Section 4 Regional Storage at Chain of Lakes

4.1 Background

As the Valley has been transformed from rural to suburban land uses, the potential for flood runoff has steadily increased. Growth has encroached on floodplain areas of the Valley, several broad arroyos have been converted to trapezoidal channels, and construction of new roads and buildings has increased the total impervious surface area in the watershed. It is predicted that these changes will result in approximately a 50 percent increase in peak runoff from the 1960's to the time of General Plan build-out for the cities of Pleasanton, Dublin, and Livermore (varies by city – up to 2034; WYA 2002b).

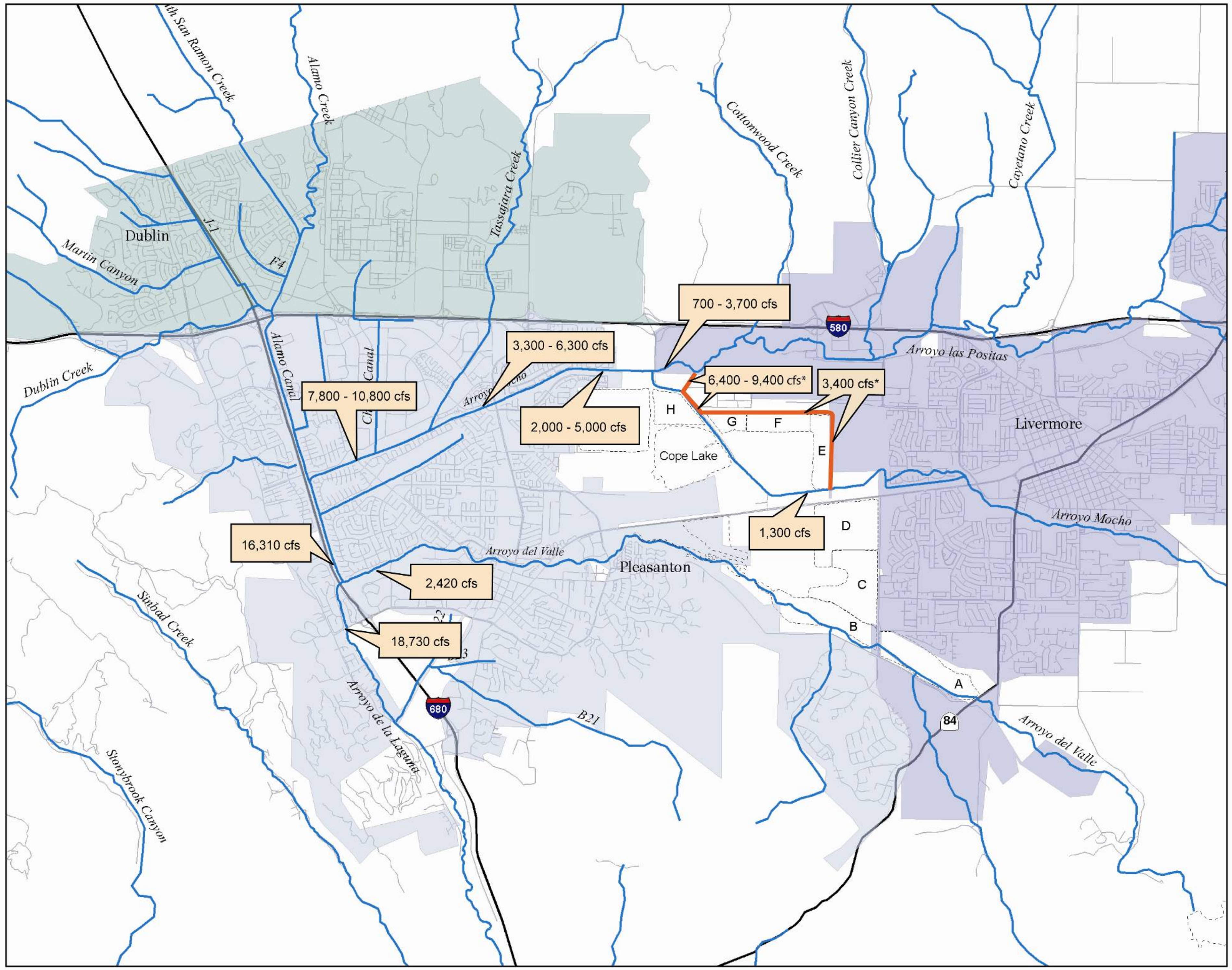
As discussed in Section 3, the Chain of Lakes and other areas of the Valley are subject to flooding in major storm events. The largest storm of record in the watershed occurred in December 1955 during which the peak flow in ADLL downstream of the confluence with Arroyo del Valle was recorded to be 18,200 cfs (USACE 1985). In some localized areas in the Valley there is a potential flooding problem, and relatively small events, such as 10- to 15-year events, have caused significant flooding in these areas. For example, the 10- to 15-year event in 1998 caused flood waters to overtop the Arroyo Mocho channel along Stanley Boulevard and resulted in flooding around the Chain of Lakes area (along Stanley Boulevard near the El Charro Road crossing).

SMMP flood protection recommendations were developed based on numerous studies conducted in recent years. An overview of these studies including a summary of their findings is provided in Appendix B. These studies were reviewed to determine flows in the watershed under three different scenarios: the "No Project Scenario", the "Green Book Scenario", and the "SMMP Scenario". These can be described as follows:

- No Project Scenario – In this case, flows were estimated assuming a 100-year flood event under future build-out development conditions. In addition, it was assumed that flood control channels would remain unchanged and therefore the channels would maintain their current conveyance capacities.
- Green Book Scenario – Under this scenario, flood control channels (with the exception of ADLL below the Bernal Avenue Bridge crossing) were assumed to be improved to Green Book standards. The channel's conveyance capacity would therefore be improved to convey future 100-year flows under build-out development conditions. ADLL, from Bernal Avenue to its confluence with Alameda Creek was assumed to retain its current channel capacity. As a result, 100-year flows would be fully conveyed through the channels up to the Bernal Avenue Bridge crossing.
- SMMP Scenario – An integral recommendation of the SMMP is to implement regional detention storage of future 100-year flows at the Chain of Lakes. This recommendation is discussed in detail in ensuing sections. Under this scenario, channels would be improved to SMMP recommendations, but not Green Book standards. Rather than increasing capacity of ADLL, flow in ADLL would be limited by diverting future build-out peak 100-year flows from Arroyo las Positas and Arroyo Mocho to detention storage facilities in the Chain of Lakes area.

Flows estimated under the SMMP Scenario are shown in Figure 4-1. A detailed discussion and comparison of flows expected to occur under the No Project, Green Book, and SMMP scenarios is provided in Appendix F (Flow Scenarios).

Figure 4-1: Peak Flows Under the SMMP Scenario



*These flows will be diverted to detention storage during the future build-out peak 100-year flow event.

4.1.1 Flood Protection Challenges

As shown on Figure 3-5, the current FEMA 100-Year Floodplain Map, the potential exists for significant flooding to occur in the Valley as a result of the 100-year storm event. The area predicted to be most affected by flooding is the commercial areas and residences within the Chain of Lakes region. Dealing with flooding in this area is truly a regional problem given that stormwater runoff is regional in origin, and considering the need to manage floodplains within the Valley, not shifting them to other areas.

The development of a regional flood solution is complex; and therefore, the previous flood control studies have either not recommended a clear solution, or have recommended a solution that would not be acceptable to regulatory agencies and the general public. The approach being taken in this SMMP is to develop a solution to regional flood protection that maximizes benefits in several resource areas, as well as minimizes costs; to enhance the potential for funding partnerships, and to enhance the potential for regulatory and public support.

There are numerous institutional and financial challenges to developing and implementing a regional flood protection solution. The three major physical and environmental challenges are the following:

- Challenge No. 1 – Major arroyos are under capacity
- Challenge No. 2 – Sediment accumulation further restricts arroyo capacity
- Challenge No. 3 – Expanding existing channels is not viable in some locations

Challenge No. 1

The hydrologic and hydraulic modeling conducted by S&W and WYA, indicates that Arroyo las Positas, Arroyo Mocho, Alamo Canal, and ADLL have reaches where bank overtopping would occur during the 100-year storm event under future build-out conditions. Arroyo del Valle does not have capacity issues because flows within Arroyo del Valle are controlled releases by the dam. A comparison of existing channel capacities with the predicted future peak flows is shown in Figure 4-1, and in Table 4-1 below. The future peak flows shown are the expected flows without implementation of regional storage and assuming that improvements to the channels have been made, allowing flows to pass.

The critical locations, as shown on Figure 4-1, are the following:

Table 4-1: Stream, Location, and Predicted Flows

Stream	Location	Flow (cfs) Current Capacity[a]	Flow (cfs) Future Peak[c]
Arroyo las Positas	Las Positas Golf Course	1,800	10,100
Arroyo Mocho	Stanley Boulevard	900	4,700
Alamo Canal	Upstream of Arroyo Mocho	8,500	9,000
Arroyo de la Laguna	Downstream of Arroyo Mocho	19,600	23,400
Arroyo de la Laguna	Downstream of Arroyo del Valle	18,730[b]	25,500

a WYA 2002b

b Based on hydraulic analyses conducted by RMC and summarized in an October 2003 TM (attached to Appendix D), the ADLL reach downstream of the Bernal Avenue Bridge has a channel capacity greater than 18,730 cfs. Based on hydraulic analyses conducted by WYA (see Alternative 2 discussion in WYA 2001b), the capacity of this reach is less than 22,180 cfs. As a result, the actual channel capacity at this reach falls somewhere between 18,730 and 22,180 cfs.

c S&W 2000. Represents flows expected if flood control channels are improved to Green Book standards (e.g. channels are improved to fully convey the estimated 100-year peak design flows under future build-out conditions).

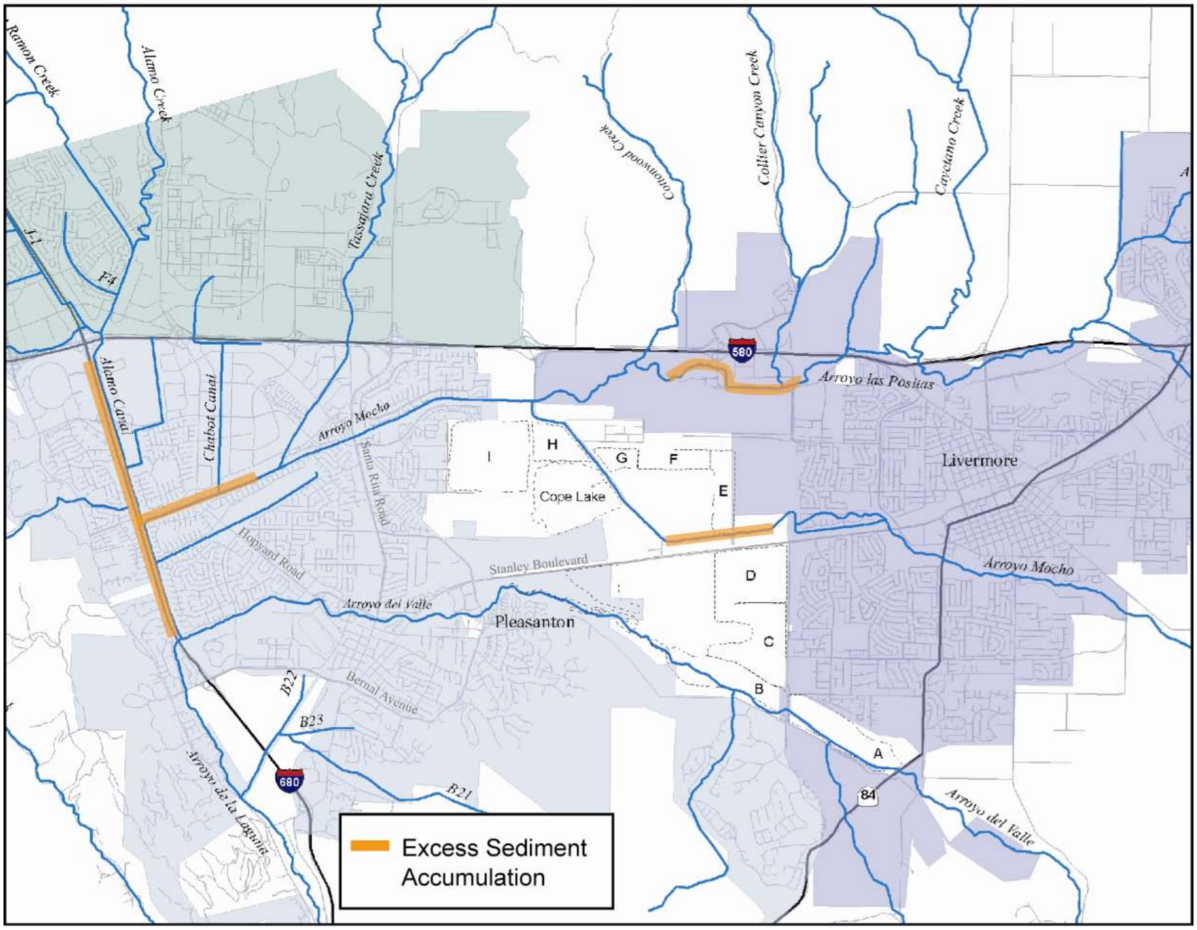
Recent improvements to the Bernal Bridge and erosion downstream of the bridge in ADLL have increased the capacity of the channel downstream of Arroyo del Valle from 17,000 cfs to greater than 18,730 cfs. As indicated, this capacity is still less than the 25,500 cfs projected for the 100-year storm event at build-out.

Challenge No. 2

The second physical challenge to finding a regional flood protection solution is the accumulation of sediment in major arroyos, including long reaches of Arroyo las Positas, Arroyo Mocho, Alamo Canal, and ADLL, where capacities are already insufficient, as described above. The capacities presented on Figure 4-1 are based on the original design dimensions of the channels without sediment. The total sediment load in major streams and arroyos is currently estimated to be approximately 350,000 cubic yards (WYA 2001b). Figure 4-2 presents the stream locations where sediment accumulation is of particular concern as it relates to the regional flood control problem. In these areas, recommendations include the completion of specific local hydraulic analyses to determine the capacity of existing channels with sediment, and whether sediment removal is still needed based on the regional storage approach which would in effect reduce peak flows from 18,200 cfs to 7,800 cfs.

