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# Los Angeles Basin Stormwater Conservation Study

## Task 4 Existing Infrastructure Response & Operations Guidelines Analysis

U.S. Department of the Interior
Bureau of Reclamation

County of Los Angeles
Department of Public Works

Los Angeles County
Flood Control District

U.S. Army Corps of Engineers
Los Angeles District

September 2014

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The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

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Cover Photo: Morris Dam along the San Gabriel River, Los Angeles County, California.

# Los Angeles Basin Stormwater Conservation Study

## Task 4. Existing Infrastructure Response & Operations Guidelines Analysis

September 2014

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# Acronyms and Abbreviations

| | |
|---|---|
| ac-ft | acre-foot (1 ac-ft = 43,560 $ft^3$). Variant (af) |
| CMIP5-BCCA | Bias Correction Constructed Analogue Coupled Model Intercomparision Project, Phase 5 |
| F-Table | Hydrologic Function Table |
| LA Basin Study | Los Angeles Basin Stormwater Conservation Study |
| LACFCD | Los Angeles County Flood Control District |
| LSPC | Loading Simulation Program in C++, synonymous with WMMS in this report |
| PMF | Probable Maximum Flood |
| RCP2.6 | Representative Concentration Pathway representing a future high mitigation scenario, with a mean radiative forcing value of 2.6 $W/m^2$ in the year 2100 |
| RCP8.5 | Representative Concentration Pathway representing a future “business-as-usual” scenario, with a mean radiative forcing value of 8.5 $W/m^2$ in the year 2100 |
| Reclamation | U.S. Department of the Interior, Bureau of Reclamation |
| USACE | U.S. Army Corps of Engineers |
| WMMS | Watershed Management Modeling System |

# Glossary

**Basin Study Watersheds (Study Area):** The Los Angeles River, San Gabriel River, South Santa Monica Bay, Ballona Creek, North Santa Monica Bay, Malibu Creek, and Dominguez Channel/Los Angeles Harbor watersheds.

**Capture Efficiency:** The ratio of total recharge captured versus the total stormwater potential at a specific facility. Potential combines both what was captured and what bypassed, representing the total possible amount of stormwater moving through a facility.

**Climate Projection:** A set of future weather projections (e.g. precipitation and evaporation) based on a single climate model. Task 4 uses 6 climate projections.

**F-Table:** Hydrologic function table. Used to simulate operations guidelines for stormwater facilities and is a generalized volume versus discharge curve. WMMS F-Tables control the discharge rate at specific volumes within the model.

**Future Period:** Projected water years 2012 through 2095.

**Historic Period:** Historic record, water years 1987 through 2000.

**LSPC:** Loading Simulation Program in C++, the hydrologic simulation program within WMMS.

**Operation Guidelines:** A set of recommended instructions that provide guidance on how to efficiently and safely operate a water conservation or flood control facility based on different stream or reservoir conditions.

**Probable Maximum Flood (PMF):** A flooding event that results from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region.

**Rating Curve:** Relationship between a reservoir water surface elevation or storage volume, and the outflow or discharge from a dam.

**Spaghetti Plot:** A method for viewing large amounts of data to help visualize select representative climate projections such as the controlling upper and lower bound, or most extreme climate cases.

**Spillway Event:** A storm event where the reservoir water surface elevation behind a dam is at or above the spillway crest elevation and is discharging flows.

**Water Control Manual:** USACE equivalent of dam operation guidelines.

**Water Year:** The 12-month period between October 1$^{st}$ through September 30$^{th}$ for any given year. Water years are written as the ending year (i.e., water year 1986-87 is written as 1987).

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# Executive Summary

The Los Angeles County Flood Control District (LACFCD) partnered with the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) to collaborate on the Los Angeles Basin Stormwater Conservation Study (LA Basin Study). The purpose of the LA Basin Study is to investigate long-range water conservation and flood risk impacts caused by projected changes in climate conditions and population in the Los Angeles region. The LA Basin Study will recommend potential modifications or changes in the operation of the existing stormwater capture systems as well as the development of new facilities that could help resolve future water supply and flood risk issues. These recommendations will be developed by identifying alternatives and conducting trade-off analyses.

For Task 4, Existing Infrastructure Response and Operations Guidelines Analysis of the LA Basin Study, Reclamation, the U.S. Army Corps of Engineers (USACE), and the LACFCD jointly analyzed the major components of the water conservation and flood risk mitigation system. For the analysis, Reclamation assessed the 14 major LACFCD dams and reservoirs, USACE analyzed their 4 major flood control dams in the region, and LACFCD assessed the 26 major spreading grounds interconnected to the water conservation system. The LACFCD also evaluated 5 major channel outlets. This report summarizes the data, methods, and results of the existing infrastructure response to the historic climate and future projections.

The purpose of Task 4 is to assess the response of existing infrastructure and analyze the operation guidelines under both the current and future climate conditions. It is important to recognize that this effort relies upon the existing configuration of the water conservation and flood risk mitigation network as the baseline condition.

This evaluation includes a ranking assessment of the current and future stormwater volumes conserved or discharged, and other impacts to the water conservation and flood risk mitigation system. The following sub-tasks were identified to conduct this assessment:

- Response to Current Climate (Water Year 1987 through 2000)
    - Analyze stormwater volumes conserved or discharged
    - Analyze infrastructure response and operations guidelines

- Response to Future Climate (Water Year 2012 through 2095)
    - Analyze stormwater volumes conserved or discharged
    - Analyze infrastructure response and operations guidelines

The response to the current climate provided a representation of the existing situation and revealed how the existing infrastructure could reasonably be expected to perform under a historical climate to which the region has become accustomed. However, this may not be the case in the future. The response to future climate assessed the existing infrastructure under varying climate conditions to understand if it would function satisfactorily. This analysis of the existing infrastructure served as a status quo assessment of historical conditions as well as a “no action” evaluation of the future.

After the analysis of the historic and future climate conditions, an assessment was conducted for the system of dams and spreading ground facilities. A water conservation ranking—or performance level—was developed to assess the overall efficiency and resilience of the facilities to both the historic and projected future climate. Although results are assigned to the individual 18 dams/reservoirs and 26 spreading grounds, each facility was analyzed within the entire system. The dams and spreading grounds were ranked according to their performance with respect to one another; these rankings were used to develop the Task 4performance levels.

**Table ES-1. Dam Water Conservation Performance Levels**

| Dams/Reservoirs – Performance Levels | | | | | | |
|---|---|---|---|---|---|---|
| Level | Rank | LACFCD Dams | | Level | Rank | LACFCD Dams |
| I | 1 | Puddingstone | | II | 11 | San Dimas |
| I | 2 | Live Oak | | III | 12 | Eaton Wash |
| I | 3 | Thompson Creek | | III | 13 | Big Tujunga |
| II | 4 | Big Dalton | | III | 14 | Devils Gate |
| II | 5 | Pacoima | | | | |
| II | 6 | Santa Anita | | Level | Rank | USACE Dams |
| II | 7 | Puddingstone Diversion | | II | - | Hansen |
| II | 8 | Cogswell | | II | - | Santa Fe |
| II | 9 | Morris | | II | - | Sepulveda |
| II | 10 | San Gabriel | | II | - | Whittier Narrows |

**Table ES-2. Spreading Ground Water Conservation Performance Levels**

| Spreading Grounds – Performance Levels | | | | | | |
|---|---|---|---|---|---|---|
| Level | Rank | Spreading Ground | | Level | Rank | Spreading Ground |
| I | 1 | Sierra Madre | | II | 14 | Branford |
| I | 2 | Irwindale | | II | 15 | Little Dalton |
| I | 3 | Sawpit | | II | 16 | Walnut |
| I | 4 | San Dimas | | II | 17 | Pacoima |
| I | 5 | Big Dalton | | II | 18 | Santa Anita |
| I | 6 | Peck Road | | II | 19 | Citrus |
| II | 7 | Ben Lomond | | III | 20 | Forbes |
| II | 8 | Rio Hondo | | III | 21 | Live Oak |
| II | 9 | San Gabriel Coastal | | III | 22 | Lopez |
| II | 10 | Santa Fe | | III | 23 | San Gabriel Canyon |
| II | 11 | Hansen/Tujunga | | III | 24 | Dominguez Gap |
| II | 12 | Eaton Basin | | III | 25 | Buena Vista |
| II | 13 | Eaton Wash | | | | |

Generally, facilities that were the least efficient resulted in being the least resilient to climate change and were assigned Performance Level III which has a high potential for enhancements. Facilities that were generally more efficient were more resilient to climate change and were assigned Performance Level II. Finally, facilities that were the most efficient tended to be the most resilient to climate change and were assigned to Performance Level I.

For the channel outlet analysis, assessment levels were developed to determine which of the five major channel outlets have the highest potential for increasing stormwater capture and reducing runoff to the Pacific Ocean. The ability to reduce the stormwater runoff that is lost to the ocean and capture it would greatly boost the potential stormwater supply in this region. The Task 4 analysis assigned assessment levels to the 5 major channel outlets and their respective watersheds.

**Table ES-3. Major Channel Outlet Assessment Levels**

| Channel Outlet Assessment | | |
|---|---|---|
| **Level** | **Rank** | **Channel (Watershed)** |
| I | 1 | Dominguez Channel |
| I | 2 | Malibu Creek |
| II | 3 | San Gabriel River |
| II | 4 | Ballona Creek |
| III | 5 | Los Angeles River |

The Los Angeles River ranked into Assessment Level III indicating that this watershed has the greatest potential for increasing stormwater supplies and should be targeted for future enhancements. For the remaining outlets, although these locations were found to have lower discharge volumes, additional capture efforts should still be targeted within these watersheds to further increase stormwater capture and improve local water supplies.

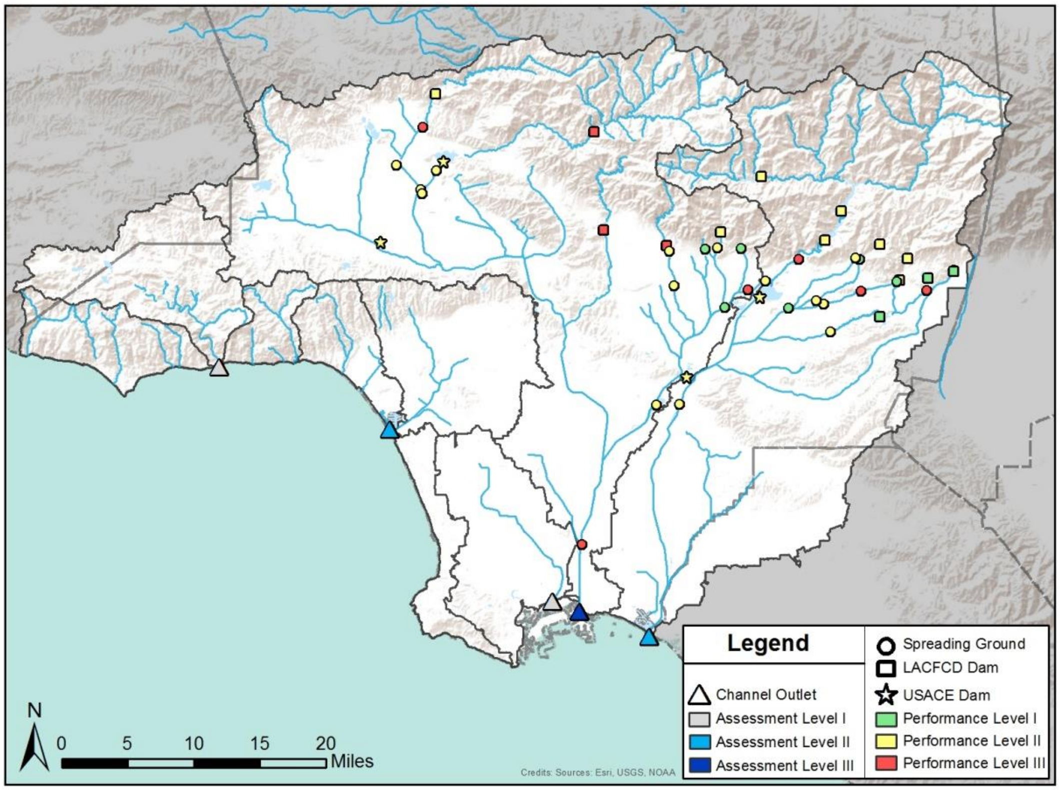


**Figure ES-1. Task 4 Existing Infrastructure Response Results**

From the Task 4 analysis, all major facilities have been determined to have some potential for enhancement, thus a higher performance level does not necessarily preclude sites from further analysis in Task 5 – Infrastructure & Operations Concepts of the LA Basin Study. As a significant distinction, these levels did not measure facility issues such as seismic or structural deficiencies. Instead, these levels assessed general efficiency, climate resilience, and water conservation improvement potential from an appraisal level analysis. The system's response to the different future projections can later be used for adaptive management and planning purposes. The facilities analyzed in Task 4 will be the subject of further analysis along with many other concepts to be developed during Task 5 – Infrastructure & Operations Concepts, and Task 6 – Trade-Off Analysis & Recommendations of the LA Basin Study.

# 1 Introduction

## 1.1 Study Purpose

The purpose of the LA Basin Study is to study long-term water conservation and flood risk impacts from projected climate conditions and population changes in the region. The LA Basin Study will recommend potential changes to the operation of stormwater capture systems, modifications to existing facilities, and development of new facilities that could help resolve future water supply and flood risk issues. The recommendations will be developed through identifying alternatives and conducting trade-off analyses.

The purpose of Task 4 is to assess the response of existing infrastructure and analyze the operation guides under both the current and future climate conditions.

## 1.2 Study Background

The LACFCD is considering large-scale enhancements to its water conservation capabilities to better meet the long-term projected needs of the Los Angeles region and also to be more prepared for and resilient to future climate conditions. From informal discussions between LACFCD and several major water agencies, this consideration was the driving force for creating the partnership between the LACFCD and Reclamation under the Basin Studies Program (Reclamation 2009).

The LA Basin Study utilizes the latest climate science and hydrologic modeling tools available to create a vision of the near-term and long-term future of stormwater capture within the Los Angeles basin. The LA Basin Study provides the opportunity for multiple water management agencies to participate in a collaborative process to plan for future local water supply scenarios. The LA Basin Study will examine opportunities to enhance existing LACFCD and other government or local agency facilities, and to develop new facilities to provide direct benefits to water agencies and local communities.

The LA Basin Study will consider technical viability of implementing innovative facility concepts that show a prospective for increasing infiltrative capacity to recharge groundwater. A trade-off analysis and adaptive planning process will be conducted to evaluate the regional impacts and the economic costs and benefits of the various stormwater capture alternatives. Additionally, the study will look at the costs of attaining different goals through a cost-effectiveness analysis. The final outcome and recommendations of the LA Basin Study concept development and trade-off analyses will serve as a guiding document for further local water supply development planning, financing strategy, and policy adoption by the LACFCD and other LA Basin Study partners.

## 1.3 Description of Study Area

The Los Angeles River, San Gabriel River, South Santa Monica Bay, North Santa Monica Bay, Ballona Creek, Malibu Creek, and Dominguez Channel/Los Angeles Harbor watersheds (Basin Study Watersheds) are the focus of this LA Basin Study and are shown in Figure 1. This study incorporates the entire watershed boundaries, including where they extend beyond the County of Los Angeles. For Task 4, the existing dam, spreading ground facilities, and major channel outlets within the study area have been analyzed.

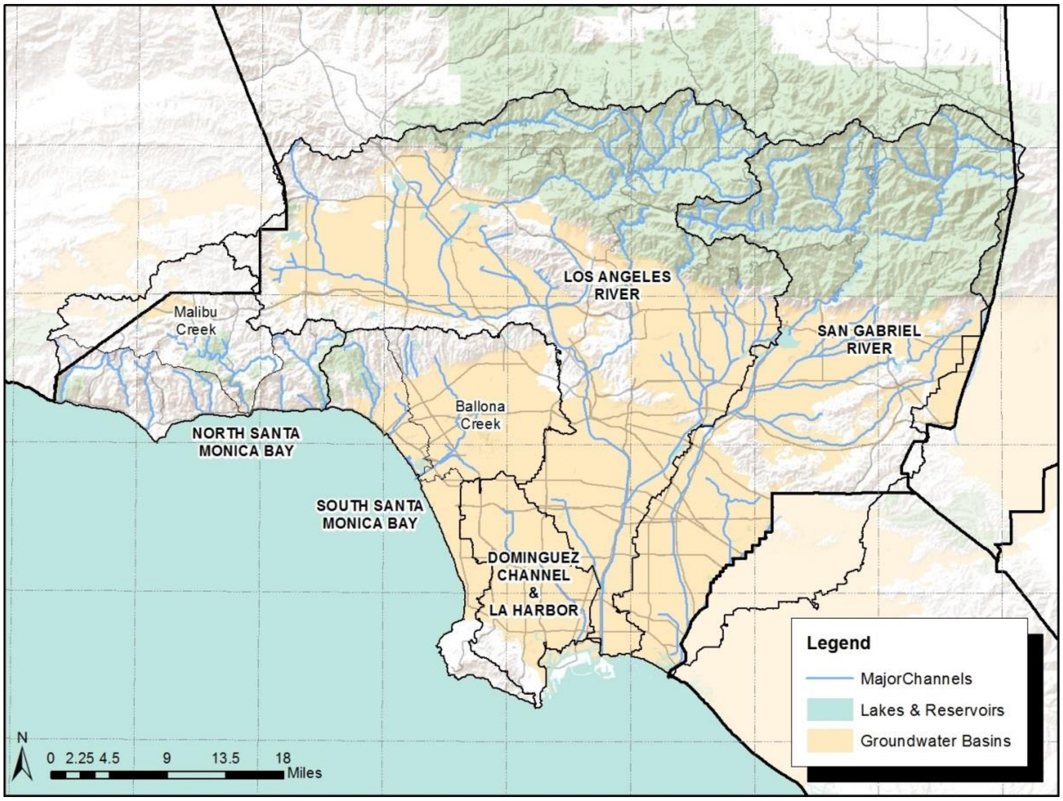


**Figure 1. Los Angeles Basin Stormwater Conservation Study Watersheds**

The LACFCD's 14 major dams and reservoirs, shown in Figure 2, are located in the front range of the San Gabriel Mountains stretching more than 40 miles from the San Fernando Valley on the west to the eastern edge of the San Gabriel Valley (Los Angeles County Department of Public Works 2013). The largely undeveloped watershed area upstream of the LACFCD dams is approximately 418 square miles with majority of it falling within the Angeles National Forest. The system also includes 4 major USACE dams which are primarily used for flood control purposes currently. Spreading grounds, which serve to infiltrate stormwater runoff, are located in areas of high permeability downstream from the major LACFCD and USACE dams. The region's major channel outlets to the Pacific Ocean and their respective watersheds are shown in Figure 3. Conceptual water conservation enhancements to these facilities will occur during Task 5.

