APPENDIXES

APPENDIX 1: DOCUMENTATION AND DESCRIPTION OF THE DIGITAL SPATIAL DATA BASE CREATED FOR THE SANTA CLARA—CALLEGUAS GROUND-WATER FLOW MODEL

Most of the information used to construct the ground-water flow model and to produce estimates of the hydrologic, geologic, geographic, and geopolitical features is documented and described in the Santa Clara–Calleguas Basin Geographic Information System (GIS) (Predmore and others, 1997). During the construction of the ground-water flow model, model-specific information was added to the GIS to document additional faults that may serve as horizontal-flow barriers to ground-water flow, to redefine selected subbasin boundaries that are based on these additional faults, to estimate seasonal precipitation for wet- and dry-climatic periods, to contour measured ground-water levels for the upper- and lower-aquifer systems, and to compile estimates of model parameters used with MODFLOW simulations of surface-water and ground-water flow. These data, estimates of physical features, and model parameters are stored in individual coverages within the GIS. A GIS coverage is composed of a set of files that contain the geographic locations of the data or features and related lists of data that are linked to specific locations within the basin. Additional files include coordinate reference and map-projection information for each coverage. The contents and features of a coverage are documented in a summary file (metadata file) that gives the name of the coverage and describes the data type, source, scale, source projection, method of entry, quality control, final projection of the data, and the final composition date of the coverage. The following metadata descriptions document these additional model-related coverages

(1.) **USGS_BASINS_GW** (fig. A1.1);
(2.) **FAULTS_USGS** (fig. A1.2);
(3.) **PRECIP_KRIG** (fig. A1.3);
(4.) **USGS_GWMODEL** (fig. A1.4);
(5.) **WL1931** (fig. A1.5);
(6.) **WL50LO, WL50UP** (fig. A1.6);
(7.) **WL91LO, WL91UP** (fig. A1.7);
(8.) **WL93LO, WL93UP** (fig. A1.8); and
(9.) **OXN_OILFIELD** (fig. A1.9).

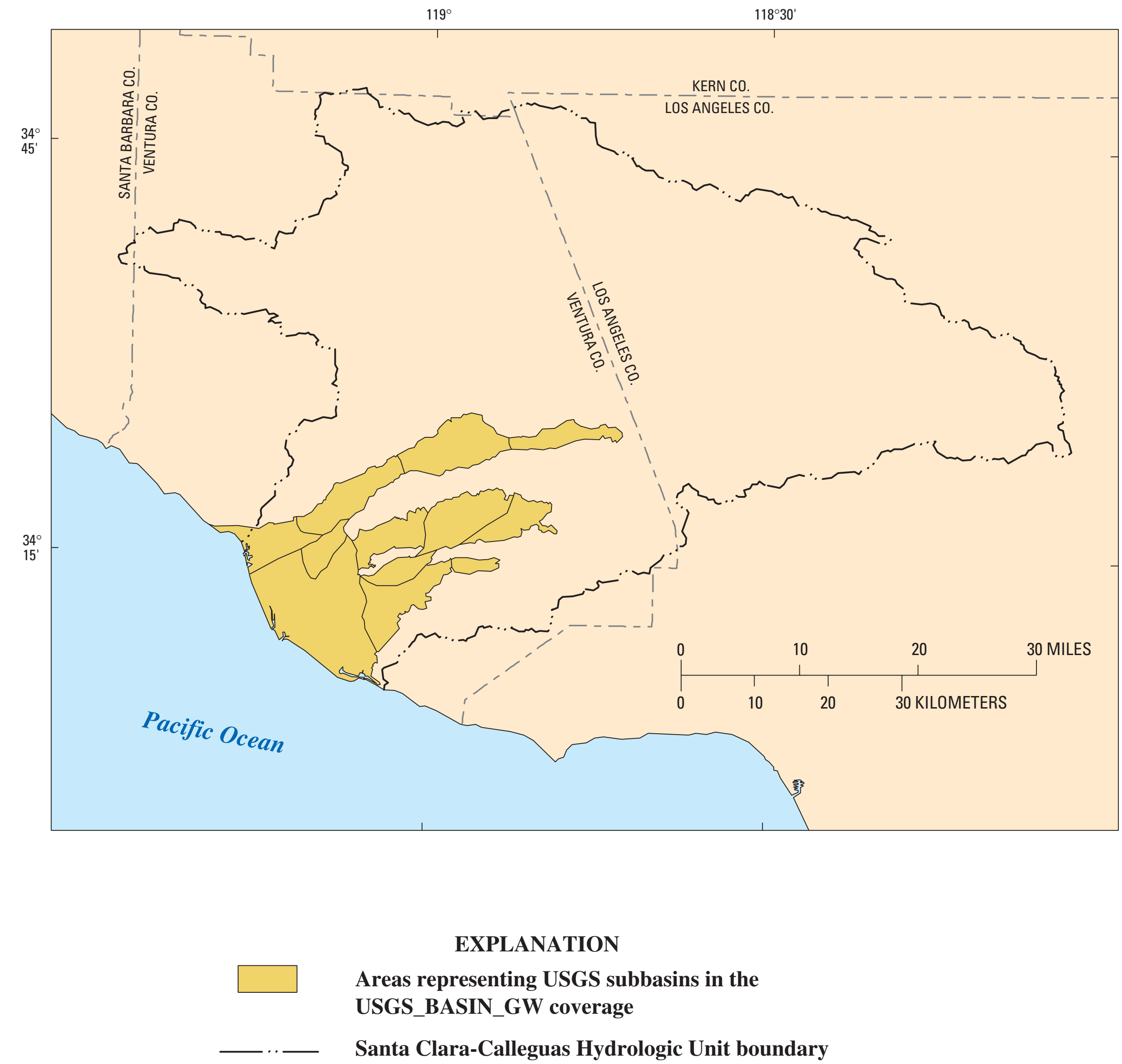


Figure A1.1. Location of USGS_BASIN_GW coverage.

Figure A.1.2. Location of FAULTS_USGS coverage.

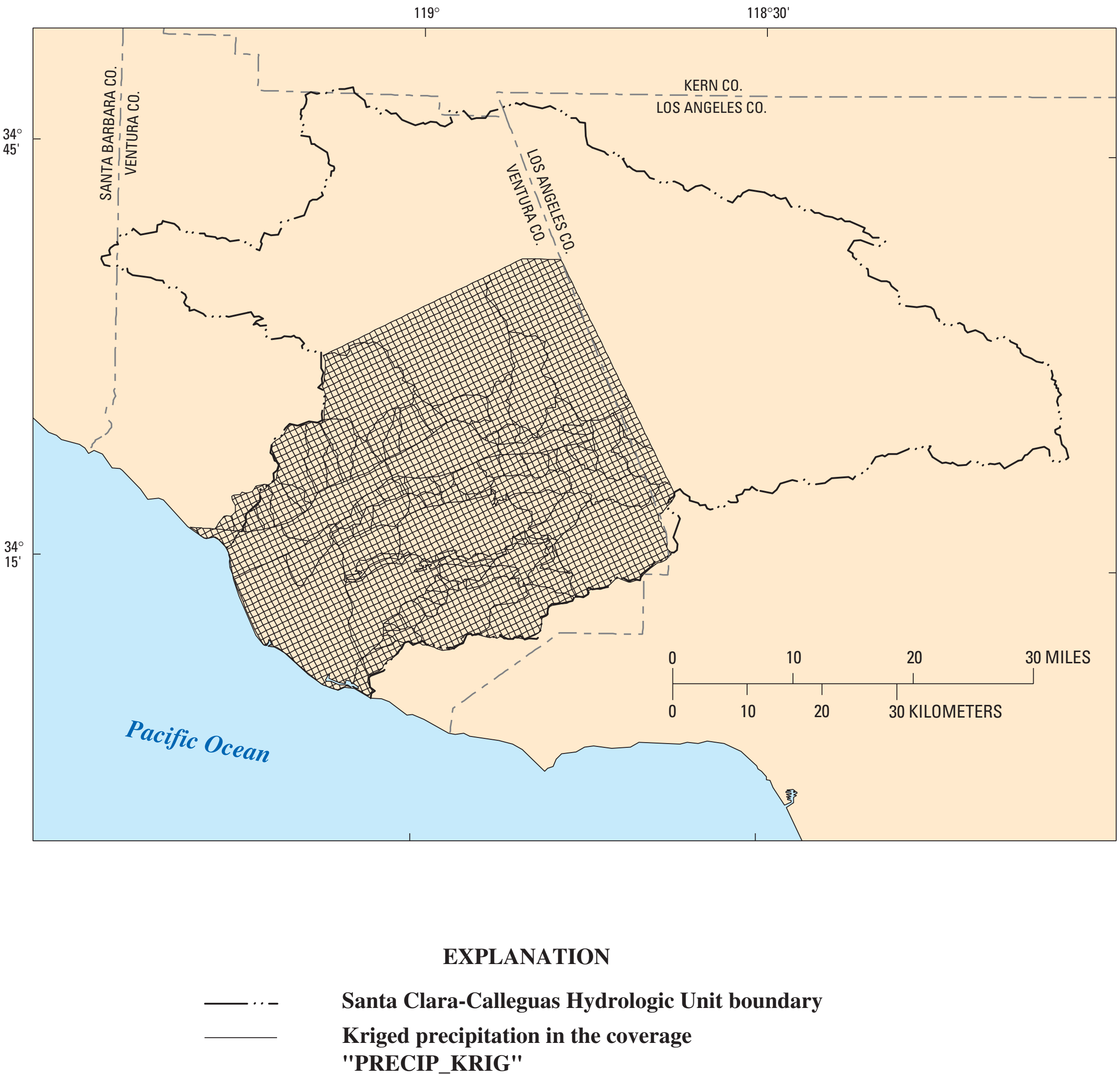


Figure A1.3. Location of PRECIP_KRIG coverage.

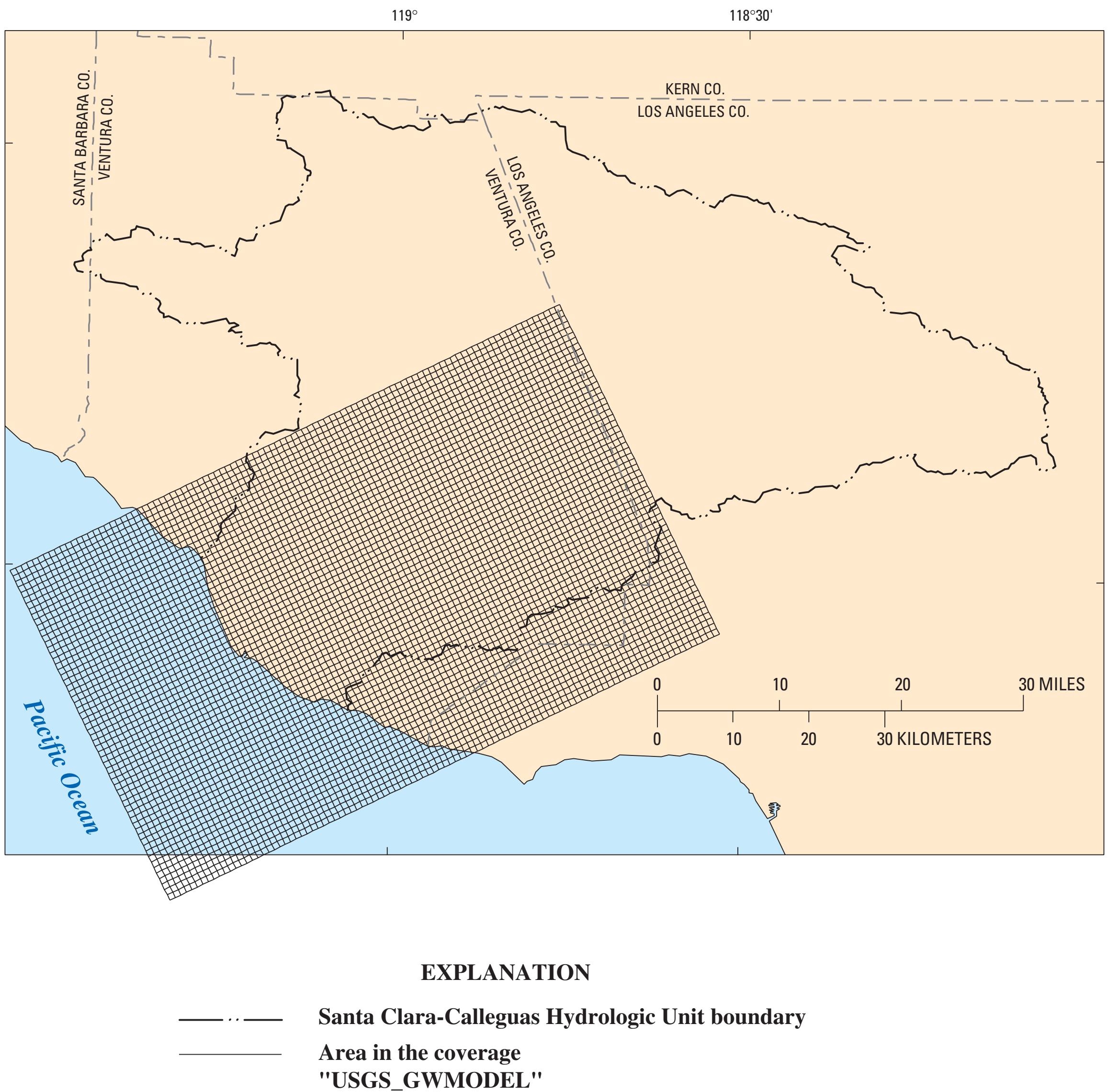
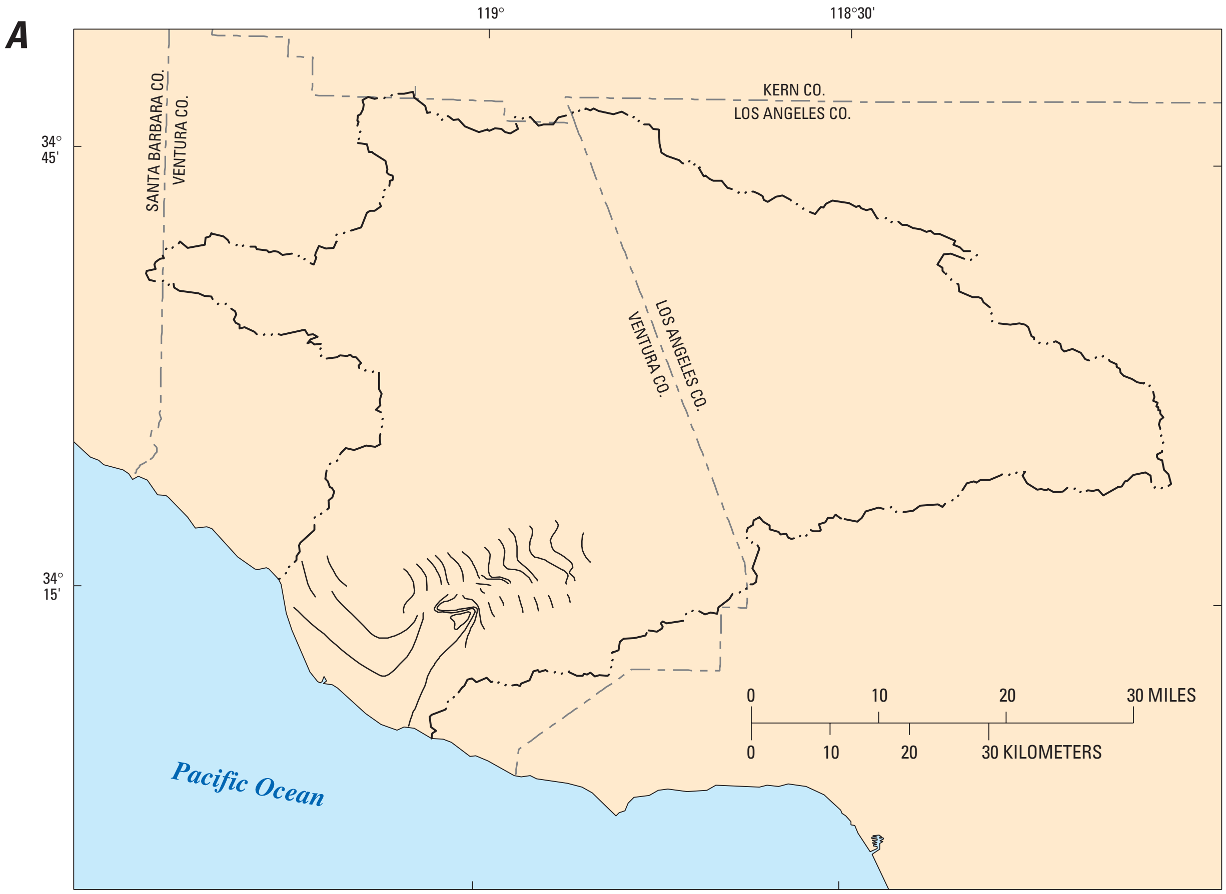


Figure A1.4. Location of USGS_GWMODEL coverage.

Figure A1.5. Location of WL1931 composite coverage for both aquifer systems.