Other areas of sediment aggradation and degradation are addressed on a reach-by-reach basis in Section 5 of this SMMP. The removal of sediment in streams will be challenging for several reasons, including the potential for disturbing established wetland habitat.

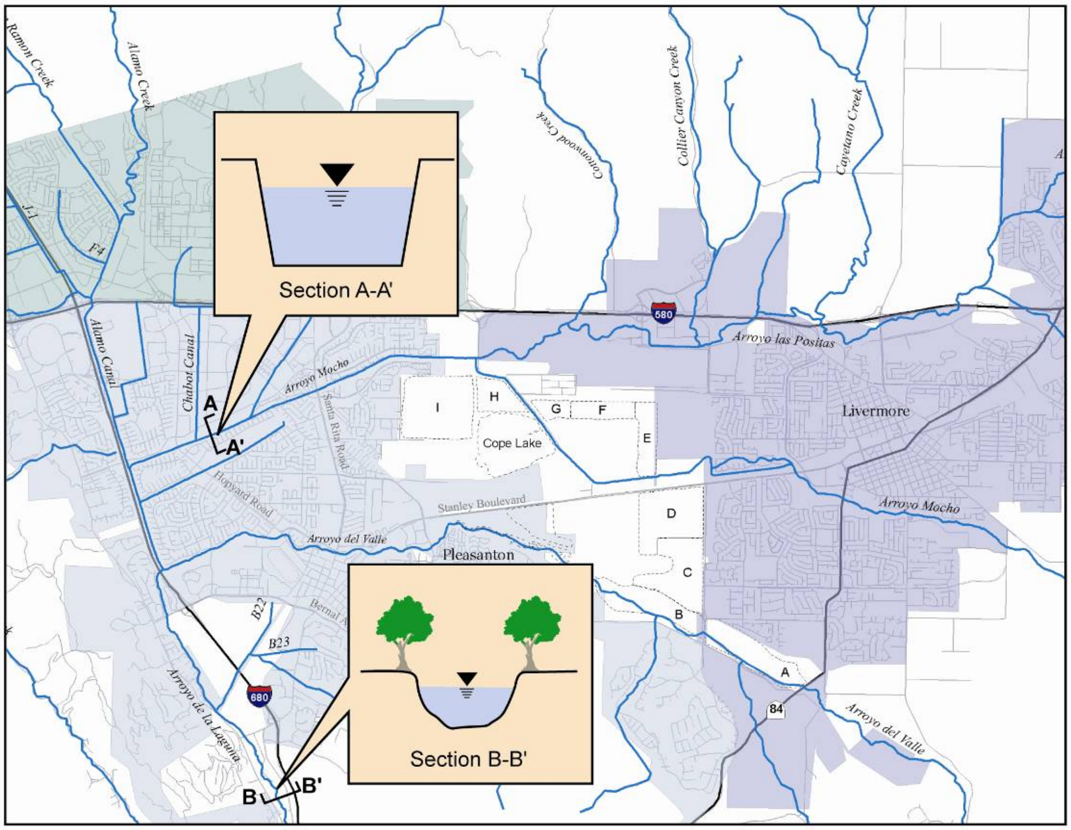
Figure 4-2: Challenge No. 2 – Sediment Accumulation



Challenge No. 3.

The third major physical challenge to solving Zone 7's regional flooding problem is the fact that expansion of existing channels is not a viable option in some locations (see Figure 4-3). Construction of trapezoidal channels in the natural reaches of ADLL for example, would potentially cause significant environmental impacts, including the removal of oak trees and other native vegetative species, and impacts to residential properties and open space areas.

Figure 4-3: Challenge No. 3 – Expanding Existing Channels Not Viable in Some Locations

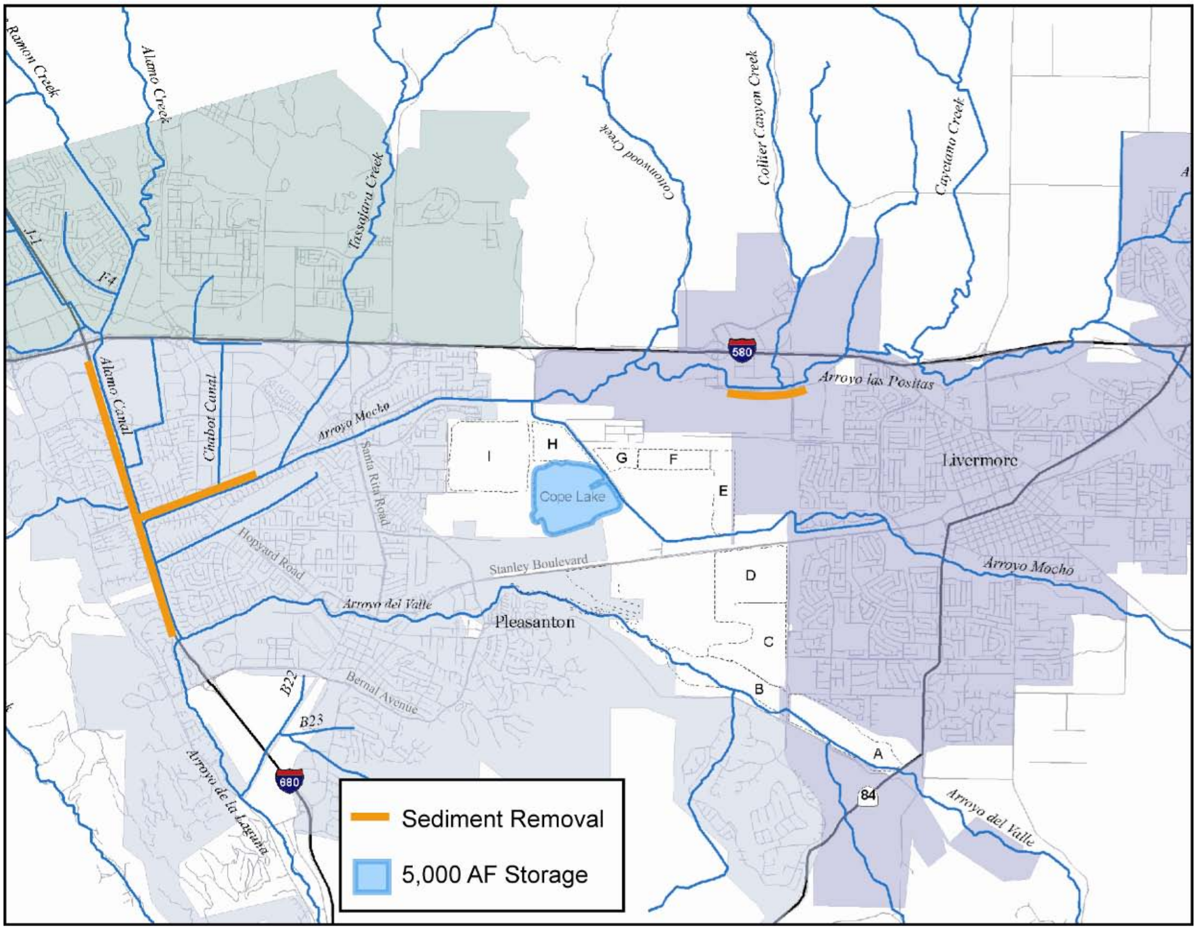


4.1.2 Regional Approach to Flood Protection

Based upon a detailed review of past flood control studies, numerous meetings and workshops with potentially affected stakeholders, and an assessment of the three challenges presented above, the regional approach presented on Figure 4-4 was developed. As indicated, the regional approach to flood protection includes two major features:

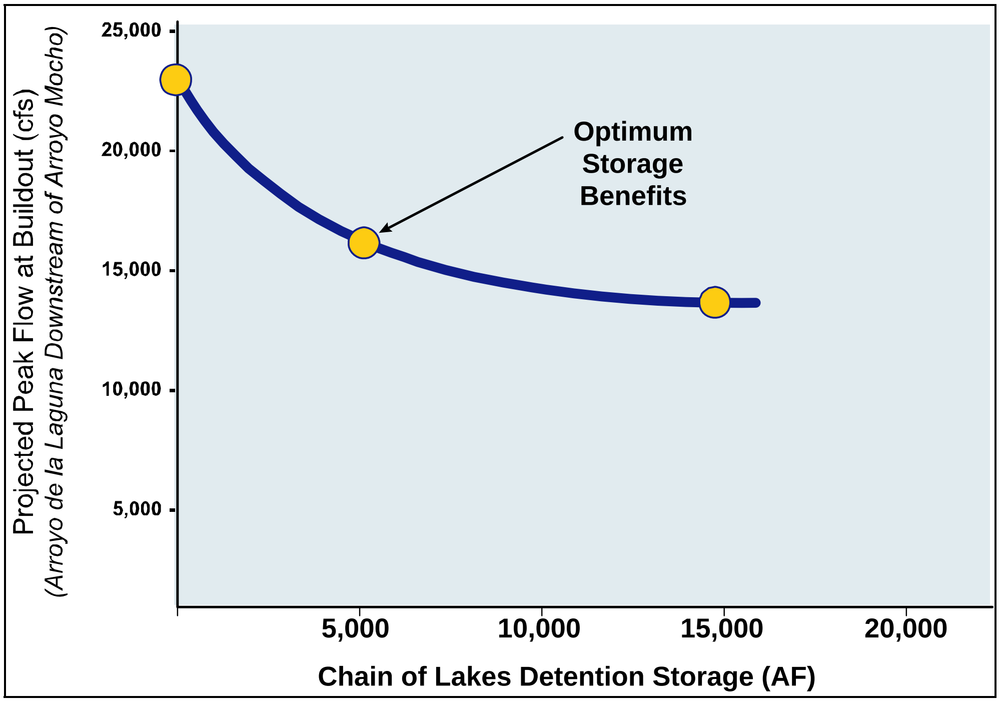
- Diversion of peak flows from Arroyo las Positas and Arroyo Mocho to Cope Lake and other lakes in the Chain of Lakes for detention storage
- Removal of excess sediment, which has accumulated along critical reaches of Arroyo las Positas, Arroyo Mocho, Alamo Canal, and ADLL

Figure 4-4: Regional Approach – Detention Storage and Sediment Removal



The volume of detention storage required to reduce future peak flows to acceptable levels was determined by an analysis of the detention storage volume versus peak flows predicted downstream in ADLL. Information from the 1985 Corps of Engineers Study (USACE 1985) and the 2001 WYA TM (WYA 2001b) were analyzed to develop the optimal storage volume, as shown in Figure 4-5. As shown, this figure compares predicted peak flow at build-out (for the 100 year storm event) in ADLL (downstream of Arroyo Mocho) versus the volume of detention storage provided in the Chain of Lakes. Based upon the available information, it appears that the optimum volume of storage will be about 5,000 AF. If this volume is provided in the Chain of Lakes area, and if diversions from Arroyo las Positas and Arroyo Mocho into Cope Lake occur at the right time (prior to the peak of the hydrograph for the future 100-year storm event), the predicted peak flow in ADLL below the confluence with Arroyo Mocho will be reduced from 23,400 cfs to approximately 16,300 cfs. This represents more than a 30 percent reduction in the future 100-year peak flow at this location.

Figure 4-5: Optimal Storage Volume



4.1.3 SMMP Assumptions

In general, the SMMP projects developed for flood protection and drainage purposes are based on the following hydrologic and hydraulic assumptions:

- **Peak Flows.** Projected peak flows in all channels with drainage areas greater than or equal to one square mile are based upon the 100-year storm event at build-out conditions using the 1997 S&W model (S&W 1997). Projected peak flows in channels with drainage areas less than one square mile are based upon the 15-year storm event at build-out conditions using the same model.
- **Channel Velocity.** The maximum allowable channel velocity for earthen channels has been assumed to be six feet per second.
- **Channel Freeboard.** The minimum allowable freeboard for excavated channels has been assumed to be one foot, and two feet within 100 feet upstream of channel crossing structures. The minimum allowable freeboard for channels with levees has been assumed to be three feet, and four and one-half feet with 100 feet upstream of channel crossing structures.
- **Floodplains.** The 100-year floodplain boundaries are assumed to be those mapped by FEMA in 1997, with specific LOMRs captured by local analyses conducted since then by the cities of Dublin, Livermore, and Pleasanton.

4.1.4 Predicted Results of Regional Approach

As shown on Figure 4-6 and Figure 4-7, the current FEMA 100-year floodplain expands across the Chain of Lakes area. Areas along Stanley Blvd., Kitty Hawk Road, and Airway Blvd. which are in the current FEMA 100-year floodplain are expected to see increased flooding (approximately 10%) under buildout conditions. With implementation of the SMMP regional storage approach, the floodplain in this area would be eliminated by diverting and containing floodwaters within the Chain of Lakes Detention System.

