IV - WATERSHED CHARACTERISTICS

4-01 General Characteristics. The Santa Ana River basin drains approximately 2,450 sq-mi, excluding a closed area of 32 sq-mi tributary to Baldwin Lake. Of the total watershed, 2,255 sq-mi (i.e., 92%) are above Prado Dam, which is the primary flood control structure on the Santa Ana River. The Santa Ana River basin and the existing water control structures are shown on Plate 4-01a. Approximately 23% of the watershed is within the rugged San Gabriel and San Bernardino Mountains, about 9% is in the San Jacinto Mountains, and 5% is within the Santa Ana Mountains. Most of the remaining area is in valleys formed by the broad alluvial fan along the base of these mountains. The numerous low hills in the alluvial valley areas include a few low hills north of San Bernardino; the Crafton Hills east of Redlands; the Jurupa Mountains north and west of Riverside; the Box Springs Mountains and the Badlands east of Riverside; and the Chino and Peralta Hills northeast of Anaheim. In general, the mountain ranges are steep and sharply dissected. Maximum elevation at San Antonio Peak in the San Gabriel Mountains is 10,064-ft; at San Gorgonio Mountain in the San Bernardino Mountains, 11,499-ft; and at Mount San Jacinto in the San Jacinto Mountains, 10,804-ft.

4-02 Topography. The San Bernardino Mountains are the source of the Santa Ana River and of two of its principal tributaries, Bear and Mill Creeks. Lytle Creek, the largest tributary originating in the San Gabriel Mountains, is in the northwest part of the drainage area. The San Jacinto River has its origin in the San Jacinto Mountains southeast of Beaumont. The major tributary in the lower part of the watershed (i.e., below Prado Dam) is Santiago Creek, which originates in the Santa Ana Mountains. The Santa Ana River has an average gradient of about 240 ft/mi in the mountains, about 20 ft/mi near Prado Dam, and about 15 ft/mi below Prado Dam. The average gradient of the tributaries is about 700 ft/mi in the mountains and 30 ft/mi in the valleys. Plate 4-01b shows the topography of the Santa Ana River watershed area and Plate 4-02 shows the profile of the Santa Ana River from its headwaters to the Pacific Ocean.

Well developed growths of white fir, ponderosa pine, sugar pine, and Jeffrey pine occur above elevations of about 5,000-ft. Sparse growths of conifers and of brush, including chaparral and manzanita, are common on the steep, rocky slopes of the higher mountains. Large areas on the higher slopes are covered by brush that has replaced timber removed by small-scale lumbering or that has been destroyed by forest fires. Oak and other deciduous trees, brush, and native grasses are the principal vegetal cover on the slopes below an elevation of about 5,000-ft. Large areas on the plateaus and hills are covered with grass and brush. Because of extensive urbanization, large segments of the valley areas have been cleared of most native vegetation. The remaining valley areas are covered mainly with orchards and crops.

4-03 Geology and Soils. The entire Santa Ana River basin is underlain by a basement complex of crystalline metamorphic and igneous rocks, which only appear on the surface in the mountainous parts of the area. In the foothills and valleys, the basement complex is overlain by a series of sandstones and shales. Unconsolidated alluvial deposits range in depth from a few feet at the base of the mountains to more than 1,000-ft on the cones and in the valleys. The existence of several precipitous mountain ranges along the upper boundaries of the area indicates that the area has been subjected to extensive folding and faulting. The soils in the mountains, which are derived mainly from metamorphic and igneous rocks, are shallow and stony. On the lower slopes of the mountains and in the foothills, the soils are mainly loams and sandy loams, ranging from less than 1-ft to 6-ft in depth. In the valleys, where the soils are usually more than 6-ft deep, the surface soils range from light, sandy alluvium to fine loams and silty clays with heavier subsoils.

The Santa Ana River basin lies in a seismically active area and has several faults within its boundaries as shown on Plate 4-03. The San Andreas fault zone is the best known of the faults and the one with the potential for the most severe earthquake. Other fault zones within the basin include: the San Jacinto fault zone; the Banning fault; the Sierra Madre-Cucamonga fault zone; the Whittier fault; the Chino fault; the Elsinore Agua Caliente fault zone; and the Newport-Inglewood fault zone.

Prado Dam, located on the east side of the Chino Hills, lies very close to the Chino fault. A total of 14 observed earthquakes with a magnitude ranging from 5.0 to 6.8 on the Richter scale have occurred within a 50 mile radius of Prado Dam. The strongest earthquake experienced by the dam was the San Fernando earthquake in 1971. Observed local earthquakes with magnitudes varying between 3.0 and 6.0 plus are also shown on Plate 4-03.

4-04 Sediment. Bed material in the Santa Ana River varies from a cobble bed, with material between two and four inches in diameter, along the upper reaches of the river to fine and medium sands along the lower reaches. The Santa Ana River is generally considered a sand bed stream with sediment having a mean diameter of 0.5 mm. The median size of the bed material varies from 0.2 mm to 0.8 mm with an average gradation coefficient of 2.

Historically the river was braided in the upper portion of the basin and meandering along the lower portion. The river bed and banks are highly erodible and over time the channel has wandered over significant portions of the floodplain. As the Santa Ana River basin has developed, the channel has been improved and controlled to its present location. However, the inherent instability of the river periodically manifests itself in the form of severe scour and bank erosion at various locations (See section 4-09h).

The sediment yield for Prado Reservoir has been estimated from a determination of sediment deposition in Prado Reservoir during the 29-year period, 1941 to 1969. During this period, sediment accumulation, up to spillway crest elevation, was 24,780 ac-ft. The watershed above Prado Dam is 2,255 sq-mi. There are three major reservoirs and lakes that virtually trap all sediment entering them: (a) San Antonio Reservoir on San Antonio Creek controls sediment from a drainage are of 27 sq-mi; (b) Lake Elsinore on the San Jacinto River traps sediment from an area of 768 sq-mi; and (c) Big Bear Lake, located in the San Bernardino Mountains, traps sediment from a drainage area of 38 sq-mi. There are other numerous small reservoirs that control sediment from approximately 235 sq-mi. Thus, the sediment producing area covers about 1,180 sq-mi and gives a sediment yield for the past 29 years of about 0.75 ac-ft per sq-mi per year.

The most recent area-capacity relation for Prado Dam is based on the survey of March 1980 and is presented on Plates 2-08 and 2-09.

4-05 Climate.

The climate of the drainage area above Prado Dam is generally temperate-subtropical and semi-arid in the lower elevations, with warm, dry summers and mild, moist winters. In the higher mountains, moderate summers and cold winters, with considerable snowfall, prevail. Nearly all precipitation occurs during the months of December to March. Rainless periods of several months during the summer are common. Most precipitation in the drainage area results from general winter storms that are associated with extra-tropical cyclones of North Pacific origin.

a. Temperature. Average daily minimum and maximum temperatures (degrees Fahrenheit) in the vicinity of Prado Dam range from about 40°F and 66°F respectively in winter to about 59°F and 92°F in summer. The corresponding figures near the top of the basin (elevations 8,000-11,000-ft) range from about 10°F and 22°F in winter to about 45°F and 60°F in summer. All-time low and high extremes of temperature are about 22°F and 114°F respectively near the dam and about -30°F and 75°F at the top of the drainage. The lower elevations do not normally experience significant periods of freezing temperatures, but above 6,000-ft subfreezing temperatures are very common for 4 to 6 months of the year.

