ATTACHMENT C

Summary of Devil's Gate Dam and Reservoir Design Standard and History
Los Angeles County Flood Control District
April 7, 2014

Devil's Gate Dam is a 100 foot high concrete gravity arch dam located in the City of Pasadena approximately 1.5 miles south of the base of the San Gabriel Mountains. It was constructed by the Los Angeles County Flood Control District (LACFCD), a component of the County of Los Angeles Department of Public Works, for flood control and water conservation. Devil's Gate Dam construction began in May 1919 and was completed in June 1920. The original capacity of the reservoir was 4,601 acre-feet below the original spillway elevation of 1,054 ft.

Due to its size, Devil's Gate Dam falls under the jurisdiction of the State Department of Water Resources Division of Safety of Dams (DSOD). DSOD requires that dams be designed to withstand a Maximum Credible Earthquake (MCE), which is the largest magnitude earthquake that experts determine a particular earthquake fault can produce. For Devil's Gate Dam, the current MCE is a Magnitude 7.5 earthquake on the Sierra Madre Fault. DSOD also requires that the dam's spillway safely pass the Probable Maximum Flood (PMF) without overtopping the dam. The PMF is the largest flood that could possibly happen based on the most severe, yet conceivable, meteorological conditions. For Devil's Gate Dam, the PMF is 36,000 cubic feet per second (cfs). This is based on the United States Weather Bureau's Hydro-meteorological Report No. 36, "interim Report – Probable Maximum Precipitation in California" and reported in the Devil's Gate Reservoir Hydrologic Reanalysis Phase IV (1993). These design standards are very conservative but have been adopted by the State to prevent the significant potential downstream damage and loss of life that could otherwise result from a seismic or flooding induced failure of the dam.

Because the dam, as originally constructed, did not meet modern MCE and PMF criteria, it was rehabilitated in 1997 to meet current standards. Rehabilitation included constructing a concrete buttress on the downstream face to increase the dam's resistance to earthquake forces and enlarging the spillway to pass the PMF. Enlarging the spillway to pass the larger PMF could have simply involved cutting a larger "notch" where the existing spillway was; however, in addition to meeting DSOD standards, the dam and spillway must also meet established LACFCD standards.

For LACFCD facilities, including major open channels, dams, and debris basins, the "Capital Flood" level of protection applies. The Capital Flood is the runoff produced by a 50-year frequency design storm falling on a burned (for undeveloped areas), saturated watershed. A 50-year frequency design storm has a probability of 1/50 (2 percent) of being equaled or exceeded in any year. The Capital Flood inflow to Devil's Gate Dam is 13,969 cfs. The method for calculating the Capital Flood is described in the County of Los Angeles Department of Public Works Hydrology Manual (January 2006), which is available online. One of the functions of Devil's Gate Dam is to reduce downstream flooding during a Capital Flood. Simply put, the storage capacity of the dam is used to capture stormwater runoff so that the peak outflow from the dam is less than the peak inflow. The design of the Devil's Gate Dam spillway modification required that, during a

Capital Flood, the dam outflow would not be more than it was before the modification; and that during a PMF, the much higher flow rate could still pass through the spillway without overtopping the dam. These requirements necessitated that the spillway be lower than the original and resulted in its unique configuration.

What is the required capacity behind Devil's Gate Dam?

LACFCD evaluates the required capacity behind dams for three functions: flood control operations, water conservation, and capturing debris. The required capacity for capturing debris is based upon a Design Debris Events (DDE). A DDE is characterized as the estimated amount of sediment that could flow into the reservoir four years after the undeveloped portion of the watershed has burned and a 50-year storm (based on a 24 hour duration) occurs. The 50-year storm and the DDE are defined by the County of Los Angeles Department of Public Work Sedimentation Manual (March 2006), which is available online. Each reservoir has its own unique DDE and the DDE for Devil's Gate Dam is approximately 2 million cubic yards (mcy).