Figure 4-6: Anticipated Floodplain within the Chain of Lakes Area without Regional Storage

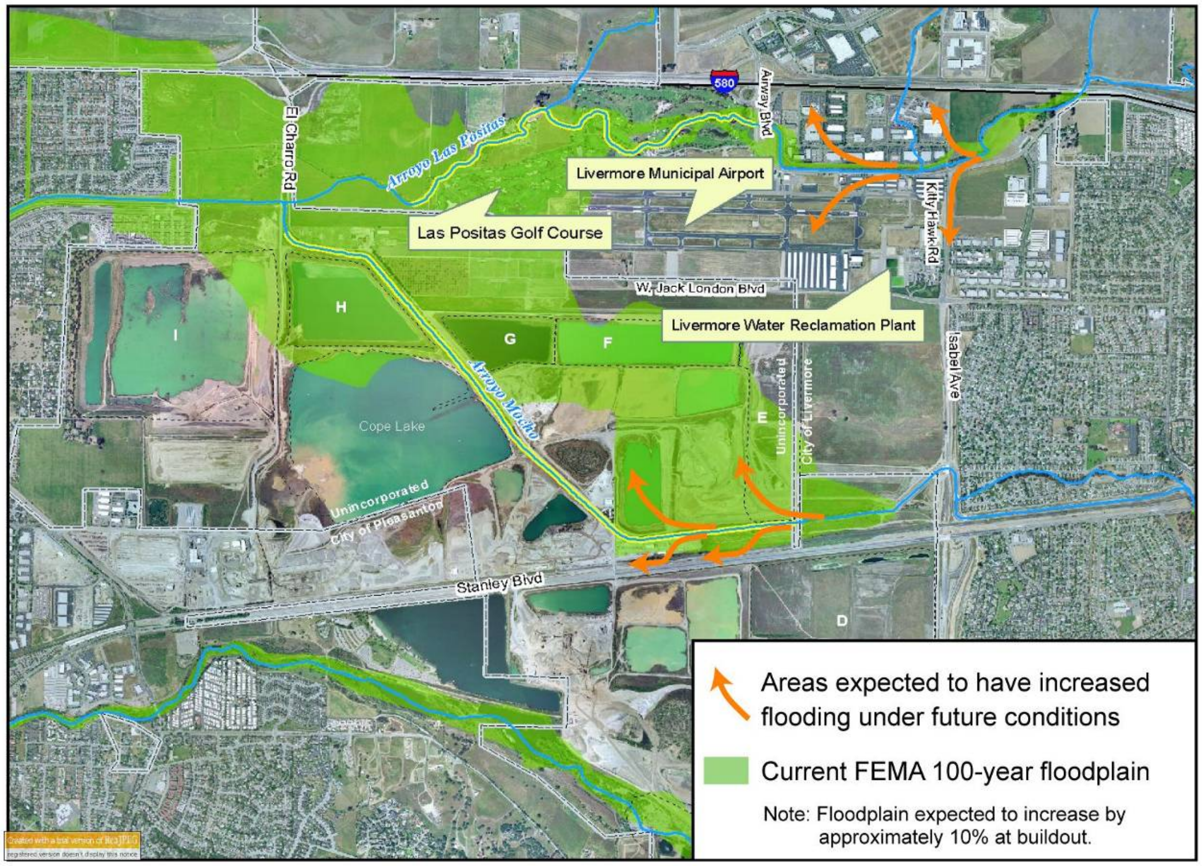
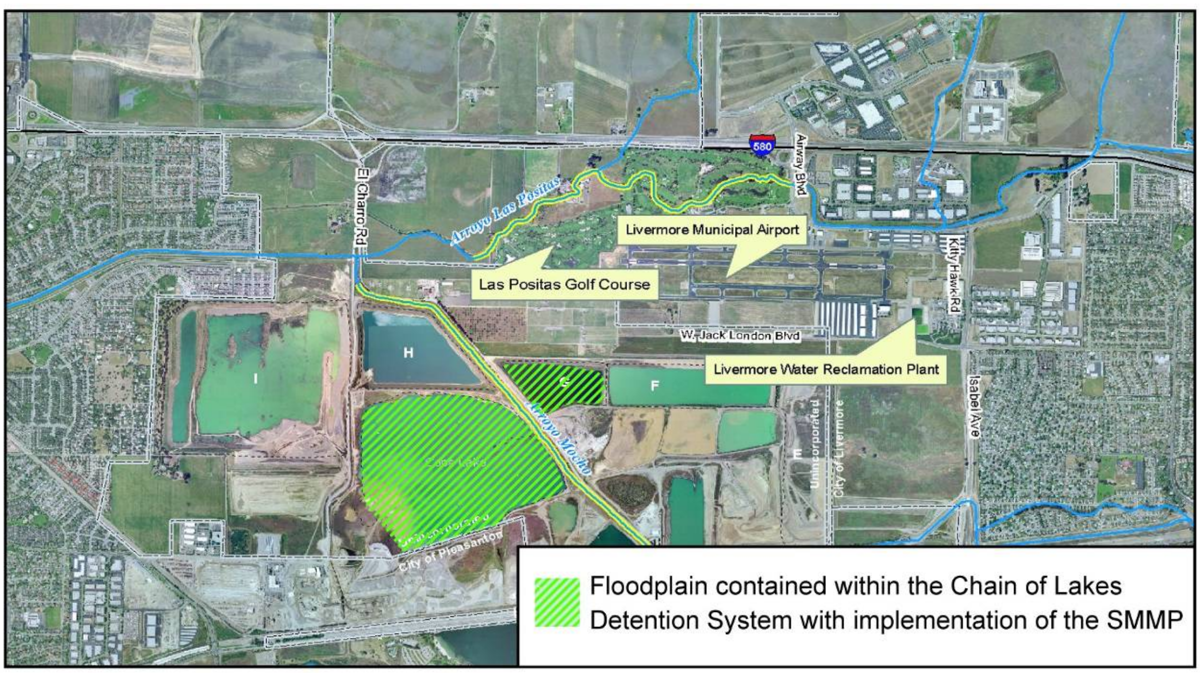


Figure 4-7: Anticipated Floodplain within the Chain of Lakes Area with Regional Storage



The detention of peak flows from Arroyo las Positas and Arroyo Mocho in the Chain of Lakes and the removal of sediment from critical reaches of Arroyo las Positas, Arroyo Mocho, Alamo Canal, and ADLL will significantly reduce the predicted peak flows downstream of the Chain of Lakes and will significantly reduce the potential for flooding. Figure 4-1 presents the predicted reduction of peak flows resulting from approximately 5,000 AF of detention storage in the Chain of Lakes area. A detailed hydraulic analysis was conducted by WYA in 2001 (WYA 2001b). A detailed discussion and comparison of flows expected to occur under different flow scenarios is provided in Appendix F (Flow Scenarios).

Figure 4-8 and Figure 4-9 compare the potential for bank overtopping without and with implementation of the regional approach, respectively. These predictions of bank overtopping were taken from hydraulic profiles developed as part of an overall hydraulic modeling effort (WYA 2001b). A detailed discussion of the hydraulic profiles expected with storage follows. For additional explanation of the estimated flooding in ADLL without, storage refer to TM No. 5 of WYA Draft Flood Control Master Plan (WYA 2001b) included in Appendix B.

Figure 4-8: Potential for Bank Overtopping without Implementation of the Regional Detention Storage Solution (WYA 2001b)

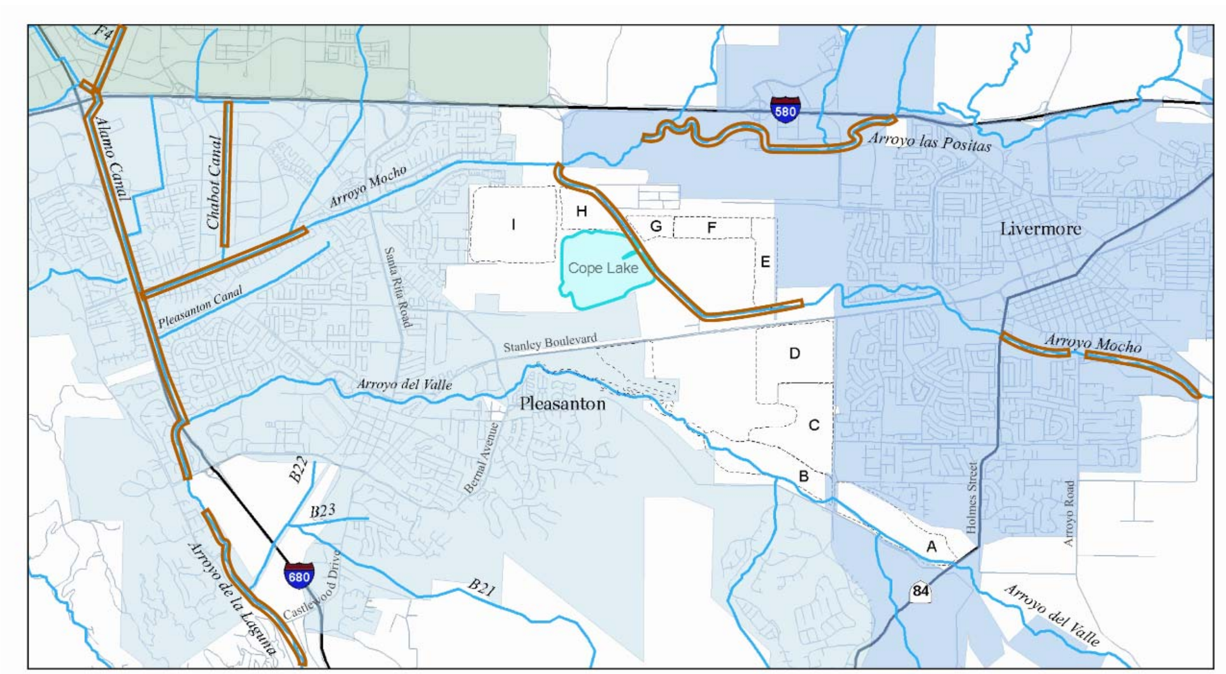
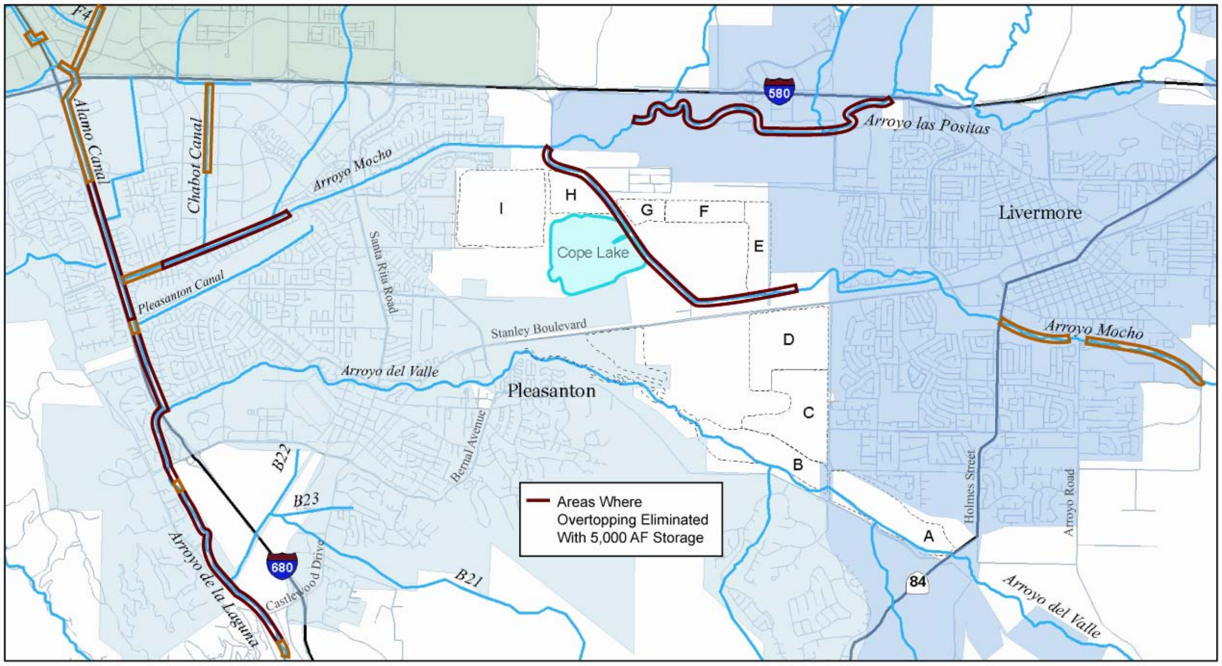


Figure 4-9: Potential for Bank Overtopping Resulting from Implementation of the Regional Detention Storage Solution (WYA 2001b)

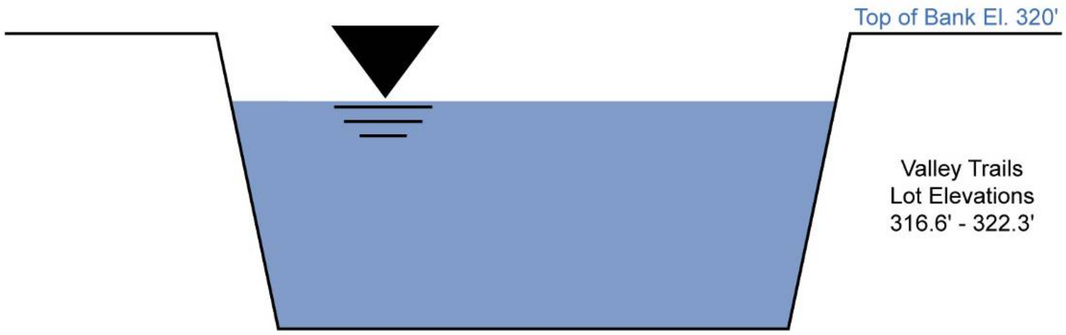


The hydraulic profile for ADLL immediately upstream of the Bernal Avenue Bridge is of particular interest from a flood protection standpoint. A portion of the Valley Trails residential area to the east of ADLL, just downstream from Arroyo Mocho, was recently removed from the current FEMA 100-year floodplain as a result of a LOMR submitted by the City of Pleasanton and approved in August 2005, as discussed in Section 1.7.1. A conceptual cross-section of the channel immediately downstream of the confluence with Arroyo Mocho is shown on Figure 4-10. As previously discussed, 5,000 AF of detention storage reduces the future peak flow to approximately 16,300 cfs at this location. This flow rate results in a water surface elevation of about 319 ft, which is about one foot below the top of bank. Since many of the lot elevations in Valley Trails are less than this elevation, even considering the recent LOMR, additional local flood control measures will likely be required in Valley Trails to handle the 100-year storm event projected for build-out land use conditions.