Plate 4-04a-d, reprinted from the NWS Climatography of the United States No. 20, consists of climatic summaries for four published NWS stations: Corona, Riverside, Upland, and Beaumont, California. Corona is the station nearest to, and most representative of, Prado Dam; Riverside reflects conditions in mid-basin; while Upland and Beaumont are more representative of foothill stations. This plate lists, among other items, the mean daily maximum and minimum temperature and the recorded highest and lowest temperatures for each month of the year at each of the four stations.

b. <u>Precipitation</u>. Plate 4-05 (reproduced from the Santa Ana River Mainstem Phase II GDM) shows the mean annual precipitation over the drainage area above Prado Dam. Within the drainage area, mean annual precipitation ranges from less than 10 inches in the area of March Air Force Base to about 45 inches atop Mt. San Gorgonio, and averages about 20 inches over the entire drainage.

Plate 4-04a-d also lists the mean and maximum monthly and annual precipitation, as well as the maximum daily precipitation for each month of the year, for each of the four climatological stations in the Santa Ana River drainage. Also listed in Plate 4-04a-d are the probabilities (from 5 to 95 per cent) for each month of the year that the monthly total precipitation at each station will be equal to or less than the indicated amounts. This plate demonstrates that there can be great year-to-year variability in annual, monthly, and daily precipitation. Not listed in this plate are the minimum observed monthly precipitation values, which for most stations are at most 0.01 or 0.02 inches for each month of the year.

Plate 4-06 consists of precipitation depth-duration-frequency tabulation for five stations in the drainage, four of which are at the same location as, or at a very nearby locations to, the four stations listed in Plate 4-04a-d, and the fifth being the mountain station of Big Bear Lake Dam. In this plate are listed the computed point-value precipitation depths at each station for durations of from 15 minutes to 24 hours, and for return periods from 2 to 200 years. Data for this plate were obtained from the State of California Department of Water Resources publication, <u>Rainfall Depth-Duration Frequency for California</u>, revised November 1982. These California Water Resources data are similar to those obtained from the National Oceanic and Atmospheric Administration (NOAA) publication, <u>NOAA Atlas 2</u>.

c. <u>Snow</u>. Snow in southern California is relatively uncommon at elevations below 6,000-ft, but occurs frequently at the higher elevations, and often remains on the ground for many weeks during the winter and spring at elevations above 7,000 to 8,000-ft. Snowmelt is normally not a major hydrologic factor in terms of contributing to runoff in the Santa Ana River basin; but, on occasion, the runoff from a warm, heavy rainstorm that has followed a cold storm that had dropped snow over the Santa Ana River basin down to 2,000 or 3,000-ft will be significantly augmented by melting snow.

d. <u>Evaporation</u>. Table 4-1 presents pan evaporation data for three stations located within the drainage area above Prado Dam. The mean monthly evaporation ranges from less than 1 inch in winter to about 8 inches in the summer in higher forested elevations, to about 2-3 inches in winter and 9-11 inches in summer in the lower elevations. On days of very strong, dry Santa Ana winds, evaporation can be greater than one inch in 24 hours.

Table 4-1

Evaporation within the
Santa Ana River Basin

	Monthly Evaporation (inches)		
Month	(712301) Prado Dam (40 year mean)	(747300) Riverside Citrus Exp. Sta. (54 year mean)	(060700) Beaumont Pumping Plant (21 year mean)
Oct	5.67	5.24	5.79
Nov	4.21	3.62	3.54
Dec	3.39	2.68	3.11
Jan	3.42	2.83	3.15
Feb	3.50	3.23	3.43
Mar	4.72	4.57	4.41
Apr	6.14	5.79	5.31
May	7.68	7.05	6.61
Jun	8.62	8.19	8.39
Jul	10.71	9.88	10.67
Aug	10.00	9.25	10.08
Sep	7.91	7.05	8.11

Note: Each evaporation station consists of a Weather Bureau Class A Pan. Readings are adjusted for observed rainfall to yield net evaporation.

Reservoir evaporation may be estimated by multiplying measured pan evaporation by a pan coefficient ranging from 0.6 to 0.8.

Location of Evaporation Stations				
CA DWR No.	Latitude	Longitude	Elev (ft)	Period of Record
712301	33°53'30"	117°38'03"	565	7/30-6/69
747300	33°58'00"	117°20'05"	1,015	1/25-6/78
060700	33°58'50"	117°57'35"	3,045	1/55-9/75

e. Wind. The prevailing wind in the Prado watershed is the sea breeze. This gentle onshore wind is normally strongest during late spring and summer afternoons, with speeds in the Santa Ana River basin typically ranging from 10 to 15 miles per hour.

The Santa Ana is a dry desert wind that blows from out of the northeast, most frequently during late fall and winter. The characteristic low humidities and strong gusts of Santa Ana winds usually create very high fire hazards, but can also be instrumental in drying a saturated watershed, thus reducing the flood hazard from later events. Santa Ana winds are often especially strong below Cajon Pass in the corridor from Devore to Fontana, where extreme gusts of more than 100 mph have been recorded. They can also be very strong in the vicinity of Prado Dam and downstream through the Santa Ana River Canyon and into northeast Orange County.

Rainstorm-related winds are the next most common type in southern California. Winds from the southeast ahead of an approaching storm average 20-30 mph, with occasional gusts to more than 40 mph. West to northwest winds behind storms can sometimes exceed 35 mph, with higher gusts.

4-06 Storms and Floods.

a. Storm Types. General storms consist of one or more cyclonic disturbances, which occur over a period of one to four or more days, and result in rain or snow over large areas. Local thunderstorms result in intense precipitation over small areas for short periods of time, and may occur independently or in association with general storms. Tropical cyclones are infrequent, but occasionally occur in late summer. A description of storm types which may impact the project area are as follows:

(1) General Winter Storms. Most precipitation in southern California coastal drainages occurs during the cool season, primarily from November through early April, as mid-latitude cyclones from the northern Pacific Ocean move inland over the area. Most of these storms are the general winter type, characterized by hours of light-to-moderate precipitation, but with occasional heavy showers or thunderstorms embedded within the storm system. Snow is common in these storms above 6,000-ft, but on occasion may fall at 2,000-ft or lower.

(2) Local thunderstorms. Local thunderstorms can occur in southern California at any time of the year. They occur fairly frequently in the coastal areas in conjunction with general winter storms. They can also occur between early July and early October, when desert thunderstorms occasionally drift westward across the mountains into coastal areas, sometimes enhanced by moisture drifting northward from tropical storms off the west coast of Mexico. These local thunderstorms can at

times result in very heavy rain for periods of one to three hours over small areas, causing very rapid runoff from small sub-basins of the Santa Ana River basin.