LACFCD's sediment removal criterion for dams providing debris control is to maintain reservoir capacity for two DDEs below a dam's spillway elevation. The reason the LACFCD has established the required capacity at two DDEs is to ensure that there is always sufficient reservoir capacity to maintain the level of downstream flood protection. By requiring two DDEs, there is likely sufficient reservoir capacity to experience a design level storm, or several smaller but significant debris events, and still maintain capacity of at least one DDE during the lengthy environmental and construction processes to remove the debris. In addition to requiring the two DDEs for debris control, some dams require additional storage capacity for providing Capital Flood regulation. Further, it should be noted that additional criteria in special circumstances related to dam safety may also dictate the need to remove sediment from a reservoir.

- Depending on the structural stability of the dam, the height of sediment against the dam may need to be limited (sediment weighs more than water and increases the forces on the dam during an earthquake).

- The volume of sediment accumulation may also be limited to prevent sediment from blocking valves/operations (if sediment or debris blocks the outlet valves, they cannot be used to regulate storm flows or to empty the dam during an emergency).

For Devil's Gate Dam, the required reservoir capacity is based on debris control and is 4.0 mcy (two DDEs) below the spillway elevation of 1,040.5 feet.

The requirement of providing capacity of two DDEs appears very conservative. How frequently have major storm events/sediment events occurred in the past?

As discussed above, a DDE is characterized as the estimated amount of sediment that could flow into the reservoir four years after the undeveloped portion of the watershed has burned and a 50-year storm (24 hour duration) occurs. It should be noted that design debris amounts can be produced from a freshly burned watershed with rainfall

amounts considerably below capital flood levels (a 5 to 10 year frequency storm). Similarly, higher intensity rainfalls could produce more debris.

As shown on the attached graphical representation (Attachment A), since the dam construction in 1920 and prior to the Station Fire in 2009, approximately 10.7 mcy of sediment accumulated in the reservoir and approximately 8 mcy was removed. In the two storm seasons following the Station Fire an additional 1.3 mcy accumulated. While a minimal amount of sediment comes into the reservoir with every storm, most of the sediment comes in large amounts during more intense storm events. The attached Devil's Gate Sediment Event History (Attachment B) describes these major sediment events. In reviewing this document it may become clearer why establishing capacity of two DDE's makes sense. Since it can take 5 to 10 years to plan and complete a large sediment removal project, there is a strong possibility of additional significant sediment events during that period. It may seem reasonable to assume that once a large debris flow has occurred, the chances of another event would be remote, but history tells a different story.

In 1934, the Brown Mountain Fire burned 3,550 acres of the Devil's Gate Dam's tributary watershed and 800,000 cubic yards (cy) of sediment was deposited in the reservoir. During the historic 1938 flood, considered a 50-year event, an additional 1.67 mcy was deposited in the reservoir. By 1942, yet another, 1.5 mcy of sediment was caught in front of the dam. By 1943, 9 years after the burn, a total of approximately 4.7 mcy had been deposited in the reservoir. In the 4^{th} through 9^{th} years after the burn (analogous to where we are now with the Station Fire recovery) 3.7 mcy accumulated.

This series of debris flows was not an isolated event. Again in 1959, one third of the watershed was burned. Between 1959 and 1962, 900,000 cy of sediment deposited in the reservoir. In 1966 an additional 900,000 cy entered the reservoir, and finally in 1969, ten years after the fire, 1.1 mcy was deposited in the reservoir burying or clogging all three valves on the dam. The 1969 storm was characterized as approximately a 50-year storm when looking at the 24 hour rainfall intensities.

In 2009, the Station Fire burned nearly the entire undeveloped watershed tributary to Devil's Gate Dam. So far, over 1.3 mcy of new sediment has accumulated in the reservoir. Past history indicates we can expect high debris flows for several more years when we receive any significant rainfall. Additionally, a large volume of sediment has washed down the mountains but remains above the reservoir area and has the potential to also be washed into the reservoir. With only 1.3 mcy of capacity remaining below the spillway, these potential sediment inflows are a major concern for the LACFCD.

