IV - WATERSHED CHARACTERISTICS

4-01 **General Characteristics**. The Santa Ana River Basin drains approximately 2,450 square miles, excluding an area of 32 square miles tributary to Baldwin Lake and 10 square miles tributary to Perris Reservoir. Of the total basin, 2,255 square miles of the drainage area is upstream from Prado Dam, which in addition to Seven Oaks Dam is the other major flood control structure on the Santa Ana River. Approximately 23 percent of the entire basin is within the San Gabriel and San Bernardino Mountains; about 9 percent is in the San Jacinto Mountains; and 5 percent is within the Santa Ana Mountains. Most of the remaining area is in the valleys formed by the broad alluvial fan along the base of these mountains. The upper Santa Ana River drainage area above Seven Oaks Dam is approximately 177 square miles, excluding the 32 square miles tributary to Baldwin Lake, and has its headwaters in the San Bernardino Mountains. The Santa Ana River basin is shown on Plate 2-01.

4-02 **Topography**. The damsite and reservoir area is within the steep-walled Santa Ana River Canyon along the southern margin of the San Bernardino Mountains. The elevation of the canyon floor at the damsite is approximately 2,060 feet, NGVD. The gradient of the canyon floor averages about 3 percent. Elevations of the ridgetops outlining the canyon range from about 3,500 feet directly above the damsite on the left (east) abutment, to almost 4,000 feet on the western flank of the canyon. The canyon walls at the right (west) abutment are very steep 1V on 0.6H just above the canyon floor and then flatten to 1V on 2H at higher elevations. The "ridge and swale" topography at the left abutment has more uniform slopes of about 1V on 1.5H. Several "hanging valleys," probably created by the rapid uplift of the San Bernardino Mountains and equally rapid down-cutting by the Santa Ana River, can be identified near the site.

The headwaters of the Seven Oaks Dam watershed lie within the rugged San Bernardino Mountains. Elevations vary from 10,664 feet, NGVD, at Anderson Peak and 11,502 feet, NGVD at San Gorgonio Peak to 2,060 feet, NGVD at the damsite, which is approximately 1 mile upstream from the canyon mouth. Generally trending southwesterly, the 27 miles of river upstream of the damsite has an average gradient of 300 feet per mile. Some smaller tributaries originating in the high mountains have gradients that exceed 1,900 feet per mile. Bear Creek, the principal tributary within the Seven Oaks canyon area, drains 55 square miles and possesses an average gradient of approximately 460 feet per mile. Well-developed growths of fir and pine occur above elevations of about 5,000 feet, NGVD. Many steep slopes within the watershed are covered with a moderate to dense growth of chaparral and sage scrub. Lower slopes carry a heavy cover of grasses and forbs. The drainage area above the dam is expected to remain largely undeveloped during the project life. The project location and topography are shown on Plate 2-02.

4-03 **<u>Geology and Soils</u>**. 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 feet 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 foot to 6 feet in depth. In the valleys, where the soils are usually more than 6 feet 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 4-01. The San Andreas Fault zone, which is the best recognized, is also 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.

a. Seismicity. Seven Oaks Dam is located in a seismically active area and is designed to withstand an earthquake magnitude measuring 8+ on the Richter scale, occurring on the nearby San Andreas Fault. Numerous other active faults exist within a 50-mile radius of the dam, capable of generating an earthquake magnitude of 7 or 7.5 on the Richter scale. Two smaller active faults, were mapped within the footprint of the embankment. Other faults, believed to be inactive, were also mapped within the dam's footprint. Displacement in bedrock due to seismic events was conservatively estimated at 4 feet for design purposes. The displacements are assumed to occur in subsidiary faults and shear zones at the damsite in response to forces from the design earthquake on the San Andreas Fault. The faults underneath the dam are not expected to move independently. Predicted earthquake motions will subject the dam to peak horizontal accelerations of 0.7g and a bracketed duration at 0.5g of 40 to 50 seconds.

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 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 0.2mm to 0.8mm 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 riverbed 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 lower portion of 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. The upper portion has been left in its natural condition.

The volume of sediment to be distributed in the Seven Oaks Reservoir was determined to be 32,000 acre-feet. This volume represents the amount of sediment that would be trapped in the reservoir after 100 years of service. At least three monumented sediment index ranges have been established within the reservoir areas of Seven Oaks Dam. These sediment ranges are used to indicate the need for updated topographic mapping of the reservoir area. Up-to-date topography is essential to accurate computations of reservoir storage, which in turn is used in the calculation of reservoir inflows. The most recent area-capacity relation for Seven Oaks Dam is based on the survey of 1999 and is presented on Plate 2-27. The area-capacity tables are shown in Exhibit B.

