RECLAMATION
Managing Water in the West

Los Angeles Basin Stormwater Conservation Study

Task 5 Infrastructure & Operations Concepts Report

U.S. Department of the Interior
Bureau of Reclamation

County of Los Angeles
Department of Public Works

Los Angeles County
Flood Control District

December 2015

Mission Statements

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.

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.

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

Los Angeles Basin Stormwater Conservation Study

Task 5. Infrastructure & Operations Concepts

December 2015

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Acronyms and Abbreviations

ac-ft	acre-foot (1 ac-ft = 43,560 ft^3)
AFY	acre-feet per year
ARBOR	Area with Restoration Benefits and Opportunities for Revitalization
BMP	Best Management Practices
cfs	cubic feet per second
DSAC	Dam Safety Action Classification
ESG	Enhanced Spreading Ground
EWMP	Enhanced Watershed Management Plan
F-Table	Hydrologic Function Table
GIS	Geographic Information System
GLAC	Greater Los Angeles County
GRASS	Greenways to Rivers Arterial Stormwater System
IRWM	Integrated Regional Water Management
LA Basin Study	Los Angeles Basin Stormwater Conservation Study
LACDPW	Los Angeles County Department of Public Works
LADWP	Los Angeles Department of Water and Power
LACFCD	Los Angeles County Flood Control District
LASAN	City of Los Angeles Department of Public Works, Bureau of Sanitation
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
MWD	Metropolitan Water District of Southern California
NSG	New Spreading Ground

O&M	Operations and Maintenance
PMF	Probable Maximum Flood
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
RIVER	Riparian Integration via Varied Ecological Reintroduction
ROW	Right-of-Way
SCMP	Stormwater Capture Master Plan
STAC	Stakeholder Technical Advisory Committee
Study Team	LACFCD and Reclamation
USACE	United States Army Corps of Engineers
WMMS	Watershed Management Modeling System

Glossary

Aquitard: Layers of low permeability soil or rock that impede the vertical movement of groundwater flow.

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

Biofiltration: Vegetated BMPs designed to capture and filter stormwater runoff through a soil layer. Following filtration, treated runoff exits through an underdrain to the downstream conveyance network.

Bioretention: Vegetated BMPs designed to capture and filter stormwater runoff through a soil layer. Following filtration, treated runoff infiltrates through underlying soils.

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

Climate Adaptation Strategies: Strategies to adjust natural or human systems in response to effectively prepare for the effects from climate change. For example, increasing stormwater conservation is an adaptation strategy to bolster water supplies.

Climate Projection: Climate conditions and meteorological parameters (e.g., temperature and precipitation) corresponding to a single global climate model simulation of future climate conditions under a given emissions scenario and initial condition.

Complete Streets: Transportation routes that are designed to accommodate the accessibility and convenience of all transportation users, including pedestrians, bicyclists, transit riders, and motorists. Complete streets also incorporate the major design elements of green streets, which include providing for stormwater treatment and management.

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

Future Period: Projected water years 2012 through 2095.

Historic Hydrology: Period of historic record encompassing water years 1987 through 2000.

Historic Period: Equivalent to Historic Hydrology (used interchangeably).

Land Use: A specific use assigned to a particular land area with a known impervious surface area, such as residential, industrial, commercial, etc.

LSPC: Loading Simulation Program in C++. LSPC is the hydrologic simulation program within the Watershed Management Modeling System (WMMS).

Nonstructural Concept: A concept that does not involve construction or physical alteration to a facility, such as changes in operations, maintenance activities, or policies.

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

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

Projected Hydrology: Future period encompassing water years 2012 through 2095.

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

RiverWare: A reservoir and river modeling software tool developed at the University of Colorado at Boulder's Center for Advanced Decision Support for Water and Environmental Systems (CADSWES), under joint sponsorship by the Tennessee Valley Authority, the U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers.

Rulebased Simulation: Operating policies, called rules in Riverware, that contain logic for operating a modeled system based on hydrologic conditions, time of year, demands, and other considerations.

Run: Performance of a single hydrologic modeling setup using an individual climate change scenario.

Simulation: Equivalent to Run (used interchangeably).

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

Stormwater (Available): The amount stormwater runoff that passes out of a subwatershed which can potentially be captured within itself at upstream locations (reported in acre-feet).

Stormwater (Recharge): The total amount of stormwater infiltrated within a subwatershed with contributions from all water conservation facilities.

Stormwater (Total): The total amount of stormwater within a subwatershed system. It is the sum of Recharge and Available (reported in acre-feet).

Stormwater Capture (% Capture): The ratio of Recharge to Total Stormwater for the subwatershed.

Structural Concept: A concept that involves the construction of or physical changes to a facility.

Subwatershed: A sub-division of a larger watershed. Smallest area unit in LSPC.

Unconfined Aquifer: An aquifer that has the water table as its upper boundary.

Water Conservation Rate: The maximum combined intake capacity for spreading grounds located directly downstream of a USACE dam.

Water Conservation Rate Exceedance: A storm event during which the rate of discharge from a USACE dam is greater than the Water Conservation Rate.

Water Control Manual: USACE dam operation guideline.

Water Year: The 12-month period from October 1 through September 30 for any given year. Water years are written as the ending year (i.e., water year 1986-87 is written as 1987).

Watershed (Drainage Area): Surface drainage area upstream of a specified point on a watercourse. A geographical portion of the Earth's surface from which water drains or runs off to a single point.

Watershed Management Modeling System (WMMS): A computer based decision support system developed by the LACFCD and TetraTech, Inc. The system models all major watersheds within Los Angeles County and simulates hydrologic and pollutant generation and transport processes and identifies cost-effective pollution reduction measures.

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Executive Summary

The Los Angeles Basin Stormwater Conservation Study (LA Basin Study) is a collaborative partnership between the Los Angeles County Flood Control District (LACFCD) and the U.S. Department of the Interior, Bureau of Reclamation (Reclamation). The purpose of the LA Basin Study is to investigate long-range water conservation and flood risk management impacts caused by projected changes in the climate and population in the Los Angeles region. The LA Basin Study provides recommendations for potential modifications and changes to the existing regional stormwater capture system, as well as for the development of new facilities and practices, which could help to resolve future water supply and flood risk management issues. The stormwater capture concepts and alternatives developed within this report will inform the *Task 6 – Trade-Off Analysis & Opportunities* report of the LA Basin Study.

The objective of Task 5, Infrastructure and Operations Concepts, is to identify and develop both structural and nonstructural (i.e., plans and policies) concepts to manage stormwater under projected climate conditions for the Los Angeles Basin watersheds, which include: 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). The efforts and results previously completed for *Task 2 – Water Supply & Water Demand Projections*, *Task 3 – Downscaled Climate Change & Hydrologic Modeling*, and *Task 4 – Existing Infrastructure Response & Operations Guidelines Analysis* serve as the foundation for Task 5. The major tasks and subtasks of Task 5 include:

- **Concept Development**
  - Identify a range of opportunities and options using stakeholder input
  - Determine preliminary concepts for further evaluation
- **Technical Analysis of Concepts**
  - Assess structural and nonstructural concepts pertaining to dams, spreading grounds, flood control channels, decentralized storage, infiltration, reuse facilities, debris basins, and other concepts
  - Develop and apply concept selection criteria
- **Appraisal-Level Analysis**
  - Evaluate selected concepts for future system reliability, efficiency, and effectiveness

In addition to any new stormwater conservation concepts that are developed, the existing facilities from the Task 4 analysis were considered for enhancement.

The Watershed Management Modeling System (WMMS), which has served as the primary hydrologic model throughout the LA Basin Study, continued to be the preferred tool and was also used for Task 5. Hydrologic simulations were conducted to analyze the potential water conservation and flood risk mitigation benefit for the various project concepts. For the future period, water years 2012 through 2095, four climate projections (Low 1, Low 2, Mid 2, and High 1) from Task 4 were used in the simulations.

Concept Development

Concept development consisted of identifying and developing stormwater capture options in a collaborative manner with stakeholders and the public. Various adaptation strategies were identified to enhance water supply and address impacts from climate change. The developed concepts included both enhancements to the existing water conservation and flood infrastructure, as well as new structural and nonstructural alternatives.

The LACFCD and Reclamation (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’s Stakeholder Technical Advisory Committee (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.

Technical Analysis of Concepts

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

- **Centralized Projects –** Structural concepts related to large recharge and storage solutions (e.g., recharge basins, dams, channels, and debris basins)
- **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)
- **Plans, Policies, & Partnerships –** Nonstructural concepts that incentivize, promote, and/or facilitate stormwater conservation

After separate scoring criteria were developed for each category based upon input from the STAC, the concepts were then scored and ranked by the Study Team to identify favorable stormwater concepts that could be incorporated into project groups for appraisal-level 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 opportunity application area and legal/institutional challenges. Lastly, additional factors for Plans, Policies, & Partnerships included expected enhancement 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.

Appraisal-Level Analysis

During the appraisal-level analysis the 126 stormwater capture concepts were further investigated and the highest scoring concepts were compared and combined into a final set of 12 project groups (see Figure ES-1). An appraisal-level evaluation was then performed to aid in selecting the most beneficial concepts. Each project group was categorized into one of the four main project categories shown below:

- **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 U.S. Army Corps of Engineers (USACE) dams and at 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.

Each of the 12 project groups within the four project categories is discussed in the following section.

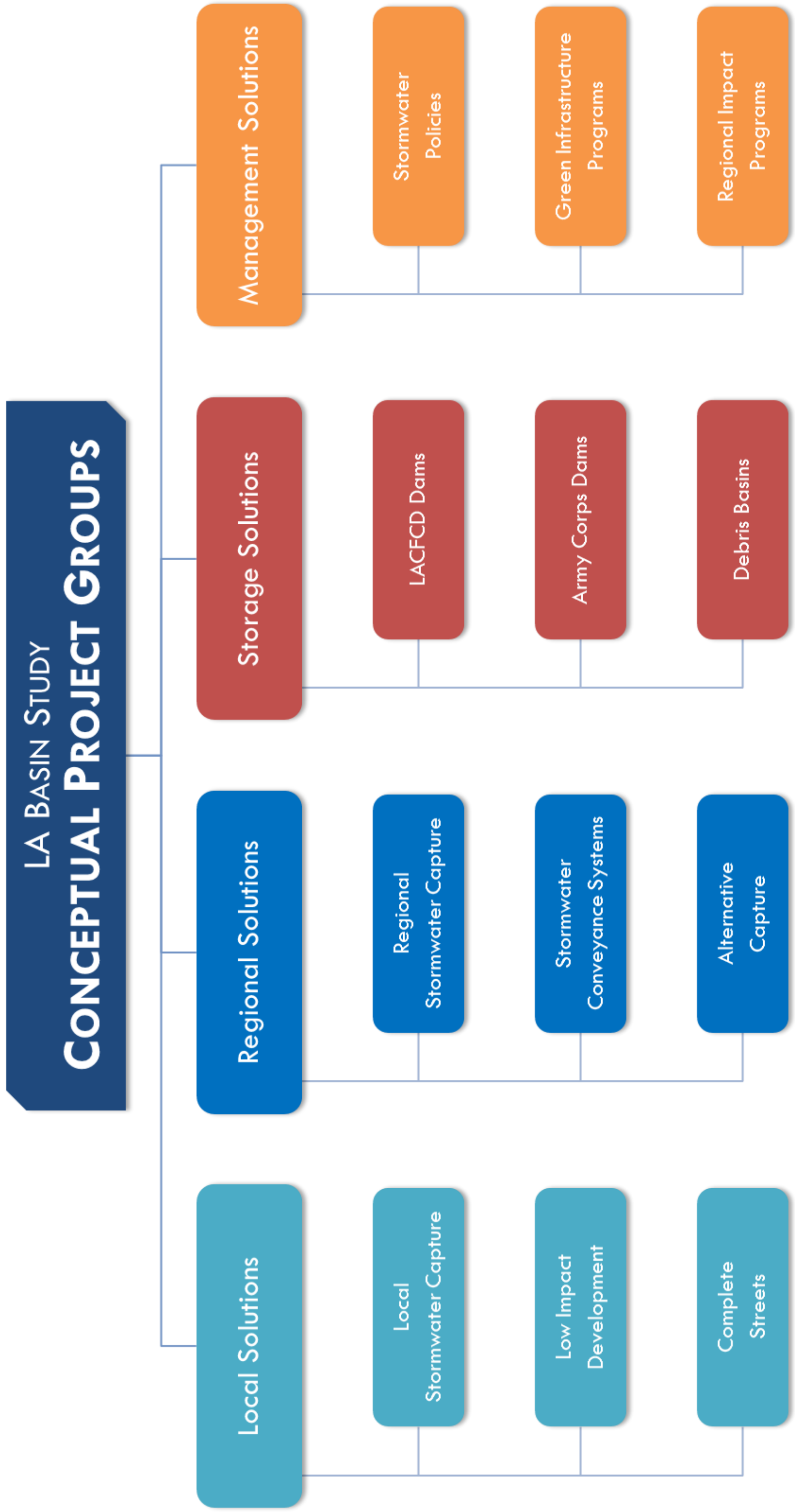

Figure ES-1. Los Angeles Basin Stormwater Conservation Study Conceptual Project Groups

Local Solutions

The Local Solutions category is comprised of three project groups:

- **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 existing parks, golf courses, and vacant land.

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

- **Low Impact Development –** 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 BMPs include 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, parkway stormwater basins, permeable surfaces, infiltration trenches, and green roofs that are 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.

- **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 viewing streets as a stream network and fully utilizing all aspects of transportation corridors such as parkways and medians to capture and infiltrate stormwater.

Regional Solutions

The Regional Solutions category is comprised of the following project groups:

- **Regional Stormwater Capture –** This project group includes concepts related to the construction of new spreading basins and enhancement of existing spreading basins that scored highly during the appraisal analysis phase. The Regional Stormwater Capture project group is comprised of the following elements:

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

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

- **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 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.

- **Alternative Capture –** This project group consists of groundwater recharge adjacent to waterways that have limited land availability for nearby recharge and 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.

Storage Solutions

The Storage Solutions category includes modification or reoperation of existing USACE and LACFCD dams and debris basins to enhance surface storage, which would eventually be released downstream to infiltrate and recharge local groundwater. The Storage Solutions category consists of three project groups:

- **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—importantly—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.

- **USACE Dams –** Similar to the LACFCD dams, a structural concept was developed for 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 water conservation operations and outlet works.

- **Debris Basins –** This project group assumes select debris basins could be retrofitted to temporarily capture stormwater and later release it to downstream spreading basins 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. The Debris Basins 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 basins.

Management Solutions

The Management Solutions category represents improvements, or more focused enhancements, to the Local Solutions category discussed previously. This category is assumed to speed up the implementation process needed to accomplish climate adaptation quicker, and is made up of the following:

- **Stormwater Policies –** Stormwater policies are control measures that encourage stormwater conservation. The Stormwater Policies project group is comprised of the following elements:
  - ***Align Regulatory Guidelines with Water Supply Goals.*** Concept includes strongly utilizing Enhanced Watershed Management Programs (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.
- **Green Infrastructure Programs –** Green infrastructure programs encourage implementation of LID across the watershed. The Green Infrastructure Programs 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 BMPs to capture and recharge rainfall where it falls.
  - ***Focus on Residential Stormwater Capture.*** Concept emphasizes distributed stormwater capture and infiltration within residential land uses.

- **Regional Impact Programs –** Regional impact programs encourage local stormwater capture solutions across the watershed. The Regional Impact Programs project group is comprised of the following elements:
  - ***Emphasize a Watershed Approach to Managing Stormwater.*** Concepts include developing policies and programs that explore floodplain reclamation, providing stormwater recharge within the waterways, further improving storage in groundwater basins to reduce evapotranspiration losses, and capturing rain where it falls to minimize stormwater runoff from individual sites.
  - ***Aggressively Use Available Space for Stormwater Capture.*** Concepts range from policies and programs which recognize that open spaces—natural or otherwise—positively 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 from stormwater to developing incentives to promote residential on-site stormwater capture.

Stormwater Capture Findings

Projected Stormwater Conservation

Enhancing the Study Area's stormwater capture is an adaptation strategy that the region can undertake to provide more locally sourced water in the face of climate change and an increased future population. The WMMS Model was run for four varying climate scenarios. The results for the range of climate projections were used to compare the potential stormwater storage or conservation for the twelve conceptual project groups.

As shown in Figure ES-2, implementation of the 12 various project groups results in a wide range of stormwater conservation and increased storage. Table ES-1 presents the range of values for stormwater conservation and increased storage, and also lists other features of each project group, such as recreation, habitat, and cost. The estimated stormwater conservation benefits along with the added features associated with each concept is based upon full implementation—or complete "build out"—for each of the 12 different project groups. However, if any of the concepts are not fully implemented, then the stormwater conservation benefits quantified and additional features listed may not be entirely realized.

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

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 provides approximately 153,000 to 225,800 AFY of stormwater conservation. The Regional Impacts Programs project group consists of increased local stormwater capture and floodplain reclamation, and provides approximately 92,000 to 195,400 AFY of stormwater conservation.

To help the region enhance its climate resiliency, a variety of stormwater capture concepts has been investigated to provide a diverse future portfolio. The maximum potential for stormwater conservation across the region would vary significantly depending on how the project groups are ultimately combined and implemented, as well as impacts due to climate variability. From the Task 2 water supply 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 in an average year. If new stormwater infrastructure is constructed and should robust policies be implemented, there will 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 bolster 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.

Capital and Operational Costs

Capital and operations and maintenance (O&M) costs were developed for each project group, and the costs were annualized over a 50-year period. The resulting annual cost per ac-ft of stormwater conserved could be used as a preliminary estimate of the cost effectiveness of each project group with respect to water supply. The LA Basin Study will more completely assess all project benefits during *Task 6 – Trade-Off Analysis & Opportunities*. A comparison of the conservation costs for each projected group is shown in Figure ES-3. Table ES-1 lists the costs for each project group along with additional details.

Although the LACFCD Dams project group provides the most stormwater surface storage and appears to be the most cost effective, it should be noted that this is only increased surface storage and would need to be released in such a way that it could be captured and infiltrated downstream.

Of the Regional Solutions, Regional Stormwater Capture is the least costly, and second least costly overall. Regional Stormwater Capture provides approximately 26,100 to 59,900 AFY of stormwater conservation, with a cost of $900 to $2,100 per AFY compared to other project groups.

In the Management Solutions, the Stormwater Policies estimates high volumes of stormwater conservation because of the potential widespread implementation of LID, but is more costly to implement than the Regional Stormwater Capture and LACFCD Dam project groups. The estimated cost is $7,800 to $11,500 per AFY. Within Local Solutions, Local Stormwater Capture and Low Impact Development are in a very similar range of costs with the Stormwater Policies. Local Stormwater Capture ranges between $8,800 to $14,400 per AFY and Low Impact Development ranges between $7,700 to $11,200 per AFY. With these higher cost estimates, however, it is important to note that the costs would be shared across the region as concepts are implemented.

Additional Project Characteristics and Benefits

All of the project groups provide multiple benefits apart from just the capture of stormwater. In addition to stormwater conservation, complementary 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 other benefits could help to identify project partners where multiple benefits can help to leverage funding. It is important to note that additional investigations, analyses, and designs would be necessary to implement any of the specific projects or project groups, which would further explore these complementary benefits and mitigate against any trade-offs, and would also consider appropriate emphasis on flood risk management. The additional benefits are summarized in Table ES-2. In addition to the benefits, there are also trade-offs that need to be considered, which could be quite significant depending on the project group and could make certain project groups more or less appealing to the region as whole. These trade-offs will be analyzed in *Task 6 – Trade-Off Analysis & Opportunities*.

Opportunities for Future Collaborative Partnerships

Collaboration and coordination through partnerships will be a necessity for the various concepts investigated in this report. Many of these concepts could be cost-prohibitive if only sponsored by one group or agency. However, these projects all provide multiple benefits to the region and would provide many opportunities for partnerships to share in both the development and cost of implementing 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 the following:

- 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
- Stormwater Capture Master Plan
- Water LA Program Collaborative

Important Concept Considerations

The 12 conceptual project groups studied in this report 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 best professional 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 such as implementation rates, changes in land use, site identification criteria, actual site availability, etc. will alter the stormwater conservation benefits and costs. For example, should the site selection criteria for the Regional Stormwater Capture project group or the implementation rates of the LID project group be changed, higher or lower stormwater conservation volumes would most likely be modeled. At the time of this report's publication, the LA Basin Study explored 12 various project groups based upon reasonable assumptions to better inform the region on its potential options for enhancing climate resiliency of the local water supply.

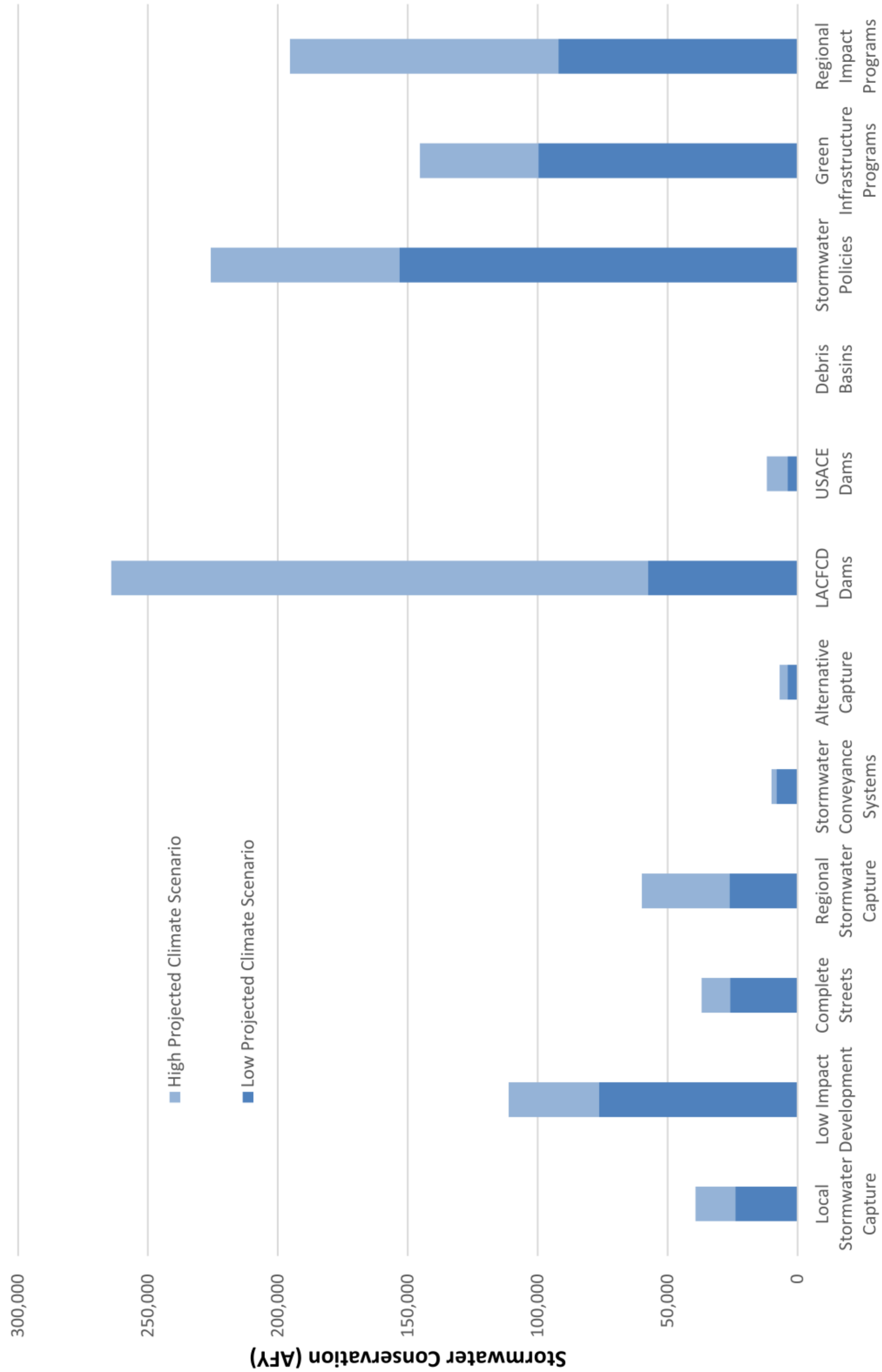

Figure ES-2. Stormwater Conservation Comparison by Conceptual Project Groups

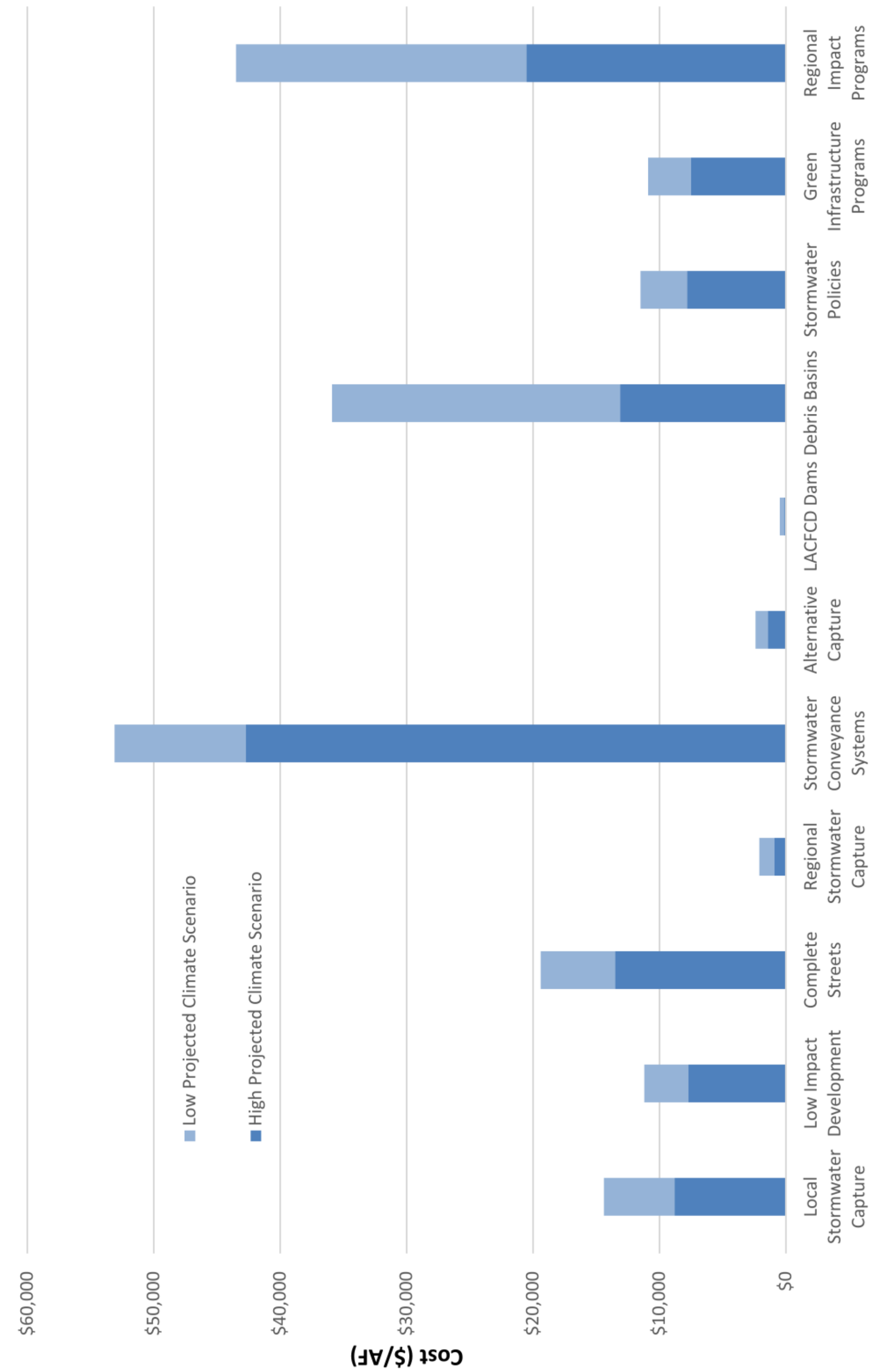

Figure ES-3. Cost per Acre-foot Conserved Comparison by Conceptual Project Groups

Table ES-1. 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

Table ES-2. 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

1. Introduction

1.1. Study Purpose

The purpose of the Los Angeles Basin Stormwater Conservation Study (LA Basin Study) is to study long-term water conservation and flood risk impacts from projected climate and population changes in the Los Angeles Basin. The LA Basin Study provides recommendations for potential modifications and changes to the existing regional stormwater capture system, as well as for the development of new facilities and practices, which could help to resolve future water supply and flood risk management issues. The recommendations are developed through identifying alternatives and conducting a trade-off analysis as part of the last step of the study, *Task 6 – Trade-Off Analysis & Opportunities*.

1.2. Study Background

The Los Angeles County Flood Control District (LACFCD) has been considering the possibility of large-scale enhancement of the LACFCD's water conservation capabilities through the study of long-term projected needs and projected climate conditions. Informal discussions occurred between LACFCD and several major water agencies on the same subject. As a result, this interest was the driving force for creating a partnership between the LACFCD and U.S. Department of the Interior, Bureau of Reclamation (Reclamation) under the Basin Studies Program (Reclamation 2009).