<u>Public Works originally proposed an emergency project and stated in older documents that one DDE was 1.67 mcy. The Draft Environmental Impact Report (DEIR) states that the project will remove up to 4.0 mcy and the DDE is 2.0 mcy. What accounts for the changes?</u>

The DDE is calculated based on the methodologies described in LACDPW's Sedimentation Manual (March 2006). Factors that affect the potential amount of debris

for a facility includes the location and size of the watershed (the entire County is mapped with different debris production zones based on geologic conditions that affect the amount of sediment they can produce), the amount of the watershed that is developed, the amount that is undeveloped and subject to wildfire, and the portion of the watershed that is controlled by other debris catching facilities such as other dams or debris basins. For Devil's Gate Dam, the DDE was previously calculated as 1.67 mcy. That previous calculation was based on the presence of debris retaining structures including the United States Forest Service's Browns Canyon Dam, located within the Angeles National Forest upstream of Devil's Gate Dam. These structures filled with sediment decades ago and no longer provide capacity to control any portion of the watershed. A subsequent analysis determined that the correct DDE, based on the absence of sediment control facilities in the forest, is 2.0 mcy. Following the Station Fire, the Public Works reviewed the DDE calculations and confirmed that 2.0 mcy is the current and appropriate volume for the DDE.

Public Works' criterion is that reservoir sediment levels be maintained at a level equivalent to two DDEs below spillway. However, in response to the Station Fire, an emergency project to remove only 1.67 mcy was initially proposed. The volume of 1.67 mcy is the previously published DDE and was considered justifiable as an emergency exemption to the California Environmental Quality Act (CEQA). Once the County of Los Angeles Board of Supervisors instructed Public Works to prepare an Environmental Impact Report, project development was begun in accordance with the required level of protection. At that time Public Works also began receiving feedback on the concurrent Sediment Management Strategic Plan (SMSP) and the interest to look at more sustainable sediment and reservoir management. As a result of the feedback and recommendations during the development of the SMSP, Public Works began evaluating ways to create a more sustainable long term way to manage its sediment and habitat. To emphasize the goals of the project, the project was given the name Devil's Gate Sediment Removal and Management Project.

The Initial Study/Notice of Preparation and the Project Scoping Meetings identified the project description as the following: "The proposed project would remove up to 4.0 mcy of sediment from the reservoir behind Devil's Gate Dam to restore it to its current design standard, and establish a reservoir configuration more suitable for routine maintenance activities including sediment management. Although approximately 2.6 mcy of sediment is the current excess amount of sediment in the reservoir, additional sediment accumulation is anticipated during the upcoming storm seasons due to the burned condition of the watershed that will have to be removed. The ultimate reservoir configuration and volume of sediment to be removed will be determined based on locations of access roads, areas for preservation or restoration of native vegetation, and the amount and location of sediment inflow that occur during the upcoming storm seasons." During the past two storm seasons, very little sediment has accumulated in the reservoir. Although more sediment could wash into the reservoir before the project is completed, based on current reservoir conditions, the DEIR's Proposed Project would require removal of 2.9 mcy, whereas the DEIR's environmentally superior alternative, Alternative 3, would require removal of 2.4 mcy.

The SMSP appears to show that Devil's Gate reservoir still has the capacity for two DDEs. If not, what percentage of one DDE can be safely contained at Devil's Gate?

