Attachment 6 – Monitoring, Assessment, and Performance Measures

6.1 Overview

This attachment presents project monitoring, assessment, and performance measures that would be used to quantify and verify the performance of the Chabot Dam Seismic Upgrade Project with respect to its benefits and objectives. The information in this attachment would go into a monitoring plan that would be developed if the grant application is successful.

The Chabot Dam Seismic Upgrade Project consists of the following principal work elements:

- *Dam (Embankment) Retrofit.* There are two construction options for the embankment retrofit: (a) an earthwork option, and (b) a cement deep soil mixing (CDSM) option. In the earthwork option, the dam would be improved by excavating soils vulnerable to strength loss during an earthquake, mixing and moisture conditioning the excavated soils to near optimal water content, and then placing and compacting them in the excavation. This would improve the strength of the soil and thereby improve the seismic performance of the dam. This option requires the installation of a temporary dewatering system to maintain safe slope stability during excavation. In the CDSM option, soils would be mixed with cement and water in-place to form a system of interconnected walls that would contain the liquefiable soils and thereby improve the seismic performance of the dam.
- *Outlet Tower Retrofit.* The outlet tower would be improved by lining the shaft, moving the valves and controls from the tower to the shaft, and relining or installing new outlet pipes from the shaft to the reservoir.

The following discussion notes the following:

- *What.* What elements would be tracked.
- *Why.* The reason(s) why certain parameters are being monitored.
- *When.* The timing, frequency and duration of the monitoring.
- *Where.* The location of the monitoring site(s).
- *Who.* The responsibility for data collection, analysis and reporting.

What:

Monitored elements to be considered in the planned monitoring, assessment and performance measures would include:

- Hydrology
- Water Quality

Why:

The monitoring tasks included in the planned monitoring, assessment, and performance measures would guide project operations and aid measurement of specific project performance criteria.

When:

Project evaluation monitoring would be conducted:

- Pre-construction, assuming that construction begins in the fall of 2014, and in light of the assumed grant agreement date of August 2013, it is assumed that monitoring would commence in early 2014.
- During construction, as necessary to monitor compliance with design parameters.
- Post-construction, until such time as the achievement of the project's objectives has been demonstrated (or as set forth in the grant agreement).

Where:

Selection of monitoring sites is a critical step in developing the monitoring, assessment and performance measures. The selected monitoring sites for the project would be located:

- Upstream of the existing reservoir pool area.
- Within the area of the work (the project area).
- Downstream of the project.

Who:

The planned project monitoring, assessment, and performance measures would define who would be responsible for the various elements of the monitoring activities. These elements would include:

- Equipment acquisition and maintenance
- Quality assurance and quality control (QA/QC)
- Data collection
- Chain of custody for lab samples
- Data organization
- Data analysis / lab testing and evaluation
- Reporting
- Information dissemination
- Review and approval

EBMUD would have the overall monitoring responsibility. Assistance could be provided by consultants, if used, to assist as part of the construction management effort.

Monitoring Plan. EBMUD would develop a monitoring plan and prepare a cost estimate for said monitoring.

Field Monitoring. EBMUD would implement monitoring plan activities, organize monitoring data into the acceptable format, and conduct QA/QC checks of the data.

Data Analysis/Lab Testing and Evaluation. EBMUD would analyze samples collected (including performance of lab tests at its in-house laboratory facilities) and would also review data and report the monitoring results. In addition, EBMUD would conduct performance evaluation(s) as needed to verify the project's performance.

Database Management. EBMUD would have the Project manager assign a staff person to act as the database coordinator. He or she shall have the duty to oversee the collection, storage, and dissemination of the data (to better ensure that the data management and deliverables are consistent with the Bay Area IRWMP standards).

Upon completion of the work, the collected data, along with its associated quality assurance/quality control information, would be provided to the State in a format that could be easily integrated into statewide data collection and tracking programs. As appropriate, the following statewide data collection programs may be referenced:

- California Environmental Resources Evaluation System (CERES), an information system developed by the California Resources Agency to facilitate access to natural resources data.
- California Environmental Data Exchange Network (CEDEN), a website developed by the State for coordinated data sharing.

6.2 Project Goals and Objectives

Lake Chabot is an important element of EBMUD's system of reservoirs and delivery network in that it serves as a local source of water in times of emergency. Further, the Lake provides important flood protection, environmental and recreational features to residents of the eastern portion of the greater San Francisco Bay region.

The project's goal is to eliminate the risk of damage to the dam that could hinder its operation following a large earthquake. The project's objectives, which would be achieved by implementing the seismic upgrade, are to:

- Reduce the flood hazard for residents and businesses that lie downstream of the dam.
- Preserve the recreational resources as established over time with the creation of the dam and the development of the adjacent park features.
- Enable the reservoir to continue to serve as a means to capture sediment that is entrained in the runoff leading into the Lake, preventing it from moving further downstream, potentially damaging environmental features as associated with lower portions of the creek / the San Francisco Bay.
- Maintain the reservoir for EBMUD's use as a water supply feature that could be activated in the event of an emergency.

6.3 Performance Measures

Tables have been developed to summarize performance measures that would be used to quantify and verify project performance with respect to the project goal and two of the objectives identified above

(i.e., reduce the flood hazard and continue to serve as a means to capture sediment (i.e., water quality benefit).

Reduce Flood Hazard

Table 6.1 and the following discussion summarizes how monitoring data and measures would be used to evaluate project performance in meeting the overall goals and objectives of the Bay Area IRWMP.