Figure 4-10: Channel Cross Section at ADLL Immediately Upstream of the Bernal Avenue Bridge Crossing

PREDICTED RESULTS OF REGIONAL APPROACH
(Arroyo de la Laguna Downstream of Arroyo Mocho)

Regional Storage (AF)	Future Peak (cfs)	Water Surface Elevation (ft)
	23,400	324.7
5,000	16,290	319.1



The water surface profile for ADLL and Arroyo Mocho (to El Charro Road) estimated as a result of regional detention is shown in Figure 4-11 and Figure 4-12, respectively. It is important to note that the hydraulic analysis conducted to develop these figures assumed clean channels free of sediment deposition. The water surface profile for ADLL, as shown in Figure 4-11, also incorporates channel geometries consistent with the addition of the proposed Bernal Avenue Bridge and recent erosion of the ADLL channel south of the bridge.

Under the regional detention storage solution, tributaries to ADLL and Arroyo Mocho are also affected due to the hydraulic profile drops along the two streams. The profile along Alamo Canal, as shown in Figure 4-13 indicates no flooding (WYA 2001b).

A description of the proposed improvements at the Chain of Lakes to implement the detention storage solution follows.

Figure 4-11: ADLL Hydraulic Profile Expected under the Regional Detention Storage Solution (RMC 2004a)

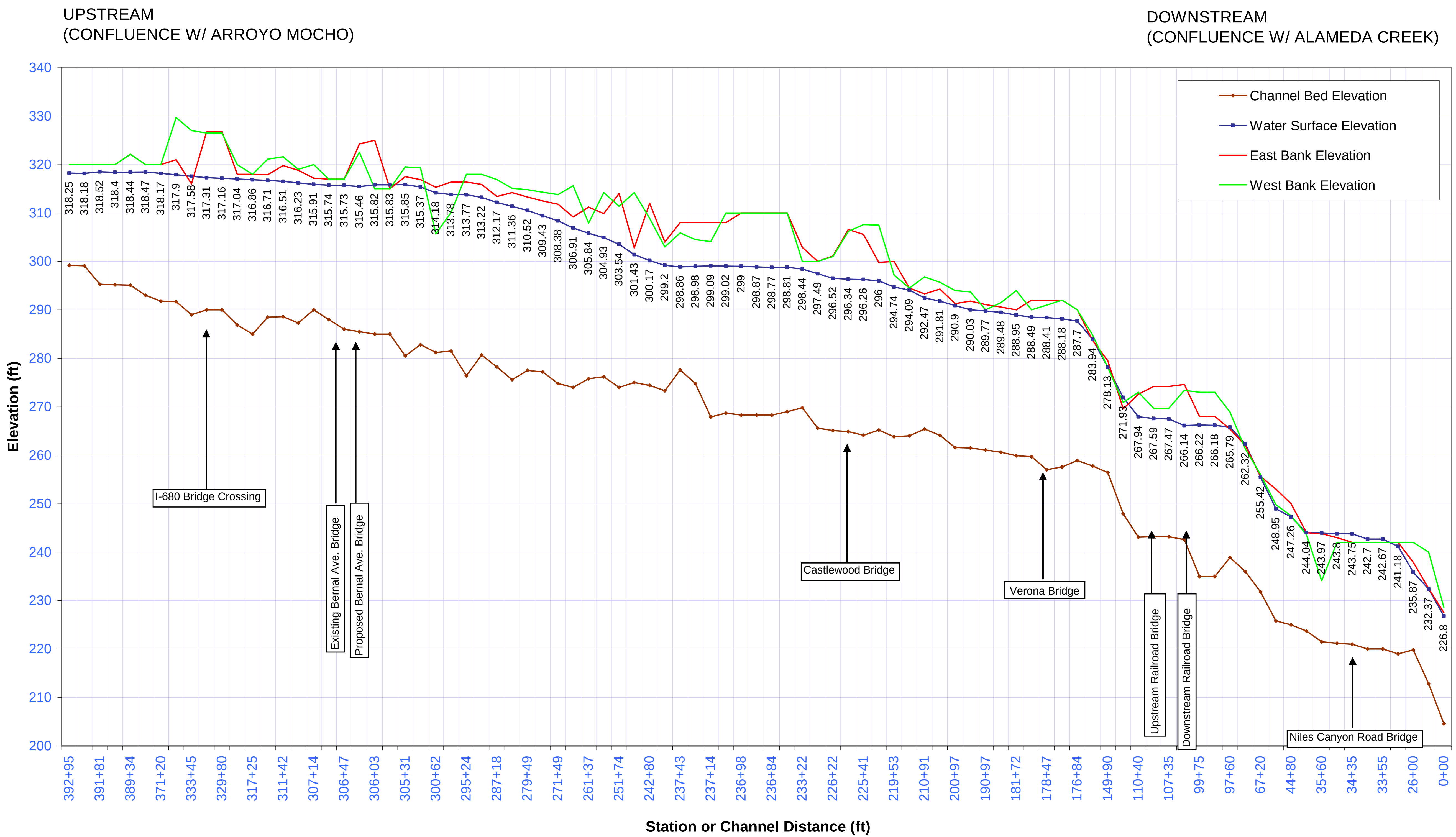


Figure 4-12: Arroyo Mocho Hydraulic Profile Expected Under the Regional Detention Storage Solution (WYA 2001b)

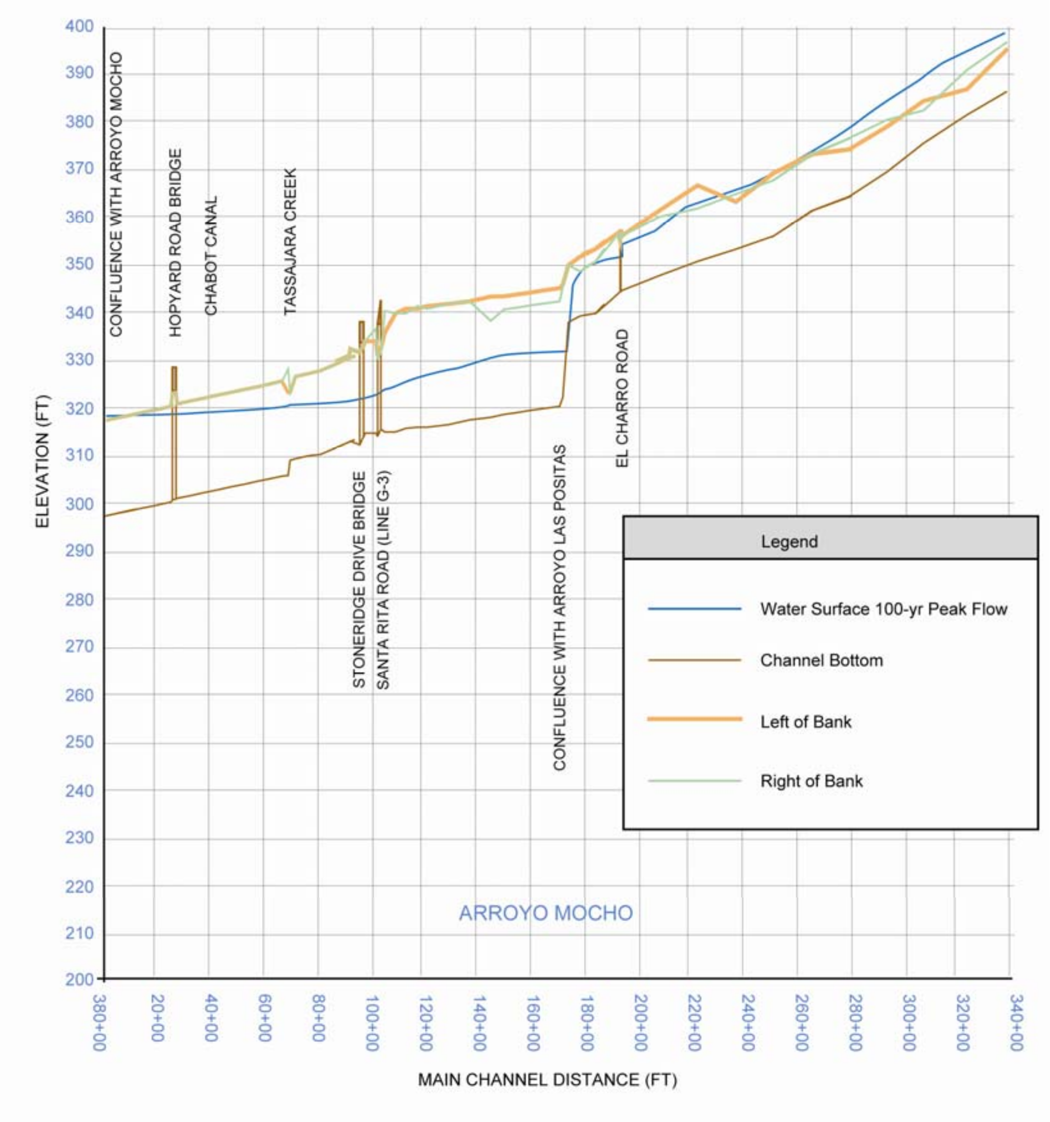
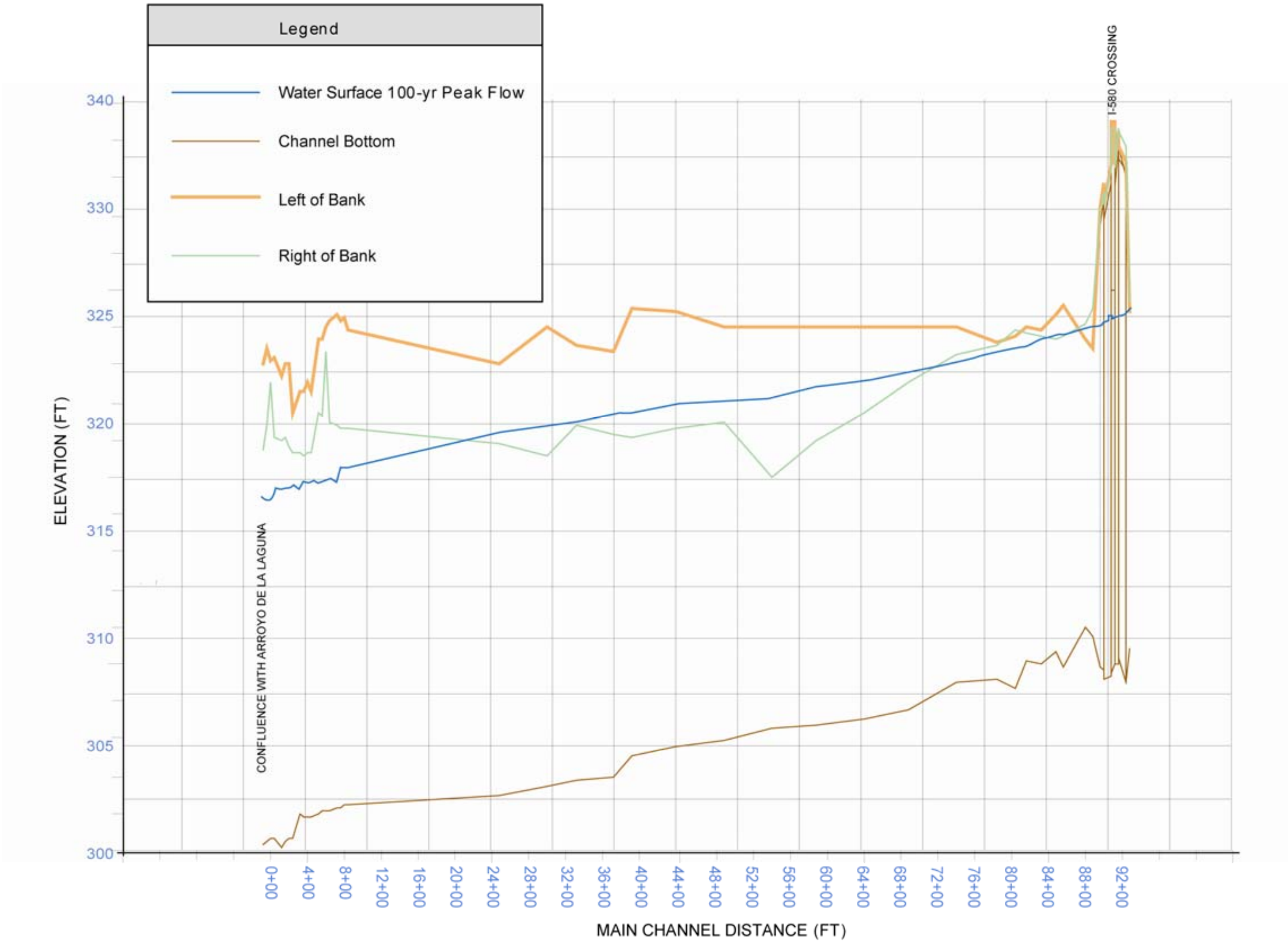
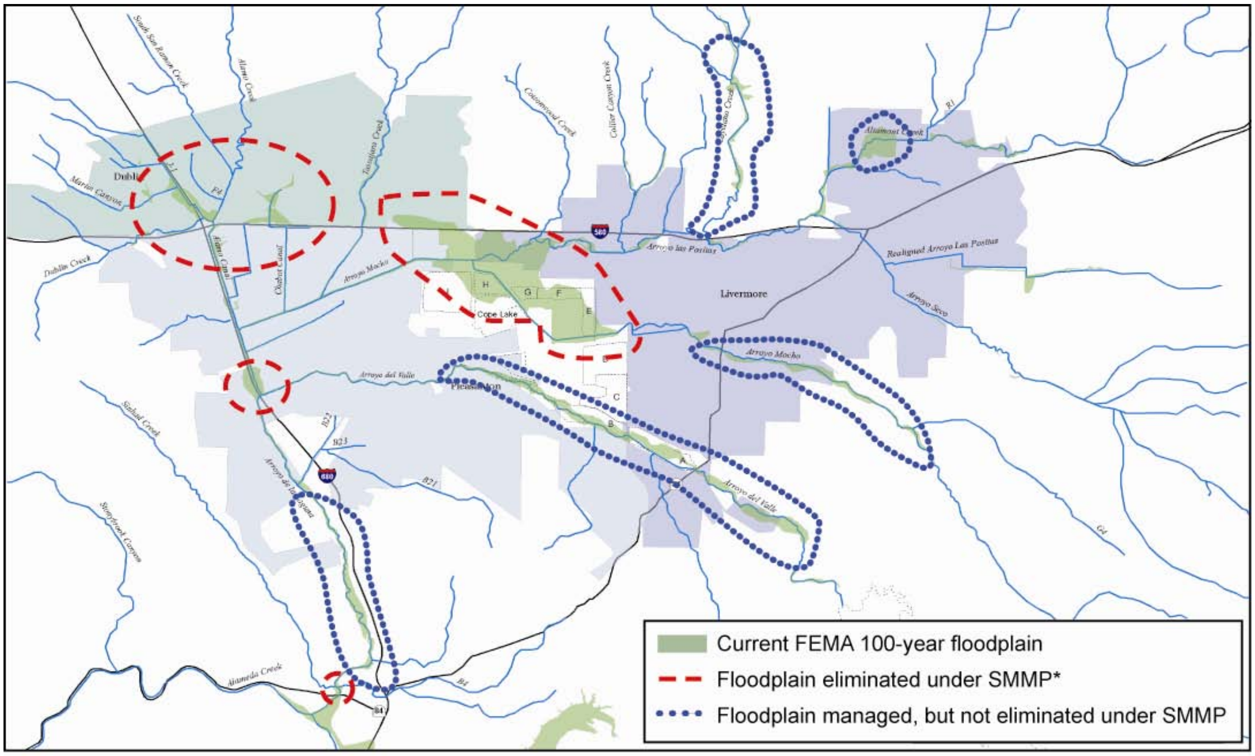


