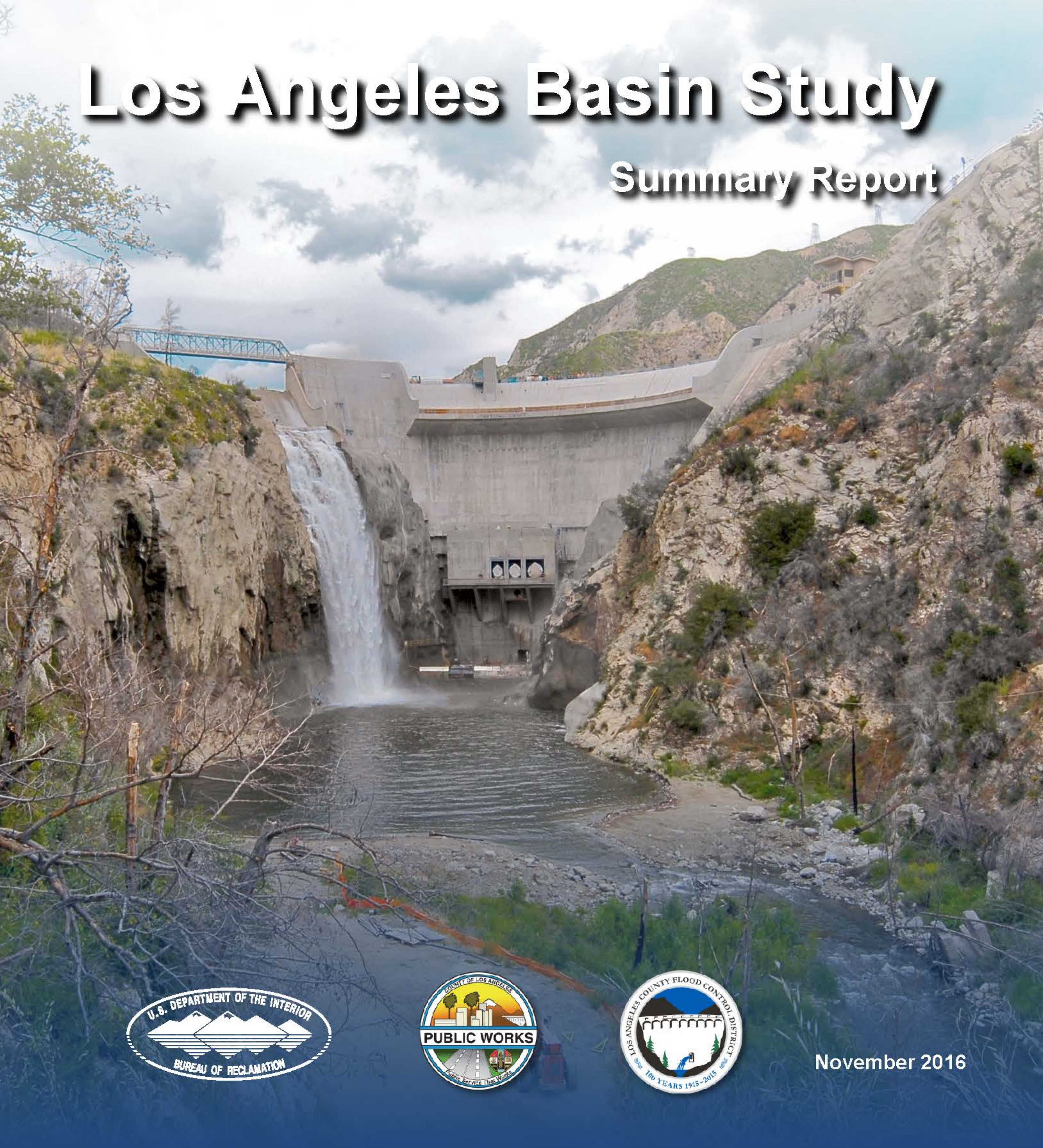
RECLAMATION

Managing Water in the West

Los Angeles Basin Study

Summary Report



November 2016

Mission Statements

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.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The mission of the County of Los Angeles Department of Public Works is to provide public infrastructure and municipal services to protect and enrich the daily lives of over 10 million people in Los Angeles County.

Cover Photo: Tujunga Dam, Los Angeles County, California.

Summary Report

Los Angeles Basin Study

November 2016

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"Anyone who can solve the problems of water will be worthy of two Nobel prizes – one for peace and one for science."

John F. Kennedy

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Effective water resources management practices are essential in Southern California to help the region sustain its water supply. The Los Angeles County Flood Control District is charged with effectively managing local stormwater to help supplement these vital natural resources. The LACFCD and its partners collaborated with the Bureau of Reclamation to complete this extensive Study. A great deal of time and energy over the past three years went into making the Los Angeles Basin Study a successful planning tool for the region to use in preparing for the challenges of climate change by capturing stormwater through enhanced conservation practices. To that end, many thanks go out to the following:

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If any names have been inadvertently omitted, the Study Team offers sincere apologies. Everyone's time and expertise contributed during this study is truly appreciated.

Participating Agencies

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RESOURCES AGENCY CALIFORNIA DEPARTMENT FISH & GAME

DEPARTMENT OF WATER RESOURCES STATE OF CALIFORNIA

Central Basin Municipal Water District

CITY OF BURBANK Water and Power Since 1913

CITY OF COMPTON

City of Glendale Water & Power GWP

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Main San Gabriel Basin Watermaster

THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

CITY OF UPLAND CALIFORNIA

Pomona Valley Protective Association
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RAYMOND BASIN MANAGEMENT BOARD

San Gabriel & Lower Los Angeles RIVERS AND MOUNTAINS CONSERVANCY

SAN GABRIEL VALLEY MUNICIPAL WATER DISTRICT

bay restoration commission STEWARDS OF SANTA MONICA BAY

SANTA MONICA MOUNTAINS CONSERVANCY

Six Basins Watermaster

The RIVER PROJECT

THREE VALLEYS MWD

TREEPEOPLE

US ARMY CORPS OF ENGINEERS

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

U.S. FISH & WILDLIFE SERVICE DEPARTMENT OF THE INTERIOR

FOREST SERVICE US DEPARTMENT OF AGRICULTURE

ULARA

UPPER SAN GABRIEL VALLEY MUNICIPAL WATER DISTRICT

WRD

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Acronyms and Abbreviations

AF	acre-foot (1 AF = 325,851 gallons)
AFY	acre-foot per year
BCCA	Bias-Correction Constructed Analogue
BCSD	Bias-Correction and Spatial Disaggregation
BMP	Best Management Practices
CMIP 3/5	Coupled Model Intercomparison Project, Phase 3/5
DWR	California Department of Water Resources
EWMP	Enhanced Watershed Management Programs
Gateway	Gateway Water Management Authority
GIS	Geographic Information Systems
GLAC	Greater Los Angeles County
gpcd	gallons per capita per day
GWAM	Groundwater Augmentation Model
IRWM	Integrated Regional Water Management
IRWMP	Integrated Regional Water Management Plan
LA Basin Study/ Basin Study	Los Angeles Basin Study
LACDPW	Los Angeles County Department of Public Works
LACFCD	Los Angeles County Flood Control District
LADWP	Los Angeles Department of Water and Power
LID	Low Impact Development
Metropolitan	The Metropolitan Water District of Southern California
O&M	Operations and Maintenance
PMF	Probable Maximum Flood

RCP	Representative Concentration Pathways
Reclamation	U.S. Department of Interior, Bureau of Reclamation
SCMP	Stormwater Capture Master Plan
STAC	Stakeholder Technical Advisory Committee
Study Area	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
Study Team	LACFCD and Reclamation
UCLA	University of California-Los Angeles
U.S.	United States
USACE	U.S. Army Corps of Engineers
UWMP	Urban Water Management Plan
VIC	Variable Infiltration Capacity
WAS	Water Augmentation Study
WMMS	Watershed Management Modeling System

1.0 Introduction

1.1 Authority

In 2009, recognizing that climate change poses a significant challenge to the protection of adequate and safe supplies of water, Congress passed the SECURE Water Act. The Act authorizes the Bureau of Reclamation, in conjunction with stakeholders, to evaluate and report on the risks and impacts from a changing climate and to identify appropriate adaptation and mitigation strategies using the best available science.

Reclamation created the Basin Study Program that addresses part of the authorities of the SECURE Water Act, which is part of the Secretary of the Interior's WaterSMART (Sustain and Manage America's Resources for Tomorrow) program. The WaterSMART program provides a framework for the Department's bureaus to collaboratively work with State, Tribal, local government, and non-governmental organizations, other Federal agencies, and local partners to identify strategies to adapt to and mitigate current or future water supply and demand imbalances, including the impacts of climate change and other stressors on water and power facilities. Basin Studies are cost-shared studies to evaluate current and future water supply and demand imbalances and to identify adaptation strategies to reduce those imbalances.

In 2013 the Los Angeles County Flood Control District (LACFCD) applied for and was selected as a two year Basin Study to evaluate impacts from climate change within the Los Angeles Basin and identify what strategies may support a more sustainable water supply in the future. From 2013 through 2015, the Los Angeles Basin Study's (LA Basin Study or Study) $2.4 million budget was cost-shared between local and federal partners. The LACFCD funded approximately $1.4 million, the Bureau of Reclamation (Reclamation) funded approximately $1 million, and 20 local project partners contributed nearly $60,000 through in-kind services.

1.2 Background

The Los Angeles region encompasses 2,040 square miles and is home to approximately 10 million people; and is in the process of diversifying and expanding its water supply portfolio to meet demand. Currently, the region relies heavily on two major water sources: imported water and groundwater. On average, imported water accounts for 57% and groundwater provides another 34% of the region's overall water supply. Considered part of the groundwater supply, stormwater capture and recharge is a critically important component that helps replenish the local groundwater aquifers, and represents 11% of the region's total supply. The remaining 9% of water supplies are sourced from recycled water for indirect use, water conservation measures, and local surface water diversions. The full supply breakdown is shown in Figure 1.

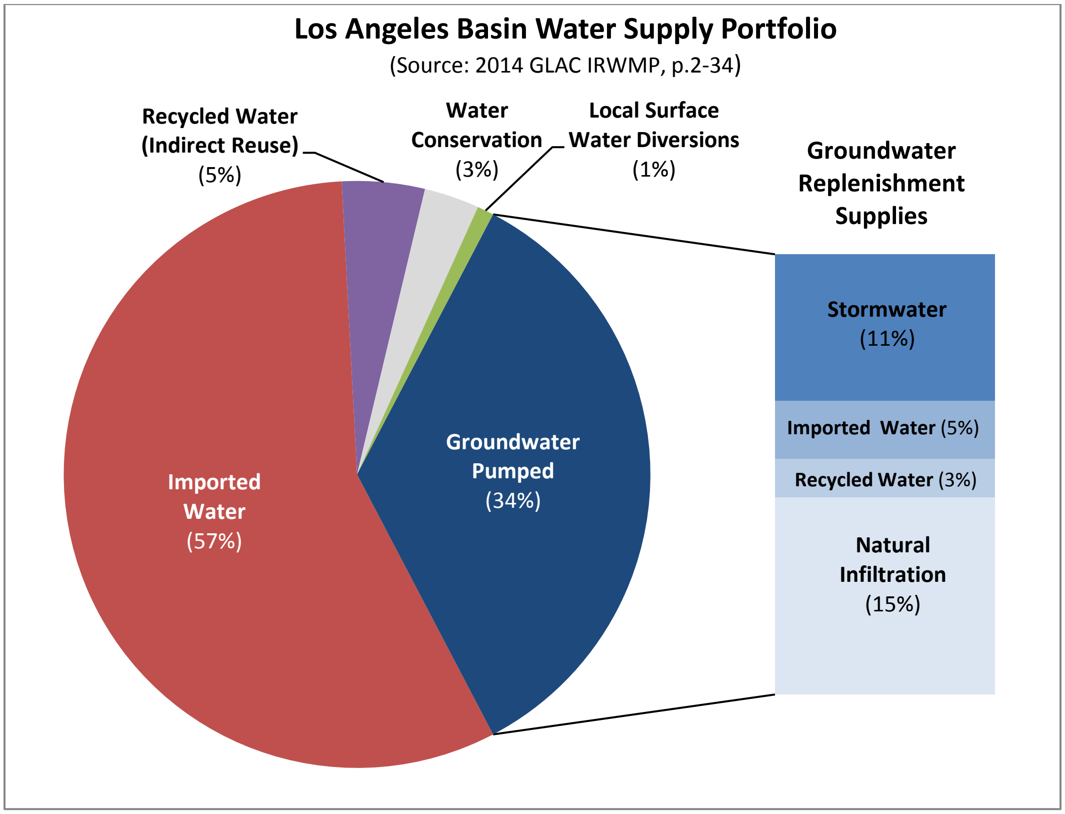

Figure 1. Los Angeles Basin Water Supply Portfolio

The Los Angeles region's imported water has historically come from Northern California and the Colorado River Basin; however, these imported supplies are growing increasingly uncertain due to a number of environmental, social, and political factors. Recurring droughts in Northern California and in the Colorado River Basin, court decisions related to endangered species in the Sacramento-San Joaquin Delta (Bay Delta), changing demographics, climate change, and competing interests for available water supplies all contribute to this uncertainty and present long-term risks to the reliability of imported water.

In addition to imported water, a key local resource for the Los Angeles Basin is its groundwater. Local groundwater supplies are a major component of its water supply portfolio and provide approximately one-third of the total supply for the Los Angeles Basin. Additionally, this local groundwater serves as a reliable and supplemental resource during times of drought, when imported supplies become scarce. In recent years, the prolonged drought, increased groundwater pumping, and groundwater contamination issues have affected the region’s ability to maximize use of its local groundwater.

Presently, Los Angeles County accounts for the largest water demand of any urbanized county in California. To help reduce its dependence on imported water supplies, the region is collectively identifying how stormwater capture, recycled water and desalination, and other local supplies may increase sustainability.

1.3 Study Purpose and Objectives

Changing demographics, climate change, and competing interests for available water supplies all present long-term risks to the stability and reliability of the region’s imported water. The region recognizes that today’s challenges require an integrated water resources management approach. For decades, this region has operated and maintained one of the most effective flood control systems in the world that protects millions of people from the impacts of flooding in the region. This system sends much of the stormwater runoff into the ocean, water that historically recharged local groundwater basins, making this region even more dependent on imported water supplies. As regulatory pressure to clean up polluted stormwater runoff continues and imported water resources diminish, this local source of water supply is becoming more and more attractive (GLAC IRWMP 2014).

Many of the region’s water management agencies have studied and planned for increasing use of local recycled and graywater supplies, ocean and brackish desalination, developing more groundwater, and implementing improved water conservation initiatives to extend existing supplies. Additionally, social trends and concerns also drive the emphasis on the use of local water supplies. However, the one major local resource that has not been studied in-depth is stormwater and its opportunities to optimize the reliability of local supplies.

To enhance the capabilities of the existing stormwater conservation infrastructure within the Los Angeles Basin, the LACFCD began to investigate long-term projected needs and future climate conditions within the region. Given that local groundwater plays such a vital role in the region’s water supply portfolio, detailed scientific, engineering, and economic analyses were conducted to identify strategies for enhancing stormwater capture for groundwater recharge.

The LA Basin Study examined the region’s water supplies and demand, and impacts from projected population growth and changing climate in the watersheds of the Los Angeles region. The objectives of the study were to:

- Use state-of-the-art climate change analysis to develop projections of future water supply and demands in the Basin.

- Analyze how the Basin's existing water infrastructure and its operations will perform in the face of changing water realities.

- Develop and highlight opportunities to adapt to current and future water demands.

- Conduct a trade-off analysis of identified opportunities.

Concepts ranged from enhancing the existing stormwater capture system and modifying existing facilities (including those capturing runoff for groundwater recharge), to developing new structural and nonstructural concepts that could help resolve future water supply and flood risk issues.

This Summary Report presents highlights of the critical tasks associated with this Basin Study and the results and findings produced throughout this collaborative study effort.

1.4 Future Challenges

The LA Basin area faces many potential water supply challenges. Some of these may include:

- Uncertainty and variability of future water supplies, including imported sources from the Colorado River and Bay-Delta;

- Changing local water supply planning strategies from short-term to long-term approaches to meet future demands; and

- Increasingly complex regulatory challenges.

1.5 Study Approach

The LA Basin Study applied the latest climate science and hydrologic modeling tools to create a vision of the near-term and long-term future water supply and demand in the Study area. The Study offered the opportunity for multiple water management agencies and numerous non-governmental organizations to participate in a collaborative process to plan for future local water supply scenarios, to examine opportunities to enhance existing LACFCD and partner facilities and operations, and to propose new concepts to demonstrate direct benefits to water agencies and local communities.

The Basin Study also used existing information on the availability and suitability of various open space and underdeveloped parcel opportunities to evaluate the potential for additional infiltration sites. Potential sites were evaluated for soil characteristics, groundwater basin conditions, conveyance/diversion/outlet requirements, site remediation requirements, property valuation and availability, environmental impact, regulatory requirements, community impact, multiuse potential, and other factors deemed necessary for assessment. The Study also considered the technical viability of implementing innovative facility concepts that demonstrate potential for increasing stormwater capture capacity to recharge groundwater.

A trade-off analysis was conducted to evaluate the regional impacts and the economic costs and benefits of the various stormwater capture alternatives. The costs of attaining different goals were also analyzed. The final outcomes of the LA Basin Study concept development and trade-off analyses can serve as guidance for further local water supply development planning for LACFCD and other Basin Study partners.

1.6 Partner/Stakeholder Involvement and Outreach

Water agencies within the Los Angeles region are actively developing local water supplies to reduce reliance on imported water from Northern California and the Colorado River. The LACFCD and Reclamation (Study Team) project managers worked with many local water agencies and numerous non-governmental organizations throughout the course of this Study. These organizations provided valuable in-kind services as part of the overall non-Federal cost-share participation in the LA Basin Study.

The Basin Study structure was designed to facilitate direct communication among participating agencies and the public to provide efficient decision-making and document reviews. In addition to two project managers, the complete Study Team organization structure included an Executive Leadership Team, a Stakeholder Technical Advisory Committee (STAC), an Independent Peer Review Panel, and Study Technical Teams.

The STAC (Table 1) was comprised of technical-level individuals from partner water agencies, non-governmental organizations, and State and local governments who provided technical support and input to the Study Team throughout all Study tasks.

Public involvement opportunities were frequently scheduled throughout the process to provide outreach to the larger community of water agencies, and to gather input from the general public, non-water agency stakeholders, and environmental organizations with an interest in the Study. Various stakeholder agencies and members of the public that did not actively participate in developing the LA Basin Study were updated on the progress and status of the effort through periodic emails, personal communications, and invitations to outreach meetings.