In terms of the flood hazard benefit of the project, reducing the flood damage to downstream property owners would be the desired outcome. Since flood damage reduction is achieved by way of flood detention, the flow hydrograph below Lake Chabot dam, the peak flow downstream of the dam, and the extent of floodplain inundation are selected as the output indicators (or measures to effectively track output). The attenuated flow hydrograph below the dam, the reduced peak flow downstream, the reduced extent of floodplain inundation, and the reduced flood damage (i.e., event benefit) relative to the without-Project conditions are selected as the outcome indicators to evaluate the change that is a direct result of the project. These output and outcome indicators, particularly for the without-Project conditions, cannot be directly measured. As such, the following analysis would be conducted:

- Hydrologic modeling to simulate water levels of Lake Chabot and the flow hydrograph downstream under without-Project conditions and compare those with the observed data under the with-Project conditions (modeling tool: HEC-HMS).
- Hydrologic modeling to simulate the flood extent and depth for both with- and without-Project conditions (modeling tool: MIKE FLOOD).
- Floodplain inundation mapping for both with- and without-Project conditions (mapping tool: GIS).
- Flood damage analysis for both with- and without-Project conditions (method as described in Attachment 7, *Technical Justification of Projects*).

The simulated flows developed through the hydrologic modeling would be used as flow inputs for the hydraulic modeling. The simulated flood extent and depth developed through the hydraulic modeling would be used to conduct floodplain inundation mapping and flood damage analysis.

Table 6.1: Lake Chabot Seismic Upgrade Project Performance Measures: Flood Hazard Benefit

Project Goal	• Reduce flood damage downstream
Bay Area IRWMP Goals and Objectives Met by Project (Refer to the Table in Section 1.11 of Attachment 3, *Work Plan*	• A – Consider and address disproportionate community impacts; • B – Minimize vulnerability of infrastructure to catastrophes • C – Control excessive erosion, manage sedimentation • E – Maintain performance of flood control facilities
Desired Outcomes	• Reduce peak discharge to San Leandro Creek • Reduce flood damage downstream
Output Indicators (Measures)	• Flow hydrograph below Lake Chabot dam • Peak flow downstream of dam • Extent of floodplain inundation
Outcome Indicators (Measures)	• Attenuated flow hydrograph below Lake Chabot dam relative to the without-Project condition • Reduced peak flow downstream of dam relative to the without-Project condition • Reduced extent of floodplain inundation relative to the without-Project condition • Reduced flood damage relative to the without-Project condition
Measurement Tools and Methods	• HEC-HMS hydrologic modeling • MIKE FLOOD hydraulic modeling • GIS floodplain inundation mapping Flood damage analysis (method: as described in Attachment 7, Economic Analysis)
Targets	• Reduce the 0.1-percent change-annual flood (or 1000-year flood) by up to 8,262 cfs downstream of the dam Reduce the 1-percent-chance-annual flood (or 100-year flood) by up to 5,021 cfs downstream of the dam • Reduce the 10-percent change-annual flood (or 10-year flood) by up to 3,689 cfs downstream of the dam Source: *San Leandro Creek Inundation Modeling Memorandum, AECOM, January 18, 2013.* (included as Appendix 6.1)

Water Quality Benefit

Table 6.2 and the following discussion summarize how monitoring data and measures would be used to evaluate project performance in meeting the overall goals and objectives of the Bay Area IRWMP.

In terms of the water quality benefit of the project (i.e., continue to keep the dam in place to allow it to act as a means to capture sediment / prevent its downstream transport), the following analysis would be conducted:

- Water quality sampling upstream of Lake Chabot during a significant rainfall event, to collect and measure turbidity as present in the runoff/streamflow (Total Suspended Solids (TSS) laboratory testing).
- Water quality sampling downstream of Lake Chabot during a significant rainfall event, to collect and measure turbidity as present in the runoff / streamflow (Total Suspended Solids (TSS) laboratory testing).

Table 6.2: Lake Chabot Seismic Upgrade Project Performance Measures: Water Quality Benefit

Project Goal	• Provide a Water Quality Benefit
Bay Area IRWMP Goals and Objectives Met by Project (Refer to the Table in Section 1.11 of Attachment 3, *Work Plan*	• D - Minimize point and non-point source pollution.
Desired Outcomes	• Reduce sediment loading in San Leandro Creek downstream of the dam
Output Indicators (Measures)	• Sediment load in San Leandro Creek upstream of the reservoir • Sediment load in San Leandro Creek downstream of the reservoir
Outcome Indicators (Measures)	• Reduced sediment loading in San Leandro Creek downstream of the reservoir
Measurement Tools and Methods	• Water quality sampling and laboratory test results for TSS
Targets	• Illustrate significant (greater than 50% lower) TSS levels in the creek during storm events less than the 100 year storm

6.4 Monitoring Systems

Table 6.3 is a summary of the monitoring plan. Flow and sediment loading would be measured upstream of the lake and downstream of the dam (see Figure 6.1). EBMUD has a recently installed a stream gauge just upstream of Lake Chabot at the Willow Creek Golf Course. This location would be used as the upstream sample point, and has been selected such that the lake level would not create backwater effects on the measurement devices.

For the downsteam monitoring location, two options are available. The first location is at the outlet of the dam's spillway, where outflows from the reservoir are currently monitored. This existing station could be modified to include sediment loading measurement. The second downstream monitoring location is an Alameda County Flood Control District stream gage between 98th Avenue and Interstate 880 that is currently accessed by EBMUD for flow readings. This existing location could also be modified to include sediment loading measurement. Either or both of these downstream locations could be utilized for the monitoring effort.