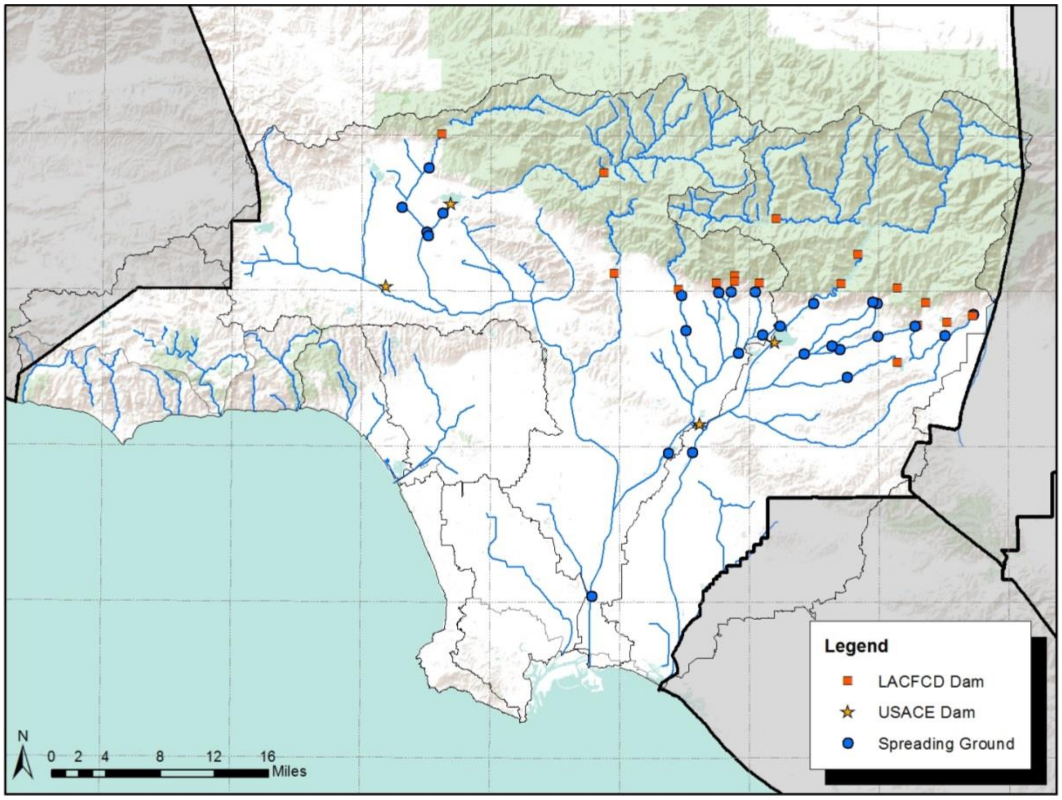


**Figure 2. Los Angeles Basin Stormwater Conservation Facilities**

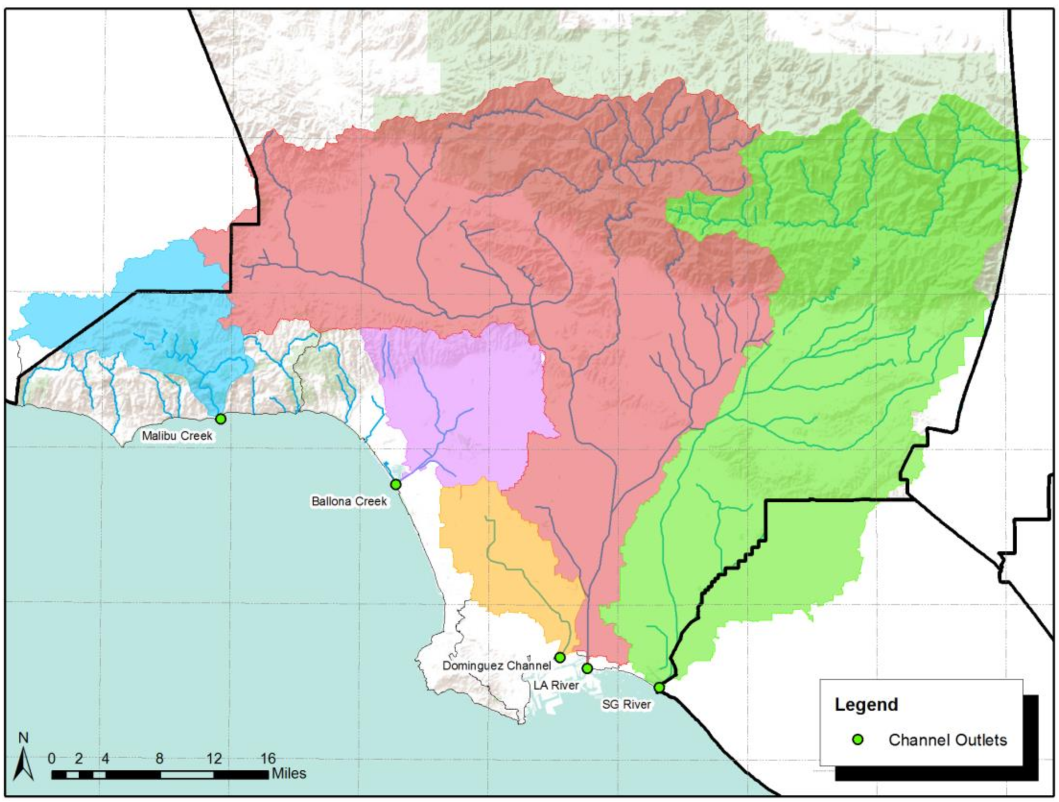


**Figure 3. Los Angeles Basin Major Channel Outlets and their Watersheds**

The Basin Study Watersheds contain more than 9 million people and cover approximately 2,000 square miles. More than 95 percent of Los Angeles County's population resides within the LA Basin Study area. This population concentration also accounts for nearly one-fourth of the State of California's population. Presently, California's population is 37.3 million people and the County of Los Angeles' population is almost 9.8 million. By 2050, the populations of California and the County of Los Angeles are projected to reach approximately 50.3 million and 11.4 million, respectively.

The State's population as a whole is projected to increase by more than 34 percent, while Los Angeles County's is projected to increase by approximately 16 percent by 2050 (Department of Finance 2013). Projected larger population growth rates outside of Los Angeles County indicate that there will be higher competition for imported sources of water and higher pressure to increased development of local water supply sources. At present, Los Angeles County accounts for the largest amount of water demand of any urbanized county in California. Total water usage within the Los Angeles County portion of the Metropolitan Water District of Southern California (MWD) service area exceeded 1.54 million acre-feet in fiscal year 2011-12 (MWD 2012).

## 1.4 Hydrology Model Used for Study

The Watershed Management Modeling System (WMMS) was used for the historic and projected hydrologic modeling for Task 4. The Loading Simulation Program in C++ (LSPC) is the underlying hydrologic program within WMMS that performs the simulations. LSPC was used to simulate the hydrologic runoff and volume outputs for all reservoirs, spreading facilities, and major channel outlets within the LACFCD system. For simplicity, LSPC will be referred as either WMMS or the model in this report.

## 1.5 Facility Modeling

Although WMMS is the primary hydrologic model used for the LA Basin Study, other models were used to help remodel or construct more accurate reservoir rating curves for WMMS. The dam and reservoir operational characteristics were fine-tuned within these external models and the resulting rating curves were converted to WMMS F-tables for the system-wide simulations. For the update, all 14 major LACFCD dams, 4 major USACE dams, and the 26 major spreading facilities within the study area were modified. However, the major channel outlets did not require a remodel and remained unchanged. The remodel was conducted in different stages by LACFCD, Reclamation, and the USACE.

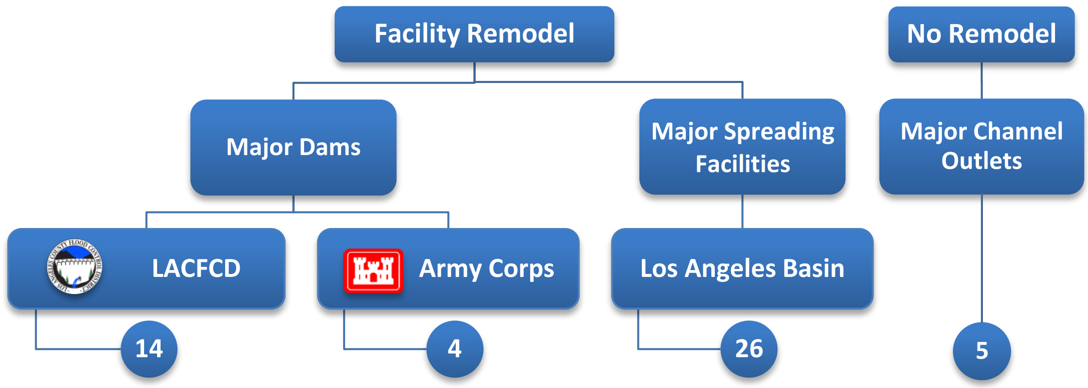


**Figure 4. Stormwater Conservation Facilities Remodel**

### 1.5.1 Dam/Reservoir Models

The LACFCD dams and reservoirs were evaluated by Reclamation using the Modified Puls level-pool reservoir routing method to model dam releases, concentrating specifically on spillway discharges for historical events with large flows. By incorporating recent reservoir surveys to account for current sediment buildup conditions, updated reservoir rating curves were developed which were then converted to F-tables for input into WMMS. This process is discussed further in Section 2.2.1.

For USACE dams, existing outlet and spillway rating curves were used as a starting point for the analysis to develop the F-tables for input into WMMS. Recent reservoir surveys were also incorporated into the rating curves to account for current sediment buildup conditions. A comparison between historic releases and the current water control manuals was conducted to determine if and when any major variations to the operating plan occurred. The approved operating schedules for USACE dams have changed over the historic period; all 4 major USACE dams have usually been operated closely to the scheduled releases with only minor variations. Per the water control manuals, as reservoir stages behind USACE dams approach spillway the outlet gates are closed on a step-wise basis in an effort to maintain the downstream channel capacity for as long as possible, which leads to fluctuating releases. Therefore, the curves were smoothed out before being converted to WMMS F-tables.

### 1.5.2 Spreading Ground Update

To improve the modeling of the spreading facilities, an update was made to the WMMS flow network. This modification involved adding a forebay and inlet structure component to the majority of the spreading facilities so that WMMS could better model a flashy storm bypassing the spreading ground. This operational characteristic was previously not been included in the hydrologic modeling and—out of necessity to improve the model for these more detailed simulations—has now been accounted for. This process is discussed further in Section 2.2.2.

## 1.6 Summary of Procedures

For the existing infrastructure response, this effort built upon the work previously completed by Reclamation and the LACFCD during Task 3:

- Task 3.1 – Development of Climate-Adjusted Hydrologic Model Inputs
- Task 3.2 – Hydrologic Modeling Report

The results from Task 3 (LACFCD 2013) were used to select a bounding set of six future climate projections to expedite the existing infrastructure analysis. These projections represent a low, central, and high tendency hydrology. In total, there were 47 climate projections developed in Task 3 (Reclamation 2013), and these projections were analyzed in order to determine two 5$^{th}$ percentile, average, median, and two 95$^{th}$ percentile bounding cases as shown in Figure 5. The methods used to find the bounding projections are discussed in Section 2.1.

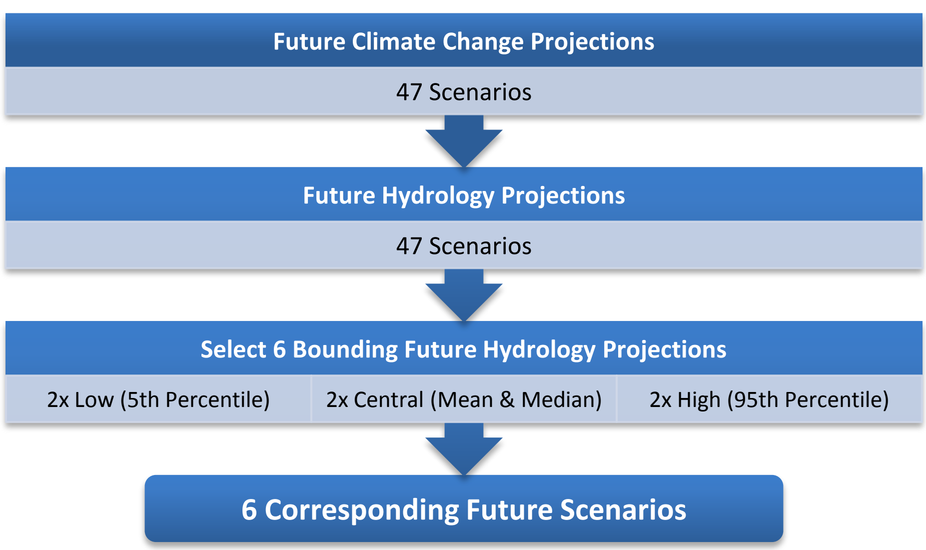


**Figure 5. Bounding Climate Change Scenarios Overview**

The six corresponding climate change scenarios were then used in WMMS to simulate the response of the existing infrastructure. The output for each of the dams, spreading ground facilities, and major channel outlets were then analyzed to better understand how efficient or resilient each of the facilities were to the varying future climatic conditions.

The 18 major dams within the system were analyzed primarily for yearly variations of stormwater captured and released, as well as the frequency of spillway events. The 26 major spreading grounds were analyzed for variations in stormwater conservation. Lastly, the major channel outlets were analyzed for the amount of stormwater runoff that is discharged to the ocean.

The main purpose of the LA Basin Study Task 4 is to investigate how the current infrastructure, as it exists today, will respond to changes caused by future climate variations. Each of the dams, spreading grounds, and major channel outlets that make up the system were analyzed to gain a better understanding of the impacts of climate change. Task 4 is a precursor to the development of concepts in Task 5. The current infrastructure response assumes that no modifications to the water conservation and flood risk mitigation system will occur from the present through 2095. While this “no action” future is not intended to be a realistic depiction, this critical assumption does provide a baseline condition for Task 5 when new or existing concepts are investigated further.

# 2 Methods

This section details the procedures used to analyze and rank all 18 major dams, 26 major spreading facilities, and 5 major channel outlets based on a number of different ranking criteria. A smaller subset of climate change scenarios was targeted and a number of steps were taken to prepare the WMMS model.

Section 2.1. details the procedure to select the subset of low, central, and high bounding future climate projections.

Section 2.2. details the model improvement process of the dams and spreading grounds.

Section 2.3. details the methods used to analyze the dams, spreading grounds, and channel outlets as well as their subsequent performance level ranking.

## 2.1 Bounding Future Climate Projections

Due to the analysis methods used in this task, a smaller subset of projections was targeted from the 47 future projections from Task 3. The dam spillway event analysis required an extensive hourly time step examination of each spillway event for each of the dams for each of the projections. Because of this approach, it would not have been feasible to analyze all 47 projections due to the magnitude of data analysis. Therefore, a subset of only six of these projections was selected to represent bounding cases for the low, central, and high cases.

The general process to select the bounding future climate projections is illustrated in Figure 6. For the 47 climate projections and their respective hydrologies analyzed during Task 3, each of the 210 target subwatersheds were assessed for four key stormwater metrics. These four key stormwater metrics are total annual stormwater runoff, maximum mean-hourly flow rate, average annual storage volume, and maximum mean-hourly volume. The different future climate scenarios that produced the low, central, and high values for the stormwater metrics across individual subwatersheds could then be identified. Next, all of these future scenarios were aggregated across the Study Area to select six representative overall projections.

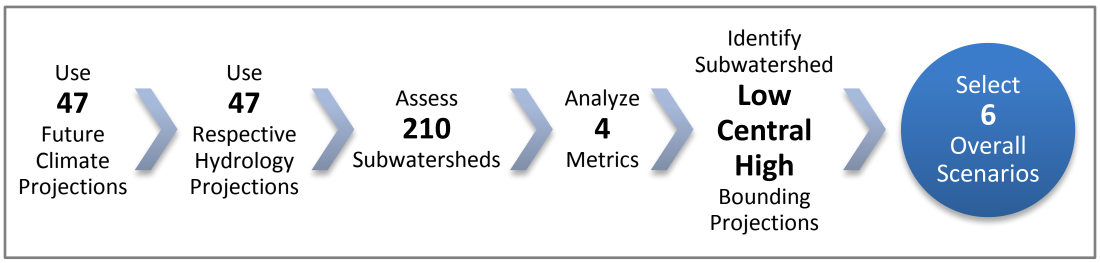


**Figure 6. Process to Determine Bounding Climate Projections**

In one common method for selecting which projections best represent the low, central, or high cases, projections are plotted on the same graph in what is known as a spaghetti plot. This is then repeated for each subwatershed and each of its stormwater metrics. Once graphed, the lowest and highest projections are visually estimated; however, this technique is highly subjective and obvious differences in judgment could result in different estimates. A typical spaghetti plot developed from the Task 3 dataset for a sample target subwatershed and one of its stormwater metrics is shown in Figure 7. For simplicity, this sample graph for the Los Angeles River outlet depicting annual stormwater runoff will be used throughout this section to describe the methodology for selecting the bounding future climate projections.

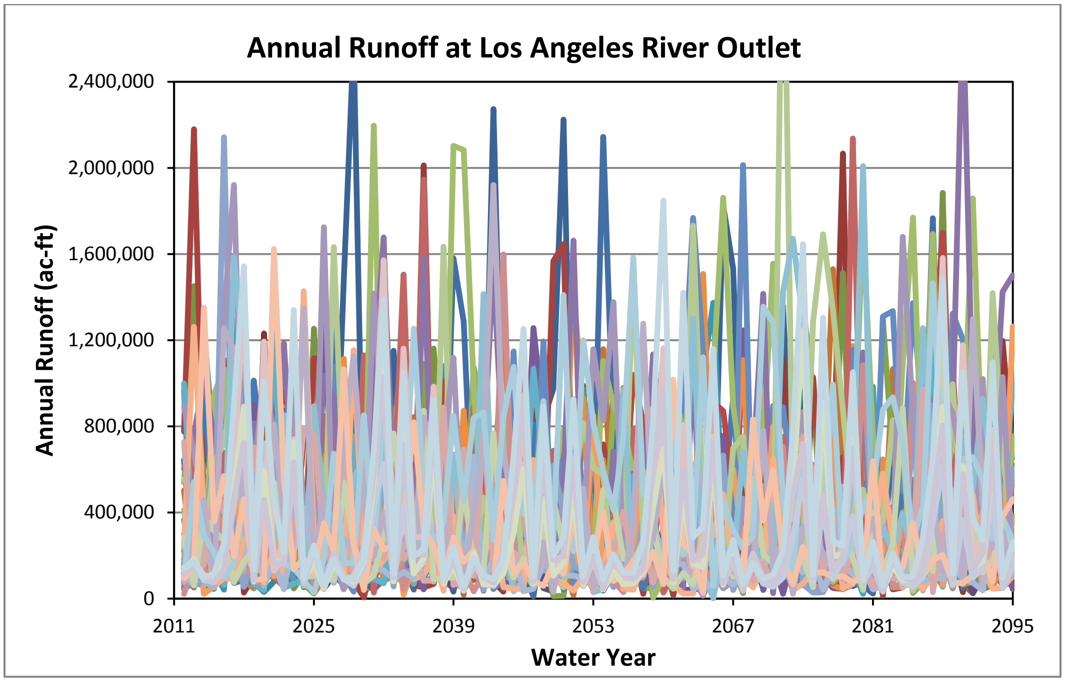


**Figure 7. Projection Spaghetti Plot**

From the plot, it is not apparent which scenario is consistently the lowest or consistently the highest. There are certainly a number of very high maximum points for different scenarios, but this does not indicate that these are scenarios with the highest overall tendencies. If one scenario is selected over others, it is difficult to verify if it is the best choice. Additionally, the visual estimation results cannot be quickly reproduced for large datasets.

Since the traditional spaghetti plot approach is highly subjective, an objective approach was developed for isolating the different bounding cases. Using a modified spaghetti plot method for each subwatershed and its stormwater metrics, the 47 projections were plotted on the same graph, but the annual hydrology results for each scenario were arranged from lowest to highest values to produce 47 ascending curves as shown in Figure 8. These curves helped to better represent the overall character of the different projections.