Table 1. STAC Representation

Representation	Organization
Regional Water Supply Planning	The Metropolitan Water District of Southern California
Local Water Supply Agencies	Central Basin Municipal Water District City of Burbank Water & Power City of Compton City of Glendale Water & Power City of Pasadena Water & Power City of San Fernando City of Santa Monica City of Torrance Crescenta Valley Water District Foothill Municipal Water District Las Virgenes Municipal Water District Los Angeles Department of Water & Power Main San Gabriel Basin Watermaster Pomona Valley Protective Association Raymond Basin Management Board San Gabriel Valley Municipal Water District Six Basins Watermaster Three Valleys Municipal Water District Upper Los Angeles River Area Watermaster Upper San Gabriel Valley Municipal Water District Water Replenishment District of Southern California
State & Federal Agencies	California Department of Fish & Wildlife California Department of Water Resources Los Angeles Regional Water Quality Control Board U.S. Army Corps of Engineers U.S. Environmental Protection Agency U.S. Fish & Wildlife Service U.S. Forest Service
Community & Environmental Organizations	Arroyo Seco Foundation Ballona Creek Renaissance Council for Watershed Health Heal the Bay The River Project TreePeople
Local Conservancies & Commissions	Mountains Recreation & Conservation Authority San Gabriel & Lower Los Angeles Rivers & Mountains Conservancy Santa Monica Bay Restoration Commission Santa Monica Mountains Conservancy Watershed Conservation Authority
Research Organizations/Others	Arid Lands Institute (Woodbury University) Building Industry Association of Southern California CSU Northridge Geosyntec Consultants Southern California Water Committee UCLA Institute of the Environment & Sustainability

1.7 Location and Description of Study Area

This Study Area incorporates the seven major watersheds within the LA Basin. These major watersheds include 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 – Figure 2). The Study Area also overlies several large groundwater basins, including the Central, Main San Gabriel, Raymond, San Fernando Valley, Six, and West Coast Basins.

The LACFCD's 14 major dams and reservoirs are located in the front range of the San Gabriel Mountains that extends more than 40 miles from the San Fernando Valley on the west to the eastern edge of the San Gabriel Valley (LACDPW 2013). The largely undeveloped watersheds upstream of the LACFCD dams cover an area of approximately 418 square miles, roughly 93% of which is within the Angeles National Forest. Spreading grounds, which serve to capture and infiltrate stormwater runoff, and a number of other water management components are located in areas of high permeability downstream of the LACFCD dams as shown in Figure 3.

The Basin Study Watersheds cover approximately 2,040 square miles and are currently home to approximately 10 million residents. Nearly 92% of Los Angeles County's population resides within the LA Basin Study Area. This population concentration also accounts for more than one-fourth of the State of California's approximately 38.8 million residents. Looking ahead for only the Basin Study Watersheds, over the next several decades the population is anticipated to grow to over 11 million.

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 Basin portion of The Metropolitan Water District of Southern California (Metropolitan) service area exceeded 1.54 million acre-feet (AF) in fiscal year 2011-12 (Metropolitan 2012), and over the next few decades, water demand within the Study Area is expected to increase to approximately 1.7 million AF per year.

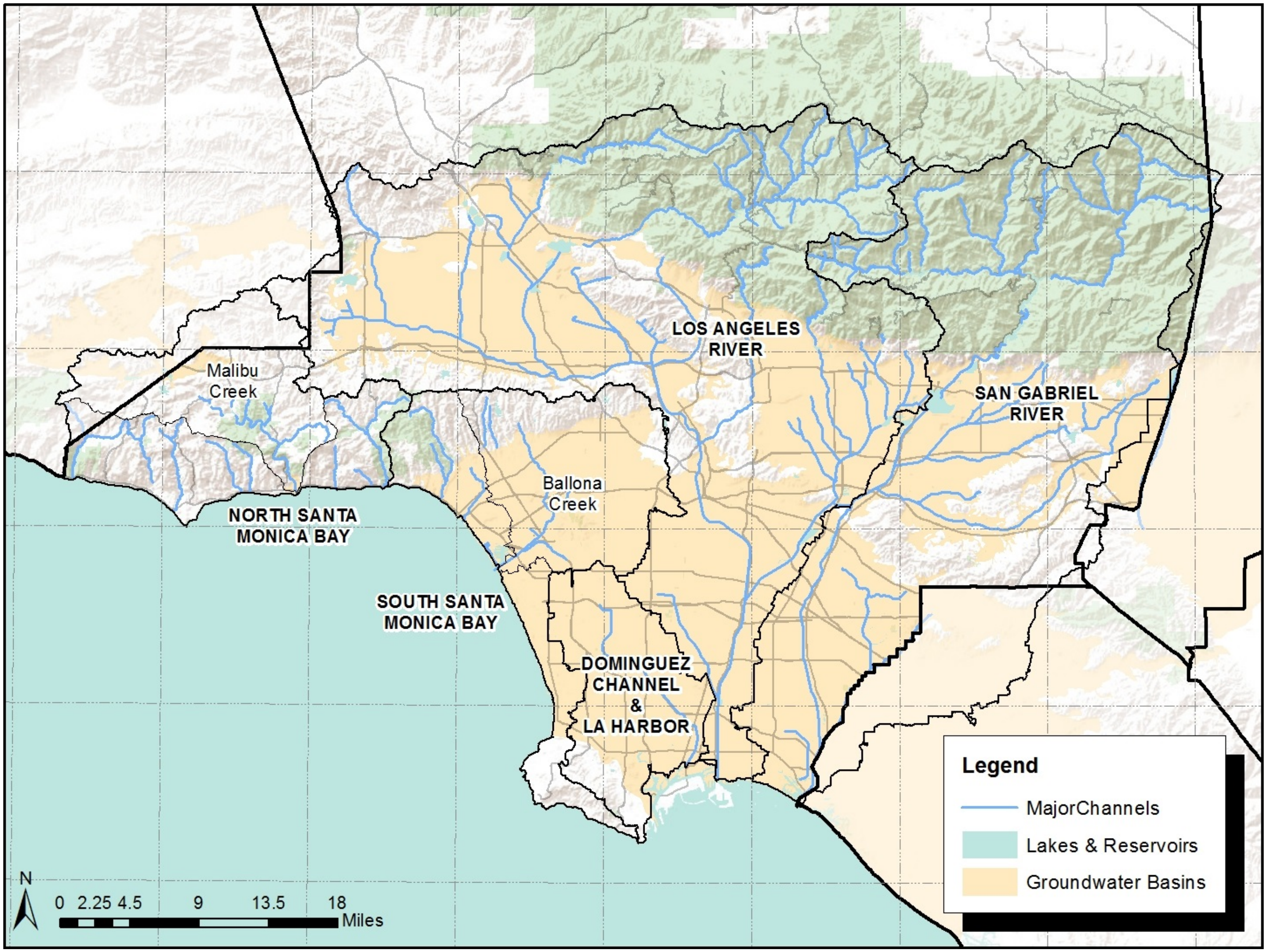

Figure 2. Los Angeles Basin Study Watersheds

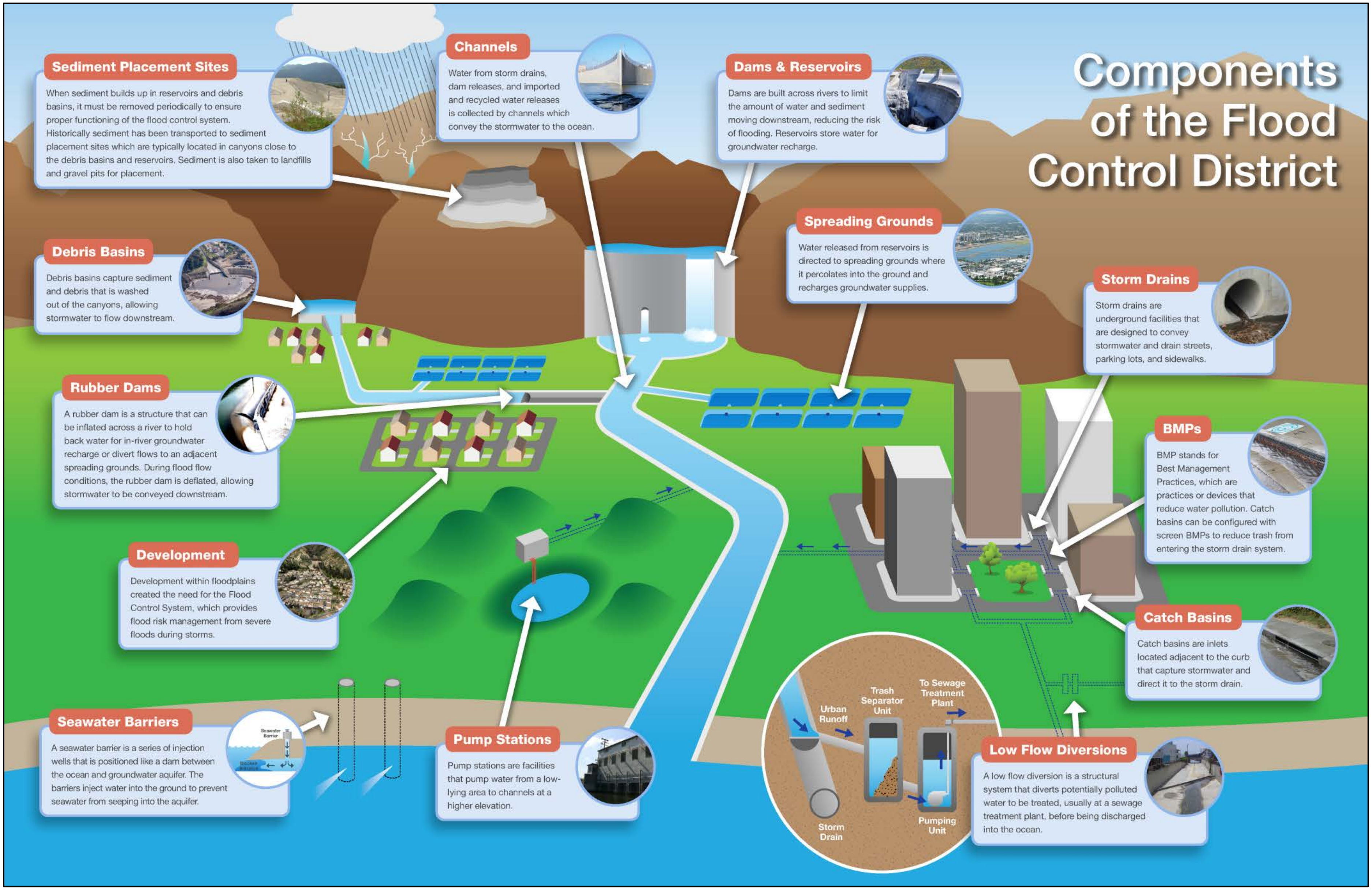

Figure 3. LACFCD Operations Components

2.0 Coordination with Other Local Efforts

The LA Basin Study process included close coordination among local agencies and Reclamation to develop valuable data and results that could support or complement the following local efforts.

2.1 Integrated Regional Water Management Planning

The Greater Los Angeles County (GLAC) Integrated Regional Water Management (IRWM) Region shares the same boundaries as the LA Basin Study and serves approximately 10 million residents, portions of four counties, 84 cities, and hundreds of agencies and districts. The GLAC IRWM Plan (IRWMP), prepared in 2006 and most recently updated in 2014, provides water supply targets and, most importantly, a regional framework that ensures agencies across the region coordinate their planning efforts to maximize project benefits and minimize costs.

The GLAC Region maintains a website at *www.lawaterplan.org* that enables GLAC IRWMP information to be easily shared with stakeholders. A database of related projects is maintained by regional participants with projects classified by primary benefits of water supply/groundwater, water quality, habitat/open space/recreation, and flood. If concepts assessed in this Study are considered for implementation, then the GLAC project list should be reviewed to identify potential opportunities for collaboration and cost sharing.

2.2 Local Stormwater Activities

The LACFCD and its partners have a number of projects that have been recently completed or are under development to enhance the capacity and efficiency of the region's stormwater conservation system. One project, the Big Tujunga Dam Seismic Retrofit project, which was co-funded by the City of Los Angeles Department of Water and Power (LADWP), was dedicated in July 2011. Due to seismic safety restrictions, the reservoir behind Big Tujunga Dam had been limited to a water surface elevation at which only 1,500 AF of water could be stored. The Retrofit Project restored the reservoir storage capacity to 6,000 AF. Other projects include the Morris Dam Inlet/Outlet Works Rehabilitation project, which has upgraded valves and automated some operations, allowing for improved delivery of water for groundwater recharge. Various spreading ground improvement projects have also been undertaken to improve operational capacity and flexibility at these facilities such as the Rio Hondo/San Gabriel Spreading

Grounds Interconnecting Drain. This project, co-funded by the Water Replenishment District of Southern California, creates a hydraulic interconnection between two spreading ground facilities to maximize efficiency of operations.

During the LA Basin Study, the LADWP developed a Stormwater Capture Master Plan (SCMP) for only the City of Los Angeles. The SCMP outlines potential strategies for the implementation of stormwater capture and watershed management programs within the City (LADWP 2015). The Basin Study expands on the SCMP findings by assessing impacts from climate change across a broader geographic area.

Additionally, in support of water quality improvement in the Study Area, several Enhanced Watershed Management Programs (EWMPs) have been developed in the Los Angeles region to manage stormwater runoff and water quality. The purpose of the EWMPs is to evaluate opportunities for multi-benefit regional projects that could capture and retain urban and stormwater runoff for beneficial uses. The EWMPs are developed through collaborative approaches among participating jurisdictions within a watershed, and maximize the use of urban and stormwater runoff as a resource, while also achieving other benefits including flood risk mitigation, enhanced open-space, and recreational opportunities, among others. Since certain concepts investigated in the LA Basin Study overlap with the EWMPs, these can help to inform EWMPs with respect to climate change resiliency.

3.0 Climate Change Assessment

Climate change in Southern California is a critical concern as any anticipated changes in the region's temperature and precipitation will affect the area's overall water supply sources. Regional and local planners used the *Climate Change Handbook for Regional Water Planning* (DWR, US EPA, USACE 2011) coupled with data, tools and guidance from both Reclamation's West-wide Climate Risk Assessment and California's Cal-Adapt web-based climate adaptation planning tool to assess projected impacts of climate change on temperatures, precipitation, snowpack, and sea-level rise. The Study Team also conducted an extensive literature review of projected climate change impacts to the region to compare and correlate the results that could lend to this analysis.

Southern California's climate is projected to change in the foreseeable future to include changes to the historical patterns and distribution of total rainfall, intensities of storm events, and seasonal temperatures. Existing storm patterns could become more extreme with climate change, including larger and more intense storms during wet periods, and longer, hotter dry periods. The LA Basin Study examined projected effects brought on by climate change throughout the geographic subareas of Los Angeles region, such as the mountains, valleys, and coastal plains.

3.1 Vulnerability to Climate Change

Climate change is projected to affect many aspects of the Los Angeles area's water resources management. A critical first step to help prevent, adapt to, and / or mitigate those impacts is identifying key water sector vulnerabilities. Below is a summary of four key vulnerabilities identified for the Basin:

Water Supply
- Local water demands in excess of local water supply
- Increased dependence on imported supply
- Inability to meet water demand during droughts
- Limited long-term operational water storage capacity

Water Quality
- Poor water quality
- Increased water treatment needs

Flooding
- Increased flash flooding and inland flooding damage
- Increased coastal flooding
- Damage to coastal stormwater and sewer systems from sea level rise

Ecosystem and Habitat
- Damage to coastal ecosystems and habitats

- Adverse impacts to threatened and sensitive species from reduced terrestrial flows and sea level rise

To determine potential risks within these vulnerabilities throughout the Basin Study Watersheds, a climate change analysis of the region was conducted, and all applicable climate change technical data was compiled about the region and the projected outlook through the year 2095. Potential climate change impacts from changes to precipitation and evapotranspiration; storm intensity; and the quantity, quality, and variability of runoff, recharge, and imported water deliveries to the region were evaluated.

3.2 Downscaled Climate Analysis

Reclamation's Technical Service Center analyzed downscaled climate projections for the Study Area from the Bias Corrected and Downscaled World Climate Research Programme's (WCRP) Coupled Model Intercomparison Project, phases 3 (CMIP 3) and 5 (CMIP 5). These climate projections represent a comprehensive and peer-reviewed effort developed from a multi-agency collaboration. Technical assessment reports documenting the climate and hydrology projections in the eight major western river basins have been published through the West-wide Climate Risk Assessments, a complementary activity to the Basin Studies within the WaterSMART Initiative.

In order to characterize the potential range of different futures, three sets of downscaled climate change projections were evaluated within the LA Basin Study:

- CMIP3-BCSD: The climate change projections from the Coupled Model Intercomparison Project, Phase 3 (CMIP3), released in 2006. The 112 projections were downscaled using the Bias-Correction and Spatial Disaggregation (BCSD) process.

- CMIP5-BCSD: The climate change projections from the Coupled Model Intercomparison Project, Phase 5 (CMIP5), released in 2013. The 100 projections were downscaled using the BCSD process.

- CMIP5-BCCA: Selected projections from CMIP5 that represent a range of potential climate futures. These 37 projections were downscaled using the Bias-Correction Constructed Analogue (BCCA) process.

The breakdown of the climate change projections and downscaling techniques used in the LA Basin Study are shown in Figure 4. Note that CMIP3 was not investigated with the BCCA downscaling technique due to the large number of additional hydrologic modeling runs that would have been required and that the projections utilized would provide a reasonable and prudent set to encompass the variability of potential future possibilities.

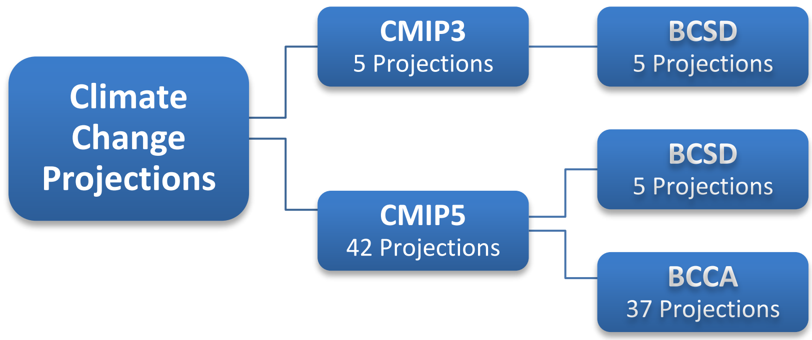

Figure 4. Los Angeles Basin Study Climate Projections

The two downscaling techniques, BCSD and BCCA, brought the coarser 200-kilometer resolution of the global climate datasets down to a more refined 12-kilometer resolution for use at a local scale. The 12-kilometer gridded, high resolution data was then used by Reclamation's Technical Service Center to determine the appropriate ensemble of scenarios for use in subsequent hydrologic modeling. The analysis:

- Reviewed available and existing projections of climate change in the LA Basin Study Area.
- Determined appropriate climate scenarios for use in developing precipitation and potential evaporation input datasets to support subsequent hydrologic modeling.
- Developed hourly precipitation and potential evaporation data.
- Determined storm event frequency for planning purposes.