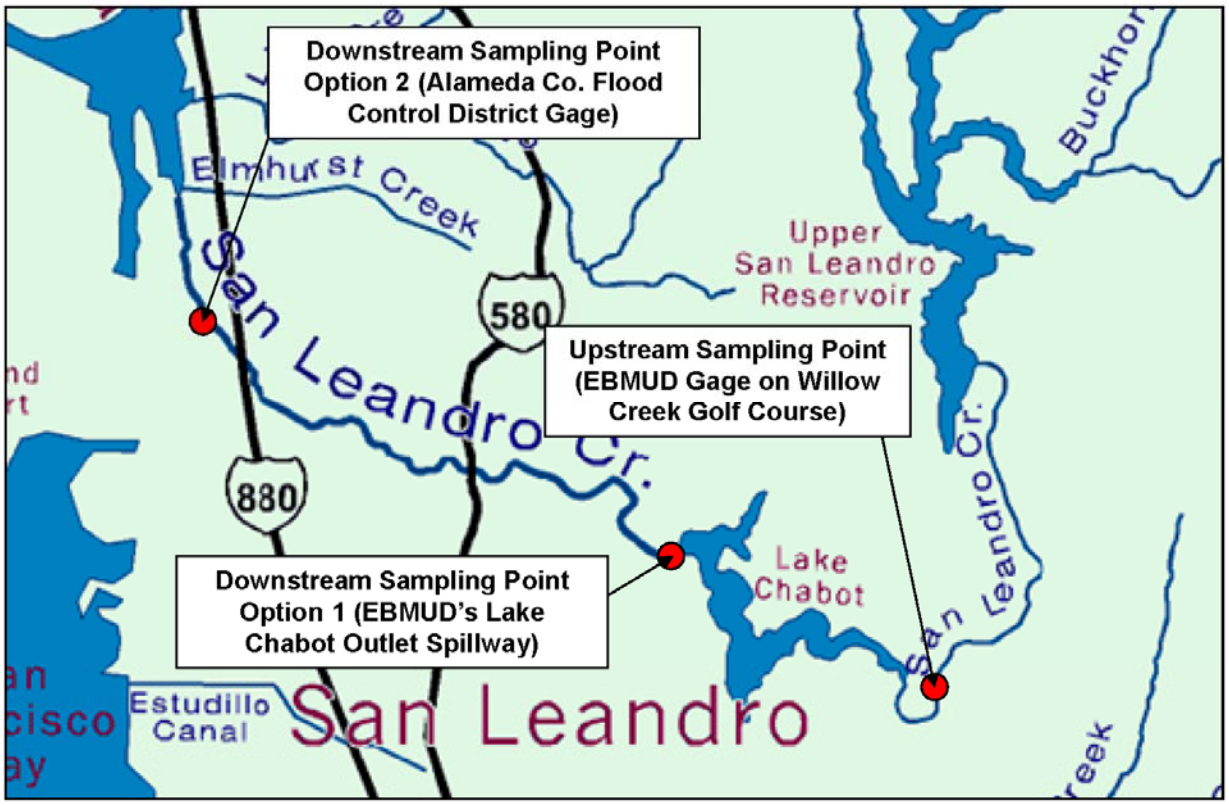

Figure 6.1: Stream Gage Locations

Table 6.3: Summary of Monitoring Plan for the Lake Chabot Seismic Upgrade Project

	Description
What	• Hydrology (streamflow) • Water Quality (sediment loading / TSS level)
Why	• Provide data for hydrologic modeling analysis as needed for evaluation of project performance • Provide data for water quality / sediment capture evaluation
When	• Continuous streamflow in the wet season (post construction) • Sampling during a storm (rainfall) event (post construction)
Where	• Upstream of Lake Chabot • Downstream of Lake Chabot
Who	• EBMUD

6.5 Data Analysis, Evaluation, and Reporting

In regard to the Flood Reduction benefit and the water quality (sediment load reduction) benefit, analysis, evaluation and reporting would be conducted in flood (wet) years to evaluate project performance. The flood year report would contain the following elements:

- Introduction (Background and Objectives)
- Project operations in the wet season
- Streamflow monitoring results in the wet season
- Water quality (sediment loading) results during a sampled storm event
- Hydrologic modeling
- Hydraulic modeling and floodplain mapping
- Flood damage analysis
- Evaluation of project performance (from both a flood damage reduction perspective and a sediment capture perspective)

Appendix 6.1: San Leandro Creek Inundation Modeling Memorandum, AECOM, January 18, 2013

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Memorandum

To	Priyanka Jain, PE	Page	1 of 12
CC	Joe Tam		
Subject	San Leandro Creek Inundation Modeling		

From	Joseph E. Thomas
Date	January 18, 2013

Introduction

On January 10th, East Bay Municipal Utility District (EBMUD) contracted AECOM to perform a hydrologic and hydraulic (H&H) analysis showing the benefits of a proposed seismic upgrade to the Lake Chabot dam located in the San Leandro Watershed, Alameda County, CA. The H&H analysis examines flooding downstream of Lake Chabot with and without the dam. The baseline condition or 'no project' condition assumes the seismic upgrades are not implemented and the dam is removed. The 'with project' condition assumes the dam is upgraded and continues to provide the same flood reduction benefits as the existing dam. The results of this study will be used in an economic benefit-cost analysis.

Scope of Services

AECOM will deliver the following no later than the close of business on January 18, 2013:

1. Hydraulic Model input and output files analyzing at least three flood scenarios for the Without and With (Lake Chabot) Dam Conditions
2. Digital Maps of inundated areas for each scenario and supporting geospatial information system (GIS) data files
3. Technical Memorandum describing the input parameters, assumptions, and references/sources of data.

Subsequent correspondence with EBMUD prior to the 18th of January indicated that the client would like the structures crossing San Leandro Creek included and that a delivery on the 22nd of January would be acceptable.

Terrain Processing

EBMUD provided AECOM with 2 foot (ft) interval contour data for Alameda County and 10 ft contour data for Alameda and Contra Costa County. The Alameda County 2 ft interval contour data was clipped to a localized scale specific to the hydraulic needs of the project. The contour data was converted to 3d using the ESRI 3d Analyst extension. This process embeds the elevation value from the attribute table into the spatial characteristics of the feature. The 3d data was imported into the Watershed Information System (WISE) computer model for surface model development. WISE produced a Triangular Irregular Network (TIN) and corresponding gridded Digital Elevation Model (DEM) sampled from the TIN. The TIN surface served as the source for elevation takeoffs, mapping floodplain boundaries and other hydraulic analyses. The WISE TIN is a binary file type and cannot be

easily viewed using GIS platforms. The 5 ft resolution DEM created from the TIN serves as the visualization surface model and was used to inspect the surface for continuity and anomalies. The 5 ft resolution DEM is included in the digital data submittal.

Hydrology

Due to the compressed schedule of this study, AECOM advised that conducting a full hydrologic study would not be feasible. AECOM recommended that only peak discharges be developed to support the hydraulic analyses. EBMUD concurred with the recommendation.