(3) General Summer Storms. General summer storms in southern California are quite rare; but on occasion between mid-August and late October, a tropical storm from off the west coast of Mexico can drift far enough northward to bring rain, occasionally heavy, to southern California, sometimes with very heavy thunderstorms embedded. On very rare occasions, southern California has received light rain from general summer storms of non-tropical origin.

b. Floods. Records of historical flood events for the Santa Ana River Basin date from 1850. References from 1769 to 1850 compiled from historical accounts, records of court cases, and statements of witnesses, indicate that significant floods occurred in the Santa Ana River basin and other coastal southern California watersheds in 1811, 1815, 1825, 1833, 1840, and 1850. A histogram of the yearly rainfall at Santa Ana since 1769 is shown in Plate 4-07. Records prior to 1909 were compiled by Lynch.

Some quantitative data are available to show that from 1850 to 1987, large winter storms and floods occurred on the Santa Ana River in January 1862, December 1867, February and March 1884, December 1889, and February 1891. Recorded data from 1897 to the present show that medium-to large-winter storms/floods occurred in April 1903, January 1910, January 1916, December 1921, February 1927, February 1937, March 1938, January 1943, April 1958, November and December 1965, December 1966, January and February 1969, February and March 1978, February 1980, February 1981, and March 1983. There was also a major tropical storm in September 1939, but no widespread flooding resulted from this event.

Following is a discussion of the major historical storm and flood events in the Santa Ana River Basin.

(1) Storm and flood of January 1862. An extreme flood event occurred in January 1862. Although very little data concerning the storms are available, it was possible to determine the flood characteristics that led to the peak discharge of January 22, 1862.

According to historical accounts, nearly continuous rainfall began on December 24, 1861. An uninterrupted series of cold storms from out of the north brought heavy snow to low elevations in the mountains. The storm track then changed, and a series of warm storms from east of Hawaii brought very heavy tropical rain to southern California. The combination of this rain, now falling on saturated ground, and massive snowmelt led to a flood with an estimated peak discharge of 317,000 cfs at Riverside Narrows. The San Bernardino County Flood

Control District discussed this estimate in their report "Agua Mansa and the Flood of January 22, 1862, Santa Ana River".

(2) Storms and floods of January 1916. Two heavy storm series hit southern California in January 1916. The 14-19 January storms dropped southward along the coast, bringing deep snowfalls to the mountains and foothills. The second series dropped southward over water, then moved onshore with very heavy warm rain that melted the previously fallen snow. Heavy flooding resulted 27-28 January. Table 3-1 lists the loss of life and property from this and other flood events, while Plate 4-08 shows the hydrographs of these floods.

(3) Storms and floods of February 1927. A series of heavy storms moved into southern California from the west during mid-February 1927, resulting in moderate flooding on the Santa Ana River and elsewhere throughout the coastal basins (see Table 3-1 and Plate 4-08).

(4) Storms and floods of February 1937. After record cold and very low snow levels in January 1937, a series of Pacific storms moved into California from the west. The short-duration rainfall of February 6th and 14th, 1937, combining with snowmelt, caused severe flood damage to both agricultural and urban areas and helped to highlight the area as a vulnerable flood hazard zone. The total damage caused to private and public properties was estimated by several agencies to have been approximately $750,000.

(5) Storm and Flood of February-March 1938. The flood of early March 1938 was, and still is, the most destructive of record since 1862 on the Santa Ana River and many other streams in southern California; and its occurrence played a major role in the justification for the construction of Prado Dam and other flood control structures. The storm developed out of a series of low-latitude north Pacific disturbances, bringing several bands of intense rainfall to southern California during a 5-day period of 27 February - 3 March. Several mountain stations in southern California reported precipitation equalling or exceeding 30 inches during the 5 days. Within the study area, total rainfall ranged from less than 5 inches near Perris to 27 inches at Big Bear Lake Dam. The heaviest rain fell on 2 March between 0000 and 1900 hours, during which Camp Baldy at the northwest edge of the Santa Ana River basin reported nearly 8 inches in 6 hours and more than 12 inches in 12 hours.

At the beginning of the storm, there was snow on the ground at elevations above about 6,000-ft. The snow cover at points of observation was not materially depleted at the end of the storm, indicating that snowmelt probably did not contribute appreciably to the flood runoff. Although accumulated seasonal precipitation at the beginning of the storm was about normal, greater than normal precipitation occurred during the month of February preceding the storm, conditioning the ground for runoff. The resulting low precipitation-loss rates, along with the unusually large precipitation volume and high intensities, caused very high rates of runoff, especially in the mountains and foothills. The result was a peak flow estimated at 100,000 cfs on the Santa Ana River through the Santa Ana Canyon. Plate 4-08 shows the storm runoff hydrograph for the March 1938 runoff event. Table 3-1 lists the loss of life and property caused by the flood.

(6) Storm and flood of January 1943. The storm of 21-24 January 1943, which in many respects is the most severe storm of record in southern California, resulted when a series of warm Pacific cyclones moving generally eastward from the area north of Hawaii combined with an intense, cold storm moving down the west coast of North America from British Columbia. The deep, low pressure center that consequently developed over Northern California and Oregon generated unusually strong southerly and southwesterly winds over southern California and produced very heavy precipitation over much of the area. Exceptionally large rainfall amounts fell in the mountain areas because of the powerful orographic uplift of these strong winds. Continuous precipitation, which included two periods of very high intensity rainfall, occurred from about noon on 21 January into the morning of 23 January. This precipitation was caused by two cold fronts, the first of which occurred about midnight on 21 January, and the second, about midnight on 22 January. Rainfall tapered off on 23 and 24 January, although certain mountain stations continued to receive substantial precipitation during these two days. Total Rainfall recorded for the storm in the study area ranged from 4.3 inches at Riverside to 29.7 inches at Glenn Ranch in the San Gabriel Mountains. Isohyets of maximum 24-hour precipitation for the storm event are shown on Plate 4-09. Plate 4-08 shows the hydrograph for the 1943 event and Table 3-1 tabulates losses caused by the event. Some snow fell during the storm, mostly above elevations of 8,000-ft. Although the storm was severe over and southwest of the mountains in Los Angeles and San Bernardino Counties, the runoff was moderate because of unusually dry antecedent conditions during the month before the storm occurred.

(7) Storm and flood of March 1943. The local storm that occurred between 2200 hours 3 March and 0100 hours 4 March 1943 resulted in short-period precipitation of near record-breaking magnitude for the southern California coastal region. The storm developed out of a moderate general storm, beginning over the southern part of Los Angeles and moving northeast toward the San Gabriel Mountains at about 7 miles an hour. Because many automatic precipitation gages were in operation, the areal distribution of precipitation was well defined. The highest observed intensities were at the Sierra Madre-Carter (7-0-133B) precipitation station located in Sierra Madre, where maximum 15-, 30-, and 60-minute intensities of 5.5, 3.6, and 2.7 inches an hour, respectively, were recorded. Runoff was moderately heavy from local areas where high precipitation intensities occurred. However, as the thunderstorm did not extend appreciably into the Santa Ana River basin, no runoff of consequence was recorded there.