Results from these four activities were shared with LACFCD and input into its Watershed Management Modeling System (WMMS) to perform hydrologic modeling over the Study Area. Reclamation's technical memorandum *Task 3.1 – Development of Climate-Adjusted Hydrologic Model Inputs* offers further details about these projections and how they were incorporated into the Study's hydrologic model. The climate change results were used to inform the water supply and demand analysis.

Within this Summary Report, the findings from the climate analysis are presented in Section 3.4, and the water supply and demand analysis is in Section 4.0.

3.3 Hydrologic Modeling

WMMS was the primary hydrologic tool used throughout the LA Basin Study to assess the effects of climate change on the region. The WMMS model is able to simulate continuous hourly, daily, monthly, and yearly hydrologic outputs at all facilities, watersheds, and subwatersheds targeted for the LA Basin Study.

Using the precipitation and evaporation projections developed by Reclamation, the LACFCD used WMMS to simulate hydrologic conditions for a variety of future weather and land-use scenarios for the Study Area. For the historic hydrology (Water Year 1987 through 2000), an observed set of precipitation and evaporation records was used to simulate the baseline conditions of the region.

Once completed, the WMMS simulations produced hydrologic outputs of stormwater runoff rates and volumes at the major dams and reservoirs, spreading grounds, stream gaging stations, and other hydrologic points of interest. The set of projected hydrologic outputs (Water Year 2012 through 2095) were then compared against the historic baseline outputs to assess the impacts of climate change on the region's water supply. More details on the hydrologic modeling can be found in the *Task 3.2 – Hydrologic Modeling* report.

3.4 Climate and Modeling Results

3.4.1 Change in Annual Average Rainfall

To assess the overall change in the annual average rainfall across the region, the complete set of available precipitation projections from the CMIP3-BCSD and CMIP5-BSCD global climate data sets were analyzed. In total, 112 projections from CMIP3-BCSD and 97 projections from CMIP5-BCSD were assessed for this regional precipitation analysis. This assessment produced an overall picture of the large-scale regional change in precipitation. Figures 5 and 6 provide the results of this assessment, and show the median as well as the maximum and minimum ranges of the different projections. Note that the median is not "the projected change" it is "a projected change" that is equally likely as any of the other projected changes.

From this analysis, the median projection of climate change within the region is near historical levels in annual average rainfall. For the CMIP3-BCSD, total rainfall is projected to remain relatively constant with only a slight decrease towards the end of the century; the CMIP5-BCSD projections remain nearly constant throughout the entire century. Towards the end of the century, the projections indicate a range of annual median precipitation changes of -11% to +3%. However, there is a large variability between the maximum and minimum projections, so although the median remains fairly constant, it is still important to consider the potential future variability when adaptation strategies are developed.

For CMIP3-BCSD, the median projections appear to indicate a slight drying trend towards the end of the century from -8% to -11% depending on the emissions scenario (B1, A1B, and A2). There is also a large variability between the minimum and maximum of the projections, ranging from as low as -42% to as high as +29% for the total change in precipitation.

For the CMIP5-BCSD projections, the median does not appear to indicate any significant increase or decrease in overall precipitation, ranging only from -3% to +3% change depending on the emissions scenario (RCP 2.6, 4.5, 6.0, and 8.5). Similar to the CMIP3-BCSD case, there is a very large variability between the minimum and maximum change for the different projections, ranging from -40% to +47%.

The projected trend in annual average precipitation was confirmed in a 2014 climate study conducted by the University of California-Los Angeles (UCLA). The study concluded that the average change in precipitation is not significant for the region, and the most likely outcome would be no net change in the region's annual average precipitation (Berg 2015). Similar to the LA Basin Study findings, the UCLA study also found a large variability in the climate projections, and stressed the need for policy makers to develop future adaptation strategies to mitigate against the uncertainties of the future climate.

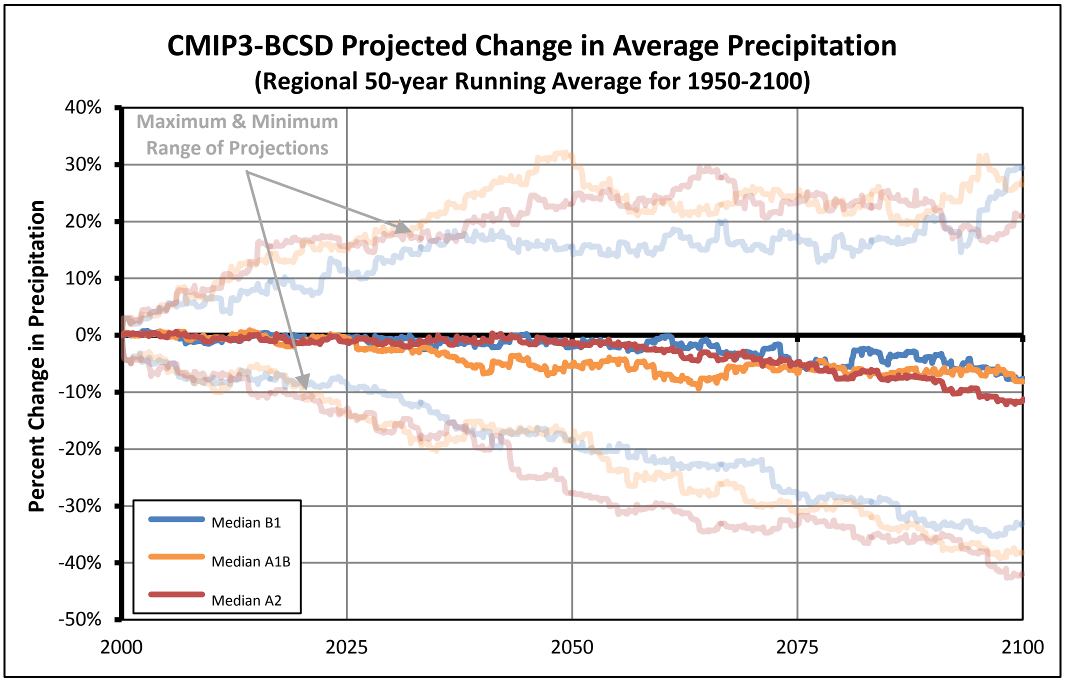

Figure 5. CMIP3-BCSD Projected Change in Average Precipitation

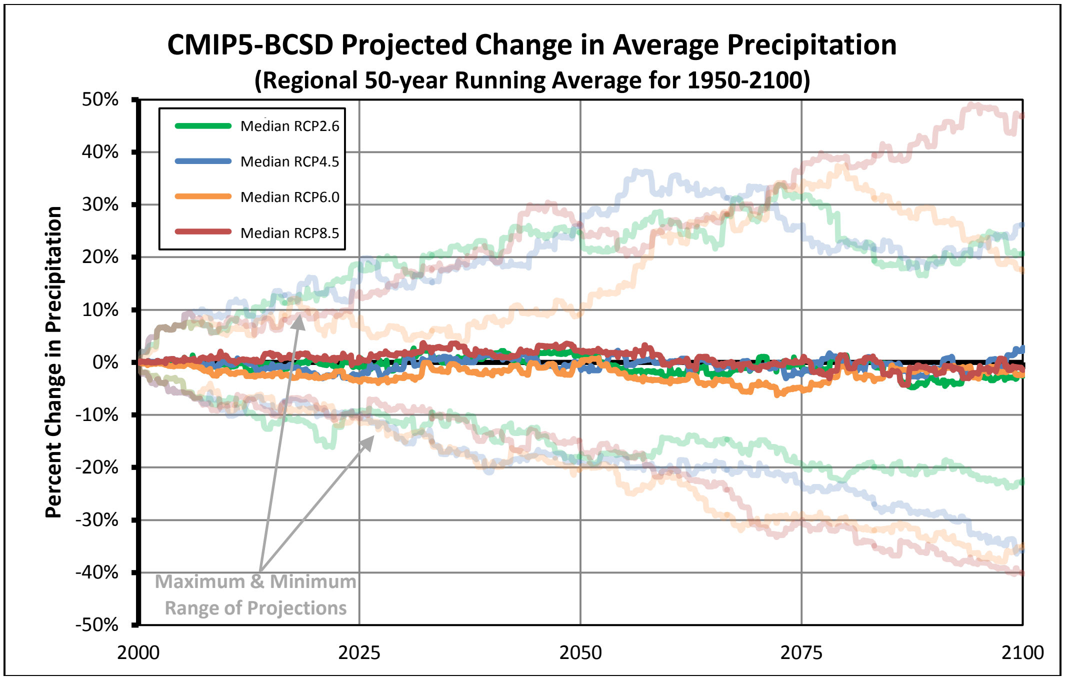

Figure 6. CMIP5-BCSD Projected Change in Average Precipitation

3.4.2 Change in Storm Event Intensity

Even though it was found that the median average annual precipitation may not change, the range of variability can be large based on the uncertainty of the projections as seen in Figure 6. Projected changes in precipitation frequency, magnitude, volume, and the cycle of wet/dry spells will likely have implications for the Los Angeles Basin stormwater infrastructure that exceed the average annual trend in total precipitation.

To determine storm event frequency, Reclamation assessed the five downscaled CMIP3-BCSD scenarios, five CMIP5-BCSD scenarios, and 37 CMIP5-BCCA projections at several recurrence intervals (5-year, 10-year, 25-year, 50-year, 100-year, and 200-year) for the 24-hour duration. The storm events were calculated at each precipitation gage within the Study Area. As the current LACFCD standard for infrastructure design is the 24-hour, 1-in-50 year storm event (LACDPW 2006), the analysis focused on that event. Maps showing the change in storm depths (i.e., the intensity of the precipitation) of the 24-hour, 1-in-50-year events between the current and potential future climate regimes were developed. For reference the current 24-hour, 1-in-50-year event intensity map is shown in Figure 7.

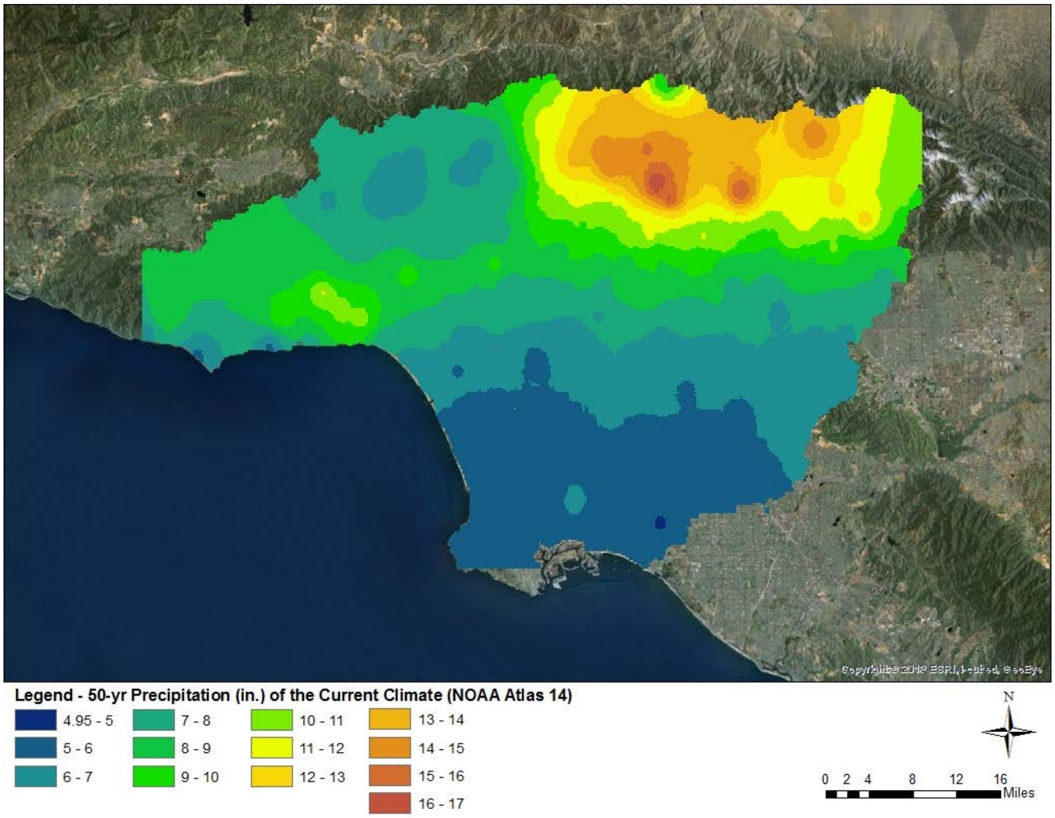

Figure 7. 24-hour, 1-in-50-year Precipitation Depths for the Current Climate

For the CMIP3-BCSD and CMIP5-BCSD scenarios with the maximum change, the precipitation frequency analysis indicates an increase in the intensity of the 1-in-50-year storm event over the higher elevation portions of the Study Area (Figure 8). Conversely, little change is detected in the intensity of the 24 hour, 1-in-50-year storm event over the central and coastal areas. The 37 CMIP5-BCCA projections indicate a more general decrease in the intensity of the 24-hour, 1-in-50-year storm event (Figure 9). For additional details, see *Task 3.1 – Development of Climate-Adjusted Hydrologic Model Inputs*, Chapter 3 and Appendix C.

Upon review of the Task 3 report results, as noted above, and from the development of the Study Area's hydrologic modeling runs (see *Task 3.2 – Hydrologic Modeling* report), the BCSD monthly downscaling technique may provide more reasonable estimates of event intensities, versus the BCCA daily downscaling technique which has been shown to underestimate climatology of daily precipitation (Hwang et al. 2013). The BCCA technique, reflecting sub-monthly projections, possesses the inherent uncertainties of the GCM it uses (Maurer et al., 2010). Additionally, the BCCA downscaling has a smoothing effect on the distribution of rainfall events throughout the month, and may indicate less severe storm events. BCCA smoothing has also been noted in its effects on temperature; however, it is deemed to be more justified. One of the reasons for this reasonable bias pattern in BCCA temperature would be that temperature fields generally have much smoother spatial patterns than precipitation (Mizukami et al. 2016).With this in mind, the results of the BCSD scenarios for rainfall intensity may be more reliable to the Los Angeles region. Therefore, BCSD also represents a more conservative target than the BCCA for flood risk mitigation since the BCSD storm event intensities appeared to be increasing as a result of the modeling runs (see Task 3.2). Overall, the multi-model climate change evaluations developed during this study will facilitate a better understanding of how the Los Angeles region can adapt to projected effects of climate change.

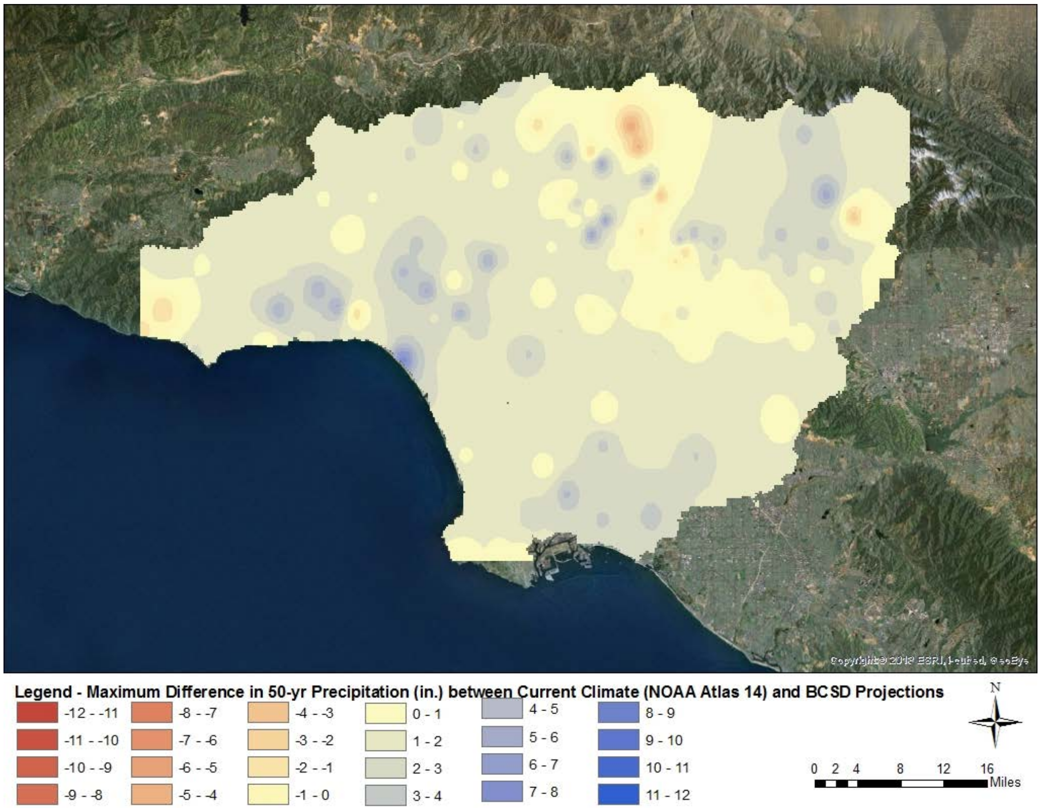

Figure 8. Maximum Change in 24-hour, 1-in-50-year Storm Event Intensities for the BCSD Scenarios

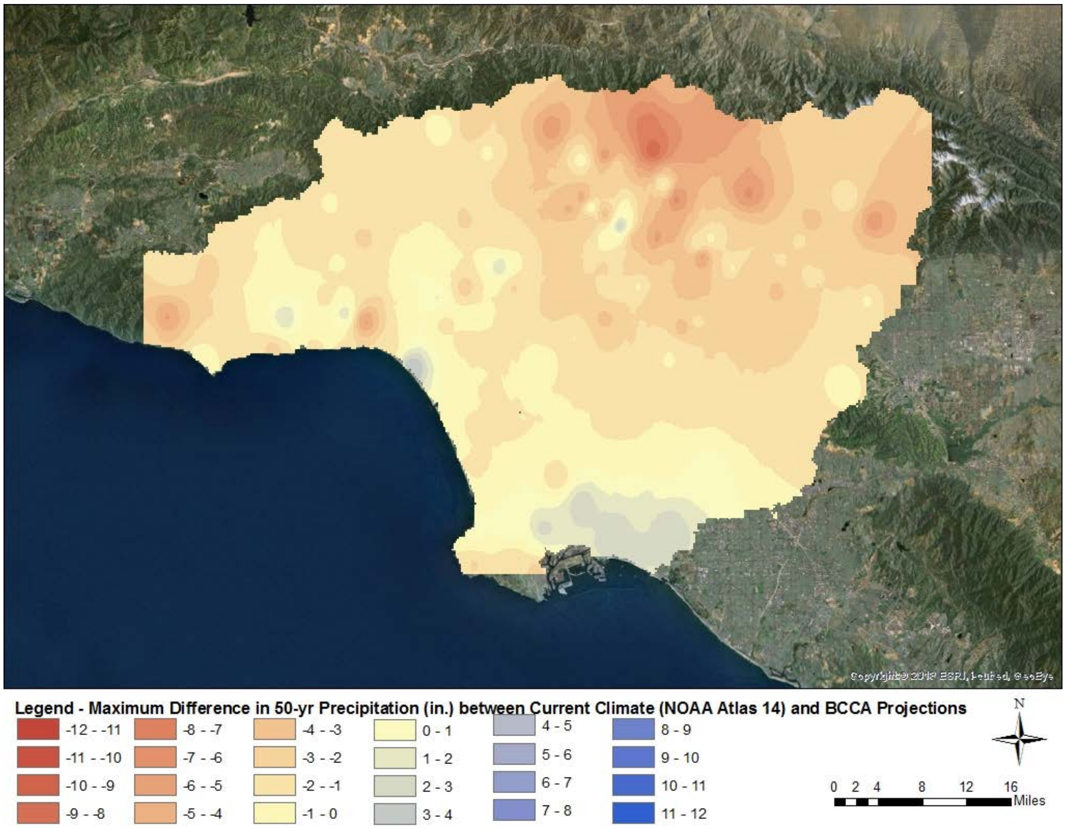

Figure 9. Maximum Change in 24-hour, 1-in-50-year Storm Event Intensities for the CMIP5-BCCA Projections

3.4.3 Change in Hydrologic Runoff

After Reclamation analyzed the storm event intensities, the LACFCD used WMMS to perform the hydrologic modeling. Combining all climate projections, Figures 10 and 11 show the percent change from the historic baseline in the average stormwater runoff and peak flow rate over the course of the century.