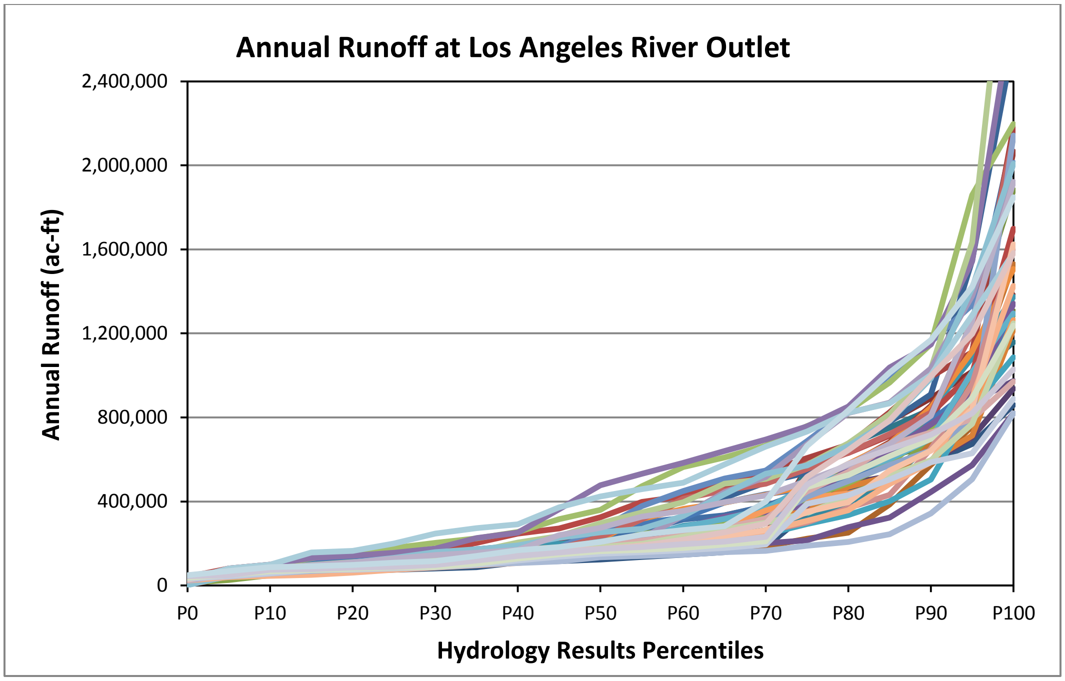


**Figure 8. Projection Percentile Curves**

After the curves were plotted, 5th percentile, mean, median, and 95th percentile curves were calculated and graphed to show the new lower bound, central, and upper bound targets in Figure 9. Next, a least squares regression analysis was performed on all 47 projections to determine which projections best fit the new bounding targets. This process was then repeated for all subwatersheds and their stormwater metrics from Task 3.

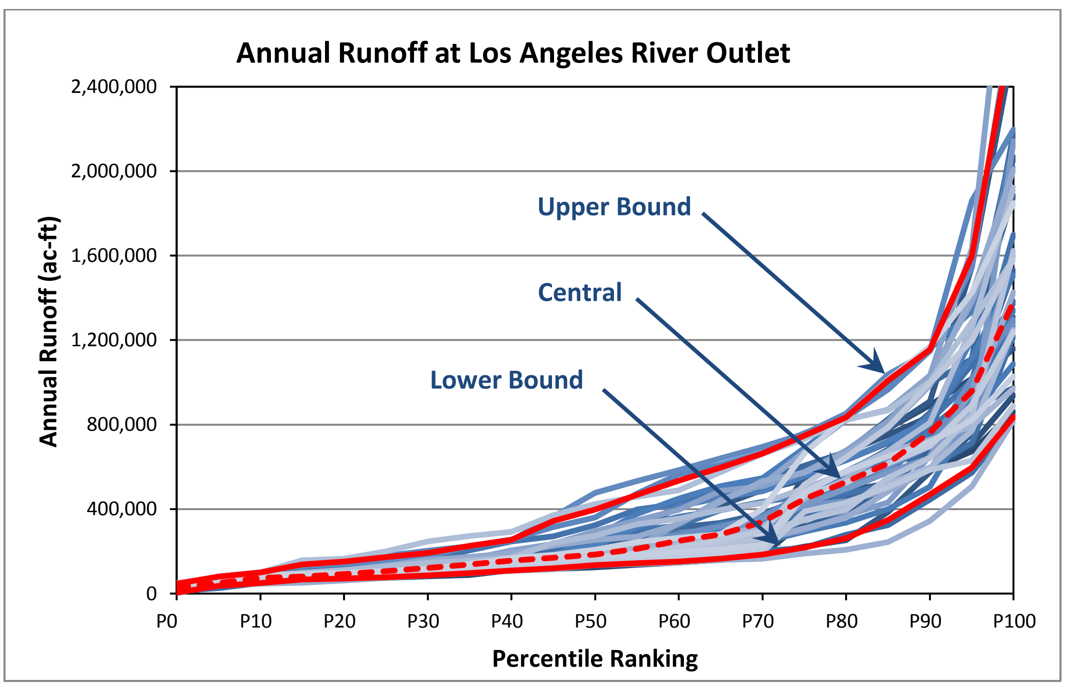


**Figure 9. Lower, Central, and Upper Bound Curves**

After the nearest matching projections were identified for all subwatersheds and stormwater metrics, the various matches were then tallied for each of the 47 projections. The projections that were consistently the closest to the lower bound, central, and upper bound curves were then chosen as the final six projections to be used for the existing infrastructure response analysis. As there were typically very close ties for the upper and lower bound targets across the subwatersheds, two projections were chosen for each case. The central target was taken as one projection best representing the mean curve and one projection best representing the median curve. Table 1 shows the final six climate change projections that were selected for the bounding cases.

**Table 1. Selected Future Climate Projections**

| Bounding Target | Projection |
|---|---|
| High 1 | CMIP5-BCCA-RCP8.5 cnrm-cm5.1.rcp85 |
| High 2 | CMIP5-BCCA-RCP8.5 mri-cgcm3.1.rcp85 |
| Middle 1 | CMIP5-BCCA-RCP8.5 csiro-mk3-6-0.1.rcp85 |
| Middle 2 | CMIP5-BCCA-RCP2.6 ccsm4.1.rcp26 |
| Low 1 | CMIP5-BCCA-RCP2.6 bcc-csm1-1.1.rcp26 |
| Low 2 | CMIP5-BCCA-RCP2.6 miroc5.1.rcp26 |

For the complete list of the original 47 projections, see the Task 3.1 report (Reclamation 2013). An interesting observation to note is that although all 47 climate projections from Task 3 were used to produce this subset of six, only projections from the CMIP5-BCCA climate set controlled the bounding scenarios. The “mitigation” pathway (RCP 2.6) produced the overall lowest runoff cases and the “business as usual” pathway (RCP8.5) produced the highest runoff cases. RCP2.6 indicates a future where greenhouse gasses are being mitigated and reduced to lower levels than currently, whereas RCP8.5 represents continued increases in greenhouse gas emissions at an increasing rate.

Figure 10 through Figure 13 show the six selected projections plotted against the full range of possible future hydrology results for the four stormwater metrics. Inspection of the graphs show that the selected projections do not always follow the lowest or highest boundaries for all points during the study horizon; the extreme highest or lowest points are generally caused by very short “burst” periods with very high or very low runoff for the varying future projections. Yet, these extreme higher or lower results do not persist for as long as they do with the selected six bounding projectionsThese graphs indicate the running annual average as a percent change compared to the historic period’s annual average.

Graphically, the historic period is shown as the baseline comparison point starting at 0% in 2011. The projection variability is characterized as the percent change from historical and ranges widely—this is the reasoning for investigating several bounding cases which help to characterize future uncertainty.

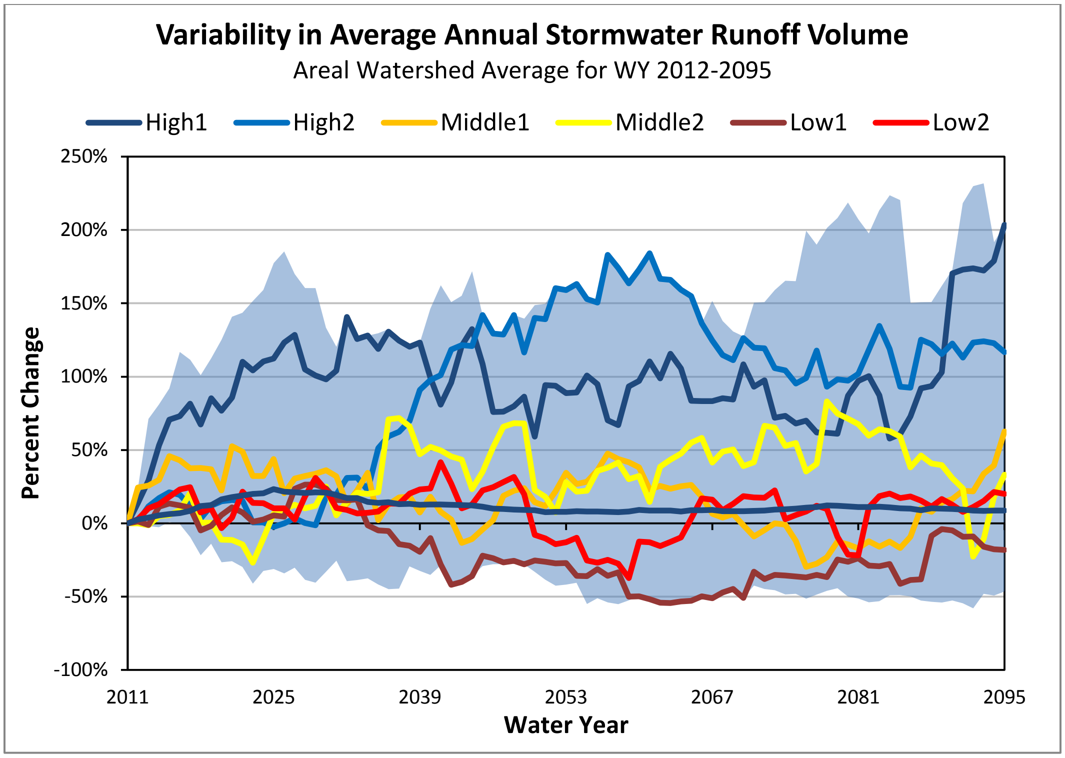


**Figure 10. Future Climate Scenario Subset – Annual Stormwater Runoff**

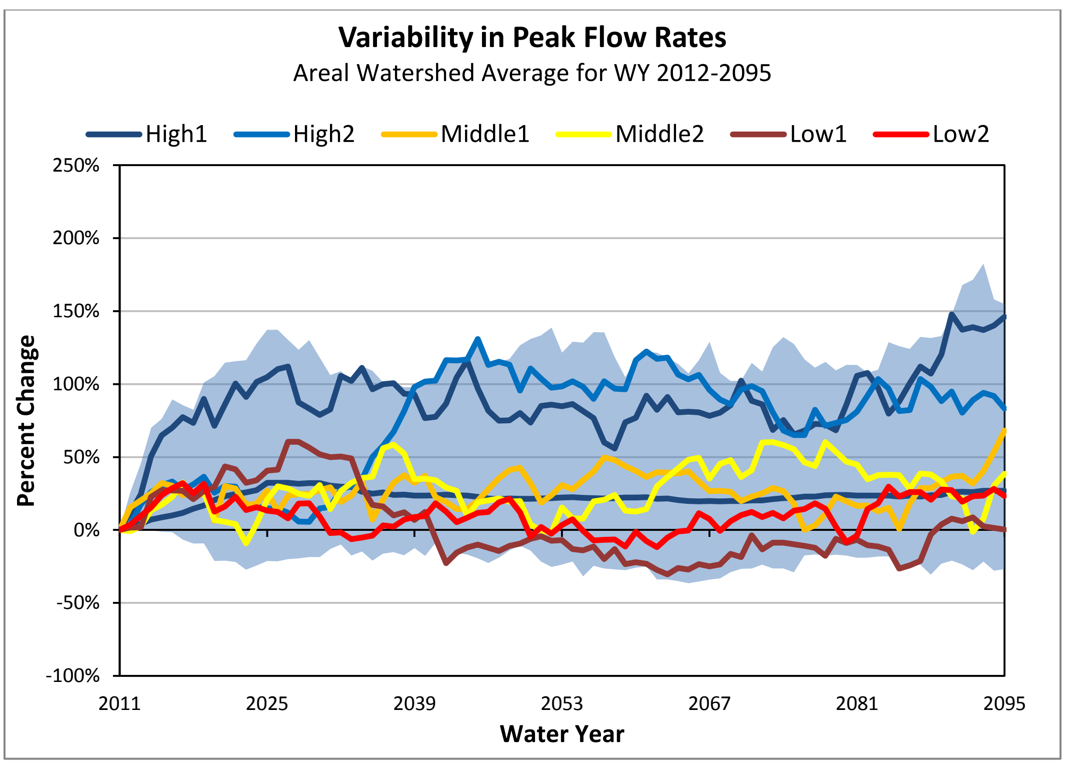


**Figure 11. Future Climate Scenario Subset – Peak Flow Rates**

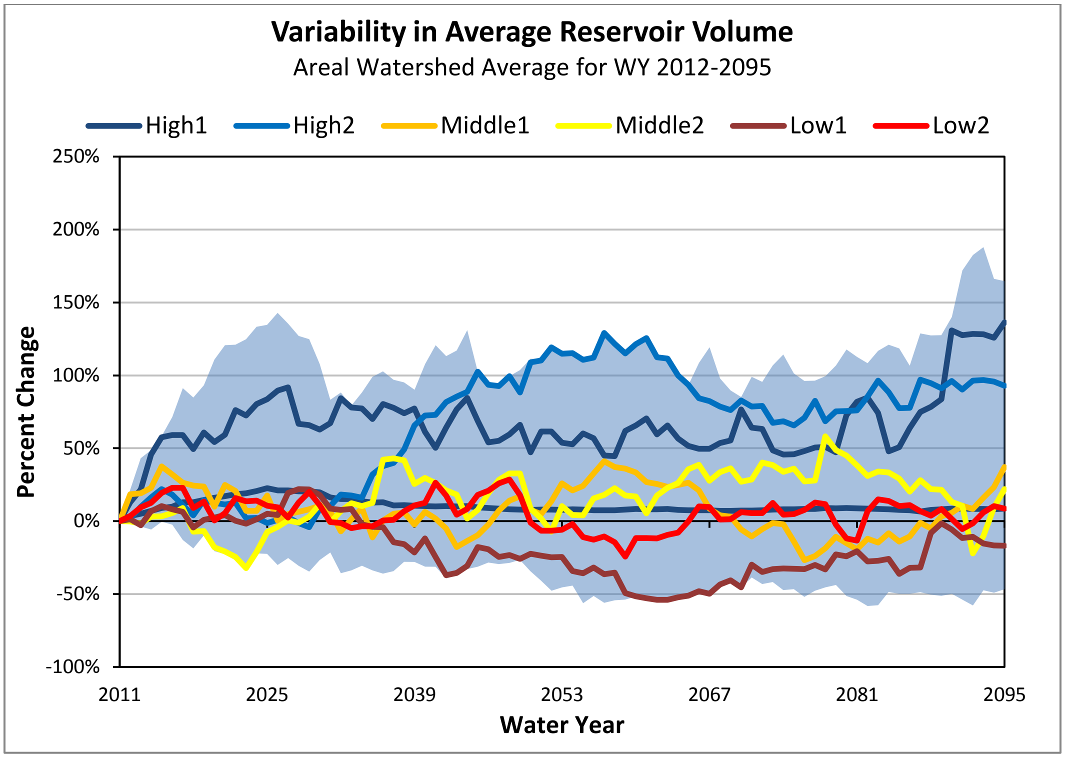


**Figure 12. Future Climate Scenario Subset – Average Reservoir Volume**

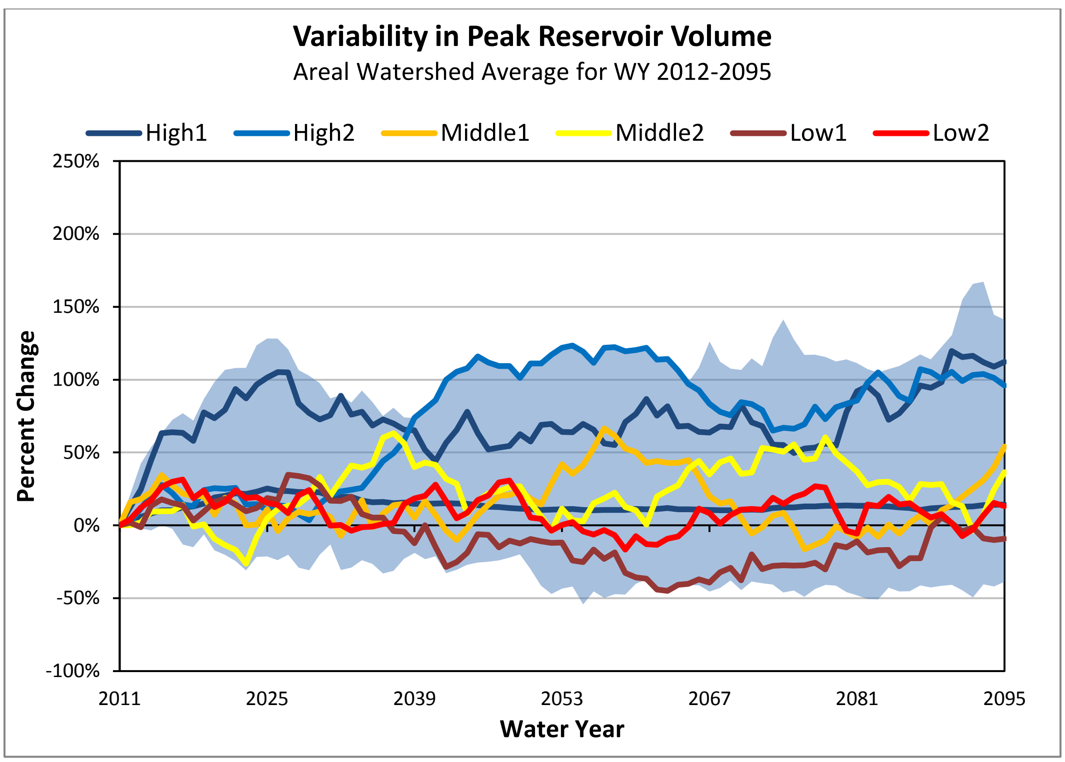


**Figure 13. Future Climate Scenario Subset – Peak Reservoir Volume**

The extreme margins, or peak regions, on the plots that lie beyond these bounding projections were found to characterize projections with comparatively neutral behavior throughout the century with an exceptionally intense and dramatic hydrology for only a brief period. For example, this behavior is demonstrated by the red curve in Figure 14. The elevated period is very high, but the period is relatively brief and remains somewhat neutral throughout the rest of the study horizon.