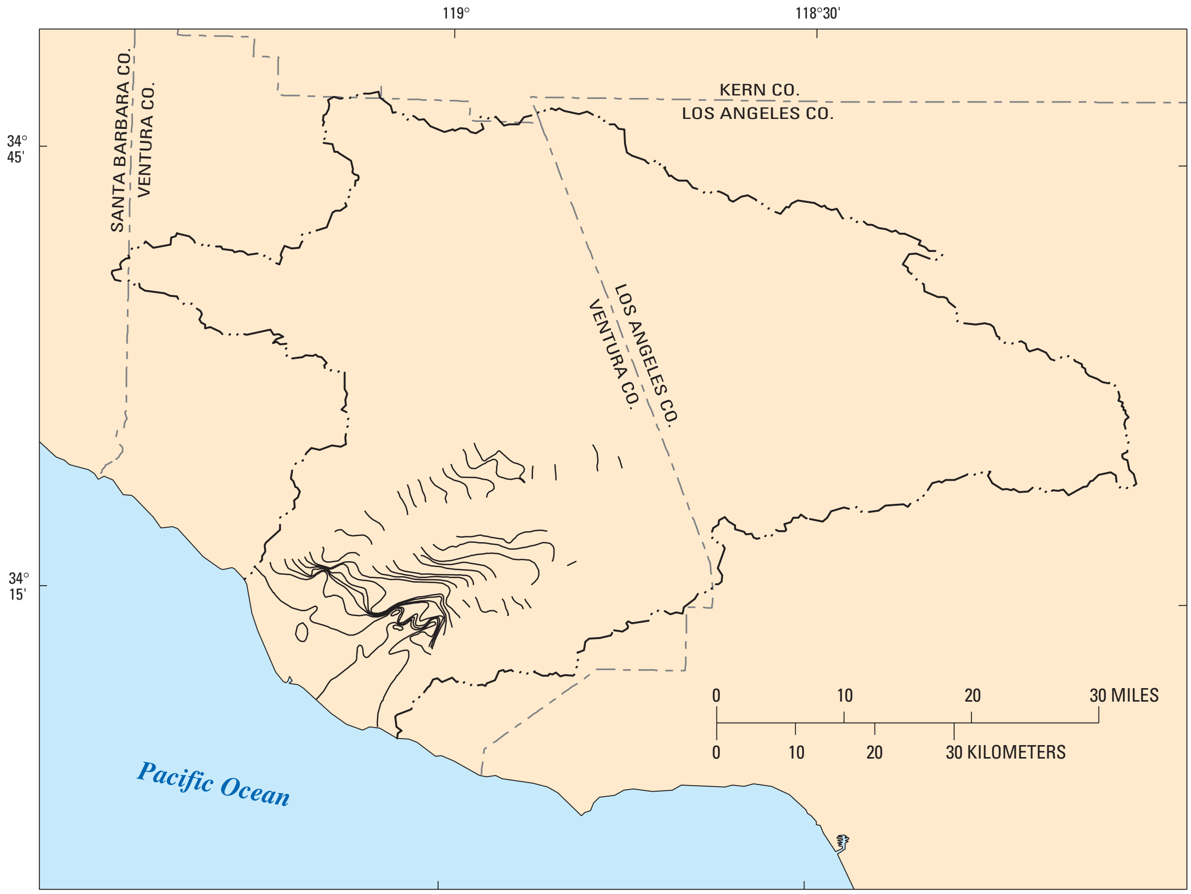
EXPLANATION

Santa Clara-Calleguas Hydrologic Unit boundary

1950 Water-level contours in the coverage "WL50LO"

Figure A1.6. Location of WL1950 coverages for both aquifer systems.

B



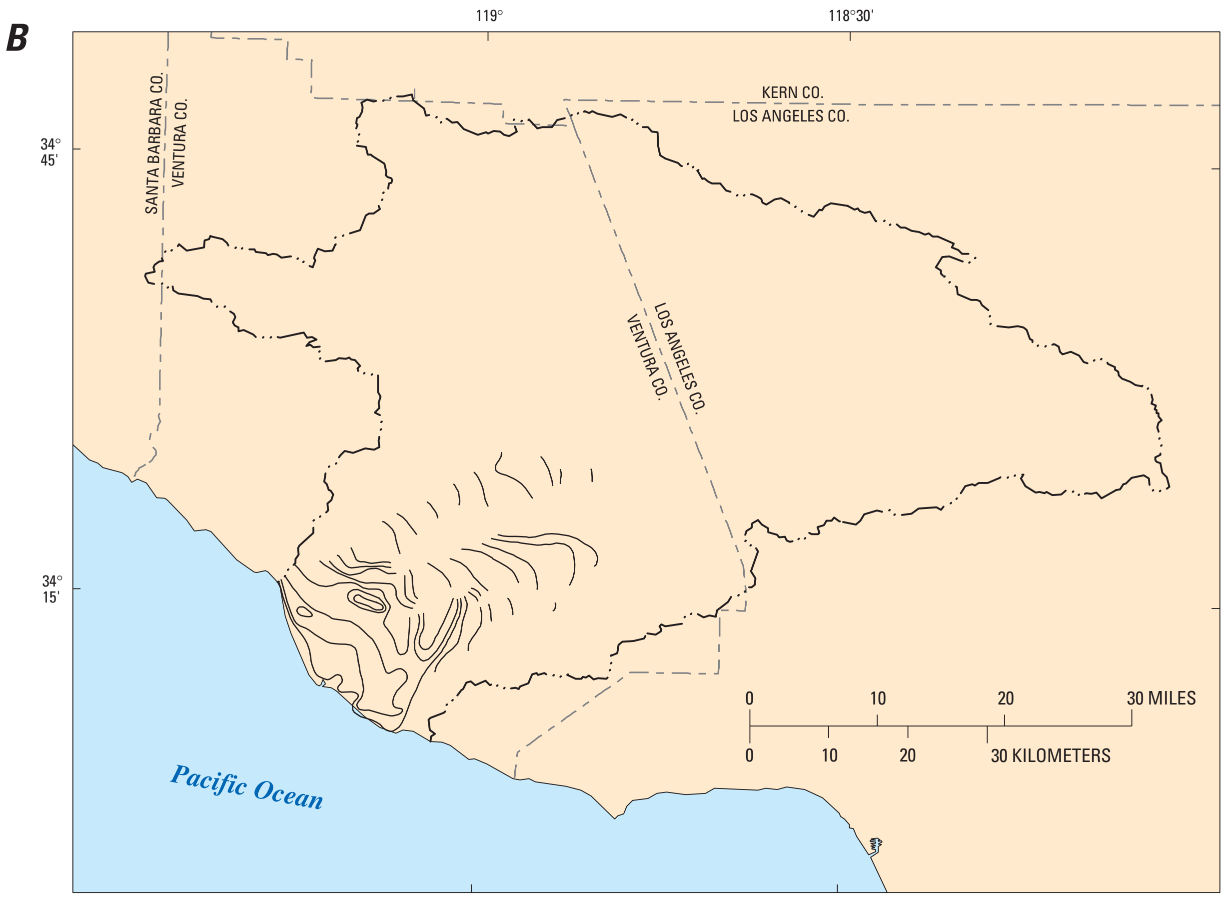
EXPLANATION

Santa Clara-Calleguas Hydrologic Unit boundary

1950 Water-level contours in the coverage "WL50UP"

Figure A1.6.—Continued.

Figure A1.7. Location of WL1991 coverages for both aquifer systems.



EXPLANATION

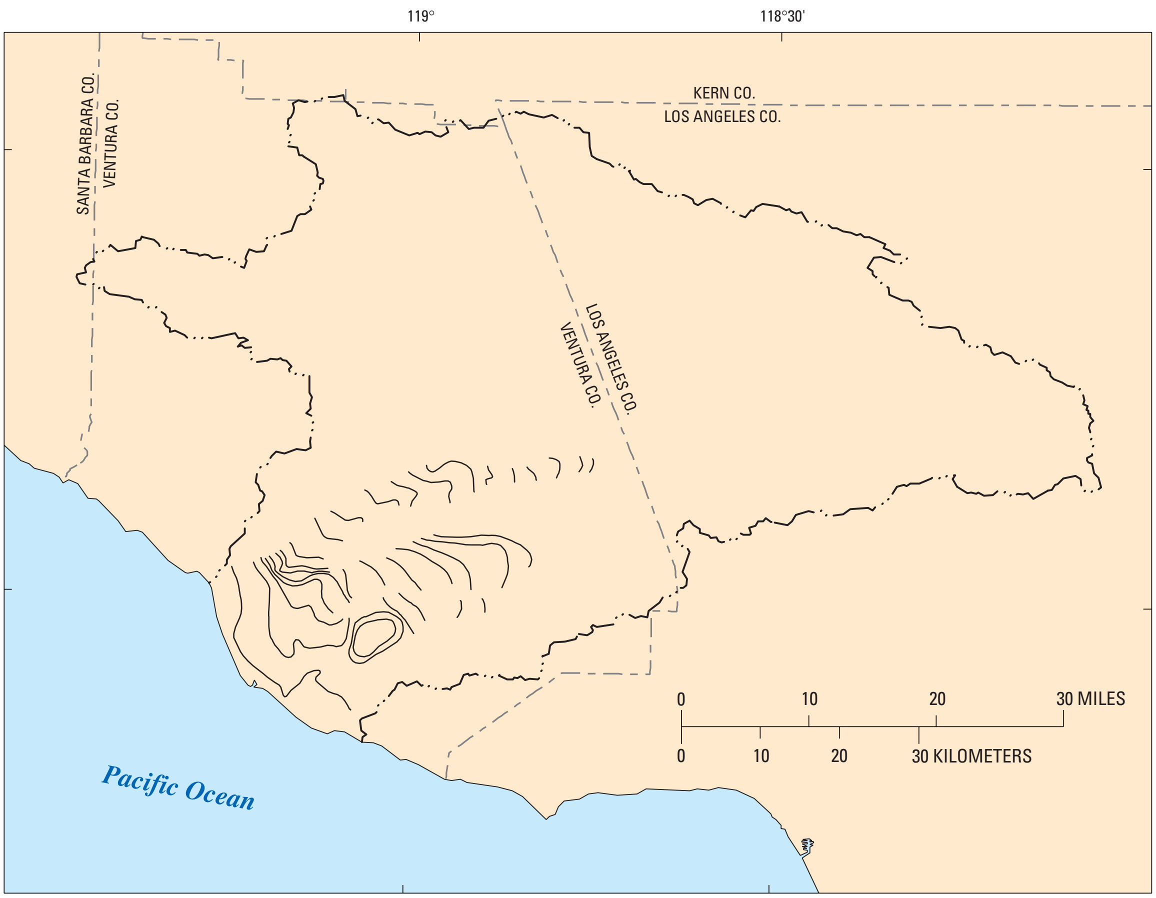
Santa Clara-Calleguas Hydrologic Unit boundary

1991 Water-level contours in the coverage "WL91UP"

Figure A1.7.—Continued.

Figure A1.8. Location of WL1993 coverages for both aquifer systems

B



EXPLANATION

Santa Clara-Calleguas Hydrologic Unit boundary

1993 Water-level contours in the coverage "WL93UP"

Figure A1.8.—Continued.

Figure A1.9. Location of OXN_OILFIELD coverage.

USGS_BASINS_GW

Description:	Selected ground-water basins and subareas within the Santa Clara–Calleguas Basin (see figure 1 for subbasin names).
Data type:	POLYGON.
Source:	Modified from: (a) Predmore, S.K., Koczot, K.M., and Paybins, K.S., 1997, Documentation and description of the digital spatial data base for the Southern California Regional Aquifer-System Analysis Program, Santa Clara–Calleguas Basin, Ventura County, California: U.S. Geological Survey Open-File Report 96-629, 100 p. (b) California Department of Water Resources, 1964, Names and areal code numbers of hydrologic areas in the southern District: [Sacramento, Calif.], California Department of Water Resources, 57 p., pl. 4. (c) California Department of Water Resources, 1975, Compilation of technical information records for the Ventura County cooperative investigation: [Sacramento, Calif.], California Department of Water Resources, v. 2, 234 p., pl. 2. (d) United Water Conservation District, 1991, Untitled: Unpublished map delineating groundwater basins in the United Water Conservation District: Ventura County, Calif. [on file with United Water Conservation District]. (e) FAULTS_USGS, WL1931, WL50LO, WL50UP, WL91LO, WL91UP, WL93LO, and WL93UP coverages.
Source scale:	(a) 1:260,000 (b) 1:126,720 (c) 1:100,000
Source projection:	(a) Unknown (b) Unknown (c) Base map from U.S. Geological Survey 30 × 60 minute topographic quadrangles.
Method of entry:	Ground-water basin polygons were manually digitized from source maps using an Altek Datatab AC40 digitizing tablet, which has a resolution of 0.002 inch. The geographic features and control points (points of known coordinate locations) were digitized and transformed into real-world coordinates. Modifications were made on the basis of additional structural and water-level data and interpretations.
Quality control:	The coverage was plotted and compared with the source maps.
Projection of data:	Universal Transverse Mercator projection: Zone 11, Y-shift–3.5 million meters.
Final update:	November 7, 1995
Description of variables:	USGS_BASINS_GW polygon attribute table.

Variable	Type	Length	Definition
NAME	Character	21	Name of ground-water basin or subarea
USGS_BASIN_GW-ID	Integer	3	Identification number
ACRES	Floating decimal	9	Acreage

FAULTS_USGS

Description:	Selected faults.
Data type:	LINE.
Source:	Modified from:

(a) Weber, F.H., Kiessling, E.W., Sprotte, E.C., Johnson, J.A., Sherburne, R.W., and Cleveland, G.B., 1976, Seismic hazards study of Ventura County, California: California Department of Conservation, California Division of Mines and Geology Open-File Report 76-5, 396 p., pls. 3A and 3B.

(b) Greene, H.G., Wolf, S.C., and Blom, K.G., 1978, The marine geology of the eastern Santa Barbara Channel, with particular emphasis on the ground-water basins offshore from the Oxnard Plain, southern California: U.S. Geological Survey Open-File Report 78-305, 104 p., pl. 2.

(c) Jakes, M.C., 1979, Surface and subsurface geology of the Camarillo and Las Posas Hills Area, Ventura County, California: Corvalis, Ore., Oregon State University, M.S. thesis, 105 p.

d) Dahlen, M.Z., Osborne, R.H., and Gorsline, D.S., 1990, Late Quaternary history of the Ventura mainland shelf, California: Marine Geology, v. 94, p. 317–340.

(e) Dahlen, M.Z., 1992, Sequence stratigraphy, sepositional history and Middle to Late Quaternary sea levels of the Ventura Shelf, California: Quaternary Research, v. 38, no. 2, p. 238–245.

(f) Turner, J.M., 1975, Ventura County water resources management study—Aquifer delineation in the Oxnard–Calleguas area, Ventura County: Technical Information Record, January 1975, Ventura County Department of Public Works Flood Control District, 45 p.

g) Yerkes, R.F., Sarna-Wojcicki, A.M., and Lajoie, K.R., 1987, Geology and Quaternary deformation of the Ventura area, *in* Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339, p. 169–178.

(h) Yeats, R.S., 1983, Large-scale Quaternary detachments in the Ventura basin, southern California: Journal of Geophysical Research, v. 88, p. 569–583.

(i) WL1931, WL50LO, WL50UP, WL91LO, WL91UP, WL93LO, and WL93UP coverages.

Source scale:	(a) 1:48,000 (b) 1:62,500
Source projection:	(a) California Coordinate System, zone 5. (b) California Coordinate System, zone 5.
Method of entry:	Fault lines were manually digitized from paper source maps using an Altek Datatab AC40 digitizing tablet, which has a resolution of 0.002 inch. The geographic features and control points (points of known coordinate locations) were digitized and transformed into real-world coordinates. Modifications were made on the basis of additional structural and water-level data and interpretations.
Quality control:	The coverage was plotted and compared with the source maps.
Projection of data:	Universal Transverse Mercator projection: Zone 11, Y-shift–3.5 million meters.
Final update:	May 15, 1996
Description of variables:	FAULTS_USGS arc-attribute table.

Variable	Type	Length	Definition
CODE	Integer	4	Unique number for each fault trace
TYPE	Character	16	Description of fault trace
SYMBOL	Integer	4	Number used to assign a line color
NAME	Character	20	Published name of fault trace
SOURCE	Character	6	Abbreviated source for fault trace
LOCATION	Character	9	Identifies fault as onshore or offshore

PRECIP_KRIG

Description: Kriged precipitation data onto extended model grid.

Data type: POLYGON.

Source: Data from:

(a) Ventura County Public Works Agency, 1990, Quadrennial report of hydrologic data. 1985–1988.

(b) California Department of Water Resources, 1964, Names and areal code numbers of hydrologic areas in the Southern District: [Sacramento, Calif.], California Department of Water Resources Office Report, 57 p., pl. 4.

(c) California Department of Water Resources, 1975, Compilation of technical information records for the Ventura County cooperative investigation: [Sacramento, Calif.], California Department of Water Resources, v. 2, 234 p., pl. 2.

(d) United Water Conservation District, 1991, Untitled: Unpublished map delineating groundwater basins in the United Water Conservation District, Ventura County, Calif., [on file with United Water Conservation District].

Estimated with:

(e) England, Evan, and Sparks, Allen, 1988, GEO-EAS (Geostatistical Environmental Assessment Software) User's Guide: Environmental Monitoring Systems Laboratory Office of Research and Development, U.S. Environmental Protection Agency, Las Vegas, Nevada, EPA600/4-88/033, variously paged.

Source scale: (a) N/A (b) 1:260,000 (c) 1:126,720 (d) 1:100,000

Source projection: (a) Geographic (b) Unknown (c) Unknown

(d) Base map from USGS 30 × 60 minute quadrangles

Cuyama, California	Santa Barbara, California
Lancaster, California	Los Angeles, California

Method of entry: Basins were selected by a staff hydrologist and combined from coverages, BASINS_HU and BASINS_SW (Predmore and others, 1997). Basins were intersected with kriged precipitation estimates made on the extended model grid with GEO-EAS from precipitation-gage data. Data were converted to a Universal Transverse Mercator projection on February 1, 1994.

Quality control: Latitude and longitude coordinates given in the original data file were assumed to be accurate.

Projection of data: Universal Transverse Mercator projection: Zone 11, y-shift–3.5 million meters

Final Update: August 25, 1995.

