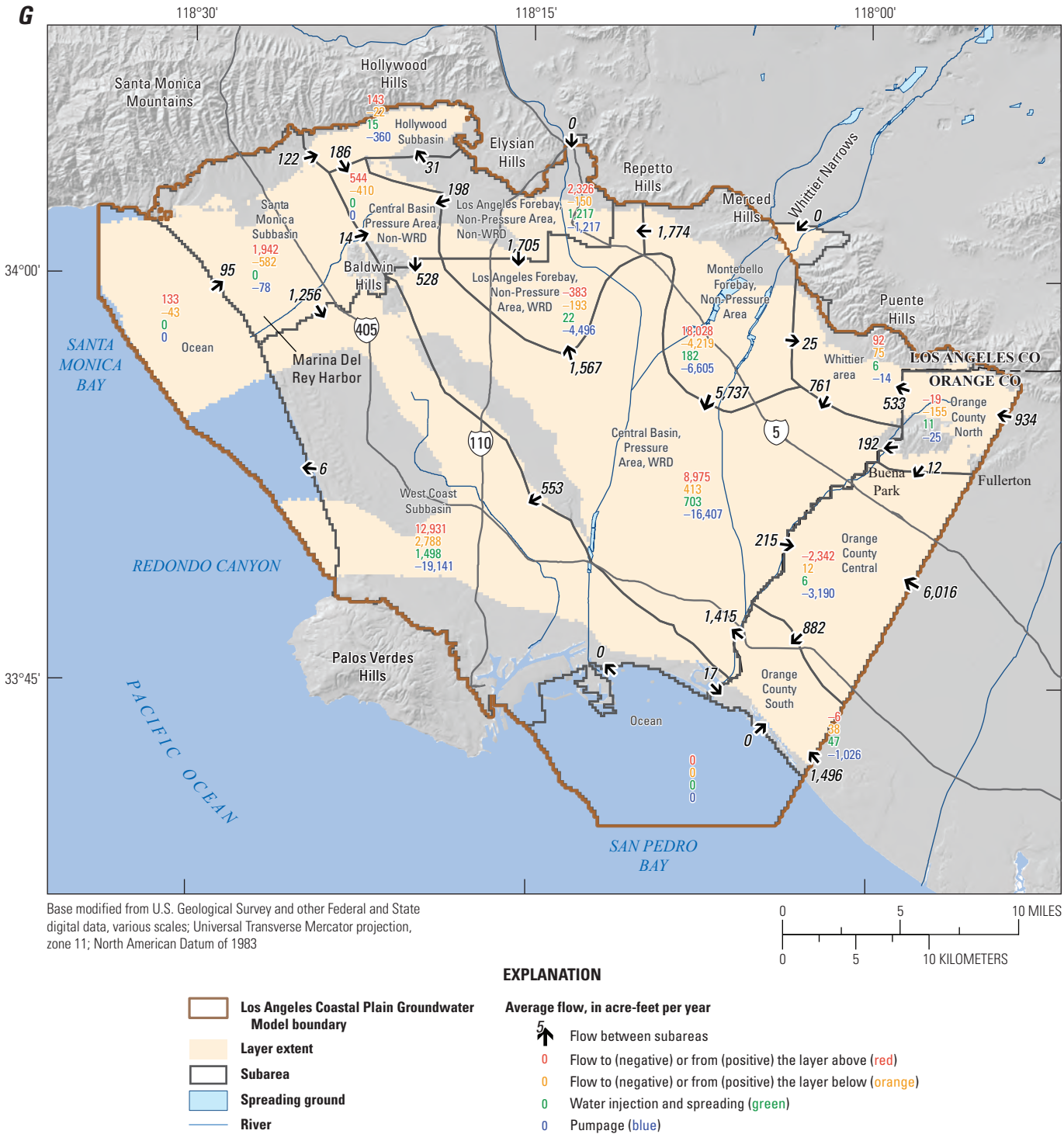


Figure 4.2.—Continued

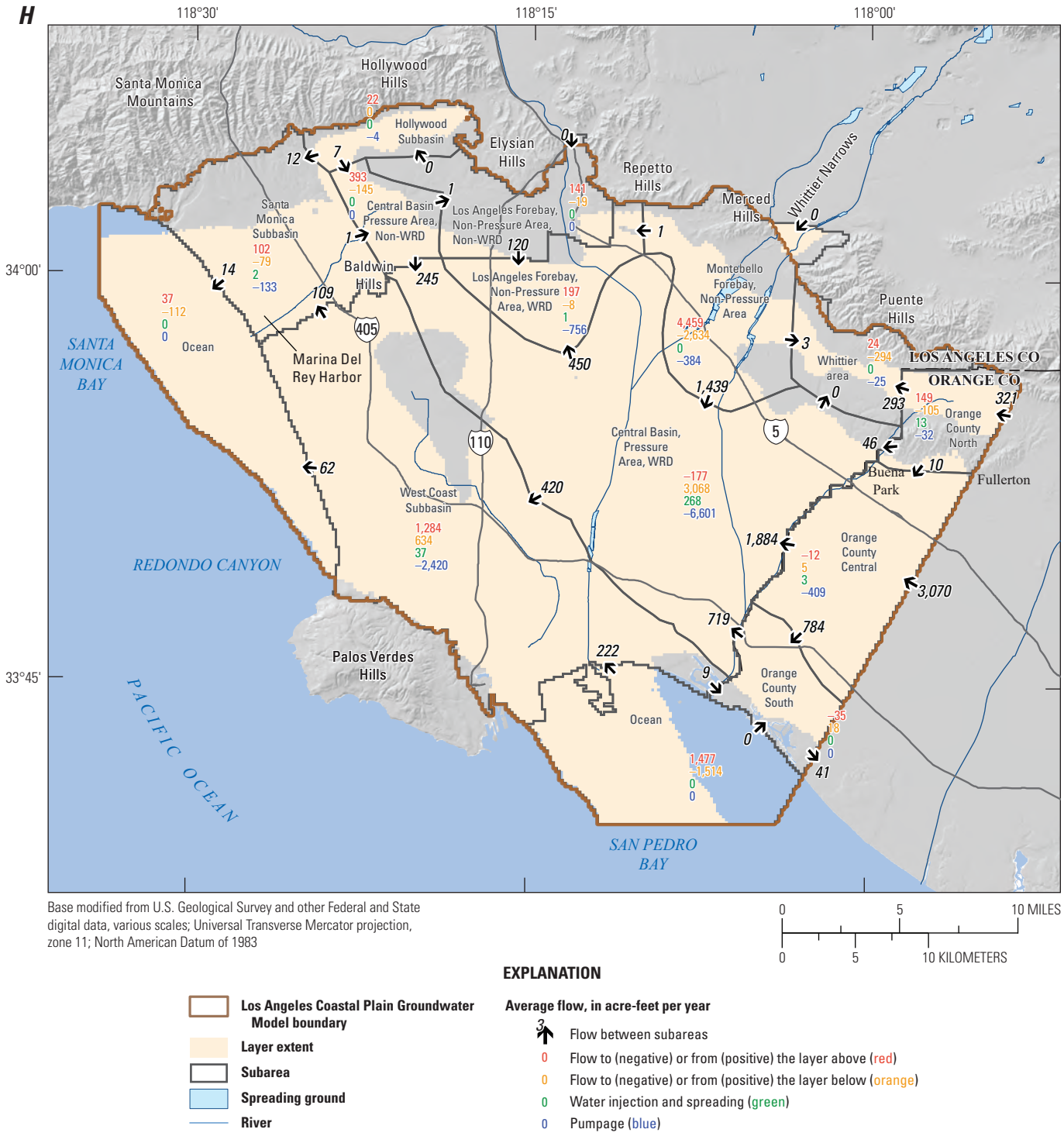


Figure 4.2.—Continued

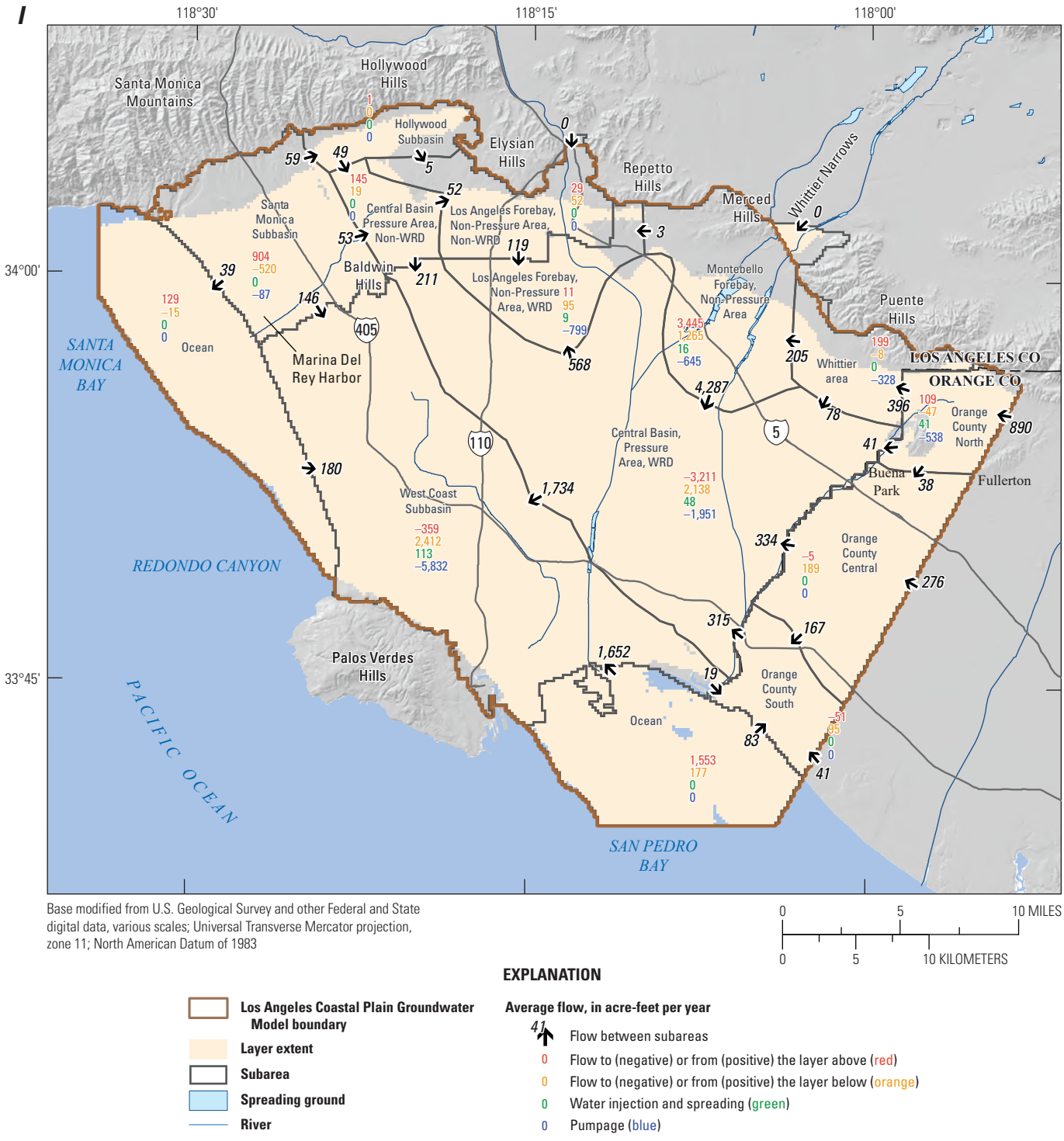


Figure 4.2.—Continued

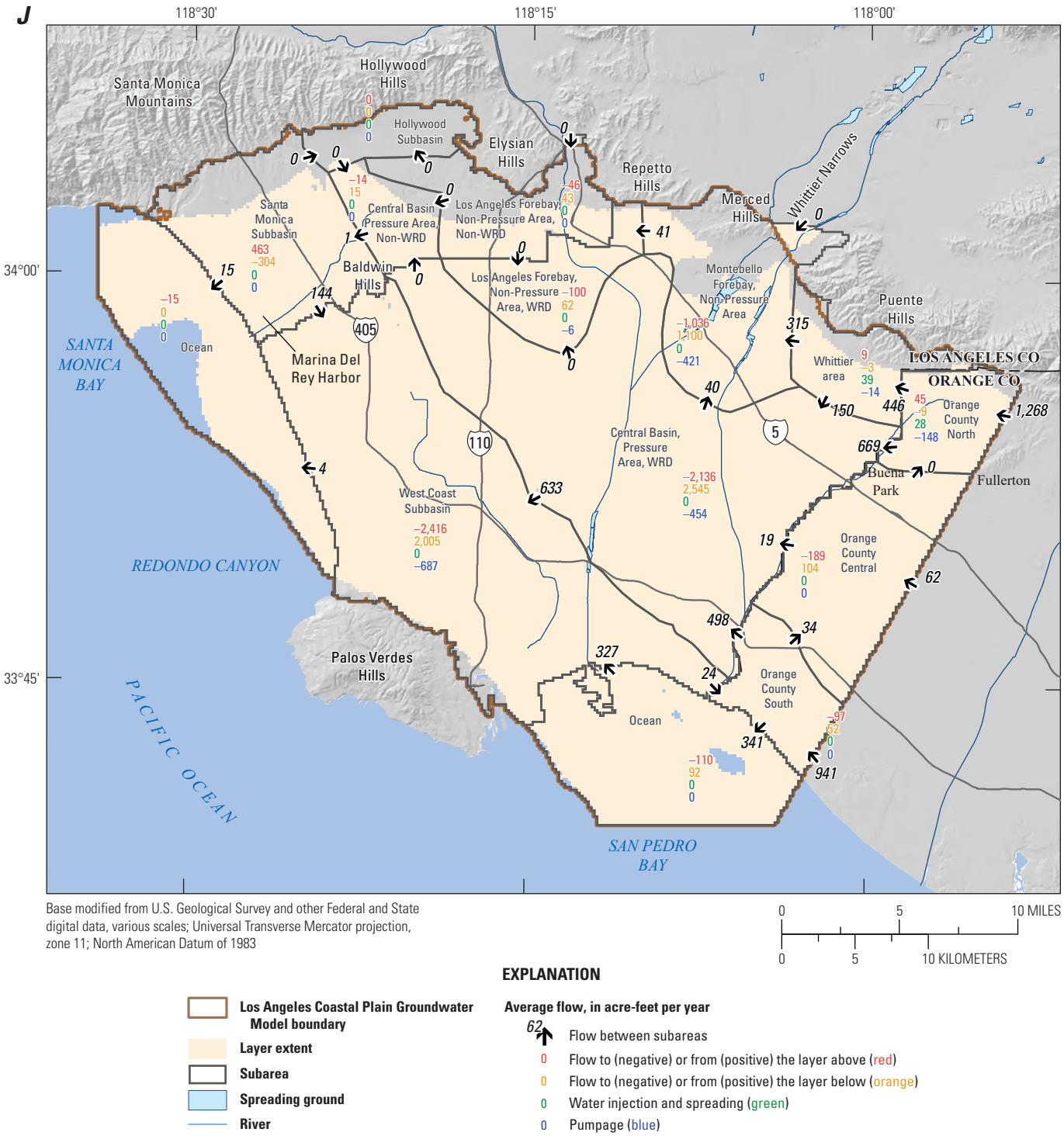


Figure 4.2.—Continued

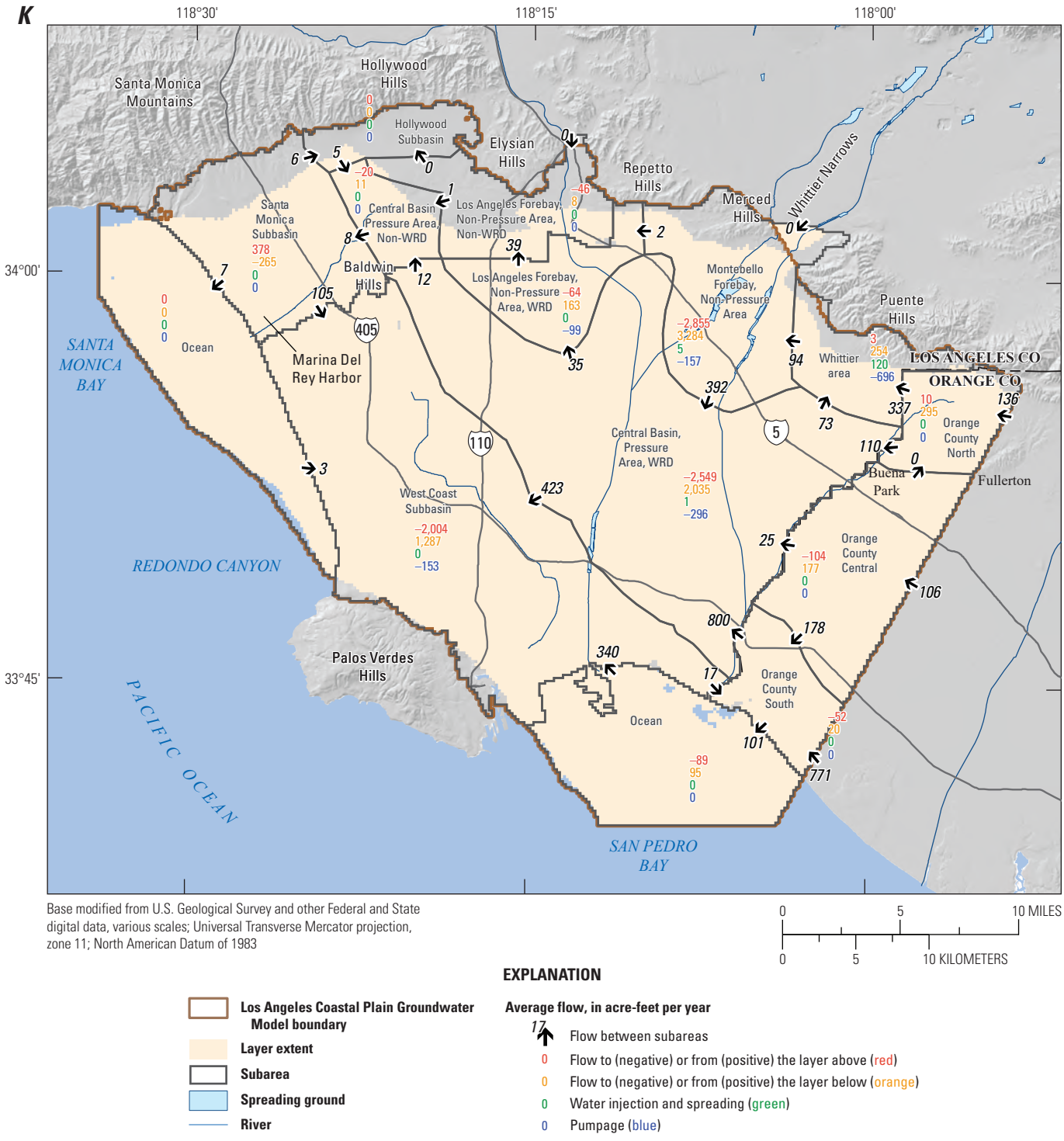


Figure 4.2.—Continued

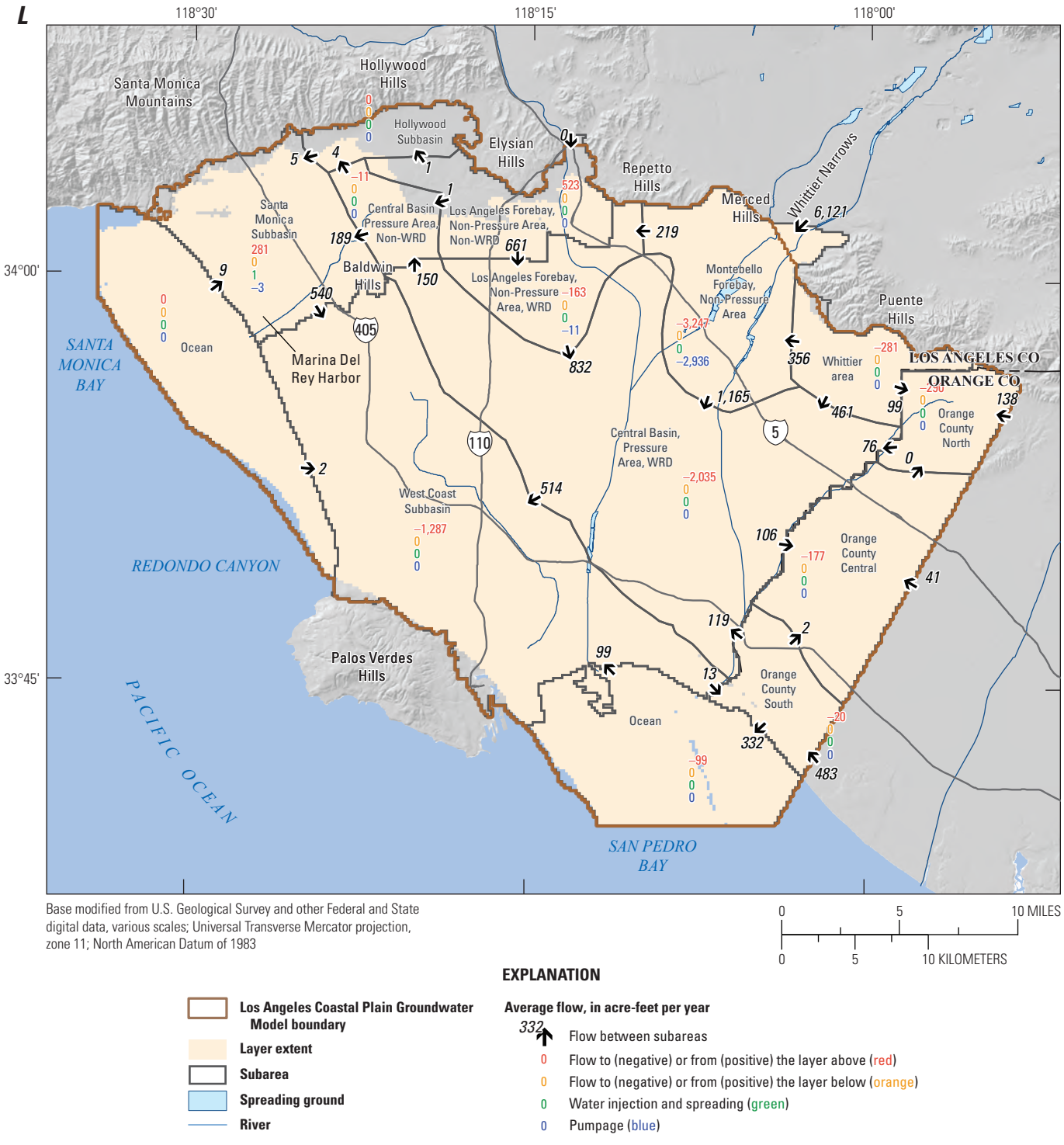


Figure 4.2.—Continued

Table 4.1. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California, 1971 to 2015.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Santa Monica Bay	Flow from San Pedro Bay
1971	115,000	35,200	–385,000	27,200	118,000	–13,000	7,950	44,900	43,300	31.3	5,650	–41.6	9,070
1972	57,000	41,900	–339,000	17,400	134,000	–5,820	8,670	31,100	48,500	30.5	6,150	–18	9,220
1973	157,000	42,300	–326,000	71,400	–18,400	–5,920	9,450	24,000	41,000	30.4	5,670	–30.3	9,790
1974	122,000	41,000	–330,000	48,200	34,000	–4,680	9,780	32,100	41,200	30.2	5,670	–4.49	9,910
1975	109,000	38,200	–334,000	34,000	49,900	–3,480	9,450	50,000	41,800	29.7	5,720	40.6	9,440
1976	71,000	45,700	–343,000	12,600	104,000	–2,260	10,600	50,600	44,800	29.8	5,940	0.522	10,600
1977	81,300	48,700	–336,000	18,300	82,600	–2,840	11,000	48,700	42,400	29.9	5,860	73.1	10,700
1978	222,000	40,700	–300,000	193,000	–241,000	–9,310	9,030	49,400	32,500	29.9	4,570	–119	9,220
1979	137,000	36,300	–327,000	104,000	–50,800	–7,270	7,920	60,300	34,000	29.9	5,050	80.6	8,310
1980	154,000	38,600	–323,000	159,000	–124,000	–11,000	7,240	59,600	35,600	30.4	4,610	–102	8,090
1981	126,000	35,200	–319,000	26,800	28,800	–6,100	8,540	53,300	40,600	31.1	5,460	124	9,140
1982	127,000	36,200	–321,000	34,400	23,800	–4,450	10,100	42,900	44,900	31.7	5,710	268	10,300
1983	145,000	47,100	–302,000	160,000	–149,000	–8,040	8,640	53,000	41,300	31.9	4,560	–68.6	8,440
1984	103,000	40,700	–321,000	36,100	38,000	–5,130	7,700	52,800	42,100	31.6	5,660	27.0	7,430
1985	88,000	32,500	–296,000	30,800	34,900	–3,770	7,340	56,400	45,400	31.2	4,620	153	6,850
1986	134,000	38,300	–306,000	70,200	–36,100	–4,660	6,700	49,000	42,800	30.4	6,220	81.1	5,830
1987	115,000	40,900	–307,000	15,400	48,500	–2,710	7,580	38,000	38,100	30.4	5,790	–44.5	7,130
1988	107,000	37,800	–300,000	23,800	41,900	–2,280	8,070	36,900	41,300	30.7	5,860	56.6	7,150
1989	110,000	32,000	–300,000	22,300	37,200	–1,900	8,470	41,800	44,900	30.4	5,020	103	7,600
1990	127,000	33,400	–292,000	7,120	28,500	–1,360	8,860	43,400	38,900	30.6	6,380	–75.1	8,010
1991	173,000	29,800	–299,000	26,000	–4,120	–5,530	9,000	40,200	25,100	30.7	5,730	116	8,100
1992	232,000	33,500	–308,000	80,400	–53,700	–61,600	8,600	48,300	14,900	30.7	5,240	167	7,550
1993	187,000	30,200	–241,000	159,000	–195,000	–20,900	6,640	48,300	20,900	30.6	4,440	–104	5,700
1994	135,000	25,400	–270,000	22,100	4,760	–8,270	6,040	53,000	25,900	30	5,560	11.0	5,020
1995	146,000	21,800	–289,000	128,000	–83,100	–9,630	5,250	47,200	28,800	29.6	4,850	–22.3	4,430
1996	145,000	29,900	–302,000	40,000	1,960	–4,570	5,960	46,000	32,000	29.5	5,420	–179	5,290
1997	118,000	28,900	–303,000	67,400	5,930	–5,950	6,270	43,800	33,100	30	5,350	–229	6,220
1998	128,000	23,600	–301,000	188,000	–109,000	–14,500	5,430	44,500	31,700	30.6	4,490	–212	6,010
1999	76,400	28,500	–321,000	25,100	106,000	–6,870	6,160	41,300	38,900	30.6	5,450	22.3	6,760
2000	122,000	32,100	–318,000	30,300	42,500	–4,910	6,640	46,500	37,800	30.9	5,520	–16.3	7,160