Figure 4-13: Alamo Canal Hydraulic Profile Expected under the Regional Detention Storage Solution (WYA 2001b)



The floodplain areas targeted under the SMMP are shown in Figure 4-14. As described above, and indicated on this Figure, the Chain of Lakes floodplain in the Chain of Lakes area would be eliminated through implementation of the regional detention approach in the SMMP. The SMMP, through both the regional project and other project recommendations, would also eliminate or manage other 100-year floodplain areas in the Valley.

Figure 4-14: Floodplain Areas Targeted by Proposed SMMP Flood Protection Projects



*The Del Prado Neighborhood in Pleasanton will be removed from the FEMA 100-year floodplain due to recently filed LOMAs not yet reflected in the FEMA floodplain map (City of Pleasanton, February 2006).

4.2 Description of Regional Storage in the Chain of Lakes

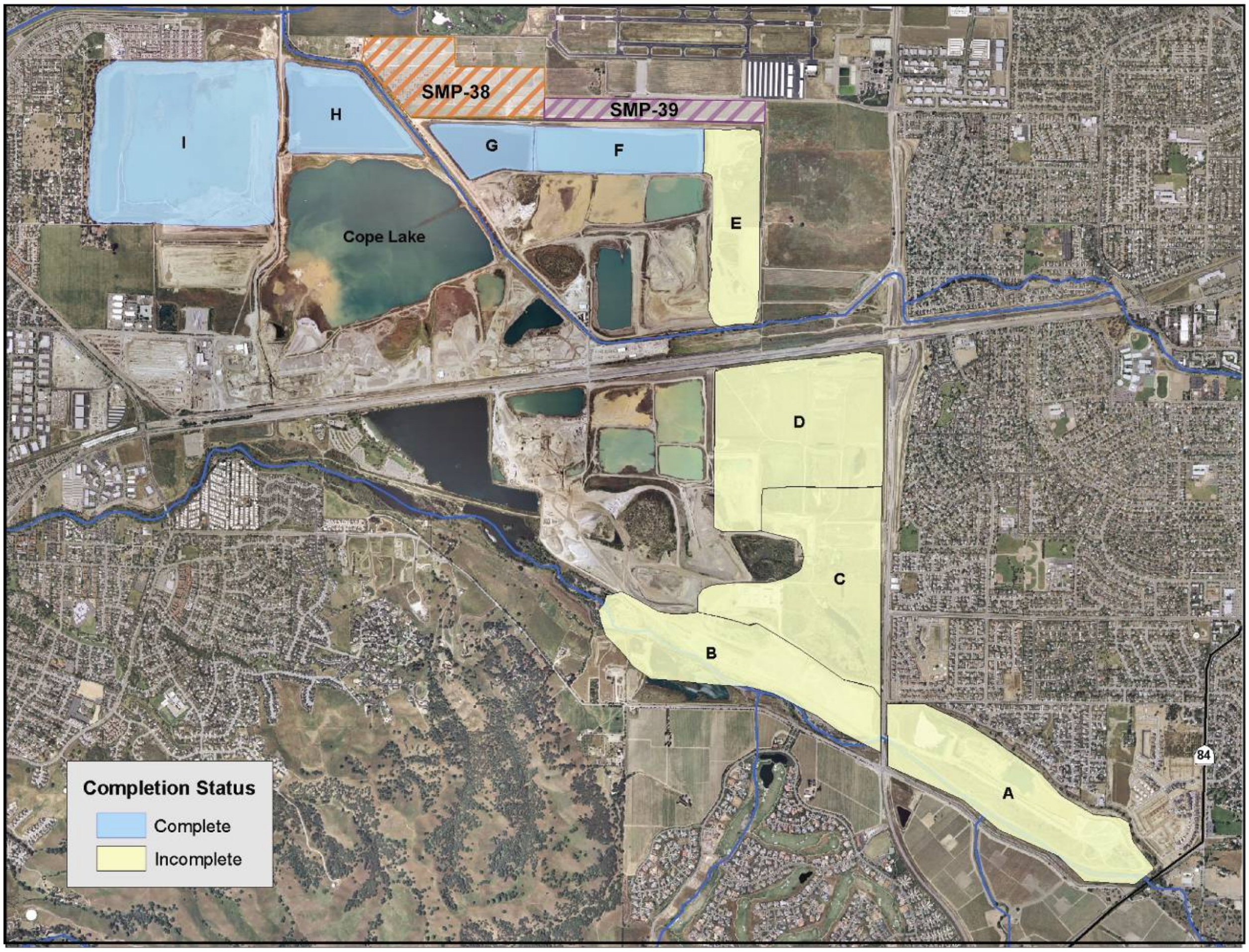
4.2.1 Chain of Lakes Characteristics

The storage lakes within the Chain of Lakes area are created by the mining of natural gravel deposits in the center of the Valley, south of I-580. The Chain of Lakes span Reaches 6 and 7; detention storage in this area is further discussed as part of the project description presentation of Section 5 in this Report for Reach 5 (Arroyo las Positas - Project R.5-3), and Reach 6 (Project R.6-2).

Completion Status and Storage Locations

Cope Lake and Lakes F, G, H and I have been completed as shown on Figure 4-15. Other lakes are scheduled to be mined and available for use by Zone 7 in the next 10 to 30 years.

Figure 4-15: Chain of Lakes Completion Status



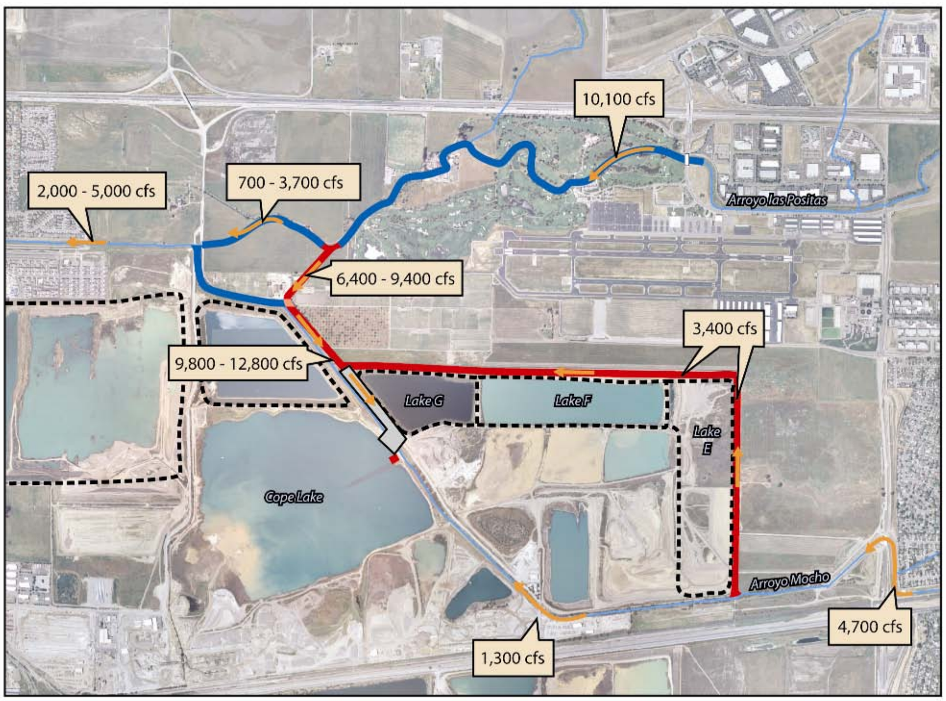
Zone 7 and other local agencies have identified multiple potential uses for the Chain of Lakes. Lakes A through I are important to Zone 7, from a potable water supply perspective. Lakes A through H will eventually provide surface water storage of approximately 100,000 AF (Zone 7, 2005). Lake I will provide recharge of Zone 7's groundwater basin (estimated to begin in 2007 to 2008) through its west face and is expected to continue providing that function in the future. Zone 7, DSRSD and the City of Livermore have expressed an interest in utilizing some portion of the Chain of Lakes area (not connected to potable supplies in Lakes A through I) for storage of recycled water. This approach could potentially increase the yield of recycled water projects by the volume stored in winter.

The potential locations for storage of stormwater in the Chain of Lakes are Cope Lake, and Lakes G, F, and E. It appears that Cope Lake would be the best site to handle baseline capacity requirements for stormwater storage. Cope Lake is not planned to be used for potable supply, it is adjacent to Arroyo Mocho, and it has a silt bottom, which inhibits infiltration of storm water into the groundwater basin. Lakes G, F, and E could be operated as secondary storage sites (in that order) after Cope Lake is filled. Two proposed mining sites north of Lakes G and F, SMP 38 and SMP 39, could potentially be utilized for floodplain purposes, thus providing some detention volume. A detailed operations plan will be required to define exactly how and when stormwater is diverted to detention storage.

Projected Flows

The possible routing of peak flows from Arroyo las Positas and Arroyo Mocho are shown on Figure 4-16. Hydrologic analyses conducted (WYA 2001) prescribed diversions of 8,700 cfs and 3,500 cfs from Arroyo las Positas and Arroyo Mocho, respectively. With channel improvements, the proposed diversion from Arroyo las Positas ranges from 6,400 to 9,400 cfs. These diversions during the future 100-year storm event will leave 700 to 3,700 cfs in Arroyo las Positas and 1,300 cfs in Arroyo Mocho. The expected flow in Arroyo Mocho (downstream of the confluence with Arroyo las Positas) when storage is triggered ranges from 2,000 to 5,000 cfs. As shown on Figure 4-1, the existing channel capacity of Arroyo Mocho is 900 cfs. The proposed storage scenario requires that the capacity in Arroyo Mocho be increased from 900 cfs to 1,300 cfs.

Figure 4-16: Peak Flows in the Chain of Lakes during the 100-Year Event



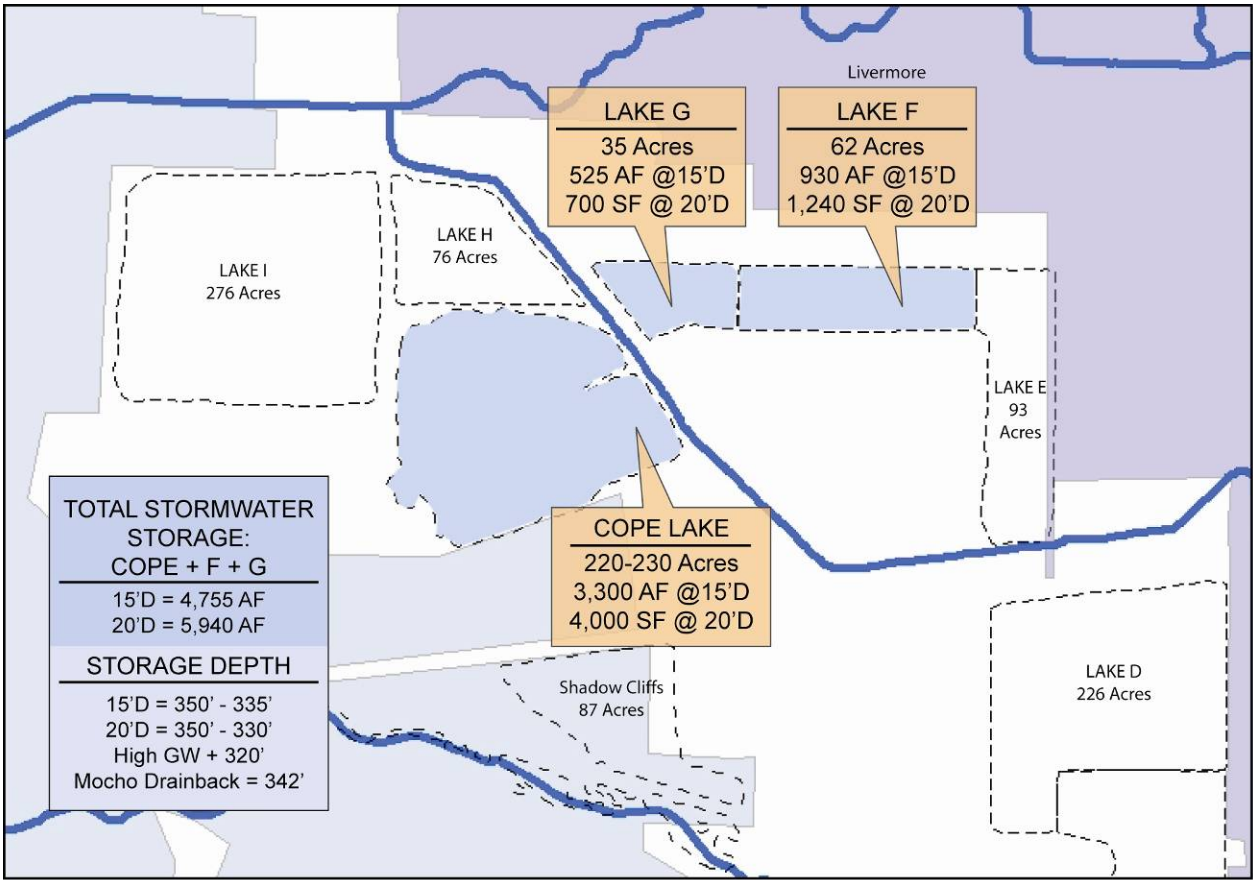
Volume of Storage

The volume of Cope Lake is estimated to be 3,300 AF for a 15-foot depth, and 4,000 AF for a 20-foot depth. A 20-foot depth is the maximum depth possible with approximately 20 feet of freeboard. Therefore, even if the entire volume of Cope Lake is devoted to storm water storage, it appears that the target of 5,000 AF will not be achieved. If Lakes G and F received storm water during major events, the total volume available will be approximately 5,940 AF if a 20-ft depth is assumed. The area and storage volume of Cope Lake, Lake G and F are shown on Figure 4-17 and summarized below in Table 4-2.