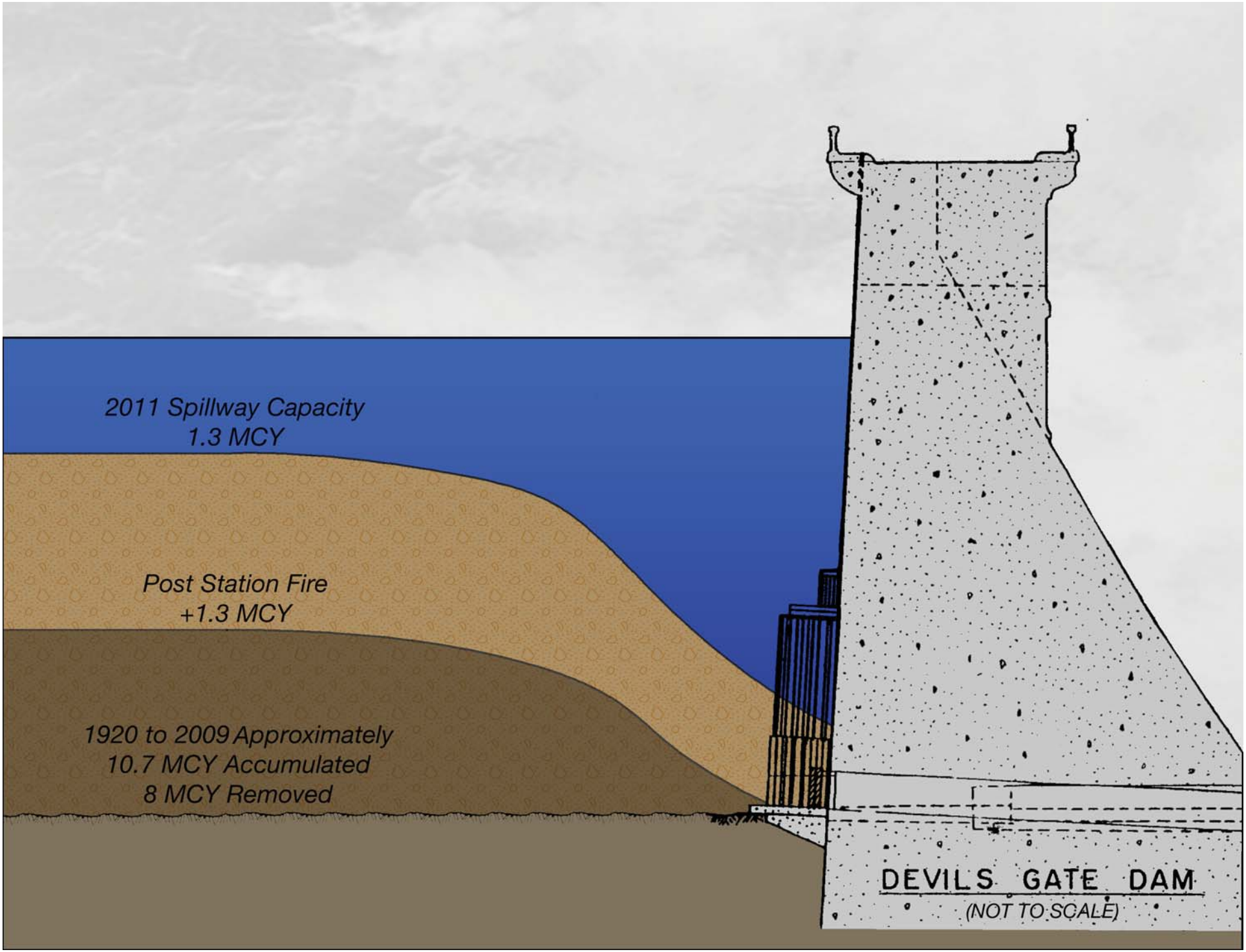
The SMSP included sediment history data to demonstrate the volume of sediment deposited into the dams and used that data along with statistical analysis to develop projected 20-year sediment volumes for County facilities. The sediment history provided for Devil's Gate Dam (pages 8-42 and 8-43 of the SMSP) correctly shows the sediment volumes accumulated at the dam; however, the column titled "Reservoir Capacity at Elevation 1,054 ft." can be somewhat confusing with respect to the current capacity in the dam. That column provides the remaining capacity below elevation 1,054 ft, which is the original spillway elevation of the dam (prior to the rehabilitation of the dam as described above). The reservoir capacity below the existing spillway (elevation of 1,040.5 ft) is the appropriate parameter for determining the current available capacity for meeting the sediment volume requirements for the dam. We have updated that sediment history table for Devil's Gate Dam by providing an additional column with the relevant capacity data for the reservoir for those years after the dam was rehabilitated (Attachment C). The current capacity in the reservoir below the spillway is 1.3 mcy. This is only 32.5 percent of the required storage capacity and only 65 percent of one DDE. Please note that additional sediment deposits and accumulates within the reservoir easement above elevation 1,054 ft. that is not reported on Attachment C. Attachment E provides graphical representation of the reservoir profile (based on most current survey data) showing the accumulation of sediment above the spillway elevation towards the back of the reservoir. This accumulated sediment has the potential to be washed toward the dam during significant storm events and further reduce the available capacity below the spillway.