4-05 **Climate**. In general, the Santa Ana River Basin has a mild climate with warm, dry summers and cool, wet winters. Both temperature and precipitation vary considerably with distance from the ocean, elevation, and topography.

a. Temperature. At the city of Corona, about 26 miles from the ocean and 710 feet above sea level, the average temperature is about 63°F, with extremes of 22°F and 118°F recorded. At Squirrel Inn, located in the San Bernardino Mountains at elevation of 5,700 feet, NGVD, the average temperature is about 53°F, with extremes of 0°F and 97°F recorded.

b. Precipitation. Precipitation increases with elevation. The 97-year mean seasonal precipitation for the Santa Ana River basin, which averages about 20 inches, varies from 10 inches south of the city of Riverside to about 45 inches in the higher mountain areas. Nearly all precipitation occurs during the months of December through March. Rainless periods of several months during the summer are common. Plate 4-02 (reproduced from the Santa Ana River Mainstem Phase II GDM, Volume 7) shows the mean annual precipitation over the Santa Ana River basin.

c. Snow. Snow in southern California is relatively uncommon at elevations below 6,000 feet, 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 feet. 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 over the Santa Ana River basin down to 2,000 or 3,000 feet can be significantly augmented by melting snow.

d. Evaporation. No formal studies of evaporation have been made in the Seven Oaks watershed. Water conservation is not part of the current operating plan; therefore, evaporation is not a major consideration for the Seven Oaks Dam water control plan. However, pan evaporation data have been collected for three stations located within the Santa Ana River Basin, as shown on Table 4-1. 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 to 3 inches in winter and 9 to 11 inches in summer in lower elevations. On days of very strong, dry Santa Ana winds, evaporation can be greater than one inch in 24 hours.

e. Wind. The prevailing wind in the Seven Oaks 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 to 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. Storms.

(1) Winter Storms. General winter storms usually occur from December through March. They originate over the Pacific Ocean as a result of the interaction between polar Pacific and tropical Pacific air masses and move eastward over the basin. These storms, which often last for several days, reflect orographic influences and are accompanied by widespread precipitation in the form of rain and, at higher elevations, some snow. The isohyets for the mean seasonal precipitation are shown on Plate 4-02.

(2) Local Storms. Local storms can occur at any time of the year, either during general storms or as isolated phenomena. Those occurring in the winter are generally associated with frontal systems. These storms cover comparatively small areas, but result in high-intensity precipitation for durations of up to 6 hours.

(3) Summer Storms. General summer storms in this area are usually associated with tropical cyclones and occur very infrequently. They are known to have occurred in the late summer and early fall months, but have not resulted in any major floods during the period of record.

b. Floods. Although historical reference to flood conditions in the general region date back to about 1769, little information is available regarding the magnitude of floods occurring prior to 1850. Historical references indicate that (from 1769 to 1850) medium-to-large floods occurred in 1825, 1833, 1840, and 1850. Some available quantitative data indicates that, from 1850 to 1897, medium-to-large winter floods occurred in 1859, 1862, 1867, 1876, 1884, 1886, 1889, and 1894. Recorded data from 1897 to the present indicate that medium-to-large winter floods occurred in 1903, 1920, 1914, 1916, 1921, 1922, 1927, 1938, 1943, 1965, 1966, 1969, 1978, 1980, 1983, and 1993. Following the historical floods of the 1800's and early 1900's, considerable changes have occurred in the drainage basin. Runoff characteristics of the majority of the valley areas have been changed by urbanization and agriculture. The mountain areas have remained relatively unchanged, although several small reservoirs, detention dams, and debris basins have been constructed at the canyon mouths. In the event that a large, historical storm occurred under present-day conditions, mountain runoff would be similar to that which occurred in the past since these small structures would have little effect on major floods on the mainstem of the Santa Ana River. Valley runoff would be considerably higher in both peak and volume because of increase in impervious cover due to development and channelization of flows. Additional information on the following storms and floods is given in the Review Report, Phase I General Design Memorandum (GDM), and the Phase I GDM Supplement.

(1) Storm and Flood of January 1862. An extreme flood event occurred in January 1862. Although very little data concerning the storm 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 interrupted series of cold storms 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 estimated peak discharge of 317,000 cfs at Riverside Narrows.

(2) Storms and Floods of January 1916. Two heavy storm series hit southern California in January 1916. The 14-19 January storm 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 on 27-28 January. The peak discharge on the Santa Ana River near Prado Dam area was estimated at 45,000 cfs with a 24-hour maximum volume of 67,200 acre-feet. The direct and indirect flood damages resulting from this storm were estimated (1949 price levels) at $2,500,000 in Orange County and $5,080,000, in San Bernardino and Riverside Counties. These estimates according to the latest 2002 price levels were $41,250,000 for Orange County, and $83,820,000 for San Bernardino and Riverside Counties.