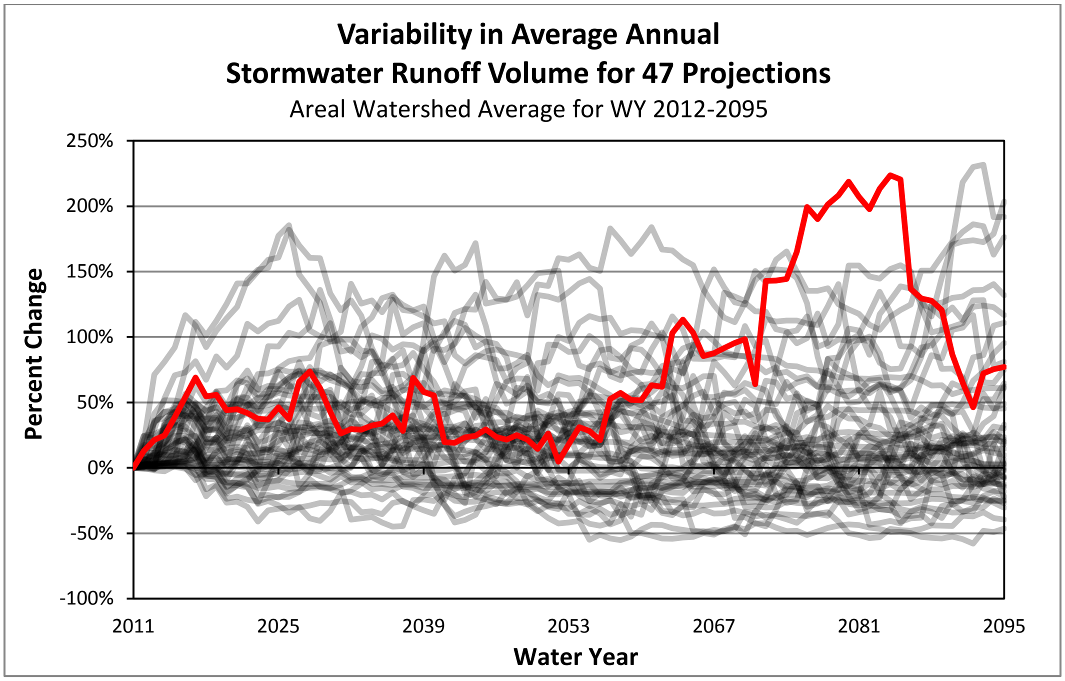


**Figure 14. Projection Variations**

For the lower and upper bound curves, it is important to understand that it is not useful to use the extreme lowest or extreme highest annual value for each year, from each of the 47 projections, and then create a combined low or high composite projection. This would generate an excessive and consistently high or low climate projection which is not within the realm of the possible projections or natural climate variability.

Such a composite projection would lead to either an extremely arid climate for 100 years with dry weather *each year* or an extremely moist climate for 100 years with wet weather *each year*; neither of which is found to be representative of any one future climate change projection. Although no single projection should be used to represent the future, it is also not possible to break apart or create composite projections. Each individual projection is built upon numerous complex initial conditions, emissions forecasts, and climate physics, and therefore should not be broken apart to construct a composite projection case. For this reason, a suite of six individual projections were targeted to represent the bounding climate cases.

## 2.2 WMMS Infrastructure Remodel

Task 4 focuses on the major LACFCD dams, the major USACE flood control dams, the region's major spreading facilities, major channel outlets, and the overall potential for increased conservation efforts at these sites. The water conservation facilities within WMMS—with the exception of the major channel outlets—were improved with more accurate discharge rating curves in order to better evaluate the system's response to the future climate.

Baseline conditions used for the Task 4 remodeling caused the simulated historical values to differ from observed historical values in some cases. This important notion is based upon a major premise:

- The existing facilities are evaluated in their *current* state.

The purpose of Task 4 is to assess the response of existing infrastructure and analyze the operation guidelines under both the current and future climate conditions. Therefore, the current physical configuration and operations of existing infrastructure were held constant in the WMMS modeling of the system for both historical and future climate conditions. As a result, simulations did not model how physical configurations or operations of any particular facility may have changed over time throughout the historical period via construction projects or changes in operation guidelines.

Section 2.2.1. describes the improvements that were employed to better model spillway flows at LACFCD and USACE dams.

Section 2.2.2. describes the improvements that were employed to better model the spreading grounds.

### 2.2.1 Dam/Reservoir Remodel

Discharges from LACFCD dams are regulated using valves at the dams for reservoir stages below spillway crest elevations. The operation guidelines for the dams allow considerable flexibility in operation of the valves to regulate releases to downstream spreading grounds. Day to day operations of the dams are influenced by field conditions including immediate and approaching weather conditions. This operational variability posed a significant challenge in modeling the projected hydrology. For reservoir stages above spillway crest elevation, however, discharges are released through the spillway, which typically have no operational controls.

Similarly, discharges from the four USACE dams are regulated using the gated outlets for reservoir stages below spillway crest elevations. It should be noted that Sepulveda and Hansen Dams also have some ungated outlets. The USACE dams are operated primarily for flood control with the objective of passing the flow to the downstream channel as quickly as possible without causing flood damage. Day to day operations are directed by using operating plans as described in each dam's water control manual. Outlet gate settings are based on the reservoir water surface elevation and are influenced from restrictions due to conditions such as channel capacity, weather forecasts, and downstream maintenance or construction projects. For reservoir stages above spillway crest elevation, discharges are released through the spillway.

At the beginning of Task 3, a large-scale effort was undertaken to prepare WMMS for simulating the future climate projections. Prior to this, all dam and reservoir discharges were based on observed historic dam discharge records. Therefore, generalized F-tables were developed from preliminary rating curves that were based upon normal operational trends during the historic time period. These F-tables characterized the relationships between the historical average dam discharges versus the surface water elevation or volume stored within each reservoir. Essentially, a typical elevation-discharge or volume-discharge relationship was developed from these observed historical records.

In moving forward with the existing infrastructure analysis, these average annual F-tables were further refined to correlate the actual rated discharge capacity of the valves and spillway at each dam. Reclamation used documentation provided by LACFCD to review and update the F-tables for the 14 major LACFCD dams. Reclamation reviewed the operation guidelines at each of the 14 dams and the discharge rating curves for both the valves and spillways. The USACE performed a similar analysis for the 4 major USACE dams.

For each dam, the F-tables were compared with the discharge rating curves for the valve and spillway operations. Upon inspection, it was determined that the average annual discharge curves developed previously were generally sufficient for reservoir stages below spillway crest elevation. In certain instances below the spillway crest elevation, the original average annual F-table discharge rate exceeded the discharge capacity of the valves, thus the lesser value was used for the newly updated F-table. For reservoir stages above the spillway crest, the established spillway rating curves were used for the F-table values.

The Modified Puls level-pool reservoir routing method was utilized to model spillway discharges for selected historical time periods with large flows to test the updated F-tables. It should be noted that the modeling requirements for this reservoir routing methodology required that the elevation-discharge relationship have a positive rate of change throughout its operational range. No flow occurs through a dam when the reservoir stage is exactly at the spillway crest elevation; therefore, the stage must rise to a certain elevation above the crest before the rated spillway discharge begins to exceed the maximum discharge through the valves. Consequently, a transition zone was created in the elevation-discharge relationship beginning at the spillway crest elevation which represents a progressive closure of the valves in conjunction with increasing flow rates through the spillway. This concept is illustrated in Figure 15.

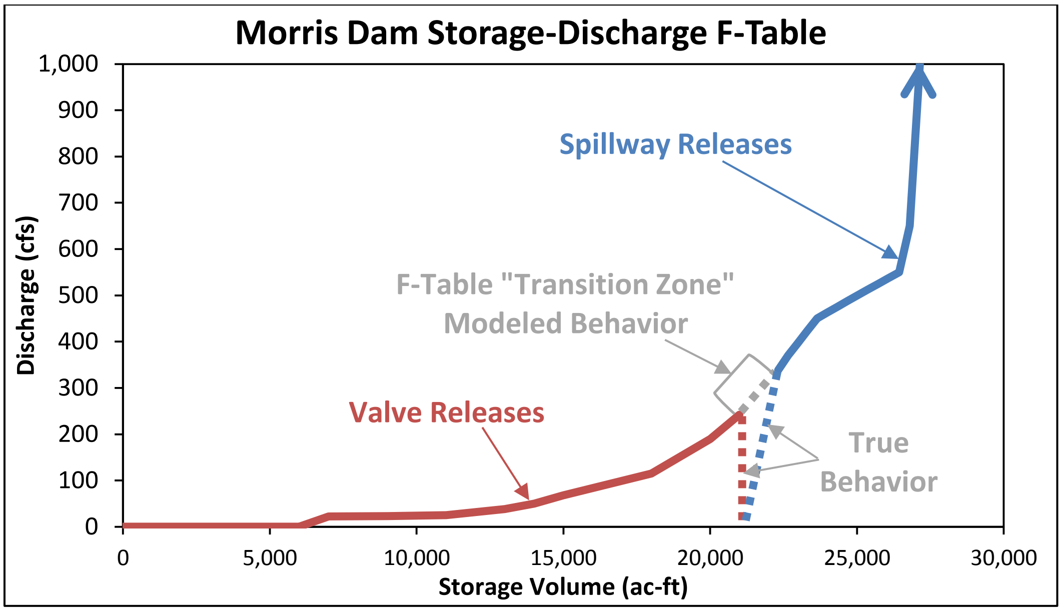


**Figure 15. WMMS Reservoir F-table Remodel**

A transition zone was used to combine the average annual operations curve below the spillway crest elevation with the established spillway discharge rating curves. This combination produced the final F-table for each dam.

### 2.2.2 Spreading Ground Remodel

In order to better represent the intricate interaction between the channel forebays, inlet structures, spreading grounds, and large storm flows, a remodel of the WMMS spreading facilities was conducted. In the previous version of the model, spreading grounds were assumed to be in-line with the storm channels, which effectively forced the spreading ground to fill to capacity before it would allow any water to move downstream. While this is not an appropriate depiction for most spreading grounds, there are a few exceptions where facilities operate in this manner. For example, the Peck Road Spreading Basin, just west of Santa Fe Dam, functions as a large in-line spreading facility where all incoming stormwater runoff has to flow through the facility before reaching the downstream outlet structure. However, the majority of facilities are not in-line and this modeling update was completed to reflect this.

The spreading ground remodel added a channel forebay and inlet structure to nearly all modeled spreading grounds. Channel forebays are designed to retain a small amount of water within the channel so that a spreading ground can control inflow from the channel. During large storm events, these forebays are quickly filled beyond capacity and once full, these forebays are designed to release all stormwater downstream. Due to this behavior, large amounts of stormwater are bypassed and cannot be captured by the spreading facility. This operational condition is standard for nearly all spreading ground facilities, where intake of stormwater runoff into the spreading ground is limited by the forebay release volume and/or the channel flow rate. Figure 16 shows how WMMS was modified to better replicate this spreading ground operational behavior.

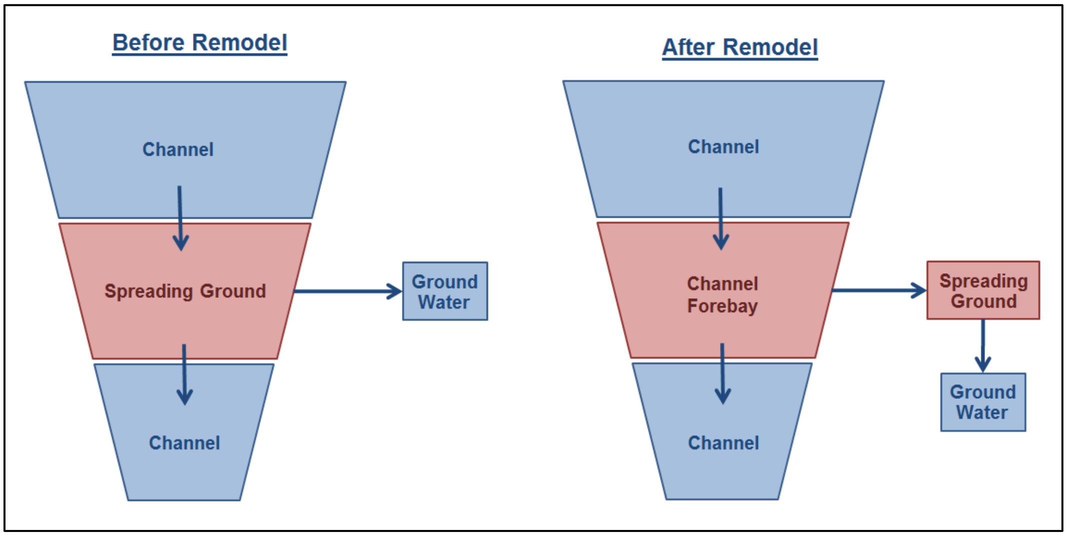


**Figure 16. Spreading Ground Remodel Schematic**

This spreading ground remodel permitted for a more accurate system to control the spreading ground operations, and additionally allowed the system to be more responsive to larger or flashier storm events.

## 2.3 Infrastructure Analysis

The existing infrastructure response was analyzed for both the historic period and future period projections. The updated WMMS model was used to produce discharge rates and volume data at each of the dams, spreading grounds, and channel outlets. WMMS performed the simulations of the water conservation and flood risk mitigation network simultaneously for the existing infrastructure. Therefore, hydrologic impacts on a specific facility are propagated to other nearby facilities due to this system modeling. The historical period includes Water Years 1987 through 2000, and the future period projections are from Water Years 2012 through 2095. The historic climate simulations serve as a baseline condition that can be presumed to represent the typical weather that the Study Area has grown accustomed—and these can then be compared against the future projections. The facility response data between the historical and future periods was then compiled, analyzed, and ranked.

For the assessment of the existing infrastructure, the individual facilities were ranked based upon their performance within the network. This allows the dams, spreading grounds, and channel outlets to be compared to their counterparts to comprehend where each stands with respect to one another. However, a certain level of institutional knowledge will be necessary when processing these performance levels. For example, certain dams and reservoirs are connected in series without spreading grounds between. In such cases, low efficiency performance of the upstream dams may be offset by high performance levels of downstream facilities and may not significantly hinder overall performance of the system.

> Section 2.3.1. describes the key dam/reservoir metrics and the ranking methods.
>
> Section 2.3.2. describes the key spreading ground metrics and the ranking methods.
>
> Section 2.3.3. describes the key major channel outlet metrics and the ranking methods.

### 2.3.1 Dams/Reservoirs

This section describes the hydrologic metrics used during the analysis of the dams/reservoirs and also discusses the assessment methods used for ranking their performance levels.

#### *2.3.1.1 Key Dam/Reservoir Metrics*

The analysis of the dams and reservoirs used four key stormwater metrics to determine their performance:

- Average Annual Volume of Stormwater Captured or Retained
- Average Annual Volume of Stormwater Discharged through Spillway
- Frequency of Spillway Events
- PMF Exceedance Events

The inflow and discharge hydrographs and the volume of stormwater runoff stored were analyzed for each of the dams. The analysis determined the average annual volume of stormwater captured in the reservoirs and the average annual volume of stormwater lost through the spillways. The analysis identified and analyzed spillway events where the water surface elevation behind a dam was at or above the spillway crest elevation. Additionally, the peak flow rates from all projections were checked to determine if flows were within the maximum rated discharge capacity of the dams. All dams are designed and rated to pass flows of their respective Probable Maximum Flood (PMF).

For the stormwater metrics, the volume of water captured in the reservoirs was considered to be available for controlled release to downstream spreading grounds. This volume thus represents available water supply. However, the volume of water released during spillway flow is likely to exceed the intake capacity of the downstream spreading facilities. This stormwater instead flows out to the ocean and is much less likely to contribute to available water supply. The ratio of the average stormwater captured by a dam versus the total amount of stormwater that flowed into the dam provides an indication of the capture efficiency of the facility for local water conservation.

From the analysis of the simulation results for possible PMF exceedances, it was found that the PMF flow rate was not exceeded for any of the future projections. Therefore, the PMF exceedance events metric was not used in determining the performance level rankings.

#### *2.3.1.2 Ranking Method*

From the analysis results, water conservation performance levels were developed for the dams and reservoirs. Specific criteria were used to assign each of the dams to one of three performance level categories ranging from “I” – potential for enhancements to “III” – high potential for enhancements.

The ranking criteria for each of the dams included the following:

D1. Historic capture efficiency
D2. Future capture efficiency
D3. Change in future capture efficiency
D4. Historic frequency of spillway events
D5. Future frequency of spillway events

The equations used for each of the ranking criterion are listed below. For ranking criteria D2 and D5, the most conservative of the six future projections was chosen to better indicate which facilities were the least efficient or least resilient to climate change.

$$D1 = \left[\frac{(Average\ Capture\ Volume)_{Historic}}{(Average\ Capture\ Volume)_{Historic} + (Average\ Spillway\ Volume)_{Historic}}\right]$$

$$D2 = Min\left[\frac{(Average\ Capture\ Volume)_{6,Future}}{(Average\ Capture\ Volume)_{6,Future} + (Average\ Spillway\ Volume)_{6,Future}}\right]$$

$$D3 = D2 - D1$$

$$D4 = \left[\frac{(Number\ of\ Spillway\ Events)_{Historic}}{(14\ Historic\ Years)}\right]$$

$$D5 = Max\left[\frac{(Number\ of\ Spillway\ Events)_{6,Future}}{(84\ Future\ Years)}\right]$$

After the values were calculated, the LACFCD dams were then ranked for each criterion. The rankings ranged from 1 through 14, with 1 representing the *best performing* facility and 14 representing the *lowest performing* facility. A ranking scale of 14 is used since there are 14 LACFCD dams. As shown below, the five dam criteria were then averaged to determine the final rank for each of the dams. The highest performing (lowest ranking quarter) dams were assigned Performance Level I. Moderately performing dams (the center half grouping) were assigned Performance Level II. The lowest performing (highest ranking quarter) were assigned Performance Level III.

$$Final\ Rank = Average\ [D1, D2, D3, D4, D5]$$

Dams in Performance Level I typically have high capture efficiencies and spillway events are rare; however, these facilities may still be considered for further enhancements and receive additional analysis in Task 5. Generally, there is always some potential to make enhancements to any facility.

Dams in Performance Level II typically have a moderate capture efficiency and/or moderate number of spillway events. These facilities are more likely to be considered for enhancements and will likely be the subject of further analysis in Task 5.

Dams in Performance Level III typically have poor capture efficiency and more frequent spillway events. Out of all of the dams, these are most likely to be considered for modifications and will be the subject of further analysis in Task 5.

The emphasis on capture efficiency and spillway events from this method does not adequately address the potential for improved performance of the USACE dams. Therefore, this method was considered but ultimately not used to determine the final performance levels of the 4 USACE dams. Each was assigned Performance Level II and will be the subject of further investigation in Task 5.

## 2.3.2 Spreading Grounds

This section describes the major hydrologic metrics that were used during the analysis of the spreading facilities as well as discusses the assessment methods used for ranking their performance levels.

### *2.3.2.1 Key Spreading Ground Metrics*

The spreading ground analysis used two key stormwater metrics to determine their performance:

- Total Annual Volume of Stormwater Recharged
- Total Annual Volume of Stormwater Bypassed

From the two metrics, the total potential annual volume of stormwater that could be captured was determined. The ratio of total recharge verses the total potential provides an indication of the efficiency of the spreading ground. In the context of this report, bypass for the spreading grounds is defined to be the stormwater that entered the channel forebay but was not recharged at that spreading ground. The total potential is the combination of the bypass plus the quantity recharged in the spreading ground.