Without Dam Condition (Baseline)

Lake Chabot Dam was built in the late 1800s. Due to age of the dam, there are no reliable pre-construction hydrologic records available. For the Without Dam Condition, discharges were calculated using the Waananen and Crippen California regression equations (WRIR 77-21). The parameters used for this regression equation are shown in Table 1, and the basin layout is shown in Figure 1. Two parameters used in this regression equation are the elevation at 10% and 85% of the channel length between the discharge site and the basin divide. For Basins SL-2, SL-3, and SL-4, the location 10% of the distance to the basin divide was within one of the two reservoirs. In each case, the elevation was linearly interpolated between the contours at the upstream end of the lake and below the dam. Mean annual precipitation was obtained from the PRISM Climate Mapping Project (Daly 2009). A shapefile consisting of the mean annual precipitation from 1961-1990 was clipped to the watershed boundary and the area weighted average was used to determine the mean annual precipitation for each subbasin.

Table 1: Waananen and Crippen Regression Parameters

Subbasin	Drainage Area (mi^2)	Mean Annual Precipitation (inches)	Elevation at 10% (ft)	Elevation at 85% (ft)
SL-1 (Watershed Outlet)	46.1	23.7	28	530
SL-2 (MacArthur Freeway)	43.0	23.8	135.5	600
SL-3 (Chabot Dam)	42.1	23.8	192.9	615
SL-4 (Upper San Leandro Reservoir)	30.3	24.1	329.7	726

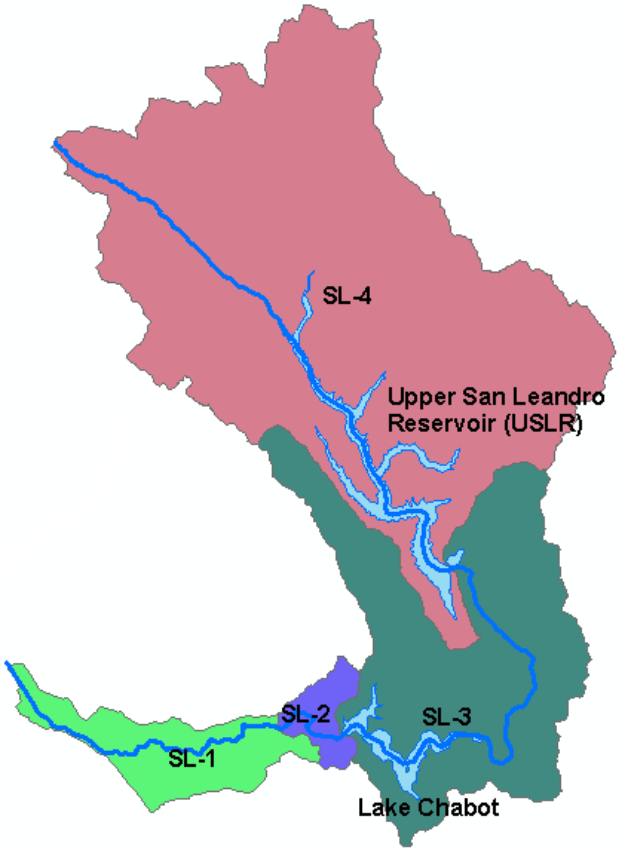

Figure 1: Basin Layout

The Waananen and Crippen regression equations provide flow rates (discharges) for recurrence intervals from 2 years to 100 years. The discharges calculated for these basins are shown in Table 2. A logarithmic curve was fit to the discharge data to determine the 500 and 1,000 year flood. Figure 2 shows the discharges and regression lines for each discharge break on San Leandro Creek. The unregulated discharge from a 1970 U. S. Army Corps of Engineers (USACE) report on channel improvements on San Leandro Creek (USACE 1970) is also included. These discharges were based on a stream gage on nearby San Lorenzo Creek.

Table 2: Waananen and Crippen Regression Discharges

Basin	Q2	Q5	Q10	Q25	Q50	Q100	Q500	Q1000
SL-1	2,614	5,062	6,775	8,991	10,906	12,478	16,613	18,362
SL-2	1,823	3,842	5,359	7,390	9,183	10,743	14,371	15,956
SL-3	1,616	3,505	4,958	6,926	8,679	10,230	13,697	15,228
SL-4	914	2,147	3,160	4,579	5,862	7,068	9,468	10,562