(3) <u>Storms and Floods of February 1927</u>. 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. The peak discharge on the Santa Ana River near Prado Dam area was estimated at 18,000 cfs with a maximum 24-hour maximum volume of 30,300 acre-feet. The direct and indirect damages resulting from this storm were estimated (1949 price levels) at $438,000 in Orange County and $594,000 in San Bernardino and Orange Counties. These estimates according to the latest 2002 price levels were $4,421,000 for Orange County, and $6,136,000 for San Bernardino and Riverside Counties.

(4) <u>Storm and Flood of 27 February - 3 March 1938</u>. The storm of February 27 - March 3, 1938 was and still is the most destructive of record since 1862 on the Santa Ana River and many other streams in Southern California. Its occurrence played a major role in the justification of many flood control structures including Prado Dam, a Corps owned and operated dam on the lower Santa Ana River. 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 equaling or exceeding 30 inches during the 5 days. Within the Santa Ana River basin, total rainfall ranged from 5 inches near Perris to 27 inches at Big Bear

Lake Dam. The heaviest rain fell on 2 March between 0000 to 1900 hours, during which Camp Baldy at the northwest edge of the 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 6,000 feet. The snow cover at points of observation was not materially depleted at the end of the storm, indicating that snow melt 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. The direct and indirect damages resulting from this storm were estimated (1949 price levels) at $6,826,000 in Orange County and $13,460,000 in San Bernardino and Riverside Counties. These estimates according to the latest 2002 price levels were $87,100,000 for Orange County, and $171,750,000 for San Bernardino and Riverside Counties.

(5) <u>Storm and Flood of January 1943</u>. 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 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 intense rainfall occurred from about noon on 21 January into the morning of 23 January. Two cold fronts, the first of which occurred about midnight on 21

January, and the second, about midnight on 22 January, caused this precipitation. 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 about 4.3 inches at Riverside to 29.7 inches at Glenn Ranch in the San Gabriel Mountains. The isohyets for the 21-24 January storm showing the maximum 24-hour precipitation are shown on Plate 4-03.

(6) <u>Storm and Flood March 1943</u>. The local storm that occurred between 2200 hours on 3 March and 0100 hours on 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 automatic precipitation gages were in operation, the aerial distribution of precipitation was well defined. The highest observed intensities were at the Sierra Madre-Carter 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 the 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. The isohyets for the 3-4 March storm showing the maximum 3-hour precipitation are shown on Plate 4-04.

(7) <u>Storms and Floods of January 1969</u>. A series of storms that began on 18 January and continued through 27 January 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. The series of storms was interrupted by a brief ridge of high pressure that moved through the area on 22 and 23 January and caused a short break in the rainfall. Except for this lull on January 22 and 23, heavy precipitation occurred during most of 18 – 26 January period. An intense downpour occurred on 25 January. Nine-day totals ranged from 10 to 20 inches in the lowlands and from 25 to more than 50 inches in the mountain areas of southern California. In the Santa Ana

River basin, total amounts for Lytle Creek Ranger Station and Big Bear Lake were 42.68 and 35.52 inches, respectively. A streamgage at Santa Ana River near Mentone measured a peak 1-hour average discharge of 15,300 cfs, which was recorded on 25 January.

(8) <u>Storms and Floods of February 1969</u>. 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. A total storm amount of 10.03 inches was recorded at Idyllwild Ranger Station in the Santa Ana River Basin area.

(9) <u>Storm and Flood of February 1978</u>. 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.

(10) <u>Storm and Flood of March 1978</u>. 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 occurrences of rainfall during the storm period: 28 February, 1 March, 4 March, and 5 March. Total rainfall 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 28 inches in the San Gabriel Mountains. The heaviest sustained rain fell during the morning of 1 March and again during the mid-day of 4 March. With the ground highly saturated from the already very wet winter, runoff from these storms was very high, especially in terms of low volumes. At Prado reservoir, the inflow during the storm period was recorded at a maximum rate of 34,700 cfs.

(11) Storms and Floods 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 heavy bursts of rain occurred on 14, 16, and 19 February. 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 feet and spilled down Temescal Creek into Prado reservoir, where the 1-hour average inflow was recorded at a maximum rate of 36,000 cfs on 17 February.

(12) Storms and Floods 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 to 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 during the period have recurrence intervals 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. 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 crossing. Discharges of 4,000 cfs were observed at Lytle Creek near Fontana.

(13) <u>Storms and Floods of January – February 1993</u>. From 6 January to 28 February 1993, a series of storms produced 20 to 40 inches of rain over much of southern California coastal and mountain areas and more than 52 inches at some stations in the San Bernardino Mountains. These storms, which coincided with a reappearance of weak "El Nino" conditions in the tropical regions of the Pacific Ocean, were driven by a regional atmospheric low-pressure system off the coast of northern California and Oregon. The first major streamflows occurred on 6-7 January, as a result of heavy rainfall on a fairly substantial snowpack that had accumulated in December 1992. The recurrence intervals of flows in the Santa Ana River Basin were about 25 to 50 years. The rain continued, and a second major runoff peak occurred late on 16 January as the low pressure system moved slightly south before moving to the east on 18 January. A nearly identical storm pattern developed in early February as a stationary atmospheric low-pressure system off the Oregon coast again generated storms. Major storms and resultant runoff peaks occurred on 8 February, and 18-19 February. Although the peak streamflows were only in the 25- to 50-year recurrence interval range, significant local flooding occurred because of saturated conditions in the watershed due to the January storms.