What would be the specific impacts downstream if Devil's Gate Dam were not able to contain one DDE? How does Public Works determine the degree of flood threat? And what areas are most likely to be impacted?

With the current, limited capacity of the reservoir, a 50-year storm event that results in a DDE would result in storm flows with sediment flowing over the spillway. Flooding with mud/sediment would occur along the portions of the Arroyo Seco in the Cities of Pasadena, South Pasadena, and Los Angeles, impacting approximately 650 parcels and requiring closure of the 110 Freeway from Orange Grove Avenue to the 5 Freeway. Additional information about the potential flood areas and analysis are shown in the Arroyo Seco Channel Hydraulic Analysis prepared by Bureau Veritas North America, Inc. available on the Project Website and on a map included as Attachment D. Please note that protocols are in place to monitor storms, reservoir conditions, and channel conditions and to communicate with emergency responders and Caltrans to execute any necessary evacuations or freeway closures.

Devil's Gate Reservoir Sediment Accumulation

ATTACHMENT A



Devil's Gate Reservoir Sediment Event History

1920	LA County Flood Control District completes construction of the dam.
1934	The Brown Mountain Fire burns 3,550 acres above the watershed above the dam. 800,000 CY is deposited in the reservoir.
1935	An additional 200,000 CY is deposited in the reservoir.
1938	**Historic Storm Event/Sediment Event** -1.7 MCY of sediment is deposited in the reservoir-the majority was most likely delivered by the March 1938 storm. The 24 hour rainfall intensity was greater than a 50 year event.
1939-42	**Historic Sediment Event** - Approximately 1.5 MCY is deposited in the reservoir, the two largest storms of this period occurred in February and March 1941. 7 years after the burn.
1943	An additional 500,000 CY is deposited in the reservoir. The 9 year total after the burn is approximately 4.7 MCY. 3.7 MCY from years 4 thru 9 after the burn (analogous to where we are now with Station Fire recovery- year 4)
1959	Woodwardia Fire burned 1/3 of the watershed above the dam
1959-62	900,000 CY was deposited in the reservoir.
1966	The Cloudburst Fire burned 27 acres of watershed above the dam. An additional 900,000 CY was deposited in the reservoir.
1969	**Historic Storm Event** - Approximately 1.1M CY deposited in the reservoir 10 years after the last major fire. All three of the dam's valves were buried and/or clogged during this storm. The 24 hour rainfall intensity was approximately a 50 year event.
1971-83	Storms deposited an additional 2.2 MCY in the reservoir.
2009	Station Fire burned nearly the entire undeveloped watershed tributary to the dam.
2010	Storms deposit 936,000 CY in the reservoir since the fire.
2011	Storms deposit an additional 394,000 CY in the reservoir.

ATTACHMENT C

UPDATE TO SEDIMENT STRATEGIC PLAN DOCUMENT
LOS ANGELES COUNTY DEPARTMENT OF PUBLIC WORKS
DEVIL'S GATE RESERVOIR SEDIMENT HISTORY