The ensemble mean, or the average of all projections, indicates that there is potential for increased stormwater runoff and recharge of approximately 13% as well as for increased peak flow rates of approximately 28% as shown in Figures 10 and 11 respectively. However, it is important to note that the ensemble mean is used only to show the central tendency of all the projections, and should only be used for reference. Any projection within the full range of projections, not just the ensemble mean, has the potential to occur. The region could experience increased or decreased runoff in the future. Moving forward, it is important to note that for stormwater runoff and peak flow rates there is a very high variability within the projections and adaptation strategies can help to address selected ranges of uncertainty.

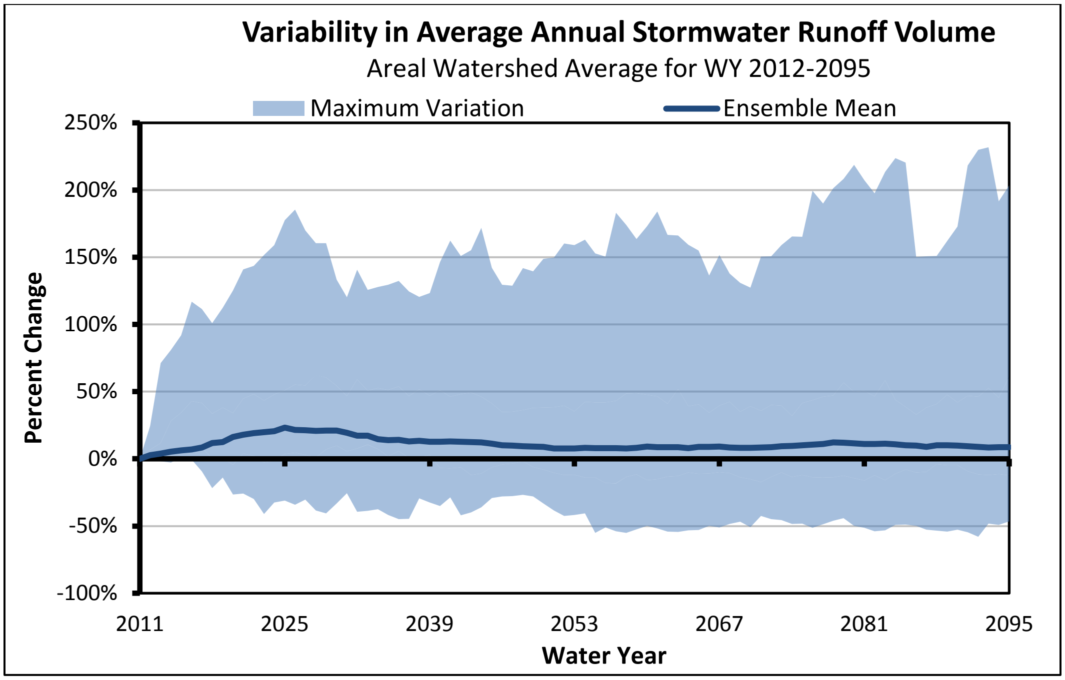

Figure 10. Projected Change in Average Annual Stormwater Runoff

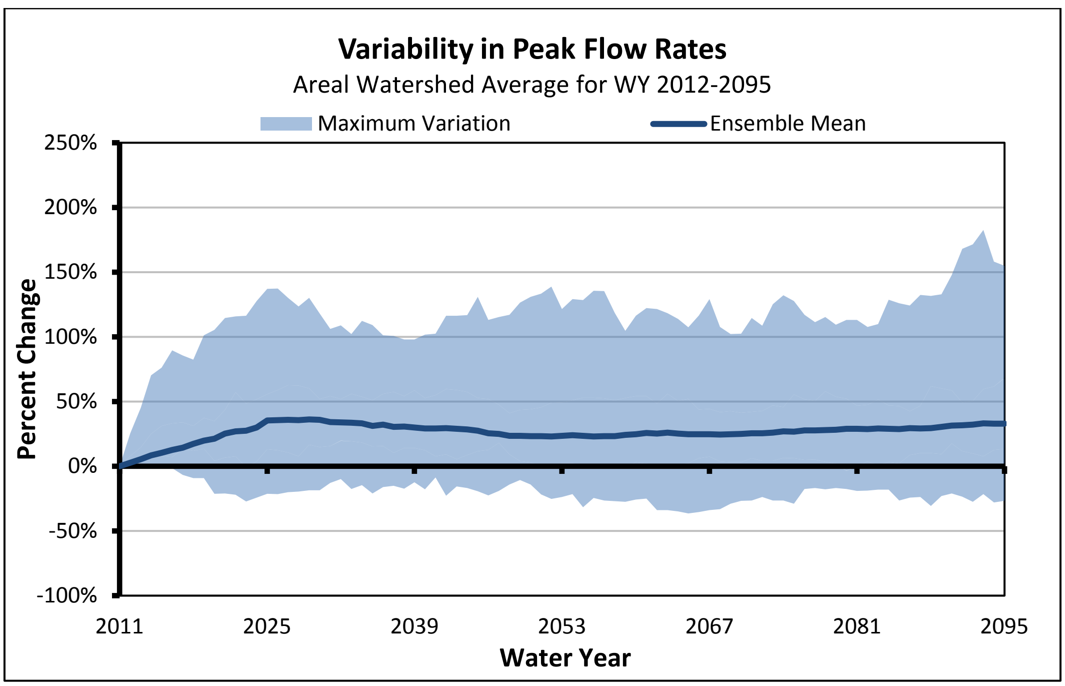

Figure 11. Projected Change in Peak Flow Rates

3.5 Other Climate Impacts

In the region, many universities, non-governmental organizations and other water agencies have conducted analysis of climate change impacts in the Study Area, ranging from water supply and demand and wildfires, to snowpack assessment and sea level rise. A large amount of references were assessed to gain additional insights from these resources on the projected impacts to region’s water supply and demand.

3.5.1 Imported Supply

Imported water for the Greater Los Angeles area will also likely be affected by the changing climate. For California, the State Water Project (SWP) Delivery Reliability Report 2013 projects a temperature increase of 1.8 to 5.4 °F by mid-21st century and 3.6 to 9 °F by the end of the century (Cayan et al. 2009). It predicts that increased temperatures will lead to less snowfall at lower elevations and decreased snowpack. By mid-century it predicts that Sierra Nevada snowpack (the source of SWP water) will reduce by 25% to 40% of its historical average. Decreased snowpack is projected to be greater in the northern Sierra Nevada, closer to the origin of SWP water, than in the southern Sierra Nevada. Furthermore, an increase in “rain on snow” events may lead to earlier runoff.

According to the SWP Delivery Reliability Report, given these changes, a water shortage worse than the 1977 drought could occur one out of every six to eight years by the middle of the 21st century and one out of every three to four years by the end of the century. In those years, it is estimated that an additional 575,000 to 850,000 AF of water would be needed to meet current regulatory requirements and to maintain minimum system operations (California Climate Change Center 2009). This could preclude the SWP from pumping as much water as it would otherwise. Also, warmer temperatures might lead to increased demand. This factor, combined with declining flows, will likely lead to decreased carryover storage from year to year. Alternative water supply options such as recycled water, rainwater harvesting, and desalination may need to be relied upon in order to meet the continually growing demand.

In the Colorado River Basin, the amount of water available and changes in the demand for water over the next 50 years are highly uncertain and dependent upon a number of factors. The potential impacts of future climate variability and climate change further contribute to these uncertainties. For the Colorado River Basin Water Supply and Demand Study, a scenario planning process was used to guide the development of scenarios that provide a broad range of future water supply and demand projections, resulting in four scenarios related to future water supply and six scenarios related to future water demand.

The range of the projected future water supply and demand in the Colorado River Basin was determined through the scenario process. Without additional future water management actions, a wide range of future imbalances is plausible primarily due to the uncertainty in future water supply. Comparing the median of water supply projections against the median of the water demand projections, the long-term projected imbalance in future supply and demand is about 3.2 million AF by 2060 (Reclamation 2012).

3.5.2 Sea-Level Rise

Climate change will contribute to global sea-level rise (SLR) through melting of glaciers and ice caps and thermal expansion of ocean waters, both of which increase the volume of water in the oceans. Regional SLR may be higher or lower than global SLR due to effects of regional ocean and atmospheric circulation.

During the last century, California's 2,000 miles of coastline have experienced seven inches of SLR, a number that is likely to increase drastically as the climate continues to change. Continued increases in sea levels could affect SWP delivery reliability to the LA region in several ways (Cayan et al. 2009).

- Most of the land in the Delta is below sea level – by as much as 20 feet – as a consequence of ongoing subsidence. Increases in sea level could place more pressure on the Delta's fragile levee system and cause levee breaches that could threaten SWP Delta exports.

- As salty water from the Pacific Ocean moves farther upstream into the Delta, the California Department of Water Resources (DWR) could be required to increase the amounts of freshwater releases from Lake Oroville to maintain compliance with Delta water quality standards.

- SLR is expected to cause salt water to flow farther inland. The resulting increase in saltwater intrusion into coastal aquifers would make increasing amounts of groundwater unsuitable for water supply or irrigation (California Climate Change Center 2009). The reduced availability of groundwater would likely contribute to further increases in demands for surface water from the SWP, especially by the coastal SWP contractors.

The Los Angeles region is a metropolis mainly perched on the edge of a coast, which can expect to experience SLR of as much as two feet by 2050 due to climate change according to current projections (Grifman et al. 2013). The area's wastewater management, stormwater management, and potable water systems are highly vulnerable to SLR.

3.5.3 Wildfire Risks

According to a recent UCLA study (Jin et al. 2015), Southern California's wildfires can be categorized by meteorology: fires typically occur either during Santa Ana winds (SA fires) in October through April, or warm and dry periods in June through September (non-SA fires). This study incorporated the influence of climate change in its assessment, finding that the two fire types contributed almost equally to burned area, yet SA fires were responsible for 80% of cumulative 1990–2009 economic losses ($3.1 billion). The damage disparity was driven by fire characteristics: SA fires spread three times faster, occurred closer to urban areas, and burned into areas with greater housing values. Non-SA fires were comparatively more sensitive to age-dependent fuels, often occurred in higher elevation forests, lasted for extended periods, and accounted for 70% of total suppression costs.

The area burned in non-SA fires is projected to increase 77% (±43%) by the mid-21st century with warmer and drier summers, and the SA area burned is projected to increase 64% (±76%), underscoring the need to evaluate the allocation and effectiveness of suppression investments.

This improved distinction of fire type has implications for future projections and management. The researchers' findings indicate that Southern California should be prepared to fight more and larger fires in the future. Finding effective strategies for curtailing the spread of non-SA fires could be very important, since these fires occur mainly in the summertime, when fire risk – and water demand – is highest throughout the Western U.S. Other studies have found increased risk of fire in the future from climate change in other areas of the Western U.S., so an increase in summertime fires in Southern California could mean greater competition with other regions for fire-fighting resources.

3.5.4 Local Snowfall

Another recent UCLA study examined the impact of climate change on snow in the LA region. This study (Sun et al. 2013) predicts that by mid-century, Los Angeles area mountains will lose 42% of their annual snowfall, if greenhouse gas emissions continue to rise on a "business as usual" path. If immediate efforts are made to substantively reduce greenhouse gas emissions (a "mitigation" scenario), mid-century and end-of-century loss of snow will be limited to about 31%. But under the business-as-usual scenario, the mountains may lose two-thirds of snowfall by the end of the century, compared with present day.

The study's results indicate that whether or not action is taken to reduce greenhouse gas emissions, substantial snowfall loss by mid-century is inevitable. Although it addresses climate change impacts on snowfall only, rising temperatures are also very likely to accelerate melting of snowpack accumulated on the ground. Under the business-as-usual scenario, mid-century, seasonal snowpack is likely to melt completely an average of 16 days earlier than usual in the spring. Less snowfall during the winter, combined with earlier snowmelt during the spring, indicates drastic changes are possible, altering important hydrological and ecosystem processes, which could further impact water supplies in the LA area.

3.6 Summary of Climate Impacts

Through Reclamation's downscaled climate change analysis, LACFCD's future hydrologic modeling, and an in-depth literature review of regional climate change impacts, the LA Basin Study fully characterized the factors that have an influence on the water conservation and flood risk infrastructure. Table 2 summarizes the climate projections and their effects on the Los Angeles region.

Table 2. Projected Climate Change Impacts in the Los Angeles Basin

Impact to	Effect
Temperature Change	**Coastal LA Basin**: Increases of 3.5 to 4°F (2040-2060) **Inland LA Basin**: Increases of 4 to 4.5°F (2040-2060) **Mountains & Desert**: Increases of 4.5 to 5.5°F (2040-2060) Source: *Walton et al 2015* **Extreme Hot Days:** Number will triple in coastal areas and central Los Angeles, quadruple in San Fernando and San Gabriel Valleys (2040-2060) Source: *Sun et al 2015*
Precipitation	**Across the entire LA Basin:** Median projections show little to no change over the next century (2011-2095) Source: *LA Basin Study Task 3.1*
Demand	Decrease of 1% in gallons per capita per day due to a combination of projected temperature increases and the ranges of precipitation. Source: *LA Basin Study Task 2, Water Supply & Demand Projections*
Imported Supply	**State Water Project:** • Delivery decrease of 7-10% by 2050 • Snowpack decrease of 48-65% (2070-2099) • Delivery decrease of 21-25% by 2100 Source: *DWR 2009* **Colorado River:** • Flows to decrease by 7-9% by 2050 • Shortages to Lower Basin of: o 1 MAF over any 2-year window up to 51% of the time o 1.5 MAF over any 5-year window up to 59% of the time Source: *Reclamation 2012* **Los Angeles Aqueduct:** • Decrease in "base-of-mountain" runoff of approximately 1.7% (2040-2069) • Decrease in "base-of-mountain" runoff of approximately 5.0% (2070-2099) Source: *LADWP UWMP 2011*
Sea Level Rise (along the LA region coastline)	Rise of 5-24 inches by 2050 Rise of 17-66 inches by 2100 Source: *Grifman et al 2013*
Wildfire Risk	**Non–Santa Ana Fires:** Burned area to increase 77% (±43%) (2040-2060). This type of fire will change the most in the future and start to dominate the summer season. **Santa Ana Fires:** Burned area to increase by 64% (±76%) (2040-2060). Source: *Jin et al 2015*

Impact to	Effect
Local Snowpack	Decreases of between 31-42% (2040-2060) Decreases of between 31-66% (2080-2100) Source: *Sun et al 2013*

4.0 Water Supply and Demand Analysis

The LA Basin Study analyzed future water supply and demand scenarios using a short-term 2035, mid-term 2050, and long-term 2095 projection. The analyses, published as *LA Basin Study Task 2 – Water Supply & Water Demand Projections* report, presents water supplies and demands by watershed, as well as the region as a whole.

The LA Basin Study characterized existing and projected water supplies and demands for the Study Area out to 2095, considering the effects of both projected climate and population growth. The Study provided a supply and demand basis for understanding the potential need and benefit of structural and nonstructural concepts to diversify the water portfolio under future conditions within the LA Basin Study Watersheds.

4.1 Methods

The methodologies used in the water supply and demand projections focus on the use of existing information and documents as references, including the *2014 GLAC IRWMP*, the *2010 Metropolitan Water District of Southern California Integrated Resources Plan*, and the *2015 LADWP SCMP*. Most of the recently published water supply and demand documents contain planning horizons that only extend through 2035 and 2040, so the 2095 projections developed in the LA Basin Study are extrapolated from these 2035/2040 estimates. For local climate change impacts within the Study Area, Reclamation's downscaled climate change and LACFCD's hydrologic modeling were used to help identify potential future changes in storm intensity, precipitation, evapotranspiration, stormwater runoff, and groundwater recharge. Additionally, since the Los Angeles region's climate and its imported water supply have been studied extensively, a literature review of local climate impacts on wildfires and sea-level rise, as well as impacts to the imported water supply was performed. This methodology was discussed and reviewed through a stakeholder process with the LA Basin Study's STAC.

Within the Study Area, many existing water supply and demand planning documents have been prepared by local and regional water agencies. California requires nearly every urban water supplier to assess the reliability of its water sources over a 20-year planning horizon. These Urban Water Management Plans (UWMPs) are prepared by the water agencies to support their long-term resource planning, and ensure adequate water supplies are available to meet existing and future water demands. It is important to note that the latest set of UWMPs only looked out to 2035 and few explicitly considered impacts due to climate change. This necessitated that the LA Basin Study augment these previous plans with climate informed science to create a more meaningful set of future water supply and demand projections.

Based on these existing planning documents, the 2010 supply and demand was calculated for each major watershed and for the Study Area as a whole. The 2010 estimate was then used to represent *current* supply and demand. The LA Basin Study's short-term 2035, mid-term 2050, and long-term 2095 water supply were determined by using 2010 as the baseline and then developing estimates of future supply projections using Reclamation's downscaled climate change findings, LACFCD's future hydrologic modeling, and other impacts identified through the literature review. Future demands beyond 2010 and out until 2095 were estimated based on assumed values for gallons per capita per day (gpcd) in combination with population growth projections. Lastly, these demands were adjusted by the local downscaled climate projections to account for impacts due to different demand patterns caused by local fluctuations in temperature and rainfall.

4.2 Supply Projections

Within the Los Angeles region, many local and regional water agencies are seeking to diversify their water supply portfolios to ensure adequate reliability to sustain projected population growth. Currently, the region as a whole receives approximately 57% of its water supply through imports from the State Water Project or the Colorado River Aqueduct and has plans to reduce its reliance on this imported water. In order for the Los Angeles region to adapt to climate change, it is important to understand its current supply sources and constraints, the region's emphasis on the use of local supplies such as stormwater, and how the full portfolio of sources could be impacted by climate change.