Table 4.1. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model, Los Angeles and Orange Counties, California, 1971 to 2015.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Santa Monica Bay	Flow from San Pedro Bay
2001	123,000	30,500	–311,000	57,400	17,300	–6,240	7,240	44,600	32,100	31.2	5,390	–39.2	7,920
2002	129,000	30,800	–307,000	9,670	61,200	–4,740	7,160	42,700	24,800	31.2	5,680	67.3	7,570
2003	95,100	29,000	–298,000	27,500	61,800	–4,500	6,690	49,300	26,900	31.5	5,600	–1.19	7,200
2004	136,000	22,800	–288,000	24,400	16,600	–3,730	6,330	46,900	32,600	31.2	5,660	59.7	6,790
2005	167,000	21,400	–274,000	166,000	–150,000	–18,500	4,230	55,200	24,600	30.8	4,230	–116	4,750
2006	144,000	21,700	–274,000	30,400	–17,000	–6,600	3,020	60,800	31,700	29.8	5,350	–107	3,450
2007	86,300	25,200	–316,000	7,490	103,000	–3,600	3,380	49,800	39,100	29.5	5,670	–55.7	4,110
2008	98,700	28,600	–310,000	32,700	58,800	–4,570	4,660	50,000	35,700	29.9	5,470	–1.42	5,200
2009	83,600	28,600	–304,000	18,300	76,200	–3,660	5,390	49,000	40,700	30.1	5,710	111	6,030
2010	155,000	30,100	–290,000	53,200	–44,500	–5,490	5,150	56,100	35,600	30.3	5,530	50.4	5,460
2011	152,000	26,200	–277,000	71,600	–72,800	–6,700	4,350	68,500	27,800	29.8	5,540	253	4,480
2012	82,200	26,700	–299,000	15,800	62,000	–2,740	4,860	66,800	38,000	29.9	5,550	149	4,690
2013	54,900	30,200	–312,000	11,200	99,500	–2,110	6,100	62,300	44,800	30.4	5,350	116	5,360
2014	69,300	36,600	–296,000	5,500	89,700	–1,780	6,230	42,400	42,300	30.1	5,510	180	5,010
2015	74,700	25,900	–262,000	23,900	35,400	–1,670	5,910	48,600	44,200	29.7	5,040	115	4,520

Table 4.2. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Montebello Forebay, Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB \PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from WRD Los Angeles Forebay	Flow from Whitter
1971	115,000	0.00	–54,000	2,120	–15,100	–29.1	—	—	43,300	—	0.00	–122,000	–2,870	2,760
1972	57,000	0.00	–44,100	1,160	–41,400	–8.44	—	—	48,500	—	0.00	–105,000	–2,350	3,810
1973	157,000	0.00	–43,500	6,340	39,000	–338	—	—	41,000	—	0.00	–118,000	–2,310	–1,210
1974	122,000	0.00	–45,900	4,200	–6,770	–24.4	—	—	41,200	—	0.00	–126,000	–2,200	–135
1975	109,000	0.00	–44,300	2,820	–14,200	–14.2	—	—	41,800	—	0.00	–122,000	–2,400	661
1976	71,000	0.00	–45,200	1,140	–38,500	0.00	—	—	44,800	—	0.00	–111,000	–2,380	2,830
1977	81,300	0.00	–41,400	1,450	–16,600	–932	—	—	42,400	—	0.00	–99,900	–2,170	2,640
1978	222,000	0.00	–43,000	18,000	93,500	–1,960	—	—	32,500	—	0.00	–127,000	–2,040	–4,900
1979	137,000	0.00	–48,000	8,820	–3,230	–538	—	—	34,000	—	0.00	–132,000	–2,600	–126
1980	154,000	0.00	–47,400	13,800	16,000	–964	—	—	35,600	—	0.00	–135,000	–2,510	–773
1981	126,000	0.00	–50,700	2,120	–8,440	–34.8	—	—	40,600	—	0.00	–125,000	–2,170	874
1982	127,000	0.00	–46,100	3,110	5,810	–107	—	—	44,900	—	0.00	–122,000	–2,400	712
1983	145,000	0.00	–43,200	14,100	21,100	–165	—	—	41,300	—	0.00	–132,000	–2,690	–1,430
1984	103,000	0.00	–49,100	2,840	–22,200	–36.0	—	—	42,100	—	0.00	–120,000	–2,300	1,230
1985	88,000	0.00	–45,700	3,030	–22,000	–18.2	—	—	45,400	—	0.00	–112,000	–1,830	1,330
1986	134,000	0.00	–43,500	5,600	20,300	–122	—	—	42,800	—	0.00	–116,000	–2,300	–118
1987	115,000	0.00	–44,900	1,070	–8,890	–183	—	—	38,100	—	0.00	–116,000	–2,270	414
1988	107,000	0.00	–46,500	1,720	–13,600	–5.99	—	—	41,300	—	0.00	–115,000	–1,910	365
1989	110,000	0.00	–45,300	1,980	–7,000	–0.177	—	—	44,900	—	0.00	–117,000	–1,980	309
1990	127,000	0.00	–43,200	615	3,450	0.00	—	—	38,900	—	0.00	–117,000	–2,070	–418
1991	173,000	0.00	–42,300	2,320	28,000	–4,090	—	—	25,100	—	0.00	–122,000	–2,010	–1,890
1992	232,000	0.00	–43,800	6,330	14,400	–58,200	—	—	14,900	—	0.00	–132,000	–2,090	–2,410
1993	187,000	0.00	–39,500	14,500	27,700	–14,100	—	—	20,900	—	0.00	–136,000	–1,980	–3,490
1994	135,000	0.00	–41,100	1,610	–11,500	–4,740	—	—	25,900	—	0.00	–126,000	–2,270	–45.0
1995	146,000	0.00	–44,400	10,700	6,100	–3,120	—	—	28,800	—	0.00	–128,000	–2,260	–1,180
1996	145,000	0.00	–46,400	3,000	6,330	–105	—	—	32,000	—	0.00	–124,000	–2,300	–345
1997	118,000	0.00	–46,600	5,560	–13,500	–41.6	—	—	33,100	—	0.00	–122,000	–2,360	375
1998	128,000	0.00	–43,200	18,900	5,300	–659	—	—	31,700	—	0.00	–126,000	–2,520	–248
1999	76,400	0.00	–48,200	2,120	–40,800	–15.0	—	—	38,900	—	0.00	–111,000	–2,540	3,100
2000	122,000	0.00	–46,200	2,320	4,750	–6.07	—	—	37,800	—	0.00	–110,000	–1,820	565

Table 4.2. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Montebello Forebay, Los Angeles and Orange Counties, California.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB \PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from WRD Los Angeles Forebay	Flow from Whitter
2001	123,000	0.00	–46,300	2,960	623	–526	—	—	32,100	—	0.00	–109,000	–1,810	584
2002	129,000	0.00	–48,600	703	–4,760	–1,160	—	—	24,800	—	0.00	–109,000	–1,640	818
2003	95,100	0.00	–46,500	4,340	–31,100	–1,170	—	—	26,900	—	0.00	–109,000	–1,710	1,010
2004	136,000	0.00	–46,500	1,990	20,100	–808	—	—	32,600	—	0.00	–102,000	–1,490	597
2005	167,000	0.00	–47,300	15,000	18,000	–9,580	—	—	24,600	—	0.00	–127,000	–1,410	–3,340
2006	144,000	0.00	–48,700	2,080	7,250	–1,120	—	—	31,700	—	0.00	–119,000	–1,600	–218
2007	86,300	0.00	–48,300	534	–35,400	–7.99	—	—	39,100	—	0.00	–113,000	–2,000	2,020
2008	98,700	0.00	–44,800	2,440	–16,200	–453	—	—	35,700	—	0.00	–108,000	–1,970	1,910
2009	83,600	0.00	–45,200	1,160	–16,300	–574	—	—	40,700	—	0.00	–96,300	–1,970	2,290
2010	155,000	0.00	–45,800	4,380	40,700	–1,770	—	—	35,600	—	0.00	–103,000	–2,220	–908
2011	152,000	0.00	–45,400	6,390	14,500	–2,390	—	—	27,800	—	0.00	–119,000	–2,330	–2,940
2012	82,200	0.00	–44,600	1,390	–30,900	–37.7	—	—	38,000	—	0.00	–107,000	–2,440	1,720
2013	54,900	0.00	–46,400	939	–37,800	0.00	—	—	44,800	—	0.00	–92,700	–2,320	3,030
2014	69,300	0.00	–42,200	377	–15,600	0.00	—	—	42,300	—	0.00	–85,800	–2,190	2,610
2015	74,700	0.00	–44,000	2,060	–5,920	0.00	—	—	44,200	—	0.00	–82,100	–1,920	1,110

Table 4.3. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Los Angeles Forebay, non-Water Replenishment District of Southern California (WRD), Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Hollywood	Flow from WRD Los Angeles Forebay	Flow from Central Basin
1971	0.00	0.00	0.00	1,640	–4,180	0.00	—	—	—	—	5,650	673	–10,700	–1,450
1972	0.00	0.00	0.00	773	–1,450	0.00	—	—	—	—	6,150	651	–8,350	–671
1973	0.00	0.00	0.00	4,720	1,550	0.00	—	—	—	—	5,670	630	–8,470	–1,000
1974	0.00	0.00	0.00	2,800	–394	0.00	—	—	—	—	5,670	640	–8,770	–731
1975	0.00	0.00	0.00	1,850	–995	0.00	—	—	—	—	5,720	664	–8,920	–310
1976	0.00	0.00	0.00	665	–1,890	0.00	—	—	—	—	5,940	665	–9,120	–42.9
1977	0.00	0.00	0.00	731	–2,030	0.00	—	—	—	—	5,860	623	–9,400	164
1978	0.00	0.00	0.00	12,300	6,770	0.00	—	—	—	—	4,570	519	–9,370	–1,210
1979	0.00	0.00	0.00	6,000	1,250	0.00	—	—	—	—	5,050	680	–9,940	–545
1980	0.00	0.00	0.00	10,000	4,530	0.00	—	—	—	—	4,610	854	–10,000	–916
1981	0.00	0.00	0.00	1,150	–1,690	0.00	—	—	—	—	5,460	1,130	–9,270	–164
1982	0.00	0.00	0.00	1,700	–789	0.00	—	—	—	—	5,710	1,190	–9,120	–273
1983	0.00	0.00	0.00	10,600	5,100	0.00	—	—	—	—	4,560	1,120	–9,910	–1,240
1984	0.00	0.00	0.00	1,650	–1,540	0.00	—	—	—	—	5,660	1,260	–9,490	–616
1985	0.00	0.00	0.00	1,680	–1,440	0.00	—	—	—	—	4,620	1,260	–8,540	–473
1986	0.00	0.00	0.00	3,990	1,540	0.00	—	—	—	—	6,220	1,180	–9,130	–712
1987	0.00	0.00	0.00	605	–1,790	0.00	—	—	—	—	5,790	1,140	–8,890	–443
1988	0.00	0.00	0.00	1,280	–836	0.00	—	—	—	—	5,860	1,050	–8,660	–367
1989	0.00	0.00	0.00	1,230	–1,680	0.00	—	—	—	—	5,020	959	–8,670	–210
1990	0.00	0.00	0.00	315	–488	0.00	—	—	—	—	6,380	873	–7,900	–159
1991	0.00	0.00	0.00	1,660	–460	0.00	—	—	—	—	5,730	769	–8,320	–300
1992	0.00	0.00	0.00	5,560	1,840	0.00	—	—	—	—	5,240	672	–8,970	–662
1993	0.00	0.00	0.00	10,100	6,830	0.00	—	—	—	—	4,440	683	–7,100	–1,300
1994	0.00	0.00	0.00	856	–1,410	0.00	—	—	—	—	5,560	928	–8,280	–473
1995	0.00	0.00	0.00	7,690	3,280	0.00	—	—	—	—	4,850	999	–9,350	–917
1996	0.00	0.00	0.00	2,250	–818	0.00	—	—	—	—	5,420	1,140	–9,050	–575
1997	0.00	0.00	0.00	3,570	427	0.00	—	—	—	—	5,350	1,180	–8,980	–686
1998	0.00	0.00	0.00	10,800	4,960	0.00	—	—	—	—	4,490	1,170	–10,300	–1,160
1999	0.00	0.00	0.00	1,060	–2,920	0.00	—	—	—	—	5,450	1,390	–10,400	–409
2000	0.00	0.00	0.00	1,990	–1,640	0.00	—	—	—	—	5,520	1,400	–10,300	–305

Table 4.3. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Los Angeles Forebay, non-Water Replenishment District of Southern California (WRD), Los Angeles and Orange Counties, California.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Hollywood	Flow from WRD Los Angeles Forebay	Flow from Central Basin
2001	0.00	0.00	0.00	3,690	–583	0.00	—	—	—	—	5,390	1,330	–10,500	–443
2002	0.00	0.00	0.00	437	–2,820	0.00	—	—	—	—	5,680	1,290	–10,200	–77.1
2003	0.00	0.00	0.00	1,640	–1,250	0.00	—	—	—	—	5,600	1,190	–9,480	–205
2004	0.00	0.00	0.00	1,340	–1,730	0.00	—	—	—	—	5,660	1,080	–9,680	–123
2005	0.00	0.00	0.00	11,900	5,840	0.00	—	—	—	—	4,230	938	–9,920	–1,280
2006	0.00	0.00	0.00	1,670	–1,620	0.00	—	—	—	—	5,350	1,100	–9,320	–423
2007	0.00	0.00	0.00	337	–2,510	0.00	—	—	—	—	5,670	1,130	–9,520	–131
2008	0.00	0.00	0.00	2,270	–999	0.00	—	—	—	—	5,470	1,040	–9,660	–109
2009	0.00	0.00	0.00	991	–1,930	0.00	—	—	—	—	5,710	965	–9,400	–201
2010	0.00	0.00	0.00	3,180	244	0.00	—	—	—	—	5,530	870	–9,070	–266
2011	0.00	0.00	0.00	4,430	2,250	0.00	—	—	—	—	5,540	805	–7,940	–587
2012	0.00	0.00	0.00	647	–1,700	0.00	—	—	—	—	5,550	812	–8,410	–297
2013	0.00	0.00	0.00	503	–2,380	0.00	—	—	—	—	5,350	758	–8,830	–169
2014	0.00	0.00	0.00	224	–2,560	0.00	—	—	—	—	5,510	674	–8,990	28.4
2015	0.00	0.00	0.00	1,430	–1,210	0.00	—	—	—	—	5,040	576	–8,230	–27.8

Table 4.4. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Los Angeles Forebay, Water Replenishment District of Southern California (WRD), Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Los Angeles Forebay	Flow from WRD Central Basin	Flow from Montebello Forebay
1971	0.00	0.00	–32,700	946	–11,000	0.00	—	—	—	—	0.00	10,700	7,180	2,870
1972	0.00	0.00	–25,600	560	–10,400	0.00	—	—	—	—	0.00	8,350	3,880	2,350
1973	0.00	0.00	–24,400	2,420	–6,410	0.00	—	—	—	—	0.00	8,470	4,750	2,310
1974	0.00	0.00	–24,600	1,590	–5,440	0.00	—	—	—	—	0.00	8,770	6,570	2,200
1975	0.00	0.00	–23,700	1,340	–5,570	0.00	—	—	—	—	0.00	8,920	5,480	2,400
1976	0.00	0.00	–24,200	571	–6,850	0.00	—	—	—	—	0.00	9,120	5,280	2,380
1977	0.00	0.00	–24,600	749	–7,770	0.00	—	—	—	—	0.00	9,400	4,460	2,170
1978	0.00	0.00	–22,800	5,660	3,000	0.00	—	—	—	—	0.00	9,370	8,730	2,040
1979	0.00	0.00	–23,100	3,390	1,050	0.00	—	—	—	—	0.00	9,940	8,190	2,600
1980	0.00	0.00	–21,700	4,850	4,980	0.00	—	—	—	—	0.00	10,000	9,360	2,510
1981	0.00	0.00	–19,500	989	811	0.00	—	—	—	—	0.00	9,270	7,830	2,170
1982	0.00	0.00	–19,000	1,270	–374	0.00	—	—	—	—	0.00	9,120	5,810	2,400
1983	0.00	0.00	–19,100	5,280	5,500	0.00	—	—	—	—	0.00	9,910	6,780	2,690
1984	0.00	0.00	–17,900	1,310	–569	0.00	—	—	—	—	0.00	9,490	4,240	2,300
1985	0.00	0.00	–15,500	1,160	208	0.00	—	—	—	—	0.00	8,540	4,220	1,830
1986	0.00	0.00	–17,800	2,230	11.0	0.00	—	—	—	—	0.00	9,130	4,180	2,300
1987	0.00	0.00	–17,500	622	–2,640	0.00	—	—	—	—	0.00	8,890	3,040	2,270
1988	0.00	0.00	–15,400	977	–2,230	0.00	—	—	—	—	0.00	8,660	1,600	1,910
1989	0.00	0.00	–16,500	899	–2,220	0.00	—	—	—	—	0.00	8,670	2,760	1,980
1990	0.00	0.00	–16,000	327	–1,600	0.00	—	—	—	—	0.00	7,900	4,110	2,070
1991	0.00	0.00	–17,300	844	–2,120	0.00	—	—	—	—	0.00	8,320	4,010	2,010
1992	0.00	0.00	–19,200	2,570	959	0.00	—	—	—	—	0.00	8,970	6,550	2,090
1993	0.00	0.00	–15,400	4,510	11,400	0.00	—	—	—	—	0.00	7,100	13,200	1,980
1994	0.00	0.00	–19,000	805	1,310	0.00	—	—	—	—	0.00	8,280	9,010	2,270
1995	0.00	0.00	–20,900	3,640	3,330	0.00	—	—	—	—	0.00	9,350	9,010	2,260
1996	0.00	0.00	–18,200	1,410	561	0.00	—	—	—	—	0.00	9,050	6,040	2,300
1997	0.00	0.00	–17,400	2,050	783	0.00	—	—	—	—	0.00	8,980	4,800	2,360
1998	0.00	0.00	–18,400	5,490	4,250	0.00	—	—	—	—	0.00	10,300	4,300	2,520
1999	0.00	0.00	–18,900	1,000	–2,640	0.00	—	—	—	—	0.00	10,400	2,310	2,540
2000	0.00	0.00	–16,300	1,170	–3,010	0.00	—	—	—	—	0.00	10,300	34.0	1,820

Table 4.4. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Los Angeles Forebay, Water Replenishment District of Southern California (WRD), Los Angeles and Orange Counties, California.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Los Angeles Forebay	Flow from WRD Central Basin	Flow from Montebello Forebay
2001	0.00	0.00	–17,300	1,900	–2,190	0.00	—	—	—	—	0.00	10,500	862	1,810
2002	0.00	0.00	–18,600	424	–4,410	0.00	—	—	—	—	0.00	10,200	1,990	1,640
2003	0.00	0.00	–16,100	1,090	–2,710	0.00	—	—	—	—	0.00	9,480	1,110	1,710
2004	0.00	0.00	–16,300	966	–3,750	0.00	—	—	—	—	0.00	9,680	407	1,490
2005	0.00	0.00	–15,600	5,180	4,890	0.00	—	—	—	—	0.00	9,920	4,000	1,410
2006	0.00	0.00	–16,600	1,280	674	0.00	—	—	—	—	0.00	9,320	5,050	1,600
2007	0.00	0.00	–16,900	337	–2,670	0.00	—	—	—	—	0.00	9,520	2,370	2,000
2008	0.00	0.00	–15,400	1,210	–2,590	0.00	—	—	—	—	0.00	9,660	–44.0	1,970
2009	0.00	0.00	–13,400	724	–3,680	0.00	—	—	—	—	0.00	9,400	–2,380	1,970
2010	0.00	0.00	–13,900	1,740	–1,320	0.00	—	—	—	—	0.00	9,070	–462	2,220
2011	0.00	0.00	–13,000	2,390	3,970	0.00	—	—	—	—	0.00	7,940	4,330	2,330
2012	0.00	0.00	–13,700	675	–484	0.00	—	—	—	—	0.00	8,410	1,670	2,440
2013	0.00	0.00	–16,200	493	–3,510	0.00	—	—	—	—	0.00	8,830	1,080	2,320
2014	0.00	0.00	–15,700	224	–5,220	0.00	—	—	—	—	0.00	8,990	–919	2,190
2015	0.00	0.00	–12,900	785	–2,940	0.00	—	—	—	—	0.00	8,230	–997	1,920

Table 4.5. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Hollywood Basin, Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Los Angeles Forebay	Flow from Santa Monica	Flow from Central Basin
1971	0.00	0.00	–2,320	1,570	–3,980	0.00	—	—	—	—	0.00	–673	322	–2,880
1972	0.00	0.00	–2,190	1,050	–4,190	0.00	—	—	—	—	0.00	–651	161	–2,570
1973	0.00	0.00	–2,020	3,640	–873	0.00	—	—	—	—	0.00	–630	399	–2,260
1974	0.00	0.00	–1,550	2,570	–1,370	0.00	—	—	—	—	0.00	–640	298	–2,060
1975	0.00	0.00	–1,040	1,300	–2,110	0.00	—	—	—	—	0.00	–664	102	–1,810
1976	0.00	0.00	–292	614	–2,140	0.00	—	—	—	—	0.00	–665	–49.4	–1,750
1977	0.00	0.00	0.00	747	–1,530	0.00	—	—	—	—	0.00	–623	–10.9	–1,640
1978	0.00	0.00	0.00	9,730	8,510	0.00	—	—	—	—	0.00	–519	760	–1,460
1979	0.00	0.00	0.00	4,720	2,900	0.00	—	—	—	—	0.00	–680	400	–1,530
1980	0.00	0.00	0.00	8,720	6,880	0.00	—	—	—	—	0.00	–854	631	–1,620
1981	0.00	0.00	0.00	1,310	–1,610	0.00	—	—	—	—	0.00	–1,130	9.29	–1,800
1982	0.00	0.00	0.00	1,470	–1,650	0.00	—	—	—	—	0.00	–1,190	–62.5	–1,860
1983	0.00	0.00	0.00	8,170	5,850	0.00	—	—	—	—	0.00	–1,120	505	–1,710
1984	0.00	0.00	0.00	1,450	–1,710	0.00	—	—	—	—	0.00	–1,260	–51.2	–1,850
1985	0.00	0.00	0.00	1,240	–1,980	0.00	—	—	—	—	0.00	–1,260	–133	–1,830
1986	0.00	0.00	0.00	3,270	442	0.00	—	—	—	—	0.00	–1,180	96.6	–1,750
1987	0.00	0.00	0.00	637	–2,520	0.00	—	—	—	—	0.00	–1,140	–235	–1,780
1988	0.00	0.00	0.00	1,000	–1,890	0.00	—	—	—	—	0.00	–1,050	–155	–1,680
1989	0.00	0.00	0.00	952	–1,790	0.00	—	—	—	—	0.00	–959	–170	–1,610
1990	0.00	0.00	0.00	262	–2,480	0.00	—	—	—	—	0.00	–873	–284	–1,590
1991	0.00	0.00	0.00	1,650	–752	0.00	—	—	—	—	0.00	–769	–87.3	–1,550
1992	0.00	0.00	0.00	5,190	3,360	0.00	—	—	—	—	0.00	–672	297	–1,460
1993	0.00	0.00	0.00	9,080	7,630	0.00	—	—	—	—	0.00	–683	618	–1,380
1994	0.00	0.00	0.00	887	–1,680	0.00	—	—	—	—	0.00	–928	–119	–1,530
1995	0.00	0.00	0.00	7,310	5,140	0.00	—	—	—	—	0.00	–999	431	–1,600
1996	0.00	0.00	0.00	2,070	–828	0.00	—	—	—	—	0.00	–1,140	–33.1	–1,730
1997	0.00	0.00	0.00	3,320	518	0.00	—	—	—	—	0.00	–1,180	126	–1,750
1998	0.00	0.00	0.00	9,030	6,780	0.00	—	—	—	—	0.00	–1,170	541	–1,620
1999	0.00	0.00	0.00	952	–2,440	0.00	—	—	—	—	0.00	–1,390	–180	–1,830
2000	0.00	0.00	–1,030	1,910	–2,450	0.00	—	—	—	—	0.00	–1,400	–83	–1,840