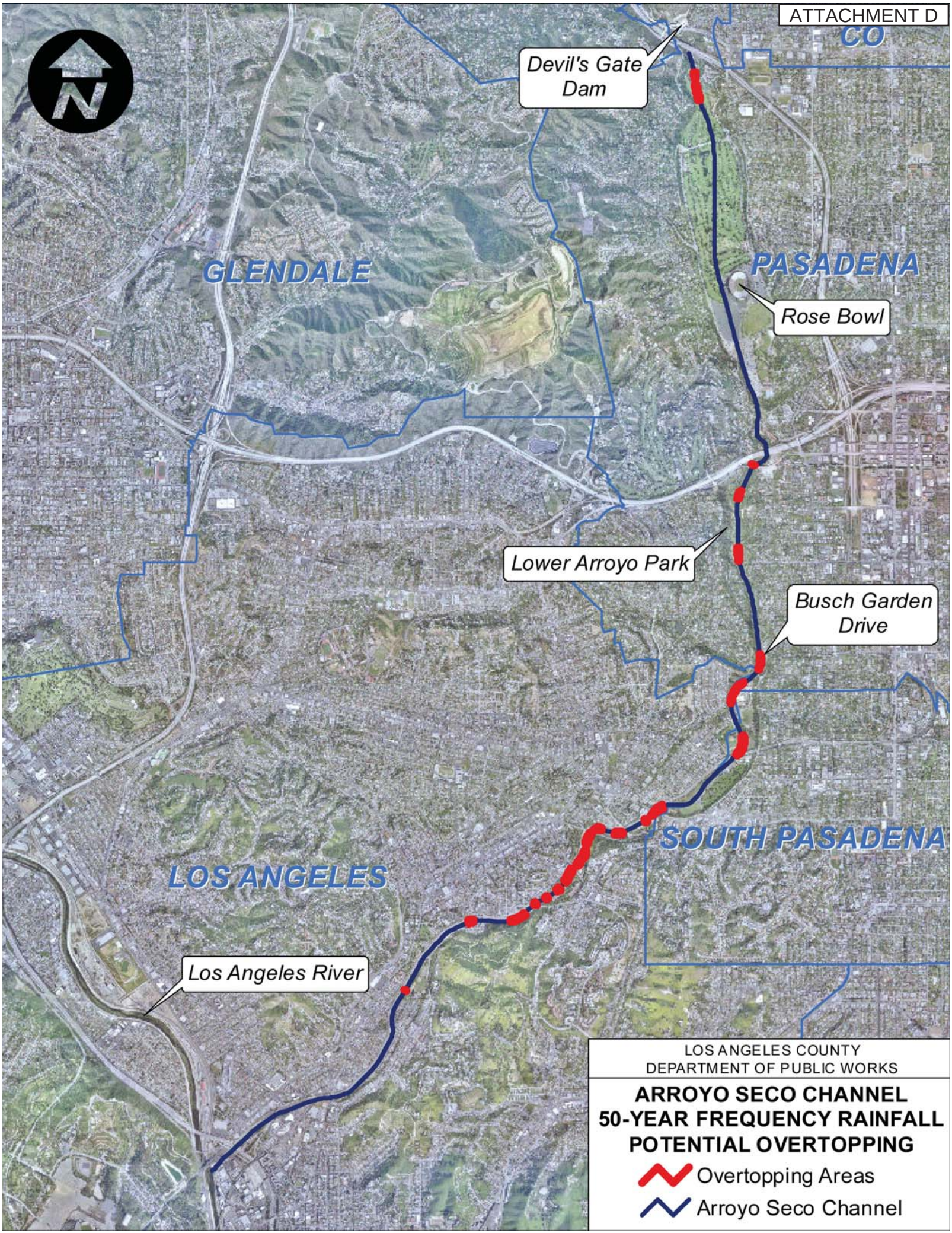
Date		Reservoir Capacity (CY)		Quantity Sluiced (CY)	Quantity Excavated (CY)	Accum. Sediment Removed (CY)	Sediment Deposited* (CY)	Cumulative Sediment Production* (CY)	Sediment in Storage* (CY)
		El. 1,054 ft	El. 1,040.5 ft						
October	1919	7,422,945	N.A.	-	-	-	-	-	-
September	1934	6,658,225	N.A.	-	75,827	75,827	840,546	840,546	764,720
June	1935	6,446,879	N.A.	-	-	75,827	211,347	1,051,893	976,066
June	1938	4,786,759	N.A.	-	-	75,827	1,660,120	2,712,013	2,636,186
January	1942	4,401,172	N.A.	1,038,986	38,720	1,153,533	1,463,293	4,175,306	3,021,773
December	1943	4,039,786	N.A.	104,867	29,040	1,287,440	495,293	4,670,599	3,383,159
Fall	1948	4,131,746	N.A.	121,000	74,213	1,482,653	103,253	4,773,852	3,291,199
July	1952	4,252,746	N.A.	413,013	137,133	2,032,800	429,147	5,202,999	3,170,199
September	1955	4,370,519	N.A.	-	117,773	2,150,573	-	5,202,999	3,052,426
December	1959	4,580,252	N.A.	-	282,333	2,432,906	72,600	5,275,599	2,842,693
May	1962	4,436,666	N.A.	-	695,347	3,128,253	838,933	6,114,532	2,986,279
September	1966	4,191,439	N.A.	82,280	595,320	3,805,853	922,826	7,037,359	3,231,506
February	1969	3,397,679	N.A.	-	32,267	3,838,119	826,026	7,863,385	4,025,266
March	1969	3,024,999	N.A.	-	-	3,838,119	372,680	8,236,065	4,397,946
November	1969	3,229,893	N.A.	191,987	12,907	4,043,012	-	8,236,065	4,193,052
December	1971	3,110,506	N.A.	-	230,707	4,273,719	350,093	8,586,158	4,312,439
October	1973	3,526,746	N.A.	-	472,707	4,746,426	56,467	8,642,625	3,896,199
March	1977	4,036,559	N.A.	-	745,360	5,491,786	235,547	8,878,171	3,386,386
March	1978	3,968,799	N.A.	-	240,387	5,732,172	308,147	9,186,318	3,454,146
July	1978	3,926,853	N.A.	-	-	5,732,172	41,947	9,228,265	3,496,093