4.2.1 Supply Framework

Supplies are limited by several factors, the first of which is availability (i.e., the ability to physically use a water supply given its close proximity to the Study Area or given existing facilities). This concept of supply availability is divided into three categories for this Study: "unlimited", "limited but not fully used", and "limited and fully used." These categories are defined below and shown graphically in Figure 12.

- **Unlimited Supplies:** These supplies are not restricted by total volume available for use and are only limited by facilities and the other factors described below. For this Study, due to the very close proximity of the Pacific Ocean to the Study Area, the only "unlimited" supply is ocean water. Use is not restricted by quantity, but rather by the constraints of cost, energy, and potential environmental impacts associated with the development of desalination facilities.

- **Limited but Not Fully Used Supplies:** These supplies have a finite upper limit, but have not been fully utilized in the Study Area. Examples of such supplies include recycled water, stormwater, and graywater.

- **Limited and Fully Used Supplies:** These supplies have a defined upper limit and have been completely utilized within the Study Area. Examples of these supplies include natural safe yield to the groundwater basins, imported water, and local surface water.

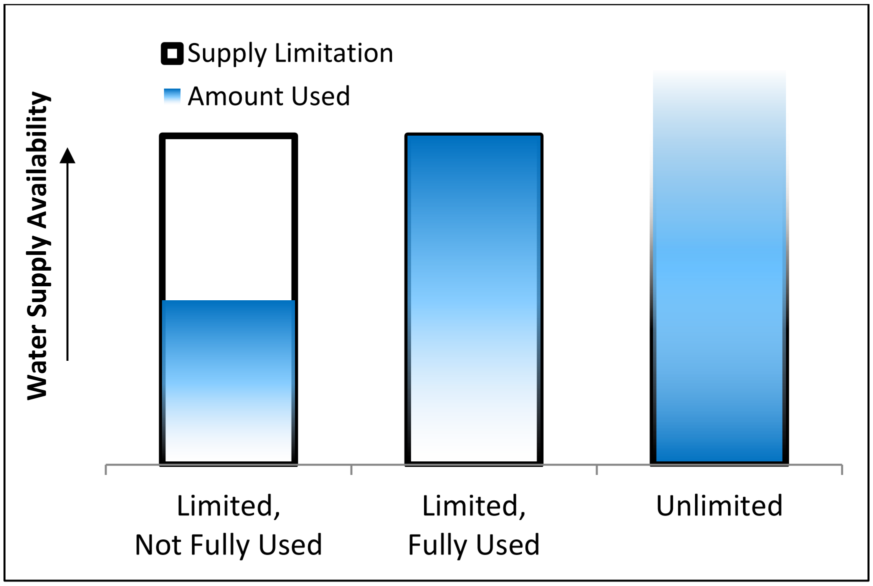

Figure 12. Types of Available Supplies

4.2.2 Supply Constraints

Once the availability of a given supply is established, other factors can constrain the ability of the region to fully use that supply. Decision-makers will have to address the following constraints:

1. **Facilities:** The extent to which agencies in the Study Area develop infrastructure (i.e., dams, spreading grounds, green stormwater infrastructures, conveyance systems, etc.) to capture, treat, convey, and use available water supplies will directly influence the degree of use of those supplies. These facilities play a critical role in the region's ability to use and manage a diverse portfolio of water supplies.

2. **Economics:** Both the general strength of the economy and the cost-effectiveness of individual projects influence the degree to which supplies can be used. The general economy affects the availability of grant, loan, bond, and capital improvement funds that can be used to implement projects, whereas the cost-effectiveness of the projects themselves influences the relative appeal of implementing one project versus another in terms of costs and monetized benefits.

3. **Public Perception:** Public perception influences the degree to which controversial or poorly-understood water supply sources can be used.

4. **Regulatory:** Regulatory constraints can take the form of existing limits that affect the degree of implementation for a given project (e.g., water quality limits, pumping rights/restrictions, blending requirements, monitoring requirements, entitlement limits, etc.), and they can also take the form of future limits or regulations that have not been established (e.g., direct potable reuse guidelines). Regulatory limits are particularly influential for recycled water projects, both for non-potable reuse and indirect potable reuse.

5. **Groundwater Basin Capacity:** Use of groundwater basins as a tool for the management of water supplies is dependent on the basin's seasonal capacities to recharge, store, and produce all types of water supplies.

6. **Environmental Impacts:** Use of a supply source can have detrimental impacts on habitat, native species survival, and environmental sustainability. Over-extraction of surface water and groundwater affects habitat, and the development of facilities such as ocean desalination plants can affect nearby species. Potential environmental impacts also influence several other constraints such as public perception and regulatory actions that can further restrict the development of a supply for use.

These factors impact the ability of agencies in the Study Area to implement projects that facilitate use of the available supplies. The extent to which a given available supply is used depends on a combination of these factors, which are unique for each type of supply and facility.

4.2.3 Current Supplies

Baseline water supplies for 2010 are higher than the demands, suggesting that not all of these supplies were used. These unused supplies are due to the Los Angeles region's robust planning efforts – bolstered in part by a keen sense of preparedness, and in part by State mandates requiring UWMPs – in order to ensure water reliability. The values for available supplies in 2010 were obtained from the GLAC IRWMP and reflect numbers reported in the various UWMPs for the Study Area.

Looking ahead, it is anticipated that climate change will increasingly make the region's baseline water supply unreliable as population growth occurs. The following section analyzes changes and impacts to the LA Basin's water supply over the next century and explores the supply at key points in the future.

4.2.4 Future Supplies

Changes in future supplies were largely based on the climate change analysis performed in Task 3 of the Study, and through a literature review of existing planning documents, such as the 2013 GLAC IRWMP. The climate change analysis was used to assess local surface water, natural infiltration, and stormwater, and the literature review was used to adjust sources of imported water. Most of the available water supply planning documents, however, did not prepare supply projections beyond 2035, so climate-informed adjustments were made to develop water supply numbers out to 2095. To assess the effects on future supplies, the region's current infrastructure was used to perform a gap analysis in a "business as usual" case assuming no new infrastructure build-out.

From the literature review for imported water sources, a 25% reduction was applied to the current water supplies to reflect potentially adverse climate change impacts. This reduction represents the maximum value for climate change impacts mentioned in studies by Reclamation for the Colorado River Aqueduct (Reclamation 2012) and DWR for the SWP (DWR 2011). For this Study, imported water for groundwater recharge was assumed to drop to zero AFY by the end of century. The Water Replenishment District of Southern California is one agency that has already begun the shift away from using imported water for replenishment.

For local supplies, the climate change and hydrologic modeling results projected an approximate 13% increase in average annual stormwater runoff volume. This increase again was applied to current levels of local stormwater, natural infiltration, and local surface water.

For recycled water sources, the current system was assumed to perform at its current capacity, assuming no new infrastructure. Thus, no increase in supply was applied to recycled water sources. Table 3 shows the current supply as well as the potential changes in water supply for all sources out to 2095.

Table 3. Water Supplies (AFY) in the Los Angeles Basin

Water Supply	2010	2035	2050	2095
Imported Water	919,800	852,200	811,600	689,900
Imported Water for Groundwater Recharge	80,700	80,700	57,000	0
Recycled Water for Groundwater Recharge	48,400	48,400	48,400	48,400
Stormwater for Groundwater Recharge	177,500	184,300	188,400	200,600
Natural Infiltration Groundwater	242,100	251,300	256,900	273,500
Recycled Water for Indirect Reuse	80,700	80,700	80,700	80,700
Local Surface Water	16,100	16,800	17,100	18,200
Total:	**1,566,700**	**1,514,400**	**1,460,100**	**1,311,300**

Notes: Values rounded to the nearest 100.

4.3 Demand Projections

Demand estimates for 2010 utilize data from the GLAC IRWMP. Future projections for 2035 and beyond build-off of the 2010 estimates and apply assumed “low”, “medium”, and “high” per capita per day water use values to population projections derived from the 2010 U.S. Census, as explained in the sections below. Climate change impacts to water use were also incorporated into the future demand projections.

4.3.1 Current Demands

Water demand for the year 2010 was used as the baseline demand. This year was utilized since population and water demand data readily existed (Tables 4 and 5). The 2010 populations for the region were calculated using block groups from the 2010 U.S. Census. Regional water demands were previously compiled in the GLAC IRWMP and originate from 2010 UWMPs for water agencies with service areas within the Study Area.

Table 4. Current Population in the Los Angeles Basin

Watershed	2010
Malibu Creek	78,700
North Santa Monica Bay	20,100
Ballona Creek	1,491,500
South Santa Monica Bay	379,000
Dominguez Channel/Los Angeles Harbor	818,000
Los Angeles River	4,455,300
San Gabriel River	2,365,000
Total Population	**9,607,600**

Note: Values rounded to the nearest 100.

Table 5. Current Water Demand in the Los Angeles Basin

Watershed	2010 (AFY)
Malibu Creek	26,800
North Santa Monica Bay	17,300
Ballona Creek	149,000
South Santa Monica Bay	93,000
Dominguez Channel/Los Angeles Harbor	109,800
Los Angeles River	636,600
San Gabriel River	426,300
Total Demand	**1,458,800**

Note: Values are rounded to the nearest 100.

4.3.2 Future Demands

Water demands are a function of many different factors, two of which are temperature and precipitation. Given the projected changes in these two variables in the LA Basin as a result of climate change, water demands are likely to be affected and long-term projections were created.

First, to estimate population beyond 2010 and out to 2095, projections for Los Angeles County from the California Department of Finance (DOF 2014) were used to calculate the percent change in population for all seven watersheds combined. This percent change was then applied to the 2010 population for each of the seven watersheds to obtain proportional increases in population from 2010 to 2060 in five-year increments. Next, the trend in percentage growth between 2040 and 2060 for Los Angeles County was used to extrapolate the percentage change in growth between 2060 and 2095, also in five-year increments. Finally, these percent changes were applied to each watershed to obtain population projections between 2060 and 2095. Table 6 summarizes the results of the projections. The overall increase in Los Angeles Basin population from 2010 to 2035 was estimated to be approximately 13%, and the increase from 2035 to 2095 was estimated to be approximately 6% as geographic constraints slow the rate of growth.

Table 6. Projected Population in the Los Angeles Basin

Watershed	2035	2050	2095
Malibu Creek	89,000	91,600	94,200
North Santa Monica Bay	22,800	23,500	24,100
Ballona Creek	1,688,100	1,735,800	1,785,400
South Santa Monica Bay	429,000	441,100	453,700
Dominguez Channel/Los Angeles Harbor	925,800	952,000	979,100
Los Angeles River	5,042,700	5,185,200	5,333,100
San Gabriel River	2,676,900	2,752,500	2,831,000
Total Population	**10,874,400**	**11,181,700**	**11,500,600**

Note: Values rounded to the nearest 100.

Next, three water use scenarios for future demand were developed: a “High” scenario based on the assumption that 2035 or “business as usual” gpcd values will be maintained, a “Medium” scenario based on the assumption that the region could attain the City of Long Beach target gpcd as listed in its *2010 Urban Water Management Plan*, and a “Low” scenario based on the assumption that the region could duplicate and surpass the urban demand management achievements in Perth, Australia by making additional progress on outdoor conservation measures.

Finally, the three water use scenarios were augmented to include the impacts of a changing climate. Annual demand factors for urban water use were obtained from MWD and reflect the variability of demand to account for temperature and precipitation. Applying the temperature and precipitation projections from the processed climate change downscaled data results in a 1% decrease in average demand for the Study Area. The decrease in demand is driven by a slight increase in local precipitation. A multi-year running average of annual demand around the year 2095 would be 1% lower, with demand variability still occurring on a month-to-month and year-to-year basis. The results are shown in Table 7 and Figure 13 below.

The future end values for 2095 for the three water use scenarios, adjusted for climate change, are:

- High “Business as Usual” demand scenario – 136 gpcd
- Medium demand scenario – 99 gpcd
- Low demand scenario – 63 gpcd

Table 7. Water Demand Projections in the Los Angeles Basin

Demand Scenario	2035 (AFY)	2050 (AFY)	2095 (AFY)
Low	1,676,300	1,491,300	817,000
Medium	1,676,300	1,602,700	1,275,200
High	1,676,300	1,719,500	1,755,800

Note: Values rounded to the nearest 100.

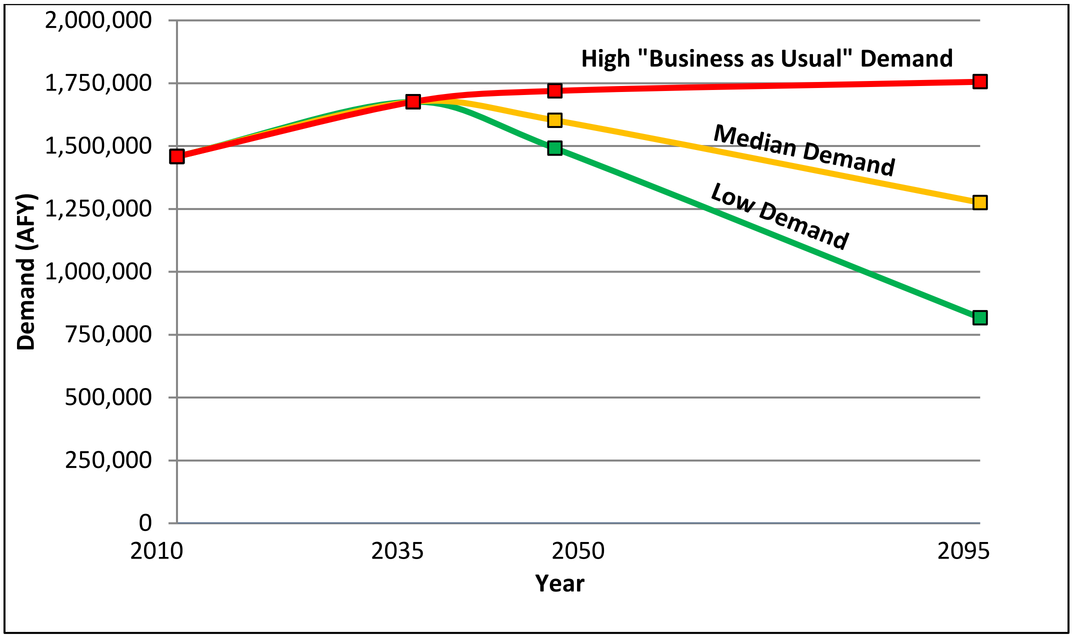

Figure 13. Los Angeles Basin Water Demand Projections

4.4 Gap Analysis

As determined by the supply and demand analysis, it is likely that through the reduction or reallocation of imported water supplies, over time the region's available supplies would not be able to meet the highest level of demand based on future projections of population growth and climate change. The current and future supply and demand projections for the LA Basin are summarized in Table 8 and Figure 14. For the region as a whole, if current 2010 supplies were not enhanced, there could be a potential supply gap of approximately 160,000 AFY by 2035, increasing to a gap of more than 440,000 AFY by 2095 for the high "business as usual" demand scenario.

Table 8. Projected Gap Analysis for the Los Angeles Basin

Water Supply (AFY)				
	2010	**2035**	**2050**	**2095**
Imported Water	919,800	852,200	811,600	689,900
Imported Water for Groundwater Recharge	80,700	80,700	57,000	0
Recycled Water for Groundwater Recharge	48,400	48,400	48,400	48,400
Stormwater for Groundwater Recharge	177,500	184,300	188,400	200,600
Natural Infiltration Groundwater	242,100	251,300	256,900	273,500
Recycled Water for Indirect Reuse	80,700	80,700	80,700	80,700
Local Surface Water	16,100	16,800	17,100	18,200
Total:	**1,566,700**	**1,514,400**	**1,460,100**	**1,311,300**
Water Demand (AFY)				
	2010	**2035**	**2050**	**2095**
Low Demand			1,491,300	817,000
Median Demand			1,602,700	1,275,200
High Demand	1,458,700	1,676,300	1,719,500	1,755,800

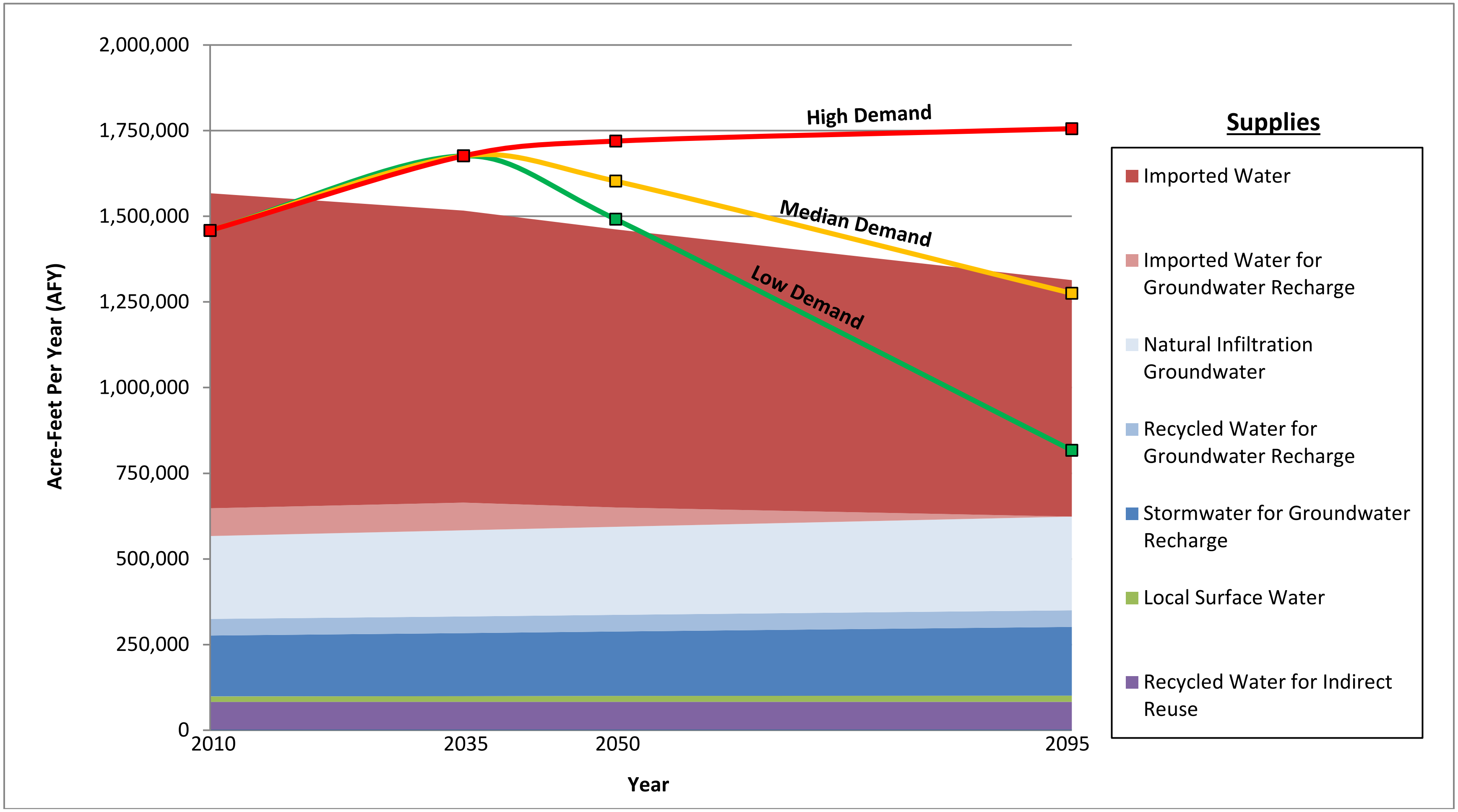

Figure 14. Los Angeles Basin Projected Water Supply Sources Compared with Demand

5.0 Existing Infrastructure Response

As part 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 protection system. For the analysis, Reclamation assessed the 14 major LACFCD dams and reservoirs, USACE examined their four major flood control dams in the region, and LACFCD assessed the 26 major spreading facilities interconnected to the water conservation system. The LACFCD also evaluated five major channel outlets. The response of the existing infrastructure was assessed and operational guidelines were then analyzed under both the current and future climate conditions.