The LA Basin Study utilizes the latest climate science and hydrologic modeling tools to create a vision of the near-term and long-term future of stormwater capture within Los Angeles County. The LA Basin Study provides the opportunity for multiple water management agencies to participate in a collaborative process to plan for future local water supply scenarios. The LA Basin Study examines opportunities to enhance existing LACFCD and LA Basin Study partner facilities and operations and develop new facilities to demonstrate direct benefits to water agencies and local communities.

The LA Basin Study utilizes, to the greatest extent practicable, existing information on the availability and suitability of various open space and underdeveloped parcel opportunities as infiltration sites. The LA Basin Study evaluates potential infiltration sites for soil characteristics, groundwater basin condition, conveyance/diversion/outlet requirements, site remediation requirements, property valuation and availability, environmental impact, regulatory requirements, community impact, multiuse potential, and other factors deemed necessary to assess a potential site.

The LA Basin Study considers the technical viability of implementing innovative facility concepts that show a prospective for increasing infiltration capacity to recharge groundwater. The trade-off analysis in Task 6 will evaluate not just the economic costs and benefits of the various stormwater capture alternatives but also various other regional effects such as increased habitat, recreation, and environmental climate adaptive benefits as well. The final outcome of the LA Basin Study concept development and trade-off analyses will serve as a guiding document for further local water supply development planning, financing strategy, and policy adoption for LACFCD and other LA Basin Study partners.

The efforts and results previously completed for *Task 2 – Water Supply & Water Demand Projections, Task 3 – Downscaled Climate Change & Hydrologic Modeling,* and *Task 4 – Existing Infrastructure Response & Operations Guidelines Analysis* serve as the foundation for Task 5. Task 2 developed an understanding of the future population and its water demand on the water portfolio. The Task 2 analysis assesses a variety of different sources of water supply and how they might satisfy the potential future demand.

Within Task 3, the climate change scenarios downscaled by Reclamation's Technical Service Center were used to develop 47 future projections of precipitation and evaporation. These future weather projections were then used by the LACFCD to perform hydrology simulations in the Watershed Management Modeling System (WMMS). A historical precipitation and evaporation data set represented the baseline conditions in WMMS and then the climate projections were used for analysis of future conditions.

For Task 4, a subset of six climate projections was used to capture the lower, average, and upper hydrologic regimes for the modeling of the LACFCD and U.S. Army Corps of Engineers (USACE) dams and the regional spreading grounds. Task 4 provided a foundation for understanding the potential future needs of the water conservation and flood risk management system with the purpose of developing infrastructure and operations concepts in Task 5. The trade-off analysis in Task 6 will be completed next and then *Task 7 – Final Report* will be compiled to finish the study.

1.3. Description of Study Area

The Los Angeles River, San Gabriel River, South Santa Monica Bay, North Santa Monica Bay, Ballona Creek, Malibu Creek, and Dominguez Channel/Los Angeles Harbor watersheds (Basin Study Watersheds) are the focus of the LA Basin Study, and are shown in Figure 1. This study incorporates the entire watershed boundaries, including where they extend beyond the County of Los Angeles.

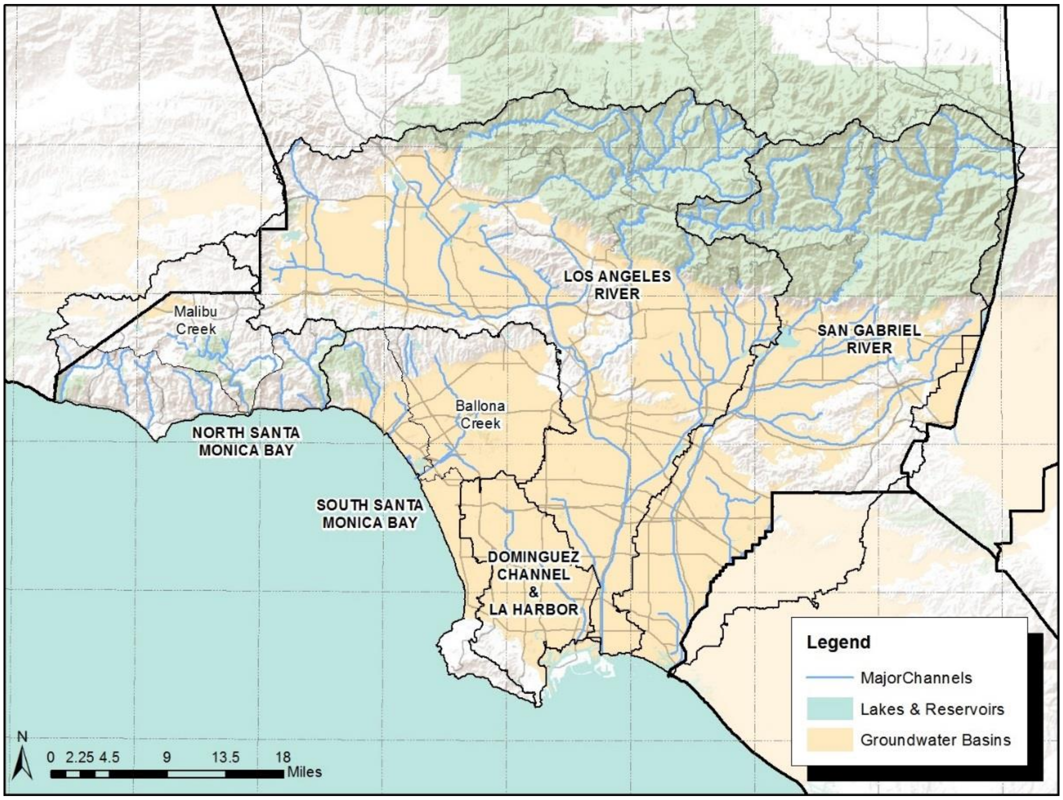

Figure 1. Los Angeles Basin Stormwater Conservation Study Watersheds

The LA Basin Study area includes several large groundwater basins, including the Central Basin, Main San Gabriel Basin, Raymond Basin, San Fernando Valley Basin, Six Basins, and West Coast Basin (Figure 2). The LACFCD's 14 major dams and reservoirs (Figure 3) are located in the front range of the San Gabriel Mountains stretching more than 40 miles from the San Fernando Valley on the west to the eastern edge of the San Gabriel Valley (LACDPW, 2013). The largely undeveloped watershed area upstream of the LACFCD dams is approximately 400 square miles and the majority of it is within the Angeles National Forest. Spreading grounds, which serve to infiltrate stormwater runoff, are located in areas of high permeability downstream from the LACFCD dams. Rubber dams are located within the natural bottom portions of the San Gabriel River to help retain and percolate stormwater through the river bottom.

The Basin Study Watersheds cover approximately 1,900 square miles and are currently home to more than 9 million residents. Nearly 95 percent 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 38.8 million residents. Looking ahead for only the Basin Study Watersheds, the population is anticipated to grow to 10.9 million by 2035 and 11.5 million towards the end of the century in 2095 (LACFCD, 2014a).

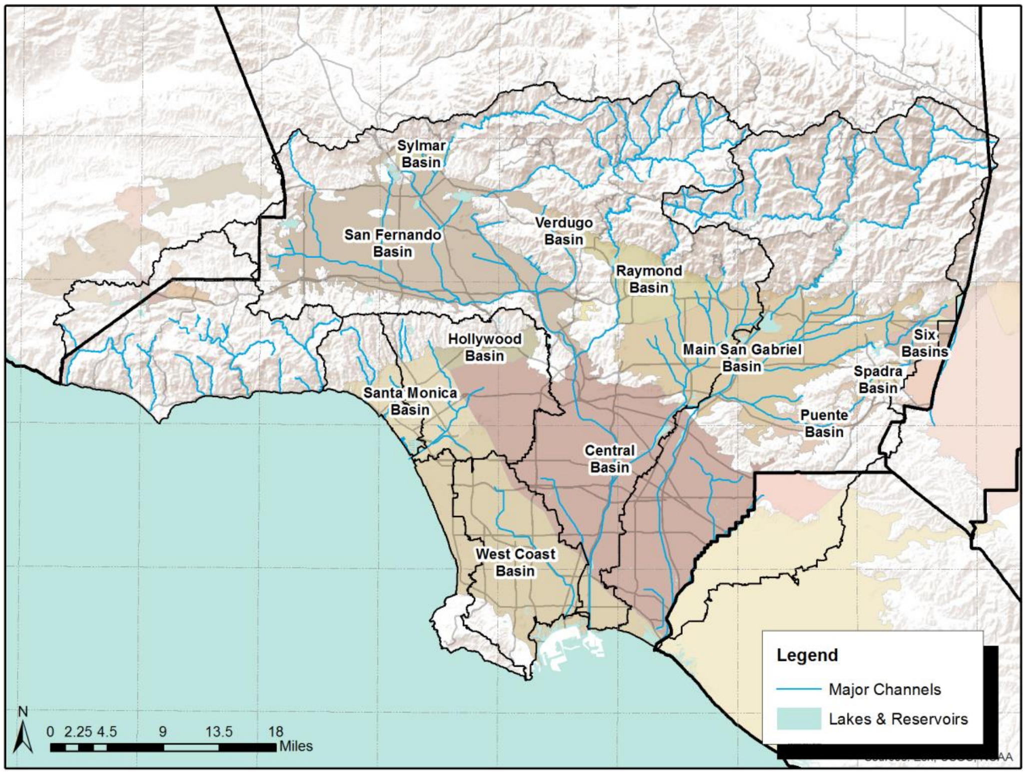

Figure 2. LA Basin Study Major Groundwater Basins

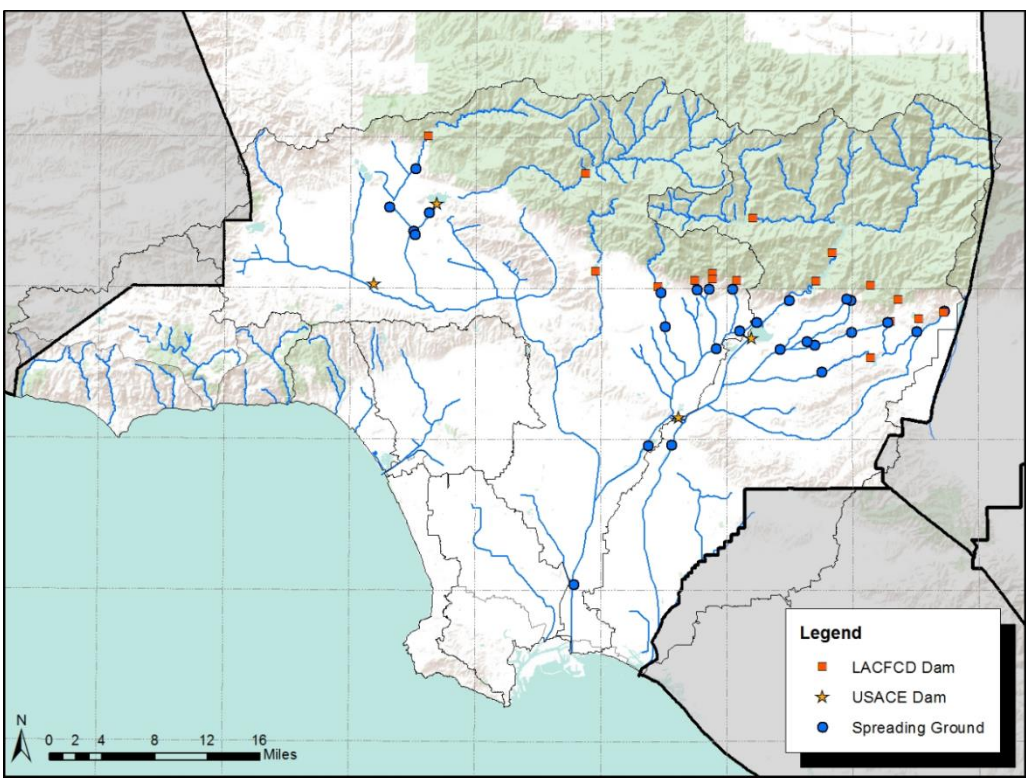

Figure 3. LACFCD Flood Control and Water Conservation Facilities

According to the California Department of Finance, the state's population as a whole is projected to increase by more than 34 percent between 2010 and 2050 (Department of Finance, 2013). Projected larger population growth rates outside of Los Angeles County indicate there will be enormous pressure and competition for ever more limited sources of water and the need for increased development of local water supply sources. At present, Los Angeles County accounts for the largest amount of water demand of any urbanized county in California. Total water usage within the Los Angeles County portion of the Metropolitan Water District of Southern California (MWD) service area—an area wholly served by the LACFCD—exceeded 1.54 million ac-ft in fiscal year 2011-12 (MWD, 2012). By 2035, water demand within the LA Basin Study area is expected to be 1.68 million ac-ft; however, by 2095 demand ranges between 0.82 and 1.76 million ac-ft and is a reflection of different water demand scenarios (LACFCD, 2014a).

1.4. Objectives and Outcomes of Task 5

The objective of Task 5 is to identify and develop structural and nonstructural concepts to manage stormwater under future conditions. These concepts build upon the selected climate change projection subset and the findings from the analysis of the existing water conservation and flood risk management facilities in *Task 4 – Existing Infrastructure Response & Operations Guidelines Analysis*. The major tasks and subtasks of Task 5 include:

- **Concept Development**
  - Identify a range of opportunities and options using stakeholder input
  - Determine preliminary concepts for further evaluation
- **Technical Analysis of Concepts**
  - Assess structural and nonstructural concepts pertaining to dams, spreading grounds, flood control channels, decentralized storage, infiltration, reuse facilities, debris basins, and other concepts
  - Develop and apply concept selection criteria
- **Appraisal-Level Analysis**
  - Evaluate selected concepts for future system reliability, efficiency, and effectiveness

In addition to any new stormwater conservation concepts that are developed, the existing facilities from the Task 4 analysis were considered for enhancement. Task 4 assessed the following LACFCD and USACE existing water conservation and flood risk management facilities (Figure 3):

- 18 major dams and reservoirs
- 26 spreading facilities

1.5. Hydrology Models Used for Study

The WMMS, which was used for the historic and projected hydrologic modeling for other tasks in the study, continued to be used for Task 5. The Loading Simulation Program in C++ (LSPC) is the underlying hydrologic model within WMMS that performs the simulations. LSPC was used to simulate the hydrologic runoff and volume outputs for all reservoirs, spreading facilities, and major channel outlets within the LACFCD system. For simplicity, LSPC is referred to as either WMMS or the model in this report.

The structural concepts developed for the selected LACFCD and USACE dams were simulated using WMMS. The nonstructural concepts developed for the selected LACFCD dams were simulated in Task 5 using Rulebased simulation in Riverware. Riverware is a river system modeling tool, developed for use as a platform for operational decision-making, responsive forecasting, operational policy evaluation, system optimization, water accounting, water rights administration, and long-term resource planning. Rulebased simulation in Riverware is driven by logical policy statements rather than explicitly specified input values for operations such as reservoir releases, storages, diversions, etc. In general, the operating policies, called rules, contain logic for operating the system based on hydrologic conditions, time of year, demands, and other considerations.

WMMS was used to simulate the structural concepts developed for the centralized water conservation facilities as well as distributed stormwater BMPs. Additionally, nonstructural concepts, such as policies and programs, and their future implications on distributed stormwater BMP implementation was modeled using WMMS.

1.5.1. Bounding and Future Climate Projections

Hydrologic simulations were conducted for the LA Basin Study with the purpose of analyzing the potential impacts that climate change may have on stormwater conservation and flood flows. WMMS used precipitation and evaporation records to produce the simulated Historic Hydrology for water years 1987 through 2000. For the future period of water years 2012 through 2095, WMMS produced hydrologic outputs corresponding to the various climate projections assessed in Task 3.

Task 4 analyzed 47 climate projections and chose six of these to be representative scenarios of the possible future climate. Two scenarios, High 1 and High 2, were selected to represent projected climates that resulted in the most precipitation; another two scenarios, Middle 1 (Mid 1) and Middle 2 (Mid 2), were selected to represent the mean and median of the projected future climates; and lastly two scenarios, Low 1 and Low 2, were selected to represent projected climates with the least amount of precipitation.

For the Task 5 modeling, four out of these six climate scenarios were chosen to decrease the overall computing time required for model simulations. The selected scenarios were High 1, Middle 2, Low 1, and Low 2. High 1 was chosen to represent the high tendency hydrology because it more consistently represented higher runoff throughout the study period. Although High 2 is slightly higher in the middle of the century, it is comparatively very dry for the first portion. For the central climate tendency, Middle 2 was chosen because it more consistently represented the average in range of variability of projected climates. For the Low tendency hydrology, Low 1 was selected because it more consistently represented the low tendency hydrology through the study period. Low 2 was also used in Task 5 modeling because it most closely resembled the Historical Hydrology. Figure 4 from the Task 4 report (LACDPW, 2014b) shows the range of variability in stormwater runoff volume and how the chosen climate scenarios relate to each other.

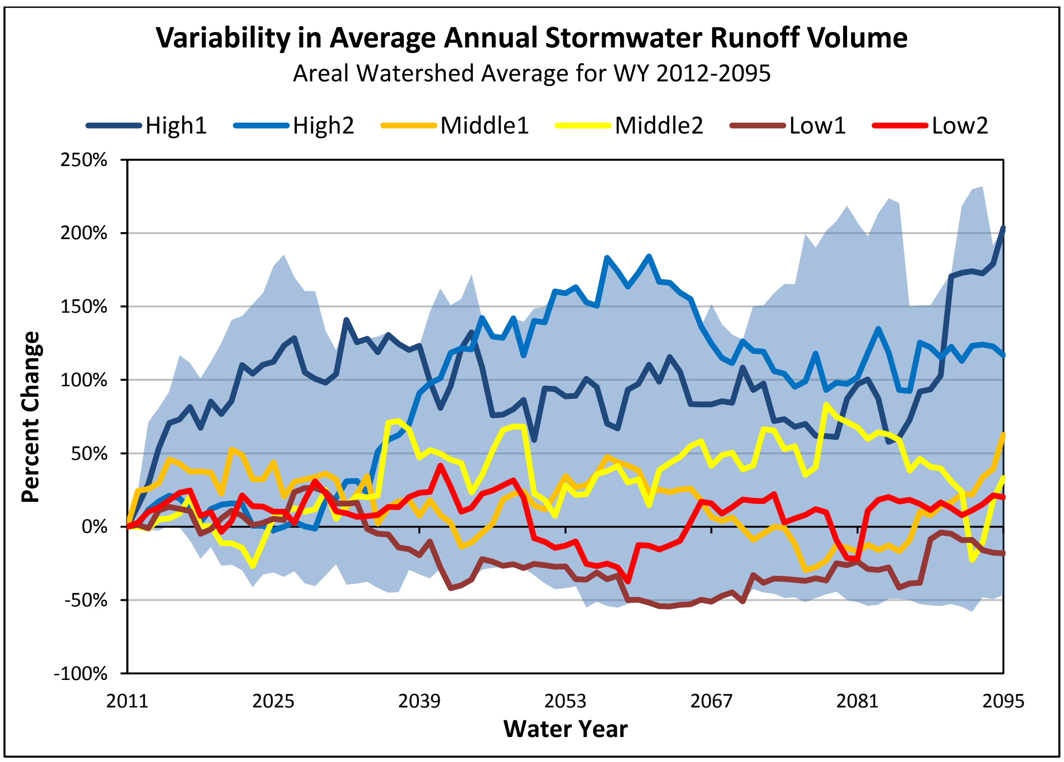

Figure 4. Projected Climate Scenario Subset – Annual Stormwater Runoff

2. Methods

This section describes the Task 5 methodology for the three main subtasks: concept development, technical analysis of the concepts, and appraisal-level analysis of the concepts.

2.1. Concept Development

Concept development consisted of identifying and developing stormwater conservation options, including enhancements to the existing water conservation and flood risk management system, in a collaborative manner with stakeholders and the public.

The LACFCD and Reclamation (Study Team) hosted two charrettes to solicit stormwater capture concepts for potential projects. The two charrettes were held on November 12, 2014, in downtown Los Angeles. The first charrette included attendees from the Stakeholder Technical Advisory Committee (STAC) and the second charrette included members of the general 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 ideas. After the charrettes and internal outreach efforts, a total of 484 stormwater capture concepts were collected. The concepts were compiled and categorized based on the following characteristics to develop the Stormwater Capture Opportunities and Options List:

- Concept Implementation Lead
- Concept Type
- Category
- Scale
- Technique
- Implementation Form

Appendix A includes the complete Stormwater Capture Opportunities and Options List.

An initial evaluation of the 484 concepts in the Stormwater Capture Opportunities and Options List was performed to identify similar or duplicate concepts. Similar and duplicate concepts were combined and cross referenced to a representative concept for subsequent screening and evaluation; 242 similar or duplicate concepts were identified. Appendix A also includes the consolidated Stormwater Capture Opportunities and Options List of 242 concepts.

An initial screening of the 242 concepts in the consolidated Stormwater Capture Opportunities and Options List was performed to identify concepts emphasizing stormwater capture. Each concept was screened based on the following general criteria: Stormwater Conservation Focus and potential Stormwater Capture. Stormwater Conservation Focus characterized and scored concepts as having a low, moderate, or high focus on stormwater conservation based upon their description (Low = 1, Moderate = 3, High = 5). Stormwater Capture characterized the general degree of capture potential that the concept has as low, moderate, or high via its infiltration ability and/or storage capacity (Low = 1, Moderate = 3, High = 5). This was based upon the implementation form, scale of the proposed concept, and best professional judgment. Next, the Stormwater Conservation Focus and Stormwater Capture scores were multiplied to establish a combined Stormwater Score (maximum of 25 points) for each concept to produce the Stormwater Conservation Matrix. Concepts with Stormwater (SW) Scores of 15 or greater were retained for further technical analysis. Based upon these criteria, a total of 126 concepts were carried forward to the next step, Technical Analysis of Concepts. Table 1 lists the concepts alphabetically based on the SW Score. *The concepts shown in Table 1 are the unedited names of the ideas generated during the charrettes and discussions.* Appendix A includes the consolidated Stormwater Conservation Matrix.

Table 1. Stormwater Conservation Concepts

Item No.	Concept (Names are unedited and presented "as submitted")	SW Score
1	Abandoned Quarry Pits for storage	25
2	Alternative streams in unconfined aquifers (e.g., Tujunga Wash Greenway)	25
3	Arroyo Seco Confluence with Los Angeles River	25
4	Construct more retention dams (rubber)	25
5	Construct the San Jose Spreading Grounds (adjacent to Cal Poly Pomona)	25
6	Deepen existing spreading grounds	25
7	Depress all sports fields for stormwater capture	25
8	EWMPs for water conservation	25
9	Golf course stormwater improvements	25
10	Implement a long-term floodplain buy-back study/program	25
11	Improve stormwater capture and habitat along Tujunga Wash corridor	25
12	Increase soft-bottom channels	25
13	Increase urban permeability	25
14	Increased & enhanced maintenance at existing spreading grounds (e.g. remove top soil)	25
15	Infiltration at parks	25
16	Investigate Little Tujunga Dam concept	25
17	Investigate more stormwater capture facilities near Santa Anita and Sierra Madre Dams	25
18	Investigate potential recharge sites around Sepulveda Dam	25
19	Investigate recharge along river embankments	25

Table 1. Stormwater Conservation Concepts

Item No.	Concept (Names are unedited and presented "as submitted")	SW Score
20	Make a regional stormwater capture plan to create projects on a watershed level	25
21	Modify Operation Guidelines at Santa Anita Dam	25
22	New basins	25
23	New centralized facility approach	25
24	New reservoirs	25
25	Offline wetland restoration with infiltration	25
26	Old Pacoima Wash	25
27	Olive Pit	25
28	Percolation ponds along Los Angeles River	25
29	Raise dams	25
30	Regional projects (e.g., public parks, schools to infiltrate flows)	25
31	Reoperate existing basins	25
32	Reoperation of USACE dams	25
33	Restore capacities at LACFCD reservoirs by performing sediment removal	25
34	Retrofit USACE dams for water conservation	25
35	River speed bumps	25
36	Santa Anita Mall and Racetrack Stormwater Capture Project	25
37	The Los Angeles Forebay – Big infiltration basins under everything	25
38	"Urban acupuncture" (many small projects over the basin)	25
39	Use parkways and road medians to capture stormwater	25
40	Verdugo Wash Confluence with Los Angeles River	25
41	"Re-plumb" individual basins within the spreading grounds for increased flexibility	15
42	Adjust safe yield during wet and dry periods to allow more storage	15
43	Advanced rainfall-hydrology modeling to quantify pre-storm capture	15
44	Align regulatory and environmental plans with water conservation/supply goals	15
45	Aquifer Storage and Recovery wells	15
46	Bring the Headworks Spreading Grounds back on line	15
47	Centralized stormwater capture at Brackett Airport	15
48	Centralized stormwater capture at La Verne University	15
49	Channel side-ponds	15
50	Check spreading grounds for stormwater linkages	15
51	Cistern use mandatory where infiltration is not suitable	15
52	Cisterns in homes	15
53	Collect stormwater from large, flat roofs in industrial areas	15
54	Commercial incentive program to capture stormwater	15
55	Conjunctive Use	15
56	Consider all open areas as a stormwater facility	15
57	Consolidate conservation programs with more efficient programs	15

Table 1. Stormwater Conservation Concepts

Item No.	Concept (Names are unedited and presented "as submitted")	SW Score
58	Consolidate less efficient systems (dams/watershed)	15
59	Construct berms in the back of debris basins to help percolate water	15
60	Construct distributed BMPs upstream of lower efficiency spreading grounds	15
61	Construct large-scale of low impact developments (LIDs) in Compton Creek Watershed	15
62	Construct permeable sidewalks and tree wells for infiltration	15
63	County roads sub-surface (ala Elmer Avenue)	15
64	County-wide parcel fee w/ mitigation rebate	15
65	Debris basin reoperation with forebay pre-treatment	15
66	Debris basin retrofit	15
67	Debris basins – Install French drains to recharge groundwater table	15
68	Detain stormwater on industrial land for eventual release into FCD channels for capture	15
69	Distributed storage tanks	15
70	Emphasize residential infiltration in high-density locations	15
71	Encourage cisterns/rain barrels	15
72	Encourage rain gardens	15
73	Encourage residential land changes for promoting infiltration	15
74	Enhanced storage in groundwater basins to reduce evapotranspiration losses	15
75	Feed-in-tariff for groundwater infiltration	15
76	Find options for cost effective stormwater treatment options	15
77	Flood plain reclamation	15
78	Freshwater reservoir at mouth of the Los Angeles River	15
79	Generate stormwater standards for high permeability soils	15
80	Green alleys	15
81	Green roofs	15
82	Green street mandate (driven by CA building code)	15
83	Green street stream tributaries	15
84	Improve in-river drop structures with water conservation design emphasis	15
85	Improve, avoid duplication of roles & expedite regulatory environment to enable stormwater projects	15
86	Increase permeable space to balance water conservation goals	15
87	Increase perviousness (meaning esp. exposed soil!)	15
88	Increase residential land use infiltration	15
89	Infiltration in Caltrans highway cloverleaf exchange open areas	15
90	Infiltration wells in-channels	15
91	Los Angeles River at Taylor Yard	15
92	Los Angeles River at the Cornfields/LA State Historic Park	15
93	Los Angeles River at the Piggyback Yard	15
94	LID/BMPs	15
95	New park space (as green infrastructure)	15

Table 1. Stormwater Conservation Concepts

Item No.	Concept (Names are unedited and presented "as submitted")	SW Score
96	Open space stormwater improvements	15
97	Parking lot storage and connectivity	15
98	Perform groundwater cleanup	15
99	Pomona Fairplex Parking Lot Multipurpose Redesign (similar to Santa Anita Park)	15
100	Porous pavement parking lots	15
101	Prioritize infiltration over storage	15
102	Prioritize these upstream areas for action because the areas are so large	15
103	Prioritized green streets based upon capture potential	15
104	Private parking lot retrofit	15
105	Rain gardens	15
106	Recapture rights-of-way as small scale infiltration areas	15
107	Relocate Irwindale racetrack or store stormwater beneath it	15
108	Remove invasive plants in system	15
109	Reoperate pump stations to capture, detain, and pump stormwater to a storage facility	15
110	School stormwater improvements	15
111	Start at top of watershed to capture more water upstream	15
112	Stormwater smart grid	15
113	Plan stormwater treatment facility to collect, treat, and use runoff	15
114	Streamline regulatory requirements for maintenance of existing and urbanize stormwater infrastructure	15
115	Stronger LID ordinances to target existing properties and not just new development	15
116	T-ditches at Rio Hondo spreading grounds (west basin)	15
117	Transfer USACE dams to Reclamation	15
118	True smart streets as permeable, filtering and conveyance systems	15
119	Under street infiltration	15
120	Underground infiltration chambers	15
121	Underground storage under airport runways	15
122	Underground storm drains connecting to groundwater	15
123	Use geology maps to target best area to infiltrate into water table (avoid perched water)	15
124	Use or pool municipal dollars for basin study every 5 years to ensure reliability	15
125	Use Bull Creek Retention Basin to store & transport water to Pacoima Wash for recharge	15
126	Utilize government parcels first for stormwater capture, storage, and infiltration	15

2.2. Technical Analysis of Concepts

As part of the technical analysis, the 126 concepts in the Stormwater Conservation Matrix were subdivided into three separate 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.*

Separate technical (scoring) criteria were developed for each category and the concepts were scored and ranked to identify favorable stormwater concepts that could be incorporated into project groups for appraisal-level analysis. Technical scoring criteria were developed to prioritize concepts with a high stormwater conservation benefit as well as other project benefits.