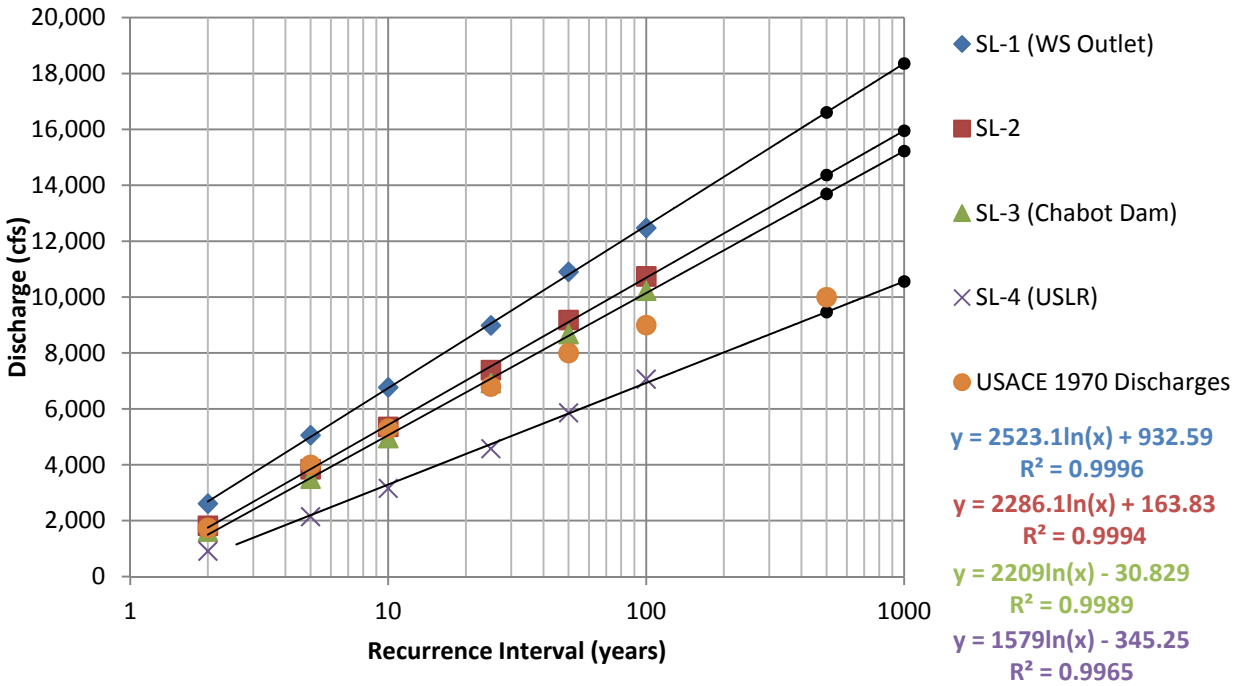

Figure 2: San Leandro Creek Discharges without Chabot Dam (WRIR 77-21)

To estimate the Lake Chabot flood reduction benefits, the approximate flood attenuation effects of Upper San Leandro Reservoir (USLR) were assessed. AECOM analyzed two storm hydrographs (April 1958 and October 1962) from the San Leandro Creek Study (USACE 1970). During the April 1958 flood event, the 6,000 cfs peak inflow to the USLR was attenuated to 1,530 cfs downstream of the USLR Dam. On this hydrograph, it was noted that "both reservoirs [were] full and spilling over 'free overflow' spillway at onset of storm runoff" (USACE 1970). For the October 1962 event, the peak inflow was attenuated from 9,800 cfs to 5,500 cfs. Flood storage below the spillway was not a factor in the development of this hydrograph as well – "reservoirs assumed to be full at onset of storm runoff". The flood hydrographs are shown in Figure 3 with data provided in Table 3.

Table 3: Reduction in Historic Peak Flows at Upper San Leandro Reservoir

Flood Event	Peak Inflow (cfs)	Peak Outflow (cfs)	Reduction in Peak Flow (cfs)	Reduction in Peak Flow (percent)
April 1958	6000	1530	4470	74.5%
October 1962	9800	5500	4300	43.9%

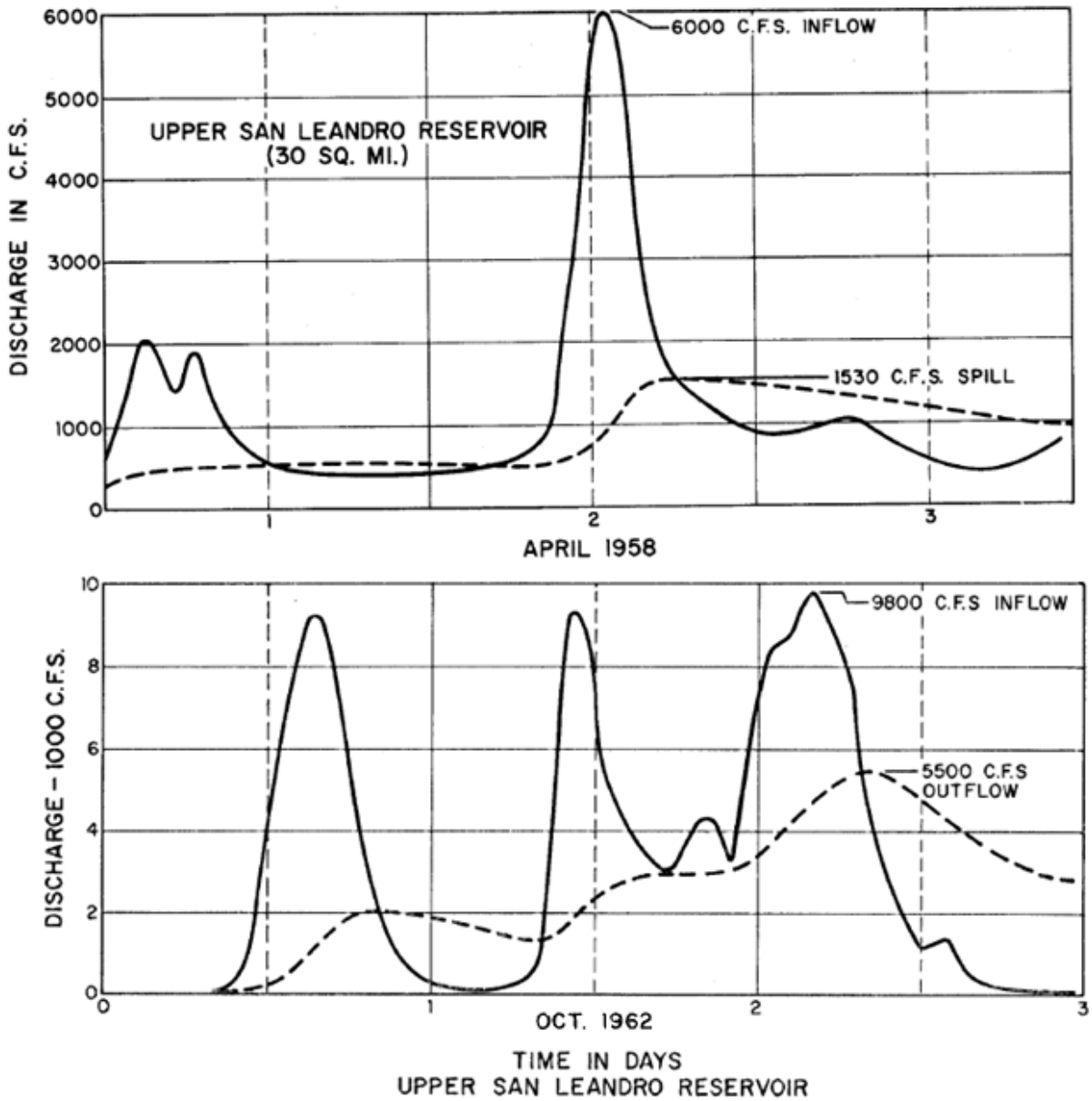

Figure 3: Flood Hydrographs for Upper San Leandro Reservoir (USACE 1970)

A relationship between the inflow to the USLR and the reduced outflow is shown graphically in Figure 4. It was assumed that small flood peaks will generally be mitigated by more than large events. This effect was applied on a percentage basis. Between 0 and 6,000 cfs, the flow is reduced between 70% and 74.5%. Between 6,000 and 9,800 cfs, the flow is reduced between 74.5% and 43.9%. Above 9,800 cfs, the reduction is assumed to be capped at 4,300 cfs.