This assessment used the existing water conservation and flood infrastructure network as the baseline condition. However, over the course of the Study assessment period (2010-2095), small- and large-scale changes are likely to occur throughout the existing system. These potential future system enhancements were not explored in the evaluation of the existing infrastructure so that a baseline or a "no action" assessment of historical conditions could be evaluated under future climate conditions.

The previous hydrologic modeling results were used as inputs to the baseline assessment. However, to increase the computing efficiency of this analysis, only six scenarios were targeted to represent bounding climate projections for the extreme high, the extreme low, and the central tendencies for the projected stormwater runoff volumes and peak flow rates (Figure 15).

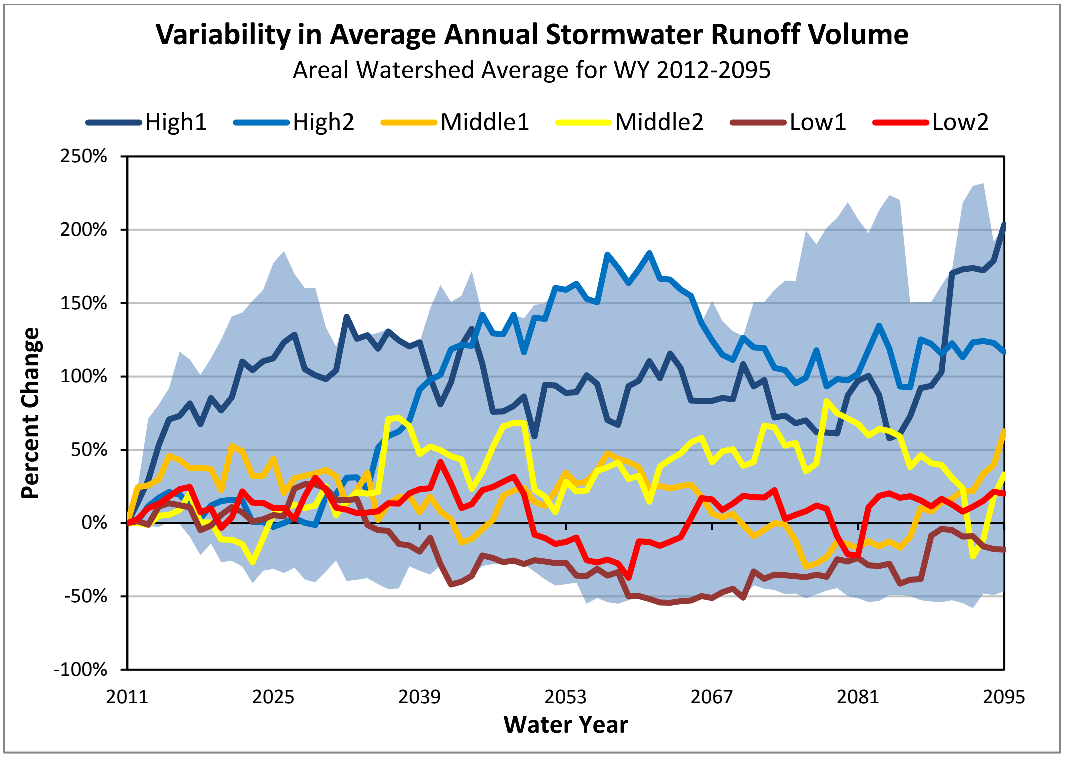

Figure 15. Six Highlighted Scenarios Used in Infrastructure Response

Next, the performance of the existing infrastructure was analyzed in order to identify the most and least resilient facilities to climate change. The various facilities were compared to each other and included a ranking assessment of the 18 dams/reservoirs and 26 spreading grounds based upon their stormwater conservation ability. These performance levels provided an assessment of the overall efficiency and resilience of the facilities to both the historic and projected future climate. Each of these major infrastructure components were analyzed as a system and ranked with respect to the other facilities in the network. Similarly, the five major channel outlets in the region were compared to each other based on their stormwater discharges to the ocean. These rankings assisted in targeting specific watersheds and facilities for potential future enhancements.

Generally, facilities that were least efficient and least resilient to climate change were assigned Performance Level III, indicating a high potential for enhancements. Facilities that were more efficient and more resilient to climate change were assigned Performance Level II. Finally, facilities that were the most efficient and most resilient to climate change were assigned Performance Level I. Figure 16, and Tables 9 and 10 provide the water conservation performance levels from this analysis.

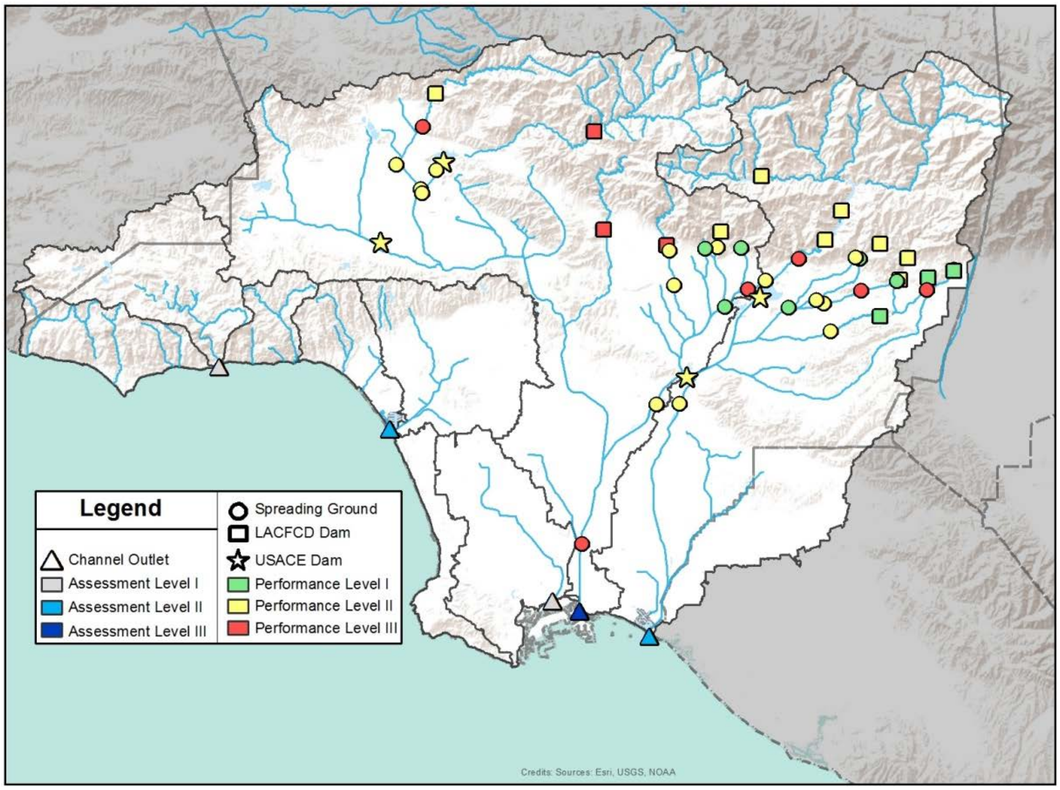

Figure 16. Dam/Reservoir, Spreading Ground, and Channel Outlet Water Conservation Performance Levels

Table 9. Dams/Reservoirs 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 10. 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			

For the major channel outlets, the Los Angeles River outlet ranked into Assessment Level III, indicating that this watershed has very high runoff and lowest capture efficiency. Because of this, it also has the greatest potential for increasing stormwater conservation and could be targeted for future enhancements. For the remaining outlets, these locations were found to have lower discharge volumes, but additional capture efforts could still be explored within these watersheds to further increase stormwater capture and improve local water supplies. Table 11 provides the assessment levels resulting from the analysis.

Table 11. 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

From the analysis of the existing infrastructure, all major facilities were determined to have some potential for enhancement; however, a higher performance level did not necessarily preclude sites from further analysis in the Adaptive Concepts section of the LA Basin Study. It should be noted that these levels did not measure facility issues such as seismic or structural deficiencies. Instead, these levels only evaluated general water conservation improvement potential, as well as each facility's individual performance with respect to the system.

6.0 Formulation of Adaptive Concepts

6.1 Objectives and Criteria

Local groundwater supplies are a key resource in the Los Angeles Basin and are a major component of the region's overall water supply portfolio. To further reduce dependence on increasingly unreliable imported water sources, the region is collectively pursuing stormwater capture, recycled water, and other local supplies as means to recharge groundwater. Diversifying the local water supply, especially enhancing stormwater capture for groundwater recharge, increases the region's water sustainability.

The LACFCD manages stormwater conservation and flood protection across the region, and as such, the LA Basin Study included a strong emphasis on stormwater capture for groundwater recharge. A vast infrastructure that includes 14 dams and reservoirs, 26 spreading grounds, 3 seawater intrusion barriers, and over 480 miles of open channels, 3,000 miles of underground storm drains, and 160 debris basins is maintained and operated by the LACFCD to capture large volumes of stormwater runoff. However, some rainfall that falls within the basin cannot currently be captured and is wasted to the ocean. This is especially true in the highly urbanized areas. Enhancing the region's ability to capture stormwater runoff would help replenish and bolster the groundwater supplies which are an important component of a diverse portfolio of water supply sources.

To explore options that could expand the use of this resource, structural and nonstructural concepts were developed to enhance effective stormwater management under the projected future conditions. These concepts built upon the climate change projections and the existing infrastructure response analysis discussed in the previous sections.

The process to develop these adaptive concepts included:

- Concept Development
    - Identify a range of opportunities and options using public and stakeholder input.
    - Determine preliminary concepts for further evaluation.
- Technical Analysis of Concepts
    - Assess structural and nonstructural concepts pertaining, but not limited to, dams, spreading grounds, flood control channels, decentralized storage, infiltration, reuse facilities, debris basins, and low impact development.
    - Develop and apply concept selection criteria.

- Evaluate selected concepts for future system reliability, efficiency, and effectiveness.

WMMS hydrologic simulations analyzed the potential water conservation and flood risk mitigation benefits for the various project concepts. For the future period, water years 2012 through 2095, four bounding climate projections (Low 1, Low 2, Mid 2, and High 1) were used in the model simulations. These projections were a sub-set of the six climate projections used during the existing infrastructure response analysis.

6.2 Approach to Concept Development

Through a collaborative process, concept development consisted of identifying and developing a full suite of stormwater conservation options, including the existing LACFCD water conservation and flood protection infrastructure.

The Study Team hosted two charrettes to solicit stormwater capture concepts for potential projects. The charrettes were held in November 2014 in downtown Los Angeles. The first charrette included attendees from the LA Basin Study STAC, and the second charrette welcomed members of the public. The STAC and public identified a wide range and comprehensive list of stormwater capture concepts. Additionally, the Study Team reached out to other LACFCD staff to gather potential concepts. From the charrettes and internal outreach efforts, nearly 500 stormwater capture concepts were collected. After a screening process, 126 of the concepts were targeted for more detailed evaluations based on their potential to enhance stormwater capture.

6.3 Technical Analysis of Concepts

As part of the technical analysis, the 126 concepts were subdivided into three categories based on the characteristics and scale of each concept:

- **Centralized Projects –** Structural concepts related to large recharge and storage solutions (e.g., recharge basins, dams, channels, and debris basins). *51 total concepts.*

- **Decentralized Projects & Distributed Programs –** Structural and nonstructural concepts related to smaller distributed recharge or direct use solutions (e.g., sub-regional infiltration, green streets, and cisterns). *34 total concepts.*

- **Plans, Policies, & Partnerships –** Nonstructural concepts that incentivize, promote, and/or facilitate stormwater conservation. *41 total concepts.*

After separate scoring criteria were developed for each category based upon input from the STAC, the concepts were then scored and ranked to identify favorable stormwater concepts that could be incorporated into project groups for further analysis.

The technical criteria for Centralized Projects included the expected stormwater conservation benefit, expected unit cost of stormwater conserved, multiple benefits and partnerships, property ownership, and implementability. Additional factors for Decentralized Projects & Distributed Programs included application area and legal/institutional challenges. Lastly, additional factors for Plans, Policies, & Partnerships included expected enhancements in stormwater conservation benefit and innovation. For all three categories, the greatest emphasis was assigned to the stormwater conservation benefit, unit cost of stormwater conserved, and multiple benefits categories to reflect the importance of these factors.

6.3.1 Centralized Projects

The Centralized Projects included 51 concepts related to the reoperation or rehabilitation of the LACFCD and USACE dams, and the LACFCD spreading grounds, debris basins, and channels. The projects also include the construction of new stormwater conservation facilities to adapt to climate change. The highest scoring concepts included reoperation and modification of existing dams to enhance regional storage of stormwater for eventual recharge into downstream recharge basins, the construction of new or reoperation of existing spreading grounds, retrofitting debris basins for stormwater conservation, and channel modifications.

6.3.2 Decentralized Projects & Distributed Programs

The Decentralized Projects & Distributed Programs concepts included 34 concepts related to the implementation of distributed recharge and direct use projects, the implementation of distributed Low Impact Development (LID) water conservation elements, and decreasing the imperviousness of the watershed. The highest scoring concepts included new park space (green infrastructure), infiltration in public spaces, right-of-ways, transportation easements, and “green street” improvements.

6.3.3 Plans, Policies, & Partnerships

The Plans, Policies, & Partnerships concepts included 41stormwater conservation concepts. The highest scoring concepts were related to incentivizing or requiring LID ordinances, the use of public land (e.g., schools, parks, and government property) for stormwater capture projects, and streamlining regulatory structures.

6.4 Adaptive Concepts Considered

The Study Team collaborated to identify specific criteria to use in the analyses of the structural, nonstructural, and/or combination concepts. These criteria were also later used to facilitate a trade-off analysis of the different project concepts.

The evaluation criteria included:

- Annual Amount of Stormwater Conserved
- Climate Resiliency
- Capital Costs
- Operations and Maintenance Costs
- Habitat Improvements
- Recreation Opportunities
- Water Quality Benefits
- Flood Risk Management
- Energy Consumption

After the concepts were evaluated using these criteria, the highest scoring concepts were integrated into 12 project groups for further analysis to support a comprehensive climate adaptation strategy. These 12 project groups were categorized into four broad categories:

- **Local Solutions –** Decentralized projects distributed across the watershed that promote infiltration via stormwater Best Management Practices (BMPs).

- **Regional Solutions –** Centralized projects that provide for additional infiltration via enhancements to existing facilities, new spreading grounds, and channel modifications.

- **Storage Solutions –** Centralized projects that provide additional storage via modifications to the existing LACFCD and USACE dams and to the LACFCD debris basins.

- **Management Solutions –** Plans, programs and policies that promote increased infiltration by providing incentives to implement the Local, Regional, and Storage solutions sooner and/or in a more widespread approach.

The final category and project groupings are shown in Figure 17.

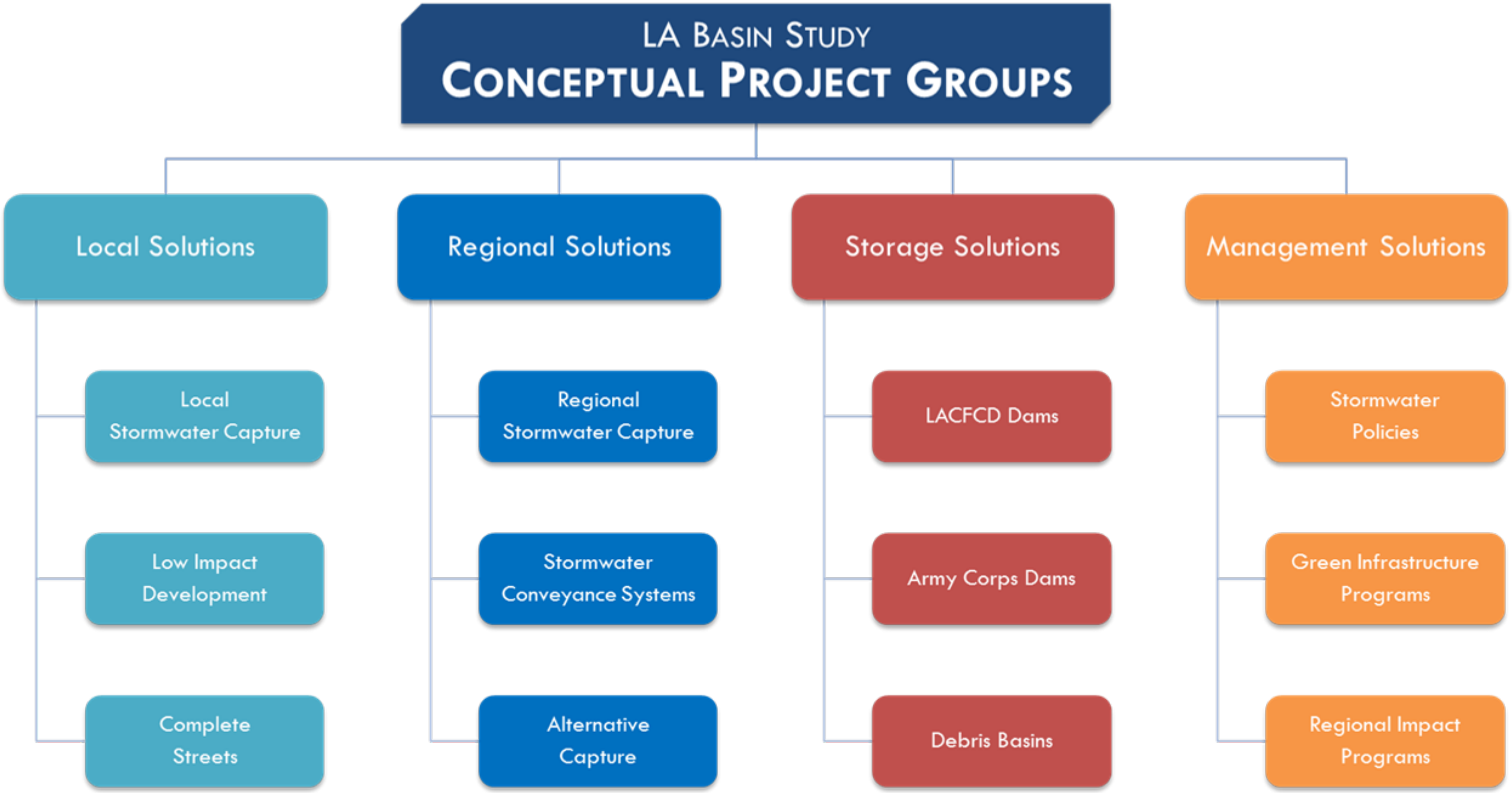

Figure 17. LA Basin Study Conceptual Project Groups

6.4.1 Local Solutions

Local Solutions are decentralized infiltration concepts that are distributed across the watershed. This category is comprised of three project groups:

- Local Stormwater Capture
- Low Impact Development
- Complete Streets

6.4.1.1 Local Stormwater Capture

This project group consists of facilities that receive moderate volumes of stormwater runoff from upstream areas for infiltration and retention. Local stormwater capture facilities may be in the form of surface infiltration basins or underground infiltration chambers. The Local Stormwater Capture project group is comprised of the following elements:

- ***Stormwater Infiltration in Open Spaces***
  Concepts include new projects in parks, golf courses, and vacant land.