(8) Storms and floods of January 1969. A series of storms that began on January 18 and continued through January 27 was caused by a strong flow into southern California of very warm, moist air originating over the tropical Pacific Ocean south and east of Hawaii. This series of storms was interrupted by a brief ridge of high pressure that moved through the area on January 22 and 23 and caused a short break in the rainfall. Except for this lull on January 22 and 23, heavy precipitation occurred during most of the January 18-26 period. An intense downpour occurred on January 25. Nine-day totals ranged from 10 to 20 inches in the lowlands and from 25 to more than 50 inches over the mountain areas of southern California. In the study area, total storm amounts for Lytle Creek Ranger Station and Big Bear Lake were 42.68 and 35.52 inches, respectively. Plate 4-10 shows a peak 1-hour average inflow to Prado Reservoir of 77,000 cfs on 25 January.

(9) Storms and floods of February 1969. The storm series that occurred in late February 1969 climaxed more than a month of extremely heavy, recurring rainfall in southern California. The storms occurred as a number of Pacific cyclones traveled southward off the west coast of the United States and then curved inland across California carrying copious quantities of moisture. Several cold fronts and other disturbances that moved across southern California from 22 February through 24 February dropped moderately heavy amounts of precipitation. Early on 25 February a strong cold front moved slowly southeastward across southern California; the front was accompanied by strong low-level winds that, when lifted by the mountains, resulted in great quantities of orographic precipitation. As a result, rainfall was generally heavy everywhere and particularly heavy in the mountains. Total storm amounts recorded at selected mountain stations in the study area were 10.03 inches at Trabuco Canyon, 6.80 inches at Santa Ana River Powerhouse, and 6.1 inches at Idyllwild Ranger Station. Plate 4-11 shows a peak inflow to Prado Dam of 75,000 cfs on 25 February.

(10) Storm and flood of February 1978. After several moderately heavy storms during January and early February 1978, one low-latitude Pacific storm developed west of southern California and moved into the area during the night of 9-10 February. After a day of heavy rain in the San Gabriel and San Bernardino Mountains on 9 February, a major cloudburst struck portions of coastal southern California during the early hours of 10 February, with brief intensities exceeding 3 inches per hour. The very heaviest rain fell in Los Angeles County, but several stations in the Santa Ana River basin reported intense rainfall between 0200 and 0400 hours on 10 February, including 1-hour amounts of 1.2 inches at Running Springs and 0.89 inches at Prado Dam. Plate 4-12 shows a peak discharge of 20,210 cfs at Prado Dam on 10 February at 1300 hours.

(11) Storm and flood of March 1978. In a pattern very similar to that of exactly 40 years earlier, a series of low-latitude Pacific storms moved into southern California at the end of February and beginning of March 1978. There were four

major periods of rainfall during the storm period: 28 February, 1 March, 4 March, and 5 March. Total rain from 27 February through 6 March ranged from less than 5 inches in the Riverside-Corona area to 22-24 inches in the San Bernardino Mountains and more than 28 inches in the eastern San Gabriel Mountains. The heaviest sustained rain fell during the mornings of 1 March and again during mid-day 4 March. With the ground highly saturated from an already very wet winter, runoff from these storms was very high, especially in terms of flow volumes. The water surface elevation behind Prado Dam reached 520.45-ft on 7 March. Plate 4-13 shows a peak flow for the storm period at Prado Dam of 34,705 cfs.

(12) Storm and flood of February 1980. The floods of February 1980 resulted from a series of low-latitude Pacific storms that moved into southern California from out of the west. The heaviest bursts of rain occurred on 14, 16, and 19 February. Some rainfall intensities of 1 inch in one hour were observed in some of the upper areas of the Santa Ana River basin. The water surface elevation for Lake Elsinore reached 1265.7-ft and spilled down Temescal Creek into Prado Dam. Plate 4-14 shows a peak 1-hour average inflow to Prado Dam of 36,000 cfs on 17 February.

The volume of water stored in Prado Dam reached 111,000 ac-ft at a maximum recorded water surface elevation of 528-ft on 22 February. This inflow hydrograph in combination with the constrained reservoir operating policy set a new record for storage in Prado Dam. The release rate from Prado Dam reached 5,992 cfs on 22 February. Extended releases of approximately 5,000 cfs were sustained for up to 7 days, after which a reduction in these releases became necessary in order to facilitate emergency channel repairs downstream. Because of the large amount of water stored in the reservoir, releases were necessary through May 1980 in order to fully empty the flood control pool.

(13) Storm and flood of February-March 1983. During the winter of 1982-1983 a series of low-latitude Pacific storms moved into southern California from the west from late November through February. These storms were the result of atmospheric flow patterns associated with the strongest El Nino condition since at least 1891. The rains climaxed between 25 February and 2 March 1983, during which a storm reminiscent of those of 5 and 45 years earlier moved into southern California at the end of February and the first of March 1983. Up to 20 inches fell in the Lytle Creek area, and several cells of intense local precipitation were observed in the upper and lower Santa Ana River basin, including 1.72 inches in 1 hour in the City of Santa Ana. This and other local Orange County rainfall events with durations between 30 minutes and 6 hours experienced return periods of up to 100 years. One Los Angeles County cloudburst of 2 inches in 5 minutes (Bel Air Hotel, 1 March 1983) was more than 4 times the 100-year rainfall for that duration at that station.

The rainfall through late February had saturated the ground everywhere, resulting in very favorable runoff conditions when the storm of 1-2 March dropped the highest volume of warm rain over the Santa Ana River basin. Plate 4-15 shows inflow and outflow at prado dam for the early March storm. Flow discharges in the lower Santa Ana River were 6,500 cfs just below Prado Dam; 11,000 cfs at E Street; and 26,200 cfs at the Metropolitan Water District (MWD) crossing. Discharges of 4,000 cfs were observed at Lytle Creek near Fontana.

4-07 Runoff Characteristics. Streamflow, which is perennial in the canyons of the Santa Ana River and in the headwaters of most of the tributaries, is generally intermittent in the valley sections. Streamflow increases rapidly in response to effective precipitation. High-intensity precipitation in combination with the effects of steep gradients and possible denudation by fire result in intense sediment-laden floods, with some debris in the form of shrubs and trees. Deposition of the sediment occurs on the mountain streams as they flow into the valley where stream gradients become flatter.

The urbanization taking place in the valley areas of the Santa Ana River basin tends to make the watershed more responsive to rainfall. Plate 4-16 shows that the percentage of impervious cover above Prado Dam has increased from about 5% at the time Prado Dam was completed to 26% today. Hence, the same rainfall occurring over an urbanized part of the watershed will generate higher peak discharges with a shorter peaking time and a greater volume than if it had occurred over the natural watershed without urbanization. The 1969 Hydrologic Review documents an increase in the SPF and PMF flood peaks and volumes (Table 4-2). These revised values are due to the increased urbanization within the basin and improved hydrologic analysis techniques and data.