Table 4.5. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Hollywood Basin, Los Angeles and Orange Counties, California.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Los Angeles Forebay	Flow from Santa Monica	Flow from Central Basin
2001	0.00	0.00	–1,370	3,570	–767	0.00	—	—	—	—	0.00	–1,330	136	–1,780
2002	0.00	0.00	–1,370	453	–4,200	0.00	—	—	—	—	0.00	–1,290	–221	–1,770
2003	0.00	0.00	–1,370	1,070	–3,340	0.00	—	—	—	—	0.00	–1,190	–156	–1,690
2004	0.00	0.00	–1,370	1,330	–2,880	0.00	—	—	—	—	0.00	–1,080	–118	–1,640
2005	0.00	0.00	–1,370	9,330	6,160	0.00	—	—	—	—	0.00	–938	610	–1,460
2006	0.00	0.00	–1,370	1,410	–2,670	0.00	—	—	—	—	0.00	–1,100	–6.22	–1,600
2007	0.00	0.00	–1,610	348	–4,200	0.00	—	—	—	—	0.00	–1,130	–174	–1,630
2008	0.00	0.00	–995	1,890	–1,660	0.00	—	—	—	—	0.00	–1,040	53.5	–1,560
2009	0.00	0.00	–1,600	643	–3,590	0.00	—	—	—	—	0.00	–965	–119	–1,550
2010	0.00	0.00	–1,290	2,750	–721	0.00	—	—	—	—	0.00	–870	135	–1,450
2011	0.00	0.00	–3,730	3,180	–2,450	0.00	—	—	—	—	0.00	–805	234	–1,320
2012	0.00	0.00	–3,840	440	–5,610	0.00	—	—	—	—	0.00	–812	–71.7	–1,320
2013	0.00	0.00	–3,890	249	–5,820	0.00	—	—	—	—	0.00	–758	–118	–1,300
2014	0.00	0.00	–688	278	–2,500	0.00	—	—	—	—	0.00	–674	–134	–1,280
2015	0.00	0.00	–107	1,220	–699	0.00	—	—	—	—	0.00	–576	–36.5	–1,200

Table 4.6. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Central Basin Pressure Area, non- Water Replenishment District of Southern California (WRD), Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Los Angeles Forebay	Flow from WRD Central Basin	Flow from Santa Monica	Flow from Hollywood
1971	0.00	0.00	–2,820	740	–1,950	–2,780	—	—	—	—	0.00	1,450	–1,850	436	2,880
1972	0.00	0.00	–2,940	421	–1,420	–1,140	—	—	—	—	0.00	671	–1,620	621	2,570
1973	0.00	0.00	–2,250	1,990	917	–780	—	—	—	—	0.00	1,000	–1,780	470	2,260
1974	0.00	0.00	–1,580	1,360	319	–568	—	—	—	—	0.00	731	–2,030	353	2,060
1975	0.00	0.00	–321	965	87	–424	—	—	—	—	0.00	310	–2,410	159	1,810
1976	0.00	0.00	–334	352	–874	–316	—	—	—	—	0.00	43.0	–2,500	131	1,750
1977	0.00	0.00	–5.74	475	–943	–247	—	—	—	—	0.00	–164	–2,710	67.6	1,640
1978	0.00	0.00	–19.0	4,820	4,180	–457	—	—	—	—	0.00	1,210	–2,770	–55.5	1,460
1979	0.00	0.00	–14.0	2,550	1,410	–468	—	—	—	—	0.00	545	–2,580	–149	1,530
1980	0.00	0.00	–8.98	4,190	3,340	–596	—	—	—	—	0.00	916	–2,550	–228	1,620
1981	0.00	0.00	–2.75	739	–513	–440	—	—	—	—	0.00	164	–2,490	–279	1,800
1982	0.00	0.00	–4.49	903	–373	–352	—	—	—	—	0.00	273	–2,790	–263	1,860
1983	0.00	0.00	–7.01	4,240	3,470	–491	—	—	—	—	0.00	1,240	–2,840	–373	1,710
1984	0.00	0.00	–12.0	928	–497	–421	—	—	—	—	0.00	616	–3,100	–356	1,850
1985	0.00	0.00	–8.01	752	–488	–343	—	—	—	—	0.00	473	–2,810	–383	1,830
1986	0.00	0.00	–8.01	1,850	505	–361	—	—	—	—	0.00	712	–3,030	–403	1,750
1987	0.00	0.00	–8.01	421	–1,130	–294	—	—	—	—	0.00	443	–3,100	–368	1,780
1988	0.00	0.00	–7.98	711	–782	–254	—	—	—	—	0.00	367	–2,900	–376	1,680
1989	0.00	0.00	–7.01	643	–790	–225	—	—	—	—	0.00	210	–2,650	–370	1,610
1990	0.00	0.00	–7.01	193	–1,150	–175	—	—	—	—	0.00	159	–2,560	–348	1,590
1991	0.00	0.00	–69.8	608	–983	–161	—	—	—	—	0.00	300	–2,900	–308	1,550
1992	0.00	0.00	–85.8	2,290	943	–242	—	—	—	—	0.00	662	–2,780	–354	1,460
1993	0.00	0.00	–114	4,100	3,840	–434	—	—	—	—	0.00	1,300	–1,900	–486	1,380
1994	0.00	0.00	–2.19	630	–329	–337	—	—	—	—	0.00	473	–2,120	–497	1,530
1995	0.00	0.00	–3.06	3,310	2,420	–434	—	—	—	—	0.00	917	–2,470	–487	1,600
1996	0.00	0.00	–3.23	1,180	–136	–379	—	—	—	—	0.00	575	–2,750	–487	1,730
1997	0.00	0.00	–3.84	1,810	556	–397	—	—	—	—	0.00	686	–2,800	–485	1,750
1998	0.00	0.00	–3.00	4,690	3,710	–583	—	—	—	—	0.00	1,160	–2,590	–588	1,620
1999	0.00	0.00	–1.12	775	–986	–457	—	—	—	—	0.00	409	–2,980	–555	1,830
2000	0.00	0.00	–62.1	988	–841	–379	—	—	—	—	0.00	305	–3,010	–530	1,840

Table 4.6. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Central Basin Pressure Area, non- Water Replenishment District of Southern California (WRD), Los Angeles and Orange Counties, California.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Los Angeles Forebay	Flow from WRD Central Basin	Flow from Santa Monica	Flow from Hollywood
2001	0.00	0.00	–1.16	1,790	–18.0	–386	—	—	—	—	0.00	443	–3,120	–511	1,780
2002	0.00	0.00	–0.308	327	–1,560	–310	—	—	—	—	0.00	77.0	–2,940	–476	1,770
2003	0.00	0.00	–0.0344	773	–1,210	–273	—	—	—	—	0.00	205	–3,170	–441	1,690
2004	0.00	0.00	–23.2	723	–1,290	–247	—	—	—	—	0.00	123	–3,130	–379	1,640
2005	0.00	0.00	–0.156	4,630	3,180	–463	—	—	—	—	0.00	1,280	–3,280	–441	1,460
2006	0.00	0.00	–0.056	987	–954	–384	—	—	—	—	0.00	423	–3,210	–377	1,600
2007	0.00	0.00	–0.64	241	–1,660	–284	—	—	—	—	0.00	131	–3,050	–331	1,630
2008	0.00	0.00	–0.212	884	–834	–254	—	—	—	—	0.00	109	–2,810	–322	1,560
2009	0.00	0.00	–0.801	528	–1,410	–213	—	—	—	—	0.00	201	–3,220	–262	1,550
2010	0.00	0.00	–0.248	1,390	–245	–230	—	—	—	—	0.00	266	–2,830	–286	1,450
2011	0.00	0.00	–0.0881	1,940	864	–280	—	—	—	—	0.00	587	–2,360	–351	1,320
2012	0.00	0.00	–9.48	451	–1,010	–230	—	—	—	—	0.00	297	–2,500	–338	1,320
2013	0.00	0.00	0.00	353	–1,280	–186	—	—	—	—	0.00	169	–2,620	–302	1,300
2014	0.00	0.00	0.00	135	–1,610	–138	—	—	—	—	0.00	–28.0	–2,600	–269	1,280
2015	0.00	0.00	0.00	642	–861	–128	—	—	—	—	0.00	28.0	–2,310	–288	1,200

Table 4.7. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Grou
Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Reple

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from Orange County
1971	0.00	2,400	–164,000	6,240	–32,800	–257	—	—	—	—	0.00	1,750
1972	0.00	3,050	–142,000	3,790	–34,600	–90.0	—	—	—	—	0.00	–3,980
1973	0.00	3,220	–138,000	16,000	–12,600	–89.0	—	—	—	—	0.00	–7,980
1974	0.00	4,160	–140,000	11,300	–10,600	–356	—	—	—	—	0.00	–7,910
1975	0.00	2,760	–146,000	9,650	–15,800	–343	—	—	—	—	0.00	–3,200
1976	0.00	2,910	–146,000	3,680	–30,500	–398	—	—	—	—	0.00	–1,510
1977	0.00	3,450	–143,000	4,740	–35,300	–424	—	—	—	—	0.00	–634
1978	0.00	3,420	–126,000	40,600	41,700	–554	—	—	—	—	0.00	969
1979	0.00	3,320	–140,000	24,400	20,800	–627	—	—	—	—	0.00	4,150
1980	0.00	2,750	–135,000	34,100	37,200	–737	—	—	—	—	0.00	3,160
1981	0.00	2,820	–132,000	7,140	4,220	–612	—	—	—	—	0.00	4,720
1982	0.00	2,770	–127,000	9,290	–719	–515	—	—	—	—	0.00	–3,610
1983	0.00	2,270	–123,000	35,400	40,500	–543	—	—	—	—	0.00	–2,760
1984	0.00	1,930	–135,000	9,940	–4,240	–546	—	—	—	—	0.00	–311
1985	0.00	2,170	–123,000	8,380	326	–546	—	—	—	—	0.00	1,300
1986	0.00	2,770	–129,000	15,600	5,250	–569	—	—	—	—	0.00	–136
1987	0.00	2,780	–131,000	4,600	–12,300	–559	—	—	—	—	0.00	–4,860
1988	0.00	2,560	–133,000	6,340	–11,200	–549	—	—	—	—	0.00	–5,930
1989	0.00	2,830	–131,000	5,910	–8,800	–551	—	—	—	—	0.00	–4,820
1990	0.00	3,040	–128,000	2,170	–9,060	–636	—	—	—	—	0.00	–2,270
1991	0.00	2,640	–127,000	5,760	–3,370	–556	—	—	—	—	0.00	–5,440
1992	0.00	3,100	–127,000	16,100	15,700	–584	—	—	—	—	0.00	–5,550
1993	0.00	2,040	–81,700	31,400	66,000	–726	—	—	—	—	0.00	–10,200
1994	0.00	2,010	–106,000	6,070	14,400	–691	—	—	—	—	0.00	–6,780
1995	0.00	1,940	–114,000	26,500	25,600	–836	—	—	—	—	0.00	–9,080
1996	0.00	2,350	–114,000	9,440	3,310	–853	—	—	—	—	0.00	–11,800
1997	0.00	2,650	–126,000	15,300	26.7	–1,500	—	—	—	—	0.00	–10,500
1998	0.00	2,490	–128,000	40,300	26,600	–4,440	—	—	—	—	0.00	–9,210
1999	0.00	2,720	–135,000	7,160	–26,600	–1,650	—	—	—	—	0.00	–11,000
2000	0.00	2,630	–134,000	6,760	–22,600	–884	—	—	—	—	0.00	–10,200
2001	0.00	2,510	–130,000	11,700	–13,900	–812	—	—	—	—	0.00	–10,100
2002	0.00	2,530	–130,000	2,620	–20,800	–806	—	—	—	—	0.00	–7,090
2003	0.00	2,730	–132,000	6,280	–13,800	–923	—	—	—	—	0.00	–3,020
2004	0.00	2,180	–135,000	6,040	–17,800	–863	—	—	—	—	0.00	753
2005	0.00	1,800	–124,000	32,300	38,300	–1,050	—	—	—	—	0.00	–245
2006	0.00	606	–124,000	7,790	7,840	–983	—	—	—	—	0.00	2,980
2007	0.00	1,340	–143,000	2,170	–24,900	–982	—	—	—	—	0.00	–2,950
2008	0.00	3,390	–139,000	7,880	–18,400	–1,080	—	—	—	—	0.00	–4,830
2009	0.00	3,110	–135,000	5,280	–23,800	–926	—	—	—	—	0.00	–4,390
2010	0.00	2,310	–134,000	11,500	–4,150	–933	—	—	—	—	0.00	1,590
2011	0.00	2,520	–111,000	17,200	31,200	–1,260	—	—	—	—	0.00	1,250
2012	0.00	2,370	–131,000	4,890	–3,870	–1,110	—	—	—	—	0.00	5,980
2013	0.00	2,770	–133,000	3,510	–22,500	–985	—	—	—	—	0.00	3,860
2014	0.00	3,040	–140,000	1,470	–33,000	–909	—	—	—	—	0.00	4,470
2015	0.00	2,520	–114,000	5,400	–12,100	–796	—	—	—	—	0.00	1,920

undwater-flow Model for Central Basin Pressure Area, Water Replenishment District of Southern California (WRD), Los Angeles and Orange

enishment District of Southern California]

Flow from West Coast	Flow from Santa Monica	Flow from WRD Los Angeles Forebay	Flow from Montebello Forebay	Flow from Whitter	Flow from Central Basin	Flow from North Orange County	Flow from South Orange County
–6,550	–4.21	–7,180	122,000	4,540	1,850	654	5,690
–5,540	–3.72	–3,880	105,000	4,480	1,620	1,050	1,440
–5,160	–5.70	–4,750	118,000	4,310	1,780	1,080	–312
–4,740	–4.82	–6,570	126,000	4,150	2,030	1,130	–170
–4,660	–3.94	–5,480	122,000	3,920	2,410	1,130	2,290
–3,790	–3.15	–5,280	111,000	3,860	2,500	1,210	1,580
–3,380	–3.06	–4,460	99,900	3,760	2,710	1,210	773
–4,860	–10.2	–8,730	127,000	3,680	2,770	1,210	2,380
–5,490	–7.60	–8,190	132,000	3,640	2,580	1,260	3,520
–5,630	–11.3	–9,360	135,000	3,730	2,550	1,260	4,750
–6,560	–4.15	–7,830	125,000	3,800	2,490	1,100	3,980
–6,160	–4.31	–5,810	122,000	3,780	2,790	943	1,440
–6,370	–10.6	–6,780	132,000	3,840	2,840	924	2,870
–6,090	–5.11	–4,240	120,000	3,570	3,100	1,100	1,890
–6,190	–4.22	–4,220	112,000	3,450	2,810	1,060	3,240
–5,950	–6.27	–4,180	116,000	3,340	3,030	1,090	3,310
–5,290	–3.95	–3,040	116,000	3,410	3,100	1,150	1,630
–3,720	–3.84	–1,600	115,000	3,280	2,900	1,290	1,630
–3,950	–3.73	–2,760	117,000	3,220	2,650	1,170	1,490
–4,750	–3.36	–4,110	117,000	3,110	2,560	1,210	1,560
–5,400	–3.4	–4,010	122,000	2,990	2,900	1,260	1,680
–4,450	–6.24	–6,550	132,000	3,040	2,780	1,280	1,950
–5,880	–10.0	–13,200	136,000	3,110	1,900	1,250	2,130
–5,930	–3.98	–9,010	126,000	3,200	2,120	1,190	1,780
–5,530	–8.74	–9,010	128,000	3,470	2,470	1,060	799
–7,520	–4.99	–6,040	124,000	3,560	2,750	1,130	468
–6,130	–6.37	–4,800	122,000	3,680	2,800	1,150	1,420
–6,240	–11.8	–4,300	126,000	3,910	2,590	1,170	1,580
–5,980	–4.69	–2,310	111,000	4,050	2,980	1,260	271
–5,050	–4.85	–34.1	110,000	4,040	3,010	1,300	354
–4,710	–6.33	–862	109,000	3,960	3,120	1,320	655
–4,230	–3.98	–1,990	109,000	3,890	2,940	1,320	1,490
–4,800	–4.00	–1,110	109,000	3,760	3,170	1,310	1,790
–4,070	–4.25	–407	102,000	3,650	3,130	1,400	3,240
–4,470	–11.0	–4,000	127,000	3,660	3,280	1,390	3,150
–3,780	–4.72	–5,050	119,000	3,530	3,210	1,440	2,970
–2,020	–3.66	–2,370	113,000	3,750	3,050	1,470	1,140
–1,300	–3.65	43.5	108,000	3,880	2,810	1,490	987
–921	–3.52	2,380	96,300	3,800	3,220	1,490	1,890
–648	–4.56	462	103,000	3,610	2,830	1,470	5,030
–3,010	–6.29	–4,330	119,000	3,410	2,360	1,430	3,910
–2,060	–3.66	–1,670	107,000	3,420	2,500	1,440	4,410
–1,140	–3.45	–1,080	92,700	3,540	2,620	1,450	3,320
–81	–3.22	919	85,800	3,570	2,600	1,440	4,350
–218	–3.94	997	82,100	3,270	2,310	1,390	2,950

Table 4.8. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Orange County North, Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Orange County	Flow from Whitter
1971	0.00	0.00	–808	431	–2,650	–2,130	—	4,460	—	—	0.00	–654	–1,630	–2,320
1972	0.00	0.00	–1,670	246	–2,400	–885	—	4,270	—	—	0.00	–1,050	–908	–2,410
1973	0.00	0.00	–1,410	1,420	–343	–490	—	4,170	—	—	0.00	–1,080	–638	–2,310
1974	0.00	0.00	–1,800	850	–1,160	–388	—	4,080	—	—	0.00	–1,130	–487	–2,290
1975	0.00	0.00	–1,710	536	–1,510	–376	—	4,010	—	—	0.00	–1,130	–390	–2,440
1976	0.00	0.00	–1,300	218	–1,420	–364	—	3,960	—	—	0.00	–1,210	–328	–2,400
1977	0.00	0.00	–1,500	221	–1,540	–347	—	3,960	—	—	0.00	–1,210	–282	–2,380
1978	0.00	0.00	–914	5,290	3,960	–630	—	3,790	—	—	0.00	–1,210	–331	–2,030
1979	0.00	0.00	–1,060	3,070	1,230	–761	—	3,660	—	—	0.00	–1,260	–325	–2,100
1980	0.00	0.00	–1,260	4,920	2,450	–1,040	—	3,470	—	—	0.00	–1,260	–370	–2,010
1981	0.00	0.00	–1,960	407	–2,390	–881	—	3,510	—	—	0.00	–1,100	–282	–2,080
1982	0.00	0.00	–2,410	639	–2,400	–774	—	3,700	—	—	0.00	–943	–238	–2,370
1983	0.00	0.00	–1,420	4,500	2,650	–1,040	—	3,750	—	—	0.00	–924	–283	–1,930
1984	0.00	0.00	–1,600	811	–1,840	–958	—	3,660	—	—	0.00	–1,100	–238	–2,430
1985	0.00	0.00	–1,320	585	–1,410	–821	—	3,810	—	—	0.00	–1,060	–203	–2,400
1986	0.00	0.00	–1,480	1,310	–1,060	–783	—	3,790	—	—	0.00	–1,090	–198	–2,620
1987	0.00	0.00	–892	236	–1,410	–694	—	3,930	—	—	0.00	–1,150	–185	–2,650
1988	0.00	0.00	–905	315	–1,490	–600	—	4,000	—	—	0.00	–1,290	–174	–2,830
1989	0.00	0.00	–1,240	407	–1,420	–536	—	4,080	—	—	0.00	–1,170	–159	–2,800
1990	0.00	0.00	–761	114	–1,160	–470	—	4,130	—	—	0.00	–1,210	–149	–2,820
1991	0.00	0.00	–625	415	–1,350	–418	—	3,400	—	—	0.00	–1,260	–144	–2,720
1992	0.00	0.00	–160	1,440	677	–436	—	3,780	—	—	0.00	–1,280	–140	–2,520
1993	0.00	0.00	–55.7	4,290	3,990	–706	—	3,850	—	—	0.00	–1,250	–200	–1,940
1994	0.00	0.00	–388	363	–171	–604	—	3,580	—	—	0.00	–1,190	–160	–1,770
1995	0.00	0.00	–3.57	3,010	2,880	–719	—	3,290	—	—	0.00	–1,060	–189	–1,440
1996	0.00	0.00	–2.28	816	521	–693	—	3,250	—	—	0.00	–1,130	–175	–1,550
1997	0.00	0.00	–8.01	1,380	853	–710	—	3,140	—	—	0.00	–1,150	–181	–1,620
1998	0.00	0.00	0.00	4,830	4,190	–1,010	—	3,290	—	—	0.00	–1,170	–255	–1,490
1999	0.00	0.00	0.00	382	–484	–876	—	3,100	—	—	0.00	–1,260	–215	–1,620
2000	0.00	0.00	0.00	380	–408	–756	—	3,240	—	—	0.00	–1,300	–199	–1,770

Table 4.8. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Orange County North, Los Angeles and Orange Counties, California.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Orange County	Flow from Whitter
2001	0.00	0.00	–78.2	666	–62.0	–715	—	3,410	—	—	0.00	–1,320	–194	–1,830
2002	0.00	0.00	–157	122	–721	–669	—	3,400	—	—	0.00	–1,320	–190	–1,910
2003	0.00	0.00	–332	386	–392	–623	—	3,610	—	—	0.00	–1,310	–185	–1,950
2004	0.00	0.00	0.00	318	–211	–622	—	3,670	—	—	0.00	–1,400	–181	–2,000
2005	0.00	0.00	0.00	4,250	3,600	–986	—	3,670	—	—	0.00	–1,390	–231	–1,710
2006	0.00	0.00	0.00	441	–350	–961	—	3,600	—	—	0.00	–1,440	–202	–1,790
2007	0.00	0.00	0.00	110	–721	–896	—	3,650	—	—	0.00	–1,470	–196	–1,930
2008	0.00	0.00	0.00	245	–684	–834	—	3,580	—	—	0.00	–1,490	–197	–1,990
2009	0.00	0.00	0.00	225	–661	–777	—	3,620	—	—	0.00	–1,490	–194	–2,040
2010	0.00	0.00	0.00	1,260	281	–778	—	3,460	—	—	0.00	–1,470	–189	–2,000
2011	0.00	0.00	0.00	1,940	1,070	–896	—	3,540	—	—	0.00	–1,430	–202	–1,880
2012	0.00	0.00	0.00	288	–631	–862	—	3,510	—	—	0.00	–1,440	–190	–1,940
2013	0.00	0.00	0.00	167	–943	–788	—	3,340	—	—	0.00	–1,450	–187	–2,020
2014	0.00	0.00	0.00	58.0	–1,420	–694	—	2,880	—	—	0.00	–1,440	–188	–2,050
2015	0.00	0.00	0.00	538	–782	–619	—	2,910	—	—	0.00	–1,390	–189	–2,040

Table 4.9. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Orange County Central, Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from North Orange County	Flow from South Orange County
1971	0.00	0.00	–36,700	1,370	–3,940	0.00	—	34,600	—	—	0.00	–1,750	1,630	–3,100
1972	0.00	0.00	–38,600	865	–9,720	0.00	—	22,600	—	—	0.00	3,980	908	476
1973	0.00	0.00	–37,700	3,520	–5,380	0.00	—	17,600	—	—	0.00	7,980	638	2,590
1974	0.00	0.00	–42,300	2,550	–3,200	0.00	—	25,100	—	—	0.00	7,910	487	3,070
1975	0.00	0.00	–43,400	1,930	575	0.00	—	39,300	—	—	0.00	3,200	390	–745
1976	0.00	0.00	–47,000	862	–3,920	0.00	—	40,200	—	—	0.00	1,510	328	222
1977	0.00	0.00	–47,500	892	–4,400	0.00	—	39,100	—	—	0.00	634	282	2,290
1978	0.00	0.00	–36,900	10,600	12,000	0.00	—	39,100	—	—	0.00	–969	331	–224
1979	0.00	0.00	–45,200	6,620	6,250	0.00	—	48,300	—	—	0.00	–4,150	325	261
1980	0.00	0.00	–45,000	9,480	7,500	0.00	—	47,400	—	—	0.00	–3,160	370	–1,560
1981	0.00	0.00	–43,500	1,520	–5,300	0.00	—	41,600	—	—	0.00	–4,720	282	–397
1982	0.00	0.00	–47,500	2,080	–4,610	0.00	—	33,700	—	—	0.00	3,610	238	3,240
1983	0.00	0.00	–44,400	9,620	9,780	0.00	—	41,400	—	—	0.00	2,760	283	112
1984	0.00	0.00	–45,400	2,380	–315	0.00	—	42,000	—	—	0.00	311	238	182
1985	0.00	0.00	–41,800	1,730	3,430	0.00	—	45,700	—	—	0.00	–1,300	203	–1,140
1986	0.00	0.00	–44,000	3,520	–1,910	0.00	—	38,600	—	—	0.00	136	198	–306
1987	0.00	0.00	–47,600	1,020	–6,540	0.00	—	30,100	—	—	0.00	4,860	185	4,900
1988	0.00	0.00	–44,400	1,200	–4,500	0.00	—	29,000	—	—	0.00	5,930	174	3,550
1989	0.00	0.00	–44,700	1,160	–2,530	0.00	—	33,500	—	—	0.00	4,820	159	2,550
1990	0.00	0.00	–43,600	524	–2,230	0.00	—	35,500	—	—	0.00	2,270	149	2,910
1991	0.00	0.00	–45,100	1,230	–1,600	0.00	—	33,300	—	—	0.00	5,440	144	3,380
1992	0.00	0.00	–50,600	3,590	1,440	0.00	—	40,200	—	—	0.00	5,550	140	2,580
1993	0.00	0.00	–49,100	8,750	8,690	0.00	—	38,700	—	—	0.00	10,200	200	–177
1994	0.00	0.00	–47,700	1,420	5,090	0.00	—	45,000	—	—	0.00	6,780	160	–560
1995	0.00	0.00	–52,100	7,060	6,440	0.00	—	40,300	—	—	0.00	9,080	189	1,880
1996	0.00	0.00	–57,800	2,360	–640	0.00	—	39,000	—	—	0.00	11,800	175	3,720
1997	0.00	0.00	–56,400	3,790	–2,110	–24.2	—	36,500	—	—	0.00	10,500	181	3,340
1998	0.00	0.00	–54,500	10,700	5,530	–434	—	37,300	—	—	0.00	9,210	255	2,990
1999	0.00	0.00	–61,300	1,480	–7,440	–92.9	—	34,500	—	—	0.00	11,000	215	6,720
2000	0.00	0.00	–61,700	1,210	–4,970	0.00	—	38,300	—	—	0.00	10,200	199	6,870