4-07 <u>Runoff Characteristics</u>. Streamflow, which is perennial in the canyons of the Santa Ana River and in the headwaters of most of its tributaries, is generally ephemeral in most valley segments. Streamflow increases rapidly in response to effective precipitation. High-intensity precipitation, in combination with the effects of steep gradients and possible denudation by wildfire may result in intense sedimentladen floods, with some debris load in the form of shrubs and trees. Deposition of sediment occurs in the stream channels as they flow from the canyon mouths onto the lower-sloped valley floor surface. The urbanization that is taking place in the valley areas of the Santa Ana River Basin tends to make the basin more responsive to rainfall. Hence, the same rainfall occurring over an urbanized segment of the basin will result in higher peak discharges, with a shorter time to the peak and a greater volume than had it occurred over a natural basin without urbanization.

4-08 **<u>Water Quality</u>**. 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 in these areas 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 in the general area.

4-09 **<u>Channel and Floodway Characteristics</u>**. The Santa Ana River downstream of Seven Oaks Dam is divided into two major divisions, namely, 1) the reach that extends from Seven Oaks Dam to Prado Dam, and 2) the lower Santa Ana River, which extends from Prado Dam to the Pacific Ocean. The reach from Seven Oaks Dam to Prado Dam is further divided into three subreaches, namely 1) from Seven Oaks Dam to the upstream end of the Lytle-Warm Creek confluence, 2) the Lytle-Warm Creek confluence area from just upstream of the East Twin Creek confluence to the Lytle-Warm Creek confluence, and 3) from the downstream end of the Lytle-Warm Creek confluence to Prado Dam. While the lower Santa Ana River is mostly improved, the reach between Seven Oaks Dam and Prado Dam is largely unimproved, with the exception of Lytle-Warm Creek confluence, the Riverside levees, and the Norco Bluffs bank protection.

a. <u>Santa Ana River between Seven Oaks Dam and Prado Dam</u>. Since much of the channel in this reach is unimproved, it is subject to constant change in dimensions, and therefore it is difficult to define its capacities. In 1991, however, a channel floodway delineation was performed by the Corps of Engineers under the Santa Ana River Mainstem Project to determine the magnitude of flows that would be generated by the operation of Seven Oaks Dam during a 100-year event and a 500-year event. From this study, it was found that the discharges resulting from the 100-year event would be fully contained within the delineated channel floodway, except for a few breakouts at reaches immediately downstream of Seven Oaks Dam. Plate 4-05 is a map showing the reaches of the Santa Ana River between Prado Dam and Seven Oaks Dam. Plate 4-05A shows the 100-year discharge within these reaches that can be contained within the channel.

(1) <u>Seven Oaks Dam Site to Lytle-Warm Creek Confluence</u>. This subreach is about 12.7 miles long and extends from the Seven Oaks Dam site to the upstream end of the Lytle-Warm Creek confluence project. Throughout the subreach, channel slopes are fairly steep and bed material is generally coarse. Starting from the outlet of Seven Oaks Dam, the river in this area has a dimensionless invert slope of about 0.028. At the upper Santa Ana Canyon, the river is natural, and the representative width for the 100-year floodplain varies from 200 to 550 feet, with 350 feet being the average. The Mill Creek confluence with the Santa Ana River occurs just downstream of the upper Santa Ana Canyon mouth. The dimensionless invert slope of the Santa Ana River low flow channel increases to 0.022 at the upstream end of the wash. The wash narrows downs and enters the upper Santa Ana Canyon about 6.7 miles upstream from the downstream end of the wash. Approximately 8.3 miles downstream from the beginning of this reach, the river becomes part of a broad wash. This wash is up to 5,000 feet wide and is bounded by high ground on the north side and by well-defined high banks on the south side. The confluence of City Creeks with the Santa Ana River is approximately 8 miles downstream from the damsite. Located between these two streams are major gravel mining operations in the right (north) overbank. The low flow channel of the river runs along the southern side of the wash, and the low flow channels of Plunge and City Creeks run along the north side of the wash. The invert slope of the Santa Ana River low flow channel varies from about 0.022 from the upstream end of the wash and 0.017 at the downstream end of the wash. Towards the downstream end of this subreach, the channel consists of a soft bottom channel with uncompacted earthen berms on both banks. The channel is about 1,800 feet wide with an invert slope of about 0.006.