Table 4-2: Storage Lakes and Associated Volumes

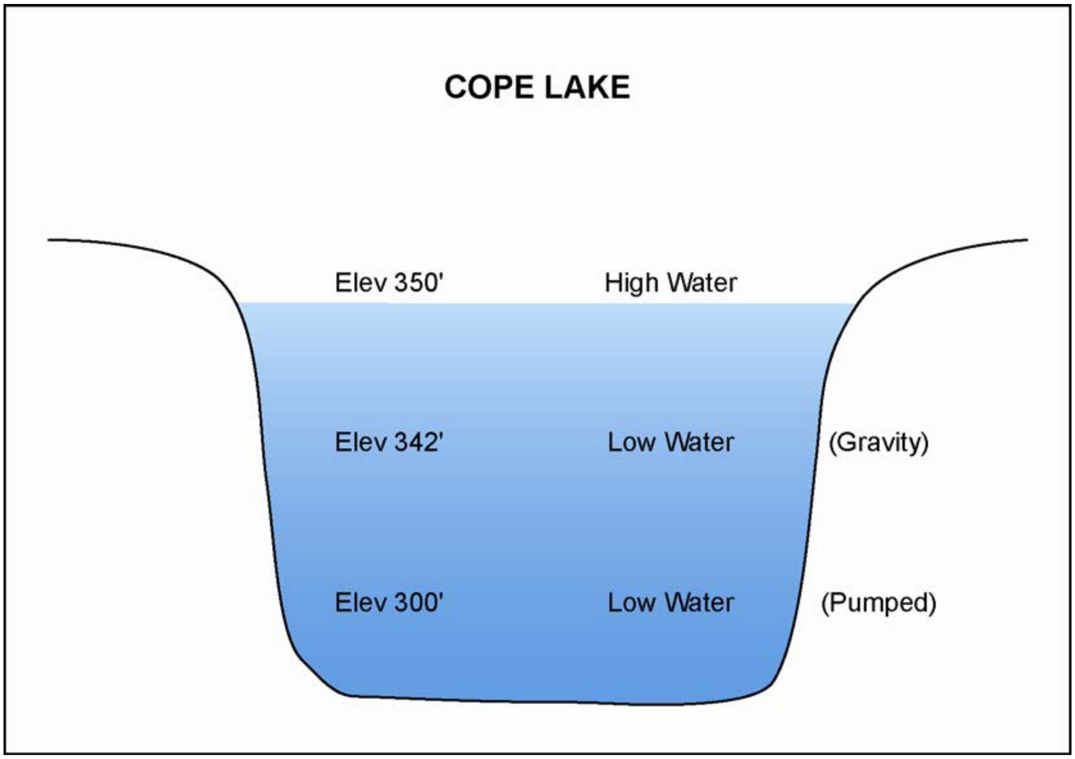
Lake	Surface Area (Acres)	Storage Volume to 15 ft. Depth (AF)	Storage Volume to 20 ft. Depth (AF)
Cope	220 (15 ft); 230 (20 ft)	3,300	4,000
G	35	525	700
F	62	930	1,240
Totals	317 (15 ft); 327 (20 ft)	4,755	5,940

Figure 4-17: Storage Volumes within the Chain of Lakes



Achieving the optimum storage benefit of 5,000 AF will require diversion of flows from Arroyo las Positas and Arroyo Mocho at the right time (before the hydrograph peak) during the future 100-year storm event, and will require the full 20-foot depth volume in the lakes to be available at the time of diversion. To provide a factor of safety, it is recommended that 20 feet of depth be utilized in Cope Lake and Lakes G and F to obtain approximately 5,940 AF of total detention storage. As shown on Figure 4-18, operation down to a 20-foot depth will require pumping out of storage below an elevation of about 342 feet to 330 feet.

Figure 4-18: Cope Lake Elevations and Draining Process

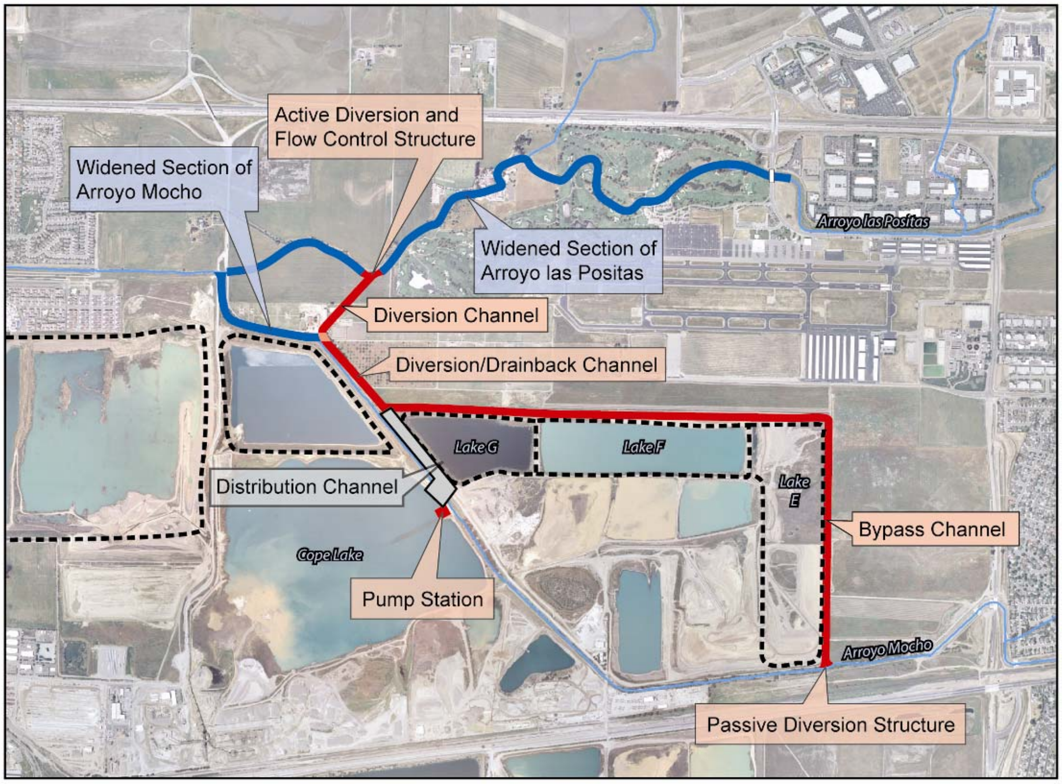


4.2.2 Regional Storage Project Components

As described above, the Chain of Lakes area has been identified as an integral part of a regional solution for flood protection in the Valley. Flow diversion from Arroyo las Positas and Arroyo Mocho to detention storage in Cope Lake, Lake G, and potentially other lakes will reduce downstream peak flows to acceptable levels (i.e. flow that can be conveyed in the 100-year storm event utilizing available capacities of Arroyo Mocho and ADLL). Each conceptual design element is shown on Figure 4-19.

Location and design details of projects and project components are conceptual and were developed to an appropriate level of detail to verify hydraulic feasibility and estimate facility costs and size. Facility location, sizing and other design details will be finalized closer to project implementation.

Figure 4-19: Chain of Lakes Project Components



The frequency of diversion into storage will be based on the peak flow in Arroyo Mocho downstream of the Chain of Lakes and resulting peak flows in ADLL at Bernal Avenue. As discussed in the Frequency of Storage Draft TM, to maintain, but not exceed, the peak flow in ADLL at its current capacity of 18,730 cfs, the peak combined flow in Arroyo Mocho (downstream of the confluence with Arroyo las Positas) should not exceed 2,000-5,000 cfs. As a result, detention storage will be triggered when flows reach 2,000-5,000 cfs in Arroyo Mocho (downstream of the confluence with Arroyo las Positas). This flow corresponds to a 6- to 7-year rainfall event.

Flow diversions from Arroyo Mocho to the bypass channel, will likely occur more frequently (on a 5-year event), due to the capacity limitations in Arroyo Mocho through the Chain of Lakes area. This diverted flow will either be transported to the confluence with Arroyo las Positas, downstream of the Chain of Lakes, or into detention storage in Cope Lake. The actual path and processes for diversion from both Arroyo las Positas and Arroyo Mocho to detention storage are discussed in detail in the following sub-sections.

The following sub-sections discuss project components starting at the diversion structures, moving through the diversion channel into storage, and ending with the stormwater return to the widened section of Arroyo Mocho. It is important to note that while the following design elements are discussed in more detail than in the SMMP Phase 1 Interim Report, the design is still conceptual. There is a need for an Operations Plan to be developed in the pre-design phase to outline the specific operations protocol for the Chain of Lakes detention system. Development of the Operations Plan is discussed further in Section 4.2.3.

Diversion Structures

The Chain of Lakes Stormwater Diversion/Storage Project utilizes two diversion structures to direct flow towards the Chain of Lakes area from local arroyos. As shown in Figure 4-19, one structure will be located on Arroyo las Positas, and the other on Arroyo Mocho.

The combined flow from the diversion structures will be a peak of 9,800 to 12,800 cfs of stormwater for the 100-year event into Cope Lake and then into Lake G and Lake F if necessary. Individual diversion structures are discussed in greater detail below.

Arroyo las Positas Stormwater Diversion Structure

The diversion structure on Arroyo las Positas shown in Figure 4-20 is proposed at Station 60+00, downstream of the Las Positas Golf Course in order to convey flood flows to storage. The conceptual design is a side-weir measuring approximately 250 feet in length combined with a flow control structure immediately downstream of the side-weir on Arroyo las Positas, as shown in Figure 4-21.

Figure 4-20: Arroyo las Positas Stormwater Diversion Structure

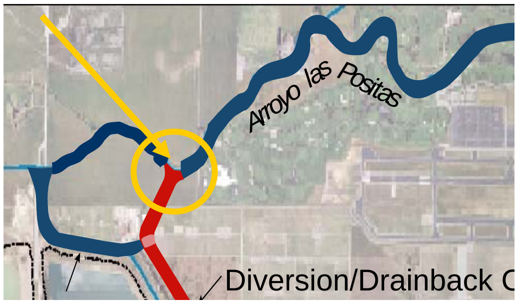
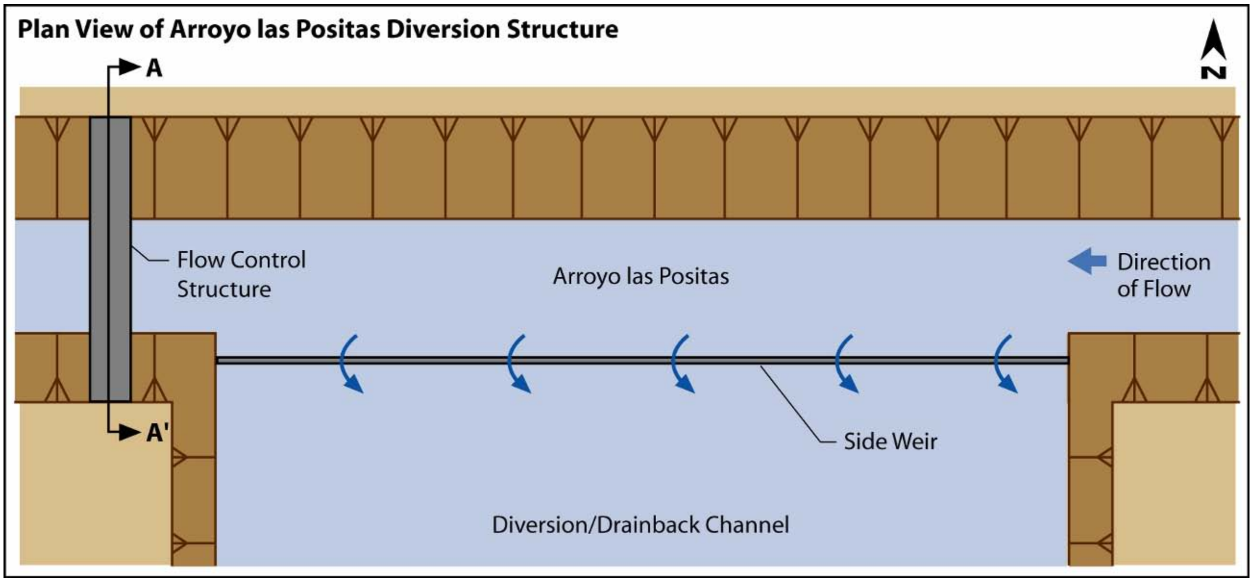


Figure 4-21: Diversion and Flow Control Structures on Arroyo las Positas

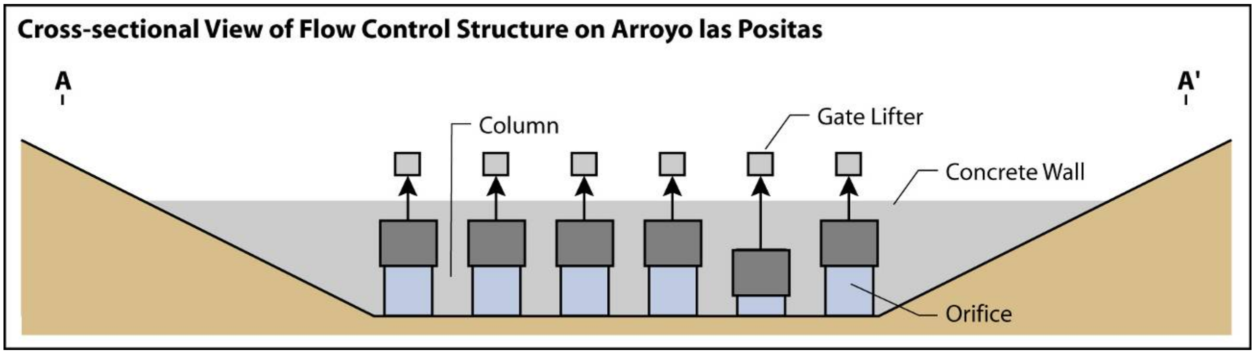


The purpose of the flow control structure will be to regulate flood flows in Arroyo Mocho downstream of the confluence with Arroyo las Positas. The flow control structure will be a concrete structure that extends across the length of Arroyo las Positas with automated gate. A schematic of the flow control structure is shown on Figure 4-22. The gates will be automated and controlled by data from stream gauging stations located in Arroyo Mocho (downstream of the confluence with Arroyo las Positas) and in ADLL. The gate height will determine the contribution of flow from Arroyo las Positas to Arroyo Mocho.