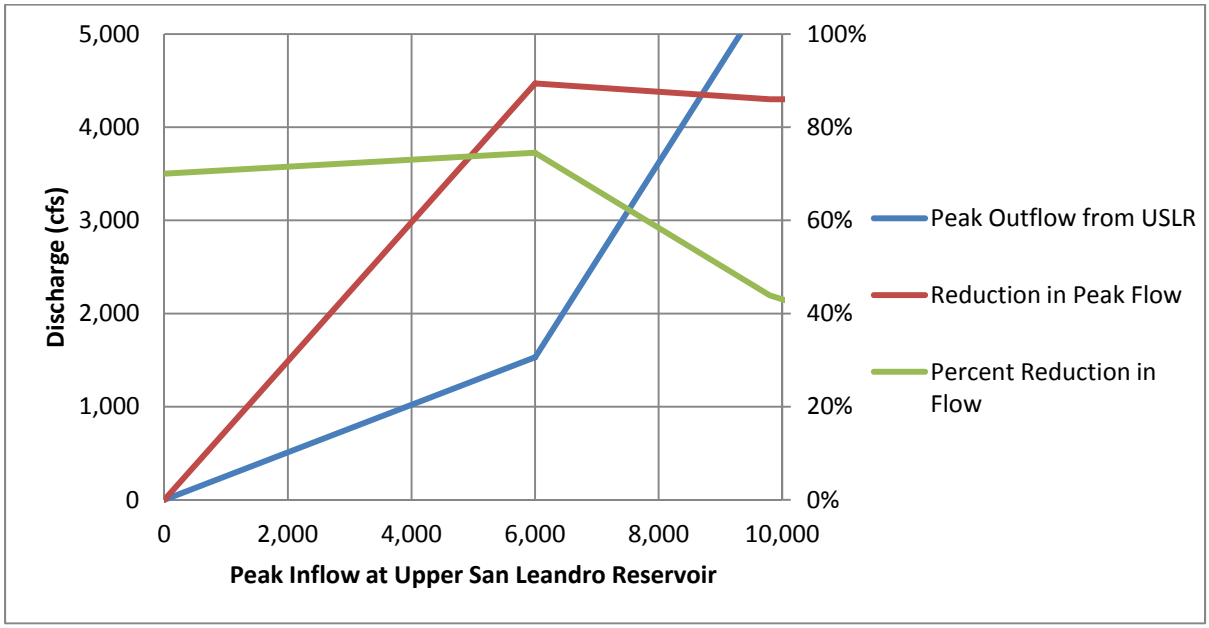

Figure 4: Reduction in Peak Flows at Upper San Leandro Reservoir

These flow reductions were applied to the Waananen and Crippen regression discharges at SL-4, and then routed down to each successive basin break. The reduced flows are shown in Table 4 and Figure 5.

Table 4: Reduced Peak Flows Due to Upper San Leandro Reservoir

	Q2	Q5	Q10	Q25	Q50	Q100	Q500	Q1000
SL-4 Regression Flows (cfs)	914	2,147	3,160	4,579	5,862	7,068	9,468	10,562
Percent Reduction	96.1%	90.9%	86.6%	80.5%	75.1%	65.9%	46.6%	40.7%
Decrease in Peak Flow (cfs)	(879)	(1,951)	(2,735)	(3,688)	(4,402)	(4,657)	(4,408)	(4,300)
SL-4 Reduced Peak Flow (cfs)	268	610	873	1,217	1,501	2,411	5,060	6,262
SL-3 Reduced Peak Flow (cfs)	969	1,967	2,671	3,563	4,317	5,573	9,289	10,928
SL-2 Reduced Peak Flow (cfs)	1,177	2,305	3,073	4,027	4,822	6,086	9,963	11,656
SL-1 Reduced Peak Flow (cfs)	1,968	3,524	4,489	5,628	6,545	7,821	12,205	14,062