There are three major areas where the 100-year discharge breaks out or expands out into the overbanks. The first area, progressing upstream, is just upstream of the AT&SF Railroad Bridge. In this reach, approximately 1,200 cfs of the peak 100-year Santa Ana River floodflows (33,000 cfs) breaks out into the right (north) overbank. The initial breakout flows are diverted away from the river by an elevated bridge approach embankment. The flows then spread out; eventually overtop the same railroad; and re-enter the river after being intercepted by East Twin Creek. The second breakout area upstream is approximately between the state Route 30 and Orange Street crossings. Floodflows for the 100-year event exceed channel capacity just downstream of Orange Street and break out into the right (north) overbank. These escaping floodflows then proceed to inundate a large active sand and gravel mining operation. For this stretch of river, the effective conveyance of the 100-year flood was primarily restricted to the immediate channel area. The last upstream breakout area occurs in the right (north) overbank reach roughly bounded by the Church Street extension and an area just downstream of where the wash enters the upper Santa Ana Canyon. Within this approximate four-mile reach, the 100-year flood overtops the existing low flow channel banks and breaks out into a "semi-alluvial fan" type overbank area.

(2) Lytle -Warm Creek Confluence. This subreach extends from just upstream of the East Twin Creek confluence to the downstream side of the Lytle-Warm Creek confluence. This area encompasses approximately 2 miles of the long subreach of the Santa Ana River. The average dimensionless channel slope through this reach is 0.005. Within this subreach, the Los Angeles District Corps of Engineers has built substantial channel improvements to confine flows and protect ten bridges. Key improvement features within this subreach include:

- A grouted-stone stabilizer 700 feet wide
- Two trapezoidal sections of earth-bottom channel with stone revetted side slopes. The channel width varies from 484 feet to 700 feet along the lower and upper channels. Both lower and upper channels are approximately 22 feet deep and have side slope of 1H:1V.
- A reinforced concrete drop structure with an approximately 9-foot drop.
- A 20-35 foot deep concrete rectangular section channel that varies in topwidth from 440 feet to 650 feet.
- Thirteen rows of energy-dissipating concrete blocks

The 100-year discharge through this section ranges from 52,000 cfs to 140,000 cfs, and it would be fully contained within the floodway, if not within the improved channel.

(3) Lytle-Warm Creek Confluence to Prado Dam. This subreach extends from 1,000 feet downstream of the Mt. Vernon Avenue Bridge (at the Lytle-Warm Creek confluence), to 0.6 miles above River Road at the upstream end of the Prado Dam Flood Control Basin. It is about 22 miles long and the channel bottom throughout the subreach is generally sandy with some finer and coarser material present. In general, the associated 100-year floodplain varies in width from 700 to 7,000 feet with 2,500 feet being a representative average. The 100-year discharge within this subreach ranges from 140,000 cfs to 166,000 cfs, all of which would be contained within the delineated floodway. In the lower third of the subreach, however, much of the overbank has either been leveed or contains agricultural improvements. The dimensionless channel slopes range from 0.003 to 0.006 with an average of 0.004. The channel width in the project reach varies from 200 to 1,300 feet. Typically, through the Riverside Narrows area just upstream of River Road, the low flow channel winds back and forth between canyon slopes with the overall river channel usually staying 150 feet in width or less. In the remaining two-thirds of this subreach just upstream of Prado Dam basin, the overbank areas are basically unimproved and support fairly dense natural vegetation.

b. Lower Santa Ana River (Prado Dam to Pacific Ocean). The lower Santa Ana River, which extends from Prado Dam downstream to 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. From Prado Dam the river winds through the narrow and relatively undeveloped lower Santa Ana Canyon for a distance of about 10 miles before it turns southwest at approximately Weir Canyon Road into the alluvial plain of the metropolitan area of northern Orange County. The Santa Ana River Mainstem flood control project also includes major improvements in the lower Santa Ana River. Within the lower Santa Ana River Canyon the project includes intermittent levee and bank protection, along with land acquisition. From downstream of the Weir Canyon Road crossing to the Pacific Ocean, the channel improvement project includes widening, deepening and reconstruction of the channel to carry project design flows ranging from 38,000 cfs to 47,000 cfs. Plate 4-06 is a schematic diagram of the lower Santa Ana River channel, showing its capacities and configurations.

4-10 Upstream Structures. Plate 4-05B shows a map of the upstream area and the inundation boundary within the reservoir. It currently remains undeveloped, therefore, no structures that would affect flood flows into the reservoir. Big Bear Dam is the only existing structure that would have any effect on the flood flows upstream of Seven Oaks Dam. Big Bear Lake is a water conservation reservoir, owned by the Big Bear Municipal Water District. Big Bear Lake has a drainage area of about 38 square miles and has surcharge storage of about 8,600 acre-feet between the top of the conservation pool and the top of the dam. Additional information about Big Bear Lake can be found in Exhibit C.