An active structure is recommended in this location to allow for greater flexibility in Arroyo Mocho. While the flow in Arroyo Mocho (downstream of the confluence with Arroyo las Positas) may not exceed 2,000-5,000 cfs, a flow control structure on Arroyo las Positas will ensure that the flow is kept at its maximum capacity (2,000-5,000 cfs) if the contribution from storage or upstream Mocho drops off.

Therefore, the flow control structure on Arroyo las Positas will provide flexibility in operation of the system.

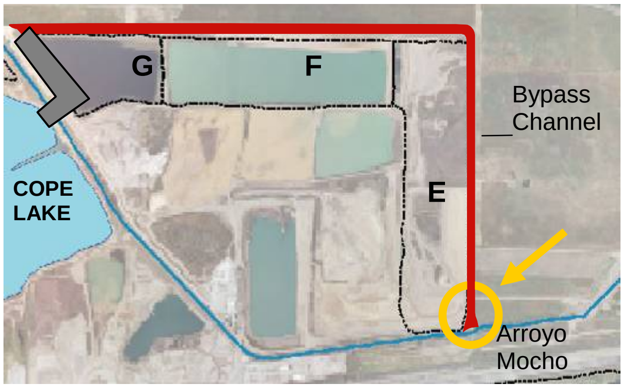
Figure 4-22: Flow Control Structure on Arroyo las Positas



Excess flows contained by the flow control structure will overtop the side weir of the diversion structure and be directed into the diversion channel which extends to Cope Lake and Lake G. It is anticipated that 6,400 to 9,400 cfs will be diverted into the diversion channel during peak flow events. In the vicinity of the flow control structure, the channel bottom will be concrete to help with velocity issues created by the flow control structure.

Arroyo las Positas is not a natural fisheries migration corridor, however, a fish barrier should be incorporated into the design of the flow control structure to encourage fish migration in Arroyo Mocho. To avoid transferring the current FEMA floodplain from the Chain of Lakes area to other locations downstream, capacity improvements to Arroyo las Positas through the golf course and the diversion structure described above must not be constructed prior to completion of the regional detention storage improvements.

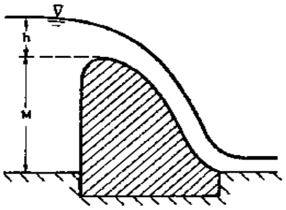
Figure 4-23: Arroyo Mocho Stormwater Diversion Structure



Arroyo Mocho Stormwater Diversion Structure

Concern about fish migration on Arroyo Mocho is a major driver in the design of the Mocho bypass structure. A passive design such as a broadcrested ogee-type weir for the overflow structure from Arroyo Mocho to the Arroyo Mocho bypass channel is recommended. The bypass channel will be constructed from Station 340+00 on Arroyo Mocho, extending north along the eastern side of Lake E and then west along the northern side of Lake E, F, and G to the diversion/drainback channel, as shown on Figure 4-23. The bypass channel will be approximately 11,000 feet in length.

Figure 4-24: Ogee-profile Weir



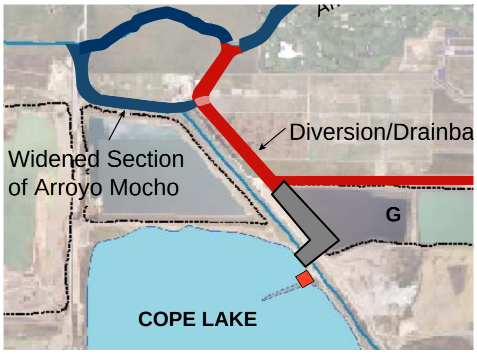
The ogee-profile, as depicted in Figure 4-24, acts to minimize turbulence immediately downstream of the weir, to provide a safer passage for fish should they overtop the weir. Precautions will be taken to minimize the likelihood of fish overtopping the weir by constructing the weir to have a very low head. Conceptually the side weir will be several hundred feet in length to keep the head to a minimum. The exact length of the weir will be determined in the design phase.

Once flows overtop the weir they will be conveyed in the Mocho bypass channel to the diversion/drainback channel. From the diversion/bypass channel, flood flows from Arroyo Mocho can be conveyed either to storage, or out of the bypass system to the widened section of Arroyo Mocho (in a bypass event). The envisioned operation process is discussed in more detail in the following sections.

Diversion/Drainback Channel

As shown on Figure 4-25, the diversion/drainback channel runs from the outlet gate to widened Mocho in the north; to the distribution channel connecting to Cope Lake, in the south. Water diverted to this channel will be carried approximately 3,000 feet along an earthen-lined, excavated-cut channel with approximately an 80-foot bottom width, 180-foot top width, and 2.5:1 side slopes. A portion of this channel, the area between the side weir on Arroyo las Positas and the gated outlet to widened Arroyo Mocho (at El Charro Road), should be designated as a floodplain.

Figure 4-25: Diversion/Drainback Channel



The Arroyo Mocho bypass channel will join the diversion/drainback channel just west of the northwest corner of Lake G.

The diversion/drainback channel is a level channel connecting two points (Cope Lake and the widened section of Arroyo Mocho). During the onset of a storage event, the water surface elevation in Cope Lake is less than that in the diversion/drainback channel and the water in the channel will be diverted to storage. The channel will act as a drainback channel to return detained stormwater to the widened section of Arroyo Mocho when the Cope Lake water elevation is greater than the water surface elevation at the outlet. This stormwater return process is discussed in more detail in the Stormwater Return System section below.

Distribution Channel and Storage

The main function of the distribution channel shown in Figure 4-26 is to divert flow to Cope Lake or Lake G for detention storage. The distribution channel consists of an approximately 1,750 foot long concrete structure (length varies with degree of space constraint), with a width ranging from about 30 feet to 100 feet, as shown in Figure 4-27.

Figure 4-26: Distribution Channel

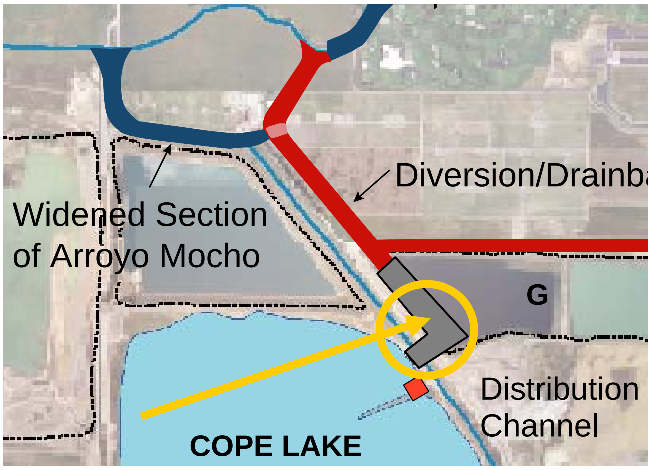
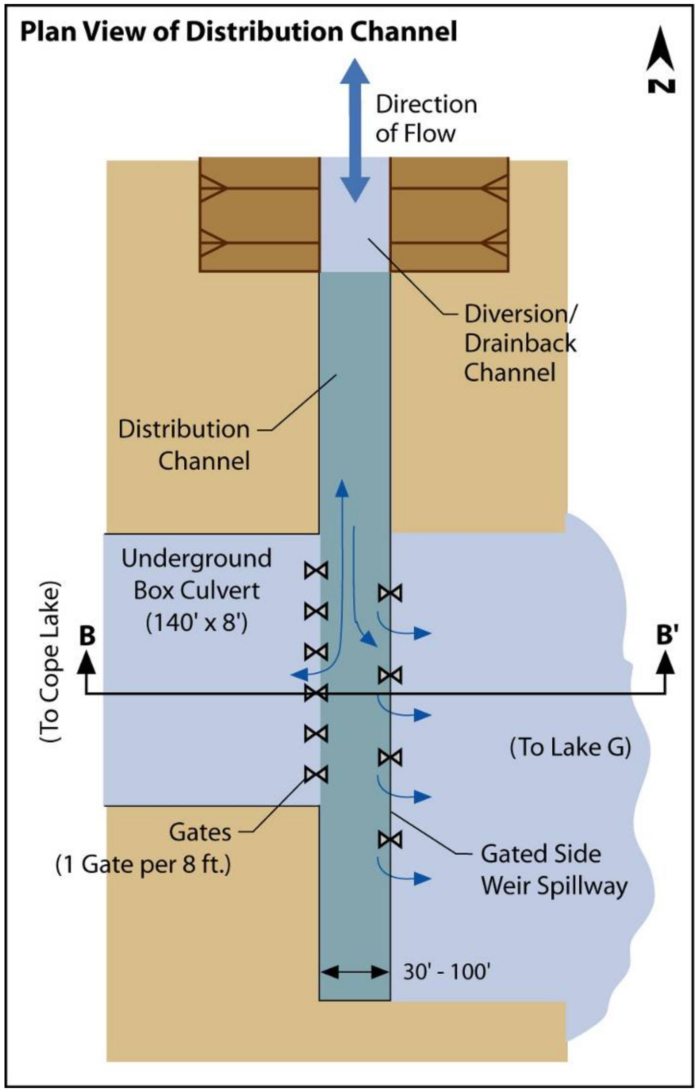
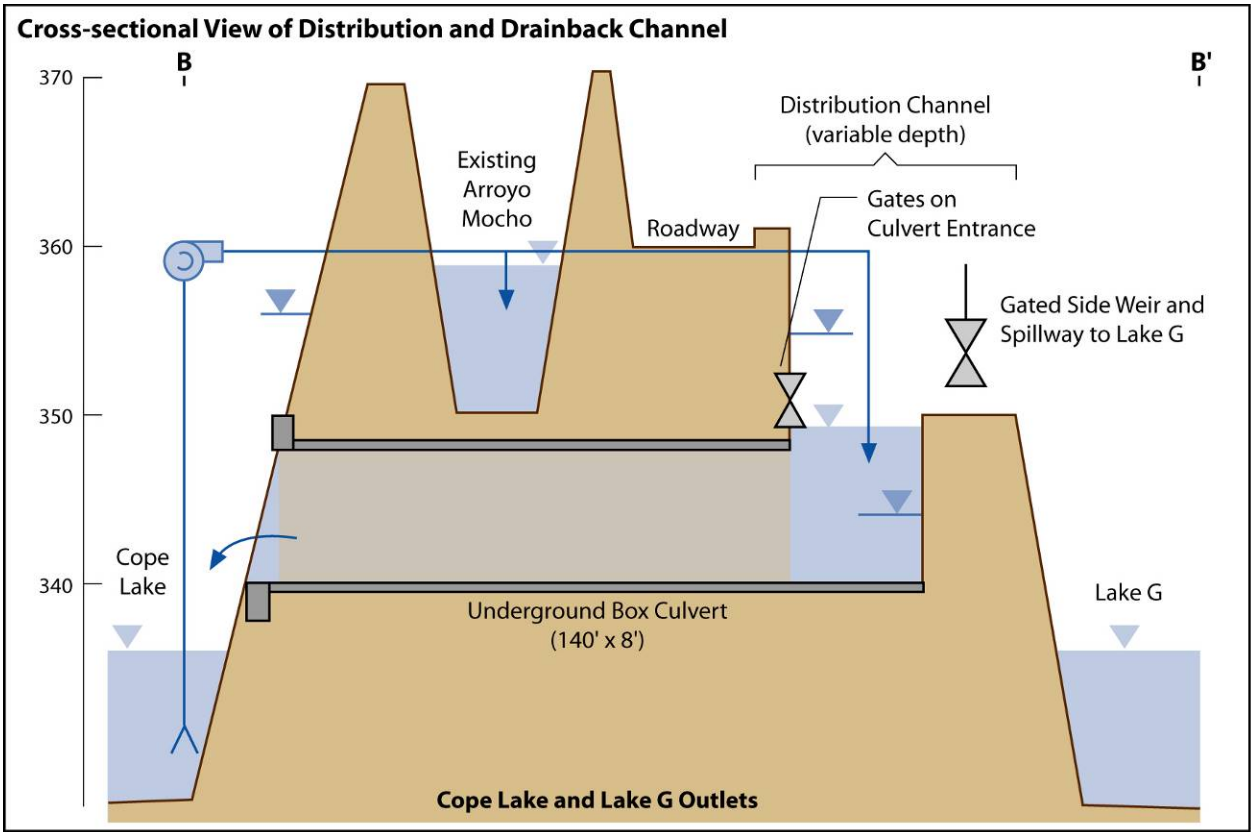


Figure 4-27: Distribution Channel Connection to the Diversion/Drainback Channel and Outlets



The west side of the channel will incorporate a 140 foot long outlet to the proposed underground box culvert, to convey flows to Cope Lake. The underground box culvert will measure approximately 140 feet across by 8 feet in height, and extend approximately 200 feet to Cope Lake. A cross-sectional view of this design is shown on Figure 4-28. Flow will be routed to Cope Lake first during a storage event, and as Cope Lake becomes full, flow will be routed to Lake G; and then from Lake G to Lake F, if necessary. The east side of the distribution channel will consist of a gated side weir to divert flows to Lake G.