Table 4.9. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Orange County Central, Los Angeles and Orange Counties, California.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from North Orange County	Flow from South Orange County
2001	0.00	0.00	–58,600	2,180	–3,290	0.00	—	36,500	—	—	0.00	10,100	194	6,340
2002	0.00	0.00	–50,500	610	–3,370	0.00	—	34,100	—	—	0.00	7,090	190	5,070
2003	0.00	0.00	–45,100	1,220	2,400	0.00	—	40,300	—	—	0.00	3,020	185	2,790
2004	0.00	0.00	–38,500	1,080	1,620	0.00	—	37,400	—	—	0.00	–753	181	2,260
2005	0.00	0.00	–41,100	8,810	14,500	0.00	—	45,900	—	—	0.00	245	231	385
2006	0.00	0.00	–43,100	1,480	7,120	0.00	—	51,800	—	—	0.00	–2,980	202	–330
2007	0.00	0.00	–60,500	547	–10,400	0.00	—	42,100	—	—	0.00	2,950	196	4,260
2008	0.00	0.00	–63,900	989	–9,300	0.00	—	40,800	—	—	0.00	4,830	197	7,720
2009	0.00	0.00	–57,400	969	–5,370	0.00	—	39,000	—	—	0.00	4,390	194	7,410
2010	0.00	0.00	–45,800	2,980	3,080	0.00	—	44,500	—	—	0.00	–1,590	189	2,740
2011	0.00	0.00	–44,600	4,470	13,500	0.00	—	56,900	—	—	0.00	–1,250	202	–2,130
2012	0.00	0.00	–48,200	1,070	3,630	0.00	—	56,100	—	—	0.00	–5,980	190	412
2013	0.00	0.00	–55,000	664	–3,390	0.00	—	51,900	—	—	0.00	–3,860	187	2,720
2014	0.00	0.00	–43,600	322	–8,750	0.00	—	33,700	—	—	0.00	–4,470	188	5,070
2015	0.00	0.00	–46,500	1,310	–2,750	0.00	—	39,500	—	—	0.00	–1,920	189	4,720

Table 4.10. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Orange County South, Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Orange County	Flow from San Pedro Bay	Flow from West Coast
1971	0.00	1,920	–8,860	290	–3,970	–132	4.37	5,850	—	—	0.00	–5,690	3,100	143	–584
1972	0.00	2,160	–9,940	193	–4,790	0.00	7.36	4,230	—	—	0.00	–1,440	–476	890	–410
1973	0.00	2,280	–8,790	694	–4,190	0.00	11.7	2,320	—	—	0.00	312	–2,590	1,860	–270
1974	0.00	3,070	–7,930	519	–2,360	0.00	13.3	2,940	—	—	0.00	170	–3,070	2,190	–250
1975	0.00	2,110	–8,570	392	374	0.00	11.0	6,720	—	—	0.00	–2,290	745	1,650	–373
1976	0.00	1,830	–9,840	159	–1,680	0.00	11.8	6,510	—	—	0.00	–1,580	–222	1,860	–395
1977	0.00	2,260	–9,360	164	–2,460	0.00	13.1	5,720	—	—	0.00	–773	–2,290	2,170	–350
1978	0.00	1,470	–6,240	2,600	3,400	0.00	10.6	6,470	—	—	0.00	–2,380	224	1,520	–274
1979	0.00	1,440	–5,480	1,310	2,440	0.00	7.76	8,310	—	—	0.00	–3,520	–261	991	–348
1980	0.00	1,460	–5,840	2,110	3,350	0.00	5.51	8,670	—	—	0.00	–4,750	1,560	497	–355
1981	0.00	1,830	–6,510	315	306	0.00	5.43	8,260	—	—	0.00	–3,980	397	424	–426
1982	0.00	1,760	–6,870	380	–2,980	0.00	9.26	5,530	—	—	0.00	–1,440	–3,240	1,240	–339
1983	0.00	2,810	–6,340	1,870	3,590	0.00	7.65	7,750	—	—	0.00	–2,870	–112	749	–279
1984	0.00	1,890	–7,900	420	–327	0.00	5.80	7,170	—	—	0.00	–1,890	–182	473	–305
1985	0.00	2,320	–6,440	326	869	0.00	4.81	6,840	—	—	0.00	–3,240	1,140	242	–319
1986	0.00	3,660	–6,500	671	1,380	0.00	4.44	6,640	—	—	0.00	–3,310	306	211	–302
1987	0.00	4,030	–4,870	197	–2,420	0.00	7.66	4,020	—	—	0.00	–1,630	–4,900	978	–238
1988	0.00	3,380	–4,990	223	–1,650	0.00	9.35	3,870	—	—	0.00	–1,630	–3,550	1,290	–234
1989	0.00	2,830	–5,210	196	–731	0.00	10.3	4,260	—	—	0.00	–1,490	–2,550	1,480	–245
1990	0.00	3,080	–4,560	92.6	–1,010	0.00	9.91	3,800	—	—	0.00	–1,560	–2,910	1,340	–281
1991	0.00	3,100	–3,870	255	–832	0.00	10.8	3,500	—	—	0.00	–1,680	–3,380	1,510	–266
1992	0.00	2,580	–4,020	726	74.0	0.00	9.54	4,370	—	—	0.00	–1,950	–2,580	1,210	–248
1993	0.00	2,520	–2,670	2,060	5,630	0.00	4.70	5,720	—	—	0.00	–2,130	177	121	–170
1994	0.00	2,070	–3,160	296	1,920	0.00	2.77	4,370	—	—	0.00	–1,780	560	–216	–215
1995	0.00	2,140	–3,280	1,580	951	0.00	2.32	3,540	—	—	0.00	–799	–1,880	–212	–130
1996	0.00	3,440	–3,160	453	84.2	0.00	3.41	3,730	—	—	0.00	–468	–3,720	19.6	–198
1997	0.00	2,890	–3,270	802	–119	0.00	4.44	4,190	—	—	0.00	–1,420	–3,340	254	–236
1998	0.00	2,560	–3,230	2,440	951	–31.1	3.36	3,930	—	—	0.00	–1,580	–2,990	31.8	–182
1999	0.00	3,180	–2,730	305	–2,290	0.00	5.39	3,680	—	—	0.00	–271	–6,720	515	–229
2000	0.00	2,640	–3,310	249	–2,160	0.00	6.64	4,970	—	—	0.00	–354	–6,870	778	–266

Table 4.10. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Orange County South, Los Angeles and Orange Counties, California.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Orange County	Flow from San Pedro Bay	Flow from West Coast
2001	0.00	3,550	–3,520	466	–1,110	–7.27	7.32	4,720	—	—	0.00	–655	–6,340	936	–260
2002	0.00	3,540	–3,350	121	–372	0.00	7.86	5,150	—	—	0.00	–1,490	–5,070	1,000	–279
2003	0.00	2,040	–3,060	198	408	0.00	6.70	5,390	—	—	0.00	–1,790	–2,790	721	–302
2004	0.00	3,580	–3,350	200	1,000	0.00	5.77	5,850	—	—	0.00	–3,240	–2,260	536	–323
2005	0.00	2,380	–2,540	2,020	3,670	0.00	2.65	5,680	—	—	0.00	–3,150	–385	–149	–195
2006	0.00	1,050	–3,370	304	291	0.00	1.94	5,400	—	—	0.00	–2,970	330	–210	–229
2007	0.00	2,250	–5,940	109	–4,660	0.00	3.90	4,040	—	—	0.00	–1,140	–4,260	479	–193
2008	0.00	3,970	–3,650	260	–1,490	0.00	7.59	5,580	—	—	0.00	–987	–7,720	1,260	–195
2009	0.00	3,700	–3,100	206	–952	0.00	8.35	6,410	—	—	0.00	–1,890	–7,410	1,370	–236
2010	0.00	2,850	–2,420	604	2,060	0.00	6.97	8,140	—	—	0.00	–5,030	–2,740	936	–295
2011	0.00	2,370	–5,580	901	3,770	0.00	3.13	8,030	—	—	0.00	–3,910	2,130	79.2	–248
2012	0.00	3,060	–5,400	213	–56.1	0.00	2.60	7,150	—	—	0.00	–4,410	–412	9.84	–277
2013	0.00	2,870	–5,240	133	–1,210	0.00	4.08	7,050	—	—	0.00	–3,320	–2,720	303	–292
2014	0.00	4,500	–2,480	68.3	–1,050	0.00	5.88	5,830	—	—	0.00	–4,350	–5,070	753	–289
2015	0.00	3,320	–2,840	278	–228	0.00	5.29	6,260	—	—	0.00	–2,950	–4,720	639	–227

Table 4.11. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Santa Monica Basin, Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Santa Monica Bay	Flow from West Coast	Flow from Hollywood	Flow from Central Basin
1971	0.00	0.00	–7,360	5,160	–15,700	–7,660	–1,050	—	—	—	0.00	4.21	–645	–3,380	–322	–436
1972	0.00	0.00	–7,900	4,200	–11,800	–3,700	–413	—	—	—	0.00	3.72	–529	–2,690	–161	–621
1973	0.00	0.00	–8,200	11,900	–4,340	–4,230	–199	—	—	—	0.00	5.70	–447	–2,310	–399	–470
1974	0.00	0.00	–7,970	8,630	–5,770	–3,350	–50.3	—	—	—	0.00	4.82	–376	–2,010	–298	–353
1975	0.00	298	–8,450	5,010	–7,810	–2,320	114	—	—	—	0.00	3.94	–314	–1,890	–102	–159
1976	0.00	718	–8,340	1,700	–8,970	–1,180	329	—	—	—	0.00	3.15	–270	–1,860	49.4	–131
1977	0.00	0.00	–8,510	3,260	–7,590	–886	453	—	—	—	0.00	3.06	–167	–1,680	10.9	–67.6
1978	0.00	1,550	–4,910	29,400	16,300	–5,700	–220	—	—	—	0.00	10.2	–526	–2,580	–760	55.5
1979	0.00	2,530	–6,490	14,700	1,960	–4,880	–316	—	—	—	0.00	7.60	–425	–2,910	–400	149
1980	0.00	1,930	–6,900	26,600	10,100	–7,630	–511	—	—	—	0.00	11.3	–394	–2,570	–631	228
1981	0.00	1,270	–6,960	4,870	–7,490	–4,130	–295	—	—	—	0.00	4.15	–179	–2,340	–9.29	279
1982	0.00	1,260	–8,430	4,830	–7,140	–2,700	54.8	—	—	—	0.00	4.31	–106	–2,380	62.5	263
1983	0.00	1,650	–9,720	22,900	6,850	–5,750	18.6	—	—	—	0.00	10.6	–125	–2,010	–505	373
1984	0.00	1,180	–10,300	5,200	–7,910	–3,150	299	—	—	—	0.00	5.11	113	–1,620	51.2	356
1985	0.00	0.00	–9,890	4,180	–7,830	–2,040	534	—	—	—	0.00	4.22	188	–1,310	133	383
1986	0.00	1,150	–10,800	11,600	–1,150	–2,820	622	—	—	—	0.00	6.27	191	–1,400	–96.6	403
1987	0.00	2,150	–9,330	2,150	–5,930	–975	738	—	—	—	0.00	3.95	126	–1,390	235	368
1988	0.00	773	–9,280	3,810	–4,770	–866	914	—	—	—	0.00	3.84	317	–972	155	376
1989	0.00	0.00	–8,340	3,550	–4,410	–585	1,070	—	—	—	0.00	3.73	346	–995	170	370
1990	0.00	0.00	–5,370	740	–4,350	–79.2	1,030	—	—	—	0.00	3.36	57.9	–1,360	284	348
1991	0.00	0.00	–6,060	4,700	–1,590	–304	979	—	—	—	0.00	3.40	88.8	–1,390	87.3	308
1992	0.00	0.00	–8,600	15,100	4,310	–2,140	1,070	—	—	—	0.00	6.24	315	–1,460	–297	354
1993	0.00	0.00	–10,000	27,000	12,300	–4,920	879	—	—	—	0.00	10.0	389	–961	–618	486
1994	0.00	0.00	–9,960	3,790	–6,340	–1,900	1,020	—	—	—	0.00	3.98	478	–397	119	497
1995	0.00	0.00	–10,600	22,200	8,150	–4,470	842	—	—	—	0.00	8.74	404	–296	–431	487
1996	0.00	0.00	–6,210	7,230	–1,250	–2,540	838	—	—	—	0.00	4.99	64.2	–1,160	33.1	487
1997	0.00	0.00	–3,240	12,700	5,050	–3,270	285	—	—	—	0.00	6.37	–151	–1,630	–126	485
1998	0.00	0.00	–3,120	29,400	16,700	–7,150	–425	—	—	—	0.00	11.8	–203	–1,900	–541	588
1999	0.00	0.00	–3,330	3,450	–5,740	–3,760	–397	—	—	—	0.00	4.69	–96.8	–2,340	180	555

Table 4.11. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Santa Monica Basin, Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Santa Monica Bay	Flow from West Coast	Flow from Hollywood	Flow from Central Basin
2000	0.00	0.00	–3,500	6,160	–2,450	–2,870	–360	—	—	—	0.00	4.85	–127	–2,380	83	530
2001	0.00	0.00	–3,310	11,900	2,200	–3,790	–465	—	—	—	0.00	6.33	–156	–2,330	–136	511
2002	0.00	0.00	–2,390	1,460	–5,420	–1,790	–402	—	—	—	0.00	3.98	–201	–2,800	221	476
2003	0.00	0.00	–1,530	3,680	–2,340	–1,500	–410	—	—	—	0.00	4.00	–322	–2,860	156	441
2004	0.00	0.00	–1,280	4,190	–1,430	–1,190	–461	—	—	—	0.00	4.25	–336	–2,860	118	379
2005	0.00	0.00	–2,250	26,800	14,000	–6,290	–745	—	—	—	0.00	11.0	–357	–3,020	–610	441
2006	0.00	0.00	–2,180	5,610	–2,800	–3,150	–564	—	—	—	0.00	4.72	–273	–2,630	6.22	377
2007	0.00	0.00	–2,390	878	–5,590	–1,430	–499	—	—	—	0.00	3.66	–199	–2,460	174	331
2008	0.00	0.00	–2,440	6,330	–1,150	–1,940	–486	—	—	—	0.00	3.65	–208	–2,670	–53.5	322
2009	0.00	0.00	–2,460	2,980	–3,850	–1,170	–402	—	—	—	0.00	3.52	–235	–2,940	119	262
2010	0.00	0.00	–3,700	8,060	–543	–1,780	–354	—	—	—	0.00	4.56	–174	–2,760	–135	286
2011	0.00	0.00	–8,410	9,030	–2,780	–1,870	–88.8	—	—	—	0.00	6.29	170	–1,730	–234	351
2012	0.00	0.00	–8,860	1,200	–8,840	–501	398	—	—	—	0.00	3.66	149	–1,630	71.7	338
2013	0.00	0.00	–10,300	1,180	–9,320	–151	740	—	—	—	0.00	3.45	169	–1,410	118	302
2014	0.00	0.00	–11,100	1,090	–9,850	–38.4	1,110	—	—	—	0.00	3.22	299	–1,590	134	269
2015	0.00	0.00	–11,000	3,870	–6,250	–130	1,400	—	—	—	0.00	3.94	308	–994	36.5	288

Table 4.12. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Whittier area, Los Angeles and Orange Counties, California

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Montebello Forebay	Flow from North Orange County
1971	0.00	0.00	–1,210	1,030	–5,160	0.00	—	—	—	—	0.00	–4,540	–2,760	2,320
1972	0.00	0.00	–1,320	520	–6,680	0.00	—	—	—	—	0.00	–4,480	–3,810	2,410
1973	0.00	0.00	–1,240	3,470	1,440	0.00	—	—	—	—	0.00	–4,310	1,210	2,310
1974	0.00	0.00	–1,270	1,910	–1,080	0.00	—	—	—	—	0.00	–4,150	135	2,290
1975	0.00	0.00	–1,540	767	–2,910	0.00	—	—	—	—	0.00	–3,920	–661	2,440
1976	0.00	0.00	–1,260	286	–5,270	0.00	—	—	—	—	0.00	–3,860	–2,830	2,400
1977	0.00	0.00	–1,080	364	–4,740	0.00	—	—	—	—	0.00	–3,760	–2,640	2,380
1978	0.00	0.00	–1,050	10,900	13,100	–1.17	—	—	—	—	0.00	–3,680	4,900	2,030
1979	0.00	0.00	–1,580	4,790	1,800	0.00	—	—	—	—	0.00	–3,640	126	2,100
1980	0.00	0.00	–1,850	8,540	5,710	–43.7	—	—	—	—	0.00	–3,730	773	2,010
1981	0.00	0.00	–1,630	602	–3,630	0.848	—	—	—	—	0.00	–3,800	–874	2,080
1982	0.00	0.00	–2,150	906	–3,360	0.237	—	—	—	—	0.00	–3,780	–712	2,370
1983	0.00	0.00	–868	7,250	5,860	–54.7	—	—	—	—	0.00	–3,840	1,430	1,930
1984	0.00	0.00	–2,540	941	–3,990	–20.8	—	—	—	—	0.00	–3,570	–1,230	2,430
1985	0.00	0.00	–1,990	1,380	–3,000	–4.42	—	—	—	—	0.00	–3,450	–1,330	2,400
1986	0.00	0.00	–2,630	2,660	–579	–2.08	—	—	—	—	0.00	–3,340	118	2,620
1987	0.00	0.00	–2,610	301	–3,480	0.00	—	—	—	—	0.00	–3,410	–414	2,650
1988	0.00	0.00	–2,880	484	–3,200	0.00	—	—	—	—	0.00	–3,280	–365	2,830
1989	0.00	0.00	–2,770	822	–2,670	0.00	—	—	—	—	0.00	–3,220	–309	2,800
1990	0.00	0.00	–2,680	150	–2,400	0.00	—	—	—	—	0.00	–3,110	418	2,820
1991	0.00	0.00	–2,540	1,320	401	0.00	—	—	—	—	0.00	–2,990	1,890	2,720
1992	0.00	0.00	–2,260	3,320	2,960	0.00	—	—	—	—	0.00	–3,040	2,410	2,520
1993	0.00	0.00	–1,550	8,710	9,490	–1.17	—	—	—	—	0.00	–3,110	3,490	1,940
1994	0.00	0.00	–885	494	–1,770	0.00	—	—	—	—	0.00	–3,200	45.0	1,770
1995	0.00	0.00	–41.8	4,950	4,060	0.00	—	—	—	—	0.00	–3,470	1,180	1,440
1996	0.00	0.00	–37.4	1,250	–457	0.00	—	—	—	—	0.00	–3,560	345	1,550
1997	0.00	0.00	–36.1	1,980	–495	0.313	—	—	—	—	0.00	–3,680	–375	1,620
1998	0.00	0.00	–25.2	8,590	6,310	–86.5	—	—	—	—	0.00	–3,910	248	1,490
1999	0.00	0.00	–22.8	430	–5,150	–21.7	—	—	—	—	0.00	–4,050	–3,100	1,620
2000	0.00	0.00	–54.7	843	–2,060	–12.0	—	—	—	—	0.00	–4,040	–565	1,770

Table 4.12. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for Whittier area, Los Angeles and Orange Counties, California

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Montebello Forebay	Flow from North Orange County
2001	0.00	0.00	–51.2	1,600	–1,180	–9.93	—	—	—	—	0.00	–3,960	–584	1,830
2002	0.00	0.00	–84.5	175	–2,710	0.00	—	—	—	—	0.00	–3,890	–818	1,910
2003	0.00	0.00	–34.8	1,230	–1,630	0.00	—	—	—	—	0.00	–3,760	–1,010	1,950
2004	0.00	0.00	–58.5	743	–1,560	0.00	—	—	—	—	0.00	–3,650	–597	2,000
2005	0.00	0.00	–66.6	8,380	9,660	–42.4	—	—	—	—	0.00	–3,660	3,340	1,710
2006	0.00	0.00	–44.6	585	–985	–6.24	—	—	—	—	0.00	–3,530	218	1,790
2007	0.00	0.00	–52.8	145	–3,760	0.00	—	—	—	—	0.00	–3,750	–2,020	1,930
2008	0.00	0.00	–53.5	759	–3,090	0.00	—	—	—	—	0.00	–3,880	–1,910	1,990
2009	0.00	0.00	–52.9	417	–3,690	0.00	—	—	—	—	0.00	–3,800	–2,290	2,040
2010	0.00	0.00	–49.0	2,900	2,150	0.00	—	—	—	—	0.00	–3,610	908	2,000
2011	0.00	0.00	–46.7	3,760	5,130	0.00	—	—	—	—	0.00	–3,410	2,940	1,880
2012	0.00	0.00	–56.4	367	–2,890	0.00	—	—	—	—	0.00	–3,420	–1,720	1,940
2013	0.00	0.00	–68.0	217	–4,400	0.00	—	—	—	—	0.00	–3,540	–3,030	2,020
2014	0.00	0.00	–47.4	88.6	–4,090	0.00	—	—	—	—	0.00	–3,570	–2,610	2,050
2015	0.00	0.00	–39.3	1,000	–1,390	0.00	—	—	—	—	0.00	–3,270	–1,110	2,040

Table 4.13. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for West Coast Basin, Los Angeles and Orange Counties, California.