4-11 <u>Downstream Structures</u>.

a. <u>From Seven Oaks Dam to Prado Dam</u>. Two major flood-control dams are located in the Santa Ana River Basin, downstream of Seven Oaks Dam. These structures are Prado Dam and San Antonio Dam, both of which were built by the Corps of Engineers. Other existing flood control improvements, including those on Cucamonga, Deer, Lytle, and Cajon Creeks, were constructed by the Corps of Engineers and local interests. These improvements include channelization, debris basins, storms 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 recreation reservoirs within the basin have storage capacities ranging in volume from less than 4 to about 182,000 acre-feet in the case of Lake Mathews. Although most of the existing water-conservation improvements affect the regimen of the lesser floodflows, major floodflows are not appreciably affected. Lake Elsinore, the terminus for the San Jacinto River, has considerable 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 acre-feet. When full, Lake Elsinore overflows into Temescal Wash, which joins the Santa Ana River just upstream of Prado Dam.

(1) <u>San Antonio Dam</u>. San Antonio Dam is a flood control and water conservation project constructed, operated and maintained by the U.S. Army Corps of Engineers, Los Angeles District. The construction of the dam was completed in May 1956. San Antonio Dam is located approximately 30 miles east of Los Angeles in the Santa Ana River Basin. The dam is situated on San Antonio Creek about 10.5 miles upstream from its confluence with Chino Creek, which is tributary to Santa Ana River within the Prado Dam reservoir. Releases from San Antonio Dam range from 80 cfs to 5,000 cfs. As the water surface elevation of the reservoir approaches the spillway, releases are increased to an average of 7,500 cfs, not exceeding 8,000 cfs. Flood releases from the dam along with all local runoff downstream of the dam flow into

Prado Dam reservoir. More information about Prado Dam can be found within the latest Prado Dam and Reservoir Water Control Manual, dated September 1994.

(2) <u>Mill Creek</u>. Prior to recent improvements, the existing flood control structure in the Mill Creek drainage area was a levee system comprised of levee embankments and masonry walls. The main levee structure is a 13,600 feet compacted earthfill embankment built by the Corps of Engineers in 1960. The levees integrated two stone masonry floodwalls constructed immediately after the heavy flooding in 1938, by local interests with Work Progress Administration (WPA) funds. About 2,000 feet of masonry walls tie into the upstream end of the Corps' levee, and about 2,400 feet of guide levees to control low flows. These structures are protected by rock and wire revetments. The lower 1,800 feet of the Corps' levee is ungrouted stone revetment, with the remaining upstream length being protected by grouted stone revetment, which was built by the Corps. This levee system, however, was insufficient to contain flows of less than design capacity, which resulted in overtopping of the levee, and transport and deposition of large amounts of sediment on the levee slopes.

The improvements made to the original project assured conveyance of the standard project flood. This will contain the design discharge of 33,000 cfs, provide for long-term aggradation, degradation trends, and control local scour and deposition. The following are the improvements made to the original Mill Creek Levee project:

(a) Raising the top of the existing levee between station 70+00 and 88+70, the downstream end of the project, and station 88+70. The levee was raised 4 feet at station 70+00 and taper to a 0 height increase at station 88+70.

(b) Grouting the riprap levee face between station 70+00 and 88+70

(c) Extending the existing levee toe an average of 7.5 feet between stations 70+00 and 129+33.33, an average of 8.5 feet between stations 130+72 and 155+00 and an average of 10 feet between stations 155+00 and 196+25.37 the upstream end of the project.

(d) Constructing a vertical floodwall, average height of 6 feet, on top of the levee from stations 70+00 to 130+20 and from stations 130+72 to 196+25.37.

(e) Restoring a 100-foot strip of streambed vegetation, adjacent to the levee to within 7 to 10 feet of the top of the levee. This strip will be maintained after each flood event.

Further details about the Mill Creek Levee project improvements can be found within the Phase II GDM, Volume 4, Mill Creek Levee.

(3) Oak Street Drain. Within the Oak Street Drain watershed, two debris basins were 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 acre-feet with a spillway capable of passing 3,100 cfs. Oak Street basin was designed to provide 253 acre-feet 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 feet upstream of the confluence with Temescal Wash. Prior to recent improvements, the existing Oak Street Drain channel from the debris basin to the confluence with Temescal Wash was a well-defined channel that had been partly improved by the Riverside County Flood Control District. The channel had pipe and wire fencing for streambank protection in the upstream reach, a concrete channel within the City of Corona, and a trapezoidal earth channel in the lowlands downstream from the Atchison Topeka and Santa Fe (AT&SF) railroad bridge. The gradient of the stream varied from 0.030 at the upstream reach just below the debris basin to 0.001 at the outlet into Temescal Wash Channel. As the stream gradient decreased, the existing channel top width increased form 18 feet below the debris basin to about 90 feet at the outlet into Temescal Wash.