2.2.1. Technical Criteria Development

Separate technical criteria were developed for: (1) Centralized Projects, (2) Decentralized Projects & Distributed Programs, and (3) Plans, Policies, & Partnerships based on valuable suggestions from the STAC. Each criterion had a maximum score of 5, which was multiplied by a weighting factor to provide a total score for that criterion. These scores were then summed to develop an overall concept score. Weighting factors ranged from 1 to 5. The maximum possible score was 100 for all concept categories. Tables 2 through 4 summarize technical criteria for these concept groups.

For Centralized Projects, the technical criteria included the following:

- Expected Annual Stormwater Conservation Benefit
- Expected Unit Cost of Stormwater Conserved
- Multiple Benefits & Partnerships
- Property Ownership
- Implementability/Permitting/Site Modification Requirements
- Legal & Institutional Challenges

The highest weights, based upon input from the STAC, were assigned to the expected annual stormwater conservation benefit, unit cost of stormwater conserved, and multiple benefits and partnerships categories to reflect the importance of these factors (Table 2). Collectively, these three categories represent 70 percent of the maximum possible score for the centralized concepts.

The technical criteria for Decentralized Projects & Distributed Programs used a similar criteria, scoring, and weighting scheme (Table 3). For decentralized projects and programs, the technical criteria included the following:

- Expected Unit Stormwater Conservation Benefit
- Expected Unit Cost of Stormwater Conserved
- Multiple Benefits & Partnerships
- Potential Opportunity Application Area
- Implementability/Permitting/Site Modification Requirements
- Legal & Institutional Challenges

To reflect the distributed nature of these concepts, however, land availability was scored in terms of potential opportunity application area, with higher scores assigned for concepts with widespread application areas. Like the centralized concepts, the stormwater conservation benefit, unit cost of stormwater conserved, and multiple benefits categories were assigned the highest weights.

The technical criteria for Plans, Policies, & Partnerships included the following:

- Expected Enhancement in Stormwater Conservation Benefit
- Innovation
- Multiple Benefits
- Partnerships
- Implementability/Jurisdictional Complexity
- Legal & Institutional Challenges

The criteria placed emphasis on the expected enhancement in stormwater conservation, innovation, and multiple benefits categories (Table 4). These criteria accounted for 70 percent of the maximum possible score for these concepts.

Table 2. Technical Criteria – Centralized Projects

Criteria	Description	Scoring Criteria	Weight
Expected Annual Stormwater Conservation Benefit	Potential annual stormwater capture, storage, groundwater recharge, or direct-use quantity. Higher scores for larger stormwater conservation benefits.	5 = > 5,000 AFY 4 = 1,500 to 5,000 AFY 3 = 1,000 to 1,500 AFY 2 = 500 to 1,000 AFY 1 = 200 to 500 AFY 0= < 200 AFY	5
Expected Cost per Unit Stormwater Conserved	Total lifecycle cost for each acre-foot of stormwater captured. Capital cost inclusive of design, permitting, and construction; plus O&M costs (20 year amortization). Higher scores for lower unit cost projects.	5 = < $250/ac-ft 4 = $250 to $500/ac-ft 3 = $500 to $1,000/ac-ft 2 = $1,000 to $1,500/ac-ft 1 = $1,500 to $2,500/ac-ft 0 => $2,500/ac-ft	5
Multiple Benefits/Partnerships	In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality, recreation, habitat/connectivity, ecosystem function, and climate resilient actions. These added benefits promote inter-agency partnerships that help to leverage resources. Higher scores for greater benefits.	5 = Five or More Additional Benefits 4 = Four Additional Benefits 3 = Three Additional Benefits 2 = Two Additional Benefits 1 = One Additional Benefit 0 = Stormwater Conservation Benefit Only	4
Property Ownership	Based on availability and relative ease of obtaining necessary land rights. Higher scores for available properties.	5 = Public Property, Available 3 = Private Property, Available 0 = Property Not Available	3
Implementability/ Permitting/ Site Modification Requirements	The relative physical difficulty associated with implementing a project and overcoming its challenges, both anticipated and unexpected. Higher scores for concepts adapting existing infrastructure.	5 = Reoperation of Existing Facility 3 = Enhancement of Existing Facility 1 = New Project	2
Legal & Institutional Challenges	The relative systematic difficulty associated with implementing a project and overcoming its legal and institutional obstacles. Higher scores for concepts with no major barriers.	5 = No Significant Barriers 4 = Some Difficulty; Multiparty Agreements, Change in Current Practices 1 = Significant Challenges	1

Table 3. Technical Criteria – Decentralized Projects & Distributed Programs

Criteria	Description	Scoring Criteria	Weight
Expected Unit Stormwater Conservation Benefit	Potential annual stormwater capture, storage, groundwater recharge, or direct-use quantity evaluated per acre of area. Higher scores for larger stormwater conservation benefits.	5 = > 1.0 AFY/ac 3 = 0.5 to 1.0 AFY/ac 0 = < 0.5 AFY/ac	5
Expected Cost per Unit of Stormwater Conserved	Total lifecycle cost for each acre-foot of stormwater captured. Projects consist of capital and O&M costs (20 year amortization), while programs include all reasonable implementation costs Higher scores for lower unit cost projects.	5 = < $1,000/ac-ft 4 = $1,000 to $2,000/ac-ft 3 = $2,000 to $5,000/ac-ft 2 = $5,000 to $10,000/ac-ft 1 = $10,000 to 15,000/ac-ft 0 = > $15,000/ac-ft	5
Multiple Benefits/Partnerships	In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality, recreation, habitat/connectivity, ecosystem function, and climate resilient actions. These added benefits promote inter-agency partnerships that help to leverage resources. Higher scores for greater benefits.	5 = Five or More Additional Benefits 4 = Four Additional Benefits 3 = Three Additional Benefits 2 = Two Additional Benefits 1 = One Additional Benefit 0 = Stormwater Conservation Benefit Only	4
Potential Opportunity Application Area	Assigned based on relative spatial scale of implementation and considering land availability. Higher scores for larger areas and greater availability.	5 = Large-scale and/or Ample Property Available 3 = Medium-scale and/or Property Available 0 = Small-scale and/or Limited/No Property Available	3
Implementability/ Permitting/ Site Modification Requirements	The relative physical difficulty associated with implementing a concept and overcoming its challenges, both anticipated and unexpected. Higher scores for concepts with fewer challenges.	5 = No Significant Challenges 3 = Some Difficulty 0 = Difficult to Implement	2
Legal & Institutional Challenges	The relative systematic difficulty associated with implementing a concept and overcoming its legal and institutional obstacles. Higher scores for concepts with no major barriers.	5 = No Significant Barriers 4 = Some Difficulty; Multiparty Agreements, Change in Current Practices 1 = Significant Challenges	1

Table 4. Technical Criteria – Plans, Partnerships, & Policies

Criteria	Description	Scoring Criteria	Weight
Expected Enhancement in Stormwater Conservation Benefit	Potential for enhancements in stormwater conservation. Higher scores for larger stormwater conservation benefits.	5= High 3= Moderate 0= Low	5
Innovation	Relative degree of innovation and natural systems integration. Higher scores for greater innovation.	5= High 3= Moderate 0= Low	5
Multiple Benefits	In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality, recreation, habitat/connectivity, ecosystem function, and climate resilient actions. Higher scores for greater benefits.	5 = Five or More Additional Benefits 4 = Four Additional Benefits 3 = Three Additional Benefits 2 = Two Additional Benefits 1 = One Additional Benefit 0 = Stormwater Conservation Benefit Only	4
Partnerships	Potential for beneficial partnerships between various entities with respect to collaboration, integration, and funding. Higher scores for greater partnership opportunities.	5= High 3= Moderate 0= Low	3
Implementability/ Jurisdictional Complexity	Based on the jurisdictional complexity associated with implementing a concept. Higher scores for concepts within fewer jurisdictions.	5 = Implementable within a Single Jurisdiction (e.g., Single City) 4 = Requires Implementation across Two Jurisdictions (e.g., City and County) 1= Requires Implementation across Multiple Jurisdictions (e.g., Multiple Cities)	2
Legal & Institutional Challenges	The relative systematic difficulty associated with implementing a concept and overcoming its legal and institutional obstacles. Higher scores for concepts with no major barriers.	5 = No Significant Barriers 4 = Some Difficulty; Multiparty Agreements, Change in Current Practices 1 = Significant Challenges	1

2.2.2. Technical Analysis

For the 126 concepts that had a SW Score of 15 or greater in the Stormwater Conservation Matrix, a technical analysis was performed in accordance with the criteria developed for each concept category as outlined in Table 4. The resulting scores were compared and ranked within categories. Importantly, scores were not compared across categories in order to ensure a diverse portfolio of stormwater capture options.

Scores for individual concepts were assigned based on published estimates, previous studies, readily available information (e.g., project descriptions and planning documents), and best professional judgment. The results for each category were placed into an Appraisal-Level Stormwater Conservation Matrix.

For this study, the titles of the concepts listed in the following Tables 5 through 7 were taken directly from the charrettes process to maintain consistency and to account for the concepts originally identified at the charrettes. Some of the concepts in these tables are similar in nature and/or open to interpretation. The concepts have been further refined and/or combined as part of the concept development and modeling in the subsequent appraisal-level analysis as discussed in Section 2.3 Appraisal-Level Analysis.

2.2.2.1 Centralized Projects

The Centralized Projects included 51 concepts relegated to the reoperation or rehabilitation of the LACFCD and USACE dams, the LACFCD spreading grounds, debris basins, and channels; or the construction of new stormwater conservation facilities to adapt to climate change. As shown in Table 5, scores for the 51 concepts ranged from 30 to 83 (out of a possible 100) based on the weighted criteria. 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.

Table 5. Technical Analysis – Centralized Project Scores

Item No.	Concept Description	Score
1	Reoperation of USACE dams	83
2	Retrofit USACE dams for water conservation	79
3	Investigate potential recharge sites around Sepulveda Dam	77
4	New basins	77
5	Olive Pit	76
6	Debris basin retrofit	73
7	Channel side-ponds	70

Table 5. Technical Analysis – Centralized Project Scores

Item No.	Concept Description	Score
8	Increased & enhanced maintenance at existing spreading grounds (e.g. remove top soil)	68
9	Restore capacities at LACFCD reservoirs by performing sediment removal	68
10	Construct the San Jose Spreading Grounds (adjacent to Cal Poly Pomona)	67
11	Old Pacoima Wash	67
12	Improve stormwater capture and habitat along Tujunga Wash corridor	66
13	Increase soft-bottom channels	66
14	Modify Operation Guidelines at Santa Anita Dam	64
15	Use Bull Creek Retention Basin to store & transport water to Pacoima Wash for recharge	63
16	Deepen existing spreading grounds	63
17	The Los Angeles Forebay – Big infiltration basins under everything	62
18	Abandoned Quarry Pits for storage	61
19	Raise dams	60
20	Alternative streams in unconfined aquifers (e.g., Tujunga Wash Greenway)	60
21	T-ditches at Rio Hondo spreading grounds (west basin)	59
22	Percolation ponds along Los Angeles River	58
23	"Re-plumb" individual basins within the spreading grounds for increased flexibility	58
24	Construct more retention dams (rubber)	58
25	Reoperate existing basins	55
26	Consolidate less efficient systems (dams/watershed)	54
27	Check spreading grounds for stormwater linkages	54
28	Start at top of watershed to capture more water upstream	52
29	Offline wetland restoration with infiltration	50
30	Improve in-river drop structures with water conservation design emphasis	49
31	Make a regional stormwater capture plan to create projects on a watershed level	49
32	Debris basin reoperation with forebay pre-treatment	48
33	Reoperate pump stations to capture, detain, and pump stormwater to a storage facility	48
34	Bring the Headworks Spreading Grounds back on line	46
35	Investigate Little Tujunga Dam concept	45
36	Arroyo Seco Confluence with Los Angeles River	45
37	Verdugo Wash Confluence with Los Angeles River	45
38	Los Angeles River at Taylor Yard	45
39	Los Angeles River at the Cornfields/LA State Historic Park	45
40	New reservoirs	45
41	Debris basins – Install French drains to recharge groundwater table	44
42	Santa Anita Mall and Racetrack Stormwater Capture Project	43
43	River speed bumps	43
44	Pomona Fairplex Parking Lot Multipurpose Redesign (similar to Santa Anita Park)	43

Table 5. Technical Analysis – Centralized Project Scores

Item No.	Concept Description	Score
45	Freshwater reservoir at mouth of the Los Angeles River	41
46	Construct berms in the back of debris basins to help percolate water	40
47	Los Angeles River at the Piggyback Yard	45
48	Infiltration wells in channels	38
49	Relocate Irwindale racetrack or store stormwater beneath it	35
50	Centralized stormwater capture at Brackett Airport	30
51	Centralized stormwater capture at La Verne University	30

2.2.2.2 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 LID water conservation elements; and decreasing the imperviousness of the watershed. As shown in Table 6, scores for the concepts ranged from 49 to 96 based on the weighted criteria. The highest scoring concepts included new park space (green infrastructure), infiltration in public spaces, right-of-ways, transportation easements, and "green street" improvements.

Table 6. Technical Analysis – Decentralized Projects & Distributed Programs Scores

Item No.	Concept Description	Score
1	New park space (as green infrastructure)	96
2	Infiltration at parks	91
3	Infiltration in Caltrans highway cloverleaf exchange open areas	91
4	Underground infiltration chambers	91
5	Use parkways and road medians to capture stormwater	91
6	"Urban Acupuncture" (many small projects over the basin)	91
7	Recapture right-of-ways as small scale infiltration areas	88
8	Construct distributed BMPs upstream of lower efficiency spreading grounds	85
9	Increase residential land use Infiltration	85
10	Rain gardens	84
11	Construct large-scale of LIDs in Compton Creek Watershed	81
12	Golf Course Stormwater Improvements	81
13	Green street mandate (driven by CA building code)	80
14	Green alleys	80
15	Increase perviousness (meaning esp. exposed soil!)	80
16	Green street stream tributaries	76

Table 6. Technical Analysis – Decentralized Projects & Distributed Programs Scores

Item No.	Concept Description	Score
17	Parking lot storage and connectivity	76
18	Prioritized green streets based upon capture potential	76
19	County roads sub-surface (ala Elmer Avenue)	75
20	Under street infiltration	75
21	Enhanced storage in groundwater basins to reduce evapotranspiration losses	70
22	Underground storm drains connecting to groundwater	67
23	Porous pavement parking lots	66
24	Construct permeable sidewalks and tree wells for infiltration	65
25	Underground storage under airport runways	63
26	Cisterns in homes	56
27	Collect stormwater from large, flat roofs in industrial areas	56
28	Distributed storage tanks	56
29	Private parking lot retrofit	56
30	True smart streets as permeable, filtering and conveyance systems	56
31	Perform groundwater cleanup	53
32	Green roofs	51
33	Detain stormwater on industrial land for eventual release into LACFCD channels for capture	50
34	Consolidate conservation programs with more efficient programs	49

2.2.2.3 Plans, Policies, & Partnerships

The Plans, Policies, & Partnerships concepts included 41 stormwater conservation concepts. As shown in Table 7, scores for the concepts ranged from 30 to 99 based on the weighted criteria. 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 water conservation projects, and streamlining regulatory structures.

Table 7. Technical Analysis – Plans, Partnerships, & Policies Scores

Item No.	Concept Description	Score
1	Open Space Stormwater Improvements	99
2	Utilize government parcels first for stormwater capture, storage, and infiltration	99
3	County-wide parcel fee w/ mitigation rebate	91
4	Flood plain reclamation	88
5	Implement a long-term floodplain buy-back study/program	88
6	Investigate recharge along river embankments	88

Table 7. Technical Analysis – Plans, Partnerships, & Policies Scores

Item No.	Concept Description	Score
7	Increase permeable space to balance water conservation goals	87
8	Encourage residential land changes for promoting infiltration	87
9	LID/BMPs	83
10	Align regulatory and environmental plans with water conservation/supply goals	81
11	School Stormwater Improvements	81
12	EWMPs for water conservation	81
13	Conjunctive Use	81
14	Regional projects (e.g., public parks and schools to infiltrate flows)	77
15	Streamline regulatory requirements for maintenance of existing & urbanize stormwater infrastructure	77
16	Advanced rainfall-hydrology modeling to quantify pre-storm capture	76
17	Prioritize infiltration over storage	76
18	Improve, avoid duplication of roles, & expedite the regulatory environment to enable stormwater projects	75
19	Cistern use mandatory where infiltration is not suitable	74
20	Remove invasive plants in system	71
21	Depress all sports fields for stormwater capture	71
22	Emphasize residential infiltration in high-density locations	71
23	Feed-in-tariff for groundwater infiltration	71
24	Increase urban permeability	71
25	Stormwater Smart Grid	67
26	Adjust safe yield during wet and dry periods to allow more storage	66
27	Commercial incentive program to capture stormwater	66
28	Generate stormwater standards for high permeability soils	62
29	New centralized facility approach	62
30	Transfer USACE dams to Reclamation	62
31	Use geology maps to target best area to infiltrate into water table (avoid perched water)	62
32	Consider all open areas as a stormwater facility	61
33	Encourage cisterns/rain barrels	61
34	Encourage rain gardens	61
35	Investigate more stormwater capture facilities near Santa Anita and Sierra Madre Dams	58
36	Stronger LID ordinances to target existing properties and not just new development	58
37	Plan stormwater treatment facility to collect, treat, and use runoff	57
38	Use or pool municipal dollars for basin study every 5 years to ensure reliability	55
39	Find options for cost effective stormwater treatment options	45
40	Aquifer Storage and Recovery wells	40
41	Prioritize these upstream areas for action because the areas are so large	30

2.3. Appraisal-Level Analysis

The objective of the appraisal-level analysis was to further investigate the 126 concepts and compare alternative features to determine the most beneficial concepts to adapt to climate change. The analysis consisted of the following steps.

1. Analysis criteria were developed to evaluate the preferred concepts.

2. Concept planning was performed to develop projects for further analysis using the ranked concepts in the Appraisal-Level Stormwater Conservation Matrix.

3. Finally, conceptual design criteria for the projects and other characteristics (e.g., recreational and habitat opportunities) were developed, the WMMS model was modified to reflect the new concepts, a new model run was performed, and the output and results was evaluated for the various project characteristics and benefits including flood, water quality, recreation, habitat, heat island mitigation, and climate resiliency.

The following sections describe the analysis criteria and concept planning for the appraisal-level analysis. The conceptual design criteria for the projects and the results of the appraisal-level analysis are presented in Section 3.

2.3.1. Analysis Criteria

Reclamation criteria for Appraisal-Level Analyses are described in Reclamation Manual Directives and Standards FAC 09-01 and CMP 09-02. In CMP 09-02, “Appraisal-Level” is defined as “the level of analysis and data collection needed to initially determine the nature of water and related resource problems and needs in a particular area, formulate and assess preliminary alternatives, determine Reclamation interest, and recommend subsequent actions.”

Under FAC 09-01, Appraisal-Level Analyses “are intended to be used as an aid in selecting the most economical plan by comparing alternative features” and are to be prepared “using the available site-specific data.” FAC 09-01 also states that “appraisal cost estimates are used in appraisal reports to determine whether more detailed investigations of a potential project are justified. These estimates may be prepared from cost graphs, simple sketches, or rough general designs which use the available site-specific design data.” Appraisal cost estimates are included in this report for selected concepts.

The Study Team collaborated to identify evaluation criteria to be used in the appraisal-level analyses. These criteria, or evaluation outputs, will be used to facilitate the economic and trade-off analysis of the projects in the last major study task, *Task 6 – Trade-Off Analysis & Opportunities*. The appraisal-level evaluation criteria are as follows:

- 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

2.3.2. Concept Planning

In general, the highest scoring concepts from the Appraisal-Level Stormwater Conservation Matrix were integrated into 12 project groups to provide a comprehensive climate adaptation strategy. Within each group, the various concepts served as general elements in developing the projects for the appraisal-level analysis. These 12 project groups were categorized into four project categories:

- **Local Solutions –**Decentralized projects distributed across the watershed that promote infiltration via stormwater 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 at the LACFCD debris basins.

- **Management Solutions –** Plans, programs and policies that promote increased infiltration by providing incentives to implement the Local solutions sooner and/or at an increased implementation rate.

The Local Solutions' project groups incorporate concepts from the Appraisal-Level Stormwater Conservation Matrix for Decentralized Projects & Distributed Programs (Table 6); the Regional Solutions' and Storage Solutions' project groups incorporate concepts from the Appraisal-Level Stormwater Conservation Matrix for Centralized Projects (Table 5); and the Management Solutions' project groups incorporate concepts from the Appraisal-Level Stormwater Conservation Matrix for Plans, Partnerships, & Policies (Table 7).

Figure 5 summarizes each of the 12 project groups within the four project categories. Table 8 outlines the concepts within each project group.

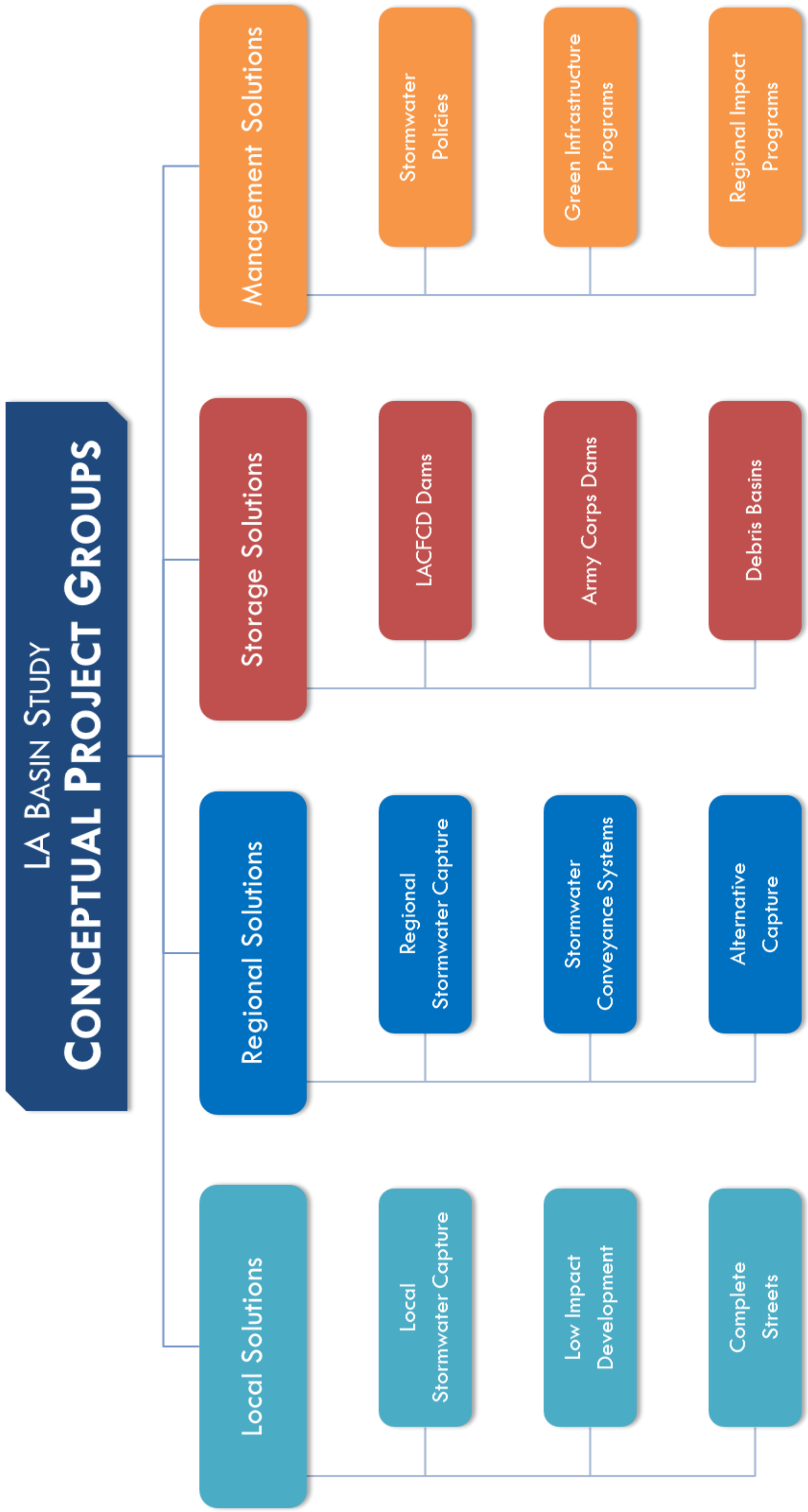

Figure 5. LA Basin Study – Conceptual Project Groups

Table 8. Conceptual Project Groups

Local Solutions	Score
1.Local Stormwater Capture	
New park space (as green infrastructure)	96
Infiltration at parks	91
Infiltration in Caltrans highway cloverleaf exchange open areas	91
Underground infiltration chambers	91
Recapture rights-of-way as small scale infiltration areas	88
Golf Course Stormwater Improvements	81
2. Low-Impact Development	
"Urban Acupuncture" (many small projects over the basin)	91
Construct distributed BMPs upstream of lower efficiency spreading grounds	85
Increase residential land use infiltration	85
Rain gardens	84
Parking lot storage and connectivity	76
Green roofs	51
3. Complete Streets	
Use parkways and road medians to capture stormwater	91
Green street mandate (driven by CA building code)	80
Green alleys	80
Green street stream tributaries	76
Prioritized green streets based upon capture potential	76
County roads sub-surface (ala Elmer Avenue)	75
Under street infiltration	75
Regional Solutions	**Score**
4. Regional Stormwater Capture	
Investigate potential recharge sites around Sepulveda Dam	77
New basins	77
Increased and enhanced maintenance at existing spreading grounds (e.g., remove top soil)	68
Construct the San Jose Spreading Grounds (adjacent to Cal Poly Pomona)	67
Deepen existing spreading grounds	63
Abandoned Quarry Pits for storage	61
5. Stormwater Conveyance Systems	
Channel side-ponds	70
Improve stormwater capture and habitat along Tujunga Wash corridor	66
Increase soft-bottom channels	66
Alternative streams in unconfined aquifers (e.g., Tujunga Wash Greenway)	60
Start at top of watershed to capture more water upstream	52
River speed bumps	43
6. Alternative Capture	
The Los Angeles Forebay – Big infiltration basins under everything	62

Table 8. Conceptual Project Groups

Storage Solutions	Score
7. LACFCD Dams	
Restore capacities at LACFCD reservoirs by performing sediment removal	68
Raise dams	60
8. USACE Dams	
Reoperation of USACE Dams	83
Retrofit USACE dams for water conservation	79
9. Debris Basins	
Debris basin retrofit	73
Debris basin reoperation with forebay pre-treatment	48
Construct berms in the back of debris basins to help percolate water	40
Management Solutions	**Score**
10. Stormwater Policies	
EWMPs for water conservation	81
Align regulatory and environmental plans with water conservation/supply goals	81
Streamline regulatory requirements for maintenance of existing and urbanize stormwater infrastructure	77
Advanced rainfall-hydrology modeling to quantify pre-storm capture	76
Remove invasive plants in system	71
Feed-in-tariff for groundwater infiltration	71
Stormwater smart grid	67
11. Green Infrastructure Programs	
Encourage residential land changes for promoting infiltration	87
Increase permeable space to balance water conservation goals	87
LID/BMPs	83
Increase urban permeability	71
Emphasize residential infiltration in high-density locations	71
Encourage cisterns/rain barrels	61
Encourage rain gardens	61
12. Regional Impact Programs	
Open Space Stormwater Improvements	99
Utilize government parcels first for stormwater capture, storage, and infiltration	99
County-wide parcel fee w/ mitigation rebate	91
Floodplain reclamation	88
Implement a long-term floodplain buy-back study/program	88
Investigate recharge along river embankments	88
School Stormwater Improvements	81
Regional projects (e.g., public parks and schools to infiltrate flows)	77
Depress all sports fields for stormwater capture	71
Enhance storage in groundwater basins to reduce evapotranspiration losses	70
Consider all open areas as a stormwater facility	61

To determine the amount of stormwater stored, captured, and/or conserved for each project group, the WMMS hydrology program was used. Although the model is capable of analyzing water quality, only the water budget portion of the model was used for this study. Each project group was developed as a separate database model for input into WMMS. The output stream files were then compared to the baseline stream output files to determine the results for each project type.

Using the unique input database for each project group, the models were run using a calculation time step of 1-hour and a yearly output stream summary file. The model output time period was from Water Year 2011-2095. Each model was run for the four climate scenarios previously discussed.

Outlined in the following sections are specifics of the modeling assumptions for each project group.

2.3.3. Local Solutions

2.3.3.1 Local Stormwater Capture Modeling

Local Stormwater Capture concepts consist of facilities that receive moderate volumes of stormwater runoff from upstream areas for infiltration and retention. Runoff is typically diverted to local stormwater facilities after it has already entered storm drains. Local stormwater capture facilities may be in the form of surface infiltration basins or underground infiltration chambers.

For Local Stormwater Capture, the high-scoring stormwater opportunities from the Appraisal-Level Stormwater Conservation Matrix are summarized below and consist of the following key 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 properties, and Caltrans right-of-ways.