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Santa Monica Bay	Flow from San Pedro Bay	Flow from Santa Monica	Flow from South Orange County
1971	0.00	30,800	–74,700	5,650	–18,100	–6.85	0.00	—	—	31.3	0.00	6,550	603	8,930	3,380	584
1972	0.00	36,700	–62,600	3,620	–4,770	0.00	0.00	—	—	30.5	0.00	5,540	511	8,330	2,690	410
1973	0.00	36,800	–58,400	15,200	9,710	0.00	0.00	—	—	30.4	0.00	5,160	417	7,930	2,310	270
1974	0.00	33,800	–55,000	9,810	3,700	0.00	0.00	—	—	30.2	0.00	4,740	371	7,720	2,010	250
1975	0.00	33,000	–55,700	7,470	–105	0.00	0.00	—	—	29.7	0.00	4,660	355	7,790	1,890	373
1976	0.00	40,200	–59,400	2,350	–1,720	0.00	0.00	—	—	29.8	0.00	3,790	271	8,770	1,860	395
1977	0.00	43,000	–59,300	4,530	2,370	0.00	0.00	—	—	29.9	0.00	3,380	241	8,520	1,680	350
1978	0.00	34,300	–58,200	42,900	34,700	–6.06	0.00	—	—	29.9	0.00	4,860	407	7,690	2,580	274
1979	0.00	29,000	–56,100	23,500	13,000	0.00	0.00	—	—	29.9	0.00	5,490	506	7,320	2,910	348
1980	0.00	32,400	–58,400	32,000	22,400	–35.5	0.00	—	—	30.4	0.00	5,630	293	7,590	2,570	355
1981	0.00	29,200	–56,100	5,670	–2,790	0.00	0.00	—	—	31.1	0.00	6,560	303	8,720	2,340	426
1982	0.00	30,400	–61,400	7,800	–4,780	0.00	0.00	—	—	31.7	0.00	6,160	373	9,080	2,380	339
1983	0.00	40,300	–54,200	35,700	38,200	0.00	0.00	—	—	31.9	0.00	6,370	56.1	7,690	2,010	279
1984	0.00	35,700	–51,700	8,190	7,100	0.00	0.00	—	—	31.6	0.00	6,090	–86.5	6,960	1,620	305
1985	0.00	28,000	–50,300	6,370	–1,530	0.00	0.00	—	—	31.2	0.00	6,190	–35.8	6,600	1,310	319
1986	0.00	30,700	–50,800	18,000	11,100	0.00	0.00	—	—	30.4	0.00	5,950	–110	5,620	1,400	302
1987	0.00	31,900	–47,800	3,550	620	0.00	0.00	—	—	30.4	0.00	5,290	–171	6,160	1,390	238
1988	0.00	31,100	–43,200	5,770	4,160	0.00	0.00	—	—	30.7	0.00	3,720	–260	5,860	972	234
1989	0.00	26,400	–45,000	4,520	–2,980	0.00	0.00	—	—	30.4	0.00	3,950	–243	6,130	995	245
1990	0.00	27,300	–47,900	1,610	–6,060	0.00	0.00	—	—	30.6	0.00	4,750	–133	6,670	1,360	281
1991	0.00	24,100	–54,100	5,200	–11,100	0.00	0.00	—	—	30.7	0.00	5,400	27.4	6,590	1,390	266
1992	0.00	27,800	–51,300	18,200	7,080	0.00	0.00	—	—	30.7	0.00	4,450	–148	6,340	1,460	248
1993	0.00	25,600	–40,600	34,100	31,300	–24.6	0.00	—	—	30.6	0.00	5,880	–493	5,580	961	170
1994	0.00	21,400	–42,000	4,890	–4,380	0.00	0.00	—	—	30.0	0.00	5,930	–467	5,240	397	215
1995	0.00	17,700	–43,200	30,000	14,600	–52.2	0.00	—	—	29.6	0.00	5,530	–426	4,640	296	130
1996	0.00	24,100	–55,200	8,540	–8,710	0.00	0.00	—	—	29.5	0.00	7,520	–243	5,270	1,160	198
1997	0.00	23,400	–50,400	15,200	1,980	–4.29	0.00	—	—	30.0	0.00	6,130	–78.4	5,970	1,630	236
1998	0.00	18,500	–51,200	42,500	24,000	–152	0.00	—	—	30.6	0.00	6,240	–9.60	5,970	1,900	182
1999	0.00	22,600	–52,400	5,990	–8,880	–2.64	0.00	—	—	30.6	0.00	5,980	119	6,240	2,340	229

Table 4.13. Overall annual groundwater flow budget and individual annual groundwater flow budgets by subarea of the Los Angeles Coastal Plain Groundwater-flow Model for West Coast Basin, Los Angeles and Orange Counties, California.—Continued

[GHB, general head boundary; OC, Orange County; WHT, Whittier; PV, Palos Verdes; CHD, time-variant specified-head; LA Narrows, Los Angeles Narrows; WRD, Water Replenishment District of Southern California]

Year	Water spreading	Injection	Pumping	Recharge	Storage	Drains	GHB Ocean	GHB OC	GHB WHT	GHB PV	CHD LA Narrows	Flow from WRD Central Basin	Flow from Santa Monica Bay	Flow from San Pedro Bay	Flow from Santa Monica	Flow from South Orange County
2000	0.00	26,900	–52,000	6,300	–4,660	0.00	0.00	—	—	30.9	0.00	5,050	111	6,380	2,380	266
2001	0.00	24,400	–50,800	15,000	3,000	0.00	0.00	—	—	31.2	0.00	4,710	117	6,990	2,330	260
2002	0.00	24,700	–51,300	2,220	–10,100	0.00	0.00	—	—	31.2	0.00	4,230	268	6,570	2,800	279
2003	0.00	24,200	–51,500	5,620	–6,850	0.00	0.00	—	—	31.5	0.00	4,800	320	6,480	2,860	302
2004	0.00	17,000	–45,100	5,460	–8,680	0.00	0.00	—	—	31.2	0.00	4,070	395	6,260	2,860	323
2005	0.00	17,200	–40,100	37,700	27,700	–44.6	0.00	—	—	30.8	0.00	4,470	241	4,900	3,020	195
2006	0.00	20,100	–34,500	6,790	2,870	0.00	0.00	—	—	29.8	0.00	3,780	166	3,660	2,630	229
2007	0.00	21,700	–38,100	1,730	–6,210	0.00	0.00	—	—	29.5	0.00	2,020	143	3,630	2,460	193
2008	0.00	21,200	–39,500	7,560	–2,410	0.00	0.00	—	—	29.9	0.00	1,300	206	3,950	2,670	195
2009	0.00	21,800	–45,600	4,140	–10,600	0.00	0.00	—	—	30.1	0.00	921	347	4,660	2,940	236
2010	0.00	24,900	–42,900	12,400	2,900	0.00	0.00	—	—	30.3	0.00	648	224	4,520	2,760	295
2011	0.00	21,300	–44,800	16,000	1,980	0.00	0.00	—	—	29.8	0.00	3,010	83.2	4,400	1,730	248
2012	0.00	21,200	–43,400	4,140	–9,370	0.00	0.00	—	—	29.9	0.00	2,060	–0.806	4,680	1,630	277
2013	0.00	24,600	–42,200	2,810	–6,950	0.00	0.00	—	—	30.4	0.00	1,140	–52.6	5,050	1,410	292
2014	0.00	29,000	–40,400	1,150	–4,080	0.00	0.00	—	—	30.1	0.00	81.0	–119	4,260	1,590	289
2015	0.00	20,000	–30,700	5,330	–217	0.00	0.00	—	—	29.7	0.00	218	–193	3,880	994	227

Table 4.14. Average annual 25-year water budget in acre-feet for base-case scenario with wet climatic conditions, Los Angeles Coastal Plain Ground

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Pumping and net interborehole flow out
Dominguez	2	0.00	–8,130	–3,020	–31.1	0.00	0.00	–1.00
Mesa	3	0.00	–8,420	–3,340	–1,190	–301	0.00	–2,650
Pacific A	4	0.00	–28,100	–7,660	–0.0004	0.00	0.00	–830
Pacific	5	0.00	–26,700	–26,600	–5,250	–628	–299	–4,620
Harbor	6	0.00	–34,700	–10,000	–11,100	0.00	0.00	–1,020
Bent Spring	7	0.00	–11,300	–2,270	–4,420	–7,370	–1,250	–3,710
Upper Wilmington A	8	–1,180	–18,700	–3,970	–14,600	–133	–1,550	–4,520
Upper Wilmington B	9	0.00	–7,240	–545	–1,840	–318	–25.2	–652
Lower Wilmington	10	0.00	–2,390	0.00	–5,810	–205	0.00	–647
Long Beach A	11	0.00	–535	0.00	–707	0.00	0.00	–6.48
Long Beach B	12	0.00	–236	0.00	–115	0.00	0.00	–97.8
Long Beach C	13	0.00	0.00	0.00	0.00	–1.29	0.00	–11.6
Total		–1,180	–146,000	–57,500	–45,100	–8,950	–3,130	–18,800
								Net flow from adjacent inland zones
Dominguez	2	–618	12,900	–2,050	46.8	19.7	–112	152
Mesa	3	–1,180	27,600	–247	1,200	–371	–1,050	3,740
Pacific A	4	–96.2	7,830	2,230	–41.9	0.00	0.00	–924
Pacific	5	–3,090	21,100	10,000	–427	230	–81.5	3,350
Harbor	6	–362	20,900	2,220	–730	–12.0	0.00	–860
Bent Spring	7	–804	12,700	931	–13.6	301	–895	1,030
Upper Wilmington A	8	–1,830	7,670	–423	1,340	–1,400	107	5,160
Upper Wilmington B	9	–167	3,770	–2,200	–183	224	–3.09	236
Lower Wilmington	10	–39.4	3,660	–337	1,420	–195	2.41	481
Long Beach A	11	–0.365	720	12.7	798	–139	–0.0166	44.0
Long Beach B	12	37.2	889	–223	536	–81.3	3.52	–10.1
Long Beach C	13	–608	1,930	130	1,040	–290	1.95	52.6
Total		–8,760	122,000	10,000	4,990	–1,710	–2,030	12,400
								Water spreading
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

water-flow Model.

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
–431	0.00	0.00	0.00	–36.2	–11,700
–5,600	–29.9	0.00	0.00	–207	–21,700
–2,870	0.00	0.00	0.00	0.00	–39,500
–17,300	–17.3	–2.44	0.00	–3,820	–85,200
–8,050	0.00	0.00	0.00	–1,090	–66,000
–2,650	0.00	–16.1	0.00	–108	–33,100
–4,590	0.00	0.00	0.00	–380	–49,600
–392	–0.746	0.00	0.00	0.00	–11,000
–446	–161	0.00	–137	0.00	–9,800
–229	0.00	0.00	0.00	0.00	–1,480
–192	0.00	0.00	0.00	0.00	–640
–4,080	0.00	0.00	0.00	0.00	–4,100
–46,800	–209	–18.5	–137	–5,640	–334,000
–12,900	–81.6	112	7.19	2,550	–2.82E–11
–31,000	–599	946	0.00	979	1.01E–11
–7,840	–304	–854	0.00	0.00	–5.26E–11
–25,500	–456	–622	–702	–3,740	–4.91E–11
–18,600	–59.7	–255	0.00	–2,270	–6.28E–11
–14,000	0.00	846	0.00	–33.2	4.12E–11
–8,340	–308	–278	–696	–1,010	–1.10E–11
–1,480	255	–191	–315	60.4	5.63E–12
–4,250	53.8	–243	–438	–111	–2.87E–11
229	–70.4	–1.49	–1,100	–488	3.41E–13
–324	–201	–0.143	–167	–459	–1.08E–12
–1,090	–1,060	–40.4	–34.3	–28.9	3.69E–13
–125,000	–2,830	–580	–3,450	–4,560	–1.88E–10
85,300	0.00	0.00	0.00	0.00	85,300
43,700	0.00	0.00	0.00	0.00	43,700
0.00	0.00	0.00	0.00	0.00	0.00
2,010	0.00	0.00	0.00	0.00	2,010
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
131,000	0.00	0.00	0.00	0.00	131,000

Table 4.14. Average annual 25-year water budget in acre-feet for base-case scenario with wet climatic conditions, Los Angeles Coastal Plain Ground

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Injection and net interborehole flow in
Dominguez	2	0.00	5.85	0.00262	35.5	0.00	0.00	0.000225
Mesa	3	0.00	743	232	1,690	9.15E–05	0.00	0.00
Pacific A	4	0.00	2,210	2,530	0.00	0.00	0.00	28.2
Pacific	5	0.00	7,530	2,020	8,060	0.0316	0.00	1,210
Harbor	6	0.00	2,040	79.6	5,250	0.00	0.00	1,410
Bent Spring	7	0.00	983	0.00	9,500	241	48.3	724
Upper Wilmington A	8	1,180	980	0.894	1,200	0.00	14.4	50.1
Upper Wilmington B	9	0.00	444	1.89	96.2	1.34	0.00	15.3
Lower Wilmington	10	0.00	66.6	0.00	94.1	0.00	0.00	34.1
Long Beach A	11	0.00	2.96	0.00	0.00	0.00	0.00	0.00482
Long Beach B	12	0.00	0.455	0.00	0.00	0.00	0.00	0.0408
Long Beach C	13	0.00	0.00	0.00	0.00	0.919	0.00	0.00
Total		1,180	15,000	4,870	25,900	243	62.7	3,470
								Areal recharge
Dominguez	2	1,450	10,400	3,740	1,430	1,780	2,210	1,720
Mesa	3	2,100	4,390	34.4	11,400	8,160	1,330	51.5
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	399	60.0	923	1,180	0.0782	0.00
Harbor	6	254	4.88	0.00	309	0.00	0.00	224
Bent Spring	7	19.0	0.00	0.00	1,030	9.73	0.00	0.00
Upper Wilmington A	8	0.00	36.1	11.8	170	82.7	0.00	44.4
Upper Wilmington B	9	0.00	0.00	0.00	21.5	12.2	0.00	0.00
Lower Wilmington	10	0.00	26.4	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	8.83	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	265	126	0.00	121	4.04	0.00	159
Total		4,090	15,400	3,840	15,400	11,200	3,540	2,200
								Flow from Santa Monica Bay
Dominguez	2	0.00	0.00	0.00	0.00	0.00113	0.00	0.00
Mesa	3	0.00	0.00	0.00	–46.8	–222	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	–19.0	–21.4	0.00	0.00
Harbor	6	0.00	0.00	0.00	–19.3	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	72.4	69.2	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	–16.7	193	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	–53.4	–4.86	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	144	–30.4	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	–3.75	–17.2	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.684	–10.0	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	3.24	9.98	0.00	0.00
Total		0.00	0.00	0.00	61.6	–33.6	0.00	0.00

water-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
5.76E–05	0.00	0.00	0.00	0.00	41.4
123	0.00	1.73	0.00	1,130	3,920
708	0.00	0.00	0.00	0.00	5,480
234	0.00	0.407	0.00	1,200	20,300
679	2.01	12.6	0.00	1,660	11,100
37.6	0.00	0.55	0.00	0.137	11,500
260	10.6	0.00	14.4	34.9	3,750
3.58	0.824	0.00	16.5	0.00	580
28.2	0.724	0.00	0.00	0.00	224
0.0143	64.7	0.00	107	0.00	174
21.5	71.6	0.00	0.00	0.00	93.6
5,000	0.00	0.00	0.00	0.00	5,000
7,100	150	15.3	137	4,020	62,200
2,620	353	540	33.5	547	26,800
1,300	465	989	0.00	273	30,500
0.00	0.00	0.00	0.00	0.00	0.00
251	594	218	999	0.00219	4,620
2.13	0.00	0.00	0.00	0.00	793
0.00	0.00	0.00	0.00	0.00	1,060
220	65.7	0.00	270	0.00	901
0.00	0.00	0.00	0.00	0.00	33.7
0.00	30.8	0.00	95.4	0.00	153
30.6	2.19	0.00	85.6	0.00	127
7.98	0.00	0.00	0.00	0.00	7.98
1,510	1,430	73.8	147	0.00	3,830
5,940	2,940	1,820	1,630	820	68,900
0.00	0.00	0.00	0.00	0.00	0.00113
0.00	0.00	0.00	0.00	0.00	–269
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	–40.4
0.00	0.00	0.00	0.00	0.00	–19.3
0.00	0.00	0.00	0.00	0.00	142
0.00	0.00	0.00	0.00	0.00	176
0.00	0.00	0.00	0.00	0.00	–58.3
0.00	0.00	0.00	0.00	0.00	114
0.00	0.00	0.00	0.00	0.00	–21.0
0.00	0.00	0.00	0.00	0.00	–9.35
0.00	0.00	0.00	0.00	0.00	13.2
0.00	0.00	0.00	0.00	0.00	28.0

Table 4.14. Average annual 25-year water budget in acre-feet for base-case scenario with wet climatic conditions, Los Angeles Coastal Plain Ground

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Flow from San Pedro Bay
Dominguez	2	0.00	0.00	0.00	162	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	–8.24	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	628	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	724	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	225	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	138	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	1,620	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	312	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	313	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	75.3	0.00	0.00	0.00
Total		0.00	0.00	0.00	4,190	0.00	0.00	0.00
								Underflow from Orange County
Dominguez	2	0.00	0.00	3,630	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	1,440	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	2,900	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	13,000	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	6,580	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	696	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	7,140	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	2,750	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	164	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	55.5	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	89.0	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	34.1	0.00	0.00	0.00	0.00
Total		0.00	0.00	38,500	0.00	0.00	0.00	0.00
								Underflow from San Gabriel Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

water-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
0.00	0.00	0.00	0.00	28.0	190
0.00	0.00	0.00	0.00	141	133
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	281	909
0.00	0.00	0.00	0.00	765	1,490
0.00	0.00	0.00	0.00	66.2	291
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	138
0.00	0.00	0.00	0.00	30.0	1,650
0.00	0.00	0.00	0.00	–366	–54.3
0.00	0.00	0.00	0.00	–105	207
0.00	0.00	0.00	0.00	–342	–267
0.00	0.00	0.00	0.00	499	4,690
0.00	0.00	0.00	0.00	82.7	3,710
0.00	0.00	0.00	0.00	544	1,980
0.00	0.00	0.00	0.00	0.00	2,900
0.00	0.00	0.00	–74.8	340	13,300
0.00	0.00	0.00	0.00	233	6,820
0.00	0.00	0.00	0.00	50.9	747
0.00	0.00	0.00	856	1,350	9,340
0.00	0.00	0.00	271	–42.1	2,980
0.00	0.00	0.00	736	39.6	939
0.00	0.00	0.00	1,100	880	2,040
0.00	0.00	0.00	58.3	610	757
0.00	0.00	0.00	61.9	388	484
0.00	0.00	0.00	3,010	4,470	45,900
0.00	0.00	0.00	0.00	0.00	0.00
26,000	0.00	0.00	0.00	0.00	26,000
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
3,460	0.00	0.00	0.00	0.00	3,460
29,400	0.00	0.00	0.00	0.00	29,400

Table 4.14. Average annual 25-year water budget in acre-feet for base-case scenario with wet climatic conditions, Los Angeles Coastal Plain Ground

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from Palos Verdes Hills
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	3.10	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.934	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.488	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	25.6	0.00	0.00	0.00
Total		0.00	0.00	0.00	30.2	0.00	0.00	0.00
								Flow from Marina Del Rey
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	567	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	567	0.00	0.00
								Flow from Port of Long Beach
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	–0.00022	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	–0.00022	0.00	0.00	0.00

water-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	3.10
0.00	0.00	0.00	0.00	0.00	0.934
0.00	0.00	0.00	0.00	0.00	0.488
0.00	0.00	0.00	0.00	0.00	25.6
0.00	0.00	0.00	0.00	0.00	30.2
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	567
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	567
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	–0.00022
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	–0.00022

Table 4.14. Average annual 25-year water budget in acre-feet for base-case scenario with wet climatic conditions, Los Angeles Coastal Plain Ground

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from San Fernando Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	5,250	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		5,250	0.00	0.00	0.00	0.00	0.00	0.00
								Drains
Dominguez	2	0.00	–1,170	–95.0	–18.9	–342	0.00	0.00
Mesa	3	0.00	–169	0.00	0.00	–1,270	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	–240	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	–1,980	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	–743	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	–2,080	–95	–18.9	–3,830	0.00	0.00
Total net flow		577	3,600	–341	5,510	–2,490	–1,560	–652
								Change in storage
Dominguez	2	–608	706	92.1	213	–1,100	–49.5	–1,330
Mesa	3	233	2,530	–9.49	4140	–664	262	171
Pacific A	4	30.1	512	–4.80	1.24	0.00	0.00	3.20
Pacific	5	28.1	–298	–23.9	242	–767	–6.98	156
Harbor	6	49.8	6.64	–15.1	205	–0.0106	0.00	189
Bent Spring	7	30.2	12.3	–16.9	460	–14.2	–477	5.37
Upper Wilmington A	8	545	39.6	–277	51.2	100	–1,290	88.0
Upper Wilmington B	9	5.51	60.6	–5.89	37.1	–22.9	–9.20	10.8
Lower Wilmington	10	74.5	36.4	–1.60	87.8	8.75	6.77	15.7
Long Beach A	11	–2.40	36.9	–9.29	36.0	3.57	0.0106	–0.799
Long Beach B	12	0.195	–3.81	–32.7	25.8	7.49	0.0575	4.21
Long Beach C	13	191	–34.6	–36.4	9.17	–46.9	1.74	31.8
Total		577	3,600	–341	5,500	–2,490	–1,560	–653

water-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	5,250
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	5,250
–142	0.00	–595	–30.3	–1.98	–2,390
0.00	0.00	0.00	0.00	–8.90	–1,450
0.00	0.00	0.00	0.00	0.00	0.00
–480	–59.6	0.00	–387	0.00	–1,170
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	–1,980
0.00	0.00	0.00	–494	0.00	–494
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	–241	0.00	–241
0.00	0.00	0.00	–22.8	0.00	–766
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
–623	–59.6	–595	–1,180	–10.9	–8,490
775	–6.28	642	13.4	–397	5,670
–94.6	–51.5	–301	47.0	–249	–2,720
–67.9	–80.7	828	0.00	–99.5	7,240
7.61	6.39	9.53	0.00	0.00	565
–5.23	–116	14.3	–89.0	–32.0	–897
–3.31	–9.05	1.09	0.00	–3.91	420
0.191	0.00	30.7	0.00	–0.602	30.7
300	29.7	10.3	–250	–1.91	–650
0.547	1.92	29.6	–3.76	–1.69	103
0.598	3.55	8.10	13.2	–0.507	253
–2.39	23.9	1.60	220	–1.81	305
1.15	6.17	4.68	17.9	–3.14	28.0
639	179	5.03	58.5	–4.68	992
776	–6.42	642	13.7	–398	5,660

Table 4.15. Average annual 25-year water budget in acre-feet for base-case scenario with dry climatic conditions, Los Angeles Coastal Plain Groundw

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Pumping and net interborehole flow out
Dominguez	2	0.00	–8,020	–3,010	–29.0	0.00	0.00	–1.00
Mesa	3	0.00	–8,360	–3,290	–1,190	–299	0.00	–2,560
Pacific A	4	0.00	–28,100	–7,710	0.00	0.00	0.00	–832
Pacific	5	0.00	–26,700	–26,700	–5,240	–626	–280	–4,620
Harbor	6	0.00	–34,700	–10,000	–11,100	0.00	0.00	–1,020
Bent Spring	7	0.00	–11,300	–2,260	–4,420	–7,370	–1,260	–3,710
Upper Wilmington A	8	–1,190	–18,600	–3,960	–14,600	–133	–1,560	–4,520
Upper Wilmington B	9	0.00	–7,200	–542	–1,840	–319	–25.0	–655
Lower Wilmington	10	0.00	–2,410	0.00	–5,810	–207	0.00	–650
Long Beach A	11	0.00	–551	0.00	–707	0.00	0.00	–6.00
Long Beach B	12	0.00	–239	0.00	–115	0.00	0.00	–98.0
Long Beach C	13	0.00	0.00	0.00	0.00	–2.00	0.00	–13.0
Total		–1,190	–146,000	–57,400	–45,100	–8,950	–3,130	–18,700
								Net flow from adjacent inland zones
Dominguez	2	–582	12,200	–2,260	45.1	19.6	–100	22.6
Mesa	3	–1,010	25,800	–313	1,120	–304	–1,050	3,390
Pacific A	4	–94.4	7,880	1,880	–43.3	0.00	0.00	–921
Pacific	5	–3,040	21,500	9,120	–437	209	–87.2	3,260
Harbor	6	–328	21,100	1,830	–716	–12.2	0.00	–856
Bent Spring	7	–789	12,500	700	–25.2	288	–883	1,030
Upper Wilmington A	8	–1,870	7,730	–475	1,340	–1,410	73.3	5,140
Upper Wilmington B	9	–165	3,720	–2,170	–202	219	–3.41	243
Lower Wilmington	10	–64.4	3,600	–357	1,410	–196	–0.334	485
Long Beach A	11	–0.374	741	13.3	788	–139	–0.0158	42.0
Long Beach B	12	34.8	919	–231	524	–85.3	3.23	–12.0
Long Beach C	13	–615	1,870	117	1,040	–307	–0.0376	53.6
Total		–8,530	120,000	7,860	4,850	–1,720	–2,040	11,900
								Water spreading
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

water-flow Model.