### *2.3.2.2 Ranking Method*

After the analysis of the different metrics was complete, all spreading facilities were ranked based upon a number of criteria. Similar to the dams, specific criteria were developed to assign each of the spreading facilities to one of the three performance level categories. The criteria used were as follows:

S1. Historic bypass
S2. Historic capture efficiency
S3. Capture volume versus spreading ground wetted area
S4. Capture volume versus spreading ground surface storage volume
S5. Capture volume versus spreading ground percolation rate
S6. Change in future recharge
S7. Change in future capture efficiency
S8. Range of potential capture

The equations used for each of the ranking criterion are listed below. The last three criteria, S6 through S8, were developed to assess the overall variation of the future projection results with respect to the historic conditions.

$$S1 = (Average\ Bypass\ Volume)_{Historic}$$

$$S2 = \left[\frac{(Average\ Recharge\ Volume)_{Historic}}{(Average\ Recharge\ Volume)_{Historic} + (Average\ Bypass\ Volume)_{Historic}}\right]$$

$$S3 = \left[\frac{(Average\ Recharge\ Volume)_{Historic}}{(Spreading\ Ground\ Wetted\ Area)}\right]$$

$$S4 = \left[\frac{(Average\ Recharge\ Volume)_{Historic}}{(Spreading\ Ground\ Storage\ Volume)}\right]$$

$$S5 = \left[\frac{(Average\ Recharge\ Volume)_{Historic}}{(Spreading\ Ground\ Percolation\ Rate)}\right]$$

$$S6 = Max\left[\frac{(Average\ Recharge\ Volume)_{6,Future}}{(Average\ Recharge\ Volume)_{Historic}}\right]$$

$$S7 = Min\left[\frac{(Average\ Recharge\ Volume)_{6,Future}}{(Average\ Recharge\ Volume)_{6,Future} + (Average\ Bypass\ Volume)_{6,Future}}\right] - S2$$

$$S8 = (Exponent\ on\ Stormwater\ Recharge\ Curve)$$

For the change in future recharge (S6), this ranking category was established to determine whether a specific facility is flexible with respect to future variation in climate. For this category, the maximum of the six future projections was chosen to better indicate which facilities were the most efficient and resilient to climate change. If annual stormwater runoff is projected to increase overall, infrastructure that is already capable of capturing additional stormwater indicates a more flexible or robust facility. This behavior is ranked higher in this criterion. Conversely, existing infrastructure that cannot readily increase its recharge with anticipated increases in annual stormwater runoff indicates less flexibility overall. This facility type is ranked lower in this criterion.

For the change in future capture efficiency (S7), this ranking category was established to indicate whether a specific facility is able to adapt to the adverse effects of climate change. For this category, the most conservative of the six future projections was chosen to better indicate which facilities were the most adaptable to climate change. Specifically, if average annual stormwater runoff is anticipated to decrease, infrastructure that is able to increase its capture efficiency indicates a more flexible or robust facility. This adaptability is ranked higher in this criterion. Conversely, existing infrastructure that cannot readily increase its future capture efficiency when runoff is expected to decrease indicates lesser overall adaptability. This facility type is ranked lower in this criterion.

For the range of potential capture (S8), the total stormwater recharge versus the maximum potential stormwater is assessed for each facility. The maximum potential represents the total amount of stormwater that could have been captured. The resulting spread of stormwater recharge data is then compared to its deviation from the maximum potential. In Figure 17, the total potential for the Ben Lomond Spreading Ground is indicated by a dashed blue line.

Theoretically, if a spreading facility was 100% efficient, it would be able to capture all incoming stormwater, and thus all data points would fall along the dashed line. However, no spreading facility can currently capture all of the incoming stormwater for all of the varying storm season sizes, so the total recharge begins to deviate from the maximum potential line as the total annual stormwater values increases. Each point of data in this figure represents the stormwater produced during a single water year; this makes it possible to avoid the effects of historic and future climate and focus primarily on the facilities natural ability to capture stormwater for different size storm seasons. It was found that the historic records and future projection trends matched closely together, but for reference both are overlaid on one plot.

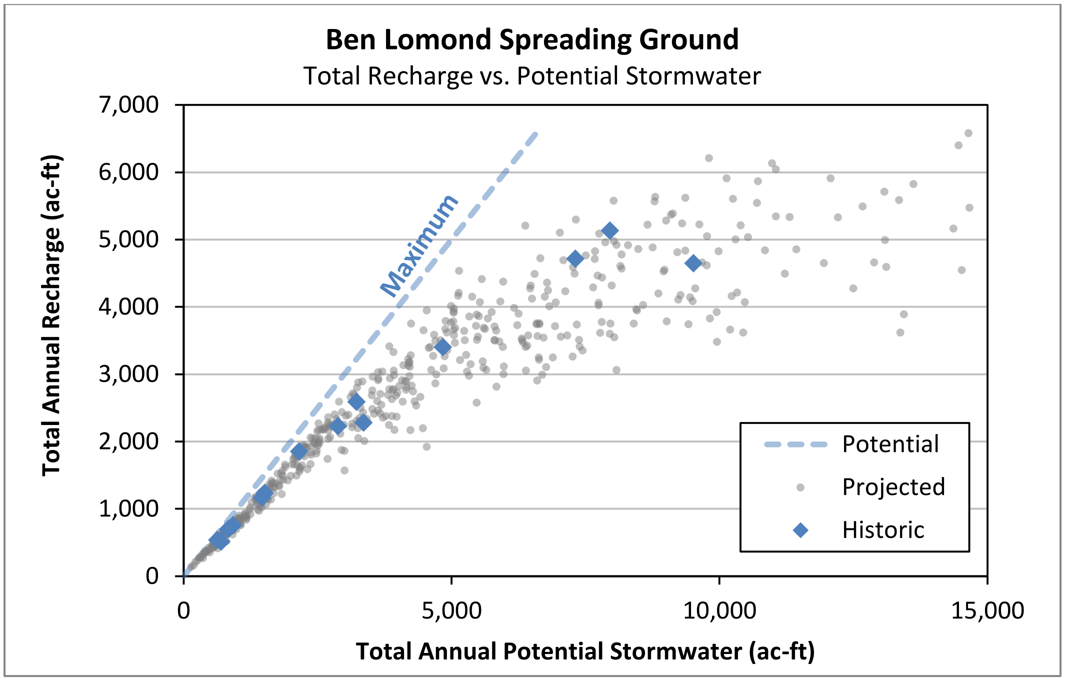


**Figure 17. Total Stormwater Recharge vs. Total Potential Stormwater**

From the shape and spread of the projections, this deviation can be generally approximated by an exponential trend line. The trend exponent provides insight into the deviation from the maximum potential line, which is related to a facility's stormwater capture efficiency. An exponent of 1.0 would indicate a perfect line or a 100% efficient spreading facility. In other words, this facility could recharge every drop of stormwater passing through the channel. Conversely, an exponent near 0.0 indicates an extremely inefficient spreading facility. As a note, this low exponent does not necessarily indicate the inability to capture, but instead provides insight into the low efficiency of a spreading ground. Typically, facilities with very low trend exponents are unaffected by changes in climate and will recharge nearly the same amount of stormwater on average regardless of hydrologic conditions. For example, Walnut Spreading ground may show an inefficient potential curve, but currently this has more to do with operational choice as it is not operated during storms. This type of facility has a large potential for enhancement through either operational changes, structural enhancements, or even potential future policy changes out to 2095.

To better demonstrate the difference between the relative curvatures of different spreading facilities, Figure 18 and Figure 19 show a high and low efficiency trend for the Ben Lomond and Walnut spreading grounds, respectively. The exponent for the first facility is 0.81 while the second facility is approximately 0.11. Inspection of these exponents identifies that the Ben Lomond spreading ground has some existing adaptability to increase its overall stormwater recharge. As an aside, the coefficient in front of the exponential trend equation is a vertical scaling factor that is independent of curvature or trend shape, and is thus not investigated further.

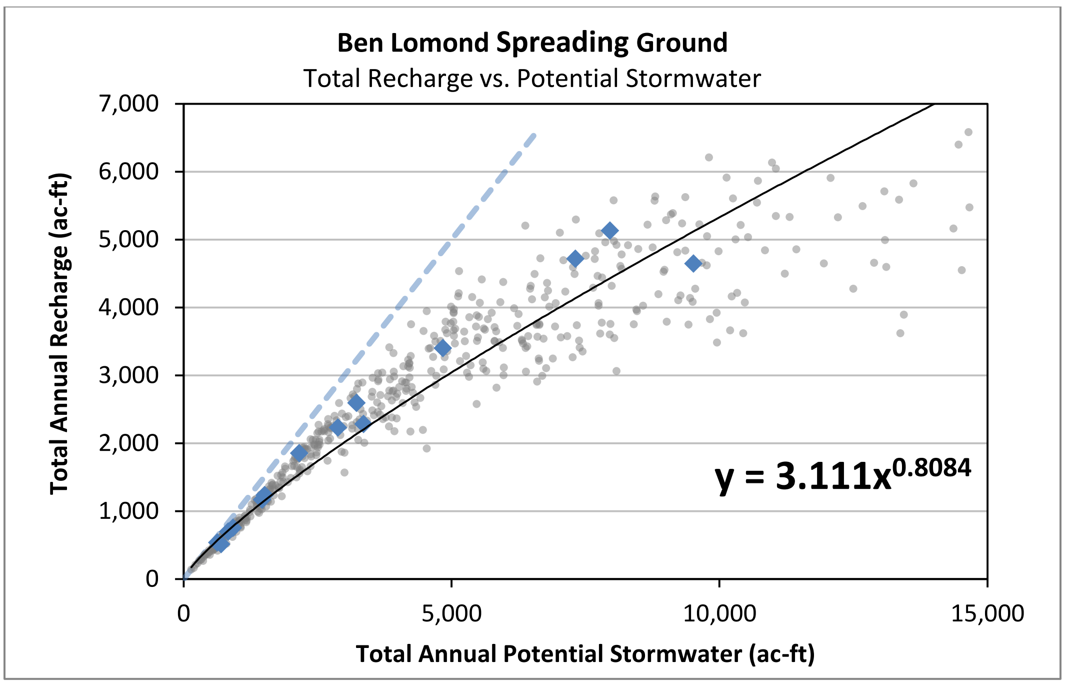


**Figure 18. High Efficiency Spreading Ground**

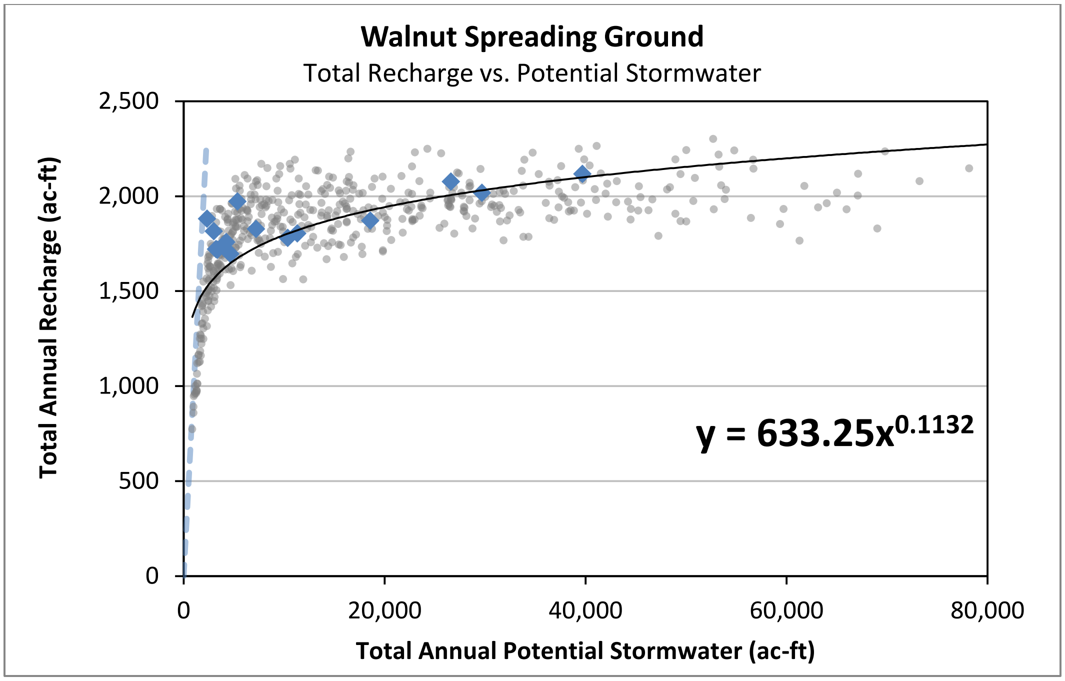


**Figure 19. Low Efficiency Spreading Ground**

Once all of the criteria were developed and analyzed, the spreading grounds were ranked for each criterion. The rankings range from 1 through 25, with 1 representing the *best performing* facility and 25 representing the *lowest performing* facility for each criterion. A ranking scale of 25 is used since there are 25 spreading grounds being analyzed. As shown below, the eight criteria were then averaged to determine the final rank for each of the spreading ground facilities. The most efficient andhighest performing (lowest ranking quarter) spreading grounds were assigned Performance Level I. The moderately efficient and performing (the center half grouping) spreading grounds were assigned Performance Level II. Finally, the least efficient andlowest performing (highest ranking quarter) spreading grounds were assigned Performance Level III.

$$Final\ Rank = Average\ [S1, S2, S3, S4, S5, S6, S7, S8]$$

### 2.3.3 Major Channel Outlets

This section describes the major hydrologic metrics that were used during the analysis for the major channel outlets as well as discusses the methods used for ranking their assessment levels.

#### *2.3.3.1 Key Major Channel Outlet Metrics*

The major channel outlet analysis used two key stormwater metrics to determine their performance:

- Average Annual Volume of Stormwater Discharged to the Ocean
- Peak Flood Flow Rate

From the two metrics, the major channel outlets could be assessed overall for their respective watershed's stormwater discharges lost to the ocean and their general flood risk mitigation ability. The quantity of stormwater volume that is discharged to the ocean from the channels provides an indication of the potential stormwater supply that could be captured within their upstream watersheds. The peak flood flow rate at the channel outlets allows for an understanding of the potential changes from the historic climate to the future projections.

#### *2.3.3.2 Ranking Method*

After the analysis of the two metrics were complete, the 5 major channels outlets were ranked based upon several criteria. Similar to the other facilities, specific criteria were developed to grade each of the channel outlets. The criteria used were as follows:

C1. Change in future discharge
C2. Change in future unit area discharge
C3. Change in future discharge per total discharge
C4. Change in future average peak flow rate

The equations used for each of the ranking criterion are listed below. For ranking criterion C4, the maximum of the six future projections was chosen to indicate which channel outlet could see the largest overall change due to climate change.

$$C1 = (Average\ Annual\ Discharge)_{Future} - (Average\ Annual\ Discharge)_{Historic}$$

$$C2 = \left[\frac{(Average\ Annual\ Discharge)_{Future} - (Average\ Annual\ Discharge)_{Historic}}{Area\ of\ Watershed}\right]$$

$$C3 = \frac{\left[\frac{Average\ Annual\ Discharge}{5\ Outlet\ Total\ Discharge}\right]_{Future} - \left[\frac{Average\ Annual\ Discharge}{5\ Outlet\ Total\ Discharge}\right]_{Historic}}{\left[\frac{Average\ Annual\ Discharge}{5\ Outlet\ Total\ Discharge}\right]_{Historic}}$$

$$C4 = \left[\frac{Max[(Average\ Peak\ Flow)_{Future}] - (Average\ Peak\ Flow)_{Historic}}{(Average\ Peak\ Flow)_{Historic}}\right]$$

After the values were calculated, the major channel outlets were then ranked for each criterion. The rankings ranged from 1 through 5, with 1 representing the *lowest discharging* watershed and 5 representing the *highest discharging* watershed. A ranking scale of 5 is used since there were 5 major channel outlets analyzed that discharge to the Pacific Ocean. As shown below, the four major channel outlet criteria were then averaged to determine the final rank for each. Due to the small amount of major channel outlets, the two lowest discharging (lowest ranking) outlets were assigned Assessment Level I. The next two higher discharging channel outlets were assigned Assessment Level II. The one remaining and highest discharging outlet was assigned Assessment Level III.

$$Final\ Rank = Average\ [C1, C2, C3, C4]$$

The channel outlets in Assessment Level I have a lower discharge volume when compared to the others. The channel outlets in Assessment Level II and III have incrementally higher stormwater discharge volumes to the ocean; this in turn means that the upstream watershed could be the focus of creating additional stormwater capture.

# 3 Results and Discussion

Analysis of the existing infrastructure response for both the historic and future climate projections was performed for this task of this LA Basin Study. This task built upon a subset of the Task 3 future projections and performed a detailed analysis of the individual water conservation facilities, dams, and channel outlets within the Basin Study Watersheds. The facilities assessed in this task were:

- 18 Dams
    - 14 Major LACFCD Dams
    - 4 Major USACE Dams
- 26 Major Spreading Ground Facilities
- 5 Major Channel Outlets

Reclamation analyzed the 14 major LACFCD dams, USACE assessed their 4 major dams, and LACFCD analyzed the 26 major spreading grounds and 5 channel outlets in the region. Although there are 26 spreading grounds, the Hansen and Tujunga facilities share the same channel forebay subwatershed within WMMS resulting in these two sites being analyzed together. Therefore, there are only 25 rankings for spreading grounds in this report.

For the dam and spreading ground performance levels, Table 2 defines specific terminology to better describe the performance and differentiate between the levels. Performance Level I indicates an existing facility that is functioning with a high efficiency and is very resilient to the projected climate. Even with this performance level, however, the facilities in this category may still have the potential for future enhancements. On the lower end of the spectrum, Performance Level III describes a facility that operates at a lower efficiency and may experience adverse impacts from the future climate projections. This type of facility is generally a higher priority and has a greater potential for enhancements.

**Table 2. Performance Levels (Dams & Spreading Grounds)**

| Performance Level | Performance Description | Prospective Enhancements | Enhancement Priority |
|---|---|---|---|
| I | • ***High*** Efficiency<br>• ***High*** Resiliency to Climate Change Projections | Potential Exists | Low |
| II | • ***Moderate*** Efficiency<br>• ***Moderate*** Resiliency to Climate Change Projections | Moderate Potential | ↕ |
| III | • ***Low*** Efficiency<br>• ***Low*** Resiliency to Climate Change Projections | High Potential | High |

For the major channel outlets, Table 3 defines specific terminology to better describe the discharges to the ocean and applies a breakdown between the outlets with respect to stormwater conservation potential. Assessment Level I indicates that a channel outlet is discharging a comparatively smaller amount of stormwater than its counterparts. On the other end of the spectrum, Assessment Level III designates a channel outlet that discharges a relatively large amount of stormwater runoff. The ability to capture this stormwater volume is highly beneficial. Efforts to increase regional stormwater capture should first be focused on the watersheds that will yield the greatest potential and then followed up by concentrating on capturing the smaller discharge volumes from the remaining watersheds.

**Table 3. Assessment Levels (Channel Outlets)**

| Assessment Level | Assessment Description | Stormwater Supply | Watershed Priority |
|---|---|---|---|
| I | • ***Low*** Discharge Volumes to the Ocean | Potential Exists | Low |
| II | • ***Moderate*** Discharge Volumes to the Ocean | Moderate Potential | ↕ |
| III | • ***High*** Discharge Volumes to the Ocean | High Potential | High |

WMMS performed the simulations of the water conservation and flood risk mitigation network simultaneously for the existing infrastructure. Therefore, hydrologic impacts on a specific facility were propagated to other interconnected facilities in the network. For the performance levels of the existing infrastructure, the individual facilities were ranked based upon their performance within the network. This allowed the dams or spreading grounds to be compared to other facilities of the same type to identify where each stands with respect to one another. This also allows a comparison of the discharges of stormwater to the ocean from each of the channel outlets. However, a certain level of institutional knowledge will be necessary when processing these performance levels in Task 5. For example, certain dams and reservoirs are connected in series without spreading grounds in between. In such cases, low efficiency performance of the upstream dams may be offset by high performance levels of downstream facilities and may not significantly hinder overall performance of the system. This will be analyzed further in Task 5.