Figure 4-28: Distribution Channel Outlets (Cope Lake and Lake G)



To provide an independent outlet to Lake G, and to bypass rather than detain Mocho bypass flows, 140 feet of gates along the inlet to the box culvert at the distribution channel will be required. During a bypass event (about a 5-year event), the gates will be closed, and no storm water will enter Cope Lake. Several factors will trigger a storage event including water levels and rate of rise in the streams. A storage event is predicted to occur when flows approach 2,000 to 5,000 cfs in Arroyo Mocho downstream of the Chain of Lakes (estimated to occur on a greater than 7-year event). When a storage event is triggered, gates to Cope Lake will be opened, and flows will be directed to Cope Lake as depicted in Figure 4-28.

Approximately 20 feet of storage in Cope Lake and potentially Lake G will be required to meet the storage needs for a 100-year event. Storage in Lake F and Lake E via conveyance piping between these lakes and Lake G will also be available to manage risk. The average lake level of Cope Lake is approximately 335 feet; therefore Cope Lake will need to be pumped down to a water surface elevation of 330 feet prior to a storage event to make 20 feet available for storage (elevation 330 feet to 350 feet). Available storage acreages were shown previously in Table 4-2.

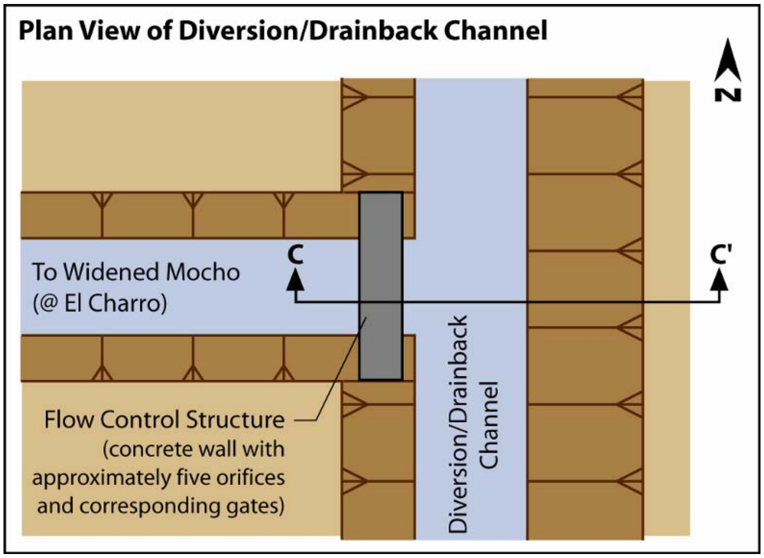
As part of the project precursors, the issue of operation of Cope Lake as a reservoir will need to be addressed. The Department of Water Resource's California Division of Safety of Dams (DSOD) may require permits for the operation of a reservoir. DSOD permits require permitting fees and annual inspection conducted by a DSOD engineer.

Stormwater Return System

The following section discusses the stormwater return system components which include a pump station in Cope Lake, a diversion/drainback channel from Cope Lake, a gated outlet from the diversion/drainback channel to a widened section of Arroyo Mocho downstream of Cope Lake.

The bypass channels from both Arroyo las Positas and Arroyo Mocho will direct overflows to a level channel (the diversion/drainback channel) connecting Cope Lake on one end to Arroyo Mocho at El Charro Road on the other. The gates existing on the Arroyo Mocho end of the diversion/drainback channel will dictate whether flow will be conveyed out of the system (down Arroyo Mocho at El Charro), or into Cope Lake and/or Lake G for detention storage.

Figure 4-29: Diversion/Drainback Channel at Outlet to the Widened Section of Arroyo Mocho



When the gates are closed during high flow events and the water level in Cope Lake is lower in elevation than the gates, stormwater will be conveyed along the diversion/drainback channel towards the distribution channel at Cope Lake.

When capacity is available in ADLL (flow is less than 18,730 cfs in ADLL), the gates at widened Mocho will be opened to allow flow contribution to Arroyo Mocho downstream of the Chain of Lakes. A flow of 2,000-5,000 cfs in Arroyo Mocho (downstream of the confluence with Arroyo las Positas) correlates to a flow of approximately 18,730 cfs in ADLL. When the gates at widened Mocho are opened, the stormwater in the diversion/drainback channel and in Cope Lake that is higher than an elevation of approximately 342 feet will be drained by gravity through the diversion/drainback channel and into the widened section of Arroyo Mocho at El Charro Road through the flow control structure, as shown on Figure 4-29. The flow control structure will moderate the release keeping flows in Arroyo Mocho downstream of the confluence with Arroyo las Positas, at a maximum of 2,000-5,000 cfs. Flow will be returned from storage to the widened section of Arroyo Mocho as soon as capacity is available downstream in ADLL in order to free-up storage capacity in Cope Lake in preparation for the next storm event.

Water below the level of the channel (about elevation 342 feet) will remain in Cope Lake and will require removal through pumping. For this reason, a pump station at Cope Lake is recommended. When Cope Lake reaches a water surface elevation of approximately 342 feet, the pumps will engage and water will be pumped into the diversion/drainback channel and/or Arroyo Mocho adjacent to Cope Lake. The gates on the underground box culvert at the distribution channel and the side-weir spillway to Lake G will be closed to keep water that is pumped into the diversion/drainback channel from flowing back into Cope Lake and Lake G.

There is a low probability that fish will enter Cope Lake because of the precautions taken in the design of the diversion structure on Arroyo Mocho. However, in the event of fish entering Cope Lake, fish screens will be incorporated into the intake structure at Cope Lake and will keep the fish from being harmed by the pumps.

Geotechnical studies conducted in the Chain of Lakes area indicate that lakes should not be lowered more than 2 feet per day or 10 feet per week to maintain structural stability. Given that Cope Lake will need to drain more rapidly than the geotechnical constraints, the walls of Cope Lake may need to be outfitted with additional structural supports. Additionally, given the potential for storage of stormwater to greater than normal volumes, and the known presence of weak walls[1]; strengthening measures will be incorporated in the design phase for the storage lakes (Cope Lake, Lakes G, F, and E).

Lake G will drain to Lake H (currently connected by a pipe), and by evaporation and percolation. Additional pump intake structures can be incorporated into Lake G to remove water more rapidly, however this is not a component of the current conceptual design.

4.2.3 Operation of Regional Storage

The following section describes the various operational modes of the Chain of Lakes system. Due to capacity limitations and fisheries issues, the system is designed to bypass and/or store flows. Bypassing flows alleviates channel capacity issues along Arroyo Mocho and in Arroyo las Positas. The ability to bypass, but not store bypassed flows, alleviates fisheries issues such as incidental “takes” which could occur if flows and thus fish are detained within the storage lakes.

As discussed earlier, the frequency of diversion into storage will be based on the resulting peak flows in ADLL at Bernal Avenue and other triggers, such as water elevation and rate of rise within the channels. To maintain, but not exceed, the peak flow in ADLL at its current capacity of 18,730 cfs, the peak combined flow in Arroyo Mocho (downstream of the confluence with Arroyo las Positas) should not exceed 2,000-5,000 cfs. As a result, detention storage is expected to be triggered when flows reach 2,000-5,000 cfs. This flow corresponds to a greater than 7-year rainfall event.

Flow diversions from the existing Arroyo Mocho, upstream of the Chain of Lakes, will likely occur more frequently (on a 5-year event), due to the capacity limitations in Arroyo Mocho through the Chain of Lakes area. This diverted flow will either be transported to the confluence with Arroyo las Positas, downstream of the Chain of Lakes, or into detention storage in Cope Lake if flows in Arroyo Mocho (downstream of the confluence with Arroyo las Positas) are 2,000-5,000 cfs or greater.

Operations

The Chain of Lakes detention system is conceptually designed to operate in four modes. These are:

1. Normal flow regime
2. Bypass event
3. Storage event
4. Drainback mode

As implied by the term normal flow regime, this mode occurs during normal flow periods. In this mode, no water is overtopping the side-weirs and all flow is carried through the system in the natural channels.

As flows increase and begin to overtop the weir along Arroyo Mocho (approaching 1,300 cfs in Arroyo Mocho downstream of the diversion structure) the system moves into bypass mode. Flows of this magnitude are expected to occur during a 5-year event. Flow overtopping the weir is carried along the bypass system to the diversion/drainback channel. Flow enters the diversion/drainback channel and is conveyed to the outlet at widened Mocho, where it enters the widened natural channel and is transported out of the system. No flow enters the storage lakes in bypass mode (gates are closed in the distribution

[1] Zone 7 indicated the presence of a weak wall along the southeast section of Cope Lake in March 2005.

channel entrance to Cope Lake). Bypass events will occur more frequently than storage events due to the capacity limitations in Arroyo Mocho through the Chain of Lakes area.

The need for storage will arise when flows approach 18,730 cfs in ADLL, correlating to 2,000–5,000 cfs in Arroyo Mocho (downstream of the confluence with Arroyo las Positas), as discussed above. When this capacity is reached, as determined by flow monitoring at gauging stations, the gates within the distribution channel at the box culvert leading to Cope Lake will open while the gates at the outlet to widened Mocho close simultaneously. From this point, flow in the diversion/drainback channel will be conveyed to Cope Lake, and then Lake G through a gated side-weir for detention, and possibly Lake F through conveyance piping between Lakes G and F. Flows will be detained within the storage lakes until flow subsides.

As the rainfall event subsides and the flow within Arroyo Mocho (downstream of the confluence with Arroyo las Positas) begins to drop below 2-000-5,000 cfs, the gates at widened Mocho will be opened. This will trigger a gravity drainage process where stormwater in the diversion/drainback channel, and stormwater in Cope Lake that is higher than an elevation of approximately 342 feet will be drained into the widened section of Arroyo Mocho. As discussed above in the Stormwater Return System section, the flow control structure will moderate the release keeping flows in Arroyo Mocho at a maximum of 2,000-5,000 cfs. In order to free-up storage capacity in Cope Lake in preparation for the next storm event, detained stormwater will be returned from storage immediately as capacity becomes available in ADLL.

As noted earlier, detained flows below the level of the channel (about elevation 342 feet) will remain in Cope Lake and will require removal through the Cope Lake pump station. The pumps will engage when the lake elevation reaches approximately 342 feet, and will return stormwater at a rate of approximately 1,000 cfs into the diversion/drainback channel and/or Arroyo Mocho adjacent to Cope Lake. Once pumps engage it will take approximately 17 hours (at this rate) to pump Cope Lake to an elevation of 335 feet; and an additional 10 hours to reach 330 feet. During pumping, the gates on the underground box culvert at the distribution channel will be closed to keep water pumped into the diversion/drainback channel from flowing back into Cope Lake. When all water is removed from storage, the distribution channel and diversion/drainback channel can also be pumped out to eliminate issues resulting from stagnant water.

Maintenance

As part of the pre-design phase of work, a maintenance procedure and Operations Plan will be developed.

While maintenance procedures have not been explored in detail, sediment maintenance will be necessary in Cope Lake, and should be addressed (along with resulting environmental impacts) on an as-needed basis. The Operations Plan discussed above will address the issue of frequency of sediment removal within the storage lakes. Sediment maintenance in the bypass and diversion channels will happen on a more frequent basis. More details on sediment maintenance, and operations and management procedures in Cope Lake will be developed in the next phase of work.

Managing Risk

In the event of back-to-back storms, where Cope Lake is full, there is room to storage additional flows in Lakes G, F, and E. If for some reason, these lakes are full, an overflow from Cope Lake to Lake H will occur before peak flows are released downstream, thereby avoiding flooding along ADLL associated with peak flows in Arroyo las Positas and Arroyo Mocho.

As shown in Table 4-2, the total storage available in Cope Lake and Lakes G and F, is approximately 5,940 AF and Lake E could provide an additional 1,860 AF, assuming a storage depth of 20 feet. Additionally, Lakes H and I could be used for storage of an additional 7,040 AF in a worst-case scenario.

4.2.4 Tie in to Section 5 Projects

As noted earlier, the Chain of Lakes diversion and storage system components are divided into two projects in Section 5 (R.5-3 and R.6-2). The components for each project are shown in Table 4-3.

Table 4-3: Design Elements and Related Projects

Design Element	Project
Arroyo las Positas stormwater diversion structure and flow control structure	R.5-3
Diversion channel from Arroyo las Positas	R.5-3
Diversion/drainback channel	R.5-3
Distribution channel	R.5-3
Underground box culvert to Cope Lake	R.5-3
Drainback outlet to widened Mocho and flow control structure	R.5-3
Widening of Arroyo las Positas through the Golf Course and downstream of the diversion	R.5-3
Arroyo Mocho stormwater diversion structure	R.6-2
Bypass Channel	R.6-2
Cope Lake pump station	R.6-2
Widening of Arroyo Mocho downstream of Cope Lake R.6-2	R.6-2

Further details on these projects are found in Section 5.