December	1978	4,433,439	N.A.	-	506,587	6,238,759	-	9,228,265	2,989,506
February	1979	4,343,092	N.A.	253,293	122,613	6,614,665	466,253	9,694,518	3,079,853
March	1980	4,501,199	N.A.	-	453,347	7,068,012	295,240	9,989,758	2,921,746
July	1981	4,628,652	N.A.	-	321,053	7,389,065	193,600	10,183,358	2,794,293
September	1982	4,549,599	N.A.	-	96,800	7,485,865	175,853	10,359,211	2,873,346
April	1983	4,476,999	N.A.	-	53,240	7,539,105	125,840	10,485,051	2,945,946
June	1988	4,630,266	N.A.	-	204,893	7,743,998	51,627	10,536,678	2,792,679
February	1992	4,799,666	N.A.	-	169,400	7,913,398	-	10,536,678	2,623,279
July	1992	4,657,692	N.A.	-	-	7,913,398	141,973	10,678,651	2,765,253
April	1993	4,683,506	N.A.	-	-	7,913,398	104,867	10,783,518	2,870,119
November	1995	4,936,799	2,345,786	-	193,600	8,106,998	-	10,783,518	2,676,519
April	2009	4,785,146 **	2,178,000	-	24,200	8,131,198	175,853	10,959,371	2,828,173
April	2010	3,994,613 **	1,535,893	-	-	8,131,198	790,533	11,749,904	3,618,706
March	2011	3,723,573 **	1,331,000	-	-	8,131,198	271,040	12,020,944	3,889,746
			Totals	2,205,426	5,925,772	8,131,198	12,020,944	12,020,944	3,889,746

NOTE:

* The deposited, cumulative, and storage sediment quantities are based on capacity below the original spillway at Elevation 1054. Please note, additional sediment deposits and accumulates within the reservoir easement above this elevation.

** These values are provided, however, the relevant capacity is provided in the next column as the capacity below the currently spillway elevation of 1040.5 feet. The spillway was enlarged with a lower elevation in 1997.

ATTACHMENT D



ATTACHMENT E

DEVIL'S GATE RESERVOIR
SEDIMENT HISTORY PROFILE

NOT TO SCALE