The analysis indicates— in certain future projections—that overall increased stormwater runoff reduces the overall efficiency of facilities. This result provides areas to target for future stormwater capture and recharge concepts whereas currently this facility may be performing at peak efficiency. This is the rationale behind all facilities being classified as having some potential for future enhancements.

Since this existing infrastructure analysis serves as the baseline condition for the development of Task 5, it was important to use operational guidelines and rating curves that existed prior to the start of the future period in water year 2012.

Additionally, any infrastructure modifications that were implemented after the start of the future period are not included in this analysis. Since the WMMS model is calibrated to match historical data and new modifications would not have sufficient data to calibrate against, these relatively recent modifications are omitted from Task 4. For instance, the modifications completed at Morris Dam to lower the minimum pool are not included in this task. However, Task 5 will consider any recent infrastructure and operational guidelines that are now used or are in short-term development for the water conservation and flood risk mitigation system. Furthermore, Task 5 will develop new infrastructure and/or operational guideline concepts in addition to these planned modifications not yet accounted for in the WMMS model.

The remainder of this section discusses the results from the analysis of the existing dams, spreading grounds, and major channel outletsfor the historical period (Water Years 1987 through 2000) and the future climate projections (Water Years 2012 through 2095).

Section 3.1. provides an overview of the results from the dam analysis.

Section 3.2. provides an overview of the results from the spreading ground analysis.

Section 3.3. provides an overview of the results from the major channel outlet analysis.

# 3.1 Dams/Reservoirs

## 3.1.1 LACFCD Dams

The analysis results and ranking criteria were used to assign performance levels to the dams and reservoirs as described previously in the methods section. The Appendix presents a summary of the results of this analysis and the performance level for each dam. The Appendix also presents the rankings for each of the criteria used to rank the dams (see Tables A-1 and A-2 for LACFCD dams). Dams with the highest potential for enhancements will be the subject of further analysis in Task 5.

**Table 4. LACFCD Dam Analysis Results**

| Performance Level | Dam |
|---|---|
| **III**<br>(High Potential) | Big Tujunga<br>Devils Gate<br>Eaton Wash |
| **II**<br>(Moderate Potential) | Big Dalton<br>Cogswell<br>Morris<br>Pacoima<br>Puddingstone Diversion<br>San Dimas<br>San Gabriel<br>Santa Anita |
| **I**<br>(Potential Exists) | Live Oak<br>Puddingstone<br>Thompson Creek |

The dams listed in Performance Level III are projected to have frequent spillway events in the most extreme climate projections along with low projected capture efficiencies. These dams have the highest potential for enhancements upstream, downstream, or to the facility itself to increase the water conservation benefit to the region. These high potential dams will be the subject of further analysis in Task 5 of the LA Basin Study.

The dams in Performance Level II typically have somewhat frequent spillway events and slightly higher capture efficiencies. These dams have a moderate potential for future enhancements.

The dams in Performance Level I have low frequencies of spillway events and high projected capture efficiencies. Although these dams are listed in Performance Level I, there is still the potential for enhancements to further increase stormwater capture.

### 3.1.2 USACE Dams

Initially, the same ranking criteria used for assessment of the LACFCD dams were used to assess the USACE dams; however, since most of the criteria focused on spillway events or capture efficiencies, the ranking for all four of the major USACE dams were initially ranked Performance Level I, indicating low potential for enhancements. Due to the large storage volume of these flood control facilities, there were either none or extremely infrequent spillway events. However, much of the water captured by the USACE dams during large storm events is operationally released to the Pacific Ocean.

This ranking method was considered, but ultimately not used to determine the final performance levels of the USACE dams. To ensure these dams were further investigated for their water conservation potential in Task 5, it was decided to assign all USACE dams to Performance Level II. This ranking places appropriate emphasis on the potential for enhancements at these flood control facilities, and each will be investigated more closely for water conservation improvements in Task 5.

**Table 5. USACE Dam Analysis Results**

| Performance Level | Dam |
|---|---|
| **II**<br>(Moderate Potential) | Hansen<br>Santa Fe<br>Sepulveda<br>Whittier Narrows |

## 3.2 Spreading Grounds

As described in the methods section, the simulated results were used to assign performance levels to each of the spreading facilities. The Appendix presents a summary of the results of this ranking and provides a more in-depth look at how the performance level was developed for each of the spreading facilities (see Tables A-3 and A-4 for spreading grounds). The least efficient or highest potential spreading facilities will likely be the subject of further analysis in Task 5 of the LA Basin Study.

It should be noted that facilities that were ranked best in overall efficiency and proved resilient will not necessarily be excluded from further analysis in Task 5. These facilities may still hold significant potential for increasing local stormwater capture. The ranking assessment serves as a tool to help target specific facilities or regions that could benefit from future operational modifications, structural improvements, or even new enhanced facilities.

Table 6 provides the final performance levels for the spreading facilities.

**Table 6. Spreading Ground Analysis Results**

| Performance Level | Spreading Ground |
|---|---|
| **III** (High Potential) | Buena Vista<br>Dominguez Gap<br>Forbes<br>Live Oak<br>Lopez<br>San Gabriel Canyon |
| **II** (Moderate Potential) | Ben Lomond<br>Branford<br>Citrus<br>Eaton Basin<br>Eaton Wash<br>Hansen/Tujunga<br>Little Dalton<br>Pacoima<br>Rio Hondo<br>San Gabriel Coastal<br>Santa Anita<br>Santa Fe<br>Walnut |
| **I** (Potential Exists) | Big Dalton<br>Irwindale<br>Peck Road<br>San Dimas<br>Sawpit<br>Sierra Madre |

Spreading grounds assigned to Performance Level III typically are the least efficient, least resilient, or have a large potential for increasing stormwater capture. Performance Level II represents facilities that are moderately efficient, moderately resilient, or have a moderate potential for increasing stormwater capture. And finally, Performance Level I showcases facilities that have an overall high efficiency, high resilience, and have some level of potential stormwater capture ability.

As a limitation for these rankings, the performance levels were developed solely from analyzing model results. Due to this, they cannot encompass every operational aspect and may not truly represent reality. A certain degree of subjective scrutiny will be required when utilizing the results in Task 5. Nevertheless, these performance levels provide valuable results to help target facilities that have the greatest opportunity for enhancing stormwater capture.

Lastly, Sierra Madre is shown to have a high performance level; however, this site could not be properly modeled within WMMS, and is potentially ranked artificially high for efficiency and resilience. Furthermore, the Hansen and Tujunga spreading grounds have been combined since these two spreading grounds share the same forebay subwatershed within the WMMS model.

## 3.3 Channel Outlets

The analysis results and ranking criteria were used to assign assessment levels to the major channels and their upstream watersheds as described previously in the methods section. The Appendix presents a summary of the results of this analysis and the assessment level for each channel outlet and its upstream watershed. The Appendix also presents the rankings for each of the criteria used to rank the channels (see Tables A-5 and A-6 for the major channel outlets). The watersheds containing the channel outlets discharging the largest amounts of stormwater to the ocean reflect the regional areas with the greatest potential for enhancements.

Table 7 shows the final assessment levels for the channel outlets and their respective watersheds.

**Table 7. Channel Outlet Analysis Results**

| Assessment Level | Channel Outlet (Watershed) |
|---|---|
| **I**<br>(Potential Exists) | Dominguez Channel<br>Malibu Creek |
| **II**<br>(Moderate Potential) | Ballona Creek<br>San Gabriel River |
| **III**<br>(High Potential) | Los Angeles River |

The rankings above specify which of the five major channel outlets have the highest average annual stormwater discharges to the Pacific Ocean. The ability to reduce the stormwater runoff that is lost to the ocean would greatly increase the potential stormwater supply in this region. While all of these major channel outlets convey a considerable amount of stormwater runoff from their watersheds to the ocean, there are relatively greater quantities for specific watersheds, which represent a potential opportunity to increase the local stormwater capture in these watersheds.

In Assessment Level III, the Los Angeles River channel outlet discharges the largest amount of stormwater to the ocean. This watershed already captures and recharges a fairly large amount of stormwater through the existing water conservation infrastructure, but the ability to further boost stormwater capture in this watershed would greatly enhance the local water supply. Adding additional water conservation facilities within the Los Angeles River watershed will be a focus of Task 5.

The Ballona Creek and San Gabriel River channel outlets were categorized into Assessment Level II. The Ballona Creek watershed currently does not have any major stormwater conservation facilities within it and this in turn causes a large amount of ocean discharges. Considering that Ballona Creek has the highest unit area discharge of all of the watersheds investigated, the realization of increased stormwater capture would meaningfully improve the local supply. In contrast, the San Gabriel River watershed currently captures nearly all of the stormwater produced within it, but there is still an appreciable volume reaching the ocean when compared to the outlets in Assessment Level I. The majority of the ocean discharges from the San Gabriel River watershed originate from its most downstream tributary, Coyote Creek. However, since the San Gabriel River watershed is uniquely situated to capture stormwater due to existence of numerous water conservation facilities and favorable geologic conditions, constructing or enhancing new facilities within this area should be a central focus during Task 5.

The remaining two channel outlets were ranked into Assessment Level I since they have the lowest overall stormwater discharges to the ocean. These watersheds, Dominguez Channel and Malibu Creek, are small watersheds and have no major stormwater conservation facilities within them. Increased capture of these stormwater discharge volumes could be attempted, but since these volumes are not as large as those of the channel outlets in the other assessment levels, these watersheds should be considered supplemental.

## 3.4 Infrastructure by Watershed

The Los Angeles River watershed contains 5 LACFCD dams, 2 USACE dams, and 13 spreading grounds (Figure 20). Both the LACFCD and USACE dams ranked no higher than a Performance Level II for water conservation. All of the spreading grounds downstream of these five dams, with the exception of Rio Hondo Coastal, were also all ranked into Performance Level II. Enhancing the dam-spreading ground nexus could lead to higher stormwater capture within the watershed.

The San Gabriel River watershed contains 9 LACFCD dams, 2 USACE dams, and 12 spreading grounds (Figure 21). The highest performing LACFCD dams are within this watershed and provide a majority of the Study Area’s stormwater conservation. The dams and spreading grounds in this watershed work extremely well in concert with one another and this is reflected by the San Gabriel River having a moderately low stormwater runoff volume. However, the majority of these facilities are in the upper San Gabriel River watershed and there is a potential to capture additional runoff from its lowest tributary, Coyote Creek.

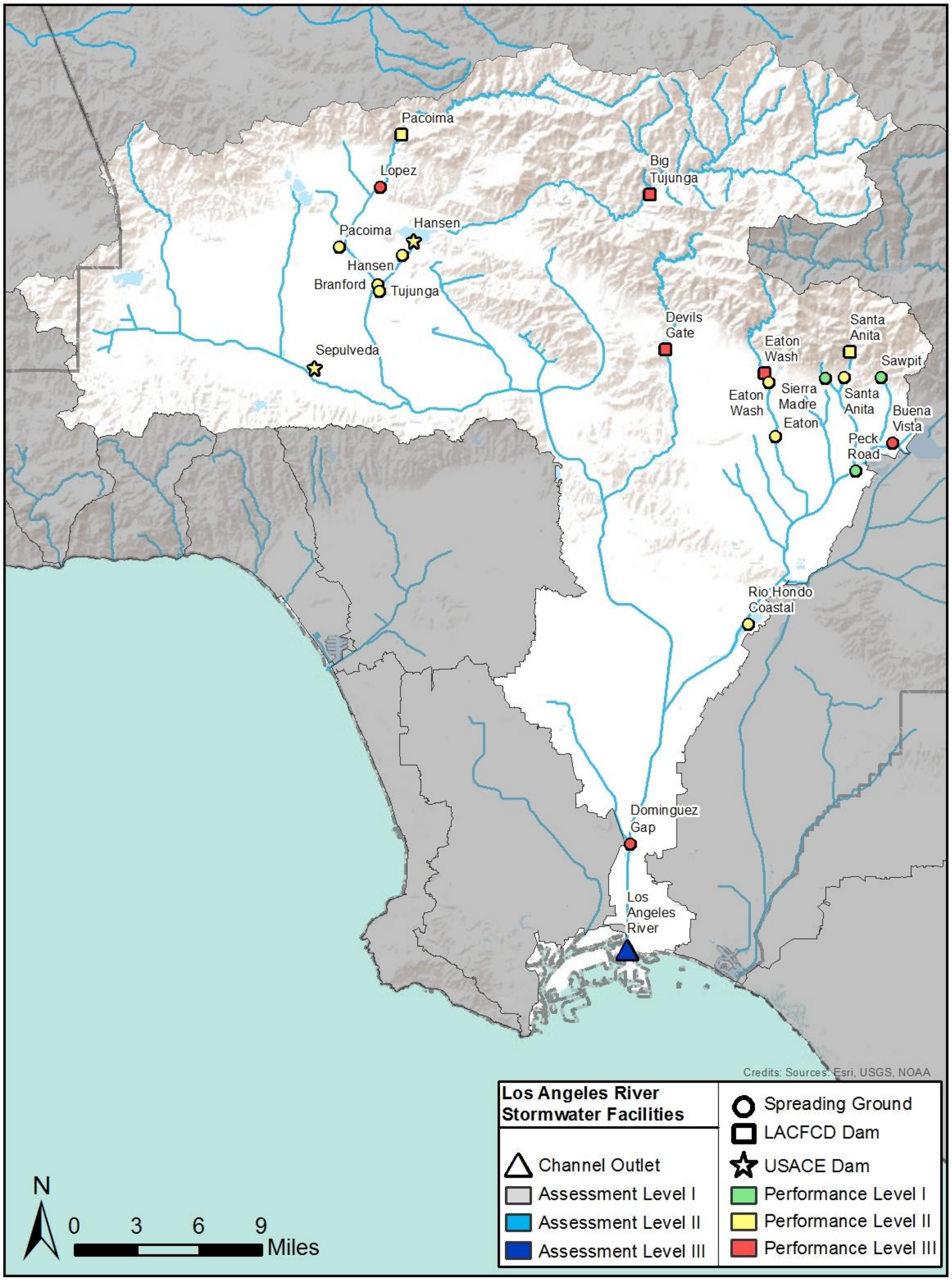


**Figure 20. Los Angeles River Watershed Infrastructure Results**

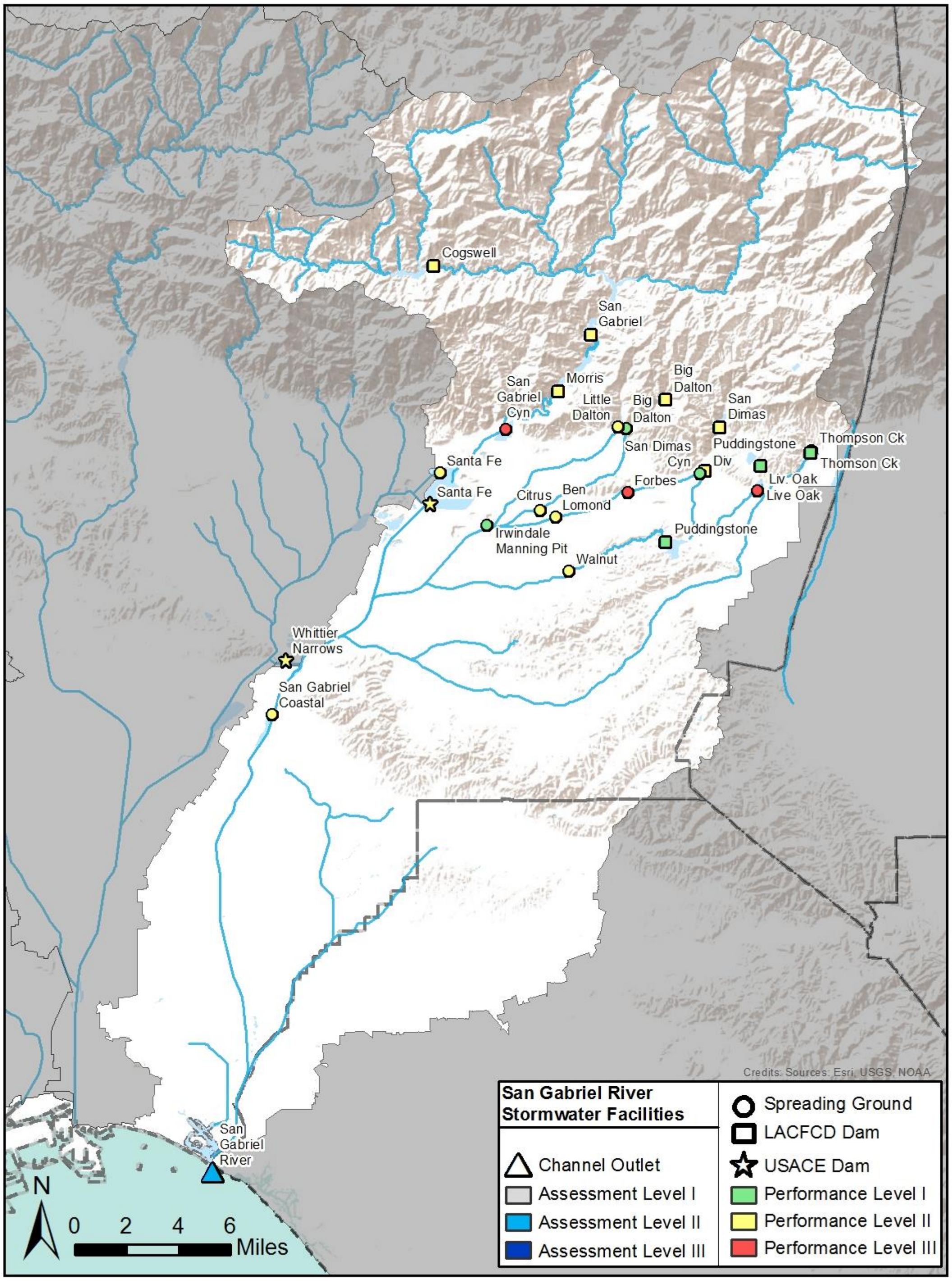


**Figure 21. San Gabriel River Watershed Infrastructure Results**

# 4 Conclusion

The objective of Task 4 was to assess the response of the existing spreading grounds, dams, and channel outlets throughout the system for both historic and projected future climate conditions and to assess the potential for increased stormwater capture. The water conservation and flood risk mitigation network includes 14 major LACFCD dams and reservoirs, 4 major USACE dams, 26 major spreading grounds, and 5 major channel outlets in the region. This task built upon the downscaled climate change projections and hydrologic modeling results of Task 3 of the LA Basin Study to assess stormwater capture and to analyze infrastructure response and operations plans for the facilities. The 18 dams/reservoirs and 26 spreading grounds were given performance levels independently; however, these major components were analyzed as a system and were ranked with respect to the other facilities in the network. Similarly, the 5 major channel outlets in the region were compared to one another for their stormwater discharges to the ocean, and were assigned assessment levels to assist in targeting specific watersheds for potential enhancements.

## 4.1 Dams/Reservoirs

### 4.1.1 LACFCD Dams

For the dams, the inflow and discharge hydrographs and the stormwater captured for each of the 14 major LACFCD dams were analyzed. The analysis was performed for the historical period, which included Water Years 1987 through 2000, and for six separate climate projections for the future period, which encompassed Water Years 2012 through 2095.