Table A1-1. Description of variables in PRECIP_KRIG polygon attribute table

Column	Type	Length	Definition
NAME	Character	21	Name of ground-water basin or subarea
RASA_KRIG-ID	Binary	4	Identification number
ID_SOURCE	Character	4	Identification number from source (b)
GAGED?	Character	2	"Y" = gaged surface water basin "N" = ungaged surface water basin Note: modified where SOURCE = RANDY
BASIN_ID	Integer	3	Identification number, 93 basins total
GROUP	Integer	3	Group number defined by USGS staff hydrologist
ACRES	Floating decimal	9	Acreage
ROW	Integer	4	Row number from model coverage USGS_GWMODEL
COL	Integer	4	Column number from model coverage USGS_GWMODEL
WINTER_DRY	Floating decimal	4	Kriged dry-winter (January, February, March) total precipitation, in inches per season
WD_AF	Floating decimal	4	Kriged dry-winter (January, February, March) total precipitation, in acre-feet per season
WD_EE	Floating decimal	4	Estimation error for kriged dry-winter (January, February, March) total precipitation, in inches per season
SPRING_DRY	Floating decimal	4	Kriged dry-spring (April, May, June) total precipitation, in inches per season
SPD_AF	Floating decimal	4	Kriged dry-spring (April, May, June) total precipitation, in acre-feet per season
SPD_EE	Floating decimal	4	Estimation error for kriged dry-spring (April, May, June) total precipitation, in inches per season
SUMMER_DRY	Floating decimal	4	Kriged dry-summer (July, August, September) total precipitation, in inches per season
SD_AF	Floating decimal	4	Kriged dry-summer (July, August, September) total precipitation, in acre-feet per season
SD_EE	Floating decimal	4	Estimation error for kriged dry-summer (July, August, September) total precipitation, in inches per season
FALL_DRY	Floating decimal	4	Kriged dry-fall (October, November, December) total precipitation, in inches per season
FD_AF	Floating decimal	4	Kriged dry-fall (October, November, December) total precipitation, in acre-feet per season
FD_EE	Floating decimal	4	Estimation error for kriged dry-fall (October, November, December) total precipitation, in inches per season
SEASON_DRY	Floating decimal	4	Average total precipitation for dry-year periods, in inches per year
SEAS.DRY_AF	Floating decimal	4	Average total precipitation for dry-year periods, in acre-feet per year
WINTER_WET	Floating decimal	4	Kriged wet-winter (January, February, March) total precipitation, in inches per season
WW_AF	Floating decimal	4	Kriged wet-winter (January, February, March) total precipitation, in acre-feet per season
WW_EE	Floating decimal	4	Estimation error for kriged wet-winter (January, February, March) total precipitation, in inches per season
SPRING_WET	Floating decimal	4	Kriged wet-spring (April, May, June) total precipitation, in inches per season
SPW_AF	Floating decimal	4	Kriged wet-spring (April, May, June) total precipitation, in acre-feet per season
SPW_EE	Floating decimal	4	Estimation error for kriged wet-spring (April, May, June) total precipitation, in inches per season
SUMMER_WET	Floating decimal	4	Kriged wet-summer (July, August, September) total precipitation, in inches per season
SW_AF	Floating decimal	4	Kriged wet-summer (July, August, September) total precipitation, in acre-feet per season

Table A1-1. Description of variables in PRECIP_KRIG polygon attribute table—Continued

Column	Type	Length	Definition
SW_EE	Floating decimal	4	Estimation error for kriged wet-summer (July, August, September) total precipitation, in inches per season
FALL_WET	Floating decimal	4	Kriged wet-fall (October, November, December) total precipitation, in inches per season
FW_AF	Floating decimal	4	Kriged wet-fall (October, November, December) total precipitation, in acre-feet per season
FW_EE	Floating decimal	4	Estimation error for kriged wet-fall (October, November, December) total precipitation, in inches per season
SEASON_WET	Floating decimal	4	Average total precipitation for wet-year periods, in inches per year
SEAS.WET_AF	Floating decimal	4	Average total precipitation for wet-year periods, in acre-feet per year
SEASON_TOT	Floating decimal	4	Total precipitation, in inches per year
SEAS.TOT_AF	Floating decimal	4	Total precipitation, in acre-feet per year

USGS_GWMODEL

Description:	U.S. Geological Survey regional ground-water flow model.
Data type:	POLYGON.
Source:	Modified from: California Department of Water Resources, 1974a, Mathematical modeling of water quality for water resources management. Volume 1, Development of the ground water quality model: [Sacramento, Calif.], California Department of Water Resources, Southern District, 204 p. California Department of Water Resources, 1974b, Mathematical modeling of water quality for water resources management, development of the ground water quality model. Volume 2, Development of historic data for the verification of the ground water quality model of the Santa Clara-Calleguas area, Ventura County: [Sacramento, Calif.], California Department of Water Resources, Southern District, 114 p. Reichard, E.G., 1995, Ground-water/surface-water management with stochastic surface-water supplies: A simulation-optimization approach: Water Resources Research, v. 31, no. 11, p. 2845–2865.
Source scale:	1:24,000
Source projection:	Albers Equal Area
Method of entry:	Model.aml was used to generate a polygon coverage of the model grid. The attributes were added to the coverage, and estimates were input initially from the previous model studies or from this study.
Quality control:	The coverage was plotted and compared with the source map.
Projection of data:	Universal Transverse Mercator projection: Zone 11, Y-shift–3.5 million meters.
Final update:	December 1, 1992
Description of variables:	USGS_GWMODEL polygon attribute table.

Table A1-2. Description of variables in USGS_GWMODEL polygon attribute table

Variable	Type	Length	Definition
NAME	Character	21	Name of ground-water basin or subarea
USGS_GWMODEL-ID	Binary	4	Identification number
ROW	Integer	4	Row number for ground-water flow model finite-difference grid
COL	Integer	4	Column number for ground-water flow model finite-difference grid
ACTIVE	Integer	2	Cell-by-cell status flag of model cells “1” = cell is active in ground-water flow model “0” = cell is inactive in ground-water flow model
LEFT	Binary	4	Cell-by-cell record number for model cell on the left face of fault trace
RIGHT	Binary	4	Cell-by-cell record number for cell on the right face of fault trace
STOR1_PRIM	Floating decimal	8	Primary Storage Coefficient for cell in layer 1
STOR1_SEC	Floating decimal	8	Secondary Storage Coefficient for cell in layer 1
STOR2_PRIM	Floating decimal	8	Primary Storage Coefficient for cell in layer 2
STOR2_SEC	Floating decimal	8	Secondary Storage Coefficient for cell in layer 2
BASIN	Character	30	Identification number
NAME	Character	30	Name of USGS 7.5 minute quadrangle where the model cell is located
SEQNUM	Integer	10	Relative number of cell in column and row order.
IBOUND11	Integer	3	Value of boundary array for cell in layer 1[1]
IBOUND22	Integer	3	Value of boundary array for cell in layer 2[1]
TRANS11	Numeric	10	Ttransmissivity for cell in layer 1 (gallons per day per foot / 100)
TRANS22	Numeric	10	Transmissivity for cell in layer 2 (gallons per day per foot / 100)
LSE(FT)	Floating decimal	4	Land-surface altitude, in feet above mean sea level

Table A1-2. Description of variables in USGS_GWMODEL polygon attribute table—Continued

Variable	Type	Length	Definition
LU12RIP11	Numeric	10	Area of riparian vegetation from 1912 land-use coverage within cell in layer 1, in acres
LU27RIP11	Numeric	10	Area of riparian vegetation from 1927 land-use coverage within cell in layer 1, in acres
LU32RIP11	Numeric	10	Area of riparian vegetation from 1932 land-use coverage within cell in layer 1, in acres
LU69RIP11	Numeric	10	Area of riparian vegetation from 1969 land-use coverage within cell in layer 1, in acres
LU50RIP11	Numeric	10	Area of riparian vegetation from 1950 land-use coverage within cell in layer 1, in acres
LURIPSS11	Numeric	10	Composite area of riparian vegetation within cell in layer 1 used to simulate evapotranspiration for predevelopment conditions, in acres
TOP11	Numeric	10	Altitude of top of upper-aquifer system within cell in layer 1 used to simulate confined and unconfined conditions, in feet above sea level
TOP22	Numeric	10	Altitude of top of upper-aquifer system within cell in layer 2 used to simulate confined and unconfined conditions, in feet above sea level
STREAM_STAGE1	Numeric	10	Estimation of stream bed altitude for cells coincident with major streams and tributaries, in feet above sea level
VCONT11	Numeric	10	Value of vertical leakance for cell in layer 1 in (feet per day × 1,000,000)
SKE11	Numeric	10	Skeletal-elastic storage coefficient for cell in layer 1 in feet^{-1}
SKV11	Numeric	10	Skeletal-inelastic storage coefficient for cell in layer 1 in feet^{-1}
SKE22	Numeric	10	Skeletal-elastic storage coefficient for cell in layer 2 in feet^{-1}
SKV22	Numeric	10	Skeletal-inelastic storage coefficient for cell in layer 2 in feet^{-1}
U_CLAY	Floating decimal	4	Estimate of fraction of total thickness of fine-grained deposits in the upper-aquifer system (model layer 1), in feet
U_N_CLAY	Floating decimal	4	Estimate of fraction of total thickness of coarse-grained deposits in the upper-aquifer system (model layer 1), in feet
L_CLAY	Floating decimal	4	Estimate of fraction of total thickness of fine-grained deposits in the lower-aquifer system (model layer 2), in feet
L_N_CLAY	Floating decimal	4	Estimate of fraction of total thickness of coarse-grained deposits in the lower-aquifer system (model layer 2), in feet
HUN_ELEV	Floating decimal	4	Estimate of the altitude of the top of the Hueneme aquifer system, in feet above sea level
BASE_ELEV	Floating decimal	4	Estimate of the altitude of the base of the San Pedro Formation in the lower-aquifer system, in feet above sea level
WL31ELV	Floating decimal	4	Estimate of the water-level altitude in 1931, in feet above sea level
UPPER_CLAY	Floating decimal	4	Estimate of total thickness of fine-grained deposits in the upper-aquifer system (model layer 1), in feet
UPPER_N_CLAY	Floating decimal	4	Estimate of total thickness of coarse-grained deposits in the upper-aquifer system (model layer 1), in feet
LOWER_CLAY	Floating decimal	4	Estimate of total thickness of fine-grained deposits in the lower-aquifer system (model layer 2), in feet
LOWER_N_CLAY	Floating decimal	4	Estimate of total thickness of coarse-grained deposits in the lower-aquifer system (model layer 2), in feet
STRM_SEG_NUM1	Integer	6	Segment number for each reach (cell) used to route streamflow in the ground-water flow model

[1]Values for subareas of IBOUND11 for model layer 1 and IBOUND22 for model layer 2 are listed in table A1-3 and figure 17B. These distributions of boundary-array index values were used for the budgetary analysis of ground-water flow for historical and future-condition simulations.

Table A1-3. Summary of boundary-array index values used for ground-water flow model of Santa Clara–Calleguas Basin

Name	IBOUND11 (layer 1)	IBOUND22 (layer 2)	Area type	Source of designation
Piru	14	26	Subbasin	DWR/UWCD
Fillmore	15	27	Subbasin	DWR/UWCD
Santa Paula	16	28	Subbasin	DWR/UWCD
Mound	17	31	Subbasin	DWR/UWCD
Oxnard Forebay	1	2	Subbasin within Oxnard Plain	DWR/UWCD
Northwestern Oxnard Plain	3	4	Subarea within Oxnard Plain	USGS
Northeastern Oxnard Plain	5	6	Subarea within Oxnard Plain	USGS
Southern Oxnard Plain	7	8	Subarea within Oxnard Plain	USGS
South Pleasant Valley	21	9	Subbasin	USGS
North Pleasant Valley	29	30	Subbasin	USGS
East Las Posas Valley	25	13	Subbasin	USGS
South Las Posas Valley	23	11	Subbasin	USGS
West Las Posas Valley	24	12	Subbasin	USGS
Offshore Mound	18	32	Subarea within Mound	USGS
Offshore northern Oxnard Plain	19	33	Subarea within northern Oxnard Plain	USGS
Offshore southern Oxnard Plain	20	34	Subarea within southern Oxnard Plain	USGS

Method of entry:	Fault lines were manually discretized from overlay of faults (FAULTS and FAULTS_USGS) coverages and model-grid coverage.
Quality control:	The coverage was plotted and compared with the source maps.
Projection of data:	Universal Transverse Mercator projection: Zone 11, Y-shift-3.5 million meters.
Final update:	May 15, 1996
Description of variables:	USGS_GWMODEL arc-attribute table.

Table A1-4. Description of variables in USGS_GWMODEL arc-attribute table

Variable	Type	Length	Definition
USGS_GWMODEL-ID	Binary	4	Unique number for each fault trace
LEFT	Binary	4	Cell-by-cell (Row, Column) pair for model cell on the left face of fault trace
RIGHT	Binary	4	Cell-by-cell (Row, Column) pair for model cell on the right face of fault trace
LAYER	Integer	1	Cell-by-cell model layer number of fault trace
ACTIVE	Integer	2	Cell-by-cell status flag of fault trace "1" = fault is active horizontal flow barrier "0" = fault is inactive horizontal flow barrier
FAULT_NAME	Character	20	Name of fault trace
REL	Binary	4	Cell-by-cell record number for fault trace
TRANS	Numeric	5	Transmissivity of the fault trace in feet^2/day

WL1931

Description:	Selected ground-water level contours for fall 1931 from State of California Department of Public Works.
Data type:	LINE.
Source:	Modified from: California Department of Public Works, 1934, Ventura County investigation: California Department of Public Works, Division of Water Resources Bulletin 46, 244 p., pl. XLIX.
Source scale:	1:108,600 (approximate)
Source projection:	Unknown.
Method of entry:	Water-level contours were manually digitized from a paper source map using an Altek Datatab AC40 digitizing tablet, which has a resolution of 0.002 inch. The geographic features and control points (points of known coordinate locations) were digitized and transformed into real-world coordinates. Contours were modified on the basis of additional early water-level data and more recent water-level data.
Quality control:	The coverage was plotted and compared with the source map.
Projection of data:	Universal Transverse Mercator projection: Zone 11, Y-shift–3.5 million meters.
Final update:	July 23, 1993
Description of variables:	WL1931 line attribute table

Variable	Type	Length	Definition
CONTOUR_31	Integer	6	Ground-water-level altitude above sea level, in feet

WL50LO and WL50UP

Description:	Selected ground-water levels for fall 1950 for the lower- and upper- aquifer systems.
Data type:	LINE.
Source:	Estimated from selected data from: (a) MASTER.WL and CONSTRUCTION database files, and WELLS_ALL point coverage from: Predmore, S.K., Koczot, K.M., and Paybins, K.S., 1997, Documentation and description of the digital spatial data base for the Southern California Regional Aquifer-System Analysis Program, Santa Clara–Calleguas Basin, Ventura County, California: U.S. Geological Survey Open-File Report 96-629, 100 p. (b) FAULTS_USGS, WL1931, WL50LO, WL50UP, WL91LO, WL91UP, WL93LO, and WL93UP coverages.
Source scale:	1:125,000
Source projection:	Universal Transverse Mercator projection: Zone 11, Y-shift-3.5 million meters.
Method of entry:	Water-level data were plotted and manually contoured and digitized from a paper source map using an Altek Datatab AC40 digitizing tablet, which has a resolution of 0.002 inch. The geographic features and control points (points of known coordinate locations) were digitized and transformed into real-world coordinates.
Quality control:	The coverage was plotted and compared with the source map.
Projection of data:	Universal Transverse Mercator projection: Zone 11, Y-shift–3.5 million meters.
Final update:	July 23, 1993
Description of variables:	WL50LO and WL50UP line attribute tables.

Variable	Type	Length	Definition
CONTOUR_50	Integer	6	Ground-water-level altitude above sea level, in feet
DASHED	Character	3	YES = ground-water-level altitude contour inferred NO = ground-water-level altitude contour estimated from data

WL91LO and WL91UP

Description:	Selected ground-water levels for fall 1991 for the lower- and upper- aquifer systems.
Data type:	LINE.
Source:	Estimated from selected data from: (a) MASTER.WL and CONSTRUCTION database files, and WELLS_ALL point coverage from: Predmore, S.K., Koczot, K.M., and Paybins, K.S., 1997, Documentation and description of the digital spatial data base for the Southern California Regional Aquifer-System Analysis Program, Santa Clara–Calleguas Basin, Ventura County, California: U.S. Geological Survey Open-File Report 96-629, 100 p. (b) FAULTS_USGS, WL1931, WL50LO, WL50UP, WL91LO, WL91UP, WL93LO, and WL93UP coverages.
Source scale:	1:125,000
Source projection:	Universal Transverse Mercator projection: Zone 11, Y-shift-3.5 million meters.
Method of entry:	Water-level data were plotted and manually contoured and digitized from a paper source map using an Altek Datatab AC40 digitizing tablet, which has a resolution of 0.002 inch. The geographic features and control points (points of known coordinate locations) were digitized and transformed into real-world coordinates.
Quality control:	The coverage was plotted and compared with the source map.
Projection of data:	Universal Transverse Mercator projection: Zone 11, Y-shift–3.5 million meters.
Final update:	July 23, 1993
Description of variables:	WL91LO and WL91UP line attribute tables.

Variable	Type	Length	Definition
CONTOUR_91	Integer	6	Ground-water-level altitude above sea level, in feet
DASHED	Character	3	YES = ground-water-level altitude contour inferred NO = ground-water-level altitude contour estimated from data

WL93LO and WL93UP

Description:	Selected ground-water levels for fall 1993 for the lower- and upper- aquifer systems.
Data type:	LINE.
Source:	Estimated from selected data from: (a) MASTER.WL and CONSTRUCTION database files, and WELLS_ALL point coverage from: Predmore, S.K., Koczot, K.M., and Paybins, K.S., 1997, Documentation and description of the digital spatial data base for the Southern California Regional Aquifer-System Analysis Program, Santa Clara–Calleguas Basin, Ventura County, California: U.S. Geological Survey Open-File Report 96-629, 100 p. (b) FAULTS_USGS, WL1931, WL50LO, WL50UP, WL91LO, WL91UP, WL93LO, and WL93UP coverages.
Source scale:	1:125,000
Source projection:	Universal Transverse Mercator projection: Zone 11, Y-shift-3.5 million meters.
Method of entry:	Water-level data were plotted and manually contoured and digitized from a paper source map using an Altek Datatab AC40 digitizing tablet, which has a resolution of 0.002 inch. The geographic features and control points (points of known coordinate locations) were digitized and transformed into real-world coordinates.
Quality control:	The coverage was plotted and compared with the source map.
Projection of data:	Universal Transverse Mercator projection: Zone 11, Y-shift–3.5 million meters.
Final update:	July 23, 1993
Description of variables:	WL93LO and WL93UP line attribute tables.