Modeling Approach. A geographic information system (GIS) analysis was performed to identify land where these projects could be potentially implemented. Favorable areas in the watershed were identified based on: unconfined aquifer conditions, permeable soil types, and proximity to appropriately sized drainage systems. This modeling approach was chosen to be consistent with the EWMPs. However, detailed implementation of this project group does not need to be limited by this criteria. For example, projects that receive water from local tributary areas could be implemented without regard to proximity to a storm drain.

Appendix C, Section 2.1 provides a more detailed discussion of the assumptions used to model this project group.

Figure 6 shows the potential application areas for Local Stormwater Capture concepts. Within this area, land use and parcel data were evaluated to identify specific project locations. In general, government properties including schools, parks, institutional land, golf courses, and vacant parcels were identified as potential locations for these projects. Caltrans stormwater infiltration projects proposed as part of the Caltrans District 7 Corridor Stormwater Management Studies were also included in this alternative.

A total of 3,009 target parcels were identified, comprising approximately 34,592 acres. Table 9 summarizes the number of projects and target parcel acreages by watershed. Parcels greater than 0.5 acre, within 1,000 feet of a 36-inch storm drain (or larger), within Hydrologic Soil Group A and B, and within an unconfined aquifer are considered potential locations for local stormwater capture. A portion (25 percent) of each target parcel was assumed to be available for construction of an infiltration basin or gallery. Based on similar types of projects recently constructed where the tributary area is approximately 10 times the basin area, the surrounding area that would drain into the new basin or gallery was assumed to be 10 times the area of the new basin or gallery. To model this effect, the amount of area draining to an infiltration or gallery basin was moved into its own land use designation within the WMMS model, and that land use was calibrated to simulate the effect of capture and infiltration for the 5-year storm.

Typically, BMPs are designed for water quality purposes and sized to retain the stormwater volume from the 85th percentile, 24-hour storm. However, for the purposes of this study, Local Stormwater Capture projects are sized for the larger 5-year storm to increase stormwater conservation, and provide a higher adaptive capacity under wet conditions.

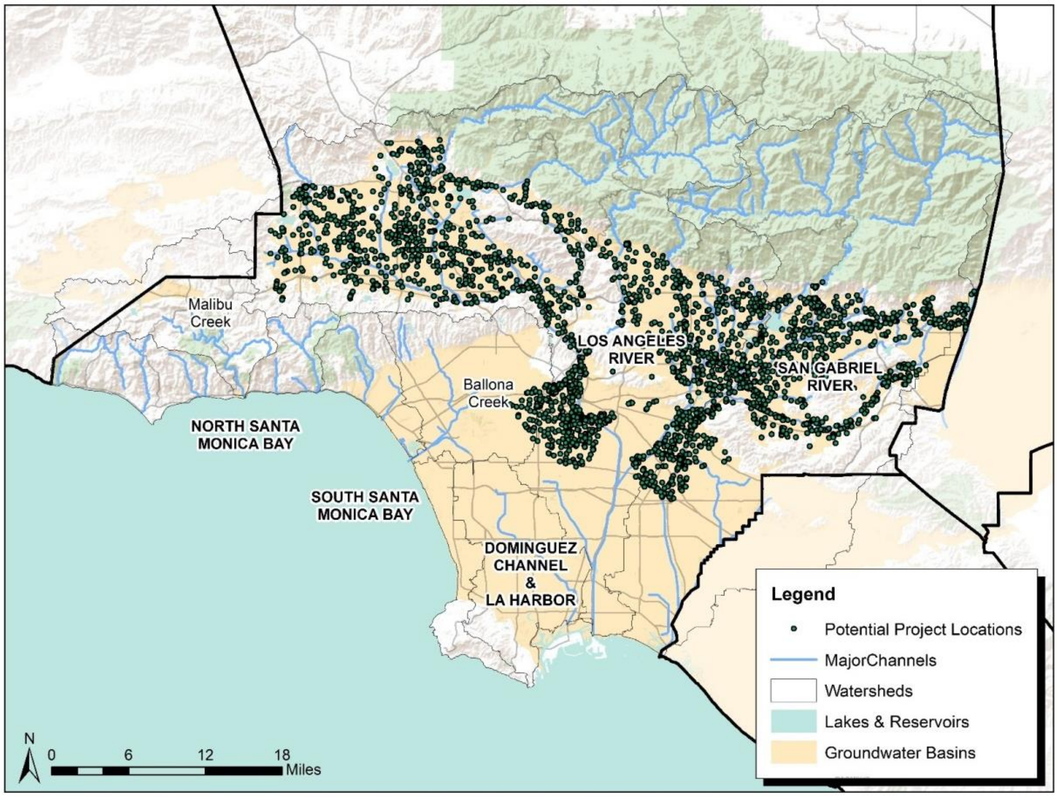

Figure 6. Local Stormwater Capture Potential Projects

Table 9. Summary of Local Stormwater Capture

Watershed	Watershed Area (acres)	Number of Projects	Implementation Area (acres)	Implementation Area (%)*	ROW (acres)	Habitat (acres)	Recreation Trails (feet)
Ballona Creek	135,090	76	672	0.5	53.4	5	12,265
Dominguez Channel	70,428	2	4	0.0	-	-	-
Los Angeles River	533,840	1,772	21,175	4.0	1,426.6	143	644,841
Malibu Creek	129,825	0	0	0.0	-	-	-
San Gabriel River	434,475	1,159	12,741	2.9	1,175.4	118	419,592
Total	**1,303,657**	**3,009**	**34,592**	**2.7**	**2,655.4**	**266**	**1,076,698**

* Percent of watershed area

2.3.3.2 Low Impact Development Modeling

Low Impact Development (LID) concepts are distributed structural BMPs that capture and infiltrate runoff close to the source, at the parcel scale. The tributary area for LID BMPs are generally smaller than the Local Stormwater Capture concepts, and include bioretention, permeable pavement, and other infiltration BMPs that prevent runoff from leaving a parcel. LID can be incorporated throughout the watersheds by the LID ordinances, residential voluntary participation of LID, and LID retrofits of public parcels.

For Low Impact Development, the high-scoring stormwater opportunities from the Appraisal-Level Stormwater Conservation Matrix are summarized below and consist of the following key elements:

- ***Widespread Low Impact Development.*** Concepts include “urban acupuncture” techniques such as rain gardens/grading, rain barrels/tanks, permeable surfaces, that are 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.

Modeling Approach. Similar to the Local Stormwater Capture concepts, a GIS analysis was performed to identify land where these LID projects could possibly be implemented. The analysis assumed a portion of the area within each land use will be likely to implement LID, and this portion will vary by land use. For example, highly regulated land uses (e.g., institutional and industrial) are more likely to implement LID to a larger extent than land uses that are not closely regulated (e.g., residential). LID implementation values developed as part of Task 3 of the LA Basin Study (LACFCD, 2013) were used as the basis to simulate the effects of future LID. LID implementation percentages were estimated for different land uses for the year 2095, as shown in Table 10.

Where LID is implemented, regardless of implementation form (e.g., rain garden or permeable pavement), it was assumed to retain the 85th percentile storm, represented by a rainfall depth of 0.75 inches for the Malibu Creek, Ballona Creek, and Dominguez Channel watersheds. For modeling, it was also assumed that BMPs would drain within 3 days in these watersheds. A rainfall depth of 0.97 inches and a draw down time of 1.5 days was assumed for the Los Angeles River and San Gabriel River watersheds. This increase in these two watersheds accounts for the increased suitability and performance of infiltration BMPs within unconfined aquifers, which cover large areas of the Los Angeles River and San Gabriel River watersheds. These values were used as approximate averages over the watershed and possible BMP types. A portion of the impervious area within the parcel was assumed to implement LID, depending on the land use. Unlike Local Stormwater Capture, which was limited to areas within Hydrologic Soil Groups A and B and within an unconfined aquifer, LID projects are proposed across the entire study area. Table 11 summarizes the application of LID throughout the watersheds.

Table 10. Estimated LID Implementation Values

WMMS Land Use Description (applied only to urban uses)	LID Implementation Value for 2095 (% Land Area)
High-Density Single-Family Residential	25%
Low-Density Single-Family Residential, Moderate Slope	20%
Low-Density Single-Family Residential, High Slope	5%
Multi-family Residential	25%
Commercial	35%
Institutional	80%
Industrial	60%
Transportation	65%
Secondary Roads	60%

Source: *Los Angeles Basin Study, Task 3.2 Hydrologic Modeling Report* (LACFCD, 2013) Table 10. Estimated LID Implementation Values

Table 11. Summary of Low Impact Development

Watershed	Watershed Area (acres)	Total Urban Impervious Area Excluding Streets (acres)	Institutional Land Use (acres)	Industrial Land Use (acres)	Commercial Land Use (acres)	Residential Land Use (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area (%)	Habitat Area (acres)
Ballona Creek	135,090	37,585	3,872	3,314	7,371	23,029	13,368	36	77
Dominguez Channel	70,428	29,825	2,670	10,412	5,854	10,889	13,136	44	77
Los Angeles River	533,840	119,149	11,440	29,180	19,149	59,379	48,063	40	279
Malibu Creek	129,825	5,092	532	405	1,327	2,829	1,761	35	10
San Gabriel River	434,475	94,778	11,695	21,455	16,705	44,922	39,181	41	229
Total	**1,303,657**	**286,430**	**30,210**	**64,767**	**50,404**	**141,048**	**115,509**	**40**	**672**

The actual model changes were accomplished by moving the portions of mitigated areas into new land uses that were calibrated to mimic the effect LID BMPs have on rainfall runoff. Appendix C, Section 2.2 provides more detail on data and assumptions used to model this project type.

2.3.3.3 Complete Streets Modeling

The goal of Complete Streets is to ensure that the safety, accessibility, and convenience of all transportation users—pedestrians, bicyclists, transit riders, and motorists—is accommodated. One aspect of Complete Streets is stormwater treatment and management providing onsite retention, filtration, and infiltration to reduce urban runoff from the roadway, driveways, and sidewalk area similar to green streets.

For Complete Streets, the high-scoring stormwater opportunities from the Appraisal-Level Stormwater Conservation Matrix are summarized below and consist of the following key 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 viewing streets as a stream network and fully utilizing all aspects of transportation corridors such as parkways and medians to capture and infiltrate stormwater.

The Complete Streets project group consists of small BMPs throughout the transportation land use portion of the LA Basin. This is very similar in model methodology to the Low Impact Development project group model except that transportation land uses were modeled instead. For this alternative, the implementation rates for the transportation urban land uses were taken from the Task 3 report and are listed in Table 10. Table 12 summarizes the application of these concepts throughout the watersheds as well as the length of recreation trails that could be integrated into the LID BMPs along complete streets.

Table 12. Summary of Complete Streets

Watershed	Watershed Area (acres)	Total Urban Impervious Street Area (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area (%)	Habitat Area (acres)	Recreation Trails (feet)
Ballona Creek	135,090	17,942	10,945	61	131	449,432
Dominguez Channel	70,428	10,258	6,309	62	76	253,830
Los Angeles River	533,840	46,295	28,371	61	341	1,679,583
Malibu Creek	129,825	986	609	62	7	24,548
San Gabriel River	434,475	23,064	14,192	62	170	836,762
Total	**1,303,657**	**98,546**	**60,427**	**61**	**725**	**3,244,155**

Appendix C, Section 2.3 provides more detail on data and assumptions used to model this project type.

2.3.4. Regional Solutions

2.3.4.1 Regional Stormwater Capture Modeling

The Regional Stormwater Capture project group consists of increasing recharge at existing spreading grounds as well as creating new spreading grounds. During Task 4, many of the basins were remodeled within WMMS to better reflect the actual design and operation of each basin (LACFCD, 2014b). Modeling methodologies for both the enhanced and new basins were modeled based on the methodology in Task 4.

For Regional Stormwater Capture, the high-scoring stormwater opportunities from the Appraisal-Level Stormwater Conservation Matrix are summarized below and consist of the following key 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.

Task 4 of the study ranked the existing spreading grounds based on performance levels. Of the 26 existing spreading grounds analyzed in Task 4, 16 are shallow basins. Potential enhanced management processes that could be implemented in the target basins as described in the 2003 *Percolation Optimization Study* (MWH, 2003). These activities included frequent (annual) removal of the clogging layer by scraping, less frequent ripping of the basins, further break up clogging layers, the construction of furrows, and use of equipment and techniques that minimize soil compaction. For the purpose of this study, these efforts are assumed to increase the recharge capacity of the basins by 20 percent. For each enhanced basin, the recharge capacity specified within the spreading ground F-Table in the baseline model was increased by 20 percent. Nine of the 16 basins analyzed in Task 4 are deep pit basins. These basins were excluded from the project group because they do not allow for complete drainage, which is required to perform the enhanced maintenance describe above.

New spreading grounds were also added to the model as part of this project group. Possible locations for several new spreading grounds were identified in the project evaluation stage. These basins were added to the model using reasonable estimates of available acreage, volume, and recharge rate.

Potential locations for new spreading basins were identified based on previous reports (CDM, 2013; Geosyntec, 2014) and a GIS search of vacant properties near main channel features that overlay unconfined groundwater basins. This analysis resulted in a large number of potential locations which were then screened on a site-by-site basis. The analysis focused on the San Fernando Valley because that area is underutilized for groundwater recharge. The remaining locations were then grouped and modeled as three spreading grounds within the Los Angeles River watershed.

Existing gravel pits in favorable areas were assumed to be repurposed as spreading basins where appropriate. The existing gravel pits are very deep and would be difficult to maintain if the entire depth was used as a recharge basin, therefore, this alternative assumes the construction of 20 foot deep basins at these locations (e.g., on the floor of the gravel pit). Representative diversion capacities and infiltration capacities were assigned based on nearby spreading basins or other published estimates.

For each new spreading basin, an F-Table was created to model the diversion capacity from off the main channel connected to a second F-Table that modeled the recharge capacity. For the purpose of simulations, basins in the general vicinity of each other and that drained to the same tributary were grouped and modeled as a single (larger) basin. If these projects are pursued further they would likely be designed and operated as separate basins.

Regardless of how the basin was identified, each spreading ground was modeled following the method described in Task 4 (LACFCD, 2014b). Refer to Appendix C, Section 2.4 for additional assumptions used to model this project group.

2.3.4.2 Stormwater Conveyance Systems Modeling

The Stormwater Conveyance Systems project group consists of in-channel infiltration within tributaries that are currently concrete lined. This would be accomplished through channel side ponds where space permits and using in-channel infiltration strips with small berms where space is limited.

For Stormwater Conveyance Systems, the high-scoring stormwater opportunities from the Appraisal-Level Stormwater Conservation Matrix are summarized below and consist of the following key elements:

- ***Expand the Soft Bottom Channel Network.*** Concepts include converting existing concrete lined channels to a soft bottom 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.

To model this alternative, GIS data was used to identify all of the concrete lined tributaries within the watershed that overlie an unconfined aquifer. The tributaries were then screened based on width using aerial imagery. Channel widths of 50 feet or more were identified as potential targets for modification.

Recharge in the Los Angeles River was considered, but given the land constraints and flooding concerns, it was not included in the model. For the San Gabriel River, most of the area within the unconfined groundwater basins are already unlined, and therefore, was not included.

For in-channel infiltration strips, a hydraulic analyses was performed assuming a 50-foot-wide channel with 20-foot maintenance easements on either side. It was determined that if the channel was widened to remove the maintenance road on one side, a 25-foot wide gravel strip could be constructed without reducing capacity.

In order to slow down low-flows and store water for infiltration, small berms were assumed at 400 feet intervals within portions of in-channel infiltration. The berm size used was a 2-foot-high, 5-foot-wide berm with 3:1 side slopes installed the width of the channel.

For channel side ponds, a 30-foot-wide, 4-foot-deep channel was assumed. Accounting for roads and trails, it was estimated that 74 feet of new right-of-way would need to be purchased. Therefore, this option was limited for most channels.

Using the candidate channels identified, F-Tables were developed for each subwatershed that the tributary crossed. Within each F-Table, one discharge was for the downstream flow and the second represented the recharge rate. Depths were assumed to vary between 0 feet and 15 feet. These assumptions are consistent with expected depths for given the channel size and verified by visual estimates from aerial images. The F-Table volume values were further adjusted to account for the volume in side channel ponds and the volume stored behind the in-channel berms.

Refer to Appendix C, Section 2.5 for additional assumptions used to model this project type.

2.3.4.3 Alternative Capture Modeling

The Alternative Capture project group consists of groundwater recharge adjacent to waterways with limited land availability. Due to limited land availability and the lack of spreading basins, captured stormwater from the certain waterways would need to be injected into the production aquifers below.

For Alternative Capture, the high-scoring stormwater opportunities from the Appraisal-Level Stormwater Conservation Matrix are summarized below and consist of the following key 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.

This concept involves injecting groundwater in eight reaches in shallow basins beside the Los Angeles River and then extracting for use as local water supply. Although functionally different than a recharge basin it acts in a similar way from a modeling standpoint.

To model the Alternative Capture concept, an F-Table was developed and placed in the model on the Los Angeles River. Based on the way the project will likely be operated, it was not necessary to set up the forebay, recharge, and bypass dummy nodes that were used to model the spreading grounds in the Regional Stormwater Capture option. Instead, the F-Table was developed with two discharges. One discharge represented the downstream flow and the second discharge represented the injection capacity.

For the injection rate, it was assumed that injection would only occur when there was a minimum base flow of 150 cubic feet per second (cfs) in the channel. Therefore, when the downstream discharge is 150 cfs, the injection rate was set to 0.0 cfs and when the downstream discharge is 200 cfs the injection rate was set to 50 cfs. For discharge between 150 and 200 cfs, the model interpolates between 0.0 and 50 cfs. Refer to Appendix C, Section 2.6 for additional assumptions used to model this project type.

2.3.5. Storage Solutions

2.3.5.1 LACFCD Dams Modeling

This section describes the methods used for development of structural and nonstructural concepts for major LACFCD dams and assessment of those concepts. The LACFCD Dams project group is comprised of the following major 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.

Structural Concepts. In Task 4, fourteen (14) major LACFCD dams were modeled and analyzed for climate projections. The results of these analyses were used to assign each of the dams to one of three Performance Levels, which indicated the level of efficiency at which each facility captures stormwater and its resilience to the climate projections.

Task 5 includes developing structural concepts for management of stormwater at major dams under projected future conditions, building upon the analyses and rankings performed in Task 4. Therefore, the results of the Task 4 analyses were reviewed and a statistical analysis was performed to facilitate selection of appropriate criteria for design of potential structural modifications to dams (see Appendix C – Section 2.7 for details).

Modeling Approach. The F-Tables that were developed in Task 4 for each of the nine dams were modified in Task 5 to incorporate the structural concept described. Discharges from LACFCD dams are regulated using valves for reservoir stages below spillway crest elevations. For reservoir stages below spillway crest elevation, the F-Tables were unchanged from Task 4. For reservoir stages above spillway crest elevation, the rate of discharge was limited to the capacity of the valves, until the reservoir stage reaches the dam high water elevation (crest of dam, in most cases). For the modeling, for reservoir stages at or above the dam high water elevation, the operable weirs and/or gates were treated as closed and the rates of discharge from spillways were adjusted the F-Tables from Task 4 on that basis. For a given dam, this model approximated the addition of a pneumatic gate at the crest of the spillway up to the dam high water elevation, which could be lowered during major runoff events as necessary to maintain flood protection.

Nonstructural Concepts. This section describes the methods used for development of nonstructural concepts (i.e., management and operational techniques) for selected major LACFCD dams and assessment of those concepts, building upon the analyses and rankings performed in Task 4.

Modeling Approach. The analyses of the Rulebased simulation model results for the nonstructural concepts used the same methodology and the same key stormwater metrics used in Task 4 and in the Task 5 analysis of the structural concepts:

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

The analyses evaluated each of these metrics for each nonstructural concept for each of the four future projections. For these nonstructural concepts, Spillway Events refer to time periods during which the water surface elevation behind a dam was at or above the spillway crest elevation and the operable spillway weir or gate would be opened.

2.3.5.2 USACE Dams Modeling

This section describes the methods used for development of the structural concept for USACE Hansen Dam and assessment of that concept. The USACE Dams project group consists of the following major element:

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

In Task 4, four (4) USACE dams were modeled and analyzed for climate projections. The results of those analyses indicated full capture of all stormwater runoff. All four of these dams were assigned to Performance Level II, indicating a moderate level of efficiency of stormwater capture and a moderate potential for enhancements.

Task 5 includes developing structural concepts for management of stormwater at major dams under future conditions, building upon the analyses and rankings performed in Task 4. Review of the results of the Task 4 analyses for the four USACE dams in Task 5 suggested that these dams have a somewhat greater potential for enhancements than indicated by the Performance Level II. This finding led to a more detailed review for Hansen Dam in Task 5 to facilitate design of potential structural modifications to the dam. Due to study constraints, Hansen Dam was the only USACE dam assessed and is discussed in the following section.

It should be noted that the Task 4 analyses of the USACE dams and the re-analysis of Hansen Dam in Task 5 were assessments of the potential for capture of stormwater runoff and did not specifically address impacts to flood risk management. The main authorized purpose for the construction of USACE dams is flood risk management and not water conservation or water supply. Therefore, a more in-depth analysis evaluating all of the possible effects of increased stormwater runoff capture would need to be performed before USACE could support increased stormwater runoff capture at USACE dams (see Appendix C – Section 2.8 for details).

Modeling Approach. The F-Table for Hansen Dam was developed by modifying the F-Table for Big Tujunga Dam, which was updated for Task 5, to represent the structural concept. For reservoir stages below the spillway crest elevation, the discharge rates for Big Tujunga Dam were distributed proportionally to account for the differences between the two dams of the depth and the volume of storage below the spillway crest. Because the height of the High Water Level above the spillway crest is approximately the same for both dams, the discharge rates for Big Tujunga Dam were unchanged and were used for the Hansen Dam F-Table for reservoir stages above the spillway crest elevation.

Like the LACFCD dams, the updated WMMS model was used to produce inflow and discharge hydrographs and the volume of stormwater runoff stored for Hansen Dam for the four climate projections. The analysis of the WMMS results for this structural concept used the same methodology and the same key stormwater metrics used in Task 4:

- Average Capture Volume

- Average Conservation Release Exceedance Volume
- Capture Efficiency
- Change in Capture Efficiency
- Frequency of Water Conservation Rate Exceedances

Additional Considerations of USACE Dam Concepts. Four USACE dams are located within the LACFCD system of water conservation and flood risk management infrastructure. As discussed above, study resources permitted an appraisal-level analysis of only one USACE facility; Hansen Dam was selected. The remaining three USACE facilities for which an appraisal-level analysis was not conducted are Santa Fe, Sepulveda, and Whittier Narrows Dams.

The USACE dams within the Study Watersheds are managed primarily for flood protection. However, this LA Basin Study is investigating options for capturing additional stormwater across the region; and the USACE dams present an opportunity to repurpose existing infrastructure to achieve multiple goals. To develop high-level recommendations for enhancing stormwater capture at these dams, the Study Team reviewed publicly available USACE documents such as Water Control Manuals and Storage Allocation Diagrams for each of the dams. The review identified general constraints and challenges associated with repurposing the USACE dams to place a greater emphasis on stormwater capture. These constraints and challenges are deemed realistic limitations that must undergo additional and in-depth study if the region wishes to pursue reoperation of the USACE dams to include water conservation in addition to their current mission of flood protection. These considerations include the following:

1. **Structural Considerations** – Generally, dams are designed with an emphasis on flood protection, water conservation, or both. For the USACE dams, the emphasis is on flood protection. To repurpose these dams to include water conservation would require an in-depth study of their physical characteristics.

    - Increasing water conservation pools at USACE dams will increase the loading time on the dams over their design criteria, which would need to be analyzed. The dams were all originally designed to provide temporary impoundment of flood waters and not long-term water conservation storage. There would be increased potential for seepage when water is stored behind the dams for longer than originally intended; and the dams would likely require structural modifications to accommodate long-term water conservation storage. Any proposed physical alterations to the dams to accommodate water conservation would need to be analyzed for increased risk to the dam and evaluated.

    - The safety of USACE dams is rated through the Dam Safety Action Classification (DSAC) Ratings. DSAC ratings are based on a combination of the probability of failure and the risk associated with the dam (USACE, 2012). The current ratings for the USACE dams, where a rating of DSAC I is considered "unsafe" and DSAC V is "adequately safe", are: Hansen = III, Santa Fe = II, Sepulveda = III, and Whittier Narrows = II (USACE, 2015). For each USACE dam, the DSAC rating would need to be further assessed prior to repurposing to include water conservation.

2. **Flood Protection Considerations** – Repurposing the USACE dams to include water conservation must consider any associated changes to their existing function within the LACFCD system of water conservation and flood risk management infrastructure, which would require in-depth study.

    - Modification of USACE dams could impact their flood protection performance within the regional system and potentially propagate negative flood protection effects to other parts of the regional flood risk management system. These effects would have to be mitigated for any new project.

    - Upstream inundations due to the increased water conservation activities would have to be investigated and mitigated. Additional land easements upstream of the USACE dams may be required.

3. **Operational Considerations** – Repurposing the USACE dams to include water conservation must consider their existing operation capabilities and evaluate potential challenges under climate change.

    - The re-analysis of the Task 4 results for Hansen Dam suggests that all four of the USACE dams have a potential for increased water conservation under the different projected climate scenarios. It is unknown to what extent operational enhancements could increase stormwater conservation at Santa Fe Dam, Sepulveda, and Whittier Narrows Dam.

    - Repurposing of USACE dams would necessitate revising the associated Water Control Plans. This potentially could prompt compliance with the California Environmental Quality Act and National Environmental Policy Act.

    - Since the primary purpose of the USACE dams is flood protection, water stored within flood risk management pool elevations for water conservation is subject to operational releases to the ocean, at any time, if storage capacity within the reservoir is required for flood operations.

- Potential maintenance and operational costs due to the additional water conservation operations should be evaluated. Current O&M funding is only for flood protection and additional funding would likely be required.

4. **Legal Considerations** – The USACE dams are operated under very specific guidelines set by the United States Congress. Any proposed structural enhancements or operational changes would likely require a lengthy process to repurpose the USACE dams to include water conservation.

   - Any modifications would need to be reauthorized through Congress to include water conservation as one of the authorized purposes of the dam.

   - To repurpose USACE dams to hold water conservation pools, agreements between the USACE and a local sponsor may be required. Since the USACE's primary mission is flood protection, there needs to be operational flexibility for USACE to release stored water to retain runoff as necessary, compatible with providing flood protection to the downstream communities.

2.3.5.3 Debris Basins Modeling

The Debris Basins project group assumes select debris basins could be modified to store stormwater and later release it for downstream groundwater recharge. The Debris Basins concept consists of the following major element:

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

To find basins beneficial for this use, a screening process was conducted. Using the LA County GIS point data of all the debris basins in the county (Los Angeles County GIS Data Portal, 2010), the following criteria was used:

- Within the Study Watersheds
- Upstream of a spreading ground
- Strong hydraulic connection to downstream spreading ground
- Debris Basins with a storage volume greater than 7 acre-feet (ac-ft)

After eliminating basins that did not meet the above criteria, 20 basins were identified as candidates for this project type. It was important to only include basins upstream of a spreading ground and with a strong hydraulic connection because metering flow would have no or little effect on recharge quantities where there was no hydraulic response. A strong hydraulic connection was determined on a case-by-case basis using professional judgment. Debris basins behind dams were eliminated, for example, because metering flow behind a dam would have minimal impact on facilities downstream of the dam outflow.

Because the debris basins still need to serve their primary purpose of flood risk management, it was assumed that 25 percent of the volume would be full of sediment when a storm occurs and, therefore, would be unavailable for stormwater storage. Using the volume and spillway elevation and assuming a rectangular debris basin and spillway geometry, a stage-storage-discharge table (F-Table) was developed and added to the model. The F-Table was created to meter the flow below the spillway elevation over 3 days to allow the downstream spreading grounds to recharge some of the flow after a large storm.

Refer to Appendix C, Section 2.9 for more detailed information on the assumptions in the model.

2.3.6. Management Solutions

2.3.6.1 Stormwater Policies Modeling

Stormwater Policies are non-constructed control measures that encourage stormwater conservation. For Stormwater Policies, the high-scoring stormwater opportunities from the Appraisal-Level Stormwater Conservation Matrix are summarized below and consist of the following key elements:

- ***Align Regulatory Guidelines with Water Supply Goals.*** Concept includes utilizing Enhanced Watershed Management Programs (EWMPs) for 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.

Stormwater Polices would influence two project groups from the Local Solutions, Low Impact Development and Complete Streets. Therefore, those project group models were combined and used as the basis for this group. To model the increase in stormwater conservation through changes in stormwater policy, both the efficiency and the implementation rates were increased above the model values used in the Local Solutions. Policies that encourage better maintenance may result in increased performance for land use types that likely have dedicated maintenance staff. To model this, the effective capture depths for institutional, commercial, industrial, and transportation were increased by 20 percent from 0.75 to 0.9 inches for the Malibu Creek, Ballona Creek, and Dominguez Channel Watersheds; and from 0.97 to 1.17 inches for Los Angeles River and San Gabriel River watersheds.

Policies that offer financial incentives to implement LID in the form of feed-in-tariffs would increase the implementation rates beyond the base rates assumed in Task 3. This was modeled by increasing all of the implementation rates proportionally by 50 percent for base rates below 40 percent, by 25 percent for base rates below 80 percent and by 10 percent for the base rate at 80 percent. A tiered approach was used because the barriers to LID implementation will increase significantly as implementation approaches the upper bound of 100 percent. Appendix C, Section 2.10 describes the specific rates and capture depths used to model the project group. All other methodologies match those described above in the Low Impact Development project group.