The analysis was performed to determine the following:

- Average Annual Volume of Stormwater Captured
- Average Annual Volume of Stormwater Discharged through Spillway
- Frequency of Spillway Events

The results were used to assign performance levels to the 14 major LACFCD dams. Specific criteria were used to assign each of the dams to one of three performance level categories, designated “I” (potential for enhancements) to “III” (high potential for enhancements). Table A-2 in the Appendix presents a summary of the results of this analysis and the performance level for each dam. The dams with the highest potential will be the primary subject of further analysis in Task 5 of the LA Basin Study. Nevertheless, certain lower potential dams may still be analyzed as well, as there is always some potential for enhancement.

**Table 8. Performance Levels by Watershed – LACFCD Dams**

| Dam Performance | |
|---|---|
| **Los Angeles River** | |
| Pacoima | II |
| Santa Anita | II |
| Big Tujunga | III |
| Devils Gate | III |
| Eaton Wash | III |
| **San Gabriel River** | |
| Live Oak | I |
| Puddingstone | I |
| Thompson Creek | I |
| Big Dalton | II |
| Cogswell | II |
| Morris | II |
| Puddingstone Diversion | II |
| San Dimas | II |
| San Gabriel | II |

### 4.1.2 USACE Dams

Similar to the LACFCD dams, the inflow and discharge hydrographs and the volume of water stored in the reservoirs for each of the four major USACE dams were analyzed; however, the results indicated Performance Level I for these dams. Because of this, the same methodology used to rank the LACFCD dams was not conducted on the USACE dams. There is considerable potential for enhancements to improve the water conservation benefit at these dams. To account for this, the four USACE dams were assigned to Performance Level II.

**Table 9. Performance Levels by Watershed – USACE Dams**

| Dam Performance | |
|---|---|
| **Los Angeles River** | |
| Hansen | II |
| Sepulveda | II |
| **San Gabriel River** | |
| Santa Fe | II |
| Whittier Narrows | II |

## 4.2 Spreading Grounds

For the analysis of the spreading facilities, the total recharge, efficiency, and future resiliency of the facilities was analyzed. The analysis was performed to determine the following:

- Total Annual Volume of Stormwater Recharged
- Total Annual Volume of Stormwater Bypassed

The results were used to assign performance levels to the 26 major spreading grounds. Specific criteria were used to assign each of the spreading grounds to one of three performance level categories, designated "I" (potential for enhancements) to "III" (high potential for enhancements). Table A-4 in the Appendix presents a summary of the results of this analysis and the performance level for each facility. The spreading ground facilities with the highest potential will be the primary subject of further analysis in Task 5 of the LA Basin Study.

**Table 10. Performance Levels by Watershed – Spreading Grounds**

| Spreading Ground Performance | | | | |
|---|---|---|---|---|
| **Los Angeles River** | | | **San Gabriel River** | |
| Peck Road | I | | Big Dalton | I |
| Sawpit | I | | Irwindale | I |
| Sierra Madre | I | | San Dimas | I |
| Branford | II | | Ben Lomond | II |
| Eaton Basin | II | | Citrus | II |
| Eaton Wash | II | | Little Dalton | II |
| Hansen/Tujunga | II | | San Gabriel Coastal | II |
| Pacoima | II | | Santa Fe | II |
| Rio Hondo | II | | Walnut | II |
| Santa Anita | II | | Forbes | III |
| Buena Vista | III | | Live Oak | III |
| Dominguez Gap | III | | San Gabriel Canyon | III |
| Lopez | III | | | |

Facilities in Performance Level III that were determined to be the least efficient and resilient, or have the highest overall potential for stormwater capture have a multitude of reasons or limitations for this ranking. Although certain facilities may not be readily adaptable or easily modified, there still is an opportunity for enhancing stormwater capture in the form of adjacent new infrastructure or even nearby regional facilities. These regional improvements could help to increase the overall capture efficiency for a specific area.

## 4.3 Channel Outlets

For the analysis of the major channel outlets, the change in future discharges and average peak flow rates were analyzed. The analysis was performed to determine the following:

- Average Annual Volume of Stormwater Discharged to the Ocean
- Peak Flood Flow Rate

The results were used to assign assessment levels to the 5 major channel outlets and their respective watersheds. Specific criteria were used to assign each of the channel outlets to one of three assessment level categories, designated "I" (low watershed priority for water conservation) to "III" (high watershed priority for conservation). Table A-6 in the Appendix presents a summary of the results of this analysis and the assessment level for each outlet. The watersheds containing the channel outlets with the highest stormwater discharges to the ocean will help to guide the analysis in Task 5 of the LA Basin Study.

**Table 11. Assessment Levels by Watershed – Major Channel Outlets**

| Channel Outlet Assessment | |
|---|---|
| Watershed | |
| Dominguez Channel | I |
| Malibu Creek | I |
| Ballona Creek | II |
| San Gabriel River | II |
| Los Angeles River | III |

## 4.4 Future Considerations

It is very important to understand that this assessment relied upon the current water conservation and flood risk mitigation system as the baseline condition, assuming that no modifications were made over the course of the study period. This uniform baseline was used to assess the current configuration and operational guidelines for two time periods:

1. Historical Climate Conditions (WY 1987-2000)
2. Future Climate Projections (WY 2012-2095)

This assessment improved the current understanding of whether or not the existing system would function adequately in the future as compared to its historical performance. It was found that there is a wide range of overall efficiency and resiliency within the existing system and that certain facilities are more readily adaptable to future changes than others. Facilities with the greatest potential for increased stormwater capture will be the subject of further analysis under Task 5 – Infrastructure & Operations Concepts.

The baseline water conservation and flood risk mitigation system used in this analysis may change considerably over the course of the future study horizon. These changes may be both large-scale and small-scale; centralized capture and decentralized capture; short, quick reforms and longer, more methodical reforms throughout the entire system over the next century. These changes were intentionally overlooked so that this analysis could serve as a status quo assessment of historical conditions and also be a “no action” evaluation of the future.

Over the course of the LA Basin Study planning horizon, major changes in technology and significant shifts in policies will certainly occur. These changes are likely to considerably alter the existing infrastructure and the operational guidelines that were used in this analysis. These changes will have major impacts on the water conservation and flood risk mitigation system as well as on the overall network of watersheds.

Additionally, one of the major changes now being embraced is the implementation of decentralized stormwater capture. Historically, stormwater capture was based on a centralized network such as the sites analyzed in Task 4. While this system has functioned well for nearly a century, newer integrated regional water management techniques are improving upon the processes. Decentralized stormwater capture will play an increasingly important role in local water supply and contribute to the broader hydrologic network to help complement the existing infrastructure. While the current goals of the existing infrastructure is to provide water conservation and flood risk mitigation to the region, future engineering techniques, improved scientific understanding, shifts in policies, and further collaboration among agencies will help to transform the existing infrastructure into a system that is well prepared to perform into the future.

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RECLAMATION

*Managing Water in the West*

# Los Angeles Basin Stormwater Conservation Study

## Task 4 Existing Infrastructure Response Appendix

U.S. Department of the Interior
Bureau of Reclamation

County of Los Angeles
Department of Public Works

Los Angeles County
Flood Control District

U.S. Army Corps of Engineers
Los Angeles District

**September 2014**

# Appendix: Existing Infrastructure Ranking Evaluation

## Tables

**Table A-1. LACFCD Dams – Ranking Evaluation (a)**

| | Average Annual Reservoir Volume Captured (ac-ft) | | | | | | |
|---|---|---|---|---|---|---|---|
| Facility Name | Historic | High 1 | High 2 | Middle 1 | Middle 2 | Low 1 | Low 2 |
| Big Dalton | 1,511 | 3,197 | 3,429 | 1,841 | 2,053 | 1,094 | 1,711 |
| Big Tujunga | 13,676 | 19,299 | 23,175 | 14,838 | 14,699 | 8,910 | 14,160 |
| Cogswell | 20,850 | 27,397 | 32,684 | 22,153 | 22,187 | 14,593 | 21,199 |
| Devils Gate | 9,870 | 12,925 | 15,652 | 10,653 | 10,324 | 6,879 | 10,103 |
| Eaton Wash | 4,231 | 6,426 | 7,278 | 4,596 | 4,780 | 2,867 | 4,226 |
| Live Oak | 563 | 1,304 | 1,301 | 690 | 801 | 413 | 638 |
| Morris | 42,629 | 53,120 | 54,959 | 46,368 | 46,560 | 42,070 | 46,067 |
| Pacoima | 7,504 | 14,354 | 15,845 | 8,305 | 8,089 | 4,387 | 7,927 |
| Puddingstone | 8,613 | 19,726 | 20,176 | 10,844 | 12,471 | 6,313 | 9,838 |
| Puddingstone Diversion | 5,975 | 12,106 | 12,968 | 7,202 | 8,010 | 4,323 | 6,783 |
| San Dimas | 4,149 | 6,798 | 7,870 | 4,621 | 4,823 | 2,883 | 4,471 |
| San Gabriel | 94,719 | 140,764 | 169,461 | 106,030 | 108,576 | 68,813 | 102,910 |
| Santa Anita | 3,775 | 6,775 | 7,387 | 4,415 | 4,589 | 2,382 | 3,919 |
| Thompson Creek | 1,102 | 2,478 | 2,494 | 1,328 | 1,542 | 810 | 1,243 |

**Table A-1. LACFCD Dams – Ranking Evaluation (b)**

| | Average Annual Reservoir Spillway Volume (ac-ft) | | | | | | |
|---|---|---|---|---|---|---|---|
| Facility Name | Historic | High 1 | High 2 | Middle 1 | Middle 2 | Low 1 | Low 2 |
| Big Dalton | 0 | 267 | 69 | 46 | 56 | 12 | 21 |
| Big Tujunga | 9,096 | 34,289 | 28,931 | 11,701 | 16,277 | 5,425 | 10,841 |
| Cogswell | 6,829 | 25,898 | 21,483 | 9,842 | 12,477 | 4,404 | 8,158 |
| Devils Gate | 5,562 | 19,277 | 14,974 | 7,230 | 9,774 | 3,770 | 6,127 |
| Eaton Wash | 640 | 2,739 | 2,186 | 921 | 1,291 | 500 | 854 |
| Live Oak | 0 | 31 | 14 | 7 | 13 | 4 | 5 |
| Morris | 74,889 | 189,341 | 196,323 | 96,129 | 109,910 | 43,516 | 84,465 |
| Pacoima | 646 | 4,123 | 2,967 | 923 | 1,368 | 613 | 651 |
| Puddingstone | 0 | 413 | 0 | 133 | 0 | 0 | 0 |
| Puddingstone Diversion | 291 | 1,975 | 1,830 | 766 | 895 | 371 | 533 |
| San Dimas | 618 | 4,066 | 3,610 | 1,525 | 2,094 | 740 | 1,144 |
| San Gabriel | 20,123 | 94,785 | 75,418 | 33,198 | 44,151 | 15,302 | 24,640 |
| Santa Anita | 205 | 1,862 | 1,115 | 448 | 644 | 282 | 382 |
| Thompson Creek | 0 | 62 | 20 | 16 | 26 | 8 | 9 |

**Table A-1. LACFCD Dams – Ranking Evaluation (c)**

| Historic and Future Capture Efficiencies | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility Name | Hist. | D1 | High 1 | High 2 | Mid. 1 | Mid. 2 | Low 1 | Low 2 | Min. | D2 | Change | D3 |
| Big Dalton | 100% | 1 | 92% | 98% | 98% | 97% | 99% | 99% | 92% | 4 | -8% | 4 |
| Big Tujunga | 60% | 13 | 36% | 44% | 56% | 47% | 62% | 57% | 36% | 13 | -24% | 13 |
| Cogswell | 75% | 11 | 51% | 60% | 69% | 64% | 77% | 72% | 51% | 11 | -24% | 12 |
| Devils Gate | 64% | 12 | 40% | 51% | 60% | 51% | 65% | 62% | 40% | 12 | -24% | 11 |
| Eaton Wash | 87% | 9 | 70% | 77% | 83% | 79% | 85% | 83% | 70% | 8 | -17% | 9 |
| Live Oak | 100% | 1 | 98% | 99% | 99% | 98% | 99% | 99% | 98% | 2 | -2% | 2 |
| Morris | 36% | 14 | 22% | 22% | 33% | 30% | 49% | 35% | 22% | 14 | -14% | 7 |
| Pacoima | 92% | 7 | 78% | 84% | 90% | 86% | 88% | 92% | 78% | 7 | -14% | 6 |
| Puddingstone | 100% | 1 | 98% | 100% | 99% | 100% | 100% | 100% | 98% | 1 | -2% | 1 |
| Pud. Div. | 95% | 5 | 86% | 88% | 90% | 90% | 92% | 93% | 86% | 5 | -9% | 5 |
| San Dimas | 87% | 8 | 63% | 69% | 75% | 70% | 80% | 80% | 63% | 9 | -24% | 14 |
| San Gabriel | 82% | 10 | 60% | 69% | 76% | 71% | 82% | 81% | 60% | 10 | -23% | 10 |
| Santa Anita | 95% | 6 | 78% | 87% | 91% | 88% | 89% | 91% | 78% | 6 | -16% | 8 |
| Thompson Crk. | 100% | 1 | 98% | 99% | 99% | 98% | 99% | 99% | 98% | 3 | -2% | 3 |

**Table A-1. LACFCD Dams – Ranking Evaluation (d)**

| Facility Name | Spillway Release Events (events/year) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Hist. | D4 | High 1 | High 2 | Mid. 1 | Mid. 2 | Low 1 | Low 2 | Max. | D5 |
| Big Dalton | 0.00 | 1 | 0.85 | 0.29 | 0.11 | 0.23 | 0.10 | 0.11 | 0.85 | 4 |
| Big Tujunga | 0.79 | 10 | 1.85 | 2.61 | 1.18 | 1.24 | 0.50 | 1.15 | 2.61 | 10 |
| Cogswell | 0.50 | 7 | 1.82 | 2.24 | 1.08 | 1.06 | 0.43 | 0.90 | 2.24 | 7 |
| Devils Gate | 1.86 | 13 | 2.94 | 3.99 | 1.98 | 2.04 | 0.93 | 1.85 | 3.99 | 13 |
| Eaton Wash | 2.07 | 14 | 5.46 | 5.18 | 2.58 | 3.14 | 1.12 | 2.20 | 5.46 | 14 |
| Live Oak | 0.00 | 1 | 0.39 | 0.20 | 0.10 | 0.17 | 0.06 | 0.11 | 0.39 | 2 |
| Morris | 0.57 | 8 | 0.96 | 1.11 | 0.80 | 0.76 | 0.46 | 0.76 | 1.11 | 5 |
| Pacoima | 0.43 | 5 | 1.70 | 1.23 | 0.60 | 0.76 | 0.20 | 0.44 | 1.70 | 6 |
| Puddingstone | 0.00 | 1 | 0.05 | 0.00 | 0.01 | 0.00 | 0.00 | 0.00 | 0.05 | 1 |
| Puddingstone Diversion | 0.86 | 12 | 3.54 | 3.06 | 1.46 | 1.77 | 0.62 | 0.94 | 3.54 | 12 |
| San Dimas | 0.79 | 10 | 2.00 | 2.76 | 1.11 | 1.45 | 0.49 | 0.94 | 2.76 | 11 |
| San Gabriel | 0.64 | 9 | 1.89 | 2.46 | 1.05 | 1.18 | 0.42 | 0.88 | 2.46 | 9 |
| Santa Anita | 0.43 | 5 | 2.38 | 2.11 | 1.05 | 1.15 | 0.49 | 0.69 | 2.38 | 8 |
| Thompson Creek | 0.00 | 1 | 0.42 | 0.19 | 0.14 | 0.14 | 0.06 | 0.12 | 0.42 | 3 |

**Table A-2. LACFCD Dams – Final Performance Levels**

| LACFCD Dams | D1 | D2 | D3 | D4 | D5 | Average | Level |
|---|---|---|---|---|---|---|---|
| **Big Dalton** | 1 | 4 | 4 | 1 | 4 | 2.8 | **II** |
| **Big Tujunga** | 13 | 13 | 13 | 10 | 10 | 11.8 | **III** |
| **Cogswell** | 11 | 11 | 12 | 7 | 7 | 9.6 | **II** |
| **Devils Gate** | 12 | 12 | 11 | 13 | 13 | 12.2 | **III** |
| **Eaton Wash** | 9 | 8 | 9 | 14 | 14 | 10.8 | **III** |
| **Live Oak** | 1 | 2 | 2 | 1 | 2 | 1.6 | **I** |
| **Morris** | 14 | 14 | 7 | 8 | 5 | 9.6 | **II** |
| **Pacoima** | 7 | 7 | 6 | 5 | 6 | 6.2 | **II** |
| **Puddingstone** | 1 | 1 | 1 | 1 | 1 | 1.0 | **I** |
| **Puddingstone Diversion** | 5 | 5 | 5 | 12 | 12 | 7.8 | **II** |
| **San Dimas** | 8 | 9 | 14 | 10 | 11 | 10.4 | **II** |
| **San Gabriel** | 10 | 10 | 10 | 9 | 9 | 9.6 | **II** |
| **Santa Anita** | 6 | 6 | 8 | 5 | 8 | 6.6 | **II** |
| **Thompson Creek** | 1 | 3 | 3 | 1 | 3 | 2.2 | **I** |