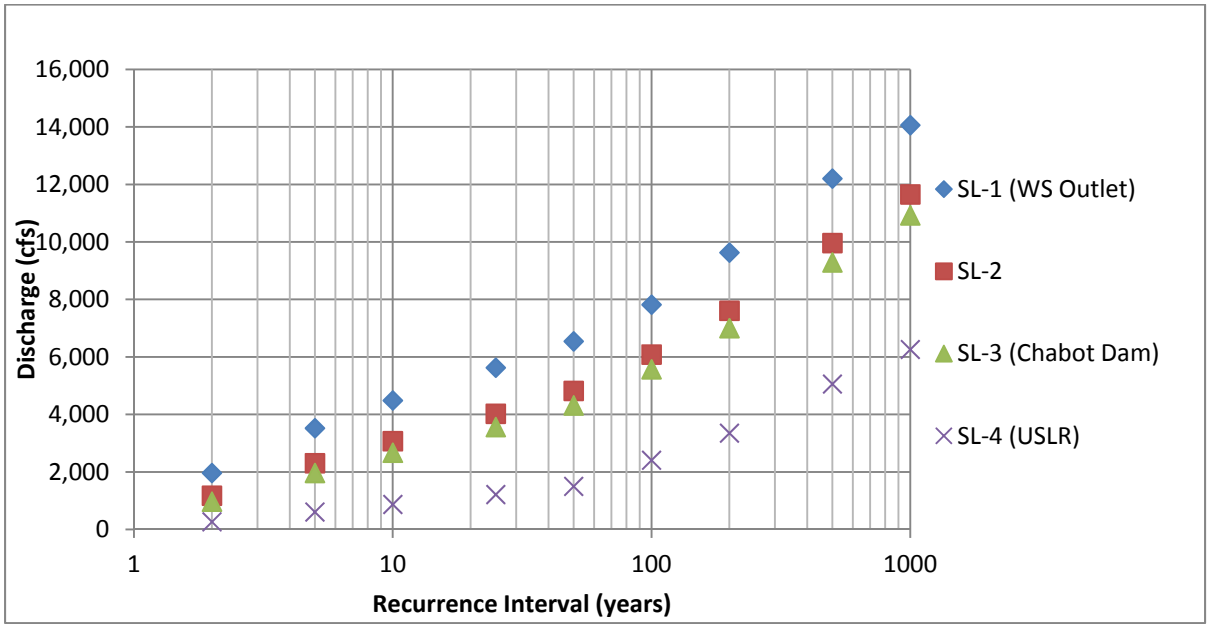

Figure 5: San Leandro Creek 'Without Lake Chabot', Waananen and Crippen discharges reduced by Upper San Leandro Reservoir

With Dam Condition

The peak flow rates published in the effective Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) (FEMA 2009) take into account reservoir storage and match the USACE's San Leandro Creek Design Study (USACE 1970). The regulated discharges at the mouth of the San Leandro Creek are shown in Table 5.

Table 5: Published Discharges for Current Conditions

	Q10	Q50	Q100	Q200	Q500	Q1000
FEMA FIS Discharges	800	2,000	2,800	*	4,800	*
USACE 1970 Discharges	800	2,100	2,800	3,600	4,800	5,800

* Data not available

Below Lake Chabot, the peak discharge should not increase significantly as the drainage area increases. The total drainage area downstream of the lake is 5.2 mi^2, or about 1/9th the total watershed area. Due to the amount of reservoir storage in the watershed, the lower portion of the watershed peaks well before the rest of the watershed. The April 1958 flood hydrograph (Figure 6; USACE 1970) shows that by the time the entire watershed peaks, the contribution from the lower portion is negligible, so there should be minimal change in peak flow downstream of the Lake Chabot Dam.

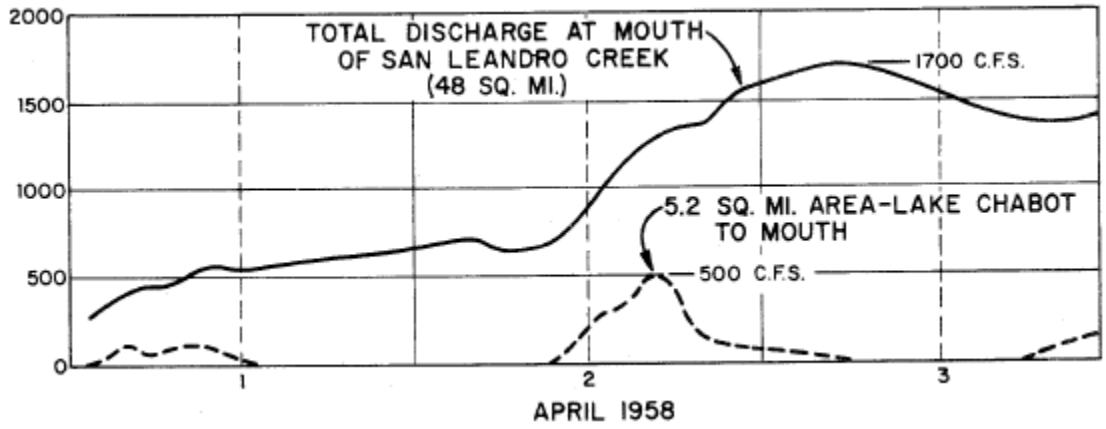

Figure 6: April 1958 Flood Hydrograph, Mouth of San Leandro Creek (USACE 1970)

In Figure 7, a logarithmic curve was fit to the discharge data to estimate recurrence intervals outside of the range of published flows. Because this curve resulted in negative discharges at recurrence intervals less than the 10 year flood, a quadratic curve was applied to estimate the discharges for more frequent events.