Variable	Type	Length	Definition
CONTOUR_93	Integer	6	Ground-water-level altitude above sea level, in feet
DASHED	Character	3	YES = ground-water-level altitude contour inferred NO = ground-water-level altitude contour estimated from data

OXN_OILFIELD

Description:	Oil and gas fields in the Oxnard Plain, 1977.
Data type:	POLYGON.
Source:	Modified from: (a) California Division of Oil and Gas, 1977, Subsidence study of Oxnard Oil Field and vicinity, Ventura County, California: California Department of Conservation, Division of Oil and Gas Report, 45 p., figs. 9 and 14.
Source scale:	(a) figure 9, 1:60,000 (approximate); figure 14, 1:47,520 (approximate)
Source projection:	(a) Unknown
Method of entry:	Oil and gas fields were digitized by hand from source (a) into table coordinates. The coverage was converted to a polyconic projection using latitude and longitude locations from source (a). Data were converted to a Universal Transverse Mercator projection on February 1, 1994.
Quality control:	Oil and gas fields were plotted and checked against source (a).
Projection of data:	Universal Transverse Mercator projection: Zone 11, y-shift–3.5 million meters
Final Update:	February 1, 1994

Column	Type	Length	Definition
—	—	—	NOTE: No variables were added to the OXN_OILFIELD polygon attribute table

APPENDIX 2: DOCUMENTATION AND DESCRIPTION OF CHANGES MADE TO THE STREAMFLOW-ROUTING PACKAGE IN THE MODFLOW GROUND-WATER FLOW MODEL

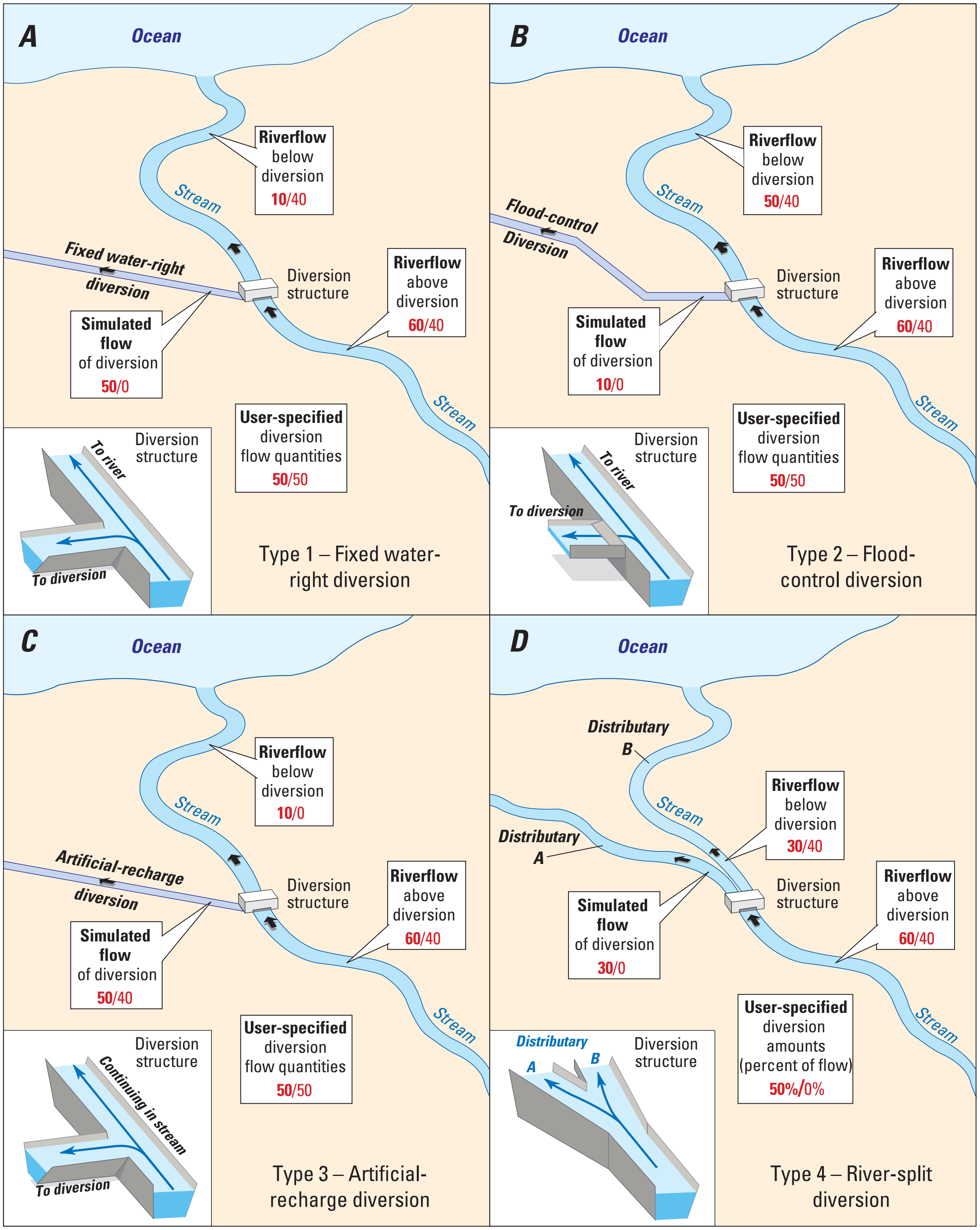
By W.R. Danskin *and* R.T. Hanson, U.S. Geological Survey, San Diego, California

As written, the MODFLOW streamflow routing package (STR1, Prudic, 1989) allows diversions of streamflow only if the streamflow routed to the cell where the diversion occurs is equal to or greater than the user-specified diversion rate. If the routed streamflow is less, no diversion occurs. To address this limitation and to allow for more types of diversions, the STR1 package was modified as part of the development of a ground-water flow model of the San Bernardino area, California, by W.R. Danskin (U.S. Geological Survey, written commun., 1992) to allow several additional types of diversions. The additional diversion types are: (1) fixed water right [original type of diversion used by Prudic (1989)], (2) flood control, (3) artificial recharge, and (4) river-split diversion (fig. A2.1). For the stream-split diversion type, the percentage of the flow that is split for the diversion is input in place of the diversion volumetric rate, and the volumetric rate is internally calculated by the model. The modifications are upwardly compatible and do not affect the use of the modified data sets with the original STR1 package input data format.

Input Data Set 6:

The revised data set 6 is:

VARIABLE	FORMAT	DESCRIPTION
IUPSEG	I10	Number of upstream segment from which water is diverted. (IDIVAR(1,NSS) in subroutine STR1RP)
IDVTYP	I10	Type of diversion, with the four types specified above allowed. (IDIVAR(2,NSS) in subroutine STR1RP)
IBRNUM	I10 ‘	Number of the segment that the remaining undiverted stream flow is routed to at the point of diversion. If not used, this variable is set to zero. (IDIVAR(3,NSS) in subroutine STR1RP)



EXPLANATION

60/40 Flow of water – River flow above and below diversion and to diversion, User specified, and simulated amounts, for example, in cubic feet per second (L^3/T) except as shown in ***D***. Each diversion type shows two cases where the numerator numbers are flows for first example and denominator numbers are flows for the second example

Figure A2-1. Examples of revised diversion tyhpes and related decision made by the MODFLOW streamflowrouting package regarding simulated distribution of diversion and streamflow.

When IDVTYP is set to a type 4 stream-split diversion, the FLOW value in data set 3 becomes the percentage of routed inflow that is split from the upstream reach and routed to the diversion or distributary channel.

The modifications to calling the streamflow routing package from the main MODFLOW program require the passing of additional variables in the subroutine argument list. The new calls use the IUNIT number that was used in both MODFLOW and MODFLOW-96 (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996) and replace the original calls as follows:

Calling Subroutine STR1AL:

```
      IF(IUNIT(18).GT.0) CALL STR1AL(ISUM,LENX,LCSTRM,ICSTRM,MXSTRM,
     1     NSTREM,IUNIT(18),IOUT,ISTCB1,ISTCB2,NSS,NTRIB,
     2     NDIV,ICALC,CONST,LCTBAR,LCTRIB,LCIVAR,LCFGAR,
     3     LCQDIV)
```

Calling Subroutine STR1RP:

```
      IF(IUNIT(18).GT.0) CALL STR1RP(X(LCSTRM),X(ICSTRM),NSTREM,
     1     MXSTRM,IUNIT(18),IOUT,X(LCTBAR),NDIV,NSS,
     2     NTRIB,X(LCIVAR),ICALC,IPTFLG)
```

Calling Subroutine STR1FM:

```
      IF(IUNIT(18).GT.0) CALL STR1FM(NSTREM,X(LCSTRM),X(ICSTRM),
     1        X(LCHNEW),X(LCHCOF),X(LCRHS),X(LCIBOU),
     2     MXSTRM,NCOL,NROW,NLAY,IOUT,NSS,X(LCTBAR),
     3     NTRIB,X(LCTRIB),X(LCIVAR),X(LCFGAR),X(LCQDIV),
     4     ICALC,CONST)
```

Calling Subroutine STR1BD:

```
      IF(IUNIT(18).GT.0) CALL STR1BD(NSTREM,X(LCSTRM),X(ICSTRM),
     1     X(LCIBOU),MXSTRM,X(LCHNEW),NCOL,NROW,NLAY,DELT,VBVL,VBNM,MSUM,
     2     KSTP,KPER,ISTCB1,ISTCB2,ICBCFL,X(LCBUFF),IOUT,NTRIB,NSS,
     3     X(LCTRIB),X(LCTBAR),X(LCIVAR),X(LCFGAR),X(LCQDIV),
     4     ICALC,CONST,IPTFLG,PERTIM,TOTIM)
```

The modifications to the subroutines all require an increase in dimensionality of the diversion array (IDIVAR) from one to three elements per stream segment. The following lines show the additional or replaced code for each of the STR1 subroutines. The numbers after the first comment character indicate where the code should be inserted. The dimension statements show the replaced variables with the changes shown in bold type.

Subroutine STR1AL:

```
C8A-----CALCULATE AMOUNT OF SPACE NEEDED FOR IDIVAR LIST.
CWES----INCREASE DIMENSION OF IDIVAR.
    LCIVAR=ISUM
    ISPE=NSS*3
    ISUM=ISUM+ISPE

C8B-----CALCULATE AMOUNT OF SPACE NEEDED FOR NDFGAR LIST.
    LCFGAR=ISUM
    ISPF=NSS
    ISUM=ISUM+ISPF

C8C-----CALCULATE AMOUNT OF SPACE NEEDED FOR QDIV LIST.
CWES----ADDED VARIABLE QDIV AND LCQDIV.
    LCQDIV=ISUM
    ISPG=NSS
    ISUM=ISUM+ISPG
    ISP=ISPA+ISPB+ISPC+ISPD+ISPE+ISPF+ISPG
```

Subroutine STR1RP:

```
    DIMENSION STRM(11,MXSTRM),ISTRM(5,MXSTRM),ITRBAR(NSS,NTRIB),
    1  IDIVAR(3,NSS)
    ---------------------------------
C8-----INITIALIZE DIVERSION SEGMENT ARRAY TO ZERO.
CWES---ADD TWO VARIABLES TO IDIVAR ZERO LOOP.
    DO 325 IK=1,3
    DO 325 JK=1,NSS
    IDIVAR(IK,JK)=0
325 CONTINUE
```

Subroutine STR1FM:

```
    DIMENSION STRM(11,MXSTRM),ISTRM(5,MXSTRM),HNEW(NCOL,NROW,NLAY),
    1       HCOF(NCOL,NROW,NLAY),RHS(NCOL,NROW,NLAY),
    2       IBOUND(NCOL,NROW,NLAY),ITRBAR(NSS,NTRIB),ARTRIB(NSS),
    3       IDIVAR(3,NSS),NDFGAR(NSS),QDIV(NSS)
    ---------------------------------
C8A-----CHECK UPSTREAM SEGMENT FOR DIVERSIONS.
    DO 40 NSFLG = 1,NSS
    IF(IFLG.NE.IDIVAR(1,NSFLG)) GO TO 40

CWES----CHECK IF DIVERSIONS HAVE ALREADY BEEN CALCULATED FOR SEGMENT.
    IF(NDFGAR(IFLG).GT.0) GO TO 40
```

```
CWES----DETERMINE SEGMENT AND REACH OF BRANCH TO DIVERSION.
    IBRSEG=IDIVAR(3,NSFLG)
    DO 35 IBR=1,NSTREM
    IF(ISTRM(4,IBR).NE.IBRSEG) GO TO 35
    IF(ISTRM(5,IBR).EQ.1) GO TO 36
35 CONTINUE
36 CONTINUE

C8B-----DETERMINE TYPE OF DIVERSION AND AMOUNT OF FLOW TO BE DIVERTED.
    DO 30 IDL=1,NSTREM
    IF(NSFLG.NE.ISTRM(4,IDL)) GO TO 30
    DO 37 IDLL=IDL,NSTREM
    IF(NSFLG.NE.ISTRM(4,IDLL))THEN
    LREACH=IDLL-1
    ELSEIF(IDLL.EQ.NSTREM)THEN
    LREACH=NSTREM
    ENDIF
37 CONTINUE
    IF(ISTRM(5,IDL).NE.1) GO TO 30
    DUM=ARTRIB(IFLG)-STRM(1,IDL)
C8C-----DIVERSION TYPE 1 “WATER RIGHT” (DIVERT AT SPECIFIED FLOW).
C-------SUBTRACT FLOW FROM UPSTREAM SEGMENT IF THERE IS ENOUGH FLOW
C-------IN UPSTREAM SEGMENT.
    IF(IDIVAR(2,NSFLG).EQ.1) THEN
    IF(DUM.GE.0.0) QBR=DUM
    IF(DUM.GE.0.0) QDV=STRM(1,L)
    IF(DUM.LT.0.0) QBR=ARTRIB(IFLG)
    IF(DUM.LT.0.0) QDV=0.
    GOTO 20
    ENDIF
C8D-----DIVERSION TYPE 2 “FLOOD CONTROL”   (DIVERT ABOVE SPECIFIED FLOW).
    IF(IDIVAR(2,NSFLG).EQ.2) THEN
    IF(DUM.GE.0.0) QBR=STRM(1,IDL)
    IF(DUM.GE.0.0) QDV=DUM
    IF(DUM.LT.0.0) QBR=ARTRIB(IFLG)
    IF(DUM.LT.0.0) QDV=0.
    GOTO 20
    ENDIF
C8E-----DIVERSION TYPE 3 “ARTIFICAL RECHARGE”   (DIVERT UP TO SPECIFIED FLOW).
    IF(IDIVAR(2,NSFLG).EQ.3) THEN
    IF(DUM.GE.0.0) QBR=DUM
    IF(DUM.GE.0.0) QDV=STRM(1,IDL)
    IF(DUM.LT.0.0) QBR=0.
    IF(DUM.LT.0.0) QDV=ARTRIB(IFLG)
    GOTO 20
    ENDIF
C8F-----DIVERSION TYPE 4 “PERCENT SPLIT” (DIVERT PERCENTAGE OF FLOW).
C SPLIT FLOW BASED ON PERCENTAGE OF INFLOW.
C INPUT PERCENTAGE IN PLACE OF DIVERSION VALUE; CALCULATE QUANTITIES IN
C DIVERSION AND BRANCH. SAVE VALUES IN QDIV AND STRM(1,IBR). MAY NEED
```

```
C OTHER SLIGHT MODIFICATIONS AND TESTING.
    IF(IDIVAR(2,NSFLG).EQ.4) THEN
      QDV=ARTRIB(IFLG)*(STRM(1,IDL)/100.)
      QBR=ARTRIB(IFLG)*(1.0-(STRM(1,NSFLG)/100.))
      GOTO 20
    ENDIF
20 CONTINUE
    NDFGAR(IFLG)=1
    STRM(1,IBR)=QBR
    ARTRIB(IFLG)=QBR+QDV
    ARTRIB(NSFLG)=STRM(9,LREACH)
    QDIV(NSFLG)=QDV
30 CONTINUE
40 CONTINUE

C-----DETERMINE IF SEGMENT IS A DIVERSION
    50 IF(IDIVAR(1,ISTSG).LE.0) GO TO 60
      FLOWIN=QDIV(ISTSG)
    60 IF(FLOWIN.GE.0.0) GO TO 300
```

Subroutine STR1BD:

```
    DIMENSION STRM(11,MXSTRM),ISTRM(5,MXSTRM),IBOUND(NCOL,NROW,NLAY),
    1  HNEW(NCOL,NROW,NLAY),VBVL(4,20),VBNM(4,20),
    2  BUFF(NCOL,NROW,NLAY),ARTRIB(NSS),ITRBAR(NSS,NTRIB),
    3  IDIVAR(3,NSS),NDFGAR(NSS),QDIV(NSS)
    --------------------------------------
C10-----CHECK UPSTREAM SEGMENT FOR DIVERSIONS.
    DO 40 NSFLG = 1,NSS
    IF(IFLG.NE.IDIVAR(1,NSFLG))GO TO 40

CWES----CHECK IF DIVERSIONS HAVE ALREADY BEEN CALCULATED FOR SEGMENT.
    IF(NDFGAR(IFLG).GT.0) GO TO 40

CWES----DETERMINE SEGMENT AND REACH OF BRANCH TO DIVERSION.
    IBRSEG=IDIVAR(3,NSFLG)
    DO 35 IBR=1,NSTREM
    IF(ISTRM(4,IBR).NE.IBRSEG) GO TO 35
    IF(ISTRM(5,IBR).EQ.1) GO TO 36
35 CONTINUE
36 CONTINUE

C11A----DETERMINE TYPE OF DIVERSION AND AMOUNT OF FLOW TO BE DIVERTED.
    DO 30 IDL=1,NSTREM
    IF(NSFLG.NE.ISTRM(4,IDL)) GO TO 30
    DO 37 IDLL=IDL,NSTREM
    IF(NSFLG.NE.ISTRM(4,IDLL))THEN
    LREACH=IDLL-1
    ELSEIF(IDLL.EQ.NSTREM)THEN
    LREACH=NSTREM
ENDIF
```

```
37 CONTINUE
    IF(ISTRM(5,IDL).NE.1) GO TO 30
    DUM=ARTRIB(IFLG)–STRM(1,IDL)
C11B----DIVERSION TYPE 1 “WATER RIGHTS”   (DIVERT AT SPECIFIED FLOW).
C-------SUBTRACT FLOW FROM UPSTREAM SEGMENT IF THERE IS ENOUGH FLOW
C-------IN UPSTREAM SEGMENT.
    IF(IDIVAR(2,NSFLG).EQ.1) THEN
    IF(DUM.GE.0.0) QBR=DUM
    IF(DUM.GE.0.0) QDV=STRM(1,IDL)
    IF(DUM.LT.0.0) QBR=ARTRIB(IFLG)
    IF(DUM.LT.0.0) QDV=0.
    GOTO 20
    ENDIF
C11C----DIVERSION TYPE 2 “FLOOD CONTROL” (DIVERT ABOVE SPECIFIED FLOW).
    IF(IDIVAR(2,NSFLG).EQ.2) THEN
    IF(DUM.GE.0.0) QBR=STRM(1,IDL)
    IF(DUM.GE.0.0) QDV=DUM
    IF(DUM.LT.0.0) QBR=ARTRIB(IFLG)
    IF(DUM.LT.0.0) QDV=0.
    GOTO 20
    ENDIF
C11D----DIVERSION TYPE 3 “ARTIFICAL RECHARGE” (DIVERT UP TO SPECIFIED FLOW).
    IF(IDIVAR(2,NSFLG).EQ.3) THEN
    IF(DUM.GE.0.0) QBR=DUM
    IF(DUM.GE.0.0) QDV=STRM(1,IDL)
    IF(DUM.LT.0.0) QBR=0.
    IF(DUM.LT.0.0) QDV=ARTRIB(IFLG)
    GOTO 20
ENDIF
C11E----DIVERSION TYPE 4 “PERCENT SPLIT” (DIVERT PERCENTAGE OF FLOW.)
C SPLIT FLOW BASED ON PERCENTAGE OF INFLOW.
C INPUT PERCENTAGE IN PLACE OF DIVERSION VALUE; CALCULATE QUANTITIES IN
C DIVERSION AND BRANCH. SAVE VALUES IN QDIV AND STRM(1,IBR).
    IF(IDIVAR(2,NSFLG).EQ.4) THEN
    QDV=ARTRIB(IFLG)*(STRM(1,IDL)/100.)
    QBR=ARTRIB(IFLG)*(1.0–(STRM(1,NSFLG)/100.))
    GOTO 20
    ENDIF
20 CONTINUE
    NDFGAR(IFLG)=1
    STRM(1,IBR)=QBR
    ARTRIB(IFLG)=QBR+QDV
    ARTRIB(NSFLG)=STRM(9,LREACH)
    QDIV(NSFLG)=QDV
30 CONTINUE
CONTINUE

C-----DETERMINE IF SEGMENT IS A DIVERSION.
    50 IF(IDIVAR(1,ISTSG).LE.0) GO TO 60
      FLOWIN=QDIV(ISTSG)
    60 IF(FLOWIN.GE.0.0) GO TO 300
```