Table 13 summarizes the application of these concepts throughout the watersheds.

Table 13. Summary of Stormwater Policies

Watershed	Watershed Area (acres)	Total Urban Imperious Area (acres)	Institutional Land Use (acres)	Industrial Land Use (acres)	Commercial Land Use (acres)	Residential Land Use (acres)	Trans. (acres)	Implemen-tation Area (acres)	Implemen-tation Ratio of Impervious Area (%)	Habitat (acres)	Recreation Trails (feet)
Ballona Creek	135,090	55,528	3,872	3,314	7,371	23,029	17,942	31,997	58	269	561,790
Dominguez Channel	70,428	40,083	2,670	10,412	5,854	10,889	10,258	25,175	63	195	317,288
Los Angeles River	533,840	165,444	11,440	29,180	19,149	59,379	46,295	99,519	60	796	2,099,478
Malibu Creek	129,825	6,079	532	405	1,327	2,829	956	3,171	52	23	30,685
San Gabriel River	434,475	117,842	11,695	21,455	16,705	44,922	23,064	69,552	59	515	1,045,952
Total	**1,303,657**	**384,975**	**30,210**	**64,767**	**50,404**	**141,048**	**63,236**	**229,414**	**60**	**1796**	**4,055,194**

2.3.6.2 Green Infrastructure Programs Modeling

The Green Infrastructure Programs project group is a set of programs to encourage green infrastructure across the watershed. For Green Infrastructure Programs, the high-scoring stormwater opportunities from the Appraisal-Level Stormwater Conservation Matrix are summarized below and consist of the following key 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 BMPs to capture and recharge rainfall where it falls.
- ***Focus on Residential Stormwater Capture.*** Concept emphasizes distributed stormwater capture and infiltration within residential land uses.

The programs identified above are all similar in nature in that they encourage or increase implementation of LID and may reduce the time it takes to reach full-scale implementation. One area is programs focused on encouraging more homeowners to voluntarily implement LID which would increase the residential implementation rate. Therefore, this approach was modeled by increasing the base rates from Task 3 for each residential land use type to 50 percent implementation. This Management Solution uses the Low Impact Development model as a baseline. Table C-9 in Appendix C describes the specific rates and model changes used to model this project group. All other methodologies match those described above in the Low Impact Development project group.

Table 14 summarizes the application of these concepts throughout the watersheds.

Table 14. Summary of Green Infrastructure Programs

Watershed	Watershed Area (acres)	Total Urban Impervious Area Excluding Streets (acres)	Institutional Land Use (acres)	Industrial Land Use (acres)	Commercial Land Use (acres)	Residential Land Use (acres)	Implementation Area (acres)	Implementation Ratio of Impervious Area (%)	Habitat (acres)
Ballona Creek	135,090	37,585	3,872	3,314	7,371	23,029	19,180	51	107
Dominguez Channel	70,428	29,825	2,670	10,412	5,854	10,889	15,877	53	91
Los Angeles River	533,840	119,149	11,440	29,180	19,149	59,379	63,052	53	357
Malibu Creek	129,825	5,092	532	405	1,327	2,829	2,547	50	14
San Gabriel River	434,475	94,778	11,695	21,455	16,705	44,922	50,537	53	288
Total	**1,303,657**	**286,430**	**30,210**	**64,767**	**50,404**	**141,048**	**151,194**	**53**	**857**

2.3.6.3 Regional Impact Programs Modeling

Regional Impact Programs encourage local stormwater capture across the region and promote a watershed approach to managing stormwater. This Management Solution assumes a model baseline for Local Stormwater Capture, and increases the stormwater conservation through regional impact programs.

The high-scoring Regional Impact Program concepts in the Appraisal-Level Stormwater Conservation Matrix are summarized below and consist of the following key elements:

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

- ***Aggressively Use Available Space for Stormwater Capture.*** Concepts range from 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 from stormwater to developing incentives to promote residential on-site stormwater capture.

To model the Regional Impact Programs infiltration style project types, the GIS analysis and land use screening from Local Stormwater Capture was used. For private open space, one of the programs identified as favorable was to emphasize open space as recharge. This was already modeled in Local Stormwater Capture. However, the greater focus of a special program may increase the number of projects. To model this, it was assumed that a larger portion of the identified private vacant parcels would be used. Therefore, 50 percent of the identified vacant parcels were assumed to be an infiltration BMP versus 25 percent assumed in the Local Stormwater Capture model. Using the same method as the Local Stormwater Capture model, the surrounding area that would drain into the new infiltration basin or gallery was assumed to be ten times the area of the new basin or gallery. Table 15 summarizes the application of these concepts throughout the watersheds.

For the floodplain reclamation and river improvement project types, a GIS analysis of the Los Angeles County open channel facility data was used to identify possible concept locations. Refer to Appendix C, Section 2.12 for additional assumptions used to model this project group.

Table 15. Summary of Regional Impact Programs

Watershed	Watershed Area (acres)	Number of Projects	Infiltration Projects Implementation Area		ROW (acres)		River Improvements (miles)	Habitat (acres)	Recreation Trails (feet)
			(acres)	(%)	Infiltration Projects	River Improvement			
Ballona Creek	135,090	76	1,187	0.9	53.4	146	10.5	151	80,237
Dominguez Channel	70,428	2	4	0	-	131	12.4	131	80,065
Los Angeles River	533,840	1,772	32,526	6.1	1,426.6	3,238	143.8	3,381	1,575,399
Malibu Creek	129,825	-	-	-	-	11	2.2	11	13,967
San Gabriel River	434,475	1,159	19,210	4.4	1,175.4	1,415	94.4	1,533	1,030,889
Total	**1,303,657**	**3,009**	**52,926**	**4.1**	**2,655**	**4,941**	**263.0**	**5,207**	**2,780,558**

3. Appraisal-Level Analysis Results and Discussion

This section presents the appraisal-level analysis and results for the Local Solutions, Regional Solutions, Storage Solutions, and Management Solutions. Within these broad categories, there are 12 different project groups that offer varying strategies to help the region adapt to climate change. By helping the Basin Study Watersheds to increase local stormwater storage and capture, this diverse portfolio of project groups will help the region enhance its preparedness for climate change and improve its resiliency. It is important to note that the estimated stormwater conservation benefits associated with each the 12 different project groups are based upon full implementation—or complete "build out"—of each individual concept. However, if any of the concepts are not fully implemented, then the stormwater conservation benefits quantified along with any additional features identified may not be entirely realized.

Additional information for each of the 12 project groups is available in the following appendices:

- Appendix B includes factsheets for each of the Local Solutions, Regional Solutions, Storage Solutions, and the Management Solutions project groups that summarize their characteristics, stormwater conservation, additional benefits, capital and O&M costs, and other information.
- Appendix C includes a detailed discussion of the hydrologic modeling and assumptions for each project group included in Appendix B.
- Appendix D includes estimated capital and operational costs for each project group included in Appendix B.
- Appendix E includes detailed results and estimated costs for the LACFCD and USACE dams.

3.1. Local Solutions

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

- Local Stormwater Capture
- Low Impact Development
- Complete Streets

The results of the appraisal-level analysis for each of these project groups are presented in the next sections.

3.1.1. Local Stormwater Capture

As previously discussed, Local Stormwater Capture concepts consist of facilities that receive moderate volumes of runoff from upstream areas for infiltration and stormwater retention compared to concepts that manage stormwater at the source. Runoff is typically diverted to local stormwater facilities after it has already entered storm drains and engineered channels. These stormwater capture facilities may be in the form of surface infiltration basins or underground infiltration chambers as shown in Figure 7.

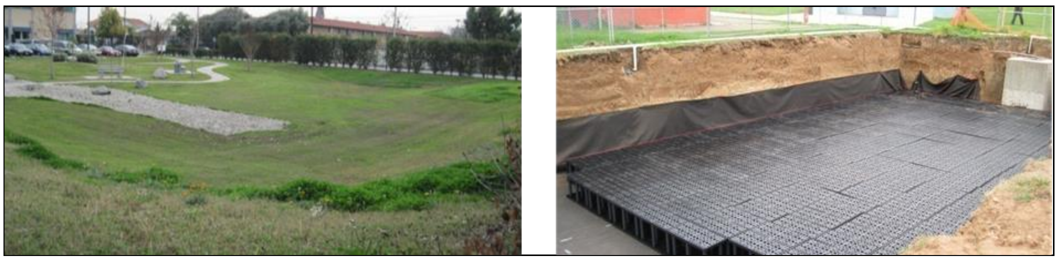

Figure 7. Surface Infiltration Basin and Underground Infiltration Chambers

In addition to stormwater conservation, some of the additional benefits of Local Stormwater Capture concepts are recreational opportunities, community enhancement, and habitat restoration. Naturalized surface systems like infiltration basins can enhance plant and bird habitat and provide educational opportunities to the local community. Underground systems can allow the current use of a site to be maintained while simultaneously managing stormwater for recharge and water quality.

Appendix B includes a factsheet for the Local Stormwater Capture concepts that summarizes important features of this project group.

3.1.1.1 Results

Using the WMMS model, the Local Stormwater Capture project group was modeled to determine the amount of stormwater conserved for four projected climate scenarios. For the Mid 2 projected climate scenario, implementation of local stormwater capture projects will provide approximately 31,123 acre-feet of stormwater conservation per year. Table 16 summarizes the future long-term average of stormwater conserved per year in each watershed for each climate scenario. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 16. Stormwater Conserved for Local Stormwater Capture

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	511	593	679	826
Dominguez Channel	70,428	2	3	3	4
Los Angeles River	533,840	14,282	16,610	18,663	23,688
Malibu Creek	129,825	-	-	-	-
San Gabriel River	434,475	9,122	10,481	11,778	14,661
Total	**1,303,657**	**23,917**	**27,687**	**31,123**	**39,179**

The Los Angeles River watershed represents the largest volume of stormwater conservation based on total volume and also as a percentage of watershed area. This is largely due to the relatively favorable soil and aquifer conditions for stormwater capture in the upper Los Angeles River watershed as compared to others.

Climate resilient stormwater capture concepts conserve more stormwater when it is available. The Local Stormwater Capture concepts provide a low to moderate level of climate resiliency with respect to stormwater conservation where the aquifer is unconfined. As shown in Table 16, the modeled stormwater conservation ranges from approximately 24,000 AFY for the Low 1 climate scenario to approximately 39,000 AFY for the High 1 climate scenario. The Local Stormwater Capture concepts are sized to contain the 5-year storm, which is a larger storm than the other Local Solution projects. However, Local Stormwater Capture concepts are not as widespread through the Basin Study Watersheds because of constrained site conditions. They are only implemented within specific parcels that are appropriate for infiltration, which limits the overall stormwater conservation.

3.1.1.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the Los Angeles Department of Water and Power (LADWP) Stormwater Capture Master Plan (Geosyntec, 2014). Capital costs include construction costs, engineering, project management, legal and permitting, and contingency. An additional property acquisition cost was assumed for purchase of private open space parcels for the use of Local Stormwater Capture concepts, totaling approximately 2,655 acres. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period. A summary of the local stormwater capture costs are presented below.

- **Capital Cost:** $3,086,000,000
- **O&M Cost:** $159,000,000/year
- **Land Acquisition:** $1,328,000,000
- **Cost per Acre-foot:** $8,800 to $14,400

These cost estimates presented are considered to be planning level only (order of magnitude), and costs may be refined as actual concepts are further developed. The financial strategy to fund these concepts will require a coordinated, regional approach to leverage funds from multiple partners who will realize benefits from these concepts across the region.

3.1.1.3 Other Project Characteristics and Benefits

Local Stormwater Capture concepts provide multiple benefits besides the retention of stormwater. In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality improvements, recreational opportunities, habitat/connectivity, ecosystem function, and climate resiliency. These other benefits can help to identify project partners as concepts with multiple benefits can help to leverage funding.

Additionally, it was assumed that when implementing concepts on vacant parcels, 10 percent of the parcel could be used for wetland habitat, and recreational trails could be constructed on the perimeter of the parcel. This results in 266 acres of habitat improvements and approximately 204 miles of new recreational trails.

3.1.2. Low Impact Development

Low Impact Development (LID) concepts are distributed structural and nonstructural BMPs that capture and infiltrate runoff close to the source and at the parcel scale as shown in Figure 8. The tributary area for LID BMPs are generally smaller than the Local Stormwater Capture concepts, and include bioretention, permeable pavement, and other infiltration BMPs that prevent runoff from leaving a parcel. LID can be incorporated throughout the watersheds by the LID ordinances, voluntary residential participation of LID, and LID retrofits of public parcels.

Figure 8. Schematic Concept of LID at the Parcel Scale

Appendix B includes a factsheet for the LID project that summarizes important features of this project group.

3.1.2.1 Results

The LID concepts were analyzed for four projected climate scenarios using the WMMS model. As an example, for the Mid 2 projected climate scenario, implementation of Low Impact Development concepts will provide approximately 94,533 acre-feet of stormwater conservation per year. Table 17 summarizes for each climate scenario the future long-term average of stormwater conserved per year in each watershed for each climate scenario. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 17. Stormwater Conserved for Low Impact Development

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	8,252	8,914	9,598	10,534
Dominguez Channel	70,428	7,091	7,684	8,400	9,307
Los Angeles River	533,840	31,509	36,146	40,112	48,868
Malibu Creek	129,825	1,209	1,296	1,327	1,454
San Gabriel River	434,475	28,284	31,612	35,097	41,108
Total	**1,303,657**	**76,345**	**85,652**	**94,533**	**111,271**

The Los Angeles River watershed represents the largest volume of stormwater conservation due to the large size of the watershed. However, the Dominguez Channel has the highest percentage of stormwater conservation relative to watershed area because the watershed is highly impervious with a larger percentage of institutional and industrial land uses compared to other watersheds These land uses, because they are highly regulated, are assumed to have a higher LID implementation rate than land uses that are not closely regulated (e.g., residential). Watersheds that are less impervious (e.g., Malibu Creek) have a lower percentage of stormwater conservation relative to watershed area.

LID concepts provide a large volume of stormwater conservation because they can be implemented over a wide range of land uses across the study area. As shown in Table 17, the modeled stormwater conservation ranges from approximately 76,000 to 111,000 AFY for the dry Low 1 and wet High 1 climate scenarios. The total volume of stormwater conservation and adaptive capacity under wet conditions illustrate the resilient nature of LID concepts.

3.1.2.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). A breakdown of BMP types was assumed for each land use to determine unit costs. No property acquisition was assumed for this concept. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period.

A summary of the Low Impact Development costs are presented below.

- **Capital Cost:** $9,696,000,000
- **O&M Cost:** $452,000,000/year
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $7,700 to $11,200

These cost estimates presented are considered to be planning level only (order of magnitude), and costs may be refined as actual concepts are further developed. The financial strategy to fund these concepts will require a coordinated, regional approach to leverage funds from multiple partners who will realize benefits from these concepts across the region. Some of the costs will be covered by typical and current activities by private developers to comply with LID ordinances as they implement these concepts into their site design for significant development and redevelopment projects.

3.1.2.3 Other Project Characteristics and Benefits

In addition to stormwater conservation, complementary benefits may include, but are not limited to, water quality improvements, recreational opportunities, aesthetics, habitat/connectivity, mitigation of urban heat island effect, and climate resiliency. These other benefits can help to identify project partners as concepts with multiple benefits can help to leverage funding.

Additionally, it was assumed that when implementing LID, select infiltration/bioretention BMP types would provide a habitat benefit. Based upon the LADWP Stormwater Capture Master Plan (Geosyntec, 2014, p. 55), its green space ratio was assumed to be equivalent to habitat for the LA Basin Study, and this percentage was applied as appropriate. This results in 672 acres of habitat improvements.

3.1.3. Complete Streets

The goal of Complete Streets is to ensure that the safety, accessibility, and convenience of all transportation users—pedestrians, bicyclists, transit riders, and motorists—is accommodated. Complete Streets serve a much larger purpose than just moving cars. They encourage healthy recreational activities such as walking, running, and bicycling. The Complete Streets Design Guide (City of Los Angeles, 2015) provides a compilation of design concepts and BMPs for streets as a companion to the Mobility Plan 2035, an update to the Mobility Element of the City of Los Angeles General Plan.

One aspect of Complete Streets is stormwater treatment and management providing onsite retention, filtration, and infiltration to reduce urban runoff from the roadway, driveways, and sidewalk area as shown in Figure 9. These stormwater management facilities in the public right-of-way are typically implemented as linear bioretention/biofiltration BMPs installed parallel to roadways to supplement or replace existing parkway landscaping. Systems receive runoff from the gutter via curb cuts or curb extensions and infiltrate through native or engineered soil media. Permeable pavement can also be implemented as part of Complete Streets.

Appendix B includes a factsheet for the Complete Street concepts that summarizes important features of this project group.

Figure 9. Schematic Concept of Complete Streets

3.1.3.1 Results

The WMMS model was run for four projected climate scenarios. For the Mid 2 projected climate scenario, implementation of Complete Street concepts will provide approximately 31,477 acre-feet of stormwater conservation per year. Table 18 summarizes the future long-term average of stormwater conserved per year in each watershed for each climate scenario. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 18. Stormwater Conserved for Complete Streets

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	4,285	4,627	4,996	5,478
Dominguez Channel	70,428	2,171	2,333	2,556	2,830
Los Angeles River	533,840	12,787	14,326	15,855	19,121
Malibu Creek	129,825	259	276	283	311
San Gabriel River	434,475	6,254	7,014	7,787	9,169
Total	**1,303,657**	**25,756**	**28,575**	**31,477**	**36,909**

The Los Angeles River watershed represents the largest volume of stormwater conservation due to the large size of the watershed. However, the Ballona Creek and Dominguez Channel watersheds have the highest percentage of stormwater conservation relative to watershed area because of their large percentage of impervious transportation areas. Malibu Creek has the least transportation land use areas, and correspondingly, the lowest amount of stormwater conservation for Complete Street implementation.

Complete Streets provide a low to moderate volume of stormwater conservation in the Basin. As shown in Table 18, the modeled stormwater conservation ranges from approximately 26,000 AFY for the Low 1 climate scenario to approximately 37,000 AFY for the High 1 climate scenario. The increase in conservation under wet conditions illustrates the resilient nature of Complete Streets. However, Complete Streets are not as widespread through the Basin Study Watersheds because they are constrained to only transportation land uses, which limits the overall stormwater conservation.

3.1.3.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). A breakdown of BMP types was assumed for each land use to determine unit costs. No property acquisition was assumed for this concept. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period.

A summary of the Complete Streets costs are presented below.

- **Capital Cost:** $5,970,000,000
- **O&M Cost:** $250,000,000/year
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $13,500 to $19,400

These cost estimates presented are considered to be planning level only (order of magnitude), and costs may be refined as actual concepts are further developed. As a note, the large conservation costs for complete streets in this section is attributed to the full cost of the improvement being linked only to the stormwater conservation benefit, whereas there are many other primary benefits provided by complete streets, such as increased modal transportation, a vehicle transportation corridor, roadway lighting, and utilities. A more in-depth cost analysis should indicate a much lower conservation cost for this type of impermanent. The financial strategy to fund these concepts will require a coordinated, regional approach to leverage funds from multiple partners who will realize benefits from these concepts across the region.

3.1.3.3 Other Project Characteristics and Benefits

Green streets have been demonstrated to provide “complete streets” benefits in addition to stormwater management, including pedestrian safety and traffic calming, street tree canopy and heat island effect mitigation, habitat, increased property values, and a boost in economic activity and visibility of storefront businesses.

Additionally, it was assumed that when implementing Complete Streets, select infiltration/bioretention BMP types would provide a habitat benefit. Based upon the LADWP Stormwater Capture Master Plan (Geosyntec, 2014, p. 55), its green space ratio was assumed to be equivalent to habitat for the LA Basin Study, and this percentage was applied as appropriate. This results in 725 acres of habitat improvements.

3.2. Regional Solutions

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

- Regional Stormwater Capture
- Stormwater Conveyance Systems
- Alternative Capture

The results of the appraisal-level analysis for each of these project groups are presented below.

3.2.1. Regional Stormwater Capture

The concepts related to the Regional Stormwater Capture project group are construction of new spreading basins and enhancement of existing basins. Concepts involved developing new basins, deepening existing spreading grounds, utilizing quarry pits, and using enhanced maintenance techniques.

The Regional Stormwater Capture project group considers the construction of eight new spreading grounds and enhancements at existing spreading grounds to increase groundwater recharge. For completeness, this project group also includes current LACFCD projects, such as two recently constructed projects and 11 planned modifications to existing spreading grounds. More details on these projects are included in Appendix C, Section 2.4. Appendix B includes a factsheet that summarizes important features of this project group.

Potential recreation and habitat enhancements for the new basins include trails or parkways and wetland forebay areas. For this Regional Solution type, 10 percent of the area of all new basins were assumed to be dedicated to habitat. In total, the group of concepts would include 42 acres of habitat and over 12 miles of recreational trail.

Figure 10 shows a schematic of a new spreading ground (NSG), and Figure 11 shows the location of the NSGs and the enhanced spreading grounds (ESG) where enhanced soil management activities would be performed. Tables 19 and 20 summarize their characteristics.

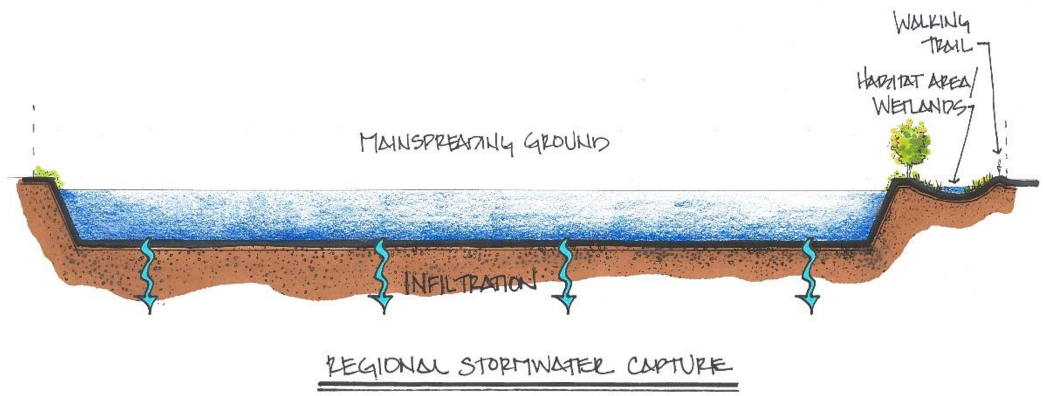

Figure 10. Schematic Concept of a New Spreading Ground

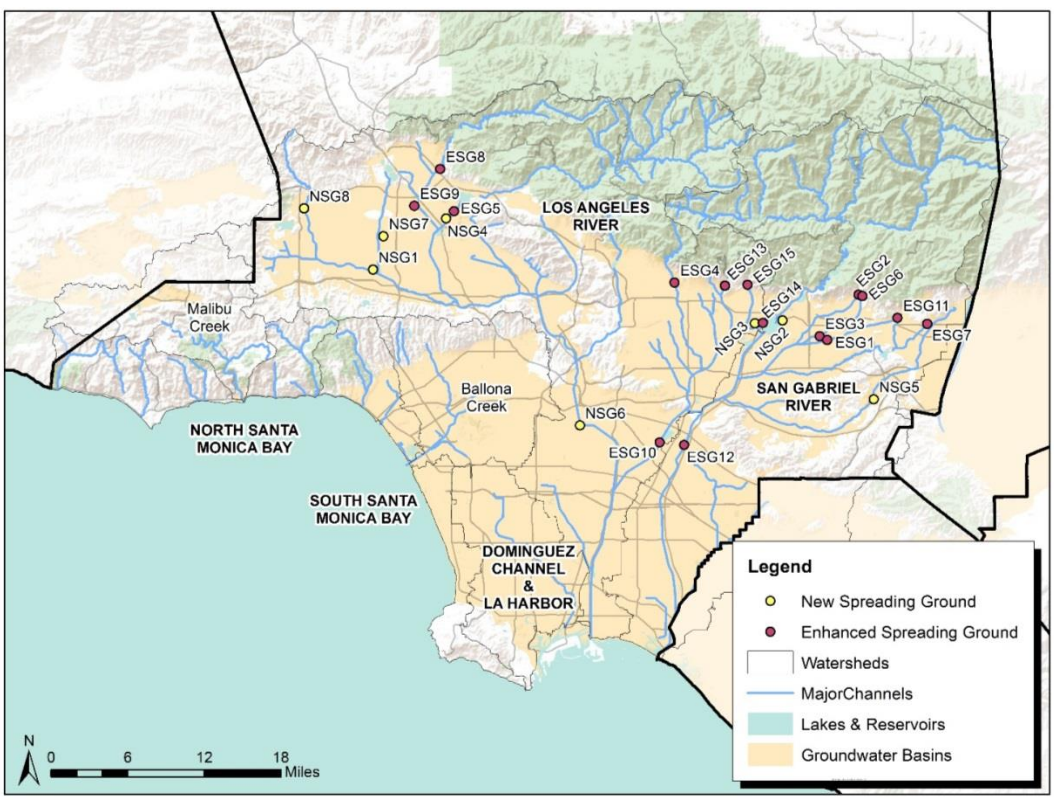

Figure 11. Regional Stormwater Capture Projects

Table 19. New Spreading Grounds

ID	Location	Wetted Area (acres)	Storage (ac-ft)	Intake (cfs)	Estimated Recharge Capacity (cfs)	ROW (acres)	Habitat[a] (acres)	Recreation Trails (feet)
NSG1	Sepulveda Dam	40.6	405.9	200	18.6	58.3	4.1	7,431
NSG2	Miller Pit	33.8	612.0	120	30.9	56.7	3.4	6,128
NSG3	Rock Pit No. 3	53.4	477.0	240[c]	25.0	89.2	5.3	7,807
NSG4	New Tujunga Spreading Grounds	219.3	4,292.1	1,200[b]	338.7	365.7	21.9	11,307
NSG5	Spadra Basin	12.3	122.8	45	10.0	17.5	1.2	3,673
NSG6	LA River Spreading Ground	23.9	26.6	48	12.1	40.0	2.7	7,666
NSG7	Bull Creek Area Spreading Grounds	16.5	11.5	21	5.2	18.2	1.2	5,454
NSG8	Browns Creek Area Spreading Grounds	35.3	24.7	45	11.2	36.1	2.5	13,993
Total		**435**	**5,973**	**479**	**452**	**682**	**42**	**63,459**

[a] Assume 10 percent of wetted area
[b] Total intake for new and enhanced Tujunga Spreading Grounds
[c] Expansion of Buena Vista Spreading Grounds

Table 20. Enhanced Spreading Grounds

ID	Location	Wetted Area (acres)	Storage (ac-ft)	Intake (cfs)	Existing Percolation Rate (cfs)	Enhanced Percolation Rate (cfs)
ESG1	Ben Lomond	17.0	168	400	30	36
ESG2	Big Dalton	6.7	8	45	15	18
ESG3	Citrus	14.6	77	245	28	34
ESG4	Eaton Wash	25.2	526	200	14	17
ESG5	Hansen/Tujunga	190.3	1,572	650	570	684
ESG6	Little Dalton	4.7	5	20	12	14
ESG7	Live Oak	3.0	13	15	12	14
ESG8	Lopez	12.0	24	25	12	14
ESG9	Pacoima	107.3	440	600	65	78
ESG10	Rio Hondo	429.0	3,575	1,950	400	480
ESG11	San Dimas	9.5	30	25	8	10
ESG12	San Gabriel Coastal	95.9	550	350	75	90
ESG13	Santa Anita	8.5	25	20	5	6
ESG14	Santa Fe	95.0	635	600	400	480
ESG15	Sawpit	4.0	13	30	12	14

3.2.1.1 Results

Implementation of the Regional Stormwater Capture concepts will provide approximately 43,311 acre-feet of additional stormwater conservation per year based on the Mid 2 projected climate scenario. Table 21 summarizes the modeled change in the future long-term average of stormwater conservation associated with the Regional Stormwater Capture project group. The historic, Task 4 baseline, and modeled stormwater conservation is provided in Table C-6 of Appendix C.

Climate resilient stormwater capture improvements conserve more stormwater when it is available. As shown in Table 21, larger amounts of stormwater conservation are projected to occur under the wet scenario versus the drier climate scenarios. The increased stormwater conserved associated with the new and expanded basins ranges from approximately 20,000 AFY for the Low 1 climate scenario to approximately 40,000 AFY for the High 1 climate scenario. The increases associated with the existing basins ranges from approximately 7,000 to 20,000 AFY for the same climate scenarios.

3.2.1.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the sizing of the basins, habitat and recreational improvements, and other associated infrastructure. The unit costs were derived from previous CH2M cost estimates for similar project work. Approximately 682 acres would be required for the recharge basins, including the private open space parcels that could be purchased are existing gravel pits that could be repurposed as recharge basins. Land acquisition cost is a significant portion of the estimated capital cost for this project group. An O&M cost of 5 percent of the construction costs was calculated, added to power consumptions costs, and annualized over a 50-year analysis period for the new basins. The additional O&M costs for the enhanced basins were inflated from 2000 unit rates costs per acre for the Rio Hondo Spreading grounds (MWH, 2003). A summary of the Regional Stormwater Capture concept costs are presented below.