- ***Stormwater Infiltration in Public Spaces***
  Concepts include new projects in public right-of-ways, schools, government facilities, and California Department of Transportation right-of-ways.

6.4.1.2 Low Impact Development

LID concepts are distributed structural BMPs that capture and infiltrate or store runoff close to the source, at the parcel scale. LID includes bioretention, permeable pavement, and other infiltration BMPs. LID was applied across the region to all types of property including residential, institutional, industrial and commercial parcels. The LID project group is comprised of the following elements:

- ***Widespread Low Impact Development***
  Concepts include “urban acupuncture” techniques such as rain gardens/grading, rain barrels/tanks, green roofs, etc. which were widely distributed over the region.

- ***Targeted Low Impact Development***
  Concepts include implementing site-appropriate stormwater BMPs that are the most efficient for a specific area, such as areas with highly permeable soils or geology favorable for groundwater recharge.

6.4.1.3 Complete Streets

Complete Streets ensure the safety, accessibility, and convenience of all transportation users such as pedestrians, bicyclists, transit riders, and motorists. Complete Streets also promote the treatment and management of stormwater through onsite retention, filtration, and infiltration. BMPs are typically implemented as linear bioretention/biofiltration BMPs. The Complete Streets project group is comprised of the following elements:

- ***Widespread Green Streets***
  Concepts include prioritizing streets based upon stormwater capture potential and using site-appropriate BMPs

- ***Re-envisioning Streets as a Vital Part of the Watershed***
  Concepts include fully utilizing all aspects of transportation corridors such as parkways and medians to capture and infiltrate stormwater

6.4.2 Regional Solutions

Regional Solutions concepts recharge groundwater by infiltrating stormwater in large spreading grounds and soft bottom channels. This category is comprised of three project groups:

- Regional Stormwater Capture
- Stormwater Conveyance Systems
- Alternative Capture

6.4.2.1 Regional Stormwater Capture

This project group includes concepts related to the construction of new spreading grounds and basins, and enhancement of existing spreading grounds. The Regional Stormwater Capture project group is comprised of the following elements:

- ***New Large Stormwater Recharge Sites***
  Concepts include construction of new spreading grounds.

- ***Enhanced Maintenance Practices***
  Concepts include enhanced maintenance at existing spreading grounds to increase groundwater recharge.

6.4.2.2 Stormwater Conveyance Systems

This project group includes potential stormwater conservation from a suite of channel modification concepts. A preliminary screening was performed to target areas that are favorable for converting portions of concrete channels to soft bottom channels, specifically focusing on tributary reaches that overlay unconfined groundwater basins. The Stormwater Conveyance Systems project group is comprised of the following elements:

- ***Expand the Soft Bottom Channel Network***
  Concepts include converting existing concrete-lined channels to a soft bottom channel in areas conducive to groundwater recharge.

- ***Enhanced Short-Term Stormwater Detention***
  Concepts include implementing “river speed bumps”, which are small in-channel earthen detention structures, and channel side ponds where easements are wide enough or land appears available for their installation.

6.4.2.3 Alternative Capture

This project group consists of groundwater recharge adjacent to waterways with limited land availability for nearby recharge and that lack downstream spreading basins. Rather than traditional spreading operations, stormwater in this project group could be injected into the production aquifers below. Alternative Capture consists of the following element:

- ***Utilize Injection Wells to Overcome Limited Land Availability***
  Concepts include diverting stormwater flows from the Los Angeles River and conveying flows to shallow recharge ponds for soil aquifer treatment which can then be injected into the aquifer.

6.4.3 Storage Solutions

Storage Solutions concepts include modification or reoperation of existing dams and debris basins to enhance surface storage, which would eventually be released to downstream spreading basins to recharge groundwater. This category consists of three project groups:

- LACFCD Dams
- USACE Dams
- Debris Basins

6.4.3.1 LACFCD Dams

Concepts were developed for nine LACFCD dams to enable them to capture an increased volume of stormwater runoff, which would entail both structural and nonstructural modifications to the dams. These concepts would not adversely impact the flood protection at these facilities, and any stormwater stored could be subject to releases to the ocean if capacity within the reservoir is required for flood operations. The LACFCD Dams project group is comprised of the following element:

- ***Enhanced Spillway Controls for Stormwater Storage***
  Concepts include installing operable weirs (e.g., pneumatic gates) and/or gates at the spillway(s) of each dam to allow stormwater to be captured at elevations above the spillway crest.

6.4.3.2 USACE Dams

Similar to the LACFCD dams, a structural concept was developed for the USACE’s Hansen Dam in an effort to maximize capture of stormwater runoff. The USACE Dams project group consists of the following element:

- ***Enhanced Outflow Controls for Stormwater Storage***
  Concept includes modifying Hansen Dam to improve the dam's water conservation operations and outlet works.

6.4.3.3 Debris Basins

The Debris Basin project group assumes select debris basins could be retrofitted to temporarily capture stormwater and later release it to downstream spreading grounds to increase groundwater recharge. A preliminary screening of the LACFCD debris basins was performed to identify candidate basins for modification. Sites with the largest storage capacities and located upstream of spreading grounds were identified for modification. This project group consists of the following element:

- ***New Outflow Controls***
  Concepts include modifying debris basins to have controlled outflow works to temporarily store and release stormwater to downstream spreading grounds.

6.4.4 Management Solutions

The Management Solutions category includes nonstructural concepts that represent improvements, or more aggressive enhancements, to the Local Solutions category discussed previously. The general assumption is that the widespread implementation of the Local Solutions category would likely occur over a longer period of time and that the Management Solutions would expedite this process. This category is made up of the following project groups:

- Stormwater Policies
- Green Infrastructure Programs
- Regional Impact Programs

6.4.4.1 Stormwater Policies

Stormwater Policies are control measures that encourage stormwater conservation. This project group is comprised of the following elements:

- ***Align Regulatory Guidelines with Water Supply Goals***
  Concept includes using EWMPs to increase stormwater conservation, removing "water thirsty" or invasive plants from the stormwater system, and streamlining regulatory requirements for maintenance of existing and urbanized stormwater infrastructure.

- ***Promote New Technology & Strategies to Increase Stormwater Capture***
  Concepts range from developing a rainfall-hydrology model to quantify pre-storm runoff capture to developing a "feed-in-tariff" for residents who infiltrate stormwater into the local groundwater basins.

6.4.4.2 Green Infrastructure Programs

Green Infrastructure Programs encourage implementation of LID across the watershed. This project group is comprised of the following elements:

- ***Increase the Permeability of the Region***
  Concept includes increasing the overall permeability of the region, with a focus on urban areas, through implementation of LID to capture and recharge rainfall where it falls.

- ***Focus on Residential Stormwater Capture***
  Concept emphasizes distributed stormwater capture and infiltration within residential land uses.

6.4.4.3 Regional Impact Programs

Regional Impact Programs encourage local stormwater capture solutions across the watershed. This project group is comprised of the following elements:

- ***Emphasize a Watershed Approach to Managing Stormwater***
  Concepts include developing programs that explore floodplain reclamation, providing stormwater recharge within the waterways, further improving storage in groundwater basins to reduce evapotranspiration losses, and minimizing stormwater runoff from individual sites.

- ***Aggressively Use Available Space for Stormwater Capture***
  Concepts include policies and programs that recognize open spaces naturally provide stormwater benefits, aggressively implementing stormwater improvements at parks and schools, depressing sports fields for stormwater capture, and utilizing government parcels first.

- ***Increase Public Awareness About Stormwater Benefits***
  Concepts range from education policies and programs to raise awareness of the benefits of stormwater to developing incentives to promote residential on-site stormwater capture.

Refer to the *Task 5 –Infrastructure and Operations Concepts* report for additional background and details on the development process of these concepts.

7.0 Evaluation and Comparison of Adaptive Concepts

7.1 Projected Stormwater Conservation

To help adapt to the effects of climate change and growing future populations, the region has targeted increased stormwater capture as a major strategy to increase locally sourced water supplies. Under a range of climate projections, various models within WMMS were used to compare the potential stormwater capture, conservation, and storage for the 12 conceptual project groups.

As shown in Figure 18, implementation of the 12 various project groups results in a wide range of stormwater conservation benefits and increased storage. Table 12 presents the range of these values and also lists other features of each project group, such as recreation, habitat, and cost. The estimated stormwater conservation, along with the added features associated with each concept, was based upon full implementation – or the complete “build-out” – for each project group. Partial implementation would result in reduced benefits.

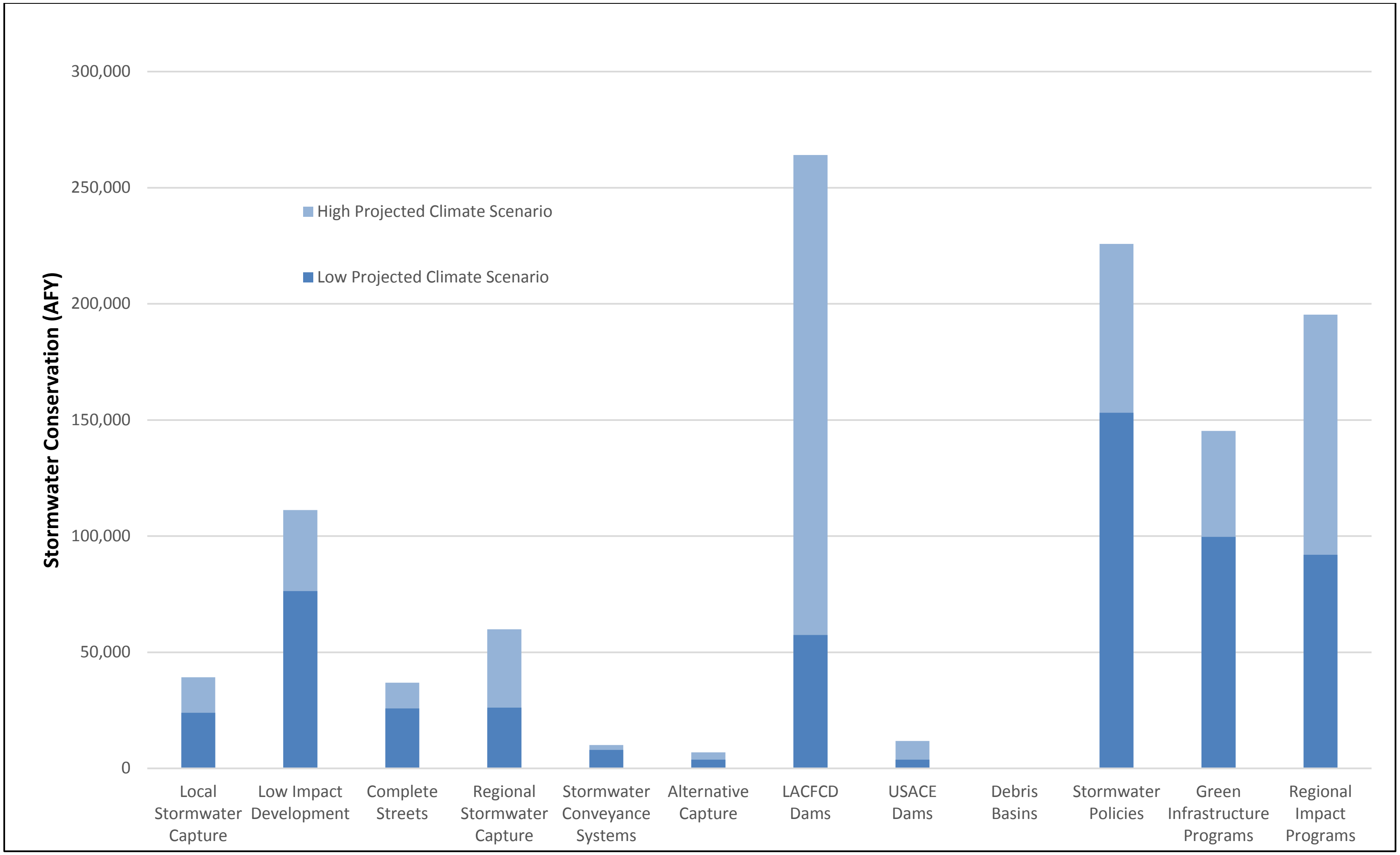

Figure 18. Stormwater Conservation Comparison by Conceptual Project Groups

Table 12. Summary of Conceptual Project Group Benefits and Costs Based on Full "Build-Out"

Project Group	Stormwater Conserved/ Storage Capacity (AFY)	Recreation (miles of trail)	Habitat (acres)	ROW Acquisition (acres)	Range of Costs ($/AF)
Local Solutions					
Local Stormwater Capture[a]	23,900 to 39,200	204	266	2,655	$8,800 to $14,400
Low Impact Development[b]	76,300 to 111,300	0	672	0	$7,700 to $11,200
Complete Streets[b]	25,800 to 36,900	614	725	0	$13,500 to $19,400
Regional Solutions					
Regional Stormwater Capture[a]	26,100 to 59,900	12	42	682	$900 to $2,100
Stormwater Conveyance Systems[a]	8,000 to 10,000	3	8	31	$42,700 to $53,100
Alternative Capture[a]	3,800 to 6,900	2	2	34	$1,400 to $2,400
Storage Solutions					
LACFCD Dams[c]	57,400 to 264,100	0	0	0	$100 to $480
USACE Dams[c, d]	3,800 to 11,800	0	0	0	-
Debris Basins[a]	90 to 230	1	0	0	$13,100 to $35,900
Management Solutions					
Stormwater Policies[b]	153,000 to 225,800	768	1,798	0	$7,800 to $11,500
Green Infrastructure Programs[b]	99,700 to 145,300	0	857	0	$7,500 to $10,900
Regional Impact Programs[a]	92,000 to 195,400	527	5,200	7,600	$20,500 to $43,500

[a] Conservation through groundwater recharge

[b] Conservation through groundwater recharge or stormwater retention for potential reuse

[c] Increased storage capacity or stormwater retention for potential reuse or recharge; costs exclude estimates for Santa Anita Dam

[d] Cost Information for USACE dams not determined for this study

On the high end, the LACFCD Dams project group could achieve 57,400 to 264,100 AFY of additional surface storage. It should be noted, however, that this increased surface storage would need to be released in such a way that it could be captured, infiltrated, or used downstream. As mentioned previously, operable weirs and/or gates could be installed at the spillway(s) of nine LACFCD dams to allow stormwater to be captured at elevations above the dam spillway crests.

The next two highest project groups for stormwater conservation include Stormwater Policies and Regional Impact Programs. The Stormwater Policies project group uses a combination of LID and Complete Streets as a model baseline, and increases the stormwater conservation through changes in stormwater policy. This group could provide approximately 153,000 to 225,800 AFY of stormwater conservation. The Regional Impact Programs project group consists of increased local stormwater capture and floodplain reclamation, and could provide approximately 92,000 to 195,400 AFY of stormwater conservation.

The maximum potential for stormwater conservation across the region would vary significantly depending on how the project groups are ultimately proposed for implementation. From the water supply and demand projections, it was estimated that in the future there is a total available supply of approximately 630,400 AFY of stormwater. Currently, the LACFCD captures and recharges approximately 200,000 AFY of stormwater on average. If new stormwater infrastructure is constructed, and should robust policies be implemented, there would be many potential opportunities for the region to capture this difference. The project groups from the Local, Regional, Storage, and Management Solutions have the ability to greatly enhance stormwater capture opportunities and enhance the region's overall water supply.

Although the LA Basin Study places an emphasis on enhancing stormwater capture across a portfolio of options and using many varied solutions and approaches, it is imperative that none of the project groups analyzed create a negative impact on flood risk protection or public safety.

7.2 Capital and Operational Costs

Capital, and operations and maintenance (O&M) cost estimates were developed for each project group, and the costs were annualized over a 50-year period. The resulting annual cost per AF of stormwater conserved could be used as a preliminary estimate of the cost effectiveness of each project group with respect to water supply. All project benefits were further assessed in the Trade-Off Analysis of the LA Basin Study. A comparison of the conservation costs for each project group is shown in Figure 19.