APPENDIX 3: DOCUMENTATION OF METHODS USED TO PROJECT CLIMATE SCENARIOS FOR THE NEXT 50 YEARS FOR THE SANTA CLARA–CALLEGUAS BASIN

By M.D. Dettinger, U.S. Geological Survey, San Diego, California

In order to develop realistic precipitation inputs for use in testing the efficacy of water-resources management approaches in the Santa Clara–Calleguas Basin, a combination of random-number synthesis and climate-cycle extrapolation was used to synthesize 50-year-long extrapolations of the historical climate record. The scheme that was developed builds on singular-spectrum-analysis (SSA) predictive methods described by Keppenne and Ghil (1992) and Jiang and others (1995). The result is a series of 50-year extrapolations of historical annual precipitation totals for an aggregate of coastal precipitation stations in the basin. Each extrapolation is realistic in its randomness but also includes proper levels of predictability at certain frequencies. The groups are natural extensions of recent climate variations in the basin but are not predictions. Any of the many different series generated *could* be the future climate, but no single one of them will prove to be precisely correct. Thus, the resulting extrapolation of precipitation totals is considered to contain typical climatic changes that may occur in the future. The approach consists of six steps:

1. The series of annual precipitation totals from 1905 to 1993 for coastal stations in the basin was analyzed by SSA, as described by Vautard and others (1992), and implemented by Dettinger and others (1995). SSA is a form of principal-component analysis in lag-time domain that is used to detect periodic signals in short, often noisy, time series. SSA automatically (data adaptively) develops filters that extract the most information from the series using the simplest forms. In this application, by considering precipitation variability with lags from 1 to 20 years, most of the variability could be described in terms of three simple oscillations: a low-frequency oscillation with a mix of periods centered on 13 and 30 years (averaging roughly 22 years), a high-frequency oscillation made up of 2.2- and 2.9-year periods, and a mid-range oscillation with a period of 5.3 years. The low-frequency oscillation contributes 25 percent of the variance of the annual series, the high-frequency oscillation contributes another 20 percent, and the mid-range oscillation contributes 15 percent. Each of the three oscillatory modes was extracted separately from the original series by application of the data-adaptive filters that SSA provides and is shown by one of the heavy curves in figure A3.1.

The remaining 40 percent of variance required (estimated using SSA) complicated temporal patterns and thus was difficult to distinguish from random noise. In spatial principal-component analysis (the spatial counterpart of SSA), 60-percent capture of variance is typical; for SSA in climate applications, capturing this proportion of variance is unusually high. Because of its complexity, the random-looking part of the precipitation record was not projected by the same scheme as were the simpler, oscillatory modes (steps 2 and 3 below), and instead was included separately.

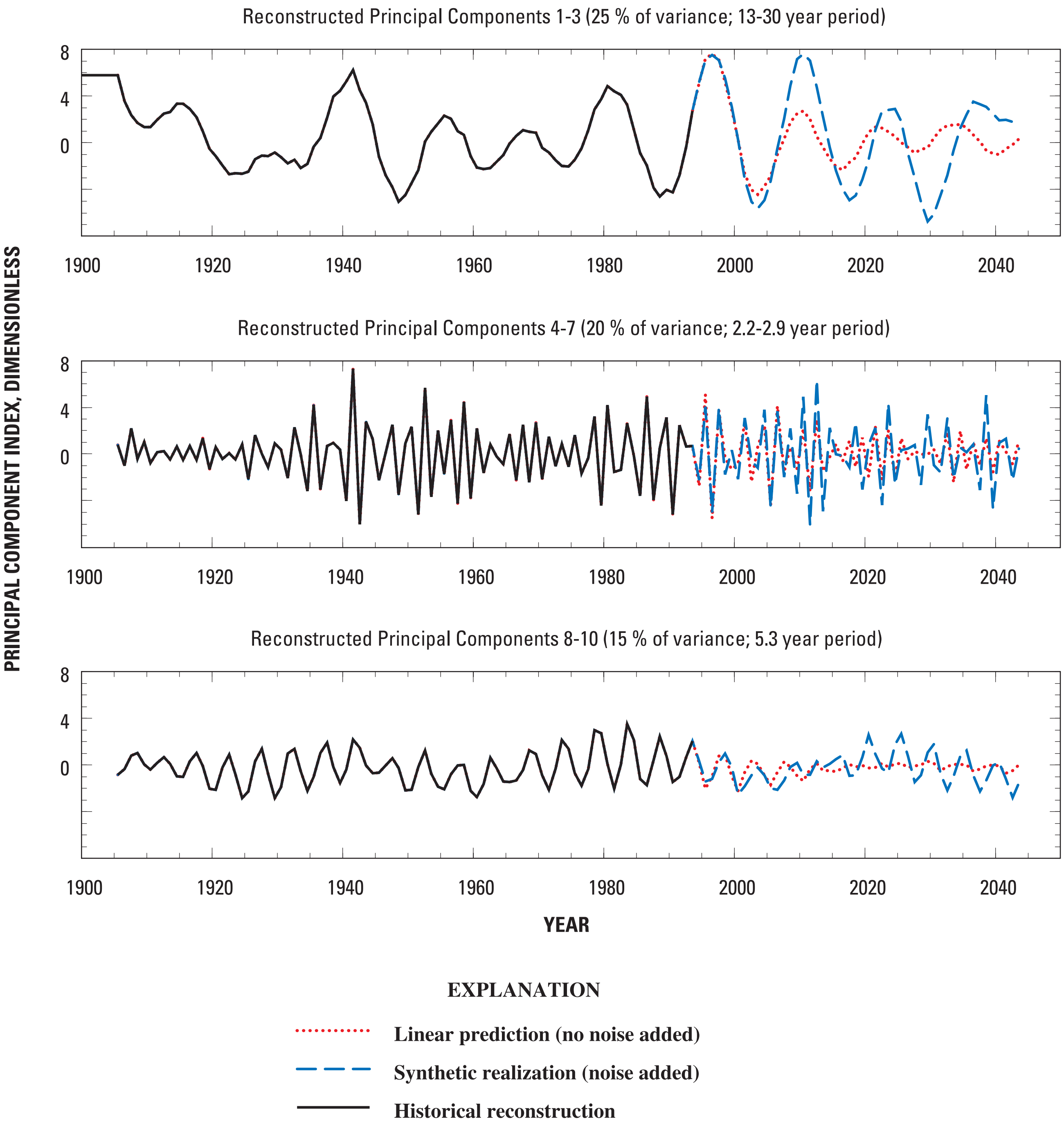


Figure A3.1. Singular-spectrum analysis (SSA) oscillatory components of Santa Clara–Calleguas precipitation, and their long-term projections.

2. Because they vary with great regularity in their narrow frequency bands, the three oscillations are more predictable than the rest of the precipitation variations. Following Keppenne and Ghil (1992), an autoregressive model was fitted to each of the oscillatory modes in turn, and those models were stepped forward to project the modes for an additional 50 years. Each autoregressive (AR) model represents the historical variations of its oscillation as

$$p_i = a_1 p_{i-1} + a_2 p_{i-2} + \ldots + a_n p_{i-n} + \varepsilon_i \,,$$

where p_i is the deviation of precipitation in year i from the long-term average, a_n is the autoregressive coefficient for time lag n, and ε_i is a normally distributed, random number with mean equal to zero and variance chosen to make the variance of p_i equal to that observed in the oscillation isolated by SSA. The AR coefficients and the variance properties of ε_i are fitted to the historical record by standard methods (Press and others, 1989). Because the SSA analysis has already isolated the predictable parts of the series from the unpredictable parts, the AR model fit is quite good. The number of lags considered, n, was chosen here to be longer than the maximum period in the SSA components (35 years), but to illustrate this equation, consider the case where only one lag is used in the AR model. If only one lag is used, the model reduces to

$$p_i = a_1 p_{i-1} + \varepsilon_i \,,$$

and it can be shown that a_1 must be the 1-year-lag autocorrelation coefficient and ε_i must have a variance equal to the variance of the series divided by $(1-a_1^2)$ in order for the lag-correlation and the variance of the autoregressive model to equal that of the original series. If a_1 is negative, then every time the precipitation is more than normal, the following year's precipitation will tend to be less than normal; the reverse is true when the precipitation is less than normal. Unless the noise term dominates, the autoregressive model will generate a series with a frequency near 2 years (1 year up, 1 year down, and so on). With the larger number of lags included in the analysis used here, much more complicated periodicities can be modeled.

Once the model coefficients are fitted, the model can be applied to predict the next value in the series by substituting p_{i-1} through p_{i-n} for the last n historical observations, and 0 for ε_i. The predicted point can then be used as if it were another historical observation to predict the next value after that, and so on. This is called 'linear prediction' (Press and others, 1989) and, as would be expected for a "safe" prediction, after a time, the predicted values collapse toward a zero deviation from the mean of the historical series. (In the simplified version above, a_1 is the lag-one correlation and thus less than 1, which means that, if $\varepsilon_i = 0$, p_i is always smaller than p_{i-1}.) This tendency is illustrated by the dotted curves in figure A3.1. A better approach to synthesizing realistic future values is to substitute random numbers with the correct variance properties for the ε_i's. The result is not a prediction since every new choice of random numbers for ε_i will yield a new projection of the series, but instead is a future-precipitation projection that maintains realistic levels of randomness around the mean. The AR model has the advantage (over synthesis of purely random precipitation values) in that it incorporates realistic periodicities and randomness. In addition, because initially the projections are a weighted sum of 35 historical observations (in this study) and one random number, the initial years of the AR-model projections are based almost entirely on historical values and only gradually become dominated by the random values added. The projections thus are smooth continuations of the trends and periodicities at the end of the historical series, with no unnatural breaks in either the smoothness of the time series or in the phase angle of the periodic components.

3. A separate AR model was fitted to each of the three oscillations isolated by SSA and was used to project the oscillation forward for 50 years. Ten thousand different sets of random numbers were substituted into the models to generate a 50-year-long projection of the oscillatory components of the series for each set. For each of the projections, the three projected oscillations were summed.

4. The projected oscillations were designed to represent 60 percent of the precipitation variability that is readily described by periodic models. The remaining 40 percent is a complex sum of minor periodicities and randomness and is not well suited to the above approach. Consequently, the difference between the historical precipitation values and the sum of the three oscillations isolated by SSA was computed for each year of the historical record. Subsets of this residual series were then added to the sum of the projections of the oscillations. Each subset added contained 50 years of consecutive residual values from the historical analysis period, with the starting point (within the historical record) of each subset chosen at random. Adding these examples of the actual residual series into the projections put any remaining variance and periodicities into the projections to yield—finally—realistic projections of annual precipitation totals for the next 50 years in the Santa Clara–Calleguas Basin.

5. The resulting projections look reasonably realistic, as evidenced by three examples shown in figure A3.2. Because they share much of the 60-percent oscillatory behavior found in the historical record, the projections look surprisingly similar. They tend to share a continuance of wet conditions through the late 1990s, followed by a marked dropoff in precipitation in the first years of the 21st century. Later, the projections share a notable low-frequency variation around the historical mean, with a tendency for dry conditions during the 2020s and the 2040s, and wet conditions during the intervening periods. The broad similarities mask important differences (especially for ground-water systems), which are better illustrated by plotting cumulative departures from the mean.

An envelope that illustrates the range of cumulative departures within which 90 percent of the projections drop can be obtained by accumulating the deviations of the projected series from the historical mean precipitation and then by sorting those cumulative departures by year. The resulting envelope is shown in figure A3.3. The influence of the historical observations on the AR model projections for the first 20 years is sufficiently strong that the range of the projections is relatively small, with nearly all the projections showing a dramatic wet period in the late 1990s followed by drought until about 2005. After that time, at least a 10-year period of less-than-normal precipitation—comparable to the droughts of the 1940s—was indicated for most series. The AR model projects mostly on the basis of its own previous projections causing the envelopes to widen more in subsequent years even with the 35-year AR model used here. Despite this, the realizations mostly converge to and then oscillate around the mean for a period of about 13 years. By the time the projections end in 2043 (50 years from the start), the average of the projected cumulative departures will be somewhat below normal, but projecting another 5 to 7 years would have resulted in an average ending cumulative departure quite near normal. The range of the 10,000 projections synthesized here follows the pattern described in this paragraph (thin-line curves in fig. A3.3) as does the mean of those projections (heavy-line curve in fig. A3.3). The individual projections, however, are generally more variable, as indicated by three examples shown in figure A3.3 as dotted curves.

6. It is worth reiterating that these projections, and even their mean and ranges, are *not* climate predictions. The projections developed here are a complex mix of predictive elements and randomness. The predictive elements are based on continuation of the several simple oscillations that can be used to describe much of the variance of precipitation in the Santa Clara–Calleguas Basin. To the extent that these oscillations have physical bases in the climate processes that bring precipitation to California—and this is still a matter of research—and to the extent that the oscillations continue reliably into the future, steps 1 and 2 above could be used to develop actual predictions of precipitation over long time periods. Keppenne and Ghil (1992) and Jiang and others (1995) have attempted to predict El Niño processes in the tropical Pacific Ocean (which operate on time scales ranging from 2 to 5 years) using just such a strategy with moderate success. In the present application to the Santa Clara—Calleguas Basin, no effort has been made to calibrate a *best* predictive scheme or to quantify the validity of the predictive components of the scenarios developed. Instead, our aim was to develop realistic precipitation scenarios for the future that smoothly mesh with the more predictable parts of the recent precipitation record.

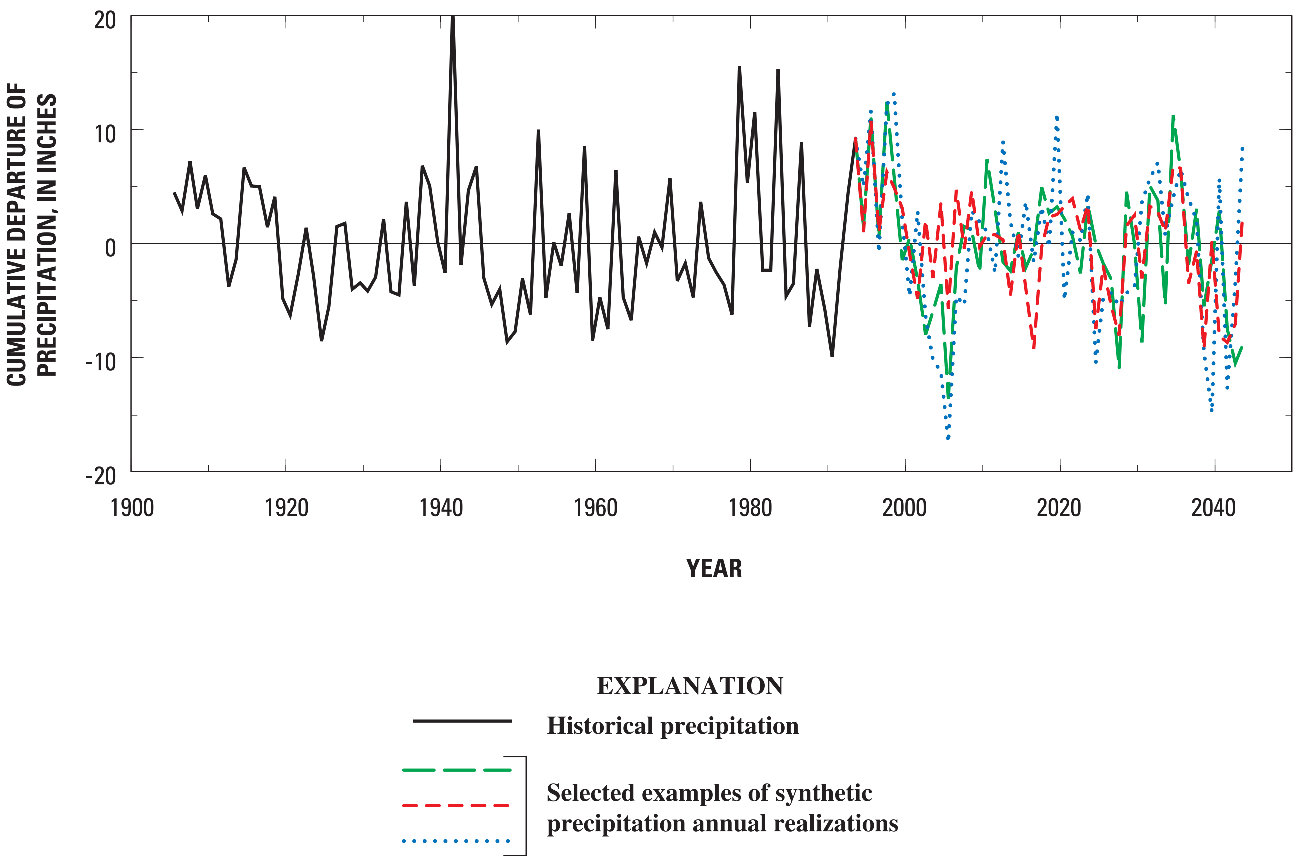


Figure A3.2. Santa Clara–Calleguas historical and selected synthetic precipitation annual realizations.