- **Capital Cost:** $652,000,000
- **O&M Cost:** $13,000,000/year
- **Land Acquisition:** $341,000,000
- **Cost per Acre-foot:** $900 to $2,100

These cost estimates presented are considered to be planning level only (order of magnitude), and costs may be refined as actual concepts are further developed. The financial strategy to fund these concepts will require a coordinated, regional approach to leverage funds from multiple partners who will realize benefits from these concepts across the region. Refer to Appendix D for a more detailed summary of capital and operational costs.

Table 21. Stormwater Conserved for Regional Stormwater Capture

Recharge Basin	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Existing Basins	**6,777**	**12,330**	**13,381**	**20,086**
Ben Lomond[a, c]	-80	-76	-43	-30
Big Dalton[a, b]	62	78	82	102
Branford[b]	175	265	282	361
Citrus[a]	53	98	94	119
Dominguez Gap[b]	1,239	1,406	1,454	1,554
Eaton Basin[c]	-60	-73	-59	-65
Eaton Wash[b]	1,171	1,904	2,059	2,843
Forbes[c]	-10	-11	-12	-15
Irwindale[c]	-178	-284	-263	-330
Little Dalton[a]	18	24	24	32
Live Oaka	16	20	22	26
Lopez[a, b]	41	44	46	52
Pacoima[a, b]	2,406	4,118	4,279	5,939
Peck Road	626	1,197	1,345	2,069
Rio Hondo[a]	1,359	2,793	3,238	5,763
San Dimas[a]	173	237	214	293
San Gabriel Canyon	0	0	0	0
San Gabriel Coastal[a]	71	579	580	1,087
Santa Anita[a]	36	40	41	50
Santa Fe[a, c]	-766	-512	-519	-360
Sawpit[a]	8	16	19	26
Sierra Madre	0	0	0	0
Walnut[b]	417	467	498	568
Expanded Basins	**5,505**	**10,724**	**12,437**	**19,466**
Buena Vista and New Rock Pit No. 3	503	786	878	1,164
Hansen/Tujunga and New Tujunga Expansion[b]	5,002	9,938	11,559	18,301
New Basins	**13,854**	**16,809**	**17,493**	**20,326**
Browns Creek Area Spreading Grounds	825	1,229	1,322	1,766
Bull Creek Area Spreading Grounds	1,175	1,348	1,382	1,569
LA River Spreading Grounds	3,976	4,317	4,474	4,825
Miller Pit (Santa Fe Dam) Spreading Ground	2,809	4,175	4,384	5,593
Sepulveda Dam Spreading Ground	3,702	4,143	4,263	4,680
Spadra Spreading Ground (Pomona)	1,367	1,596	1,668	1,892
Net Change	**26,136**	**39,863**	**43,311**	**59,878**

[a] Recharge rate enhanced 20 percent through improved maintenance

[b] Includes planned modifications to existing basin volume, recharge rate, and/or intake rate.

[c] Negative numbers represents a reduction in recharge compared to the baseline condition, and results from reduction in available water due to increased capture upstream.

3.2.1.3 Other Project Characteristics and Benefits

Implementation of Regional Stormwater Capture concepts will provide approximately 42 acres of wetland habitat, and over 12 miles of recreational trails. In addition, the new and enhanced basins could help to mitigate the urban heat island effect.

3.2.2. Stormwater Conveyance Systems

The Stormwater Conveyance Systems project group provides stormwater conservation benefits through a suite of channel modification concepts. Concepts involved increasing soft bottom channel reaches, developing “river speed bumps”, and creating channel side ponds to enhance stormwater recharge.

A preliminary screening of areas favorable for conversion to soft bottom channels was performed focusing on tributary reaches overlying unconfined groundwater basins. The main channel reaches were eliminated for evaluation of potential streambed modification because of the greater potential for impacts to flood risk management. Potential recreation and habitat opportunities include trail networks, parkways, and riparian habitat corridors along the naturalized channel easements. Figure 12 shows the locations of tributaries identified for streambed modification.

Two approaches were evaluated to enhance short-term stormwater detention within existing or converted soft bottom channels areas. “River speed bumps”, small in-channel earthen detention structures, were assumed for all modified channel reaches. Channel side ponds, which are narrow recharge basins built along existing channels as shown in Figure 13, were considered where easements are wide enough or land appears available for their installation. Table 22 summarizes the characteristics of the channel modifications. Appendix B includes a factsheet that summarizes important features of this project group.

The potential for adverse impacts to capacity, freeboard and flood protection associated with naturalizing the channels and potential strategies to mitigate these issues would need to be evaluated during subsequent studies. These studies would also need to evaluate design details to ensure that the percolation has no adverse impact to the existing channels.

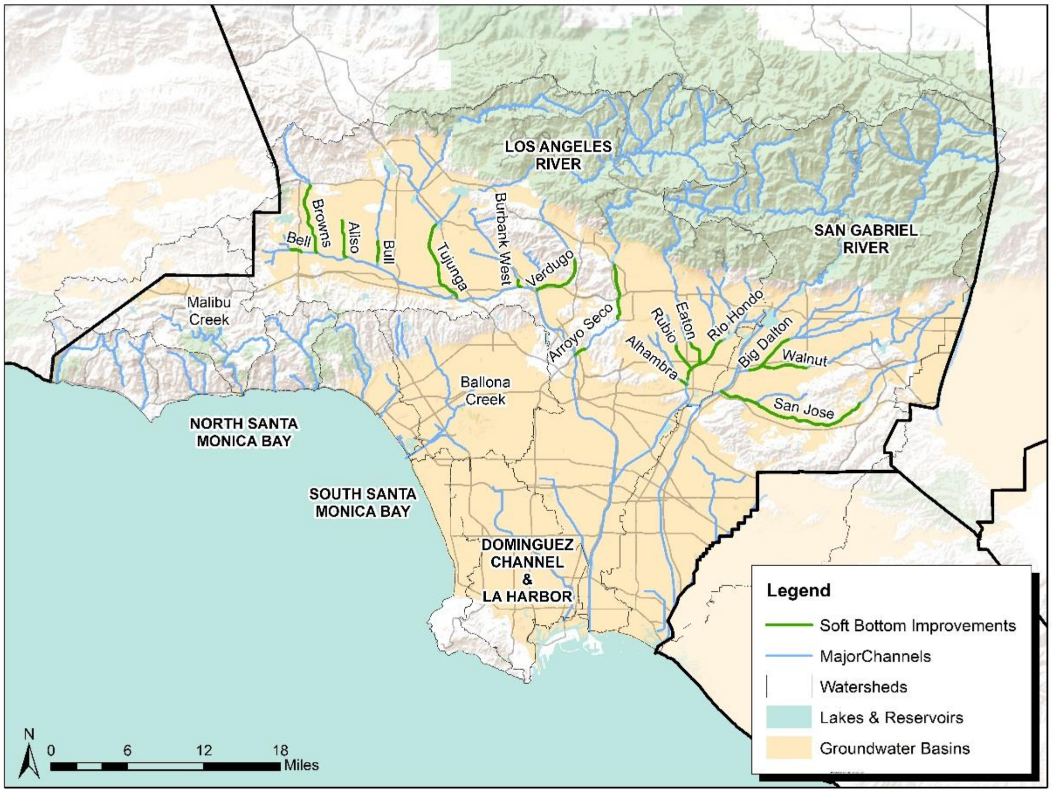

Figure 12. Stormwater Conveyance Systems

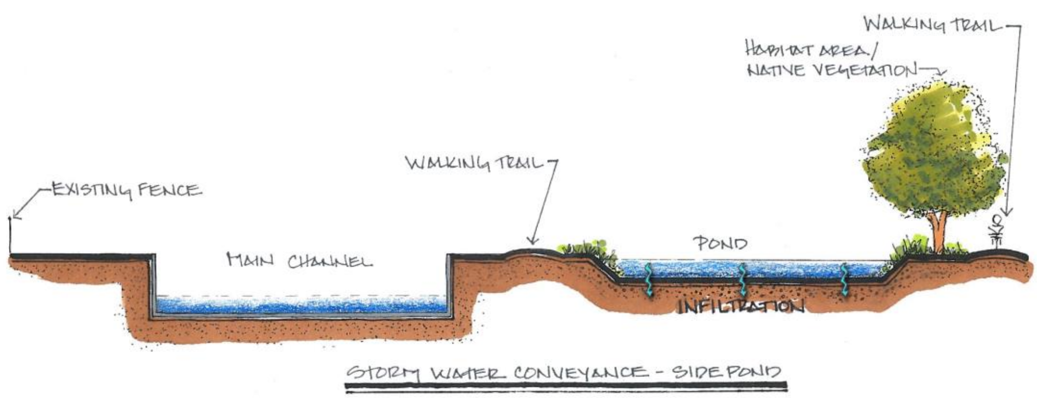

Figure 13. Schematic of Stormwater Conveyance Systems

Table 22. Channel Modifications

Channel	Width (feet)	Modification Length (feet)	Length of Side Pond (feet)	Percolation Rate (cfs)	ROW (acres)	Habitat (acres)	Recreation Trails (feet)
Alhambra Wash	50	2,572	135	0.2	0.2	0.1	135
Aliso Creek	50	9,269	6,179	1.3	10.5	2.8	6,179
Arroyo Seco Channel	50	28,764	1,514	2.7	2.6	0.7	1,514
Bell Creek	50	4,590	-	0.3	-	-	-
Big Dalton Wash	60	15,354	808	1.9	1.4	0.4	808
Browns Creek	50	28,531	1,502	2.3	2.6	0.7	1,502
Bull Creek	60	7,954	80	0.7	0.1	0.0	80
Burbank Western System	50	3,132	-	0.2	-	-	-
Eaton Wash	50	10,338	544	2.2	0.9	0.2	544
Rio Hondo	75	21,205	1,116	2.6	1.9	0.5	1,116
Rubio Wash	50	11,056	582	1.4	1.0	0.3	582
San Jose Creek	70	60,868	3,204	6.8	5.4	1.5	3,204
Tujunga Wash	70	34,988	-	3.7	-	-	-
Verdugo Wash	80	21,531	1,133	2.7	1.9	0.5	1,133
Walnut Creek Channel	50	23,195	1,221	2.8	2.1	0.6	1,221
Total		**283,346**	**18,018**	**31.7**	**30.6**	**8.3**	**18,018**

3.2.2.1 Results

Implementation of the Stormwater Conveyance Systems concepts will provide approximately 9,188 acre-feet of stormwater conservation per year based on the Mid 2 projected climate scenario. Table 23 summarizes the modeled increase in the future long-term average of stormwater conservation relative to baseline conditions.

Table 23. Stormwater Conserved for Stormwater Conveyance Systems

Channel	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Alhambra Wash	66	71	73	77
Aliso Creek	337	393	401	428
Arroyo Seco Channel	863	908	932	1,012
Bell Creek	104	115	118	129
Big Dalton Wash	429	489	487	532
Browns Creek	497	578	601	669
Bull Creek	227	251	257	275
Burbank Western System	73	78	81	87
Eaton Wash	195	218	220	241
Rio Hondo	635	725	740	812
Rubio Wash	255	285	291	320
San Jose Creek	2,052	2,346	2,389	2,566
Tujunga Wash	911	1,048	1,076	1,160
Verdugo Wash	849	914	947	1,033
Walnut Creek Channel	522	566	575	627
Total	**8,014**	**8,987**	**9,188**	**9,968**

The modeled stormwater conservation ranges from approximately 8,000 to 10,000 AFY for the dry Low 1 and wet High 1 climate scenarios shown in Table 23. The increase in conservation under wet conditions illustrates the resilient nature of these improvements. The adaptive capacity of these modifications, however, is limited by the finite capacity the modified channels to recharge groundwater and to convey food stage flows. The channel modification concepts appear to be less resilient than the Regional Stormwater Capture projects.

3.2.2.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on width of channel improvements, habitat and recreational improvements, and other associated infrastructure. The unit costs were derived from previous CH2M cost estimates for similar project work. Approximately 31 acres of vacant land would need to be acquired where the existing easement is not wide enough to accommodate channel side ponds. An

O&M cost of 5 percent of the construction costs was calculated and annualized over a 50-year analysis period. A summary of the Stormwater Conveyance System concept costs are presented below.

- **Capital Cost:** $7,139,000,000
- **O&M Cost:** $127,000,000/year
- **Land Acquisition:** $15,000,000
- **Cost per Acre-foot:** $42,700 to $53,100

These cost estimates presented are considered to be planning level only (order of magnitude), and costs may be refined as actual concepts are further developed. The financial strategy to fund these concepts will require a coordinated, regional approach to leverage funds from multiple partners who will realize benefits from these concepts across the region. Refer to Appendix D for a more detailed summary of capital and operational costs.

3.2.2.3 Other Project Characteristics and Benefits

Additional benefits associated with the new Stormwater Conveyance Systems include habitat space and recreational opportunities. Implementation of the Stormwater Conveyance Systems project group will provide 8 acres of habitat and approximately 3 miles of recreational trail, as well as urban heat island mitigation and water quality benefits.

3.2.3. Alternative Capture

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

Although significant recharge of stormwater derived from the Rio Hondo and San Gabriel River occur within the Central Basin, there are no managed groundwater recharge facilities on the Los Angeles River in the Central Basin, with the exception of the Dominguez Gap spreading grounds. One reason for this is the limited land available within the Los Angeles Forebay area for spreading basins. The *Ground Water Basins Master Plan Water Replenishment District of Southern California* identified a concept where flows would be diverted from the Los Angeles River and conveyed to shallow recharge ponds constructed along power line easements (CH2M HILL, 2012). The infiltration provides soil aquifer treatment of the diverted flows. The area is underlain by a shallow aquitard, which limits the potential for direct recharge of the unconfined aquifer system. Shallow extraction wells along the perimeter of the basins would extract the treated groundwater, which would then be injected below the shallow aquitard into the production aquifer. Groundwater in the shallow aquifer system would need to be evaluated to confirm it is of sufficient quality for deep injection before proceeding with the project. Figure 14 shows the assumed location of this facility and Figure 15 shows a schematic. Table 24 summarizes its characteristics. Appendix B includes a factsheet that summarizes important features of this project.

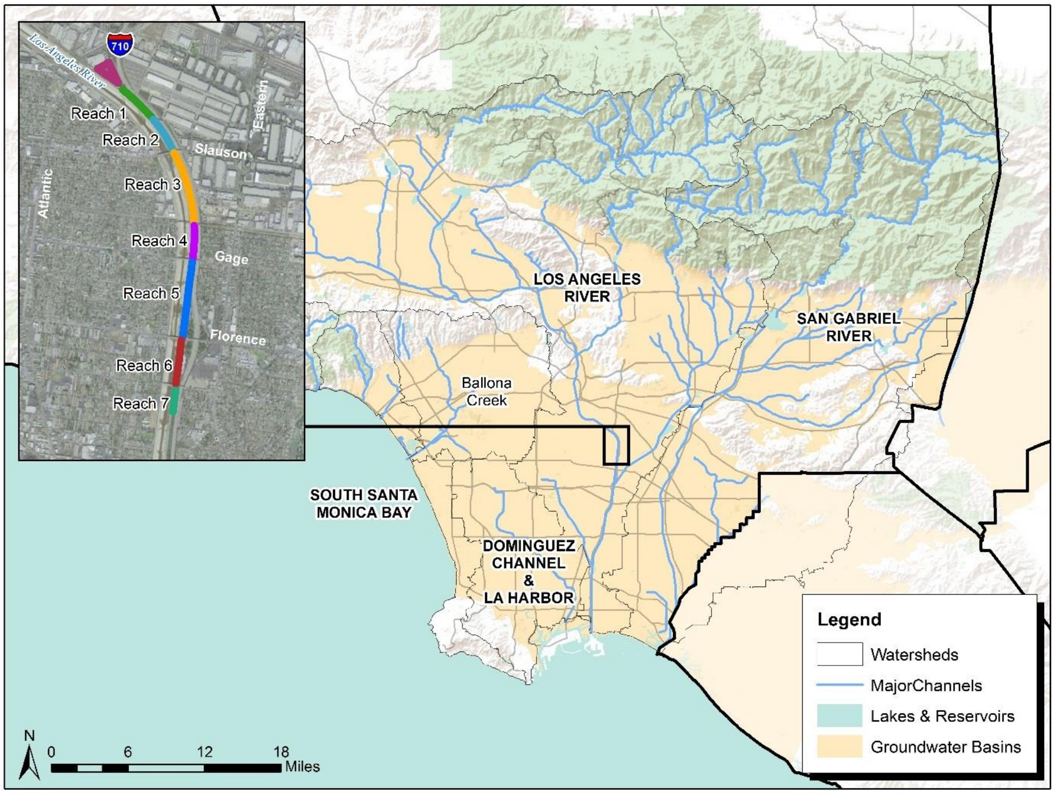

Figure 14. Alternative Capture

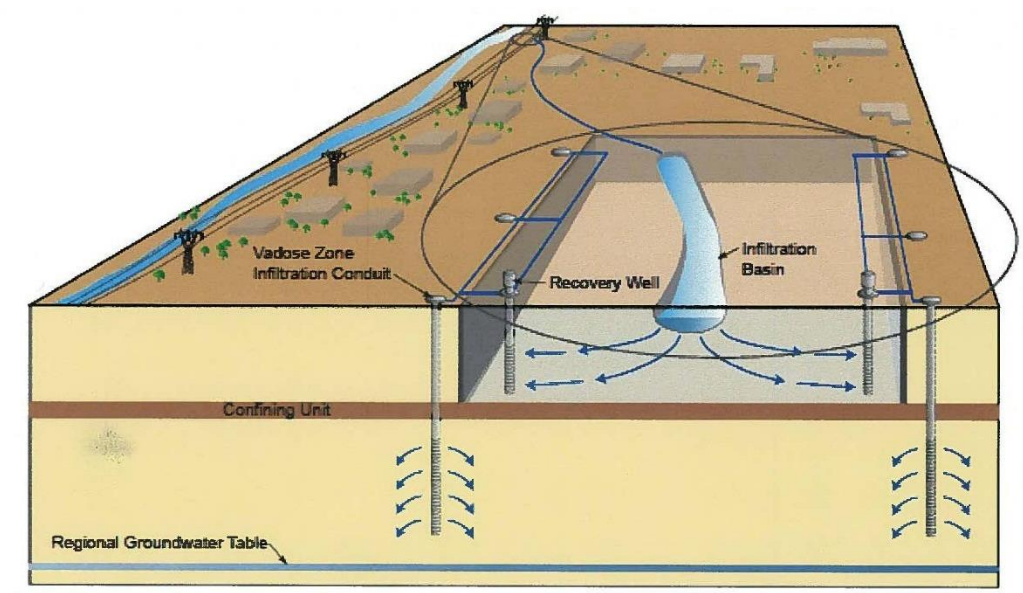

Figure 15. Alternative Capture Schematic

Table 24. Alternative Capture

Reach No.	Infiltration Area (acres)	No. of Extraction Wells	No. of Injection Wells	Reach Length (feet)	ROW (acres)	Habitat (acres)	Recreation Trails (feet)
0	3.8	4	8	1,300	6.3	0.4	1,300
1	1.5	2	4	1,255	2.5	0.2	1,255
2	2.4	2	4	1,230	4.0	0.2	1,230
3	5.1	6	12	2,530	8.5	0.5	2,530
4	2.7	4	8	1,170	4.5	0.3	1,170
5	2.5	2	4	2,600	4.2	0.3	2,600
6	1.4	2	4	1,355	2.3	0.1	1,355
7	0.7		4	1,355	1.2	0.1	1,355
Total	**20.1**	**24**	**48**	**12,795**	**33.5**	**2.0**	**12,795**

3.2.3.1 Results

Implementation of the Alternative Capture concept will provide approximately 5,587 acre-feet of stormwater conservation per year based on the Mid 2 projected climate scenario. Table 25 summarizes the additional future long-term average of stormwater conservation relative to baseline conditions.

Table 25. Stormwater Conserved for Alternative Capture

Channel	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Los Angeles River	3,847	5,324	5,587	6,884

The modeled stormwater conservation ranges from 3,847 to 6,884 AFY for the dry Low 1 and wet High 1 climate scenarios shown in Table 25. The increase in conservation under wet conditions illustrates the resilient nature of these improvements. The adaptive capacity of these modifications, however, is limited by the capacity of the recharge basins. The resiliency could be enhanced through increased pumping to eliminate groundwater mounding, however the upper limit would be the percolation capacity of the soil.

3.2.3.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the size of the basin segments, recreational improvements, and other associated infrastructure. The unit costs were derived from previous estimates. Approximately 34 acres of land acquisition from an existing power easement would be required where the existing channel easement is not wide enough to accommodate the recharge basins. An O&M cost of 5 percent of the construction costs was calculated and added to power consumption costs. The resulting O&M costs were annualized over a 50-year analysis period. A summary of the Alternative Capture concept costs are presented below.

- **Capital Cost:** $135,000,000
- **O&M Cost:** $3,000,000/year
- **Land Acquisition:** $16,750,0000
- **Cost per Acre-foot:** $1,400 to $2,400

These cost estimates presented are considered to be planning level only (order of magnitude), and costs may be refined as actual concepts are further developed. The financial strategy to fund these concepts will require a coordinated, regional approach to leverage funds from multiple partners who will realize benefits from these concepts across the region. Refer to Appendix D for a more detailed summary of capital and operational costs.

3.2.3.3 Other Project Characteristics and Benefits

Implementation of Alternative Capture concepts will provide 2 miles of recreational trails and 2 acres of habitat improvements. In addition, the Alternative Capture recharge basins provide water quality benefits though soil aquifer treatment and an associated reduction in pollutant loading to receiving waters.

3.3. Storage Solutions

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

- LACFCD Dams
- USACE Dams
- Debris Basins

The results of the appraisal-level analysis for each of these project groups are presented below. It is *important to recognize* that for all structural and nonstructural improvements in this section, the volume of increased stormwater capture is only an increase in the total or operational storage capacity at each facility. This volume is potentially available for groundwater recharge at a later point in time and does not represent an actual increase in total stormwater recharged.

3.3.1. LACFCD Dams

3.3.1.1 Structural Concepts

As previously discussed in Section 2.4.3.1, structural concepts were developed for the nine remaining LACFCD dams. These structural concepts were developed to enable these dams to capture the maximum volume of stormwater runoff. Operable weirs (pneumatic gates) and/or slide gates would be installed at the spillway(s) of each dam to allow stormwater to be captured at elevations above the spillway crest under certain conditions.

3.3.1.2 Results

A summary of the results for the nine LACFCD dams considered for each of the four climate scenarios analyzed in Task 5 is presented in Tables 26 through 29 on the following pages. The Task 5 results for the Structural Concepts for the key metrics are presented for comparison alongside the corresponding Task 4 results. Selected results are also provided for the Historical period for comparison (a separate summary of these results for each dam is presented in Tables E-1 through E-10 in Appendix E).

For seven of the nine dams, Capture Ratios are generally near 100 percent for all of the scenarios. For the other two dams (Big Tujunga and Morris), Capture Ratios are much lower, but higher for the Task 5 Structural Concepts than for either the Historic period or the corresponding Task 4 projected climate scenarios.

It is noteworthy that Capture Ratios are typically higher for the drier projected climate scenarios. Because the volumes captured are generally smaller for drier periods, the reservoirs can be drawn down more quickly after a runoff event, making storage capacity more readily available for capture of runoff during subsequent events.

Table 26. LACFCD Dams Structural Concept Results – High 1 Scenario

Dam Name	Mean Annual Volume Captured* (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Big Tujunga	12,845	19,299	40,753	34,289	12,846	64.2%	35.9%	75.9%	-28.2%	11.7%	1.85	3.61
Cogswell	19,282	27,397	51,680	25,898	1,624	75.5%	51.4%	96.9%	-24.2%	21.3%	1.82	0.36
Devil's Gate	9,570	12,925	32,204	19,277	0	66.9%	40.1%	100.0%	-26.8%	33.1%	2.94	0.00
Eaton Wash	3,681	6,426	9,105	2,739	61	86.6%	70.1%	99.3%	-16.5%	12.7%	5.46	0.10
Morris	44,980	53,120	156,526	189,341	86,017	39.8%	21.9%	64.5%	-17.9%	24.7%	0.96	1.49
Pacoima	6,219	14,354	18,009	4,123	468	87.0%	77.6%	97.3%	-9.5%	10.3%	1.70	0.49
Puddingstone Diversion	6,452	12,106	14,053	1,975	29	94.9%	86.0%	99.8%	-8.9%	4.9%	3.54	0.02
San Dimas	4,474	6,798	10,771	4,066	93	82.1%	62.5%	99.0%	-19.6%	16.9%	2.00	0.15
San Gabriel	90,825	140,764	224,166	94,785	11,438	82.1%	59.8%	95.1%	-22.3%	13.1%	1.89	0.88
Totals	**198,329**	**293,188**	**557,267**	**376,492**	**112,576**	**64.6%**	**43.8%**	**83.2%**	**-20.8%**	**18.6%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

Table 27. LACFCD Dams Structural Concept Results – Mid 2 Scenario

Dam Name	Mean Annual Volume Captured* (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Big Tujunga	12,845	14,699	26,485	16,277	4,496	64.2%	47.3%	85.2%	-16.9%	21.1%	1.24	1.48
Cogswell	19,282	22,187	33,949	12,477	721	75.5%	63.9%	97.8%	-11.6%	22.3%	1.06	0.18
Devil's Gate	9,570	10,324	20,071	9,774	28	66.9%	51.4%	99.9%	-15.6%	32.9%	2.04	0.02
Eaton Wash	3,681	4,780	6,057	1,291	15	86.6%	78.7%	99.8%	-7.9%	13.1%	3.14	0.04
Morris	44,980	46,560	118,413	109,910	38,094	39.8%	29.7%	75.6%	-10.0%	35.9%	0.76	0.83
Pacoima	6,219	9,419	10,678	1,404	145	87.0%	86.8%	98.4%	-0.3%	11.3%	0.57	0.08
Puddingstone Diversion	6,452	8,011	8,898	895	8	94.9%	90.0%	99.9%	-4.9%	5.1%	1.77	0.01
San Dimas	4,474	4,823	6,864	2,095	53	82.1%	69.5%	99.0%	-12.6%	16.9%	1.45	0.08
San Gabriel	90,825	108,576	147,980	44,152	4,770	82.1%	71.1%	96.9%	-11.0%	14.8%	1.18	0.25
Totals	**198,329**	**229,379**	**379,394**	**198,274**	**48,330**	**64.6%**	**53.6%**	**88.6%**	**-10.9%**	**24.1%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

Table 28. LACFCD Dams Structural Concept Results – Low 1 Scenario

Dam Name	Mean Annual Volume Captured* (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Big Tujunga	12,845	8,910	12,509	5,425	1,827	64.2%	61.7%	86.6%	-2.5%	22.5%	0.50	0.45
Cogswell	19,282	14,593	18,630	4,404	370	75.5%	76.7%	97.9%	1.1%	22.3%	0.43	0.10
Devil's Gate	9,570	6,879	10,649	3,770	0	66.9%	64.6%	100.0%	-2.3%	33.1%	0.93	0.00
Eaton Wash	3,681	2,867	3,351	500	15	86.6%	85.2%	99.5%	-1.5%	12.9%	1.12	0.02
Morris	44,980	42,070	72,169	43,516	13,435	39.8%	49.1%	84.2%	9.3%	44.4%	0.46	0.32
Pacoima	6,219	4,387	4,977	613	23	87.0%	87.1%	98.9%	0.1%	11.8%	0.20	0.01
Puddingstone Diversion	6,452	4,323	4,686	371	8	94.9%	92.1%	99.8%	-2.8%	5.0%	0.62	0.01
San Dimas	4,474	2,883	3,592	740	31	82.1%	79.1%	98.5%	-3.0%	16.4%	0.49	0.05
San Gabriel	90,825	68,813	82,523	15,302	1,603	82.1%	81.8%	98.1%	-0.3%	16.0%	0.42	0.13
Totals	**198,329**	**155,724**	**213,086**	**74,641**	**17,313**	**64.6%**	**67.5%**	**92.4%**	**3.0%**	**27.8%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

Table 29. LACFCD Dams Structural Concept Results – Low 2 Scenario

Dam Name	Mean Annual Volume Captured[a] (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Big Tujunga	12,845	14,160	22,480	10,841	2,523	64.2%	56.4%	89.5%	-7.8%	25.4%	1.15	1.06
Cogswell	19,282	21,199	29,000	8,158	359	75.5%	72.1%	98.6%	-3.4%	23.1%	0.90	0.11
Devil's Gate	9,570	10,103	16,230	6,127	0	66.9%	62.2%	100.0%	-4.7%	33.1%	1.85	0.00
Eaton Wash	3,681	4,226	5,064	854	16	86.6%	83.2%	99.7%	-3.4%	13.0%	2.20	0.06
Morris	44,980	46,067	109,524	84,465	21,026	39.8%	35.3%	83.8%	-4.5%	44.1%	0.76	0.56
Pacoima	6,219	7,927	8,546	651	31	87.0%	92.1%	99.3%	5.0%	12.2%	0.44	0.02
Puddingstone Diversion	6,452	6,783	7,298	533	19	94.9%	92.7%	99.7%	-2.2%	4.9%	0.94	0.02
San Dimas	4,474	4,471	5,564	1,144	50	82.1%	79.3%	98.7%	-2.8%	16.7%	0.94	0.08
San Gabriel	90,825	102,910	125,292	24,640	2,270	82.1%	80.7%	98.2%	-1.4%	16.1%	0.88	0.15
Totals	**198,329**	**217,846**	**328,999**	**137,412**	**26,296**	**64.6%**	**61.3%**	**92.5%**	**-3.3%**	**28.0%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

Figure 16 and Figure 17 show the Annual Volume Captured (blue) and Annual Spillway Discharge Volume (red) for the Mid 2 projected climate scenario for both the existing and proposed structural enhancements to Devil's Gate Dam. The prominence of the plot for Annual Volume Captured emphasizes the high Capture Ratios of the structural concept for this dam; and comparison of the chart of the Task 4 results provides a graphic depiction of the significant improvement of Capture Ratios resulting from the structural concept for this dam. Corresponding charts for the structural concepts for six of the other LACFCD dams are graphically similar to the charts for Devil's Gate Dam below.