Table 4-2

Revised Design Floods for Prado Dam

	Original Design 1941	Revised Hydrology	
		Present	Future
Reservoir Design			
Peak Discharge (cfs)	193,000	282,000	317,000
Storm Volume (ac-ft)	275,000 (7 day)	488,000 (4 day)	574,000 (4 day)
Spillway Design			
Peak Discharge (cfs)	289,000	670,000	700,000
Storm Volume (ac-ft)	233,000 (1 day)	1,447,000 (6 day)	1,543,000 (6 day)

Plate 4-17 graphically shows the monthly mean, maximum and minimum flows at Prado Dam for the period of Record. Plate 4-18 is a tabulation of this data. The maximum runoff values occur during the winter flood season. During the summer non-flood season the mean flows through Prado Dam range from 90 to 100-cfs for the period of record. Due to the increased urbanization and the consequent increase in the discharge of wastewater effluent to the Santa Ana River from the upper basin over the past ten years, the average mean flow during the non-flood season has increased to approximately 150-cfs. Plate 4-19 shows the wastewater effluent contribution to the Santa Ana River since 1950 projected to the year 2000.

Plate 4-20 tabulates the maximum values for inflow, outflow, and water surface elevation at Prado Dam for the period of record. Plate 8-04 is the inflow and outflow discharge frequency curve for Prado Dam.

4-08 Water Quality. The quality of surface water and groundwater varies considerably throughout the Santa Ana River basin. Generally, the surface waters flowing out of the rugged and undeveloped mountains to the valley floors are of excellent quality. These waters recharge the groundwater in these areas, consequently, groundwater in these areas is also excellent. As one progresses downstream, however, water quality progressively deteriorates due in large part to heavy water use and waste disposal practices, and to the relatively poor quality of some of the imported water (Colorado River water delivered to the watershed has a TDS of about 900 mg/l).

The California Regional Water Quality Control Board, Santa Ana Region, which has set criteria for local water quality, has identified increasing amounts of dissolved minerals (total dissolved solids, or TDS, from multiple reuse) as the major problem in the Santa Ana River. The target for TDS into Prado Reservoir is 700 mg/l and the downstream target is 650 mg/l. Initial runoff will normally exceed these limits and then improve with succeeding events.

Other factors of concern at Prado include high concentrations of organic materials and nutrients (apparently from wastewater treatment plants, dairy runoff, and inundated vegetation), suspended solids, and metals and low dissolved oxygen concentration. While water quality data is generally inadequate to fully assess water quality trends, the data indicate that certain State-established standards have, at times, not been met, including magnesium, iron, mercury, lindane, PCB's, cadmium, and lead.

4-09 Channel and Floodway Characteristics. The Santa Ana River between Prado Dam and the Pacific Ocean is approximately 30.5 miles in length. The upstream 2.5 miles are located in Riverside County, and the remaining 28 miles are within the

Orange County limits. The river winds through the narrow and relatively undeveloped Santa Ana Canyon for a distance of about 10 miles before it turns southwest into the alluvial plain of the metropolitan area of Orange County. Over the years, the lower Santa Ana River has been improved by local interests from the Santa Ana Canyon to the Pacific Ocean.

Plate 4-21a-b is a schematic of the Santa Ana River showing the long- and short-term channel capacities. Plate 4-22 shows the locations of the existing eleven drop structures and eleven bed stabilizers on the lower Santa Ana River. Plate 4-23 shows the typical cross sections of the improved channel and Plate 4-24 shows a typical cross section of one of the eleven drop structures on the Santa Ana River. Table 4-3 lists the location of the existing drop structures and bed stabilizers.

a. Prado Dam to Weir Canyon Road. Much of the upper reach of the river is unimproved. Within the Santa Ana Canyon, slope protection has been constructed by various local entities at freeway and railroad embankments, and at existing private developments adjoining the river. Slope protection for freeway embankments includes rip-rap and soil cement side slopes. The private developments have constructed rip-rap or grouted rip-rap slope protection. The Atchison Topeka and Santa Fe (AT&SF) Railroad has constructed rip-rap slope protection and installed sheet piles at critical areas. The Green River Golf Course, a 345-acre, 36-hole golf course is located within the streambed of the canyon reach. The improved low-flow channel through the golf course has a non-damaging capacity of about 2,000-cfs. Within the Santa Ana Canyon, flows enter an improved channel immediately upstream from the Weir Canyon Road bridge. Just upstream of the Weir Canyon Road bridge, the Santa Ana Valley Irrigation (SAVI) Ranch Development has constructed a levee embankment for flood control protection.

b. Weir Canyon Road to Katella Avenue. From the Weir Canyon Road bridge to approximately 1,100-ft south of Katella Avenue, a distance of about 9.6 miles, the existing channel is trapezoidal in cross section with a soft-bottom invert and stone revetted side slopes. This reach contains eight drop structures which function as hydraulic energy dissipators and streambed stabilizers. The OCWD maintains earthen L-dikes within the river bed beginning at Imperial Highway. Flows in excess of approximately 600-cfs will washout these L-dikes.

c. Katella Avenue to the Garden Grove Freeway. From Katella Avenue to the Garden Grove Freeway, a reach of about 2.1 miles, an upstream 500-ft portion of the soft-bottom channel has concrete side slopes. The remaining channel has stone revetted side slopes. There are two drop structures located approximately 1 mile apart within this reach.

Table 4-3

Drop Structures and Bed Stabilizers on the Lower Santa Ana River

Type	OCEMA Station	General Location
Drop Structure	1198+50	d/s of Weir Canyon Rd.
Bed Stabilizer	1129+00	u/s of Imperial Hwy.
Drop Structure	1022+98	d/s of OCWD intake works
Bed Stabilizer	1119+00	u/s of Imperial Hwy.
Drop Structure	970+00	d/s of Lakeview Ave.
Drop Structure	907+00	d/s of Tustin Ave.
Drop Structure	884+00	d/s of AT&SF crossing
Drop Structure	836+50	d/s of E02 (Carbon Creek Diversion)
Drop Structure	803+50	d/s of Lincoln Ave.
Drop Structure	737+50	d/s of Ball Rd.
Drop Structure	682+00	u/s of 57 Orange Freeway
Drop Structure	637+00	u/s of Chapman Ave.
Drop Structure	593+35	d/s of 22 Garden Grove Freeway
Bed Stabilizer	574+00	d/s of Garden Grove Blvd.
Bed Stabilizer	517+00	u/s of Seventeenth St.
Bed Stabilizer	498+00	d/s of Fairview St.
Bed Stabilizer	474+00	u/s of Fifth St.
Bed Stabilizer	448+50	d/s of First St.
Bed Stabilizer	420+00	d/s of McFadden Ave.
Bed Stabilizer	383+00	d/s of Edinger Ave.
Bed Stabilizer	329+30	d/s of Warner Ave.
Bed Stabilizer	275+00	d/s of Talbert Ave.

d. Garden Grove Freeway to Seventeenth Street. The easterly side of the river is improved with a grouted rock revetment running from the Santiago Creek confluence to approximately 500-ft north of Seventeenth Street, a distance of approximately 3,600-ft. There is a reinforced concrete lining on both sides of the river from Seventeenth Street to the point where it joins the revetted side slope. The westerly side has approximately 700-ft of grouted rip-rap at the confluence with Santiago Creek; the remainder between the concrete lining north of Seventeenth Street and Garden Grove Boulevard has minimal protection of a pipe and wire revetment installed after the 1938 flood. The golf course turf, located just downstream of the Garden Grove Freeway, provides no stabilization except for very minor annual floods. The bicycle trail-crossing near Seventeenth Street functions as a grade stabilizer with heavy rock revetment, which was placed as a protective measure during the floods of 1978 and 1980. There is also a grouted rock stabilizer at the downstream side of the Garden Grove Boulevard bridge.