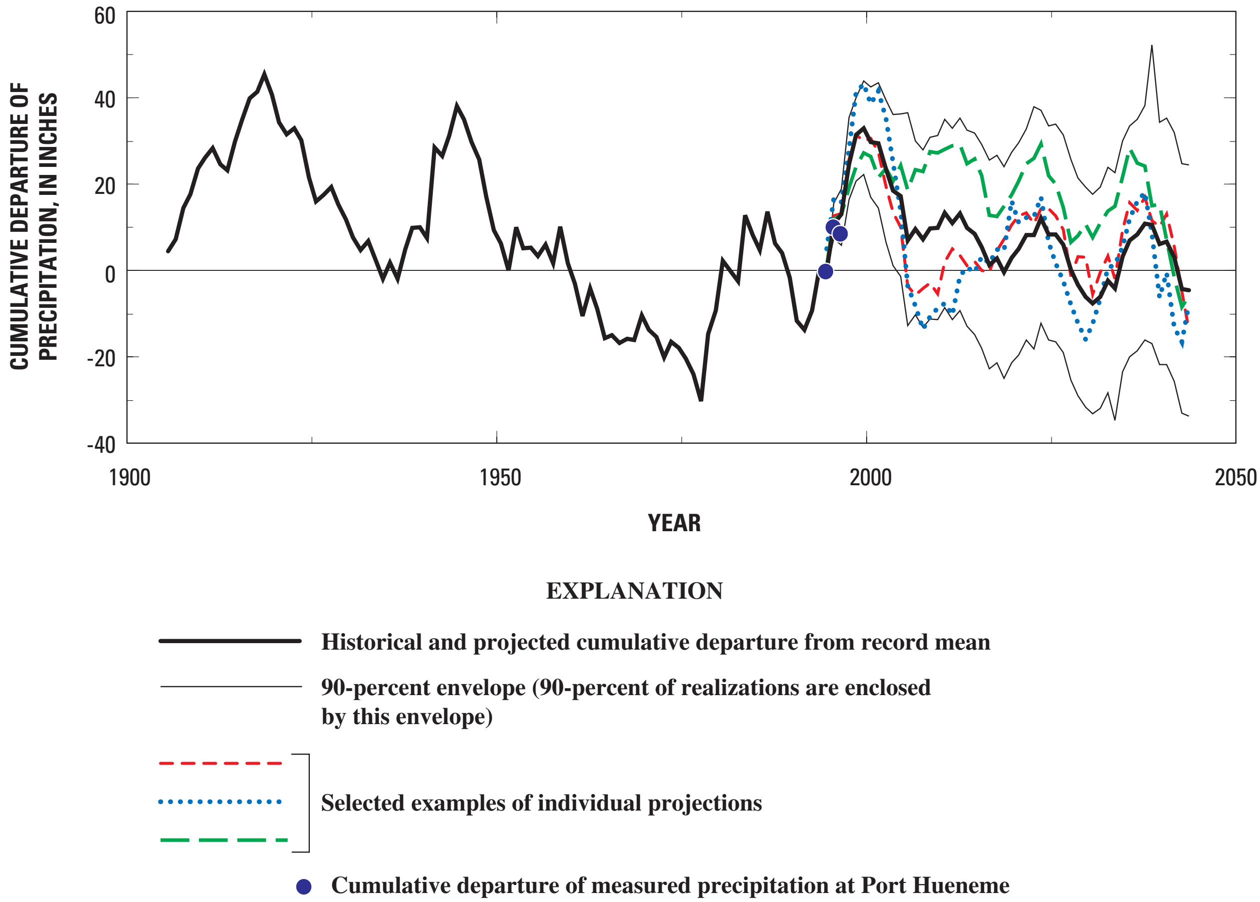


Figure A3.3. Santa clara–Calleguas cumulative departures of annual precipitation from the mean.

If, instead, predictions were the objective, steps 1 and 2 of the process described here would have to be redone for various subsets of the historical record, and predictions based on each subset would have to be compared to the subsequent historical record. Then a “best” predictor could be chosen and estimates could be developed of how well and how long the predictions performed, but we have no guarantees that the predictions would be particularly successful. Thus, the relatively simple randomized projections developed here are a quick, albeit small, first step on the path to reliable predictions.

APPENDIX 4. SUMMARY OF STREAMFLOW REGRESSIONS USED TO ESTIMATE HISTORICAL AND FUTURE STREAMFLOW

Data from selected streamflow-gaging stations with continuous, long-term, unregulated streamflow were used to develop nonlinear regression relations between precipitation and the logarithm of streamflow for seasonal total flows segregated into wet and dry periods (fig. 4). These relations were used to estimate historical streamflow prior to the installation of the gaging stations and to estimate future streamflow from spectral estimates of future precipitation (Appendix 3; fig. 27*D*). These streamflow estimates were, in turn, used as part of the input data used to simulate streamflow in the Santa Clara—Calleguas ground-water flow model during time periods when measured data were not available.

Other gaging stations that were used to estimate streamflow with the modified rational method or whose measured, regulated streamflow data were used directly as streamflow input for the simulation of historical streamflow are listed below (figs. 4 and 18):

(1) Piru Creek below Santa Felicia Dam (11109800/714);

(2) Arundell Barranca at Arrundell Ave. (—/700);

(3) Conejo Creek at Thousand Oaks (11106400)/800); and

(4) Arroyo Hondo near Somis (11107000/—);

Other downstream gaging stations, some of which were used for streamflow comparison with simulated streamflow, are the following (figs. 4 and 18):

(1) Calleguas Creek near Camarillo (11106000/—);

(2) Calleguas Creek above Highway 101 (11106550/805);

(3) Calleguas Creek near Camarillo (—/806);

(4) Arroyo Las Posas at Hitch Road (—/841);

(5) Beardsley Wash near Somis (11107500/—); and

(6)Revolon Slough at Laguna Road (—/776)

The following four tables summarize the statistical analyses completed for relations between precipitation and gaged streamflow on a seasonal basis. The tables summarize relations for most of the gaged streams and are segregated into wet and dry seasonal estimates for streamflow and three precipitation predictors, and streamflow and one precipitation predictor.

Table A4.1. Summary of streamflow regressions used to extrapolate historical winter streamflow in the Santa Clara-Calleguas Basin, Ventura County, California

Streamflow-gaging station (station number)[1]	Number of seasons (period of record)	Regression equation[2] (inches/season)	Correlation coefficient[3]	Root-mean square error (log units)
Santa Clara River at County Line[4] (11108500/707)	24(1927–91)	$Log(Q)_{dry} = -3.037 + .1789P_c$	0.28	1.13
	20 (1953–91)	$Log(Q)_{wet} = -2.733 + .1627P_c$	.51	1.14
	13(1927–71)[5]	$Log(Q)_{dry} = -4.385 - .7377P_c + .3468P_i + .4094P_m$	.45(87%)	1.25
	11(1953–71)[5]	$Log(Q)_{wet} = -3.377 - .3760P_c + .6421P_i - .1288P_m$	.75	1.02
Piru Creek near Piru (11110000/—)	16(1912–55)	$Log(Q)_{dry} = -1.970 + .1572P_c$	.17 (89%)	.80
	13(1912–55)	$Log(Q)_{wet} = -1.786 + .1793P_c$	.76	.57
	16(1912–55)	$Log(Q)_{dry} = -2.249 - .0187P_c - .1910P_i + .2870P_m$	.37 (87%)	.75
	13(1912–55)	$Log(Q)_{wet} = -1.697 - .0237P_c - .1685P_i + .2771P_m$	.83	.55
Hopper Creek near Piru (11110500/701)	30(1931–91)	$Log(Q)_{dry} = -2.022 + .2375P_c$	.56	.73
	28 (1931–91)	$Log(Q)_{wet} = -1.676 + .1999P_c$	.74	.80
	30(1931–91)	$Log(Q)_{dry} = -2.047 - .0313P_c + .0452P_i + .1361P_m$	.69	.64
	28(1931–91)	$Log(Q)_{wet} = -1.507 - .0442P_c + .1200P_i + .0585P_m$	.84	.66
Pole Creek at Sespe Avenue, Fillmore (–-/713)	9(1974–91)	$Log(Q)_{dry} = -1.135 + .0264P_c$	.01 (21%)	.77
	9(1974–91)	$Log(Q)_{wet} = -1.028 + .1252P_c$	.66	.78
	8(1974–91)	$Log(Q)_{dry} = 0.0286 - .0212P_c - .2308P_i + .0676P_m$	.54 (68%)	.54
	9(1974–91)	$Log(Q)_{wet} = -1.011 - .2353P_c + .2479P_i + .0467P_m$	.79	.73
Sespe Creek near Fillmore (11113000/710) and Fillmore Irrigation Canal[6] (11113001/—)	34(1927–91)	$Log(Q)_{dry} = -1.101 + .2174P_c$	.46	.83
	29(1927–91)	$Log(Q)_{wet} = -.7576 + .1781P_c$	.75	.68
	34(1927–91)	$Log(Q)_{dry} = -1.148 - .0017P_c - .0275P_i + .1632P_m$	.55	.77
	29(1927–91)	$Log(Q)_{wet} = -.6154 + .0080P_c + .0193P_i + .0935P_m$	.84	.56
Santa Paula Creek near Santa Paula (11113500/709)	35(1927–91)	$Log(Q)_{dry} = -.9497 + .2099P_c$	.45	.80
	29(1927–91)	$Log(Q)_{wet} = -.4937 + .1709P_c$	.69	.77
	34(1927–91)	$Log(Q)_{dry} = -.9987 - .0116P_c - .0425P_i + .1771P_m$	.57	.73
	29(1927–91)	$Log(Q)_{wet} = -.3164 - .0535P_c + .0574P_i + .0995P_m$	.82	.61
Santa Clara River at Montalvo (11114000/708) and Saticoy Diversion (11113910/—)	18(1955–91)	$Log(Q)_{dry} = -2.629 + .2289P_c$	.60	.81
	17(1955–91)	$Log(Q)_{wet} = -2.071 + .1775P_c$	.69	.89
	17(1955–91)	$Log(Q)_{dry} = -2.772 - .1078P_c + .1592P_i + .0947P_m$	.66	.81
	17(1955–91)	$Log(Q)_{wet} = -2.005 - .0916P_c + .1806P_i + .0319P_m$	.82	.72
Arroyo Simi near Simi (11105850/—)[7] and Arroyo Simi at Royal Avenue (–/802)	20(1933–90)	$Log(Q)_{dry} = -4.163 + .2292P_c$	.13 (89%)	2.30
	25(1933–90)	$Log(Q)_{wet} = -4.573 + .2718P_c$	.52	1.66
	20(1933–90)	$Log(Q)_{dry} = -4.931 - .1.056P_c + .1.129P_i - .0226P_m$	.31 (89%)	2.17
	25(1933–90)	$Log(Q)_{wet} = -4.322 - .0301P_c + .1989P_i + .0303P_m$	.58	1.61

[1]U.S. Geological Survey and Ventura County Flood Control District gaging station numbers. —, indicates no gaging station number.

[2]Response variable Q is total seasonal streamflow. Predictor variables are total normalized precipitation for coastal (P_c), intermontane (P_i), and mountain (P_m) precipitation stations.

[3]Correlation coefficient significant at 90 percent confidence level. If not significant at this level, number in parentheses indicates the confidence level of the correlation coefficient.

[4]Streamflow data combined with streamflow data from Santa Clara River near Piru (11109000) for period 1927–32.

[5]Data for regression restricted to streamflow records prior to releases from Lake Castaic.

[6]Fillmore Irrigation Canal diversion data included for period 1940–91.

[7]Streamflow data combined from Arroyo Simi at Royal Avenue for period fall 1970 to spring 1990.

Table A4.2. Summary of streamflow regressions used to extrapolate historical spring streamflow in the Santa Clara-Calleguas Basin, Ventura County, California

Streamflow-gaging station (station number)[1]	Number of seasons (period of record)	Regression equation[2] (inches/season)	Correlation coefficient[3]	Root-mean square error (log units)
Santa Clara River at County	23(1927–91)	$Log(Q)_{dry} = -2.796 - .2835P_c$	0.03 (59%)	1.22
Line[4] (11108500/707)	11 (1953–71)[5]	$Log(Q)_{wet} = -3.304 + .3443P_c$	.22 (85%)	1.25
	13(1927–71)[5]	$Log(Q)_{dry} = -3.156 + 1.013P_c - .0747P_i - .6987P_m$	.12 (25%)	1.22
	11(1953–71)[5]	$Log(Q)_{wet} = -3.382 + .0266P_c - .4491P_i + .5021P_m$	.32 (59%)	1.32
Piru Creek near Piru	16(1912–55)	$Log(Q)_{dry} = -2.422 - .0213P_c$	.0004 (.06%)	.95
(11110000/—)	13 (1912–55)	$Log(Q)_{wet} = -1.086 + .1842P_c$	.06 (56%)	1.02
	16(1912–55)	$Log(Q)_{dry} = -2.649 + .1478P_c - 1.035P_i + .8194P_m$	.07 (18%)	.99
	13(1912–55)	$Log(Q)_{wet} = -.7627 + 1.225P_c - 1.121P_i + .0349P_m$	.18 (40%)	1.05
Hopper Creek near Piru	29(1927–91)	$Log(Q)_{dry} = -3.683 + .5696P_c$	.08 (85%)	1.61
(11110500/701)	28 (1927–91)	$Log(Q)_{wet} = -2.289 + .6658P_c$	.35	1.38
	29(1927–91)	$Log(Q)_{dry} = -3.914 - 2.141P_c + .8122P_i + 1.060P_m$	.28	1.48
	28(1927–91)	$Log(Q)_{wet} = -2.288 + .7434P_c - .7047P_i + .4137P_m$	.38	1.41
Pole Creek at Sespe Avenue,	8(1974–91)	$Log(Q)_{dry} = -1.452 - .0444P_c$	.004 (12%)	.45
Fillmore	9(1974–91)	$Log(Q)_{wet} = -1.173 + .6875P_c$	.76	.47
(—/713)	8(1974–91)	$Log(Q)_{dry} = -1.392 - .5293P_c + .3821P_i - .0660P_m$	.11 (9%)	.52
	9(1974–91)	$Log(Q)_{wet} = -1.160 + .4651P_c + .2231P_i - .0244P_m$	.76	.56
Sespe Creek near Fillmore	33(1927–91)	$Log(Q)_{dry} = -1.242 + .0526P_c$	.002 (20%)	.89
(11113000/710) and	29(1927–91)	$Log(Q)_{wet} = -.5556 + .3931P_c$	.30	.91
Fillmore Irrigation Canal[6]	33(1927–91)	$Log(Q)_{dry} = -1.338 - .5084P_c - .0060P_i + .4028P_m$	.07 (44%)	.89
(11113001/—)	29(1927–91)	$Log(Q)_{wet} = -5216 + .6411P_c - .8541P_i + .4202P_m$	.37	.90
Santa Paula Creek near	34(1927–91)	$Log(Q)_{dry} = -.8260 - .0964P_c$	.003 (25%)	1.31
Santa Paula	29(1927–91)	$Log(Q)_{wet} = -.0098 + .3153P_c$	.20	.96
(11113500/709)	34(1927–91)	$Log(Q)_{dry} = -.8023 - .8849P_c + .5579P_i + .0428P_m$	.04 (27%)	1.33
	29(1927–91)	$Log(Q)_{wet} = .0083 + .4735P_c - .7315P_i + .3961P_m$	.26	.96
Santa Clara River at	17(1955–91)	$Log(Q)_{dry} = -2.650 + .2540P_c$	.02 (39%)	1.34
Montalvo (11114000/708)	17(1955–91)	$Log(Q)_{wet} = -1.588 + .2891P_c$	.15 (88%)	1.16
and Saticoy Diversion	17(1955–91)	$Log(Q)_{dry} = -2.553 - .7318P_c + .6528P_i + .0148P_m$	.07 (18%)	1.40
(11113910/—)	17(1955–91)	$Log(Q)_{wet} = -1.615 - .3589P_c - .4842P_i + .2836P_m$	.18 (54%)	1.23
Arroyo Simi near Simi	8(1933–90)	$Log(Q)_{dry} = -2.999 - .5296P_c$	.05 (42%)	1.62
(11105850/—)[7] and	14(1933–90)	$Log(Q)_{wet} = -6.229 + 1.045P_c$	.47	1.90
Arroyo Simi at	8(1933–90)	$Log(Q)_{dry} = -4.053 - 2.308P_c + .0723P_i + 1.351P_m$	.33 (38%)	1.67
Royal Avenue	14(1933–90)	$Log(Q)_{wet} = -6.354 - .0511P_c + .0246P_i + .7132P_m$	.54	1.95
(—/802)				

[1]U.S. Geological Survey and Ventura County Flood Control District gaging station numbers. —, indicates no gaging station number.

[2]Response variable Q is total seasonal streamflow. Predictor variables are total normalized precipitation for coastal (P_c), intermontane (P_i), and mountain (P_m) precipitation stations.

[3]Correlation coefficient significant at 90 percent confidence level. If not significant at this level, number in parentheses indicates the confidence level of the correlation coefficient.

[4]Streamflow data combined with streamflow data from Santa Clara River near Piru (11109000) for period 1927–32.

[5]Data for regression restricted to streamflow records prior to releases from Lake Castaic.

[6]Fillmore Irrigation Canal diversion data included for period 1940–91.

[7]Streamflow data combined from Arroyo Simi at Royal Avenue for period fall 1970 to spring 1990.