Following the latest improvements to this project, the Oak Street Drain channel can now convey the 100-year flood design discharge varying from 4,300 cfs at the debris basin to 8,000 cfs at the Temescal Wash confluence. The features of the improvements included the following:

(a) An entrenched rectangular channel 3-1/2 miles in length from the debris basin spillway to a point 500 feet downstream from the railroad bridge

(b) A leveed channel 1/2 mile in length in the lowland next to the water treatment ponds at the downstream outlet.

Further details about the improvements to the Oak Street Drain project are discussed within the Phase II GDM, Volume 5, Oak Street Drain.

b. Lower Santa Ana River from Prado Dam to the Pacific Ocean.

(1) Prado Dam. Prado Dam is a flood control and water conservation project constructed, operated, and maintained by the U.S. Army Corps of Engineers, Los Angeles District. Construction of the project was completed in April 1941. The project is located at the upper end of the Lower Santa Ana River Canyon, which is a natural constriction controlling 2,255 square miles of the 2,450 square mile Santa Ana River watershed. The dam is located on the Santa Ana River approximately 30.5 miles upstream of the Pacific Ocean. The dam embankment is located in Riverside County, California approximately 2 miles west of the City of Corona. Portions of the reservoir are in both Riverside and San Bernardino Counties. Authorization of the project construction is contained in the Flood Control Act of June 22, 1936 (PL 745-738).

Prado Dam provides flood control and water conservation storage for Orange County, California. It is the downstream reservoir element of the Santa Ana River flood control system. The purpose of the project is to collect runoff from the uncontrolled drainage areas upstream along with releases from other storage facilities. All water conservation releases made are coordinated with the Orange County Water District and are based upon the capacity of their groundwater recharge facilities and agreements with other agencies. When making flood control releases, releases are gradually increased to match inflow up to 5,000 cfs. If flood forecasting indicates that half or more of the reservoir storage may be used during a flood event, flood control releases will be increased up to 9,200 cfs. Inflows exceeding reservoir releases are stored behind the dam. Plans are underway to improve Prado Dam itself by increasing its storage and release capacities. These improvements will enable the dam to take full advantage of the improved channel capacity downstream and will greatly increase the level of flood protection it provides to the communities of Orange County in the Santa Ana River floodplain.

(2) 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 Los Angeles District of the Corps of Engineers. The drainage area controlled by the dam is 19.3 square miles. 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 OCPF&RD'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. 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 Carbon Canyon Creek which flows into Coyote Creek and then into the San Gabriel River. Refer to Exhibit C of this manual and the Carbon Canyon Dam Water Control Manual for additional information.

(3) Other Improvements. Other existing flood control improvements were 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).

(4) Santiago Creek. Santiago Creek is a tributary which joins the Lower Santa Ana River from the east approximately 20 miles downstream of Prado Dam. Facilities on Santiago Creek include Villa Park Dam and Santiago Dam.

i. Villa Park Dam. Villa park Dam is located approximately 2 miles upstream of the Santiago Gravel Pits (i.e., Blue Diamond and Bond Pits) in the foothills of the Santa Ana Mountains. It has a drainage area of 83.4 square-miles including the 63.1 square-mile Santiago Dam drainage. Villa Park Dam was constructed by the Orange County Flood Control District in 1963. The Orange County Public Facilities and Resources Department (OCPF&RD), which assumed the administrative and operation 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 conservation. Dam releases are scheduled according to the water surface elevations of both the Villa Park Dam and the uncontrolled Santiago Reservoir. 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. Refer to the Villa Park Dam Operation manual (an OCPF&RD document) for additional information.

ii. Santiago Dam (Irvine Lake). Santiago Dam, located 3.2 miles upstream from Villa Park Dam, is a water conservation reservoir constructed by the Irvine Company in 1933. Its uncontrolled flood releases flow into Villa Park Dam. It has a drainage area of 63.2 square miles. The total storage capacity is 25,000 acre-feet.

iii. 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 crossing upstream through Hart Park. Within Hark Park, the channel bottom has been paved for use as a parking lot. Rip-rap has been placed along the west bank of the creek upstream from Chapman Avenue for the protection of adjacent homes. Downstream from Prospect Avenue, concrete side-slope-protection was placed to protect homes that were damaged by flooding in 1969. On Handy Creek, a concrete channel runs from just downstream of Orange Park Boulevard to its confluence with Santiago Creek. Large gravel pits (Blue Diamond and Bond Pits), downstream from Villa Park Dam, can 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 into the downstream channel.