e. Seventeenth Street to Adams Avenue. From approximately 1,200-ft upstream from Seventeenth Street to about 3,000-ft downstream from Adams Avenue, a reach of 7.4 miles, the existing Santa Ana River is a soft-bottom trapezoidal channel. The side slopes are protected with reinforced concrete.

f. Adams Avenue to the Pacific Coast Highway. From Adams Avenue to 0.6 miles upstream of the Pacific Coast Highway the channel is a soft-bottom trapezoidal channel with side slopes protected with reinforced concrete. From 0.6 miles upstream of the Pacific Coast Highway, the channel invert transitions from grouted stone to concrete. The channel shape transitions from trapezoidal to rectangular within this 0.6 mile section.

g. Santa Ana River Outlet. The outlet channel is located south of the Pacific Coast Highway, discharging into the Pacific Ocean. The 700-ft long outlet channel consists of a transition section, from rectangular concrete to trapezoidal stone jetty with a soft-bottom invert. The existing Santa Ana river mouth includes the Greenville-Banning Channel running parallel to the southeast, the Talbert Channel running parallel to the northwest, and the Santa Ana River Channel in between.

h. Flood Problems. Portions of the existing Santa Ana River channel can convey flows ranging from 30,000 to 40,000-cfs for short periods of time. Severe erosion of the unlined channel invert will occur when long-term releases greater than 2,500-cfs are maintained. Long-term discharges of more than 2,500-cfs from Prado Dam have, in the past, undermined drop structures, bed stabilizers, the toe of channel embankments, and eroded the foundation materials underneath the piers of many bridges. Table 4-4 is a brief chronology of erosion problems on the lower Santa Ana River. Photo 4-1 shows the erosion which occurred at the Fifth Street bridge during the 1980 flood season. The OCEMA has been continuously improving the capacity of the Santa Ana River channel during the last 30 years, but the invert of the entire channel system must be stabilized and the channel banks strengthened before the channel can safely convey large long duration flows. The spillway outflows from Prado Dam under present conditions are 50,000-cfs for the 100-yr flood event and

160,000-cfs for the 200-yr flood event. These flood events would not be contained by the existing channel improvements and would cause widespread flooding within the lower river area (Plate 4-25).

i. Diverting Flows from the Santa Ana River to Coyote Creek. Flows from the Santa Ana River can be diverted at Imperial Highway through OCWD's spreading facilities to Coyote Creek via the Anaheim Lake Transfer Facility. Approximately 180-cfs can be accommodated through this diversion. Such a diversion must be approved and coordinated with the OCWD and the OCEMA. Normally such a diversion is only initiated under unusual conditions when water can not be impounded at Prado Dam and the channel downstream of Imperial Highway needs to be free of all flows.

Photo 4-1: Scour under the Fifth Street Bridge downstream of Prado Dam following the floods of February 1980

4-10 **Upstream Structures**. Refer to Plate 4-01a for the location of the following described structures.

a. **Upper Santa Ana River**. Big Bear Dam is the only existing structure which would affect flood flows in this watershed. Big Bear Lake is a water conservation reservoir, owned by the Big Bear Municipal Water District. The lake has a drainage area of about 38 sq-mi and has a surcharge storage of about 8,600 ac-ft between the top of the conservation pool and the top the dam.

b. **Santa Ana River to Prado Dam**. Two major flood control dams are located in the Santa Ana River Basin; Prado Dam and San Antonio Dam.

(1) **San Antonio Dam**. San Antonio Dam, completed by the Corps in 1956, is located on San Antonio Creek and controls runoff from a drainage of 26.7 sq-mi. San Antonio Dam is the second largest flood control facility operated and maintained by the LAD within the Santa Ana River watershed. Releases of up to 8,000 cfs from San Antonio Dam enter Prado Reservoir via San Antonio Creek/Chino Creek. Refer to Exhibit B of this manual and the San Antonio Water Control Manual for additional information.

(2) **Other Improvements**. Other existing flood control improvements, including those on Cucamonga, Deer, Lytle, and Cajon Creeks, have been constructed by the Corps of Engineers and local interests. These improvements include channelization, debris basins, storm drains, levees, stone and wire-mesh fencing, and stone walls along the banks of stream channels. The principal existing water conservation improvements are spreading grounds and reservoirs. The more than 100 water conservation and recreational reservoirs within the basin have storage capacities ranging in volume from less than 5 ac-ft to Lake Mathews' 182,000 ac-ft. Although most of the existing water conservation improvements affect the regimen of lesser flood flows, major flood flows are not appreciably affected.

c. **Lake Elsinore**. Lake Elsinore, the terminus for the 768 sq-mi San Jacinto River basin, has considerable potential influence on flood runoff, especially if its water surface elevation is low at the beginning of a storm. Lake Elsinore has a dead storage capacity of about 130,000 ac-ft. When full, lake Elsinore overflows into Temescal Wash, which joins the Santa Ana River near Prado Dam. The Lake Elsinore overflow is a small manmade outlet channel which allows water to either spill due to gravity flow or by pumping. The lake is only pumped during extreme flood events. During the 1980 and 1983 flood events, the California Department of Water Resources had pumps brought to Lake Elsinore. The pumps operated at a maximum monthly average of 80 cfs.

Table 4-4

Brief Chronology of Erosion on the Lower Santa Ana River

Water Year	Extended Discharge (cfs)	Duration	Description of Damage/Action
1969	4,500-5,000 1,200-2,400 4,000-5,000 1,200-1,000	25Jan-27Jan 27Jan-26Feb 26Feb- 7Mar 7Mar-20Apr	Heavy erosion and silting all along the Santa Ana River Erosion to levees required emergency rip-rapping. All gates at Prado were closed, only ungated release were made from Jan 27-29 and Feb 12-26. Piping occurred through the levee into Burris Pit Foundation of Santa fe RR bridge in the City of Orange was damaged 3,000 chickens were lost in Santa Ana Canyon due to bank erosion
1978	1,900-1,400 500- 500 2,500-2,000 0- 0 1,000-1,000	10Feb-21Feb 21Feb- 2Mar 2Mar-16Mar 16Mar-20Mar 20Mar-28Mar	Drop structure near Katella Ave failed on 12Feb78. Considerable invert erosion results in damage to a Sanitation District Sewer Crossing.
1980	5,000-6,000 1,500-2,000 4,000-5,000 2,600-2,800 0- 0 1,500-1,500	19Feb-28Feb 25Feb- 1Mar 1Mar-10Mar 10Mar-17Mar 17Mar-25Mar 25Mar-19Apr	Damage to downstream channel required reduction of outflow to accommodate flood fight. Severe erosion of channel invert and lining, particularly between 17th St. and Harbor Blvd. Scour averaged 6'-8' with localized scour of up to 20'. Several bridges undermined exposing pile caps and piles. Bridges affected included: Fairview St. P.E. Railroad 5th St. 1st St. McFadden Ave. Edinger Ave.
1983	4,000-5,000 0- 0 1,000-2,000 0- 0 1,000-1,500	27Feb- 8Mar 8Mar- 9Mar 9Mar-29Mar 29Mar-31Mar 31Mar- 8Apr	Levee just upstream of 405 (San Diego) Freeway experiences severe scour damage at the toe. Footing piles are exposed on bridges: 5th St. 1st St. McFadden Ave. Edinger Ave. Bridge scour is not as sever as in 1980, no bridges were closed to traffic.
1990	-	-	Since water year 1983, drop structures, bed stabilizers, new bridges, and other improvements have been added to the OCEMA maintained Santa Ana River. The Corps still considers 5,000 cfs to be the maximum long-term release capacity of the Santa Ana River