Table A4.3. Summary of streamflow regressions used to extrapolate historical summer streamflow in the Santa Clara-Calleguas Basin, Ventura County, California

Streamflow-gaging station (station number)[1]	Number of seasons (period of record)	Regression equation[2] (inches/season)	Correlation coefficient[3]	Root-mean square error (log units)
Santa Clara River at County Line[4] (11108500/707)	12(1927–71)[5]	$Log(Q)_{dry} = -5.899 - 2.099P_c$	0.02 (35%)	2.75
	20(1953–91)	$Log(Q)_{wet} = -4.504 + 2.480P_c$	.35	1.62
	12(1927–71)[5]	$Log(Q)_{dry} = -5.148 - 44.73P_c + 26.75P_i - 3.572P_m$	.45 (84%)	2.30
	20(1953–91)	$Log(Q)_{wet} = -4.511 + .1.877P_c + 1.059P_i - .6027P_m$	.36	1.71
Piru Creek near Piru (11110000/—)	13(1912–55)	$Log(Q)_{dry} = -4.451 - 7.362P_c$	.21 (89%)	1.26
	13(1912–55)	$Log(Q)_{wet} = -2.801 + 1.331P_c$	.11 (74%)	1.22
	13(1912–55)	$Log(Q)_{dry} = -4.486 - 7.887P_c - .1201P_i + .4173P_m$	.22 (49%)	1.38
	13(1912–55)	$Log(Q)_{wet} = -3.006 - 1.504P_c - 14.34P_i + 14.49P_m$	.23 (51%)	1.26
Hopper Creek near Piru (11110500/701)	8(1931–91)	$Log(Q)_{dry} = -5.472 + .4097P_c$	.11 (57%)	2.02
	16(1931–91)	$Log(Q)_{wet} = -3.391 + .7627P_c$	.05 (60%)	1.81
	8(1931–91)	$Log(Q)_{dry} = -5.361 - 1.697P_c - 2.145P_i + 2.459P_m$	.35 (40%)	2.12
	16(1931–91)	$Log(Q)_{wet} = -3.476 + .4776P_c - 1.325P_i + 1.802P_m$	.11 (29%)	1.89
Pole Creek at Sespe Avenue, Fillmore (—/713)	7(1974–91)	$Log(Q)_{dry} = -4.173 + .2732P_c$	.06 (40%)	2.04
	9(1974–91)	$Log(Q)_{wet} = -2.654 + 1.347P_c$	.50	.81
	6(1974–91)	$Log(Q)_{dry} = -3.465 - 8.042P_c + 2.957P_i + 3.897P_m$	.27 (14%)	.99
	9(1974–91)	$Log(Q)_{wet} = -2.711 + .9798P_c + .2783P_i + .0632P_m$	.51 (73%)	.95
Sespe Creek near Fillmore (11113000/710) and Fillmore Irrigation Canal[6] (11113001/—)	26(1927–91)	$Log(Q)_{dry} = -3.167 + .2304P_c$	.03 (61%)	1.19
	29(1927–91)	$Log(Q)_{wet} = -2.276 + .8711P_c$	.20	.80
	25(1927–91)	$Log(Q)_{dry} = -3.038 + .1412P_c - .1330P_i + .1093P_m$	.03 (13%)	1.08
	29(1927–91)	$Log(Q)_{wet} = -2.266 + 1.368P_c - .9341P_i + .5110P_m$	.21 (89%)	.82
Santa Paula Creek near Santa Paula (11113500/709)	31(1927–91)	$Log(Q)_{dry} = -2.107 - .0656P_c$	.005 (27%)	.87
	29(1927–91)	$Log(Q)_{wet} = -1.290 + .9434P_c$	.23	.79
	30(1927–91)	$Log(Q)_{dry} = -2.097 - .3208P_c - .1186P_i + .3193P_m$	.01 (5%)	.90
	29(1927–91)	$Log(Q)_{wet} = -1.269 + 1.401P_c - .6047P_i + .1889P_m$	.24	.82
Santa Clara River at Montalvo (11114000/708) and Saticoy Diversion (11113910/—)	15(1959–91)	$Log(Q)_{dry} = -3.836 + .0468P_c$	.001 (9%)	1.89
	15(1955–91)	$Log(Q)_{wet} = -2.695 + 1.268P_c$	.11 (78%)	1.85
	14(1955–91)	$Log(Q)_{dry} = -3.534 + 2.167P_c + .3866P_i - 1.6679P_m$	.09 (21%)	1.97
	15(1955–91)	$Log(Q)_{wet} = -2.638 + 1.278P_c + .3279P_i - .4293P_m$	.12 (31%)	2.00
Arroyo Simi near Simi (11105850/—)[7] and Arroyo Simi at Royal Avenue (—/802)	5(1933–90)	$Log(Q)_{dry} = -5.658 - .4725P_c$	.29 (65%)	1.64
	4(1933–90)	$Log(Q)_{wet} = -8.102 + 3.281P_c$	.86	1.10
	5(1933–90)	$Log(Q)_{dry} = -6.521 + .8605P_c + 4.216P_i - 2.406P_m$	.92 (65%)	.94
	4(1933–90)	$Log(Q)_{wet} = -7.630 + 12.57P_c - 11.01P_i + 3.187P_m$	1.0	.00

[1]U.S. Geological Survey and Ventura County Flood Control District gaging station numbers. —, indicates no gaging station number.

[2]Response variable Q is total seasonal streamflow. Predictor variables are total normalized precipitation for coastal (P_c), intermontane (P_i), and mountain (P_m) precipitation stations.

[3]Correlation coefficient significant at 90 percent confidence level. If not significant at this level, number in parentheses indicates the confidence level of the correlation coefficient.

[4]Streamflow data combined with streamflow data from Santa Clara River near Piru (11109000) for period 1927–32.

[5]Data for regression restricted to streamflow records prior to releases from Lake Castaic.

[6]Fillmore Irrigation Canal diversion data included for period 1940–91.

[7]Streamflow data combined from Arroyo Simi at Royal Avenue for period fall 1970 to spring 1990.

Table A4.4 Summary of streamflow regressions used to extrapolate historical fall streamflow in the Santa Clara-Calleguas Basin, Ventura County, California

Streamflow gaging station (station number)[1]	Number of seasons (period of record)	Regression equation[2] (inches/season)	Correlation coefficient[3]	Root-mean square error (log units)
Santa Clara River at County Line[4] (11108500/707)	13(1927-71)[5]	$Log(Q)_{dry} = -4.865 + .2786P_c$	0.29	1.49
	11(1953-71)[5]	$Log(Q)_{wet} = -5.066 + .4470P_c$	.67	1.05
	12(1927-71)[5]	$Log(Q)_{dry} = -5.377 - .1508P_c + .1587P_i + .2264P_m$	.47 (85%)	1.51
	11(1953-71)[5]	$Log(Q)_{wet} = -4.992 + .2771P_c +.1204P_i + .0063P_m$	.68	1.17
Piru Creek near Piru (11110000/—)	16(1911-55)	$Log(Q)_{dry} = -4.320 + .3641P_c$	.63	.79
	13(1911-55)	$Log(Q)_{wet} = -2.984 + .1978P_c$	.28	1.04
	16(1911-55)	$Log(Q)_{dry} = -4.319 + .0471P_c + .2326P_i + .0291P_m$	.66	.83
	13(1911-55)	$Log(Q)_{wet} = -3.274 - .0525P_c + .2672P_i + .0477P_m$	.38 (78%)	1.07
Hopper Creek near Piru (11110500/701)	23(1931-91)	$Log(Q)_{dry} = -3.787 + .4639P_c$	.58	1.05
	28(1931-91)	$Log(Q)_{wet} = -3.622 + .4182P_c$	.57	1.10
	23(1931-91)	$Log(Q)_{dry} = -4.104 - .2312P_c + .5355P_i + .0758P_m$	.70	.94
	28(1931-91)	$Log(Q)_{wet} = -3.695 + .0549P_c + .1946P_i + .1254P_m$	.70	.94
Pole Creek at Sespe Avenue, Fillmore (—/713)	8(1974-91)	$Log(Q)_{dry} = -2.80 + .2675P_c$	.68	.47
	9(1974-91)	$Log(Q)_{wet} = -1.567 + .1851P_c$	.49	.51
	7(1974-91)	$Log(Q)_{dry} = -3.1519 + .3447P_c - .2621P_i + .2271P_m$	.88	.40
	9(1974-91)	$Log(Q)_{wet} = -1.478 - .0694P_c + .2566P_i - .0487P_m$	.61 (83%)	.53
Sespe Creek near Fillmore (11113000/710) and Fillmore Irrigation Canal[6] (11113001/—)	33(1927-91)	$Log(Q)_{dry} = -3.039 + .3846P_c$	.60	.90
	29(1927-91)	$Log(Q)_{wet} = -2.423 + .3248P_c$	.64	.74
	32(1927-91)	$Log(Q)_{dry} = -3.1636 - .1870P_c + .2836P_i + .1819P_m$	.70	.82
	29(1927-91)	$Log(Q)_{wet} = -2.463 + .0443P_c + .0326P_i + .1917P_m$	.84	.51
Santa Paula Creek near Santa Paula (11113500/709)	34(1927-91)	$Log(Q)_{dry} = -2.1693 - .2550P_c$	.40	.89
	29(1927-91)	$Log(Q)_{wet} = -1.455 + .2160P_c$	.43	.75
	33(1927-91)	$Log(Q)_{dry} = -2.218 - .3009P_c + .2761P_i + .1695P_m$	.52	.81
	29(1927-91)	$Log(Q)_{wet} = -1.526 - .1327P_c + .2032P_i + .1069P_m$	.77	.49
Santa Clara River at Montalvo (11114000/708) and Saticoy Diversion (11113910/—)	17(1959-91)	$Log(Q)_{dry} = -4.683 + .4202P_c$	.33	1.74
	17(1955-91)	$Log(Q)_{wet} = -2.665 + .2201P_c$	.23	1.16
	16(1955-91)	$Log(Q)_{dry} = -3.949 - .1655P_c - .2650P_i + .5361P_m$	.76	0.58
	17(1955-91)	$Log(Q)_{wet} = -2.434 - .3029P_c + .4163P_i - .0105P_m$	.39	1.11
Arroyo Simi near Simi (11105850/—)[7] and Arroyo Simi at Royal Avenue (—/802)	14(1933-90)	$Log(Q)_{dry} = -4.470 - .3686P_c$	.21	1.67
	19(1933-90)	$Log(Q)_{wet} = -5.181 + .4527P_c$	.35	1.71
	14(1933-90)	$Log(Q)_{dry} = -5.320 - .0880P_c - .1451P_i + .5376P_m$	.43 (88%)	1.56
	19(1933-90)	$Log(Q)_{wet} = -5.145 - .2144P_c + .8507P_i - .2195P_m$	.54	1.53

[1]U.S. Geological Survey and Ventura County Flood Control District gaging station numbers. ---, indicates no gaging station number.

[2]Response variable Q is total seasonal streamflow. Predictor variables are total normalized precipitation for coastal (Pc), intermontane (Pi), and mountain (Pm) precipitation stations. Single predictor used for period 1891–1904.

[3]Correlation coefficient significant at 90% confidence level. If not significant at this level, number in parentheses indicates the confidence level of the correlation coefficient.

[4]Streamflow data combined with streamflow data from Santa Clara River near Piru (11109000) for period 1927-32.

[5]Data for regression restricted to streamflow records prior to releases from Lake Castaic.

[6]Fillmore Irrigation Canal diversion data included for period 1940-91.

[7]Streamflow data combined from Arroyo Simi at Royal Avenue for period fall 1970 to spring 1990.

APPENDIX 5. SUMMARY OF SELECTED GEOPHYSICAL LOGS FOR SEVERAL RASA SEAWATER INTRUSION COASTAL MONITORING WELLS AND FLOWMETER LOGS FOR SELECTED PRODUCTION WELLS USED FOR THE SANTA CLARA—CALLEGUAS GROUND-WATER FLOW MODEL

The development of the conceptual model of regional flow and seawater intrusion, as well as the preparation of selected model input data sets for MODFLOW, required the collection and analysis of selected geophysical logs. The typical occurrence of seawater intrusion was determined through the collection of electromagnetic-induction and natural gamma logs. Examples of the vertical distribution of seawater intrusion were determined from the combination of geophysical logs (fig. A5.1). The estimation of the vertical distribution of pumpage from wells that are screened across parts of the upper- and lower-aquifer systems was determined through the collection of flowmeter logs from selected production wells. Examples of the flowmeter logs demonstrate the vertical distribution of wellbore inflow (fig. A5.2) and were used to estimate the percentage of pumpage for each model layer for wells that were completed in both aquifer systems (table 5).

The USGS completed 20 multiple-well monitoring sites as part of the RASA project (fig. 15). The data from these sites were used for stratigraphic analysis (figs. 7 and 8) and for comparison between measured and simulated water levels (fig. 13). Table A5.1 provides a summary of these well completions with the aquifers and depth below land surface of the screened interval for each monitoring. Detailed descriptions of well construction, lithology, and geophysical logs are presented by Densmore (1996).

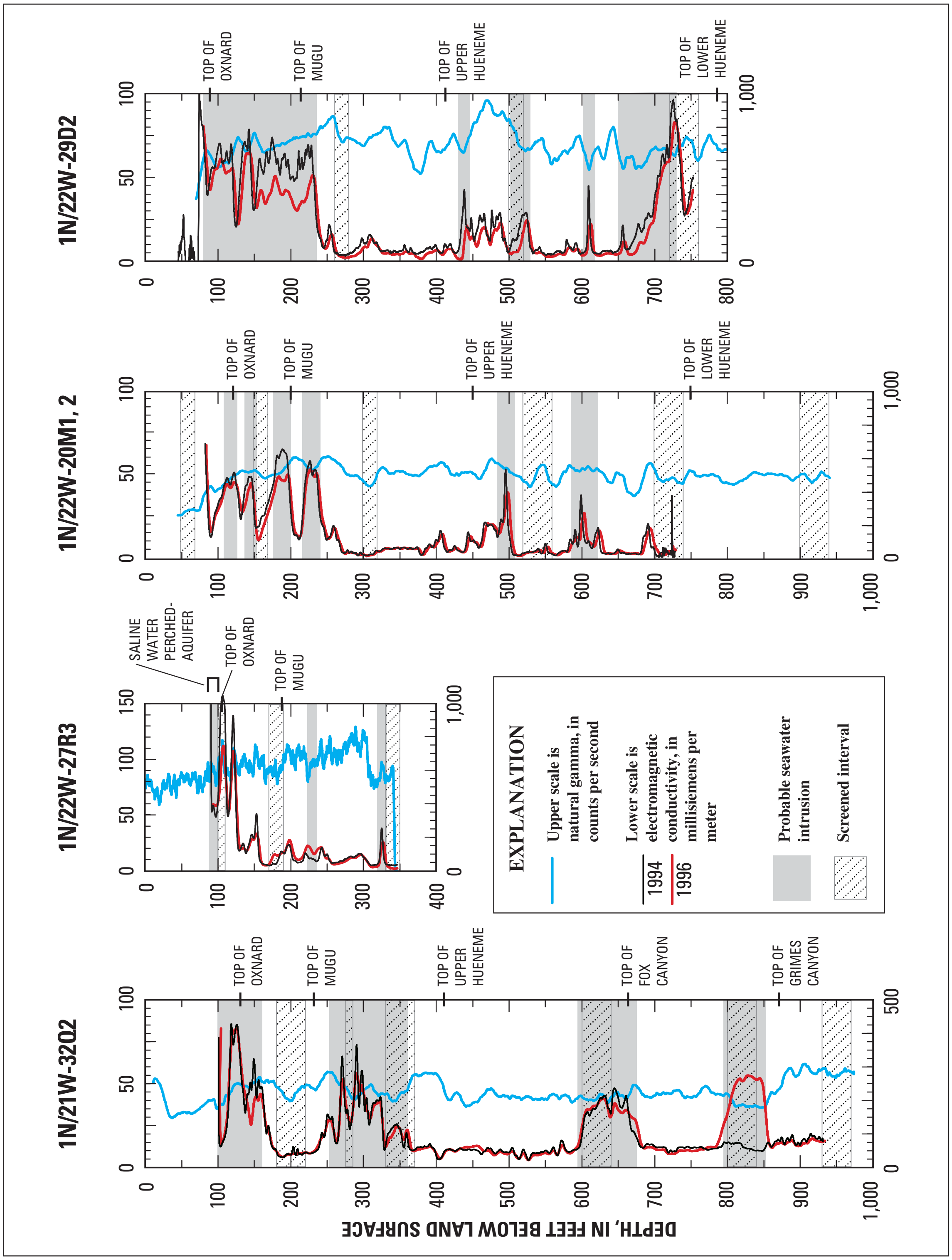


Figure A5.1. Selected electromagnetic conductivity logs and natural gamma logs for selected wells in the Santa Clara-Calleguas ground-water basin

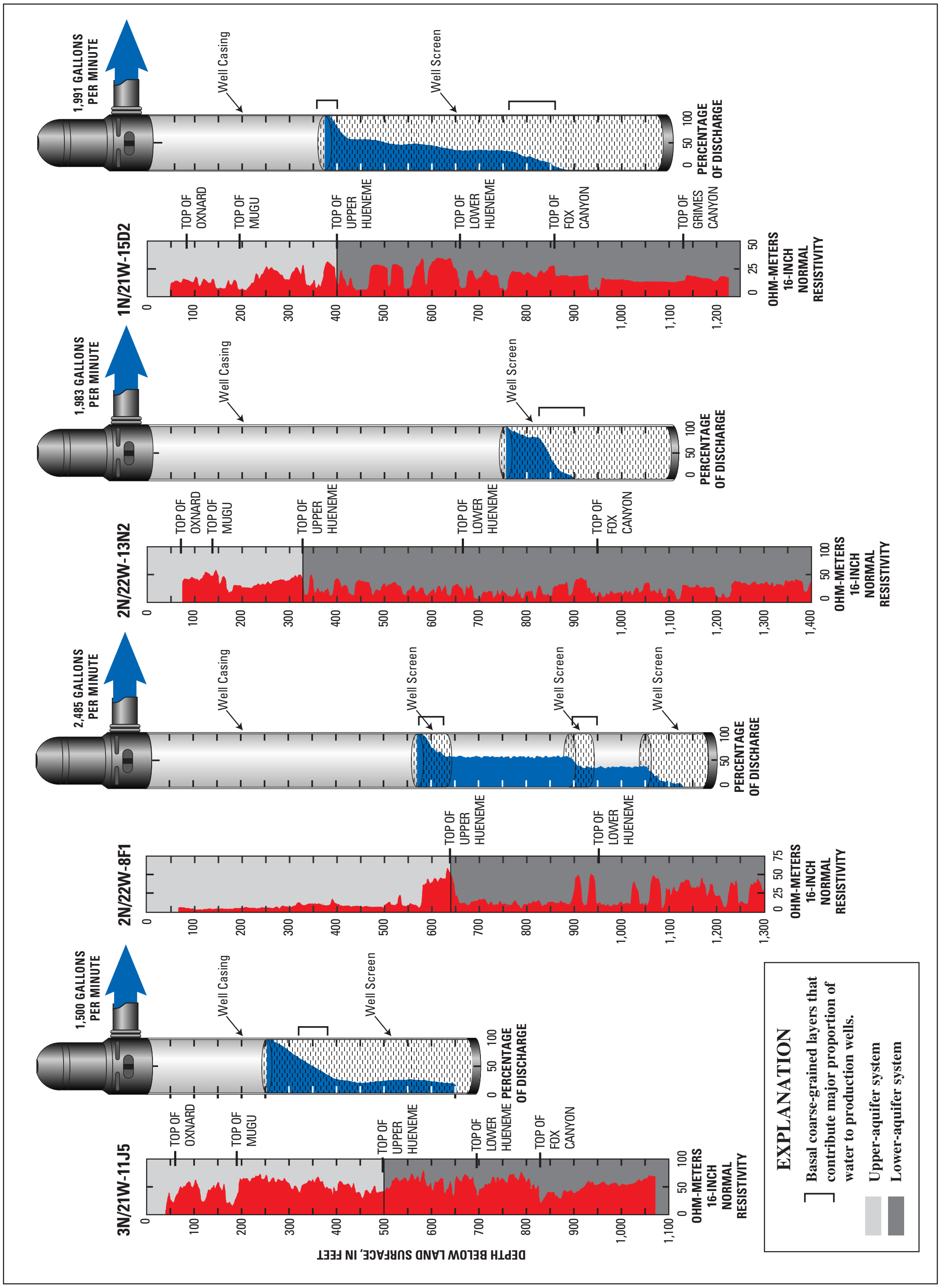


Figure A5.2. Resistivity logs (red) and flowmeter logs (blue) for selected wells in the Santa Clara–Calleguas basin.