4-12 Economic Data. In 2001, an economic study for the Seven Oaks Dam project was performed, where the methodology of the study was based on the current ER 1104-2-100 and ER 110-2-8156 regulations and is detailed throughout the following text. Backup data is on file with the Corps of Engineers, Los Angeles District. The compilation of demographic data was collected for the area within the watershed and the downstream area. The evaluation of flood damages was based on a 100-year project life using an interest rate of 5 7/8%. Flood damages were based on October 2002 price level reflecting damages prevented from the operation of Seven Oaks and Prado Dams.

a. Population. The California Department of Finance shows that the populations of San Bernardino, Riverside and Orange Counties as 1,833,000, 1,705,500, and 2,978,800, respectively in 2003. These figures when compared to the

U.S. Census populations taken in 1990 reflect increases of 29 percent in San Bernardino County, 46 percent in Riverside County and 24 percent in Orange County. Population projections from the Economic Research Department of the Southern California Association of Government (SCAG) indicate continuous increase of the population within the area, with the greater percentages to occur in San Bernardino and Riverside Counties. This is due to the fact that developable lands in Orange County are running out at a rapid rate due to the current level of urbanization. Since San Bernardino and Riverside Counties have extensive undeveloped acreage, accelerated urban growth is projected to extend inland from the now well-developed coastal areas of Orange County.

b. Agriculture. Land use for agriculture within the Santa Ana River floodplain amounts to a total of approximately 7,500 acres. Total agricultural acreage is projected to decrease in the area downstream of Prado Dam due to the intensity of the urbanization of the area. Agricultural crops produced in the area include wheat, barley, cotton, hay strawberries, citrus and variety of vegetables. Dairy farming exists mainly upstream of Prado Dam.

c. Industry. Commercial and Industrial developments in the Santa Ana River floodplain was estimated to cover approximately 17,000 acres and mostly concentrated below Prado Dam in the lower reach of the Santa Ana River. Industry data for the Year 2000 collected by the California Department of Finance indicate that the labor force in San Bernardino and Riverside Counties totaled to approximately 1,549,200 and the labor force in Orange County totaled to approximately 1,496,100. Total labor force for the three counties was widely distributed between manufacturing, trade, government, finance and services. Construction and public utilities, and transportation related industries make up a small portion of this labor force.

d. Damage-Discharge Curves. The damage discharge curves were derived using the expected annual flood damages program (HEC-EAD) models developed for two Corps studies. These studies were performed in 2001 and are documented in the report "The Limited Economic Re-evaluation Report for Santa Ana River Basin, California, dated April 1998, and also in a study performed by the LA District's Corps of Engineers Economics Section using HEC-EAD, entitled, Canyon Lands Economic Analysis. These analyses were recently updated to reflect 2002 and 2099 dollars. The damage discharge curves for 2002 and 2099 dollars are shown on Plates 4-07A and 4-07B, respectively.

Table 4-1. Evaporation within the Santa Ana River Basin

<table>
<tr><th></th><th colspan="4">Monthly Evaporation (inches)</th></tr>
<tr><th>Month</th><th>(712301)
Prado Dam
(40 year mean)</th><th>(747300)
Riverside Citrus
Exp. Sta.
(54 year mean)</th><th colspan="2">(060700)
Beaumont Pumping
Plant
(21 year mean)</th></tr>
<tr><td>Oct</td><td>5.67</td><td>5.24</td><td colspan="2">5.79</td></tr>
<tr><td>Nov</td><td>4.21</td><td>3.62</td><td colspan="2">3.54</td></tr>
<tr><td>Dec</td><td>3.39</td><td>2.68</td><td colspan="2">3.11</td></tr>
<tr><td>Jan</td><td>3.42</td><td>2.83</td><td colspan="2">3.15</td></tr>
<tr><td>Feb</td><td>3.50</td><td>3.23</td><td colspan="2">3.43</td></tr>
<tr><td>Mar</td><td>4.72</td><td>4.57</td><td colspan="2">4.41</td></tr>
<tr><td>Apr</td><td>6.14</td><td>5.79</td><td colspan="2">5.31</td></tr>
<tr><td>May</td><td>7.68</td><td>7.05</td><td colspan="2">6.61</td></tr>
<tr><td>Jun</td><td>8.62</td><td>8.19</td><td colspan="2">8.39</td></tr>
<tr><td>Jul</td><td>10.71</td><td>9.88</td><td colspan="2">10.67</td></tr>
<tr><td>Aug</td><td>10.00</td><td>9.25</td><td colspan="2">10.08</td></tr>
<tr><td>Sep</td><td>7.91</td><td>7.05</td><td colspan="2">8.11</td></tr>
<tr><td colspan="5">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.</td></tr>
<tr><th colspan="5">Location of Evaporation Stations</th></tr>
<tr><td>CA DWR No.</td><td>Latitude</td><td>Longitude</td><td>Elev (ft)</td><td>Period of Record</td></tr>
<tr><td>712301</td><td>33°53'30"</td><td>117°38'03"</td><td>565</td><td>7/30-6/69</td></tr>
<tr><td>747300</td><td>33°58'00"</td><td>117°20'05"</td><td>1,015</td><td>1/25-6/78</td></tr>
<tr><td>060700</td><td>33°58'50"</td><td>117°57'35"</td><td>3,045</td><td>1/55-9/75</td></tr>
</table>