d. <u>Mill Creek</u>. The only existing flood control structure in the Mill Creek drainage area is a levee system comprised of levee embankments and masonry walls. The main levee structure is a 13,600-ft compacted earthfill embankment built by the Corps of Engineers in 1960. Local interests had previously built about 2,000-ft of masonry walls which tie into the upstream end of the Corps' levee, and about 2,400-ft of guide levees to control low flows. These structures are protected by rock and wire revetments. The lower 1,800-ft of the Corps' levee is ungrouted stone revetment, with the remaining upstream length being protected by grouted stone revetment.

e. Oak Street Drain. Within the Oak Street Drain watershed, two debris basins have been constructed by the Riverside County Flood Control and Water District (RCFCWD). Mabey Canyon and Oak Street debris basins were completed in late 1973 and 1979, respectively. Together, these basins control debris emanating from Kroonen, Hagador, Tin Mine, and Mabey Canyons. Mabey Canyon debris basin was designed to provide debris storage of 108 ac-ft with a spillway capable of passing 3,100 cfs. Oak Street debris basin was designed to provide 253 ac-ft of debris storage with a spillway capable of passing 7,700 cfs. Other structures affecting runoff are Mangular Border Drain (downstream of Mabey Canyon debris basin), and Main Street Drain. Main Street Drain discharges flow into Oak Street Drain approximately 1,500-ft upstream of the confluence with Temescal Wash. The existing Oak Street Drain channel from the debris basin to the confluence with Mangular Border Drain consist of steel rail and wire mesh bank protection with a natural earth channel bottom. A concrete-lined channel extends from this confluence downstream to Railroad Street. The remaining reach downstream to Temescal Wash is a natural channel.

4-11 Downstream Structures. Refer to Plate 4-01a for the location of the following described structures.

a. Lower Santa Ana River from Prado Dam to the Pacific Ocean. Two major flood control dams are located in the Santa Ana River Basin below Prado Dam; Carbon Canyon Dam and Villa Park Dam. Villa Park Dam is described in paragraph 4-11-b-(1) "Santiago Creek".

(1) Carbon Canyon Dam. Carbon Canyon Dam, completed by the Corps in 1961, is located on the Carbon Canyon Creek in the Chino Hills about 4 miles east of the city of Brea. It is currently operated and maintained by the LAD. The drainage area is 19.3 sq-mi. The reservoir release schedule allows a maximum average outflow of 1,000 cfs. The downstream channel is concrete lined for one mile at which point it becomes an improved earth channel, which diverts flows into the OCEMA's Miller Stilling Basin located a distance of 3.5 miles downstream from Carbon Canyon Dam.

The outflow from the Retarding Basin flows through the Carbon Creek Diversion Channel into the Santa Ana River between Lincoln Avenue and Glassell Street (Plate 2-10). Waters entering the Miller Basin Complex are normally diverted to the Santa Ana River via the Carbon Creek Diversion Channel. Under extreme conditions, flows will be split between the Carbon Creek Diversion Channel and the Carbon Canyon Creek, which flows into Coyote Creek and then into the San Gabriel

River. Refer to Exhibit B of this manual and the Carbon Canyon Water Control Manual for additional information.

(2) Other improvements. Other existing flood control improvements have been constructed by local interests. These improvements include channelization, storm drains, levees, rip-rap and concrete side slope protection, and drop structures. The principle existing water conservation improvements are spreading grounds, recharge basins, and Irvine Lake (i.e., Santiago Dam).

(a) Santa Ana River Infiltration Enhancement Facility. OCWD operates a system of ground water spreading facilities in and along the Santa Ana River between Imperial Highway and Ball Road. This reach of river is composed of two channels. One channel, located on the northerly side of the Santa Ana River, is used for groundwater recharge purposes. The other is the main channel of the Santa Ana River which is used for both flood flows and recharge during low flows. Recharge in the main channel is accomplished through a series of earthen berms, known as L-dikes, which are washed out when flows downstream of Prado Dam exceed 600 cfs. The groundwater recharge system includes permanent gated off-channel basins to maximize percolation capacity. Plate 4-26 shows the general plan of the recharge facilities.

The general characteristics and specifications of the sub-basins are summarized in Table 4-5. The upstream inlet structure to the spreading grounds is located just downstream of Imperial Highway. It consists of a set of three rectangular six by six foot electrically operated gates. A sand dike with a set of four 36 inch diameter pipes is used to backhold water to provide sufficient head to allow flow to be diverted through the gates. The approximate maximum inlet capacity of the Imperial Fore-bay structure is 500 cfs and is highly dependent on the water surface elevation in the Santa Ana River. An additional transfer facility is located at the junction of the Carbon Creek Diversion and the Santa Ana River. The long term percolation rate of the entire system is currently estimated to be approximately 350 cfs.

OCWD has completed (April 1990) a pumped storage facility which will allow it to capture additional storm flows. The capacity of the pumping facility is 200 cfs. Water is pumped from Burris Pit, located along the Santa Ana River, to Bond Pit located about 6 miles away on the Santiago Creek via a 66 inch pipeline. Buttressing of the side walls of the gravel pits with permeable material has been completed to elevation 230-ft.

Because any significant flow within the Santa Ana River overtops and washes away the L-dikes and consequently destroys the in-channel spreading basins, OCWD maintains a full time maintenance crew at the spreading grounds. OCWD estimates that a one week period at a cost of about $10,000 is required to rebuild the in-channel L-dikes.

b. Santiago Creek. Villa Park Dam, a multi-purpose facility is located on the Santiago Creek.

Table 4-5

General Characteristics of the OCWD
Santa Ana River Infiltration
Enhancement Facility

Basin	Invert Elevation (ft)	Maximum WSE (ft)	Maximum Surface Area (ft)	Maximum Storage (ac-ft)
Imperial Desilting Basins	---	---	33	--
Huckleberry	207	246	24	865
Con-Rock Basin	200	241	35	1,205
Warner Basin	190	236	65	2,521
Olive Pit	200	227	3	60
Glassel Basin	---	---	98	--
Fives Coves Basin	170	201	29	690
Lincoln Basin	170	190	10	120
Burris Pit	100	170	60	3,836
Ball Road Basin	155	160	11	53
Anaheim Lake	175	224	73	2,370
Miller/Placentia/ Raymond*	---	---	53	---
Kramer Basin	170	215	38	1,200
Santiago Basins	160	280	179	11,060
* OCEMA allows use for water conservation during non-flood season.				