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	–397	0.00	0.00	0.00	–36.8	–11,500
	–5,560	–22.0	0.00	0.00	–205	–21,500
	–2,870	0.00	0.00	0.00	0.00	–39,500
	–17,300	–14.2	–1.99	0.00	–3,870	–85,300
	–8,050	–5.83	0.00	0.00	–1,120	–66,000
	–2,650	0.00	–16.3	0.00	–96.3	–33,100
	–4,590	0.00	0.00	0.00	–322	–49,500
	–392	–0.777	0.00	0.00	0.00	–11,000
	–446	–163	0.00	–135	0.00	–9,820
	–230	0.00	0.00	0.00	0.00	–1,490
	–193	0.00	0.00	0.00	0.00	–645
	–4,080	0.00	0.00	0.00	0.00	–4,090
	–46,700	–206	–18.3	–135	–5,660	–333,000
	–11,800	–78.3	92.2	6.05	2,460	–2.05E–11
	–28,700	–715	799	0.00	928	2.80E–11
	–7,570	–289	–845	0.00	0.00	–2.59E–11
	–24,900	–448	–591	–660	–3,890	4.23E–11
	–18,100	–97.8	–257	0.00	–2,590	–5.37E–11
	–13,700	0.00	827	0.00	–34.6	1.72E–11
	–8,130	–292	–259	–719	–1,120	7.05E–12
	–1,440	261	–195	–322	61.6	5.68E–14
	–4,120	60.8	–238	–456	–125	–1.49E–11
	258	–65.0	–1.36	–1,140	–502	1.25E–12
	–311	–194	4.22	–167	–486	–4.83E–12
	–1,050	–941	–36.8	–94.0	–42.0	–1.05E–11
	–120,000	–2,800	–701	–3,550	–5,340	–6.55E–11
	80,100	0.00	0.00	0.00	0.00	80,100
	40,700	0.00	0.00	0.00	0.00	40,700
	0.00	0.00	0.00	0.00	0.00	0.00
	1,850	0.00	0.00	0.00	0.00	1,850
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	123,000	0.00	0.00	0.00	0.00	123,000

Table 4.15. Average annual 25-year water budget in acre-feet for base-case scenario with dry climatic conditions, Los Angeles Coastal Plain Groundw

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Injection and net interborehole flow in
Dominguez	2	0.00	4.13	0.00252	35.5	0.00	0.00	0.000261
Mesa	3	0.00	742	238	1,690	0.000164	0.00	0.00
Pacific A	4	0.00	2,190	2,480	0.00	0.00	0.00	29.0
Pacific	5	0.00	7,390	2,030	8,060	0.0247	0.00	1,170
Harbor	6	0.00	2,000	81.5	5,250	0.00	0.00	1,370
Bent Spring	7	0.00	979	0.00	9,500	241	44.1	724
Upper Wilmington A	8	1,190	980	0.844	1,190	0.00	14.1	50.4
Upper Wilmington B	9	0.00	444	4.44	95.1	0.610	0.00	14.8
Lower Wilmington	10	0.00	63.0	0.00	93.0	0.00	0.00	32.3
Long Beach A	11	0.00	2.82	0.00	0.00	0.00	0.00	0.00126
Long Beach B	12	0.00	0.380	0.00	0.00	0.00	0.00	0.0128
Long Beach C	13	0.00	0.00	0.00	0.00	0.112	0.00	0.00
Total		1,190	14,800	4,830	25,900	241	58.2	3,390
								Areal recharge
Dominguez	2	1,130	7,810	2,740	1,070	1,470	1,760	1,340
Mesa	3	1,650	3,350	19.9	8,840	6,290	1,010	38.1
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	294	34.2	709	925	0.0392	0.00
Harbor	6	189	2.99	0.00	240	0.00	0.00	177
Bent Spring	7	14.7	0.00	0.00	815	6.40	0.00	0.00
Upper Wilmington A	8	0.00	25.2	7.05	139	64.2	0.00	31.7
Upper Wilmington B	9	0.00	0.00	0.00	16.6	8.94	0.00	0.00
Lower Wilmington	10	0.00	19.3	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	4.99	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	211	94.8	0.00	93.8	3.08	0.00	126
Total		3,200	11.600	2.800	11,900	8,760	2,770	1,710
								Flow from Santa Monica Bay
Dominguez	2	0.00	0.00	0.00	0.00	0.00114	0.00	0.00
Mesa	3	0.00	0.00	0.00	–48.8	–220	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	–15.8	–21.7	0.00	0.00
Harbor	6	0.00	0.00	0.00	–17.4	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	95.3	66.9	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	–16.3	194	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	–51.7	–4.75	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	145	–30.4	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	–3.36	–16.1	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	1.62	–9.02	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	4.90	12	0.00	0.00
Total		0.00	0.00	0.00	93.8	–28.6	0.00	0.00

water-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	8.23E-05	0.00	0.00	0.00	0.00	39.6
	113	0.00	1.14	0.00	1,130	3,910
	686	0.00	0.00	0.00	0.00	5,380
	226	0.00	0.558	0.00	1,190	20,100
	656	0.00126	12.7	0.00	1,640	11,000
	35.9	0.00	0.764	0.00	1.34	11,500
	250	10.7	0.00	15.6	69.1	3,770
	3.45	0.849	0.00	17.0	0.00	580
	27.9	0.747	0.00	0.00	0.00	217
	0.014	62.2	0.00	102	0.00	167
	21.0	73.5	0.00	0.00	0.00	94.9
	5,000	0.00	0.00	0.00	0.00	5,000
	7,020	148	15.1	135	4,040	61,800
	1,960	258	431	23.5	410	20,400
	969	336	778	0.00	198	23,500
	0.00	0.00	0.00	0.00	0.00	0.00
	198	428	178	696	0.000584	3,460
	1.35	0.00	0.00	0.00	0.00	610
	0.00	0.00	0.00	0.00	0.00	837
	172	39.5	0.00	176	0.00	654
	0.00	0.00	0.00	0.00	0.00	25.5
	0.00	21.4	0.00	60.5	0.00	101
	24.3	1.09	0.00	56.4	0.00	86.8
	6.05	0.00	0.00	0.00	0.00	6.05
	1,220	1,080	55.3	116	0.00	3,000
	4,550	2,160	1,440	1,130	608	52,700
	0.00	0.00	0.00	0.00	0.00	0.00114
	0.00	0.00	0.00	0.00	0.00	–268
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	–37.6
	0.00	0.00	0.00	0.00	0.00	–17.4
	0.00	0.00	0.00	0.00	0.00	162
	0.00	0.00	0.00	0.00	0.00	178
	0.00	0.00	0.00	0.00	0.00	–56.4
	0.00	0.00	0.00	0.00	0.00	115
	0.00	0.00	0.00	0.00	0.00	–19.5
	0.00	0.00	0.00	0.00	0.00	–7.41
	0.00	0.00	0.00	0.00	0.00	16.8
	0.00	0.00	0.00	0.00	0.00	65.2

Table 4.15. Average annual 25-year water budget in acre-feet for base-case scenario with dry climatic conditions, Los Angeles Coastal Plain Groundw

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Flow from San Pedro Bay
Dominguez	2	0.00	0.00	0.00	200	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	7.92	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	772	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	823	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	293	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	150	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	1,650	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	316	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	319	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	80.9	0.00	0.00	0.00
Total		0.00	0.00	0.00	4,610	0.00	0.00	0.00
								Underflow from Orange County
Dominguez	2	0.00	0.00	4,910	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	1,380	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	3,360	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	14,000	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	6,970	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	970	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	7,000	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	2,710	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	179	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	56.4	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	91.5	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	35.2	0.00	0.00	0.00	0.00
Total		0.00	0.00	41,700	0.00	0.00	0.00	0.00
								Underflow from San Gabriel Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

water-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
0.00	0.00	0.00	0.00	26.4	227
0.00	0.00	0.00	0.00	125	133
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	219	991
0.00	0.00	0.00	0.00	690	1,510
0.00	0.00	0.00	0.00	60.5	354
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	150
0.00	0.00	0.00	0.00	47.3	1,690
0.00	0.00	0.00	0.00	–353	–36.9
0.00	0.00	0.00	0.00	–102	217
0.00	0.00	0.00	0.00	–329	–248
0.00	0.00	0.00	0.00	384	4,990
0.00	0.00	0.00	0.00	72.7	4,980
0.00	0.00	0.00	0.00	399	1,780
0.00	0.00	0.00	0.00	0.00	3,360
0.00	0.00	0.00	–46.8	1,180	15,200
0.00	0.00	0.00	0.00	671	7,640
0.00	0.00	0.00	0.00	77.9	1,050
0.00	0.00	0.00	899	1,320	9,220
0.00	0.00	0.00	284	–51.6	2,950
0.00	0.00	0.00	751	36.6	967
0.00	0.00	0.00	1,180	882	2,110
0.00	0.00	0.00	68.5	630	790
0.00	0.00	0.00	79.2	389	503
0.00	0.00	0.00	3,210	5,610	50,500
0.00	0.00	0.00	0.00	0.00	0.00
27,000	0.00	0.00	0.00	0.00	27,000
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
3,200	0.00	0.00	0.00	0.00	3,200
30,200	0.00	0.00	0.00	0.00	30,200

Table 4.15. Average annual 25-year water budget in acre-feet for base-case scenario with dry climatic conditions, Los Angeles Coastal Plain Groundw

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from Palos Verdes Hills
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	3.15	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.947	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.494	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	25.8	0.00	0.00	0.00
Total		0.00	0.00	0.00	30.4	0.00	0.00	0.00
								Flow from Marina Del Rey
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	659	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	659	0.00	0.00
								Flow from Port of Long Beach
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	–0.00017	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	–0.00017	0.00	0.00	0.00

water-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	0.00	0.00

Table 4.15. Average annual 25-year water budget in acre-feet for base-case scenario with dry climatic conditions, Los Angeles Coastal Plain Groundw

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from San Fernando Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	5,330	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		5,330	0.00	0.00	0.00	0.00	0.00	0.00
								Drains
Dominguez	2	0.00	–666	–55.8	–9.70	–333	0.00	0.00
Mesa	3	0.00	–168	0.00	0.00	–957	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	–267	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	–1,550	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	–737	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	–1,570	–55.8	–9.70	–3,110	0.00	0.00
Total net flow		–3.05	–1,760	–308	2,320	–4,140	–2,340	–1,710
								Change in storage
Dominguez	2	–788	–2,050	150	1.12	–1,350	–138	–1,790
Mesa	3	72.6	431	–7.85	1,780	–1,210	–310	–201
Pacific A	4	25.7	416	–3.01	1.23	0.00	0.00	1.57
Pacific	5	16.0	–428	–20.4	–39.8	–1,510	–15.7	87.5
Harbor	6	16.2	–18.7	–14.3	119	–0.0193	0.00	115
Bent Spring	7	10.2	–10.5	–15.1	322	–32.2	–534	3.61
Upper Wilmington A	8	467	–0.84	–290	24.9	68.5	–1,340	62.5
Upper Wilmington B	9	5.17	11.3	–6.05	17.2	–32.6	–9.52	7.03
Lower Wilmington	10	44.8	12.5	–3.25	71.5	–5.42	3.78	11.2
Long Beach A	11	–3.72	16.5	–13.3	21.0	0.508	0.00574	–4.09
Long Beach B	12	–0.590	–41.7	–40.3	15.9	2.18	0.00989	–2.04
Long Beach C	13	131	–95.9	–45.2	–16.8	–68.6	–0.238	0.746
Total		–3.20	–1,760	–308	2,320	–4,140	–2,340	–1,710

water-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	5,330
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	5,330
	–146	0.00	–541	–20.9	–2.26	–1,780
	0.00	0.00	0.00	0.00	–10.7	–1,140
	0.00	0.00	0.00	0.00	0.00	0.00
	–356	–19.7	0.00	–275	0.00	–918
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	–1,550
	0.00	0.00	0.00	–445	0.00	–445
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	–224	0.00	–224
	0.00	0.00	0.00	–37	0.00	–774
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	–502	–19.7	–541	–1,000	–12.9	–6,820
	–2,330	–714	196	–208	–370	–11,400
	–1,410	–74.6	–362	45.6	–257	–8,030
	–1,100	–368	490	0.00	–73.6	–495
	–10.4	–6.09	7.67	0.00	0.00	433
	–95.2	–211	3.83	–172	–23.0	–2,410
	–30.6	–55.3	0.746	0.00	–3.16	129
	–0.958	0.00	20.5	0.00	–0.362	–237
	131	13.2	8.94	–305	–1.33	–1,160
	–1.98	1.78	19.4	–5.72	–1.77	4.19
	–3.15	0.101	6.19	1.80	–1.15	139
	–23.0	23.2	0.0887	215	–1.37	231
	–19.7	1.12	1.50	6.03	–3.26	–80.8
	240	–39.4	–0.629	7.16	–5.05	107
	–2,330	–714	196	–208	–371	–11,400

Table 4.16. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with wet climatic conditions, Los Angeles Coastal Pla

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Pumping and net interborehole flow out
Dominguez	2	0.00	–8,360	–3,060	–41.0	0.00	0.00	–1.00
Mesa	3	0.00	–8,990	–3,380	–1,270	–301	0.00	–2,710
Pacific A	4	0.00	–31,800	–7,660	0.00	0.00	0.00	–844
Pacific	5	0.00	–28,700	–26,700	–8,720	–631	–298	–4,730
Harbor	6	0.00	–37,800	–9,940	–15,000	0.00	0.00	–1,010
Bent Spring	7	0.00	–15,100	–2,270	–6,490	–7,360	–1,250	–3,710
Upper Wilmington A	8	–1,240	–20,600	–3,960	–21,800	–132	–1,550	–5,390
Upper Wilmington B	9	0.00	–7,950	–547	–1,870	–320	–25.0	–655
Lower Wilmington	10	0.00	–2,990	0.00	–6,570	–210	0.00	–654
Long Beach A	11	0.00	–722	0.00	–724	0.00	0.00	–8.00
Long Beach B	12	0.00	–253	0.00	–116	0.00	0.00	–99.0
Long Beach C	13	0.00	0.00	0.00	0.00	–1.00	0.00	–21.0
Total		–1,240	–163,000	–57,500	–62,600	–8,960	–3,130	–19,800
								Net flow from adjacent inland zones
Dominguez	2	–592	12,600	–2,510	10.7	19.2	–110	68.7
Mesa	3	–1,230	27,000	–382	1,340	–377	–1,030	3,740
Pacific A	4	–181	9,750	1,830	–69.4	0.00	0.00	–1,760
Pacific	5	–3,080	23,200	8,930	–583	147	–76.9	4,160
Harbor	6	–404	23,600	1,320	–763	–18.1	0.00	–1,480
Bent Spring	7	–886	14,600	360	261	301	–978	823
Upper Wilmington A	8	–1,990	8,180	–1,060	2,770	–2,290	29.1	6,000
Upper Wilmington B	9	–170	4,450	–2,990	74.5	202	–6.43	253
Lower Wilmington	10	–122	3,760	–443	1,980	–267	–4.08	478
Long Beach A	11	–0.459	787	14.9	942	–178	–0.0199	45.4
Long Beach B	12	35.8	1,280	–264	572	–114	4.00	–24.9
Long Beach C	13	–659	2,150	115	1,250	–445	–1.71	52.6
Total		–9,280	131,000	4,920	7,780	–3,020	–2,180	12,300
								Water spreading
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

in Groundwater-flow Model.

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
–424	0.00	0.00	0.00	–39.0	–11,900
–5,640	–22.0	0.00	0.00	–209	–22,500
–2,880	0.00	0.00	0.00	0.00	–43,100
–18,000	–20.0	–4.00	0.00	–3,970	–91,700
–8,080	–6.00	0.00	0.00	–1,090	–72,900
–2,630	0.00	–18.0	0.00	–107	–39,000
–5,340	0.00	0.00	0.00	–337	–60,400
–392	–1.00	0.00	0.00	0.00	–11,800
–447	–161	0.00	–137	0.00	–11,200
–233	0.00	0.00	0.00	0.00	–1,690
–194	0.00	0.00	0.00	0.00	–661
–4,100	0.00	0.00	0.00	0.00	–4,120
–48,300	–210	–22.0	–137	–5,750	–371,000
–12,000	–103	105	7.28	2,550	–1.41E–11
–30,200	–733	876	0.00	1,000	–3.51E–11
–8,230	–299	–1,040	0.00	0.00	2.71E–11
–27,000	–473	–606	–701	–3,830	–3.00E–11
–19,100	–78.7	–342	0.00	–2,730	–1.46E–11
–15,300	0.00	852	0.00	–43.3	1.98E–12
–9,020	–321	–234	–716	–1,340	–2.80E–11
–1,580	260	–223	–321	55.0	–1.26E–11
–4,520	44.6	–267	–445	–200	3.81E–12
257	–71.6	–1.07	–1,120	–675	–1.14E–12
–338	–208	2.92	–175	–768	–4.66E–12
–1,130	–1,090	–50.9	–43.9	–152	–4.09E–12
–128,000	–3,070	–925	–3,510	–6,140	–1.47E–10
85,300	0.00	0.00	0.00	0.00	85,300
43,700	0.00	0.00	0.00	0.00	43,700
0.00	0.00	0.00	0.00	0.00	0.00
2,010	0.00	0.00	0.00	0.00	2,010
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
131,000	0.00	0.00	0.00	0.00	131,000

Table 4.16. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with wet climatic conditions, Los Angeles Coastal Pla

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Injection and net interborehole flow in
Dominguez	2	0.00	1.18	0.00268	33.1	0.00	0.00	0.000259
Mesa	3	0.00	759	238	1,630	9.51E–05	0.00	0.00
Pacific A	4	0.00	2,400	2,560	0.00	0.00	0.00	33.3
Pacific	5	0.00	7,760	2,030	8,080	0.0343	0.00	1,260
Harbor	6	0.00	2,160	97.6	5,340	0.00	0.00	1,370
Bent Spring	7	0.00	1,310	0.00	9,760	245	48.0	758
Upper Wilmington A	8	1,240	1,120	0.968	1,790	0.00	14.3	62.9
Upper Wilmington B	9	0.00	502	0.0913	95.2	0.00	0.00	15.7
Lower Wilmington	10	0.00	47.9	0.00	107	0.00	0.00	30.7
Long Beach A	11	0.00	2.96	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.254	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	1.06	0.00	0.00
Total		1,240	16,100	4,930	26,800	246	62.3	3,530
								Areal recharge
Dominguez	2	1,450	10,400	3,740	1,430	1,780	2,210	1,720
Mesa	3	2,100	4,390	34.4	11,400	8,160	1,330	51.5
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	399	60.0	923	1,180	0.0782	0.00
Harbor	6	254	4.88	0.00	309	0.00	0.00	224
Bent Spring	7	19.0	0.00	0.00	1,030	9.73	0.00	0.00
Upper Wilmington A	8	0.00	36.1	11.8	170	82.7	0.00	44.4
Upper Wilmington B	9	0.00	0.00	0.00	21.5	12.2	0.00	0.00
Lower Wilmington	10	0.00	26.4	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	8.83	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	265	126	0.00	121	4.04	0.00	159
Total		4,090	15,400	3,840	15,400	11,200	3,540	2,200
								Flow from Santa Monica Bay
Dominguez	2	0.00	0.00	0.00	0.00	0.00115	0.00	0.00
Mesa	3	0.00	0.00	0.00	–75.3	–291	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	73.8	–33.7	0.00	0.00
Harbor	6	0.00	0.00	0.00	–2.31	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	395	–89.8	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	–1.51	128	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	–51.8	–13.2	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	188	–42.4	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	–2.89	–16.6	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	6.94	–7.74	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	15.6	26.8	0.00	0.00
Total		0.00	0.00	0.00	545	–340	0.00	0.00

in Groundwater-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
7.29E–05	0.00	0.00	0.00	0.00	34.2
121	0.00	1.27	0.00	1,130	3,880
719	0.00	0.00	0.00	0.00	5,720
236	0.00	0.0582	0.00	1,180	20,500
703	0.00132	16.7	0.00	1,750	11,400
38.6	0.00	0.925	0.00	2.66	12,200
266	11.7	0.00	14.5	56.2	4,570
3.76	0.926	0.00	16.6	0.00	634
29.2	0.815	0.00	0.00	0.00	215
0.0153	65.1	0.00	106	0.00	174
21.4	73.1	0.00	0.00	0.00	94.8
5,000	0.00	0.00	0.00	0.00	5,000
7,140	152	18.9	137	4,120	64,500
2,620	353	540	33.5	547	26,800
1,300	465	989	0.00	273	30,500
0.00	0.00	0.00	0.00	0.00	0.00
251	594	218	999	0.00219	4,620
2.13	0.00	0.00	0.00	0.00	793
0.00	0.00	0.00	0.00	0.00	1,060
220	65.7	0.00	270	0.00	901
0.00	0.00	0.00	0.00	0.00	33.7
0.00	30.8	0.00	95.4	0.00	153
30.6	2.19	0.00	85.6	0.00	127
7.98	0.00	0.00	0.00	0.00	7.98
1,510	1,430	73.8	147	0.00	3,830
5,940	2,940	1,820	1,630	820	68,900
0.00	0.00	0.00	0.00	0.00	0.00115
0.00	0.00	0.00	0.00	0.00	–367
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	40.2
0.00	0.00	0.00	0.00	0.00	–2.31
0.00	0.00	0.00	0.00	0.00	305
0.00	0.00	0.00	0.00	0.00	127
0.00	0.00	0.00	0.00	0.00	–65
0.00	0.00	0.00	0.00	0.00	146
0.00	0.00	0.00	0.00	0.00	–19.5
0.00	0.00	0.00	0.00	0.00	–0.797
0.00	0.00	0.00	0.00	0.00	42.4
0.00	0.00	0.00	0.00	0.00	206

Table 4.16. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with wet climatic conditions, Los Angeles Coastal Pla

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Flow from San Pedro Bay
Dominguez	2	0.00	0.00	0.00	330	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	21.4	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	1,420	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	1,430	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	606	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	241	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	1,880	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	368	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	395	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	139	0.00	0.00	0.00
Total		0.00	0.00	0.00	6,830	0.00	0.00	0.00
								Underflow from Orange County
Dominguez	2	0.00	0.00	3,990	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	1,540	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	3,270	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	14,200	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	7,340	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	1,200	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	7,810	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	3,550	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	255	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	60.7	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	103	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	39.5	0.00	0.00	0.00	0.00
Total		0.00	0.00	43,300	0.00	0.00	0.00	0.00
								Underflow from San Gabriel Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

in Groundwater-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	27.1	357
	0.00	0.00	0.00	0.00	147	168
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	279	1,700
	0.00	0.00	0.00	0.00	856	2,290
	0.00	0.00	0.00	0.00	64.0	670
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	241
	0.00	0.00	0.00	0.00	87.3	1,970
	0.00	0.00	0.00	0.00	–372	–3.98
	0.00	0.00	0.00	0.00	–111	284
	0.00	0.00	0.00	0.00	–347	–208
	0.00	0.00	0.00	0.00	631	7,460
	0.00	0.00	0.00	0.00	94.2	4,080
	0.00	0.00	0.00	0.00	584	2,130
	0.00	0.00	0.00	0.00	0.00	3,270
	0.00	0.00	0.00	–74.7	542	14,600
	0.00	0.00	0.00	0.00	404	7,740
	0.00	0.00	0.00	0.00	84.1	1,280
	0.00	0.00	0.00	861	1,590	10,300
	0.00	0.00	0.00	275	–25.4	3,790
	0.00	0.00	0.00	739	49.7	1,040
	0.00	0.00	0.00	1,110	1,090	2,260
	0.00	0.00	0.00	60.6	907	1,070
	0.00	0.00	0.00	64.6	518	622
	0.00	0.00	0.00	3,030	5,840	52,200
	0.00	0.00	0.00	0.00	0.00	0.00
	28,300	0.00	0.00	0.00	0.00	28,300
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	3,820	0.00	0.00	0.00	0.00	3,820
	32,100	0.00	0.00	0.00	0.00	32,100

Table 4.16. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with wet climatic conditions, Los Angeles Coastal Pla

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from Palos Verdes Hills
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	3.63	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	1.10	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.583	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	27.0	0.00	0.00	0.00
Total		0.00	0.00	0.00	32.3	0.00	0.00	0.00
								Flow from Marina Del Rey
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	1,210	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	1,210	0.00	0.00
								Flow from Port of Long Beach
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.000212	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.000212	0.00	0.00	0.00

in Groundwater-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	3.63
0.00	0.00	0.00	0.00	0.00	1.10
0.00	0.00	0.00	0.00	0.00	0.583
0.00	0.00	0.00	0.00	0.00	27.0
0.00	0.00	0.00	0.00	0.00	32.3
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	1,210
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	1,210
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.000212
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.000212

Table 4.16. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with wet climatic conditions, Los Angeles Coastal Pla

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from San Fernando Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	5,330	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		5,330	0.00	0.00	0.00	0.00	0.00	0.00
								Drains
Dominguez	2	0.00	–425	–34.9	–6.39	–329	0.00	0.00
Mesa	3	0.00	–136	0.00	0.00	–1,260	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	–203	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	–1,960	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	–723	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	–1,280	–34.9	–6.39	–3,760	0.00	0.00
Total net flow		136	–1,760	–558	–5,170	–3,400	–1,710	–1,750
								Change in storage
Dominguez	2	–653	–1,380	–41.5	–303	–1,320	–53.8	–1,720
Mesa	3	158	321	–12.1	–3,780	–785	243	–235
Pacific A	4	22.0	283	–5.38	1.13	0.00	0.00	1.06
Pacific	5	11.5	–588	–25.8	–840	–1,120	–8.72	53.1
Harbor	6	18.2	–41.3	–17.9	–96.2	–0.0238	0.00	100
Bent Spring	7	20.2	–31.8	–21.7	130	–25.5	–503	2.72
Upper Wilmington A	8	426	–39.9	–301	–49.8	61.9	–1,370	45.6
Upper Wilmington B	9	4.53	–46.9	–7.59	–62.5	–66.4	–9.73	5.02
Lower Wilmington	10	–12.0	–5.61	–5.06	–7.63	–23.7	0.931	7.50
Long Beach A	11	–5.69	–8.09	–15.9	–39.6	–1.93	0.00312	–7.77
Long Beach B	12	–1.36	–79.9	–49.2	–22.4	–2.75	–0.0125	–8.11
Long Beach C	13	147	–134	–53.9	–105	–108	–1.89	6.64
Total		136	–1,750	–557	–5,170	–3,400	–1,710	–1,750

in Groundwater-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	5,330
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	5,330
	–73.6	0.00	–581	–30.1	–1.98	–1,480
	0.00	0.00	0.00	0.00	–3.16	–1,400
	0.00	0.00	0.00	0.00	0.00	0.00
	–350	–51.4	0.00	–385	0.00	–990
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	–1,960
	0.00	0.00	0.00	–488	0.00	–488
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	–239	0.00	–239
	0.00	0.00	0.00	–18.0	0.00	–741
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	–423	–51.4	–581	–1,160	–5.14	–7,300
	–825	–242	311	–9.13	–483	–15,400
	–740	–60.9	–318	46.9	–305	–6,850
	–646	–207	564	0.00	–114	–4,490
	–5.13	–1.72	6.75	0.00	0.00	302
	–58.1	–135	8.66	–90.5	–35.0	–2,830
	–18.9	–33.5	0.692	0.00	–4.65	–93.5
	–0.845	0.00	24.9	0.00	–0.772	–406
	106	24.2	9.06	–256	–2.7	–1,350
	–1.34	1.85	16.7	–3.94	–2.09	–172
	–2.14	2.91	4.20	12.4	–2.18	–30.5
	–18.4	23.3	–1.09	217	–3.59	139
	–9.81	4.32	–0.499	14.7	–5.89	–161
	573	139	–4.18	49.9	–7.49	501
	–823	–242	311	–8.80	–484	–15,400

Table 4.17. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with dry climatic conditions, Los Angeles Coastal Plai

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Pumping and net interborehole flow out
Dominguez	2	0.00	–8,200	–3,040	–38.0	0.00	0.00	–0.987
Mesa	3	0.00	–8,920	–3,310	–1,260	–300	0.00	–2,600
Pacific A	4	0.00	–31,700	–7,710	0.00	0.00	0.00	–846
Pacific	5	0.00	–28,700	–26,700	–8,710	–629	–279	–4,730
Harbor	6	0.00	–37,800	–9,930	–15,000	0.00	0.00	–1,010
Bent Spring	7	0.00	–15,100	–2,260	–6,490	–7,360	–1,260	–3,700
Upper Wilmington A	8	–1,250	–20,600	–3,950	–21,800	–132	–1,560	–5,400
Upper Wilmington B	9	0.00	–7,910	–544	–1,870	–320	–25.2	–658
Lower Wilmington	10	0.00	–3,000	0.00	–6,570	–212	0.00	–657
Long Beach A	11	0.00	–738	0.00	–724	0.00	0.00	–7.81
Long Beach B	12	0.00	–255	0.00	–116	0.00	0.00	–99.4
Long Beach C	13	0.00	0.00	0.00	0.00	–2.00	0.00	–22.5
Total		–1,250	–163,000	–57,500	–62,600	–8,960	–3,130	–19,700
								Net flow from adjacent inland zones
Dominguez	2	–560	12,000	–2,780	14.6	19.2	–98.6	–53.8
Mesa	3	–1,050	25,200	–458	1,260	–306	–1,030	3,330
Pacific A	4	–176	9,800	1,460	–69.7	0.00	0.00	–1,750
Pacific	5	–3,020	23,500	8,030	–580	126	–81.2	4,060
Harbor	6	–362	23,800	914	–748	–18.4	0.00	–1,480
Bent Spring	7	–867	14,500	122	248	287	–962	821
Upper Wilmington A	8	–2,050	8,240	–1,120	2,770	–2,300	–2.71	5,980
Upper Wilmington B	9	–169	4,400	–2,970	55.4	197	–6.66	261
Lower Wilmington	10	–150	3,700	–464	1,970	–267	–7.65	481
Long Beach A	11	–0.472	809	15.5	932	–179	–0.0191	43.3
Long Beach B	12	33.1	1,310	–272	560	–119	3.67	–26.8
Long Beach C	13	–667	2,100	101	1,250	–462	–3.93	53.7
Total		–9,030	129,000	2,580	7,660	–3,030	–2,190	11,700
								Water spreading
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

n Groundwater-flow Model.