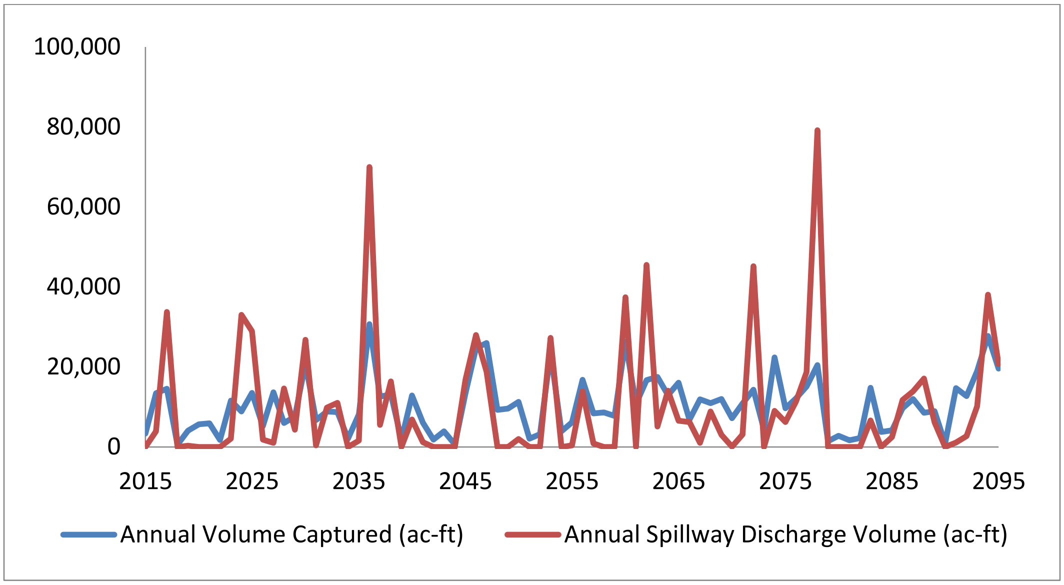

Figure 16. Existing Devil's Gate Dam Results (Task 4) – Mid 2 Scenario

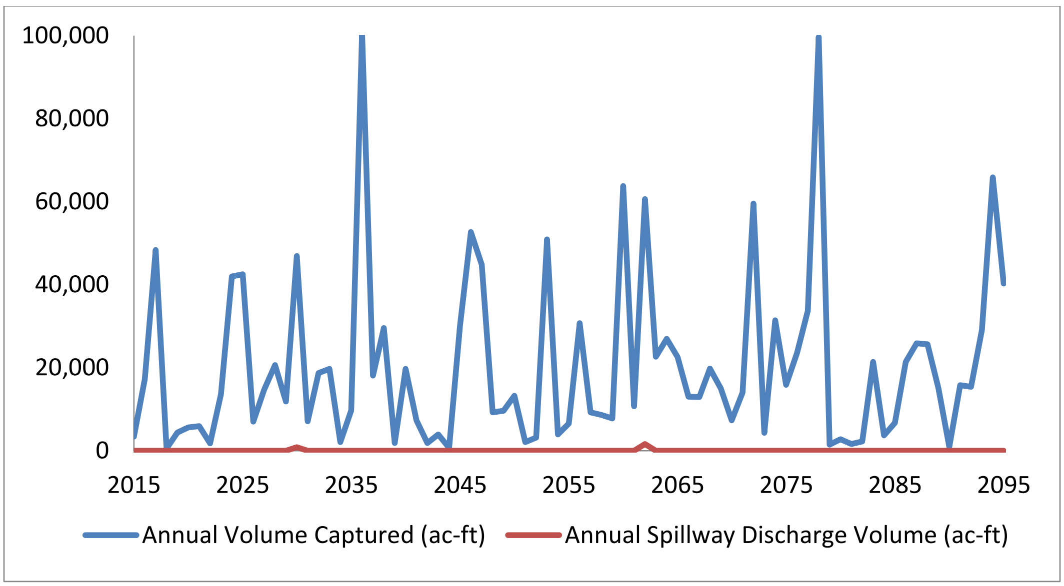

Figure 17. Devil's Gate Dam Structural Concept Results – Mid 2 Scenario

Corresponding charts for the structural concepts for Big Tujunga Dam and Morris Dam exhibit much more prominent Annual Spillway Discharge Volume plots, which emphasize the lower Capture Ratios of these two dams. As an example, the corresponding charts for Morris Dam (Figures 18 and 19) are presented below. Corresponding charts for Big Tujunga Dam are graphically similar to the charts for Morris Dam below.

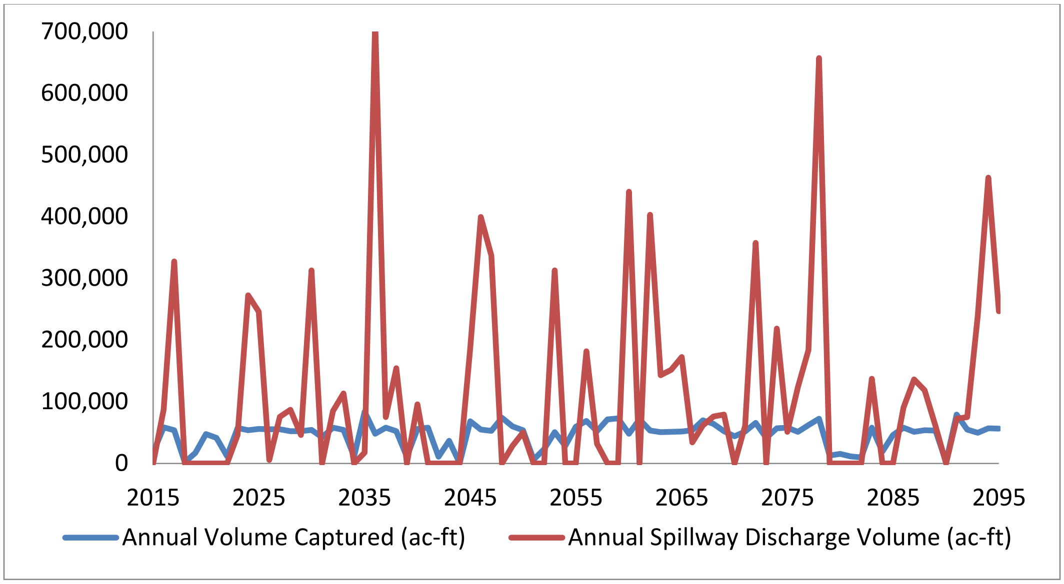

Figure 18. Existing Morris Dam Results (Task 4) – Mid 2 Scenario

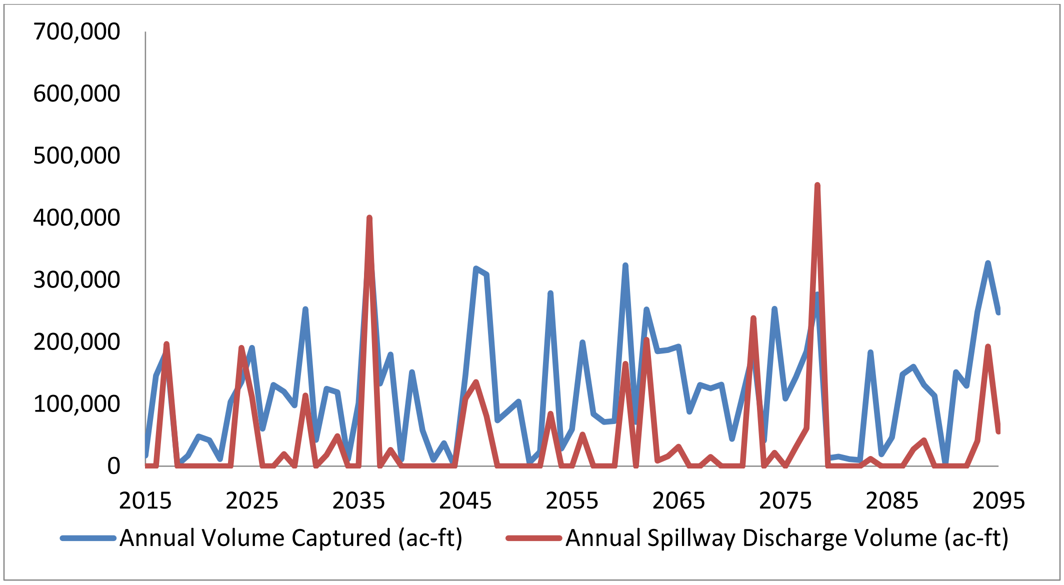

Figure 19. Morris Dam Structural Concept Results – Mid 2 Scenario

3.3.1.3 Capital and Operational Costs

A summary of the appraisal-level cost estimates for the structural concepts for each of the nine LACFCD dams considered in Task 5 is presented in Table 30. Included in this table are the estimated costs per acre-foot of water captured at each dam for the Middle 2 projected climate scenario, which was used as the design criterion for the structural concepts, as discussed in Section 2.4.1. A more extensive summary of the results for each of the projected climate scenarios for each dam is also presented in Appendix E in Table E-14 and in Figures E-7 through E-16.

Table 30. LACFCD Dams Summary of Estimated Costs of Structural Concepts (Mid 2 Scenario)

Dam Name	Estimated Total Annual Cost	Change of Mean Annual Volume Captured* (Mid 2 Scenario) (ac-ft)	Estimated Annual Cost per ac-ft of Additional Volume Captured (Mid 2 Scenario)
Big Tujunga	$1,099,474	11,786	$93
Cogswell	$1,145,670	11,762	$97
Devil's Gate	$4,634,504	9,747	$475
Eaton Wash	$1,351,402	1,277	$1,059
Morris	$3,798,384	71,853	$53
Pacoima	$3,029,836	1,259	$2,407
Puddingstone Diversion	$466,349	888	$525
San Dimas	$1,366,958	2,041	$670
San Gabriel	$10,550,903	39,404	$268
Totals	**$27,443,480**	**150,015**	**$183**

* Volume captured represents the additional stormwater available for conservation releases. It does not represent increased volume of increased recharge.

The financial strategy to fund these concepts should employ a regional approach to leverage funds from multiple partners who will realize benefits from these concepts across the region. Detailed appraisal-level cost estimates for the structural concepts for the nine selected LACFCD dams are included in the Appendix E of this report.

As discussed previously, the structural concepts for the nine LACFCD dams involved structural modifications to the dams and nonstructural modifications to the operating guidelines. The costs of developing and implementing modifications to operating guidelines are treated as incidental to the costs of structural modifications in the cost estimates for the structural concepts.

Operable weirs (e.g., pneumatic gates) and/or slide gates would be installed at the spillway(s) of each dam to allow stormwater to be captured at elevations above the spillway crest. Each cost estimate was developed by identifying major characteristics of the spillway facilities at each of the nine dams, including spillway types, dimensions and any operational controls, such as pneumatic gates, slide gates, etc.

Pneumatic gates were selected for seven dams: Big Tujunga, Cogswell, Devil's Gate, Eaton Wash, Puddingstone Diversion, San Dimas, and San Gabriel. Slide gates were selected for Pacoima Dam, which has tunnel spillways. Slide gates were also included in the concept for Devil's Gate at eleven port openings in the base of the ogee spillway headworks. Existing drum gates at the Morris Dam spillway could be used to control water up to approximately five feet below the high water elevation. These drum gates would need to be modified or replaced to enable capture of the full volume of stormwater proposed in the structural concept for this dam.

As discussed previously, capture ratios are lower for the nonstructural concepts considered in Task 5 than for either the Historic or the corresponding Task 4 projected climate scenarios for those three LACFCD dams. In addition, the nonstructural concepts considered would involve only operational changes at the dams with no significant capital improvements identified. And, since the nonstructural concepts would offer no increased benefits, no cost estimates were prepared for the nonstructural concepts.

3.3.1.4 Other Project Characteristics and Benefits

The structural concepts for LACFCD dams are climate resilient. By increasing the capture and storage of stormwater, these concepts offer opportunities for some increased flood risk management. These concepts may also provide a water quality benefit.

3.3.1.5 Nonstructural Concepts

The Rulebased simulation models represent the nonstructural concepts and were developed in an effort to optimize releases of captured stormwater, maximize utilization of spreading grounds, and optimize available reservoir storage capacity. The Rulebased simulation models were used to create hydrographs of discharge and volumes of stormwater runoff stored for the respective dam to produce discharge and hydrographs for each dam for all four projected period projections.

3.3.1.6 Results

A summary of the results for the three LACFCD dams considered for Nonstructural Concepts in Task 5 for the Mid 2 projected climate scenario is presented in Table 31. Summaries of the corresponding results for these dams considered for the other three climate scenarios analyzed in Task 5 are presented in Tables E-11 through E-13 in Appendix E. The Task 5 results for the Nonstructural Concepts for the key metrics are presented alongside the corresponding Task 4 results for comparison. Selected results are also provided for the Historical period for comparison.

Table 31. LACFCD Dams Nonstructural Concept Results – Mid 2 Scenario

Dam Name	Mean Annual Volume Captured* (ac-ft)			Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio			Capture Ratio Change from Historical		Mean Annual Frequency of Spillway Event	
	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Historical	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)	Task 4	Task 5 (Structural Concept)
Devil's Gate	9,570	10,324	9,241	9,774	10,335	66.9%	51.4%	46.0%	-15.6%	-21.0%	2.04	2.82
Eaton Wash	3,681	4,780	2,264	1,291	3,166	86.6%	78.7%	37.3%	-7.9%	-49.3%	3.14	17.43
Santa Anita	3,312	4,589	4,377	644	806	92.9%	87.6%	83.6%	-5.3%	-9.3%	1.15	1.80
Totals	**16,564**	**19,693**	**15,882**	**11,709**	**14,307**	**74.9%**	**62.7%**	**50.6%**	**-12.2%**	**-24.3%**	**NA**	**NA**

* Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

The results for the Capture Ratio metric are lower for the Task 5 Nonstructural Concepts than those for either the Historic period or for the corresponding projected climate scenarios from the Task 4 analyses. These results indicate that the flexibility of the existing operation guidelines has allowed for highly efficient operation of the dams. These results suggest that captured stormwater is released at high rates, making reservoir capacity available as quickly as the system will allow, resulting in high stormwater runoff capture ratios.

Therefore, the Nonstructural Concepts developed and analyzed for this study did not serve to identify any operational efficiency improvements at the three LACFCD dams considered. While there may be opportunities to improve the operational efficiency of the dams, these results suggest that it would be necessary to undertake a more intensive and detailed modeling effort to identify any such improvements.

3.3.1.7 Capital and Operational Costs

As discussed in the previous section, capture ratios are lower for the nonstructural concepts considered in Task 5 than for either the Historic or the corresponding Task 4 projected climate scenarios for those three LACFCD dams. In addition, the nonstructural concepts considered would involve only operational changes at the dams with no significant capital improvements identified. And, since the nonstructural concepts would offer no increased benefits, no cost estimates were prepared for the nonstructural concepts.

3.3.1.8 Other Project Characteristics and Benefits

Since no increased benefits were identified for the nonstructural concepts, no other project characteristics or benefits were identified. However, if a more intensive and detailed effort were undertaken to model the nonstructural concepts, and if that effort did identify opportunities to improve the operational efficiency of the dams, then project characteristics and benefits would be the same as those discussed in the LACFCD Dams Structural Concepts section.

3.3.2. USACE Dams

Like the LACFCD dams, a structural concept was developed for Hansen Dam in an effort to maximize capture of stormwater runoff. Because the hydrologic conditions at Hansen Dam closely resemble those at LACFCD Big Tujunga Dam upstream, the structural concept for Big Tujunga Dam was used as the template for the structural concept for Hansen Dam. To do this, the Task 5 F-Table for Big Tujunga Dam was scaled and modified for the development of a new F-Table for Hansen Dam.

3.3.2.1 Results

A summary of the results for Hansen Dam for each of the four climate scenarios analyzed in Task 5 is presented in Table 32. The Task 5 results for the key metrics are presented for comparison alongside the corresponding updated Task 4 results. Selected results are also provided for the Historical period.

As with the LACFCD Dams, the Capture Ratios for the Structural Concept are typically higher for the drier scenarios. Additionally, Capture Ratios were found to be higher for the Task 5 Structural Concepts than for either the Historic or the corresponding Task 4 projected climate scenarios.

3.3.2.2 Capital and Operational Costs

Limited study resources constrained the investigation by the Study Team of USACE dams. Estimates of capital and operational costs were not developed for Hansen Dam.

3.3.2.3 Other Project Characteristics and Benefits

Project characteristics and benefits would be the same as those discussed for the LACFCD Dams Structural Concepts in Section 3.3.1.4.

3.3.2.4 Concepts at Other USACE Dams

Due to limited study resources, a detailed concept could only be developed for Hansen dam; however, a number of high-level recommendations were identified for future efforts towards improving the water conservation of the other USACE dams. Santa Fe, Sepulveda, and Whittier Narrows Dams require a more in-depth analysis, but the following are a number of opportunities that could be explored further in future studies.

- Conduct a more in-depth feasibility study to increase water conservation
- Increasing the storage capacity behind the dam through sediment removal
- Increasing the dam and spillway heights to provide additional storage
- Improving functionality of the dam outlook works for water conservation
- Improving downstream spreading grounds intake capacity
- Developing a seasonal water conservation pool similar to Prado Dam

Although the LA Basin Study is investigating stormwater conservation and places a great emphasis on capturing stormwater for recharge, the USACE dams will need to continue to address flood control. The USACE dams’ primary purpose is flood risk management and it must not be compromised by proposed changes for water conservation. Therefore, any stormwater conservation concepts will need to work within the flood control mandate that the USACE adheres to. However, a balanced approach of stormwater conservation and flood control should be able to be achieved to make the region become more resilient to climate change. Future study of these USACE dams and enhanced partnerships with agencies interested in increasing stormwater capture should be pursued.

Table 32. Hansen Dam Structural Concept Results

Scenario	Mean Annual Inflow (ac-ft)		Mean Annual Volume Captured[a] (ac-ft)		Mean Annual Spillway Discharge Volume (ac-ft)		Capture Ratio		Capture Ratio Change from Historical		Mean Annual Frequency of Water Conservation Rate Exceedances	
	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)	Task 4 (Updated)	Task 5 (Structural Concept)
Historical	37,181	NA	18,523	NA	18,659	NA	49.8%	NA	NA	NA	4.12	NA
High 1	96,128	96,099	24,633	36,448	71,495	59,650	25.6%	37.9%	-24.2%	-11.9%	3.99	1.56
Middle 2	55,605	55,588	19,518	27,555	36,088	28,033	35.1%	49.6%	-14.7%	-0.2%	3.36	1.01
Low 1	27,019	27,012	13,610	17,379	13,410	9,633	50.4%	64.3%	0.6%	14.5%	2.86	0.50
Low 2	44,773	44,760	19,494	27,230	25,278	17,530	43.5%	60.8%	-6.3%	11.0%	3.75	0.92

Note:
[a] Volume captured does not indicate volume of water used for stormwater recharge. Volume captured indicates total increased volume of storage available for potential water conservation use.

3.3.3. Debris Basins

The Debris Basins project group assumes select debris basins will be modified with controlled outflow works to temporarily store and then release stormwater to downstream spreading basins to increase groundwater recharge. A preliminary screening of the LACFCD debris basins was performed to identify candidate basins for modification. Debris basins with the largest storage capacities and located upstream of spreading grounds were identified for modification. These modifications could require future pipelines or construction of other facilities to allow for increased percolation downstream. Further studies would be required to determine the exact nature of these facilities.

Regular maintenance to remove sediment and other debris is needed to maintain the flood control and debris function. For this alternative, maintenance after storm events is critical to restore the basin storage capacity for flood risk management. In addition, more frequent sediment removal will be required to maintain storage capacity for stormwater conservation

Figure 20 shows a typical section of the debris basin and Figure 21 shows the location of the selected debris basins. Table 33 summarizes their characteristics. Appendix B includes a factsheet that summarizes features of the debris basin project.

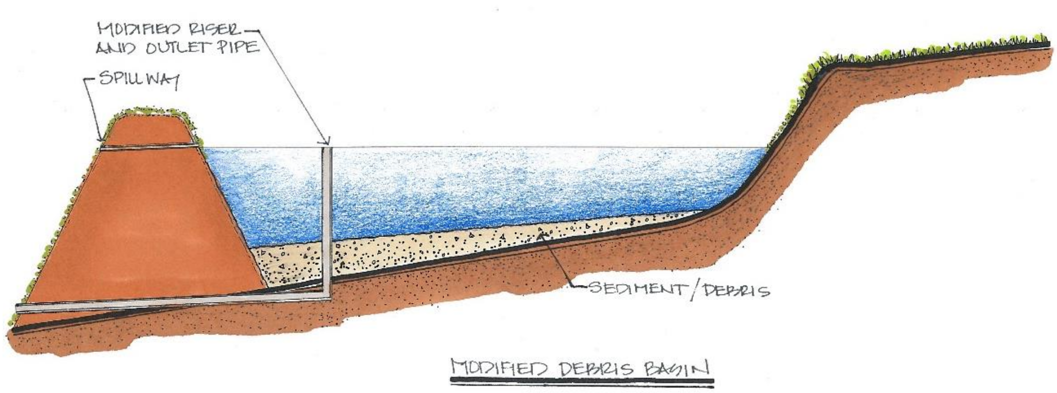

Figure 20. Schematic of Debris Basin Modification

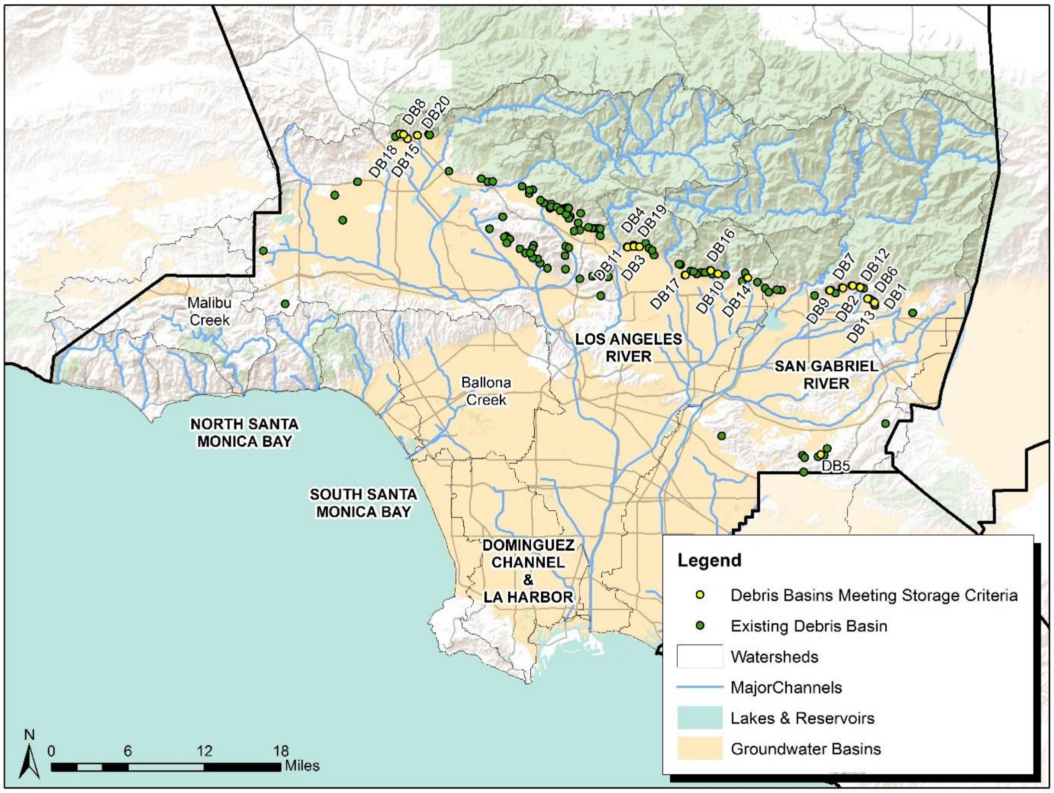

Figure 21. Debris Basins

3.3.3.1 Results

Installation of outlet structures at the 20 debris basins will provide a storage capacity of approximately 552 acre-feet which can be utilized to capture stormwater and infiltrate it at the downstream spreading grounds. Implementation of the Debris Basins concepts will provide approximately 145 acre-feet of stormwater conservation per year based on the Mid 2 projected climate scenario. Table 36 summarizes the modeled change in the future long-term average of stormwater conservation by watershed relative to baseline conditions.

The amount of stormwater conserved, shown in Table 34, is very low relative to other stormwater capture alternatives investigated for this study. Sediment loading to the basins under the climate scenarios was not evaluated explicitly, but sedimentation is expected to increase under hotter climate scenarios due to increased wildfire risks, which may limit the surface water storage capacity and climate resiliency of this project group.

3.3.3.2 Other Project Characteristics and Benefits

This concept offers limited opportunities for habitat benefits because it does not include new right-of-way designated for this purpose. It was assumed that recreational trails would be built around a portion of the perimeter of the 20 modified basins providing approximately 3,270 linear feet of trail.

Table 33. Debris Basins

ID	Facility	Storage (ac-ft)	ROW (acres)	Habitat (acres)	Recreation Trails (feet)
DB1	Crescent Glen	6.2	-	-	92.9
DB2	Englewild	13.8	-	-	129.1
DB3	Fair Oaks	9.1	-	-	119.5
DB4	Fern	10.2	-	-	84.1
DB5	Fullerton (PD2202-U2)	5.4	-	-	86.1
DB6	Gordon	7.4	-	-	87.8
DB7	Harrow	10.3	-	-	167.7
DB8	Hog	7.2	-	-	114.8
DB9	Hook West	7.6	-	-	112.0
DB10	Lannan	5.3	-	-	84.5
DB11	Lincoln	11.0	-	-	103.5
DB12	Little Dalton	182.5	-	-	443.9
DB13	Morgan	13.9	-	-	114.6
DB14	Sawpit	77.8	-	-	195.5
DB15	Schoolhouse	16.4	-	-	253.4
DB16	Sierra Madre Dam	35.7	-	-	136.6
DB17	Sierra Madre Villa	59.8	-	-	319.6
DB18	Sombrero	11.6	-	-	89.7
DB19	West Ravine	11.3	-	-	340.9
DB20	Wilson	49.4	-	-	193.6
Total		**552**			**3,270**

Table 34. Stormwater Conserved for Debris Basins

Watershed	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Los Angeles River	34	34	48	63
San Gabriel River	52	69	97	167
Total	**86**	**104**	**145**	**230**

3.3.3.3 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Unit rates for riser and basin modification were derived from previous estimates. O&M includes costs for more frequent sediment removal. The resulting O&M costs were annualized over a 50-year analysis period. A summary of the Debris Basin concept costs are presented below.

- **Capital Cost:** $41,000,000
- **O&M Cost:** $1,300,000/year
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $13,100 to $35, 900

Refer to Appendix D for a more detailed summary of capital and operational costs.

3.4. Management Solutions

Management Solutions represent considerable improvements and more ambitious enhancements to the Local Solutions discussed in Section 3.1. The general assumption is that the implementation of Local Solutions may not be achieved quickly and that widespread uptake would likely occur over a long period of time. Some of the Management Solutions may speed up the incremental increase of stormwater for each year until 2095.Management Solutions consists of three main project groups:

- Stormwater Policies
- Green Infrastructure Programs
- Regional Impact Programs

The results of the appraisal-level analysis for each of these project groups are presented below.

3.4.1. Stormwater Policies

Stormwater Policies are non-constructed control measures that encourage stormwater conservation. In general, these policies work towards aligning stormwater regulatory frameworks to share regional goals for water supply and promoting new technology and strategies that can help to increase stormwater capture over the region. Concepts range from utilizing Enhanced Watershed Management Programs (EWMPs) for stormwater conservation and streamlining regulatory requirements for maintenance of existing and urbanized stormwater infrastructure, to developing a rainfall-hydrology model to quantify pre-storm runoff capture and developing a “feed-in-tariff” for residents who infiltrate stormwater into the local groundwater basins.

Using the methodology described in Section 2, the additional implementation area that could be added to the LID and Complete Streets implementation area is shown in Figure 22.