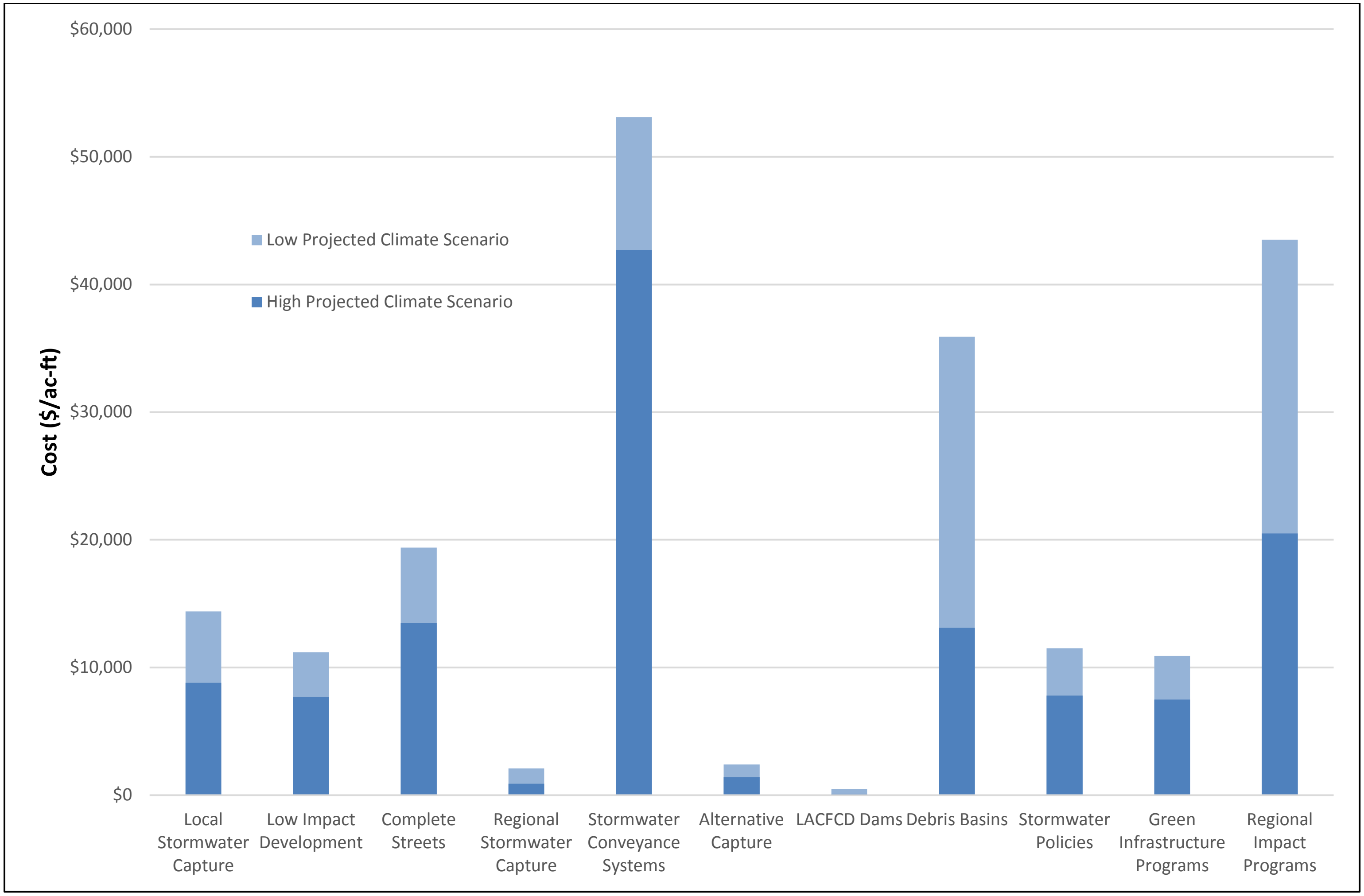

Figure 19. Cost per AF Conserved Comparison by Conceptual Project Groups

The concept analysis demonstrates that the LACFCD Dams project group would provide the most stormwater surface storage (ranging from 57,400 to 264,100 AFY) and also appears to be the most cost effective ($100 to $480 per AF). However, as previously noted, this concept quantifies only increased surface storage and this storage would need to be released in such a way that it could be captured and infiltrated downstream.

The second least costly project group, Regional Stormwater Capture would provide approximately 26,100 to 59,900 AFY of stormwater conservation. This project group is estimated to cost between $900 to $2,100 per AF. With a lower conservation estimate, the Alternative Capture project group could provide approximately 3,800 to 6,900 AFY at a cost of $1,400 to $2,400 per AF.

The remaining project groups have considerably higher cost estimates.

The Management Solutions project groups, Stormwater Policies and Green Infrastructure Programs, estimate high volumes of stormwater conservation, but both would be more costly to implement than the Regional Stormwater Capture, Alternate Capture, and LACFCD Dam project groups. The estimated costs range from $7,800 to $11,500 per AF and $7,500 to $10,900 per AF for the two project groups respectively.

Within Local Solutions, Local Stormwater Capture, and Low Impact Development are in a very similar range of costs with the Stormwater Policies and Green Infrastructure Programs. Local Stormwater Capture ranges between $8,800 to $14,400 per AF and Low Impact Development ranges between $7,700 to $11,200 per AF.

For the much higher project group cost estimates, however, it is important to note that these costs would likely be shared across the region if these concepts are implemented.

7.3 Additional Project Characteristics and Benefits

All the project groups provide multiple benefits apart from just stormwater conservation. Additional benefits may include, but are not limited to, increased flood risk management, improved water quality, recreation, habitat/connectivity, ecosystem function, and enhancing local climate resiliency. These additional benefits could help identify project partners where multiple benefits can help leverage funding. It is important to note that additional investigations, analyses, and designs would be necessary to implement any specific projects or project groups. These efforts would further explore the additional benefits, mitigate against any negative trade-offs, and consider appropriate emphasis on flood risk management. The additional benefits are summarized in Table 13.

Trade-offs were considered based on the various benefits developed in this analysis. These trade-offs are analyzed in the next section – 8.0-*Trade-Off Analysis and Opportunities*.

Table 13. Summary of Conceptual Project Group Additional Benefits

Project Group	Flood	Water Quality	Recreation	Habitat	Aesthetics	Heat Island Mitigation	Climate Resilient
Local Solutions							
Local Stormwater Capture	◑	●	●	◑	●	●	◑
Low Impact Development	◑	●	○	◑	●	●	●
Complete Streets	◑	●	●	◑	◑	◑	◑
Regional Solutions							
Regional Stormwater Capture	◑	●	◑	◑	◑	●	●
Stormwater Conveyance Systems	◑	◑	○	○	●	●	○
Alternative Capture	○	●	○	○	◑	●	○
Storage Solutions							
LACFCD Dams	◑	○	○	○	◑	○	●
USACE Dams	◑	○	◑	○	◑	◑	◑
Debris Basins	○	◑	○	○	○	○	◑
Management Solutions							
Stormwater Policies	◑	●	●	●	◑	◑	◑
Green Infrastructure Programs	◑	●	○	◑	●	●	●
Regional Impact Programs	◑	●	●	●	●	●	●

NOTE: These qualitative benefits for each project group are scored relative to one another.

○ = Low/No Benefit

◑ = Moderate Benefit

● = High Benefit

7.4 Opportunities for Future Collaborative Partnerships

Collaboration and coordination through partnerships would be necessary to implement the various concepts investigated. These projects all provide multiple benefits to the region, and would provide many opportunities for partnerships to share in the development of these projects. There are a number of ongoing programs and studies in the Los Angeles region related to stormwater management where these partnerships could be developed. These programs and studies include:

- Enhanced Watershed Management Programs
- Greater LA Water Collaborative
- Greater Los Angeles County Integrated Regional Water Management Plan
- Greenways to Rivers Arterial Stormwater System
- Los Angeles River Ecosystem Restoration Feasibility Study
- One Water LA
- Stormwater Capture Master Plan
- Water LA Program Collaborative

7.5 Important Concept Considerations

The 12 conceptual project groups studied were developed as a diverse portfolio of future stormwater capture and/or storage options to aid in bolstering the climate resiliency of the region’s local water supply. The assumptions used to model these concepts were based largely upon referencing other local studies, working with the STAC and Study Team members, and using engineering judgment. As studied, these concepts produce specific stormwater conservation benefits and cost estimates. The benefits and cost estimates associated with each concept is based upon full implementation – or complete “build-out” – of the 12 different project groups.

Should any future iteration be undertaken to reassess certain concepts, altering the assumptions including, but not limited to, implementation rates, changes in land use, site identification criteria, and actual site availability will alter the stormwater conservation benefits and costs.

8.0 Trade-Off Analysis and Opportunities

After completing the evaluation and comparison of the various adaptive concepts, the Local, Regional, Storage, and Management Solutions and their associated 12 project groups were further evaluated to assess both the quantitative and qualitative benefits and costs. Quantifiable benefits and costs were evaluated using a standard economic analysis of the estimated present value of benefits and costs over a 50-year planning period. Qualitative benefits and costs are evaluated using a trade-off analysis.

A trade-off analysis provides a methodology for comparing different types of benefits and costs, including economic, financial, environmental, and social effects.

- ***Economic and financial effects*** include the benefits associated with different types of goods and services supported by the different concepts, the costs of the different concepts, the impacts of the different concepts on the regional economy through changes in the amount and type of spending, and the cost effectiveness of different concepts.

- ***Environmental effects*** reflect the type and quality of environmental and natural resources that would be potentially influenced by a concept. Environmental effects would include items such as water quality, energy consumption, impacts on habitat, and ecosystem function.

- ***Social effects*** reflect the social characteristics of a community or region. Examples of social effects include education, environmental justice, and quality of life.

Benefits were quantified for stormwater conserved or stored in AFY, for recreational trails in terms of miles, and habitat acreages. Stormwater conservation benefits were valued as an improvement in water supply reliability, trail-based recreation benefits were valued as general recreation activities similar to outdoor activities at a local park, and habitat and acreage benefits were evaluated as a type of ecosystem improvement providing potential benefits in terms of storm protection, improved water quality, carbon storage, regulating services such as climate and disease regulation, and cultural services.

The trade-off analysis includes the quantified benefits and costs as well as qualitative information on flood risk mitigation, water quality, aesthetics, heat island mitigation, and climate resiliency obtained from earlier efforts of the LA Basin Study. Additional information was obtained from the California Communities Environmental Health Screening Tool to evaluate additional social, environmental, and environmental justice effects.

An economic analysis of quantified benefits was used to evaluate the magnitude of potential benefits of each concept, recognizing that many additional benefits may exist that are not accounted for in a traditional benefit analysis. Quantified benefits and costs from the analysis are summarized in Table 14.

Table 14. LA Basin Study Project Concepts
Benefits and Costs Estimates over the 50-year period of analysis

Concept	Present Value of the Best or Mid-point Estimate of Quantified Benefits (millions)	Present Value of Capital, Land, and Operation & Maintenance Costs (millions)
Local Solutions		
Local Stormwater Capture	$787	$8,410
Low Impact Development	$460	$21,055
Complete Streets	$159	$12,253
Regional Solutions		
Regional Stormwater Capture	$251	$1,320
Stormwater Conveyance Systems	$54	$10,346
Alternative Capture	$33	$227
Storage Solutions		
LACFCD Dams	$832	668
USACE Dams	$40	N/A
Debris Basins	$3	$74
Management Solutions		
Stormwater Policies	$3,309	$43,362
Green Infrastructure Programs	$601	$26,681
Regional Impact Programs	$2,424	$97,211

It is important to note that benefits can only be quantified for a select subset of the total beneficial effects associated with the concepts identified previously. There are numerous benefits associated with environmental and social improvements, flood risk mitigation, environmental justice, and other effects that are potentially very large, but cannot be evaluated quantitatively at this level of analysis. These unquantified benefits may be larger than quantified benefits in some cases and smaller in others. A qualitative assessment provides an indication of the potential relative magnitude of these unquantified benefits.

The results of the economic analysis indicate the LACFCD Dams concept plan is the only plan that appears to generate quantified benefits that exceed costs (based on preliminary estimates included within this report). Stormwater Policies, Regional Impact Programs, and Local Stormwater Capture generate benefits that are of a higher or similar magnitude as the LACFCD Dams concept, but at a much higher cost. The remaining concepts generate substantially lower benefits. As a note, the quantified economic benefits and costs are only one aspect of the effects from the concepts and should not be used in isolation to make planning decisions.

Because the categories of effects included in the trade-off analysis are not of equal importance to local stakeholders or to the general public, input was provided by STAC members to help determine the relative importance of each category of effects. This information was then used as the basis for weighting each effect category to determine a final score that represents a combination of all the categories. The weights used in the trade-off analysis are summarized below in Table 15.

Table 15. Weights Used for Impact Categories in the Trade-Off Analysis

Impact Measure	Final Weights Used in Trade-Off Analysis
Stormwater Conservation	10.0
Water Quality Impact	8.86
Climate Adaptation	7.99
Flood Risk Mitigation	7.98
Pollutant & Environmental Impact	7.66
Operations & Maintenance Cost	7.15
Ecosystem Function	6.93
Environmental Justice Impacts	6.82
Energy Impact	6.74
Capital Cost	6.67
Connectivity	6.52
Habitat	6.31
Environmental Compliance and Regulatory Permitting	5.90
Recreation	5.46
Financial Impact	5.20

The weights used for the concept scores indicate that Stormwater Conservation and Water Quality are the most important measures, and are substantially higher than other categories. Other important measures included Climate Adaptation, Flood Risk Mitigation, and Pollutant & Environmental Impact. These results indicate that project concepts targeting these five categories would provide the greatest overall level of benefit to the region. Of the top five impact categories, Stormwater Conservation was the only category that had quantified impacts and economic values. This insight provided support for the use of a trade-off analysis to aid in understanding the full benefits of the project concepts.

The trade-off analysis incorporated information for both the quantitative and qualitative impacts for each concept, and the weights used to reflect importance to calculate a final weighted score for each concept. The results of the trade-off analysis, including different categories of impacts, are shown in Table 16. The resulting rankings of the top five concepts are shown in Table 17.

Table 16. Average Trade-Off Weighted Scores of Concepts Based on Selected Impact Categories

Concept	Final Weighted Scores of Concepts		
	Average including Stormwater Conservation and Cost Categories	Average Including Top 4 Impact Categories and Cost Categories	Average Including all Impact Categories
Local Solutions			
Local Stormwater Capture	47	58	52
Low Impact Development	49	59	54
Complete Streets	44	57	49
Regional Solutions			
Regional Stormwater Capture	53	57	48
Stormwater Conveyance Systems	43	49	45
Alternative Capture	47	38	40
Storage Solutions			
LACFCD Dams	74	57	41
USACE Dams	NA	NA	20
Debris Basins	46	44	41
Management Solutions			
Stormwater Policies	53	61	52
Green Infrastructure Programs	51	60	50
Regional Impact Programs	25	47	48

The scores shown in Table 16 highlight promising opportunities based on select impact categories: 1) the most important benefit identified by the stakeholders (stormwater conservation); 2) the four most important benefits identified by the stakeholders (stormwater conservation, water quality, climate adaptation, and flood risk mitigation); or 3) all impact categories combined. All three scoring methods included the concept cost

The scores in Table 16 can also be used to rank a variety of concept plans, but as Table 17 shows, the concept rankings vary depending on which impact categories are prioritized. If only stormwater conservation and costs are considered (indicated by the STAC members as important measures for evaluation), the LACFCD Dams is the highest ranked concept, followed by Regional Stormwater Capture and Stormwater Policies. However, when the top four impact and cost categories are considered, some of the Management Solutions and Local Solutions rank relatively higher. Thus, other combinations of impact categories can be used to rank various concepts.

It is also important to recognize that these rankings do not consider financial feasibility or the ability of project beneficiaries to pay for a project. Therefore, it is possible that relatively expensive projects, such as Stormwater Policies and Green Infrastructure Programs, rank high but may not be financially feasible. A more in-depth analysis would have to be conducted to determine financial viability of a project.

Table 17. Concept Rankings Based on Selected Impact Categories

Rank	Including Stormwater Conservation and Cost Categories	Including Top 4 Impact Categories and Cost Categories	Including all Impact Categories
1st	LACFCD Dams	Stormwater Policies	Low Impact Development
2nd	Stormwater Policies	Green Infrastructure Programs	Local Stormwater Capture
3rd	Regional Stormwater Capture	Low Impact Development	Stormwater Policies
4th	Green Infrastructure Programs	Local Stormwater Capture	Green Infrastructure Programs
5th	Low Impact Development	Complete Streets, Regional Stormwater Capture, LACFCD Dams	Complete Streets

Independent of the three scoring methodologies, there are a few concepts that appear to consistently be within the top five rankings, and may represent multi-benefit opportunities worthy of further consideration. These concepts are Stormwater Policies, Low Impact Development, and Green Infrastructure Programs. However, the final results of the economic analysis should not be used in isolation to evaluate and compare the project groups due to the large number of important benefit categories that could not be quantified. The results of the economic analysis combined with the trade-off analysis can be used as a baseline evaluation of concepts. The results of the trade-off analysis can be adjusted to further evaluate concepts and to incorporate more detailed site specific estimates of resource impacts and values.

Lastly, it is critical to understand that an economic analysis and a broader trade-off analysis both require inputs from other disciplines to understand and measure the impacts on resources and activities attributable to a project or action, and the value of those impacts. The final results of the economic and trade-off analysis should be used as a baseline evaluation, and for future planning efforts, they can be adjusted to represent particular resources and impacts of interest.

9.0 Next Steps & Future Considerations

The LA Basin Study was a collaborative partnership between the LACFCD and Reclamation to explore long-term water conservation opportunities and flood risk management impacts based on projected climate conditions and population changes in the Los Angeles Basin. The Study explores enhancements to the existing water conservation and flood infrastructure and identifies a number of potential opportunities to develop new local infrastructure and stormwater management techniques to help reduce the region's dependence on imported water sources.

Through the LA Basin Study, the LACFCD and its partners have taken the next steps towards developing a strategy aimed at achieving water independence in the region. The results of this Study – assessing the increased potential of stormwater capture and conservation while evaluating the impacts of a changing climate – demonstrate significant progress towards accomplishing this goal.

Disclaimer

The LA Basin Study was funded jointly by the Bureau of Reclamation and the Los Angeles County Flood Control District, and is a collaborative product of the Study participants identified in the Introduction of this report. The purpose of the Study is to assess current and future water supply and demand in the Los Angeles Basin, and to identify a range of possible concepts to address any projected imbalances. The Study is a technical assessment and does not provide recommendations or represent a statement of policy or position of Reclamation, the Department of the Interior, or the Los Angeles County Flood Control District. The study does not propose or address the feasibility of any specific project, program or plan. Nothing in the study is intended, nor shall the study be construed, to interpret, diminish, or modify the rights of any participant under applicable law. Nothing in the study represents a commitment for provision of Federal funds. All cost estimates included in this study are preliminary and intended only for comparative purposes.

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Appendix A:

Reports Produced During the LA Basin Study

The LA Basin Study objectives were to:

- Use state-of-the-art climate change analysis to develop projections of future water supply and demands in the Basin.
- Analyze how the Basin's existing water infrastructure and its operations will perform in the face of changing water realities.
- Develop and highlight opportunities to adapt to current and future water demands.
- Conduct a trade-off analysis of identified opportunities.

Each objective was met with detailed scientific, engineering, and economic analyses as listed below, the contents of which are available on the Study website at www.usbr.gov/lc/socal/basinstudies/LABasin.html.

Table A-1: Tasks Related to and Reports Produced for the LA Basin Study

Report Name	Author	Published
Task 1 – Project Management		
Task 2 – Water Supply & Water Demand Projections Final Report	LACFCD (RMC)	December 2014
Task 3 – Downscaled Climate Change & Hydrologic Modeling		
Task 3.1 - Development of Climate-Adjusted Hydrologic Model Inputs	Reclamation	October 2013
Task 3.1 - Climate Change and Hydrologic Projections Appendices	Reclamation	October 2013
Task 3.2 - Hydrologic Modeling Report	LACFCD	December 2013
Task 3.2 - Annual Hydrologic Results Workbook	LACFCD	December 2013
Task 4 - Existing Infrastructure Response & Operations Guidelines Analysis Final Report	LACFCD and Reclamation	December 2014
Task 5 - Infrastructure & Operations Concepts Final Report	LACFCD (CH2M) and Reclamation	December 2015
Task 6 - Trade-off Analysis & Opportunities Final Report	Reclamation	December 2015