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
–389	0.00	0.00	0.00	–39.1	–11,700
–5,590	–20.4	0.00	0.00	–207	–22,200
–2,880	0.00	0.00	0.00	0.00	–43,100
–18,000	–16.8	–3.54	0.00	–4,010	–91,800
–8,080	–7.54	0.00	0.00	–1,130	–73,000
–2,630	0.00	–17.8	0.00	–96.2	–39,000
–5,350	0.00	0.00	0.00	–281	–60,300
–392	–0.557	0.00	0.00	0.00	–11,700
–447	–164	0.00	–135	0.00	–11,200
–234	0.00	0.00	0.00	0.00	–1,700
–196	0.00	0.00	0.00	0.00	–667
–4,100	0.00	0.00	0.00	0.00	–4,120
–48,300	–209	–21.4	–135	–5,760	–371,000
–11,000	–85.2	86.7	6.12	2,430	2.96E–11
–27,800	–832	730	0.00	949	–7.17E–11
–7,960	–284	–1,030	0.00	0.00	9.78E–12
–26,400	–464	–576	–658	–3,980	–7.96E–11
–18,500	–128	–343	0.00	–3,050	9.64E–11
–14,900	0.00	826	0.00	–44.5	–4.55E–11
–8,810	–305	–214	–739	–1,450	7.28E–12
–1,540	266	–228	–329	56.1	–2.19E–11
–4,370	51.9	–262	–463	–213	1.02E–11
286	–66.2	–0.950	–1,150	–689	–9.09E–13
–324	–201	7.14	–175	–795	–2.05E–12
–1,080	–973	–47.4	–104	–165	–1.99E–12
–122,000	–3,020	–1,050	–3,610	–6,950	–4.91E–11
80,100	0.00	0.00	0.00	0.00	80,100
40,700	0.00	0.00	0.00	0.00	40,700
0.00	0.00	0.00	0.00	0.00	0.00
1,850	0.00	0.00	0.00	0.00	1,850
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
123,000	0.00	0.00	0.00	0.00	123,000

Table 4.17. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with dry climatic conditions, Los Angeles Coastal Plai

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Injection and net interborehole flow in
Dominguez	2	0.00	0.178	0.00265	33.1	0.00	0.00	0.000297
Mesa	3	0.00	757	243	1,630	0.000162	0.00	0.00
Pacific A	4	0.00	2,370	2,510	0.00	0.00	0.00	34
Pacific	5	0.00	7,600	2,030	8,080	0.0275	0.00	1,210
Harbor	6	0.00	2,120	100	5,340	0.00	0.00	1,320
Bent Spring	7	0.00	1,310	0.00	9,760	244	43.8	758
Upper Wilmington A	8	1,250	1,120	0.922	1,780	0.00	14.1	63.3
Upper Wilmington B	9	0.00	501	0.261	94	0.00	0.00	15.3
Lower Wilmington	10	0.00	45.3	0.00	106	0.00	0.00	28.8
Long Beach A	11	0.00	2.82	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.295	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.248	0.00	0.00
Total		1,250	15,800	4,880	26,800	245	58	3,430
								Areal recharge
Dominguez	2	1,130	7,810	2,740	1,070	1,470	1,760	1,340
Mesa	3	1,650	3,350	19.9	8,840	6,290	1,010	38.1
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	294	34.2	709	925	0.0392	0.00
Harbor	6	189	2.99	0.00	240	0.00	0.00	177
Bent Spring	7	14.7	0.00	0.00	815	6.40	0.00	0.00
Upper Wilmington A	8	0.00	25.2	7.05	139	64.2	0.00	31.7
Upper Wilmington B	9	0.00	0.00	0.00	16.6	8.94	0.00	0.00
Lower Wilmington	10	0.00	19.3	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	4.99	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	211	94.8	0.00	93.8	3.08	0.00	126
Total		3,200	11,600	2,800	11,900	8,760	2,770	1,710
								Flow from Santa Monica Bay
Dominguez	2	0.00	0.00	0.00	0.00	0.00115	0.00	0.00
Mesa	3	0.00	0.00	0.00	–52.4	–284	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	80.0	–33.5	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.941	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	421	–90.5	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	–0.93	130	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	–50.1	–13.1	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	190	–42.4	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	–2.49	–15.5	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	7.89	–6.72	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	17.2	28.8	0.00	0.00
Total		0.00	0.00	0.00	611	–327	0.00	0.00

n Groundwater-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
9.81E–05	0.00	0.00	0.00	0.00	33.3
109	0.00	0.587	0.00	1,130	3,860
696	0.00	0.00	0.00	0.00	5,600
227	0.00	0.137	0.00	1,180	20,300
679	0.00134	16.6	0.00	1,740	11,300
36.7	0.00	0.887	0.00	4.43	12,200
255	11.8	0.00	15.6	90.4	4,600
3.63	0.952	0.00	17.1	0.00	632
28.9	0.839	0.00	0.00	0.00	210
0.0151	62.4	0.00	102	0.00	168
21	74.9	0.00	0.00	0.00	96.2
5,000	0.00	0.00	0.00	0.00	5,000
7,060	151	18	135	4,140	64,000
1,960	258	431	23.5	410	20,400
969	336	778	0.00	198	23,500
0.00	0.00	0.00	0.00	0.00	0.00
198	428	178	696	0.000584	3,460
1.35	0.00	0.00	0.00	0.00	610
0.00	0.00	0.00	0.00	0.00	837
172	39.5	0.00	176	0.00	654
0.00	0.00	0.00	0.00	0.00	25.5
0.00	21.4	0.00	60.5	0.00	101
24.3	1.09	0.00	56.4	0.00	86.8
6.05	0.00	0.00	0.00	0.00	6.05
1,220	1,080	55.3	116	0.00	3,000
4,550	2,160	1,440	1,130	608	52,700
0.00	0.00	0.00	0.00	0.00	0.00115
0.00	0.00	0.00	0.00	0.00	–336
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	46.5
0.00	0.00	0.00	0.00	0.00	0.941
0.00	0.00	0.00	0.00	0.00	331
0.00	0.00	0.00	0.00	0.00	129
0.00	0.00	0.00	0.00	0.00	–63.2
0.00	0.00	0.00	0.00	0.00	147
0.00	0.00	0.00	0.00	0.00	–18.0
0.00	0.00	0.00	0.00	0.00	1.16
0.00	0.00	0.00	0.00	0.00	46.0
0.00	0.00	0.00	0.00	0.00	284

Table 4.17. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with dry climatic conditions, Los Angeles Coastal Plai

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Flow from San Pedro Bay
Dominguez	2	0.00	0.00	0.00	362	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	35.7	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	1,560	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	1,530	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	672	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	253	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	1,910	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	372	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	401	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	144	0.00	0.00	0.00
Total		0.00	0.00	0.00	7,230	0.00	0.00	0.00
								Underflow from Orange County
Dominguez	2	0.00	0.00	5,320	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	1,500	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	3,740	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	15,200	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	7,740	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	1,480	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	7,680	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	3,510	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	270	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	61.5	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	105	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	40.6	0.00	0.00	0.00	0.00
Total		0.00	0.00	46,700	0.00	0.00	0.00	0.00
								Underflow from San Gabriel Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

n Groundwater-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	25.8	388
	0.00	0.00	0.00	0.00	131	167
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	218	1,770
	0.00	0.00	0.00	0.00	782	2,310
	0.00	0.00	0.00	0.00	58.3	730
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	253
	0.00	0.00	0.00	0.00	105	2,010
	0.00	0.00	0.00	0.00	–359	13.5
	0.00	0.00	0.00	0.00	–107	294
	0.00	0.00	0.00	0.00	–334	–190
	0.00	0.00	0.00	0.00	519	7,750
	0.00	0.00	0.00	0.00	84.8	5,400
	0.00	0.00	0.00	0.00	441	1,940
	0.00	0.00	0.00	0.00	0.00	3,740
	0.00	0.00	0.00	–46.7	1,390	16,600
	0.00	0.00	0.00	0.00	844	8,580
	0.00	0.00	0.00	0.00	111	1,590
	0.00	0.00	0.00	903	1,570	10,200
	0.00	0.00	0.00	288	–34.9	3,770
	0.00	0.00	0.00	754	46.7	1,070
	0.00	0.00	0.00	1,180	1,090	2,340
	0.00	0.00	0.00	70.8	927	1,100
	0.00	0.00	0.00	82	518	640
	0.00	0.00	0.00	3,240	6,990	56,900
	0.00	0.00	0.00	0.00	0.00	0.00
	29,300	0.00	0.00	0.00	0.00	29,300
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	3,570	0.00	0.00	0.00	0.00	3,570
	32,900	0.00	0.00	0.00	0.00	32,900

Table 4.17. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with dry climatic conditions, Los Angeles Coastal Plai

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from Palos Verdes Hills
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	3.68	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	1.12	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.589	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	27.2	0.00	0.00	0.00
Total		0.00	0.00	0.00	32.5	0.00	0.00	0.00
								Flow from Marina Del Rey
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	1,280	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	1,280	0.00	0.00
								Flow from Port of Long Beach
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.000254	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.000254	0.00	0.00	0.00

n Groundwater-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	3.68
	0.00	0.00	0.00	0.00	0.00	1.12
	0.00	0.00	0.00	0.00	0.00	0.589
	0.00	0.00	0.00	0.00	0.00	27.2
	0.00	0.00	0.00	0.00	0.00	32.5
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1,280
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1,280
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.000254
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.000254

Table 4.17. Average annual 25-year water budget in acre-feet for increased-pumpage scenario with dry climatic conditions, Los Angeles Coastal Plai

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from San Fernando Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	5,400	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		5,400	0.00	0.00	0.00	0.00	0.00	0.00
								Drains
Dominguez	2	0.00	–411	–36.9	–5.53	–308	0.00	0.00
Mesa	3	0.00	–131	0.00	0.00	–955	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	–232	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	–1,540	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	–717	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	–1,260	–36.9	–5.53	–3,030	0.00	0.00
Total net flow		–436	–7,490	–563	–8,320	–5,060	–2,480	–2,860
								Change in storage
Dominguez	2	–819	–4,130	–18.6	–492	–1,550	–140	–2,130
Mesa	3	7.46	–1,950	–10.9	–5,840	–1,330	–327	–700
Pacific A	4	3.07	40.9	–3.63	0.690	0.00	0.00	–0.583
Pacific	5	–4.61	–770	–22.3	–1,340	–1,900	–17.9	–27.5
Harbor	6	–6.98	–68.8	–17.2	–210	–0.0327	0.00	25.0
Bent Spring	7	3.00	–56.5	–20.0	–27.7	–47.9	–560	0.888
Upper Wilmington A	8	344	–84.4	–315	–77.4	24.3	–1,420	14.7
Upper Wilmington B	9	4.20	–99.1	–7.79	–83.0	–75.8	–10.0	1.11
Lower Wilmington	10	–45.1	–30.0	–6.76	–24.2	–37.9	–2.94	2.83
Long Beach A	11	–7.03	–28.9	–20.0	–54.8	–5.01	–0.00182	–11.1
Long Beach B	12	–2.13	–118	–56.9	–32.5	–8.10	–0.0607	–14.4
Long Beach C	13	87.0	–196	–62.8	–131	–130	–4.09	–24.4
Total		–436	–7,490	–562	–8,320	–5,060	–2,480	–2,860

n Groundwater-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	5,400
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	5,400
	–109	0.00	–528	–20.7	–2.26	–1,420
	0.00	0.00	0.00	0.00	–7.48	–1,090
	0.00	0.00	0.00	0.00	0.00	0.00
	–307	–16.8	0.00	–273	0.00	–829
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	–1,540
	0.00	0.00	0.00	–439	0.00	–439
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	–222	0.00	–222
	0.00	0.00	0.00	–30.1	0.00	–748
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	–417	–16.8	–528	–985	–9.74	–6,290
	–3,980	–936	–139	–232	–471	–33,000
	–1,970	–76.7	–375	45.5	–327	–12,000
	–1,790	–476	231	0.00	–90	–12,300
	–23.0	–14.9	1.41	0.00	0.00	3.87
	–150	–233	–3.56	–174	–25.9	–4,670
	–54.3	–85.1	0.319	0.00	–3.94	–421
	–2.03	0.00	8.93	0.00	–0.536	–702
	–79.6	7.04	7.59	–312	–2.14	–1,890
	–3.93	1.71	5.72	–5.98	–2.18	–275
	–5.99	–0.601	0.943	0.833	–2.83	–152
	–39.5	22.6	–2.61	213	–3.16	63.2
	–31.6	–0.58	–3.69	2.80	–6.02	–271
	172	–79.8	–9.85	–1.55	–7.86	–389
	–3,980	–935	–139	–232	–472	–33,000

Table 4.18. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with wet conditions, Los Angeles Coastal P

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Pumping and net interborehole flow out
Dominguez	2	0.00	–8,430	–3,030	–35.0	0.00	0.00	–1.01
Mesa	3	0.00	–9,000	–3,350	–1,210	–301	0.00	–2,940
Pacific A	4	0.00	–31,800	–7,660	0.00	0.00	0.00	–843
Pacific	5	0.00	–28,600	–26,700	–9,150	–625	–299	–4,710
Harbor	6	0.00	–37,900	–9,980	–15,200	0.00	0.00	–1,010
Bent Spring	7	0.00	–15,200	–2,270	–6,500	–7,370	–1,250	–3,720
Upper Wilmington A	8	–1,230	–20,600	–3,960	–21,800	–134	–1,550	–5,400
Upper Wilmington B	9	0.00	–7,870	–543	–1,880	–320	–25.2	–654
Lower Wilmington	10	0.00	–2,980	0.00	–6,490	–205	0.00	–651
Long Beach A	11	0.00	–709	0.00	–717	0.00	0.00	–7.97
Long Beach B	12	0.00	–246	0.00	–113	0.00	0.00	–98.7
Long Beach C	13	0.00	0.00	0.00	0.00	–1.00	0.00	–17.8
Total		–1,230	–163,000	–57,500	–63,100	–8,950	–3,130	–20,100
								Net flow from adjacent inland zones
Dominguez	2	–601	14,100	–1,880	–21.7	19.4	–111	202
Mesa	3	–1,200	30,500	–189	817	–371	–1,040	4,170
Pacific A	4	–213	9,710	2,280	–69.7	0.00	0.00	–1,800
Pacific	5	–3,010	23,000	10,500	–1,270	159	–70.7	4,250
Harbor	6	–388	24,000	2,180	–1,510	–4.15	0.00	–1,500
Bent Spring	7	–867	14,700	783	36.0	336	–953	833
Upper Wilmington A	8	–1,920	8,020	–633	1,500	–1,320	58.2	6,030
Upper Wilmington B	9	–167	4,150	–2,550	–70.5	223	–4.83	260
Lower Wilmington	10	–84.5	4,080	–376	1,630	–223	–1.55	474
Long Beach A	11	–0.432	821	13.7	801	–157	–0.0204	48.5
Long Beach B	12	39.9	1,120	–242	495	–98.5	4.56	–16.0
Long Beach C	13	–626	2,070	128	1,090	–355	0.796	60.9
Total		–9,030	136,000	9,980	3,430	–1,790	–2,120	13,000
								Water spreading
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

lain Groundwater-flow Model.

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	–479	0.00	0.00	0.00	–38.5	–12,000
	–5,720	–39.9	0.00	0.00	–209	–22,800
	–2,880	0.00	0.00	0.00	0.00	–43,200
	–18,000	–16.9	–4.56	0.00	–3,940	–92,000
	–8,080	0.00	0.00	0.00	–1,110	–73,200
	–2,630	0.00	–17.2	0.00	–102	–39,000
	–5,340	0.00	0.00	0.00	–323	–60,400
	–392	–0.853	0.00	0.00	0.00	–11,700
	–448	–161	0.00	–137	0.00	–11,100
	–230	0.00	0.00	0.00	0.00	–1,660
	–191	0.00	0.00	0.00	0.00	–648
	–4,090	0.00	0.00	0.00	0.00	–4,110
	–48,500	–219	–21.7	–137	–5,720	–372,000
	–14,200	–54.4	108	7.18	2,450	9.55E–12
	–33,900	–539	913	0.00	850	–4.38E–11
	–8,590	–331	–984	0.00	0.00	–4.49E–11
	–27,700	–454	–577	–702	–4,040	–7.96E–11
	–19,700	–63.0	–332	0.00	–2,660	–9.64E–11
	–15,700	0.00	834	0.00	–42.0	2.98E–11
	–9,300	–306	–236	–691	–1,210	–1.86E–11
	–1,630	255	–208	–313	56.6	–2.88E–12
	–4,700	55.2	–259	–437	–154	4.35E–12
	206	–68.1	–0.681	–1,100	–565	2.61E–12
	–345	–205	2.37	–169	–589	4.66E–12
	–1,160	–1,070	–38.7	–35.2	–75.3	1.68E–12
	–137,000	–2,780	–778	–3,440	–5,980	–2.66E–10
	95,300	0.00	0.00	0.00	0.00	95,300
	50,600	0.00	0.00	0.00	0.00	50,600
	0.00	0.00	0.00	0.00	0.00	0.00
	2,160	0.00	0.00	0.00	0.00	2,160
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	148,000	0.00	0.00	0.00	0.00	148,000

Table 4.18. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with wet conditions, Los Angeles Coastal P

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Injection and net interborehole flow in
Dominguez	2	0.00	4.90	0.0026	85	0.00	0.00	0.000235
Mesa	3	0.00	1,120	231	4,680	8.54E–05	0.00	0.00
Pacific A	4	0.00	2,400	2,530	0.00	0.00	0.00	31.7
Pacific	5	0.00	8,280	2,020	20,800	0.0305	0.00	1,380
Harbor	6	0.00	2,220	87.3	13,300	0.00	0.00	1,470
Bent Spring	7	0.00	1,300	0.00	17,500	237	48.3	761
Upper Wilmington A	8	1,230	1,100	0.840	2,000	0.00	14.3	59
Upper Wilmington B	9	0.00	503	6.05	133	1.18	0.00	15.5
Lower Wilmington	10	0.00	52.3	0.00	139	0.00	0.00	32.5
Long Beach A	11	0.00	2.95	0.00	0.362	0.00	0.00	0.00
Long Beach B	12	0.00	0.371	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.979	0.00	0.00
Total		1,230	17,000	4,880	58,600	240	62.6	3,750
								Areal recharge
Dominguez	2	1,450	10,400	3,740	1,430	1,780	2,210	1,720
Mesa	3	2,100	4,390	34.4	11,400	8,160	1,330	51.5
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	399	60.0	923	1,180	0.0782	0.00
Harbor	6	254	4.88	0.00	309	0.00	0.00	224
Bent Spring	7	19.0	0.00	0.00	1,030	9.73	0.00	0.00
Upper Wilmington A	8	0.00	36.1	11.8	170	82.7	0.00	44.4
Upper Wilmington B	9	0.00	0.00	0.00	21.5	12.2	0.00	0.00
Lower Wilmington	10	0.00	26.4	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	8.83	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	265	126	0.00	121	4.04	0.00	159
Total		4,090	15,400	3,840	15,400	11,200	3,540	2,200
								Flow from Santa Monica Bay
Dominguez	2	0.00	0.00	0.00	0.00	0.00111	0.00	0.00
Mesa	3	0.00	0.00	0.00	17.3	–122	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	–322	–0.902	0.00	0.00
Harbor	6	0.00	0.00	0.00	–137	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	–418	512	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	–49.6	431	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	–104	5.71	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	204	–28.5	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	–1.69	–15.7	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	3.14	–8.39	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	7.27	15.5	0.00	0.00
Total		0.00	0.00	0.00	–801	789	0.00	0.00

lain Groundwater-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
5.66E–05	0.00	0.00	0.00	0.00	89.9
138	0.00	1.54	0.00	1,640	7,810
756	0.00	0.00	0.00	0.00	5,720
248	0.00	0.0311	0.00	1,660	34,400
735	12.0	16.1	0.00	2,040	19,900
42.1	0.00	0.901	0.00	3.15	19,900
283	10.4	0.00	14.4	63.9	4,770
3.93	0.803	0.00	16.5	0.00	680
29.3	0.705	0.00	0.00	0.00	254
0.0123	64.4	0.00	106	0.00	174
22.4	72.4	0.00	0.00	0.00	95.1
5,000	0.00	0.00	0.00	0.00	5,000
7,260	161	18.6	137	5,420	98,800
2,620	353	540	33.5	547	26,800
1,300	465	989	0.00	273	30,500
0.00	0.00	0.00	0.00	0.00	0.00
251	594	218	999	0.00219	4,620
2.13	0.00	0.00	0.00	0.00	793
0.00	0.00	0.00	0.00	0.00	1,060
220	65.7	0.00	270	0.00	901
0.00	0.00	0.00	0.00	0.00	33.7
0.00	30.8	0.00	95.4	0.00	153
30.6	2.19	0.00	85.6	0.00	127
7.98	0.00	0.00	0.00	0.00	7.98
1,510	1,430	73.8	147	0.00	3,830
5,940	2,940	1,820	1,630	820	68,900
0.00	0.00	0.00	0.00	0.00	0.00111
0.00	0.00	0.00	0.00	0.00	–105
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	–323
0.00	0.00	0.00	0.00	0.00	–137
0.00	0.00	0.00	0.00	0.00	94.0
0.00	0.00	0.00	0.00	0.00	382
0.00	0.00	0.00	0.00	0.00	–97.9
0.00	0.00	0.00	0.00	0.00	175
0.00	0.00	0.00	0.00	0.00	–17.4
0.00	0.00	0.00	0.00	0.00	–5.25
0.00	0.00	0.00	0.00	0.00	22.8
0.00	0.00	0.00	0.00	0.00	–12.2

Table 4.18. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with wet conditions, Los Angeles Coastal P

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Flow from San Pedro Bay
Dominguez	2	0.00	0.00	0.00	9.99	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	–21.4	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	288	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	388	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	–109	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	89.4	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	1,530	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	318	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	313	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	86.1	0.00	0.00	0.00
Total		0.00	0.00	0.00	2,890	0.00	0.00	0.00
								Underflow from Orange County
Dominguez	2	0.00	0.00	3,510	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	1,400	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	2,840	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	12,600	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	6,600	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	806	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	7,310	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	3,090	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	198	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	57.5	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	94.3	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	36.1	0.00	0.00	0.00	0.00
Total		0.00	0.00	38,600	0.00	0.00	0.00	0.00
								Underflow from San Gabriel Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

lain Groundwater-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	26.5	36.5
	0.00	0.00	0.00	0.00	136	114
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	278	566
	0.00	0.00	0.00	0.00	771	1,160
	0.00	0.00	0.00	0.00	67.2	–42.0
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	89.4
	0.00	0.00	0.00	0.00	61.4	1,590
	0.00	0.00	0.00	0.00	–354	–36.2
	0.00	0.00	0.00	0.00	–104	209
	0.00	0.00	0.00	0.00	–341	–255
	0.00	0.00	0.00	0.00	540	3,430
	0.00	0.00	0.00	0.00	79.4	3,590
	0.00	0.00	0.00	0.00	515	1,910
	0.00	0.00	0.00	0.00	0.00	2,840
	0.00	0.00	0.00	–74.8	205	12,800
	0.00	0.00	0.00	0.00	208	6,810
	0.00	0.00	0.00	0.00	58.9	865
	0.00	0.00	0.00	854	1,440	9,600
	0.00	0.00	0.00	270	–34.7	3,320
	0.00	0.00	0.00	735	43.1	976
	0.00	0.00	0.00	1,100	952	2,110
	0.00	0.00	0.00	58.5	730	883
	0.00	0.00	0.00	62.0	434	533
	0.00	0.00	0.00	3,000	4,630	46,200
	0.00	0.00	0.00	0.00	0.00	0.00
	23,100	0.00	0.00	0.00	0.00	23,100
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	3,140	0.00	0.00	0.00	0.00	3,140
	26,300	0.00	0.00	0.00	0.00	26,300