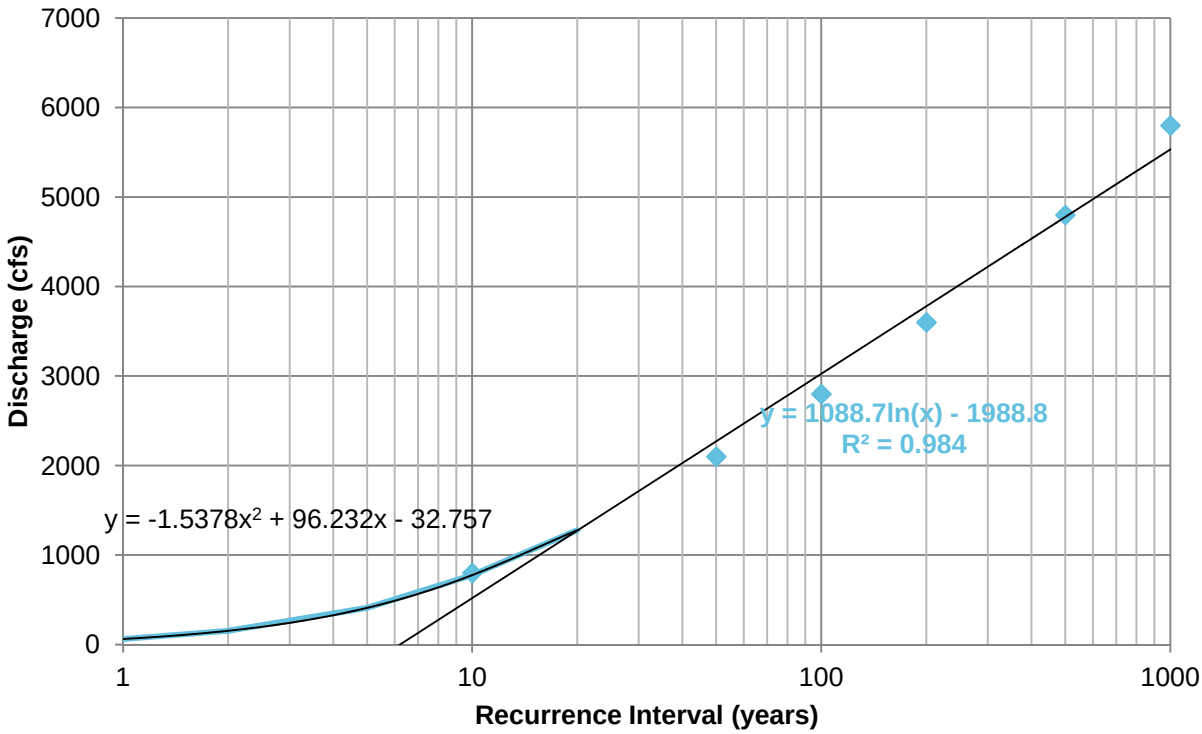

Figure 7: San Leandro Creek Discharges, With Lake Chabot Dam

Channel Capacity

The channel capacity was determined by applying Manning's equation to a representative cross section. It was determined that the capacity of the flood control channel was approximately 1774 cfs. This flow rate corresponds to the 50-percent-annual-chance flood in the 'without dam' condition. With Lake Chabot Dam in place, a flood of this same annual exceedance probability has a flow rate of approximately 154 cfs.

Hydrology Summary

The selected discharges from the Waananen and Crippen regression analysis and the USACE San Leandro Creek Report (1970) are shown in Table 6.

Table 6: Selected Discharges for San Leandro Creek

Condition	Basin	10% Annual Chance Event	1% Annual Chance Event	0.1% Annual Chance Event
With Dam	SL-1	800	2,800	5,800
	SL-2	800	2,800	5,800
Without Dam	SL-1	4,489	7,821	14,062
	SL-2	3,073	6,086	11,656

Hydraulics

The San Leandro Creek watershed consists of one reach identified to be studied by enhanced approximate methods. Field survey data was not included in the model such as surveyed cross sections and structures; however, strucuture data was acquired from as-builts and design drawings.. Table 7 lists the downstream and upstream limits of the flooding source. A location map showing the modelstream and cross section alignment for the studied stream is shown in Figure 8.

Figure 8: Study Area

Table 7: Flooding Sources Studied

Flooding Source	Reach Limits (Downstream)	Reach Limits (Upstream)	Length (mi.)
San Leandro Creek	Confluence with San Leandro Bay	Just downstream of Lake Chabot Dam	6.1

Methodology

Processing

The approximate study methodology incorporates WISE (Watershed Concepts) as a preprocessor to HEC-RAS (USACE 2010). WISE utilizes georeferenced data from the terrain model and miscellaneous shapefiles (including streams, cross sections, etc.) and with user input creates the input data files for HEC-RAS. HEC-RAS ver. 4.1.0 (USACE 2010) is then executed to determine the flood elevation at each cross section of the modeled stream. The resulting elevations are then imported back to WISE for creation of the flood boundaries. The techniques and tools utilized to perform the analyses meet FEMA's adopted standards. No individual community calculation criteria

were incorporated within this study. HEC-RAS Version 4.1 is the computer program used to build the hydraulic models.

Cross Sections
Model cross sections are placed along the San Leandro Creek corridor using the terrain data (described above). Initial placement was every 500 ft. This initial placement was refined based upon engineering judgment and interim model results. The HEC-RAS preprocessor within WISE samples the terrain data to generate the HEC-RAS model geometry for the channel and floodplain.

Hydraulic Structures
East Bay Municipal Utility District supplied as-built drawings for the below crossings of San Leandro Creek:

Table 8: Hydraulic Structures on San Leandro Creek

Structure	Stream Station*
Hegenberger Road	4,822
98th Avenue	6,947
South Pacific Railroad	9,732
Nimitz Freeway/I-880	10,189
Rail Road Tracks Transit	14,539
Alvarado Street	16,018
BART Railroad Tracks	16,615
San Leandro Boulevard	17,023
E 14th Street/CA-185	18,836
Bancroft Avenue	21,956
MacArthur Boulevard	25,528
MacArthur Freeway/I-580	25,650
Benedict Drive	25,785

* In feet above confluence with San Leandro Bay

These structures were added to the hydraulic model based on dimensions shown in these as-built drawings. Terrain data and aerial photography was used to assist in the placement of the structures. The terrain data was additionally used to develop HEC-RAS cross sections 2 and 3 for each structure. No field survey was conducted for this study. All structures were modeled using both the momentum and energy methods, as well as the Yarnell method if applicable.

Parameter Estimation
To estimate the Manning's roughness coefficients a land use polygon was acquired from the California Resources Agency – University of California Davis (CRA 2004). The polygons within the dataset were assigned roughness coefficients based off of the land use type. Table 9 indentifies the range of roughness coefficients used in this study.

Table 9: Summary of Manning's Roughness Coefficients

Flooding Source	Channel	Overbanks
San Leandro Creek	0.014-0.045	0.030-0.140

Modeling Considerations
The HEC-RAS computer model was run using a steady state flow analysis (peak discharge does not change in time). The downstream boundary (starting) condition for the San Leandro Creek model was set to mean higher high water (MHHW) equal to 6.6 ft NAVD at San Francisco Bay. No high water mark or other calibration data were available for the reach; therefore no model calibration was performed.

Mapping
Inundation boundaries were created using the WISE Raster mapping tool. This tool takes cross sections attributed with water surface elevations and generates a water surface elevation raster based upon a ground DEM. The resultant inundation boundaries were further cleaned by removing inundated areas that were not hydraulically connected to San Leandro Creek. The inundation maps are presented in the digital data.

Conclusion
Results from the HEC RAS model analysis can be digital data submittal. The inundation extents for each scenario in the 'with' and 'without dam' conditions are presented on the digital maps. The final results of the HEC RAS model hydraulic analyses are located with the digital data.

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