## Table A-3. Spreading Ground - Ranking Evaluation (a)

| | S.G. Parameters | | | Modeled Historic Recharge Efficiency | | | | | Recharge to Spreading Ground Ratios | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility Name | Area (acres) | Vol. (af) | Perc. (cfs) | Rech. (af) | S1 | Bypass (af) | Eff. (%) | S2 | Area (af/ac) | S3 | Vol. (af/af) | S4 | Perc. (af/cfs) | S5 |
| Ben Lomond | 17.0 | 168 | 30 | 2,852 | 7 | 1,406 | 74% | 6 | 168 | 7 | 17 | 11 | 95 | 14 |
| Big Dalton | 6.7 | 8 | 15 | 590 | 4 | 772 | 67% | 10 | 88 | 13 | 77 | 1 | 39 | 22 |
| Branford | 7.0 | 137 | 1.5 | 604 | 2 | 556 | 65% | 11 | 86 | 14 | 4 | 19 | 403 | 2 |
| Buena Vista | 10.0 | 170 | 6 | 321 | 20 | 19,677 | 15% | 24 | 32 | 24 | 2 | 24 | 53 | 18 |
| Citrus | 14.6 | 77 | 28 | 1,245 | 13 | 4,750 | 36% | 19 | 85 | 15 | 16 | 12 | 44 | 19 |
| Dominguez Gap | 24.0 | 234 | 1 | 499 | 25 | 262,224 | 0% | 25 | 21 | 25 | 2 | 23 | 499 | 1 |
| Eaton Basin | 10.0 | 284 | 20 | 1,284 | 10 | 2,058 | 60% | 14 | 128 | 10 | 5 | 18 | 64 | 16 |
| Eaton Wash | 25.2 | 526 | 14 | 1,418 | 8 | 1,716 | 68% | 9 | 56 | 21 | 3 | 21 | 101 | 13 |
| Forbes | 8.0 | 87 | 5 | 338 | 6 | 1,370 | 42% | 18 | 42 | 23 | 4 | 20 | 68 | 15 |
| Hansen/Tujunga | 190.3 | 1572 | 570 | 21,627 | 19 | 18,561 | 80% | 4 | 114 | 11 | 14 | 15 | 38 | 23 |
| Irwindale | 53.0 | 1133 | 30 | 10,339 | 5 | 1,119 | 96% | 1 | 195 | 3 | 9 | 16 | 345 | 4 |
| Little Dalton | 4.7 | 5 | 12 | 326 | 9 | 1,875 | 46% | 17 | 69 | 17 | 69 | 2 | 27 | 24 |
| Live Oak | 3.0 | 13 | 12 | 202 | 3 | 643 | 48% | 16 | 67 | 18 | 16 | 13 | 17 | 25 |
| Lopez | 12.0 | 24 | 15 | 629 | 17 | 13,908 | 32% | 20 | 52 | 22 | 26 | 7 | 42 | 20 |
| Pacoima | 107.3 | 440 | 65 | 6,945 | 18 | 16,793 | 54% | 15 | 65 | 19 | 16 | 14 | 107 | 12 |
| Peck Road | 105.0 | 3347 | 25 | 8,110 | 16 | 11,562 | 73% | 7 | 77 | 16 | 2 | 22 | 324 | 5 |
| Rio Hondo | 429.0 | 3575 | 400 | 64,500 | 22 | 43,523 | 83% | 3 | 150 | 9 | 18 | 10 | 161 | 9 |
| San Dimas | 9.5 | 30 | 8 | 1,650 | 12 | 4,263 | 60% | 13 | 174 | 6 | 55 | 4 | 206 | 8 |
| San Gabriel Canyon | 124.0 | 8170 | 50 | 12,048 | 24 | 121,353 | 24% | 23 | 97 | 12 | 1 | 25 | 241 | 7 |
| San Gabriel Coastal | 95.9 | 550 | 75 | 20,937 | 21 | 20,089 | 77% | 5 | 218 | 2 | 38 | 6 | 279 | 6 |
| Santa Anita | 8.5 | 25 | 5 | 547 | 14 | 6,518 | 31% | 22 | 65 | 20 | 22 | 9 | 109 | 11 |
| Santa Fe | 95.0 | 635 | 400 | 15,745 | 23 | 68,308 | 64% | 12 | 166 | 8 | 25 | 8 | 39 | 21 |
| Sawpit | 4.0 | 13 | 12 | 755 | 11 | 2,686 | 73% | 8 | 189 | 5 | 58 | 3 | 63 | 17 |
| Sierra Madre | 7.8 | 35 | 10 | 1,500 | 1 | 294 | 91% | 2 | 192 | 4 | 43 | 5 | 150 | 10 |
| Walnut | 7.3 | 199 | 5 | 1,757 | 15 | 9,698 | 32% | 21 | 241 | 1 | 9 | 17 | 351 | 3 |

**Table A-3. Spreading Ground - Ranking Evaluation (b)**

| | Future Average Annual Recharge (ac-ft) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Facility Name | High 1 | High 2 | Mid. 1 | Mid. 2 | Low 1 | Low 2 | Max | Change | S6 |
| Ben Lomond | 3,910 | 4,591 | 3,212 | 3,114 | 2,264 | 3,194 | 4,591 | 161% | 5 |
| Big Dalton | 693 | 730 | 586 | 591 | 527 | 571 | 730 | 124% | 17 |
| Branford | 674 | 769 | 618 | 604 | 510 | 601 | 769 | 127% | 15 |
| Buena Vista | 319 | 319 | 313 | 311 | 307 | 312 | 319 | 100% | 24 |
| Citrus | 1,479 | 1,607 | 1,276 | 1,285 | 1,064 | 1,240 | 1,607 | 129% | 14 |
| Dominguez Gap | 499 | 499 | 500 | 499 | 500 | 500 | 500 | 100% | 23 |
| Eaton Basin | 1,708 | 1,951 | 1,406 | 1,379 | 990 | 1,313 | 1,951 | 152% | 9 |
| Eaton Wash | 1,719 | 1,863 | 1,468 | 1,469 | 1,179 | 1,385 | 1,863 | 131% | 13 |
| Forbes | 391 | 417 | 344 | 342 | 304 | 334 | 417 | 123% | 18 |
| Hansen/Tujunga | 31,048 | 36,165 | 24,102 | 23,704 | 15,468 | 22,820 | 36,165 | 167% | 3 |
| Irwindale | 16,533 | 19,175 | 11,515 | 12,234 | 7,721 | 11,113 | 19,175 | 185% | 2 |
| Little Dalton | 384 | 404 | 321 | 330 | 289 | 315 | 404 | 124% | 16 |
| Live Oak | 228 | 239 | 201 | 203 | 175 | 192 | 239 | 119% | 19 |
| Lopez | 690 | 720 | 635 | 647 | 615 | 615 | 720 | 114% | 20 |
| Pacoima | 8,558 | 9,395 | 7,411 | 7,393 | 6,020 | 7,054 | 9,395 | 135% | 10 |
| Peck Road | 11,318 | 12,881 | 9,265 | 9,079 | 6,219 | 8,785 | 12,881 | 159% | 7 |
| Rio Hondo | 86,748 | 101,618 | 67,166 | 68,329 | 44,680 | 61,614 | 101,618 | 158% | 8 |
| San Dimas | 2,070 | 2,228 | 1,745 | 1,710 | 1,502 | 1,674 | 2,228 | 135% | 11 |
| San Gabriel Canyon | 11,832 | 11,779 | 11,764 | 11,952 | 11,966 | 11,647 | 11,966 | 99% | 25 |
| San Gabriel Coastal | 24,245 | 27,682 | 20,783 | 20,940 | 15,333 | 19,492 | 27,682 | 132% | 12 |
| Santa Anita | 583 | 596 | 538 | 535 | 502 | 515 | 596 | 109% | 21 |
| Santa Fe | 22,740 | 25,202 | 18,165 | 18,221 | 12,891 | 17,690 | 25,202 | 160% | 6 |
| Sawpit | 1,142 | 1,258 | 931 | 951 | 562 | 845 | 1,258 | 167% | 4 |
| Sierra Madre | 2,747 | 2,848 | 1,724 | 1,824 | 929 | 1,537 | 2,848 | 190% | 1 |
| Walnut | 1,793 | 1,817 | 1,725 | 1,730 | 1,654 | 1,672 | 1,817 | 103% | 22 |

**Table A-3. Spreading Ground - Ranking Evaluation (c)**

| | Future Annual Average Bypass (ac-ft) | | | | | |
|---|---|---|---|---|---|---|
| Facility Name | High 1 | High 2 | Mid. 1 | Mid. 2 | Low 1 | Low 2 |
| Ben Lomond | 4,038 | 3,663 | 1,921 | 2,209 | 1,099 | 1,665 |
| Big Dalton | 2,146 | 2,098 | 1,028 | 1,172 | 493 | 929 |
| Branford | 1,174 | 1,031 | 677 | 738 | 505 | 604 |
| Buena Vista | 33,197 | 38,663 | 22,294 | 23,146 | 11,225 | 20,263 |
| Citrus | 11,615 | 11,390 | 6,051 | 6,764 | 3,384 | 5,550 |
| Dominguez Gap | 619,878 | 560,489 | 327,574 | 371,099 | 199,974 | 282,736 |
| Eaton Basin | 5,216 | 5,006 | 2,511 | 2,953 | 1,207 | 2,219 |
| Eaton Wash | 4,125 | 4,166 | 2,077 | 2,411 | 993 | 1,875 |
| Forbes | 2,798 | 3,084 | 1,782 | 1,806 | 1,007 | 1,690 |
| Hansen/Tujunga | 62,848 | 52,544 | 23,086 | 30,696 | 11,081 | 21,023 |
| Irwindale | 8,356 | 5,077 | 2,602 | 3,252 | 1,141 | 1,787 |
| Little Dalton | 4,951 | 4,920 | 2,470 | 2,812 | 1,261 | 2,237 |
| Live Oak | 1,614 | 1,578 | 821 | 963 | 475 | 753 |
| Lopez | 32,247 | 32,375 | 15,783 | 18,673 | 8,485 | 14,680 |
| Pacoima | 41,312 | 39,626 | 19,422 | 23,000 | 10,231 | 17,905 |
| Peck Road | 24,460 | 25,805 | 13,494 | 14,898 | 6,077 | 11,752 |
| Rio Hondo | 186,117 | 157,164 | 73,968 | 92,684 | 34,543 | 59,171 |
| San Dimas | 11,219 | 11,737 | 5,774 | 6,694 | 2,927 | 5,230 |
| San Gabriel Canyon | 263,952 | 272,939 | 149,916 | 165,405 | 84,601 | 136,453 |
| San Gabriel Coastal | 65,814 | 60,972 | 29,884 | 36,015 | 13,372 | 24,316 |
| Santa Anita | 14,783 | 14,493 | 8,125 | 8,756 | 4,227 | 7,121 |
| Santa Fe | 189,321 | 190,530 | 90,158 | 105,637 | 40,203 | 78,470 |
| Sawpit | 8,493 | 7,014 | 3,277 | 4,748 | 1,433 | 2,945 |
| Sierra Madre | 1,045 | 891 | 401 | 492 | 235 | 360 |
| Walnut | 23,460 | 23,066 | 12,683 | 14,273 | 7,025 | 11,169 |

**Table A-3. Spreading Ground - Ranking Evaluation (d)**

| | Future Recharge Efficiencies | | | | | | | | | Capture Range | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Facility Name | High 1 | High 2 | Mid 1 | Mid 2 | Low 1 | Low 2 | Max. | Change | S7 | Exponent | S8 |
| Ben Lomond | 59% | 62% | 71% | 68% | 75% | 74% | 75% | 0% | 19 | 0.81 | 3 |
| Big Dalton | 42% | 38% | 61% | 59% | 77% | 64% | 77% | 9% | 1 | 0.59 | 9 |
| Branford | 45% | 49% | 56% | 55% | 59% | 58% | 59% | -6% | 25 | 0.54 | 13 |
| Buena Vista | 6% | 4% | 12% | 12% | 19% | 16% | 19% | 4% | 14 | 0.01 | 23 |
| Citrus | 20% | 19% | 30% | 29% | 37% | 33% | 37% | 1% | 18 | 0.40 | 17 |
| Dominguez Gap | 0% | 0% | 0% | 0% | 1% | 1% | 1% | 0% | 20 | 0.00 | 25 |
| Eaton Basin | 40% | 39% | 54% | 53% | 65% | 59% | 65% | 5% | 11 | 0.59 | 8 |
| Eaton Wash | 46% | 43% | 63% | 62% | 76% | 66% | 76% | 8% | 4 | 0.57 | 11 |
| Forbes | 23% | 19% | 35% | 36% | 47% | 38% | 47% | 5% | 10 | 0.34 | 18 |
| Hansen/Tujunga | 54% | 56% | 74% | 71% | 83% | 76% | 83% | 3% | 15 | 0.74 | 4 |
| Irwindale | 79% | 86% | 91% | 90% | 95% | 94% | 95% | 0% | 21 | 0.87 | 2 |
| Little Dalton | 21% | 17% | 40% | 37% | 54% | 43% | 54% | 8% | 3 | 0.44 | 16 |
| Live Oak | 24% | 21% | 40% | 37% | 50% | 43% | 50% | 1% | 16 | 0.33 | 19 |
| Lopez | 9% | 8% | 23% | 21% | 33% | 27% | 33% | 1% | 17 | 0.18 | 21 |
| Pacoima | 32% | 30% | 47% | 46% | 58% | 50% | 58% | 5% | 12 | 0.45 | 15 |
| Peck Road | 48% | 45% | 67% | 64% | 81% | 71% | 81% | 8% | 6 | 0.62 | 6 |
| Rio Hondo | 52% | 55% | 72% | 69% | 82% | 76% | 82% | -1% | 22 | 0.64 | 5 |
| San Dimas | 33% | 28% | 51% | 49% | 66% | 54% | 66% | 6% | 7 | 0.55 | 12 |
| San Gabriel Canyon | 10% | 8% | 23% | 23% | 30% | 26% | 30% | 6% | 9 | 0.01 | 24 |
| San Gabriel Coastal | 45% | 46% | 64% | 62% | 76% | 70% | 76% | -1% | 23 | 0.49 | 14 |
| Santa Anita | 11% | 9% | 25% | 25% | 37% | 31% | 37% | 6% | 8 | 0.22 | 20 |
| Santa Fe | 32% | 27% | 52% | 51% | 72% | 57% | 72% | 8% | 5 | 0.60 | 7 |
| Sawpit | 41% | 36% | 63% | 57% | 82% | 65% | 82% | 9% | 2 | 0.58 | 10 |
| Sierra Madre | 80% | 81% | 88% | 88% | 90% | 89% | 90% | -1% | 24 | 0.92 | 1 |
| Walnut | 16% | 14% | 27% | 27% | 36% | 31% | 36% | 4% | 13 | 0.11 | 22 |

**Table A-4. Spreading Ground – Final Performance Levels**

| Spreading Ground | S1 | S2 | S3 | S4 | S5 | S6 | S7 | S8 | Average | Level |
|---|---|---|---|---|---|---|---|---|---|---|
| Ben Lomond | 7 | 6 | 7 | 11 | 14 | 5 | 19 | 3 | 10.8 | II |
| Big Dalton | 4 | 10 | 13 | 1 | 22 | 17 | 1 | 9 | 9.6 | I |
| Branford | 2 | 11 | 14 | 19 | 2 | 15 | 25 | 13 | 12.6 | II |
| Buena Vista | 20 | 24 | 24 | 24 | 18 | 24 | 14 | 23 | 21.4 | III |
| Citrus | 13 | 19 | 15 | 12 | 19 | 14 | 18 | 17 | 15.9 | II |
| Dominguez Gap | 25 | 25 | 25 | 23 | 1 | 23 | 20 | 25 | 20.9 | III |
| Eaton Basin | 10 | 14 | 10 | 18 | 16 | 9 | 11 | 8 | 12.0 | II |
| Eaton Wash | 8 | 9 | 21 | 21 | 13 | 13 | 4 | 11 | 12.5 | II |
| Forbes | 6 | 18 | 23 | 20 | 15 | 18 | 10 | 18 | 16 | III |
| Hansen/Tujunga | 19 | 4 | 11 | 15 | 23 | 3 | 15 | 4 | 11.8 | II |
| Irwindale | 5 | 1 | 3 | 16 | 4 | 2 | 21 | 2 | 6.8 | I |
| Little Dalton | 9 | 17 | 17 | 2 | 24 | 16 | 3 | 16 | 13.0 | II |
| Live Oak | 3 | 16 | 18 | 13 | 25 | 19 | 16 | 19 | 16.1 | III |
| Lopez | 17 | 20 | 22 | 7 | 20 | 20 | 17 | 21 | 18.0 | III |
| Pacoima | 18 | 15 | 19 | 14 | 12 | 10 | 12 | 15 | 14.4 | II |
| Peck Road | 16 | 7 | 16 | 22 | 5 | 7 | 6 | 6 | 10.6 | I |
| Rio Hondo | 22 | 3 | 9 | 10 | 9 | 8 | 22 | 5 | 11.0 | II |
| San Dimas | 12 | 13 | 6 | 4 | 8 | 11 | 7 | 12 | 9.1 | I |
| San Gabriel Canyon | 24 | 23 | 12 | 25 | 7 | 25 | 9 | 24 | 18.6 | III |
| San Gabriel Coastal | 21 | 5 | 2 | 6 | 6 | 12 | 23 | 14 | 11.1 | II |
| Santa Anita | 14 | 22 | 20 | 9 | 11 | 21 | 8 | 20 | 15.6 | II |
| Santa Fe | 23 | 12 | 8 | 8 | 21 | 6 | 5 | 7 | 11.3 | II |
| Sawpit | 11 | 8 | 5 | 3 | 17 | 4 | 2 | 10 | 7.5 | I |
| Sierra Madre | 1 | 2 | 4 | 5 | 10 | 1 | 24 | 1 | 6.0 | I |
| Walnut | 15 | 21 | 1 | 17 | 3 | 22 | 13 | 22 | 14.3 | II |

**Table A-5. Major Channel Outlets – Ranking Evaluation (a)**

| | Average Annual Discharge (AFY) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Location | Historic | High 1 | High 2 | Mid 1 | Mid 2 | Low 1 | Low 2 | Avg | Change | C1 |
| Ballona Creek | 57,400 | 102,600 | 98,400 | 68,100 | 72,500 | 45,000 | 59,700 | 74,383 | 16,983 | 3 |
| Dominguez Channel | 27,200 | 45,200 | 43,200 | 33,300 | 32,900 | 21,700 | 27,800 | 34,017 | 6,817 | 1 |
| Malibu Creek | 25,700 | 64,400 | 56,000 | 30,100 | 36,100 | 17,500 | 27,300 | 38,567 | 12,867 | 2 |
| San Gabriel River | 84,000 | 196,200 | 179,200 | 108,200 | 126,000 | 69,100 | 91,000 | 128,283 | 44,283 | 4 |
| Los Angeles River | 266,600 | 596,300 | 537,600 | 326,800 | 365,200 | 204,500 | 281,500 | 385,317 | 118,717 | 5 |

**Table A-5. Major Channel Outlets – Ranking Evaluation (b)**

| | Unit Area Discharge (AFY/mile$^2$) | | | | | % Total Average Discharge (AFY) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Area | Historic | Future | Change | C2 | Historic Total | % Total | Future Total | % Total | %Change | C3 |
| Ballona Creek | 125.1 | 459 | 594 | 136 | 4 | 460,900 | 12% | 660,567 | 11% | -10% | 2 |
| Dominguez Channel | 71.9 | 378 | 473 | 95 | 2 | | 6% | | 5% | -13% | 1 |
| Malibu Creek | 109.9 | 234 | 351 | 117 | 3 | | 6% | | 6% | 5% | 4 |
| San Gabriel River | 638.6 | 132 | 201 | 69 | 1 | | 18% | | 19% | 7% | 5 |
| Los Angeles River | 831.9 | 320 | 463 | 143 | 5 | | 58% | | 58% | 1% | 3 |

**Table A-5. Major Channel Outlets – Ranking Evaluation (c)**

| | Average Peak Flow Rates (cfs) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Des Cap | Historic | High 1 | High 2 | Mid 1 | Mid 2 | Low 1 | Low 2 | Max | %Change | C3 |
| Ballona Creek | 46,000 | 9,800 | 16,500 | 15,300 | 11,600 | 11,400 | 9,200 | 9,700 | 16,500 | 68% | 5 |
| Dominguez Channel | 13,925 | 4,500 | 9,400 | 8,300 | 7,300 | 6,200 | 5,200 | 5,100 | 9,400 | 109% | 2 |
| Malibu Creek | - | 7,800 | 17,700 | 14,800 | 9,000 | 9,900 | 6,500 | 8,200 | 17,700 | 127% | 1 |
| San Gabriel River | 55,600 | 12,500 | 25,800 | 24,200 | 18,500 | 18,600 | 14,400 | 15,400 | 25,800 | 106% | 3 |
| Los Angeles River | 182,000 | 23,000 | 46,200 | 39,700 | 28,800 | 29,700 | 23,200 | 24,100 | 46,200 | 101% | 4 |

**Table A-6. Major Channel Outlets – Final Assessment Levels**

| Major Channel Outlet Metric Rankings | | | | | | |
|---|---|---|---|---|---|---|
| Location | C1 | C2 | C3 | C4 | AVG | Level |
| Ballona Creek | 3 | 4 | 2 | 5 | 3.50 | II |
| Dominguez Channel | 1 | 2 | 1 | 2 | 1.50 | I |
| Malibu Creek | 2 | 3 | 4 | 1 | 2.50 | I |
| San Gabriel River | 4 | 1 | 5 | 3 | 3.25 | II |
| Los Angeles River | 5 | 5 | 3 | 4 | 4.25 | III |