Table A5.1 Summary of USGS multiple-well monitoring sites, Ventura County, California

[Number shown in aquifer categories is the sequence number part of the state well number. The number in parenthesis is the screened interval, in feet below land surface]

State well No. (local name)	Aquifers						
	Shallow	Oxnard	Mugu	Upper Hueneme	Lower Hueneme	Fox Canyon	Grimes Canyon or other units
1S/21W-8L (CM-1A)		4/5 (200-220/200-220)		3 (525-565)			
1S/22W-1H (CM-6)		4 (180-200)	3 (310-330) 2 (380-400)	1 (490-550)			
1N/21W-19L (SCE)	14 (18-38)	13/12 (110-130/200-220)	11/10 (300-320/394-414)				
1N/21W-32Q (Q2)		7 (275-285)	6/5 (330-370/180-220)	4 (600-640)		3 (800-840)	2 (930-970)
1N/22W-20J (A1)		8 (155-195)	7/6 (280-320/385-425)	5 (640-680)	4 (870-890 /910-930)		
1N/22W-20M (A2)	6 (50-70)	5 (150-170)	4 (300-320)	3 (520-560)	2 (700-740)	1 (900-940)	
1N/22W-26J (SWIFT)	5 (55-65)	4 (185-205)	3 (310-350)				
1N-22W-27C (SW)	4 (55-65)	3 (175-195)	2 (275-295)				
1N/22W-27R (CM7)	5 (100-110)	4 (170-190)	3 (330-350)				
1N/22W-28G (CM4)		5 (180-200)	4 (255-275)	3 (720-760)	2 (995-1,095)	1 (1,295-1,395)	
1N/22W-29D (CM2)		4 (260-280)		3/2 (500-520/720-760)	1 (830-870)		
1N/22W-35E (CM5)		5 (200-220)	4 (300-320)	3 (420-470)	2 (840-890)	1 (1,140-1,200)	
1N/22W-36K (DP)		9 (175-195)	8 (310-330)	7 (410-450)	6 (540-580)	5 (680-720)	
1N/23W-1C (CM3)		5 (120-145)		4 (630-695)	3 (965-1,065)	2 (1,390-1,410 1,430-1,450 1,470-1,490)	
2N/20W-16A (TKS)	4 (90-100)	3 (170-180)	2 (260-280)				
2N/21W-7L (SAT)		6 (135-155)	5 (270-310)		4 (500-540)	3 (640-700)	
2N/21W-11J (LP1)		6 (190-220) (Dry Well)	5 (340-380)		4 (615-655)	3 (1,018-1,078)	

Table A5.1 Summary of USGS multiple-well monitoring sites, Ventura County, California

State well No. (local name)	Aquifers						
	Shallow	Oxnard	Mugu	Upper Hueneme	Lower Hueneme	Fox Canyon	Grimes Canyon or other units
2N/21W-34G (PV)		5 (170-190)	4 (360-380)	6 (431-436)	3 (800-860)	2 (938-998)	
2N/22W-23B (SG)		7 (260-300)	6 (460-500)	5 (830-870)	4 (1,110-1,150)	3 (1,210-1,250)	
3N/20W-35R (P7)			4 (490-530)			3/2 (800-900/ 1,050-1,110)	
3N/21W-15G (SP1)	5 (60-80)		4/3 (260-280/ 370-390)	2/1 (520-540/ 660-680)			
3N/21W-16H (SP2)	8 (50-70)	7 (150-170)	6 (290-310)	5 (530-550)			
4N/18W-31D (RP1)	7 (50-70)	6 (140-160)	5/4 (220-240/ 310-330)		3 (590-610)		

APPENDIX 6. SUMMARY OF FLOWCHARTS OF DATA PREPARATION FOR SELECTED INPUT DATA SETS FOR THE SANTA CLARA—CALLEGUAS GROUND-WATER FLOW MODEL

The preparation of selected model-input data sets for MODFLOW required the spatial and temporal estimation and compilation of a variety of data that represent inflows and outflows to the regional-aquifer systems through historical and future time periods. Flowcharts that summarize the data preparation for the Recharge Package (fig. A6.1), the Streamflow Package (fig. A6.2), and the Well Package (fig. A6.3) help to clarify the flow of information used in the construction of these data sets for the simulation of surface-water and ground-water flow.

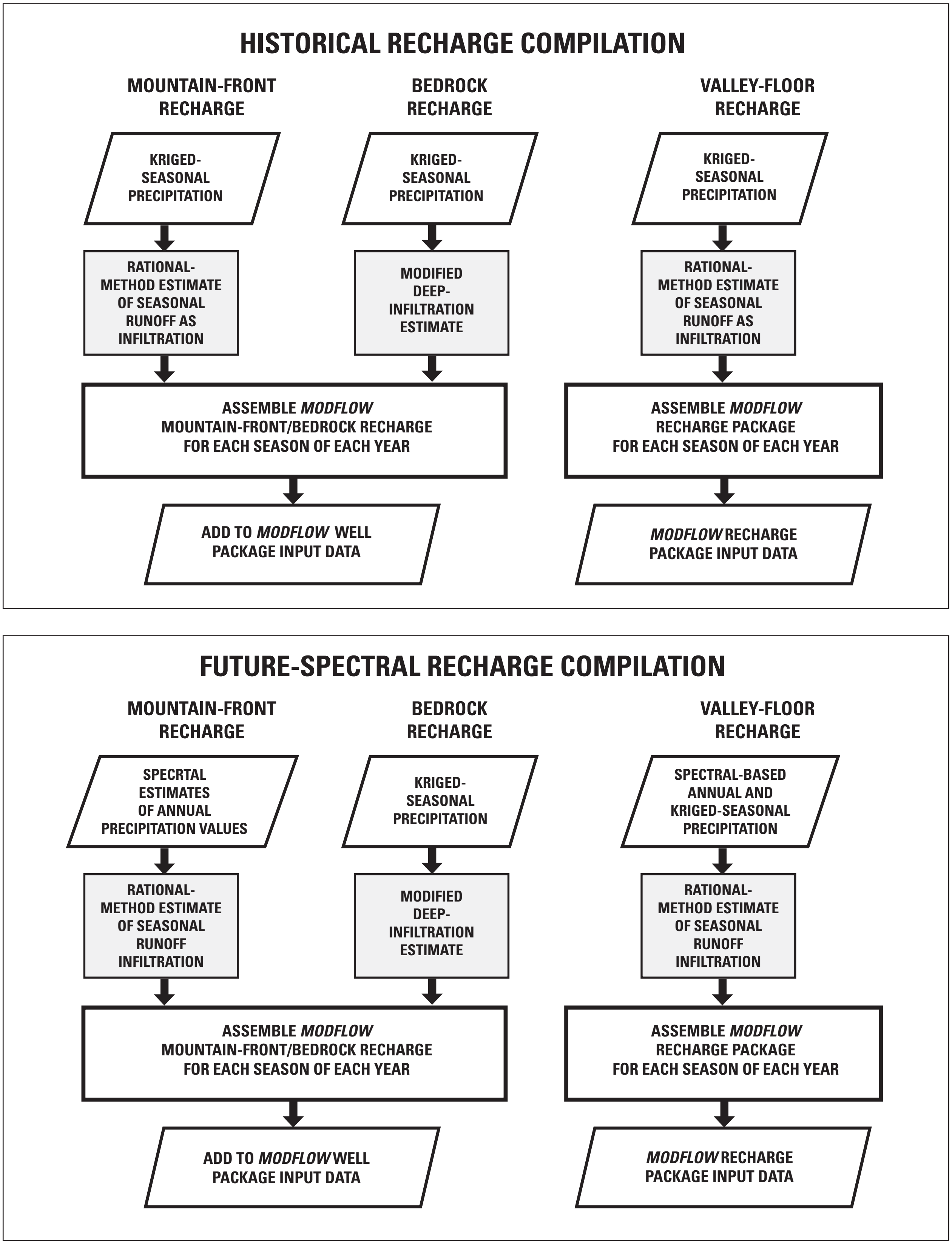
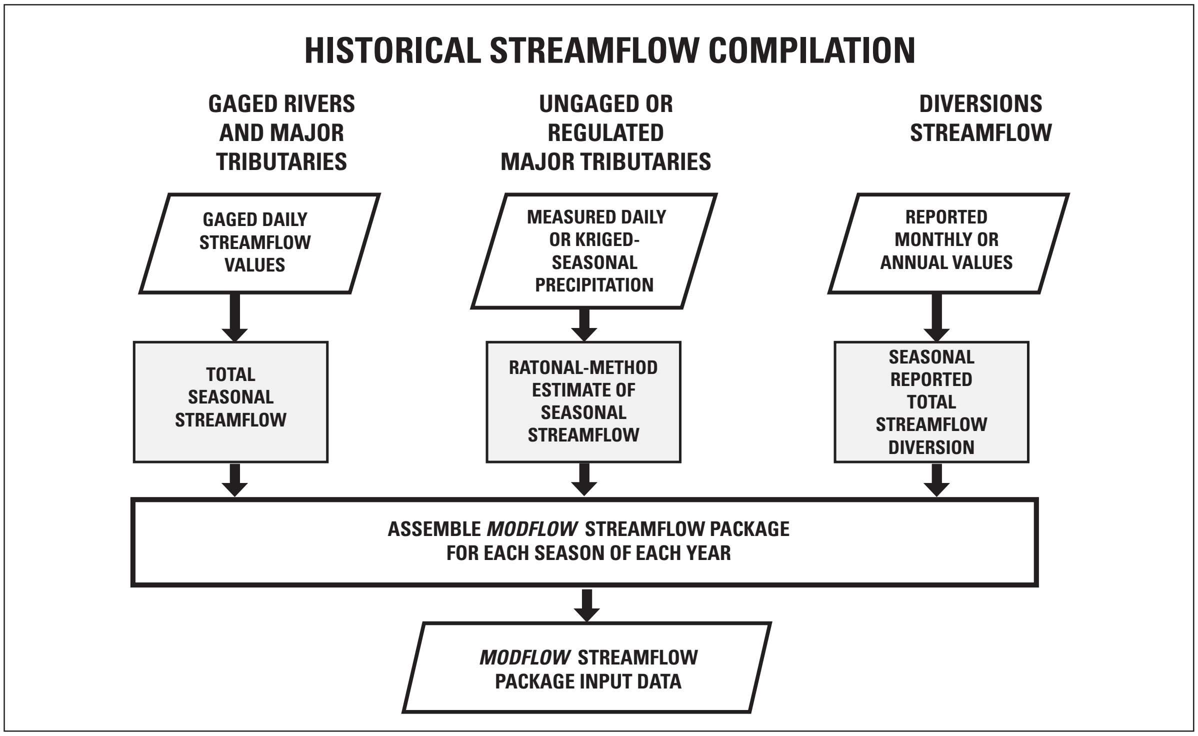


Figure A6.1. Flow of information in the preparation of the Recharge Package for the Santa Clara-Calleguas ground-water model.



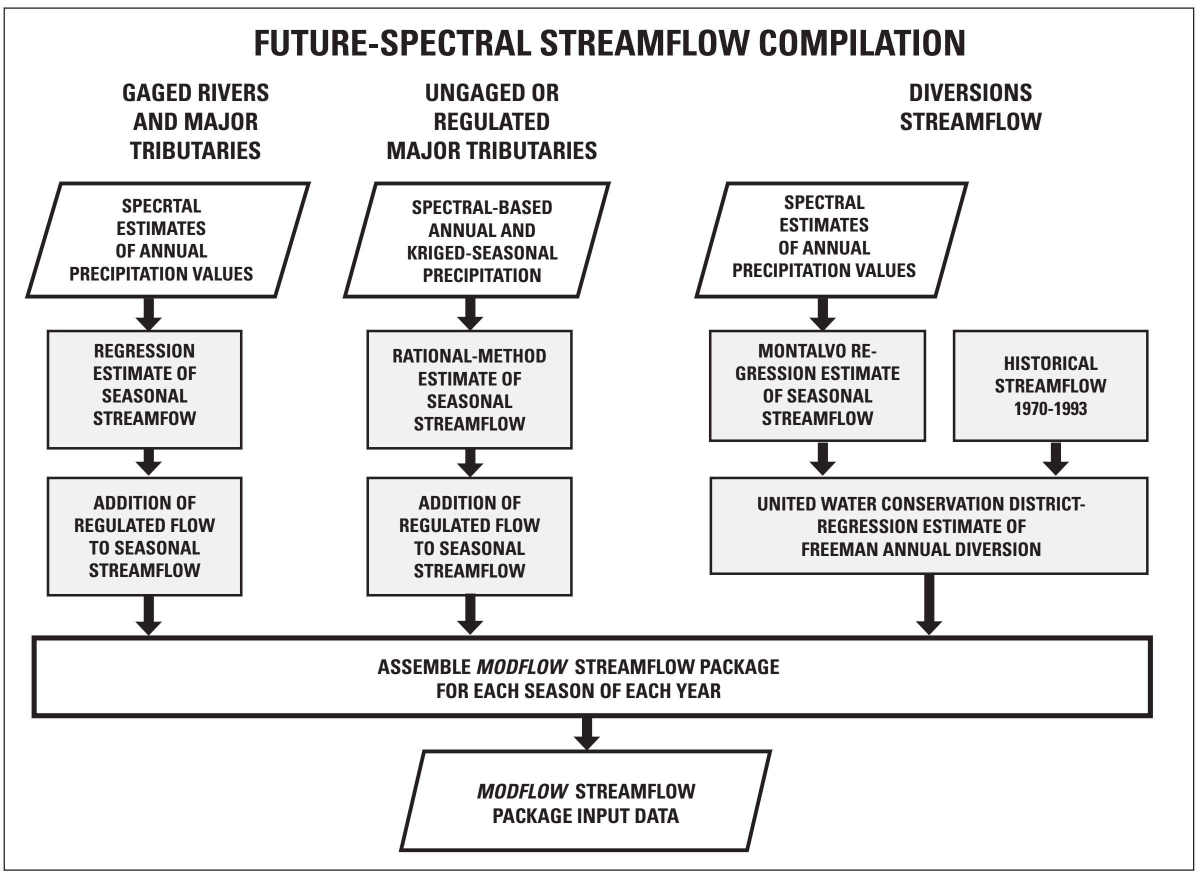


Figure A6.2. Flow of information in the preparation of the Streamflow Package for the Santa Clara-Calleguas ground-water model.

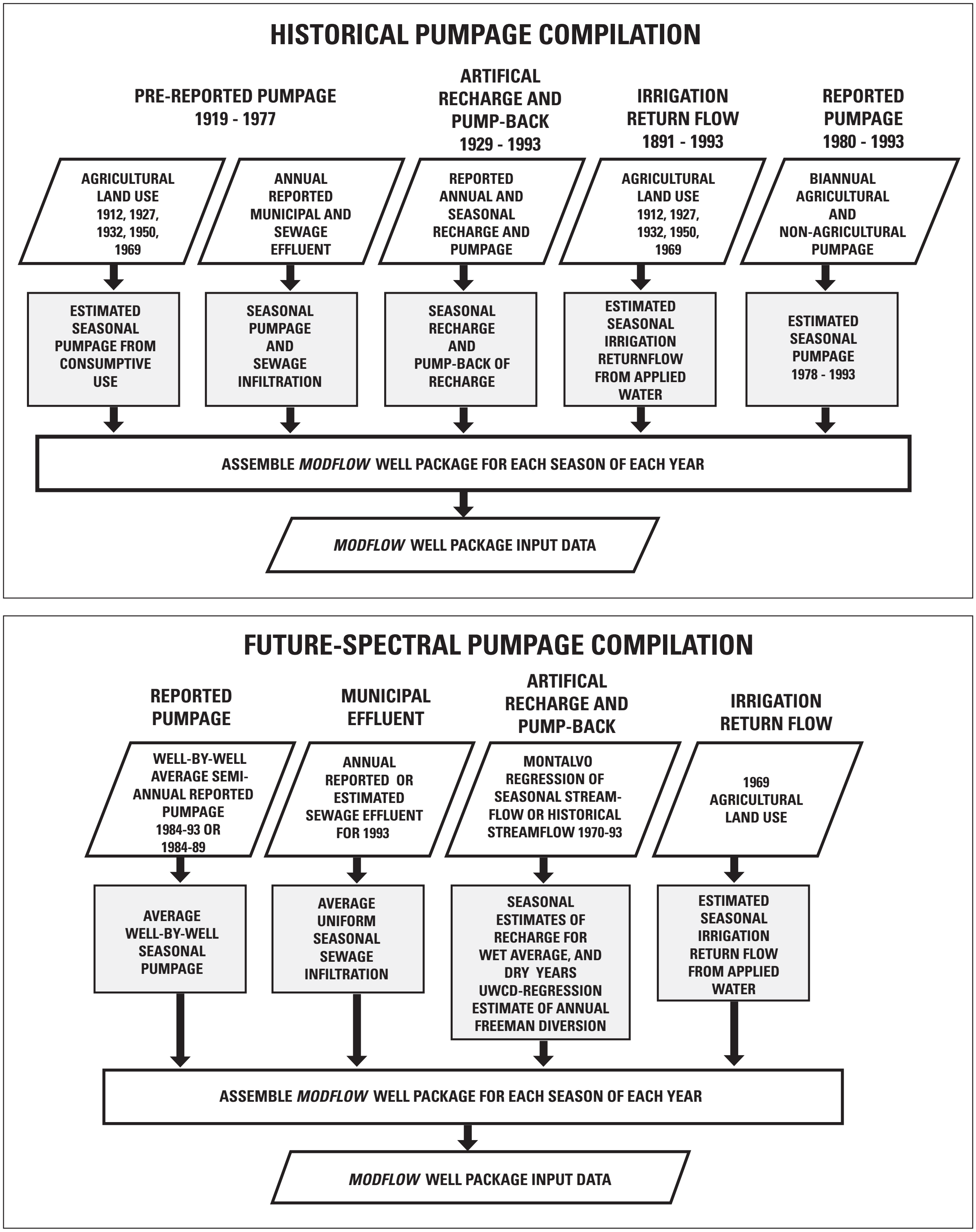


Figure A6.3. Flow of information in the preparation of the Well Package for the Santa Clara-Calleguas ground-water model.