Table 4.18. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with wet conditions, Los Angeles Coastal P

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from Palos Verdes Hills
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	2.92	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.902	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.486	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	25.7	0.00	0.00	0.00
Total		0.00	0.00	0.00	30.0	0.00	0.00	0.00
								Flow from Marina Del Rey
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	137	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	137	0.00	0.00
								Flow from Port of Long Beach
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	–0.00156	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	–0.00156	0.00	0.00	0.00

lain Groundwater-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	2.92
0.00	0.00	0.00	0.00	0.00	0.902
0.00	0.00	0.00	0.00	0.00	0.486
0.00	0.00	0.00	0.00	0.00	25.7
0.00	0.00	0.00	0.00	0.00	30.0
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	137
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	137
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	–0.00156
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	–0.00156

Table 4.18. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with wet conditions, Los Angeles Coastal P

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from San Fernando Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	5,290	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		5,290	0.00	0.00	0.00	0.00	0.00	0.00
								Drains
Dominguez	2	0.00	–1,560	–147	–32.0	–416	0.00	0.00
Mesa	3	0.00	–426	0.00	–1,500	–1,280	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	–299	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	–1,980	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	–750	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	–2,740	–147	–1,540	–3,970	0.00	0.00
Total net flow		348	2,640	–354	14,900	–2,320	–1,650	–1,090
								Change in storage
Dominguez	2	–635	503	103	389	–1,030	–52.0	–1,480
Mesa	3	191	2,040	–9.44	12,700	–628	251	35.1
Pacific A	4	27.8	468	–4.83	1.24	0.00	0.00	2.14
Pacific	5	19.9	–297	–23.9	656	–685	–7.80	102
Harbor	6	32.6	–5.95	–15.7	319	–0.00627	0.00	145
Bent Spring	7	24.6	–5.45	–18.3	719	–12.2	–493	3.92
Upper Wilmington A	8	482	0.0495	–282	33.6	106	–1,340	64.4
Upper Wilmington B	9	4.97	7.33	–6.61	32.5	–21	–9.53	7.81
Lower Wilmington	10	29.8	18.6	–2.89	68.3	9.17	3.96	11.5
Long Beach A	11	–3.94	18.4	–11.8	16.3	2.91	0.00725	–4.04
Long Beach B	12	–0.505	–32.9	–38.8	15.4	5.78	0.0274	–0.923
Long Beach C	13	175	–70.2	–42.8	–24.1	–64.9	0.577	22.5
Total		348	2,640	–354	14,900	–2,320	–1,650	–1,090

lain Groundwater-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	5,290
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	5,290
	–504	0.00	–585	–30.4	–3.57	–3,280
	0.00	0.00	0.00	0.00	–77.7	–3,280
	0.00	0.00	0.00	0.00	0.00	0.00
	–812	–64.1	0.00	–388	0.00	–1,560
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	–1,980
	0.00	0.00	0.00	–497	0.00	–497
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	–241	0.00	–241
	0.00	0.00	0.00	–24.9	0.00	–775
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	–1,320	–64.1	–585	–1,180	–81.2	–11,600
	960	40.0	454	12.0	–373	13,600
	96.7	–46.2	–311	47.0	–227	–2,640
	2.15	–37.0	674	0.00	–93.6	15,100
	7.60	6.65	8.13	0.00	0.00	517
	–7.13	–115	11.5	–88.8	–31.2	–466
	–2.54	–4.88	0.833	0.00	–3.97	464
	–0.0136	0.00	27.6	0.00	–0.659	245
	217	30.0	9.60	–250	–2.26	–931
	0.377	1.93	22.6	–3.76	–1.88	34.7
	0.424	3.57	6.35	13.2	–1.06	161
	–5.82	23.9	0.332	220	–2.43	254
	0.974	5.77	2.69	17.2	–4.18	–29.4
	652	171	1.71	56.9	–5.70	872
	962	40.0	454	11.9	–374	13,600

Table 4.19. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with dry conditions, Los Angeles Coastal Pl

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Pumping and net interborehole flow out
Dominguez	2	0.00	–8,320	–3,010	–33.2	0.00	0.00	–0.985
Mesa	3	0.00	–8,930	–3,290	–1,210	–299	0.00	–2,850
Pacific A	4	0.00	–31,700	–7,700	–0.000369	0.00	0.00	–845
Pacific	5	0.00	–28,600	–26,700	–9,140	–623	–280	–4,710
Harbor	6	0.00	–37,900	–9,970	–15,200	0.00	0.00	–1,010
Bent Spring	7	0.00	–15,200	–2,260	–6,500	–7,370	–1,260	–3,710
Upper Wilmington A	8	–1,240	–20,600	–3,950	–21,800	–134	–1,560	–5,400
Upper Wilmington B	9	0.00	–7,830	–540	–1,880	–320	–25.2	–657
Lower Wilmington	10	0.00	–3,000	0.00	–6,490	–206	0.00	–654
Long Beach A	11	0.00	–724	0.00	–717	0.00	0.00	–7.95
Long Beach B	12	0.00	–248	0.00	–113	0.00	0.00	–99.1
Long Beach C	13	0.00	0.00	0.00	0.00	–1.78	0.00	–19.2
Total		–1,240	–163,000	–57,400	–63,100	–8,950	–3,130	–20,000
								Net flow from adjacent inland zones
Dominguez	2	–567	13,400	–2,090	–17.9	19.3	–99.1	73.4
Mesa	3	–1,030	28,700	–254	737	–301	–1,030	3,790
Pacific A	4	–211	9,770	1,930	–70.5	0.00	0.00	–1,800
Pacific	5	–2,950	23,400	9,590	–1,290	139	–75.9	4,170
Harbor	6	–350	24,100	1,790	–1,490	–4.42	0.00	–1,490
Bent Spring	7	–850	14,600	554	25.3	322	–939	834
Upper Wilmington A	8	–1,970	8,080	–684	1,500	–1,340	25	6,010
Upper Wilmington B	9	–165	4,100	–2,510	–88.7	219	–5.11	268
Lower Wilmington	10	–111	4,020	–396	1,620	–223	–4.74	478
Long Beach A	11	–0.444	842	14.2	791	–157	–0.0196	46.5
Long Beach B	12	37.4	1,150	–249	483	–102	4.25	–17.8
Long Beach C	13	–633	2,020	115	1,100	–372	–1.42	62.1
Total		–8,790	134,000	7,810	3,300	–1,800	–2,130	12,400
								Water spreading
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

ain Groundwater-flow Model.

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
–443	0.00	0.00	0.00	–39	–11,800
–5,680	–28.3	0.00	0.00	–207	–22,500
–2,880	0.00	0.00	0.00	0.00	–43,200
–18,000	–14.0	–3.63	0.00	–3,990	–92,100
–8,080	0.00	0.00	0.00	–1,150	–73,300
–2,630	0.00	–17.5	0.00	–90.7	–39,000
–5,340	0.00	0.00	0.00	–267	–60,400
–392	–0.884	0.00	0.00	0.00	–11,600
–448	–164	0.00	–135	0.00	–11,100
–231	0.00	0.00	0.00	0.00	–1,680
–192	0.00	0.00	0.00	0.00	–653
–4,090	0.00	0.00	0.00	0.00	–4,110
–48,400	–207	–21.1	–135	–5,740	–371,000
–13,100	–59.8	88.5	6.04	2,360	–4.87E–11
–31,600	–654	764	0.00	797	1.32E–11
–8,330	–314	–973	0.00	0.00	–1.93E–12
–27,100	–445	–546	–660	–4,190	1.33E–10
–19,200	–95.7	–333	0.00	–2,980	–6.50E–11
–15,300	0.00	812	0.00	–43.3	–1.22E–11
–9,100	–290	–216	–714	–1,310	–1.36E–11
–1,600	261	–213	–320	57.8	–9.48E–12
–4,570	62.1	–254	–454	–167	6.85E–12
235	–62.7	–0.559	–1,130	–578	–3.07E–12
–332	–198	6.63	–169	–615	–6.82E–13
–1,120	–950	–35.1	–94.8	–88.4	7.35E–12
–131,000	–2,750	–900	–3,540	–6,760	–1.46E–11
90,100	0.00	0.00	0.00	0.00	90,100
47,600	0.00	0.00	0.00	0.00	47,600
0.00	0.00	0.00	0.00	0.00	0.00
1,990	0.00	0.00	0.00	0.00	1,990
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
140,000	0.00	0.00	0.00	0.00	140,000

Table 4.19. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with dry conditions, Los Angeles Coastal Pl

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Injection and net interborehole flow in
Dominguez	2	0.00	3.33	0.00247	85.1	0.00	0.00	0.00027
Mesa	3	0.00	1,120	237	4,670	0.000164	0.00	0.00
Pacific A	4	0.00	2,370	2,490	0.00	0.00	0.00	32.4
Pacific	5	0.00	8,140	2,020	20,800	0.0238	0.00	1,330
Harbor	6	0.00	2,190	89.6	13,300	0.00	0.00	1,430
Bent Spring	7	0.00	1,300	0.00	17,500	237	44.0	761
Upper Wilmington A	8	1,240	1,100	0.791	1,990	0.00	14.1	59.2
Upper Wilmington B	9	0.00	503	9.66	132	0.986	0.00	15.0
Lower Wilmington	10	0.00	48.8	0.00	138	0.00	0.00	30.7
Long Beach A	11	0.00	2.81	0.00	0.335	0.00	0.00	0.00
Long Beach B	12	0.00	0.334	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.172	0.00	0.00
Total		1,240	16,800	4,850	58,600	238	58.1	3,660
								Areal recharge
Dominguez	2	1,130	7,810	2,740	1,070	1,470	1,760	1,340
Mesa	3	1,650	3,350	19.9	8,840	6,290	1,010	38.1
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	294	34.2	709	925	0.0392	0.00
Harbor	6	189	2.99	0.00	240	0.00	0.00	177
Bent Spring	7	14.7	0.00	0.00	815	6.4	0.00	0.00
Upper Wilmington A	8	0.00	25.2	7.05	139	64.2	0.00	31.7
Upper Wilmington B	9	0.00	0.00	0.00	16.6	8.94	0.00	0.00
Lower Wilmington	10	0.00	19.3	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	4.99	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	211	94.8	0.00	93.8	3.08	0.00	126
Total		3,200	11,600	2,800	11,900	8,760	2,770	1,710
								Flow from Santa Monica Bay
Dominguez	2	0.00	0.00	0.00	0.00	0.00112	0.00	0.00
Mesa	3	0.00	0.00	0.00	13.1	–123	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	–319	–1.35	0.00	0.00
Harbor	6	0.00	0.00	0.00	–136	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	–396	510	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	–49.1	432	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	–102	5.82	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	205	–28.4	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	–1.31	–14.6	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	4.05	–7.39	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	8.90	17.4	0.00	0.00
Total		0.00	0.00	0.00	–773	791	0.00	0.00

ain Groundwater-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
8.08E–05	0.00	0.00	0.00	0.00	88.4
128	0.00	0.925	0.00	1,640	7,800
732	0.00	0.00	0.00	0.00	5,620
239	0.00	0.0791	0.00	1,660	34,200
712	0.375	16.1	0.00	2,030	19,800
40.2	0.00	0.863	0.00	4.97	19,900
273	10.5	0.00	15.6	98.6	4,800
3.80	0.828	0.00	17.0	0.00	681
29.1	0.728	0.00	0.00	0.00	247
0.0120	61.9	0.00	102	0.00	167
21.9	74.3	0.00	0.00	0.00	96.6
5,000	0.00	0.00	0.00	0.00	5,000
7,180	149	17.9	135	5,430	98,300
1,960	258	431	23.5	410	20,400
969	336	778	0.00	198	23,500
0.00	0.00	0.00	0.00	0.00	0.00
198	428	178	696	0.000584	3,460
1.35	0.00	0.00	0.00	0.00	610
0.00	0.00	0.00	0.00	0.00	837
172	39.5	0.00	176	0.00	654
0.00	0.00	0.00	0.00	0.00	25.5
0.00	21.4	0.00	60.5	0.00	101
24.3	1.09	0.00	56.4	0.00	86.8
6.05	0.00	0.00	0.00	0.00	6.05
1,220	1,080	55.3	116	0.00	3,000
4,550	2,160	1,440	1,130	608	52,700
0.00	0.00	0.00	0.00	0.00	0.00112
0.00	0.00	0.00	0.00	0.00	–110
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	–320
0.00	0.00	0.00	0.00	0.00	–136
0.00	0.00	0.00	0.00	0.00	114
0.00	0.00	0.00	0.00	0.00	383
0.00	0.00	0.00	0.00	0.00	–96.0
0.00	0.00	0.00	0.00	0.00	176
0.00	0.00	0.00	0.00	0.00	–15.9
0.00	0.00	0.00	0.00	0.00	–3.34
0.00	0.00	0.00	0.00	0.00	26.3
0.00	0.00	0.00	0.00	0.00	17.9

Table 4.19. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with dry conditions, Los Angeles Coastal Pl

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Flow from San Pedro Bay
Dominguez	2	0.00	0.00	0.00	50.3	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	–5.26	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	430	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	486	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	–41.5	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	102	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	1,550	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	322	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	319	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	91.7	0.00	0.00	0.00
Total		0.00	0.00	0.00	3,310	0.00	0.00	0.00
								Underflow from Orange County
Dominguez	2	0.00	0.00	4,780	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	1,340	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	3,290	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	13,700	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	6,980	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	1,080	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	7,170	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	3,050	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	212	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	58.3	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	96.8	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	37.2	0.00	0.00	0.00	0.00
Total		0.00	0.00	41,700	0.00	0.00	0.00	0.00
								Underflow from San Gabriel Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	0.00	0.00	0.00

ain Groundwater-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
0.00	0.00	0.00	0.00	24.9	75.1
0.00	0.00	0.00	0.00	119	114
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	216	646
0.00	0.00	0.00	0.00	695	1,180
0.00	0.00	0.00	0.00	61.5	20.1
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	102
0.00	0.00	0.00	0.00	78.6	1,630
0.00	0.00	0.00	0.00	–341	–18.9
0.00	0.00	0.00	0.00	–100	219
0.00	0.00	0.00	0.00	–329	–237
0.00	0.00	0.00	0.00	426	3,730
0.00	0.00	0.00	0.00	69.2	4,850
0.00	0.00	0.00	0.00	368	1,710
0.00	0.00	0.00	0.00	0.00	3,290
0.00	0.00	0.00	–46.8	1,050	14,700
0.00	0.00	0.00	0.00	645	7,630
0.00	0.00	0.00	0.00	85.9	1,160
0.00	0.00	0.00	897	1,420	9,480
0.00	0.00	0.00	283	–44.3	3,290
0.00	0.00	0.00	750	40.1	1,000
0.00	0.00	0.00	1,170	953	2,190
0.00	0.00	0.00	68.7	750	915
0.00	0.00	0.00	79.4	435	551
0.00	0.00	0.00	3,210	5,770	50,700
0.00	0.00	0.00	0.00	0.00	0.00
24,100	0.00	0.00	0.00	0.00	24,100
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
2,880	0.00	0.00	0.00	0.00	2,880
27,000	0.00	0.00	0.00	0.00	27,000

Table 4.19. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with dry conditions, Los Angeles Coastal Pl

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from Palos Verdes Hills
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	2.96	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.916	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.492	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	25.9	0.00	0.00	0.00
Total		0.00	0.00	0.00	30.3	0.00	0.00	0.00
								Flow from Marina Del Rey
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	0.00	241	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	0.00	241	0.00	0.00
								Flow from Port of Long Beach
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	0.00	0.00	0.00	–0.00152	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	0.00	0.00	–0.00152	0.00	0.00	0.00

ain Groundwater-flow Model.—Continued

	Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	2.96
	0.00	0.00	0.00	0.00	0.00	0.916
	0.00	0.00	0.00	0.00	0.00	0.492
	0.00	0.00	0.00	0.00	0.00	25.9
	0.00	0.00	0.00	0.00	0.00	30.3
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	241
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	241
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	–0.00152
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	–0.00152

Table 4.19. Average annual 25-year water budget in acre-feet for optimized increased-pumpage scenario with dry conditions, Los Angeles Coastal Pl

[WRD, Water Replenishment District of Southern California]

Chronostratigraphic unit name	Model layer	Los Angeles Forebay	WRD Central Basin	Orange County	West Coast	Santa Monica	Hollywood	WRD Los Angeles Forebay
								Underflow from San Fernando Basin
Dominguez	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesa	3	5,370	0.00	0.00	0.00	0.00	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		5,370	0.00	0.00	0.00	0.00	0.00	0.00
								Drains
Dominguez	2	0.00	–1,040	–84.6	–16.6	–427	0.00	0.00
Mesa	3	0.00	–428	0.00	–1,290	–959	0.00	0.00
Pacific A	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pacific	5	0.00	0.00	0.00	0.00	–297	0.00	0.00
Harbor	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bent Spring	7	0.00	0.00	0.00	0.00	–1,550	0.00	0.00
Upper Wilmington A	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upper Wilmington B	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lower Wilmington	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach A	11	0.00	–744	0.00	0.00	0.00	0.00	0.00
Long Beach B	12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Long Beach C	13	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total		0.00	–2,210	–84.6	–1,310	–3,230	0.00	0.00
Total net flow		–224	–2,720	–312	12,000	–3,950	–2,420	–2,160
								Change in storage
Dominguez	2	–806	–2,190	170	182	–1,280	–139	–1,910
Mesa	3	35.8	–54.1	–7.7	10,400	–1,170	–320	–372
Pacific A	4	15.7	312	–3.02	1.23	0.00	0.00	0.534
Pacific	5	6.50	–430	–20.3	476	–1,420	–16.7	28.2
Harbor	6	4.16	–30.7	–14.8	248	–0.0147	0.00	71.5
Bent Spring	7	6.01	–28.6	–16.4	602	–28.1	–550	2.17
Upper Wilmington A	8	402	–40.2	–294	8.38	72.8	–1390	36.6
Upper Wilmington B	9	4.64	–41.9	–6.75	12.4	–30.6	–9.84	4.05
Lower Wilmington	10	–1.24	–4.90	–4.51	52.6	–4.90	0.491	7.10
Long Beach A	11	–5.24	–1.68	–15.7	1.82	–0.132	0.00241	–7.31
Long Beach B	12	–1.27	–70.2	–46.3	5.75	0.51	–0.0199	–7.07
Long Beach C	13	115	–131	–51.5	–49.6	–86.4	–1.62	–8.34
Total		–224	–2,720	–311	12,000	–3,950	–2,420	–2,160

ain Groundwater-flow Model.—Continued

Montebello Forebay	Whitter	Central Basin	North Orange County	South Orange County	Total
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	5,370
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	5,370
–462	0.00	–532	–21.1	–7.95	–2,590
0.00	0.00	0.00	0.00	–72.6	–2,750
0.00	0.00	0.00	0.00	0.00	0.00
–614	–22.4	0.00	–276	0.00	–1,210
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	–1,550
0.00	0.00	0.00	–448	0.00	–448
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	–224	0.00	–224
0.00	0.00	0.00	–39	0.00	–783
0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00
–1,080	–22.4	–532	–1,010	–80.5	–9,560
–2,100	–666	6.64	–210	–342	–3,130
–1,200	–73.0	–370	45.6	–232	–7,810
–1,010	–322	338	0.00	–67.4	7,470
–10.3	–5.73	5.12	0.00	0.00	316
–92.8	–209	0.177	–172	–22.2	–1,870
–28.6	–49.6	0.477	0.00	–3.21	197
–1.14	0.00	14.6	0.00	–0.416	–0.109
45.3	13.8	8.20	–305	–1.68	–1,440
–2.1	1.79	12.1	–5.71	–1.96	–64.0
–3.25	0.152	3.78	1.83	–1.68	45.5
–26.1	23.2	–1.16	215	–1.98	181
–19.3	0.785	–0.459	5.38	–4.28	–137
256	–46.7	–3.90	5.61	–6.05	–8.24
–2,100	–666	6.40	–209	–342	–3,130

Appendix 5. Rainfall-Recharge Analysis

By Scott Paulinski

Future temporal extension (updating) of the Los Angeles Coastal Plain Groundwater Model (LACPGM) would require additional data, including areal recharge, pumpage, water spreading, injection, and water-level data near boundaries. In the LACPGM, areal recharge is based on estimates from a model developed by Hevesi and Johnson (2016). To enable updating LACPGM without further updates to the Hevesi and Johnson (2016) model, a rainfall versus recharge analysis was done to establish a simple relation between recharge in each model cell and recent rainfall amounts. In this analysis, recharge derived from Hevesi and Johnson's (2016) model was compared to precipitation data from downtown Los Angeles from calendar year 1971 to 2014 (Los Angeles Almanac, 2018) to develop the relation between precipitation and recharge.

Quarterly recharge data derived from Hevesi and Johnson's (2016) model and used in the LACPGM (Paulinski and others, 2021) were plotted against average (mean) current and antecedent precipitation data ranging from one quarter of a year of antecedent data to four continuous quarters of a year of antecedent data. The best fit was found at the current quarter of a year and two quarters of a year of antecedent data. The fit was improved upon by weighting the influence of each of the three antecedent quarters differently. Weights were determined by manual adjustment. Weights of 1.0 for the current quarter, 0.59 for the first antecedent quarter, and 0.35 (0.59×0.59) for the second antecedent quarter were assigned. Upon examination of the antecedent-precipitation index versus recharge plot (fig. 5.1), we noted that the data followed two different curves, one for antecedent-precipitation index values below 15.5 inches and one for precipitation index values of 15.5 inches and above. Therefore, piecewise regression using two curves achieved the best fit to the data (fig. 5.1). The lower precipitation values were fit with a second order polynomial curve, which had an R^2 of 0.57. For the higher precipitation values, a linear fit had an R^2 of 0.86 (fig. 5.1).

Quarterly recharges for the future water management scenarios presented in Chapter D were estimated for each model cell using the average recharge for the model cell and the relation shown in figure 5.1. To estimate recharge for each quarter beyond 2014, a weighted-average precipitation index for the current quarter and the antecedent two-quarters was first calculated. Model-area recharge for each quarter was approximated using the relation between antecedent-precipitation index and recharge shown in figure 5.1. A recharge multiplier was then calculated by dividing the model area recharge for the quarter by the model area recharge averaged over 1971 through 2014. Recharge for each quarter in each model cell was estimated using the equations shown in figure 5.1 and multiplying that model cell's average recharge by the corresponding recharge and zone multipliers described in Chapter D.

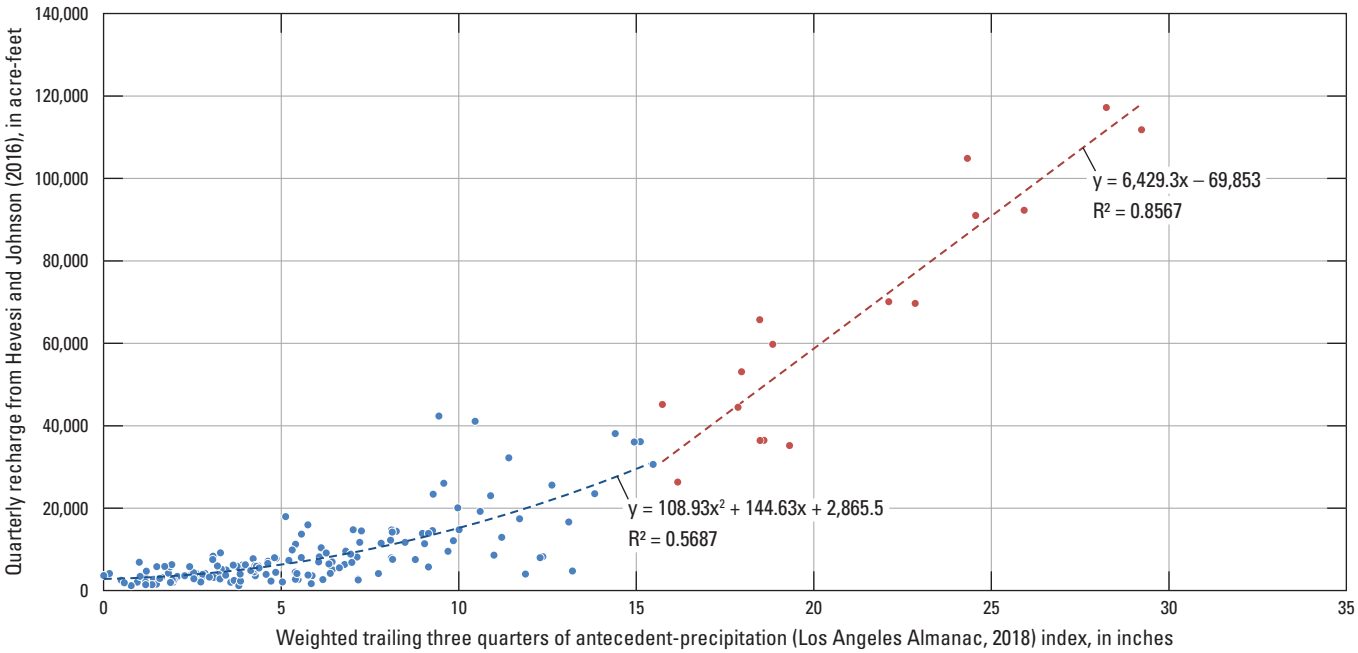


Figure 5.1. Weighted trailing three quarters index of antecedent precipitation (Los Angeles Almanac, 2018) versus quarterly recharge from Hevesi and Johnson (2016) from 1971 to 2014, for the Los Angeles Coastal Plain, California. Two separate curves fitted to data, one for the lower precipitation values and one for the higher precipitation values.

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