(1) Villa Park Dam. Villa Park Dam is located approximately 2 miles upstream of the Santiago Gravel Pits (i.e., Blue Diamond and Bond Pits) at the foothills of the Santa Ana Mountains. It has a drainage area of 83.4 sq-mi, this includes the 63.1 sq-mi Santiago Dam drainage. Villa Park Dam was constructed by the OCFCD in 1963. The OCEMA, which has assumed the administrative and operational obligations of the Flood Control District, currently maintains and operates the facility. Villa Park Dam is operated as a multipurpose reservoir with varying seasonal storages for both flood control and water supply. Dam releases are scheduled according to the water surface elevations of both the Villa Park Dam and the uncontrolled Santiago Reservoir which is located 3.2 miles upstream of Villa Park Dam. The maximum scheduled release from Villa Park Dam is 6,000 cfs. The flood control and conservation storage allocations are scheduled on a seasonal basis as

shown in Table 4-6. Refer to Exhibit B of this manual and the Villa Park Dam Operation Manual (an OCEMA document) for additional information. The basic operation of Villa Park Dam is as follows:

1. The water surface elevation in Santiago Reservoir determines the water surface elevations in Villa Park Reservoir at which the gates are first opened for flood control releases. The lowest level at which releases from Villa Park Dam are made is when the WSE at Villa Park Dam reaches 510-ft.

2. When the specified WSE's at Villa Park and Santiago Dam are reached, the gates are operated so that outflow is approximately equal to inflow up to the normal maximum of 3,500 cfs (higher gated outflow rates of up to 6,000 cfs are allowable under certain conditions, as described in the "Villa Park Dam Operation Manual").

3. During times when outflow is being set approximately equal to inflow, a deviation of 1-ft in the water surface elevation above or below that specified in the gate regulation schedule is permissible at the discretion of the operator.

Table 4-6

Seasonal Storage Allocations for
Villa Park Dam

Period	Conservation Storage (ac-ft)	Flood Control Storage (ac-ft)
Jan01-Apr01	20	15,324
Apr01-Apr15	6,031	9,313
Apr15-May15	11,130	4,214
May15-Jun01	14,398	946
Jun01-Oct01	15,344	0
Oct01-Oct15	12,997	2,347
Oct15-Nov01	2,296	13,048
Nov01-Dec01	629	14,715
Dec01-Jan01	20	15,324

Flood control releases from Villa Park Dam commence when the WSE at Villa Park exceeds 510-ft and the WSE at Santiago Dam exceeds 710-ft.

(2) Santiago Dam (Irvine Lake). Santiago Dam, located upstream from Villa Park Dam, is a water supply reservoir constructed by the Irvine Company in 1933. Its uncontrolled flood releases enter Villa Park Dam. It has a drainage area of 63.2 sq-mi. The total storage capacity is 25,000 ac-ft.

(3) Other Improvements. The Santiago Creek channel has been improved over the years by local interests. During the 1930's, masonry walls were constructed from the Santa Ana Freeway through Hart Park, Within Hart Park, the channel bottom has been paved for use as a parking lot. Rip-rap was placed along the west bank upstream from Chapman Avenue for the protection of homes along the bank. Downstream from Prospect Avenue, concrete sideslope protection has been placed to protect homes that were damaged by the 1969 floods. On Handy Creek, a concrete channel runs from just downstream of Orange Park Boulevard to its confluence with Santiago Creek. The large gravel pits (Blue Diamond and Bond Pits), downstream from Villa Park Dam, act as reservoirs for floodwater. During minor floods, flows are completely contained within the pits and never reach the downstream channel. However, during major floods, water will fill the pits and overflow to the downstream channel.

4-12 Economic Data.

a. Area of Flood Protection. The Prado Dam Flood Control Basin presently serves as the major flood control facility along the Santa Ana River corridor. The Prado Dam watershed is essentially the heavily populated downstream and upstream areas that lie in the counties of Orange, San Bernardino, and Riverside. This area is commonly referred to as the South Coast hydrologic subregion. The area is among the most populous and economically diverse areas in the nation. Existing flood control features protect approximately 110,000 acres of urbanized area. The majority of this area is located in the cities of Anaheim, Santa Ana, Huntington Beach, Garden Grove, and Fullerton. Plate 4-25 taken from the Santa Ana River GDM depicts the projected Standard Project Flood (SPF) overflow area.

b. Population. The major concentrations of population within the aforementioned overflow area reside and/or work in the cities listed in Table 4-7.

In addition to these cities, an estimated 1 million people are currently living in other portions of the overflow area downstream of Prado Dam. Hence the flood control dam currently protects over 2 million people living in the flood plain.

Statistical information from both the State of California, Department of Finance, Demographic Research Unit and the southern California Association of Governments (SCAG) show steady population increases range between 2.4% and 4% annually. This trend is expected to continue through the year 2010 and add another 1.5 million residents to the overflow area.

Table 4-7

Major Population Centers Downstream of Prado Dam

City	Estimated Population*
Anaheim	244,300
Fountain Valley	56,100
Garden Grove	134,800
Huntington Beach	188,700
Los Alamitos	12,150
Orange	106,400
Santa Ana	237,300
Seal Beach	27,350
Stanton	28,350
Westminster	73,300
TOTAL	1,108,750

*Source: State of California, Department of Finance, Demographic Research Unit; "Population Estimates of California Cities and Counties, January 1, 1988 to January 1, 1989"

c. <u>Economic Activity</u>. The flood plain associated with the Prado Dam is characterized as primarily highly urbanized. Existing residential development is extensive throughout the overflow area. As a result associated service industries have grown in conjunction with residential development. Major industrial activities abound within this area as well. Manufacturing facilities such as McDonnell-Douglas, Rockwell International, Monsanto Chemical, Nabisco Foods, and Georgia Pacific are located within the downstream overflow area of Prado Dam. Key regional warehousing operations for Goodyear, Lucky Foods, Kimberly-Clark, J.C. Penny Company, Radio Shack, and Yamaha are also located in the lower Santa Ana River flood plain. Additionally within this area are several world renown tourist attractions. Disneyland, Knott's Berry Farm, Movieland Wax Museum, Huntington Beach, and Newport Beach Harbors are situated on the flood plain. These activities employ tens of thousands of people and are vital to southern California's diverse economy.

d. Residential Development. Based upon the SCAG Regional Growth Management Plan (1988) and assuming a growth factor of ±3% the estimated number of existing residential units within the overflow area is 806,350. The projected number of housing units for the year 2010 is estimated at 1,186,400.

e. Flood Damages. The Phase II GDM of the Santa Ana River Mainstem (August 1988) estimates expected flood damages to structures and contents in the Lower Santa Ana River area as $14.7 billion in 1987 dollars for a flood with two-tenths of one percent chance of occurrence (500 year frequency). The damages in 1989 dollars are estimated to be $16.2 billion.