3.4.1.1 Results

The WMMS model was run for four climate projections. For the Mid 2 projected climate scenario, implementation of Stormwater Policies will provide approximately 191,096 acre-feet of stormwater conservation per year. Table 35 summarizes the future long-term average of stormwater conserved per year in each watershed for each climate scenario. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

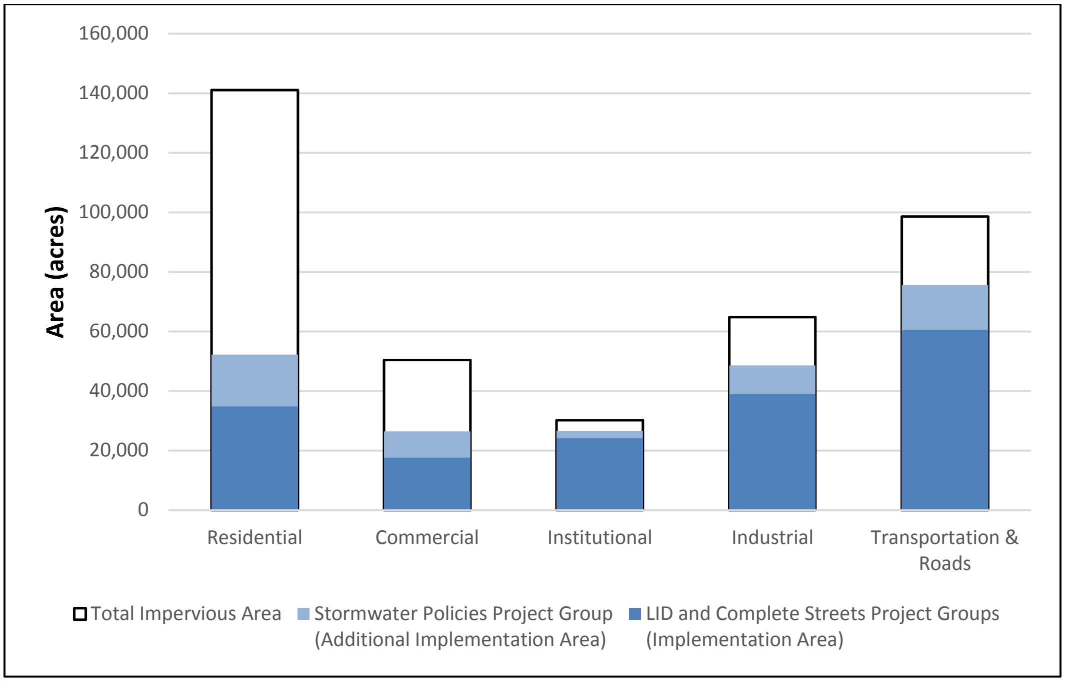

Figure 22. Implementation Area – Stormwater Policies Project Group

Table 35. Stormwater Conserved for Stormwater Policies

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	20,872	22,286	24,576	27,118
Dominguez Channel	70,428	14,515	15,444	17,430	19,447
Los Angeles River	533,840	65,849	75,961	84,286	103,045
Malibu Creek	129,825	2,147	2,475	2,559	2,820
San Gabriel River	434,475	49,690	55,849	62,246	73,371
Total	**1,303,657**	**153,073**	**172,015**	**191,096**	**225,800**

The Los Angeles River watershed represents the largest volume of stormwater conserved due to the large size of the watershed. However, the Dominguez Channel has the highest percentage of stormwater conserved relative to watershed area because the watershed is highly impervious with a large percentage of institutional and industrial land uses. These land uses, because they are highly regulated, are assumed to have a higher LID implementation rate than land uses that are not closely regulated (e.g., residential). Watersheds that are less impervious (e.g., Malibu Creek) have a lower percentage of stormwater conserved relative to watershed area.

The Stormwater Policies management solution combines the LID and Complete Streets models and increases the efficiency and implementation rates above the model values through changes in stormwater policies. LID and Complete Streets provide a large volume of stormwater conservation because they can be implemented over a wide range of land uses across the study area. As shown in Table 35, the modeled stormwater conservation ranges from approximately 153,000 to 226,000 AFY for the dry Low 1 and wet High 1 climate scenarios. The total volume of stormwater conservation and adaptive capacity under wet conditions illustrate the resilient nature of Stormwater Policies.

3.4.1.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). A breakdown of BMP types were assumed for each land use to determine unit costs. No property acquisition was assumed for this concept. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period.
A summary of the Stormwater Policies concept costs are presented below.

- **Capital Cost:** $20,443,000,000
- **O&M Cost:** $912,000,000/year
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $7,800 to $11,500

3.4.1.3 Other Project Characteristics and Benefits

Project characteristics and benefits are the same as those discussed for Low Impact Development and Complete Streets (see Section 3.1.2 and Section 3.1.3, respectively). And specifically for habitat benefits, it is estimated that Stormwater Policies could contribute 1,798 acres of improved habitat.

3.4.2. Green Infrastructure Programs

Green Infrastructure Programs encourage implementation of LID across the watershed. When deployed across numerous parcels throughout the watershed, LID projects can collectively make a significant impact on stormwater capture. LID can retain rainfall at the source before it runs off from the parcel and travels downstream.

The Municipal Separate Storm Sewer System (MS4) Permit and local ordinances require significant development and redevelopment projects to incorporate LID concepts into their site design. Existing residential parcels also provide an important opportunity for LID implementation. Runoff from residential parcels often flow directly to a curb and gutter or other conveyance system on the street. A well-designed residential LID or “urban acupuncture” program including rain tanks, rain grading, parkway stormwater basins, permeable surfaces and infiltration trenches can engage individual homeowners to reduce their contribution to stormwater runoff.

Using the methodology described in Section 2, the additional implementation area that could be added to the LID implementation area is shown in Figure 23.

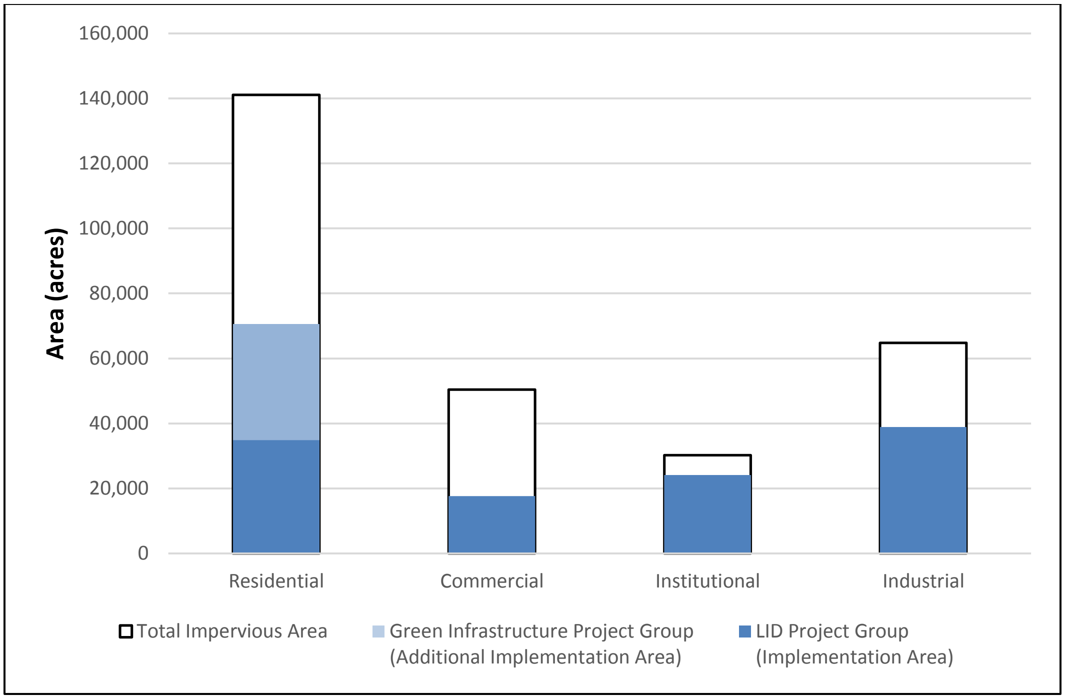

Figure 23. Implementation Area – Green Infrastructure Project Group

3.4.2.1 Results

The WMMS model was run for four climate projections. For the Mid 2 projected climate scenario, implementation of Stormwater Policies will provide approximately 123,510 acre-feet of stormwater conservation per year. Table 36 summarizes the future long-term average of stormwater conserved per year in each watershed for each climate scenario. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 36. Stormwater Conserved for Green Infrastructure Programs

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	11,833	12,785	13,765	15,105
Dominguez Channel	70,428	8,608	9,312	10,180	11,280
Los Angeles River	533,840	41,242	47,370	52,570	63,966
Malibu Creek	129,825	1,752	1,878	1,923	2,107
San Gabriel River	434,475	36,305	40,583	45,073	52,837
Total	**1,303,657**	**99,741**	**111,928**	**123,510**	**145,295**

The Los Angeles River watershed represents the largest volume of stormwater conservation due to the large size of the watershed. However, the Dominguez Channel has the highest percentage of stormwater conservation relative to watershed area because the watershed is highly impervious with a large percentage of institutional and industrial land uses. These land uses, because they are highly regulated, are assumed to have a higher LID implementation rate than land uses that are not closely regulated (e.g., residential). Watersheds that are less impervious (e.g., Malibu Creek) have a lower implementation rate of LID.

The Green Infrastructure Programs project group uses the LID model as a baseline and increases the implementation rates above the model values. LID projects provide a large volume of stormwater conservation because they can be implemented over a wide range of land uses across the study area. As shown in Table 36, the modeled stormwater conservation ranges from approximately 100,000 to 145,000 AFY for the dry Low 1 and wet High 1 climate scenarios. The total volume of stormwater conservation and adaptive capacity under wet conditions illustrate the resilient nature of Green Infrastructure Programs..

3.4.2.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). A breakdown of BMP types were assumed for each land use to determine unit costs. No property acquisition was assumed for this concept. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period.
A summary of the Green Infrastructure Programs concept costs are presented below.

- **Capital Cost:** $12,508,000,000
- **O&M Cost:** $564,000,000/year
- **Land Acquisition:** $0
- **Cost per Acre-foot:** $7,500 to $10,900

3.4.2.3 Other Project Characteristics and Benefits

Project characteristics and benefits are the same as those discussed in Low Impact Development (see Section 3.1.2). And specifically for habitat benefits, it is estimated that Green Infrastructure Programs could contribute 857 acres of improved habitat.

3.4.3. Regional Impact Programs

Regional Impact Programs encourage Local Stormwater Capture concepts across the watershed and regional implementation of a floodplain reclamation program. Local Stormwater Capture concepts are comprised of facilities that receive moderate volumes of stormwater runoff from upstream areas for infiltration and stormwater retention. Floodplain reclamation considers buying back properties adjacent to the channels as they become available and returning the land to a restored waterway that provides natural areas for recharge, habitat, and other beneficial uses. Figure 24 shows a typical cross section of a restored waterway. Floodplain reclamation could be implemented as a new program that uses funds that would otherwise have been paid as flood insurance, through Enhanced Infrastructure Financing Districts, or from partnering with other agencies.

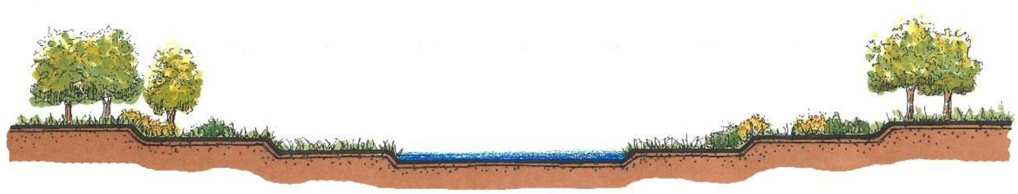

Figure 24. Floodplain Reclamation Typical Section

This project group can be driven by continuing to place an ever greater emphasis on a watershed approach to managing stormwater, which could result in policies and programs that explore floodplain reclamation, further improving storage in groundwater basins to reduce evapotranspiration losses, and minimizing stormwater runoff from individual sites. Additionally, available space within the urban environment should be beneficially used for stormwater capture. The benefits of promoting improved stormwater stewardship can be made clear to the public to help raise awareness for the importance of stormwater and can help the region more rapidly adapt to climate change.

3.4.3.1 Results

Before presenting the results of Regional Impact Programs, it is important to note that the vast majority of benefit for this project group stems directly from the assessment of floodplain reclamation. For more information on how floodplain reclamation was modeled, and the assumptions used, please refer to Appendix C, Section 2.12.

The WMMS model was run for four climate projections. For the Mid 2 climate scenario, implementation of regional impact programs projects will provide approximately 145,400 ac-ft of stormwater conservation per year. Table 37 summarizes the future long-term average of stormwater conserved per year in each watershed for each climate scenario. The values listed are the net results and have been adjusted to account for any reduction in conservation at regional facilities.

Table 37. Stormwater Conserved for Regional Impact Programs

Watershed	Watershed Area (acres)	Low 1 (AFY)	Low 2 (AFY)	Mid 2 (AFY)	High 1 (AFY)
Ballona Creek	135,090	786	1,032	1,083	1,290
Dominguez Channel	70,428	82	103	115	140
Los Angeles River	533,840	71,947	103,474	117,162	159,320
Malibu Creek	129,825	8	8	9	11
San Gabriel River	434,475	19,158	24,941	27,026	34,611
Total	**1,303,657**	**91,981**	**129,557**	**145,395**	**195,372**

The Los Angeles River watershed represents the largest volume of stormwater conservation based on total volume and also as a percentage of watershed area. This is due primarily to the significant amount of water conserved through floodplain reclamation and the relative favorable soil and aquifer conditions for stormwater capture in the Los Angeles River watershed compared to other watersheds. The San Gabriel River, although a fairly large watershed as well, has historically very high levels of stormwater capture through numerous spreading grounds and soft bottom channel reaches (LACFCD, 2014b), so there is not as much runoff to capture as compared to the Los Angeles River.

The Regional Impact Programs management solution uses the Local Stormwater Capture model as a baseline and increases the parcel area that can be used for an infiltration BMP. The model also includes stormwater conservation benefits from floodplain reclamation and river improvement projects. As shown in Table 37, the modeled stormwater conservation ranges from approximately 92,000 to 195,000 AFY for the dry Low 1 and wet High 1 climate scenarios. The total volume of stormwater conservation is somewhat large compared to other project groups, and the adaptive capacity under wet conditions illustrates the resilient nature of Regional Impact Programs. The majority of the volume is based on floodplain reclamation and river improvement projects that have a significant impact on groundwater recharge and provides resiliency in stormwater conservation when more water is available.

3.4.3.2 Capital and Operational Costs

Capital costs were developed based on a line item unit cost approach. Quantities of each line item were calculated based on the BMP storage volume and typical design configurations. The unit costs for the local stormwater capture projects were derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014). An additional property acquisition cost was assumed for purchase of private open space parcels totaling approximately 2,655 acres for the use of Local Stormwater Capture concepts, and private parcels with existing residential and commercial uses along channel systems totaling 4,941 acres. An O&M cost was calculated using BMP storage volumes and unit costs derived from the LADWP Stormwater Capture Master Plan (Geosyntec, 2014) and annualized over a 50-year analysis period. A summary of the Regional Impact Programs costs are presented below.

- **Capital Cost:** $50,103,000,000
- **O&M Cost:** $1,055,000,000/year
- **Land Acquisition:** $20,596,000,000
- **Cost per Acre-foot:** $20,500 to $43,500

3.4.3.3 Other Project Characteristics and Benefits

Regional Impact Programs provide significant multiple benefits besides the retention of stormwater. Floodplain reclamation is an important component of the Regional Impact Programs and provides many of the additional benefits in addition to the significant amount of stormwater conserved. Floodplain reclamation would restore the natural waterways and provide recreation and habitat areas, while also providing water quality and aesthetic benefits. In addition to stormwater conservation, complementary benefits may include, but are not limited to, flood risk management, water quality improvements, new recreational opportunities, habitat/connectivity enhancements, ecosystem function, cooling impacts on urban heat island, and climate resiliency. These other benefits can help to identify project partners as concepts with multiple benefits can help to leverage funding.

4. Stormwater Capture Findings

The key objectives of Task 5 were to identify and develop long-term structural and nonstructural (i.e., management techniques) concepts and climate adaptation strategies to manage stormwater under future conditions. These concepts built upon projected climate conditions and population changes in the Los Angeles Basin. Potential changes to the operation of stormwater capture systems, modifications to existing facilities, and development of new concepts were analyzed to help resolve future water supply and flood risk management issues.

The 12 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. These alternatives were identified and analyzed to determine their potential stormwater conservation benefits and associated costs. It is important to note that any future iterations and changes in assumptions will alter the stormwater conservation benefits and costs for each of the different concepts. A summary of the benefits and costs—*as studied*—for each alternative is presented in Table 38.

4.1. Stormwater Conservation

Stormwater is an invaluable local resource to the region. Currently, stormwater plays a significant role in the LA Basin's water supply portfolio by helping the region meet its water demand. Looking ahead, stormwater will play an ever larger role by providing local resiliency to future climate change stressors on the Los Angeles region's water supply. The LACFCD already recharges a significant amount of stormwater at regional spreading basins, but there is potential for enhancements to existing stormwater capture infrastructure, as well as development of new infrastructure and techniques to provide greater capacities to adapt to climate change impacts.

It is important to note that the estimated stormwater conservation benefits associated with each the 12 different project groups are based upon full implementation—or complete "build out"—of each individual concept. However, if any of the concepts are not fully implemented, then the stormwater conservation benefits quantified along with any additional benefits may not be entirely realized.

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

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 provides approximately 153,000 to 225,800 AFY of stormwater conservation. The Regional Impacts Programs project group consists of increased local stormwater capture and floodplain reclamation, and provides approximately 92,000 to 195,400 AFY of stormwater conservation.

To help the region enhance its climate resiliency, a variety of stormwater capture concepts has been investigated to provide a diverse future portfolio. The maximum potential for stormwater conservation across the region would vary significantly depending on how the project groups are ultimately combined and implemented, as well as impacts due to climate variability. From the Task 2 water supply 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 in an average year. If new stormwater infrastructure is constructed and should robust policies be implemented, there will 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 bolster 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.

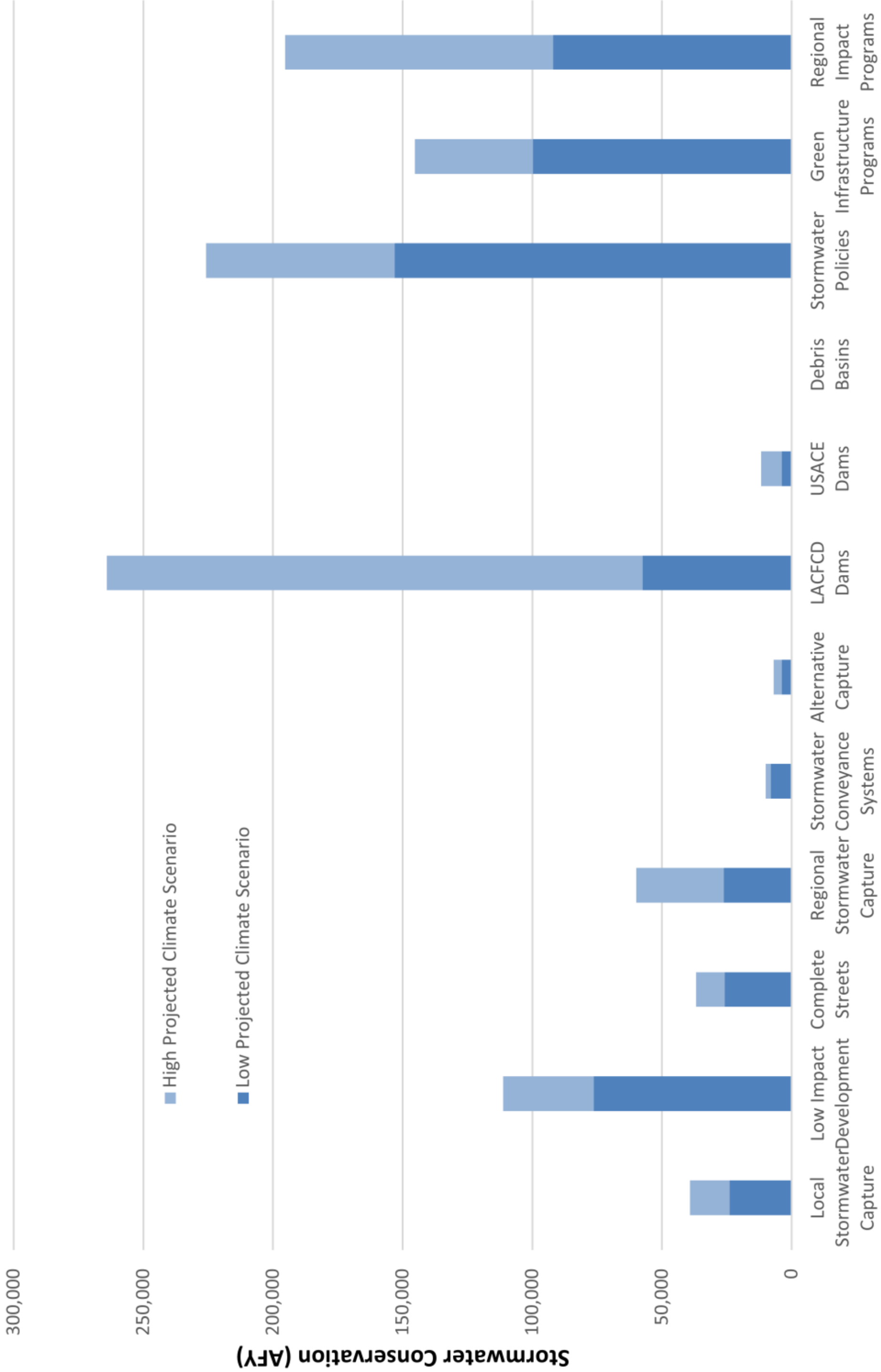

Figure 25. Stormwater Conservation Comparison by Conceptual Project Groups

Table 38. 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 111,200	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]	153,100 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 195,000	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

4.2. Capital and Operational Costs

Capital and O&M costs were developed for each project group, and the costs were annualized over a 50-year analysis period. The resulting annual cost per acre-foot of stormwater conserved may be used as a preliminary estimate of the cost effectiveness for each of the 12 project groups. Figure 26 below shows a comparison of the cost per acre-foot of stormwater for the various project groups.

Although the LACFCD Dams project group provides the most stormwater surface storage and appears to be the most cost effective, it should be noted that this is only increased surface storage and would need to be released in such a way that it could be captured and infiltrated downstream.

Of the Regional Solutions, Regional Stormwater Capture is the least costly, and second least costly overall. Regional Stormwater Capture provides approximately 26,100 to 59,900 AFY of stormwater conservation, with a cost of $900 to $2,100 per AFY compared to other project groups.

In the Management Solutions, the Stormwater Policies estimates high volumes of stormwater conservation because of the potential widespread implementation of LID, but is more costly to implement than the Regional Stormwater Capture and LACFCD Dam project groups. The estimated cost is $7,800 to $11,500 per AFY. Within Local Solutions, Local Stormwater Capture and Low Impact Development are in a very similar range of costs with the Stormwater Policies. Local Stormwater Capture ranges between $8,800 to $14,400 per AFY and Low Impact Development ranges between $7,700 to $11,200 per AFY. With these higher cost estimates, however, it is important to note that the costs would be shared across the region as concepts are implemented.

The financial strategy to fund these concepts will require a coordinated, regional approach to leverage funds from multiple partners who will realize benefits from these concepts across the region. For example, LACFCD, LADWP, and USACE could share project capital and operational costs for those facilities that mutually benefit all three. Some of the costs for LID implementation may be funded by private developers to incorporate LID concepts into their new or redeveloped sites. Other costs for residential stormwater BMPs may be taken on by homeowners seeking to retrofit their properties with LID features such as rain barrels. Incentive programs can potentially be aligned with existing water conservation programs such as turf replacement or watershed management incentives.

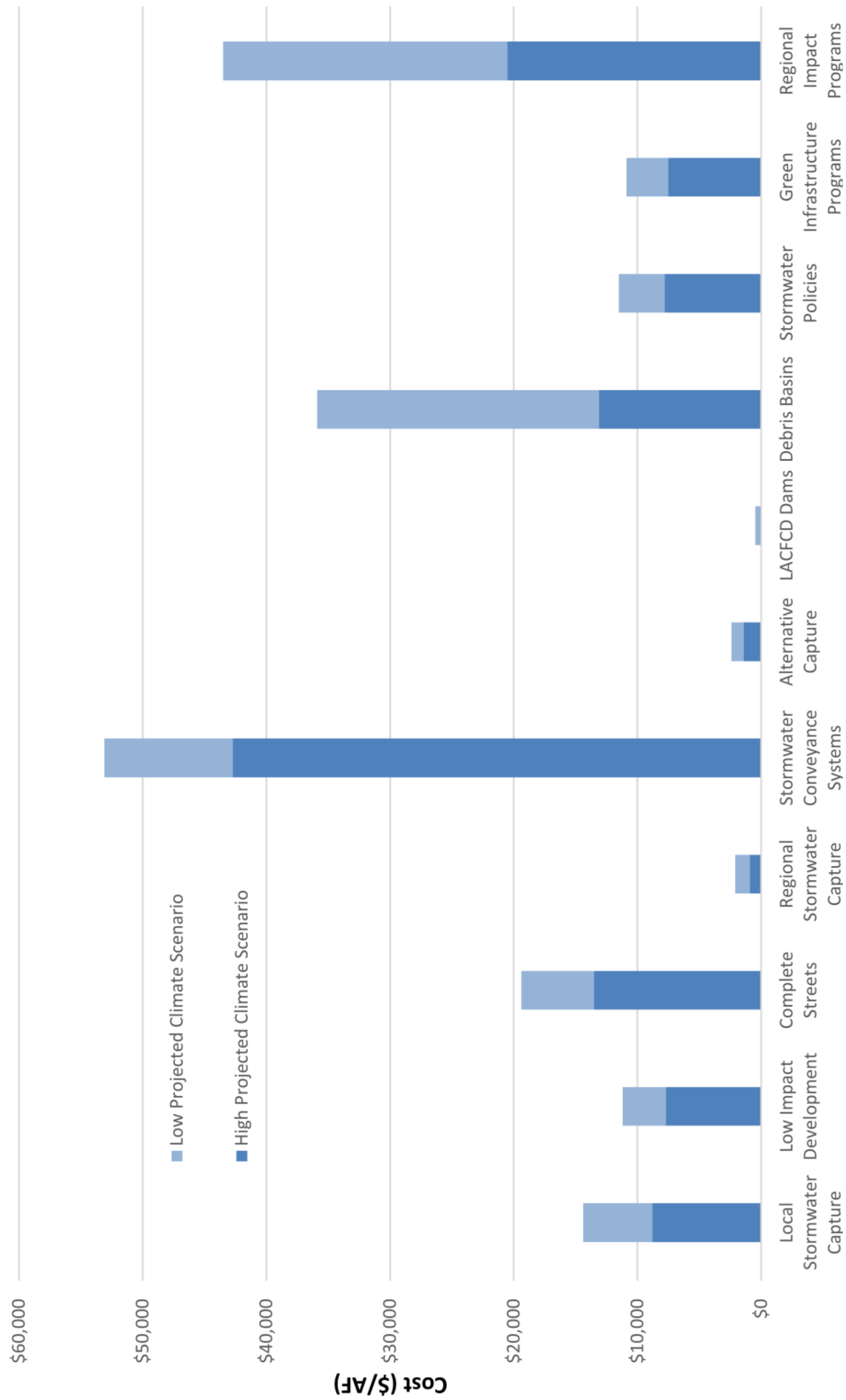

Figure 26. Cost per Acre-foot Conserved Comparison by Conceptual Project Groups

4.3. Other Project Characteristics and Benefits

Most of the 12 different project groups provide multiple benefits besides the main focus of stormwater capture. In addition to stormwater conservation, complementary benefits may include, but are not limited to, increased flood risk management, improved water quality, new recreational opportunities, habitat/connectivity enhancements, ecosystem functions, climate resiliency and other climate adaptive measures. These other benefits could help to identify project partners as concepts with multiple benefits help to leverage funding. The additional benefits are summarized in Table 39.

Local Stormwater Capture and the Regional Solutions project groups can provide community enhancement through bikeways or passive walking and hiking trails, in addition to habitat restoration. Naturalized infiltration basins can enhance plant and bird habitats, provide educational opportunities, and mitigate the urban heat island effect. Underground systems can allow the current use of a site to be continued and used as a park or sports field while simultaneously managing stormwater.

In addition to stormwater management, green streets have been demonstrated to provide “complete streets” benefits, including pedestrian safety and traffic calming, street tree canopy and urban heat island effect mitigation, increased property values, and a boost in economic activity and visibility of storefront businesses. The additional benefit of climate resiliency helps to prepare the region for a changing climate by offering projects that increase water supply and reduces vulnerability to adverse climate change impacts.

Table 39. Summary of 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

4.4. Opportunities for Future Collaborative Partnerships

There are a number of recently completed or major ongoing programs, studies, and collaborative frameworks in the Los Angeles region related to stormwater management. Collaboration and coordination with these efforts is necessary and will provide opportunities to share in the development and costs of implementing projects to achieve multi-benefits. Several of the more important efforts are discussed below.

4.4.1. Enhanced Watershed Management Programs

Several Enhanced Watershed Management Programs (EWMP) have been developed in the Los Angeles region for management of stormwater flows. The purpose of the EWMPs is for water quality improvement in the receiving water for regulatory compliance with the 2012 Los Angeles County MS4 Permit, through a comprehensive evaluation of opportunities for multi-benefit regional projects that, where feasible, would capture and retain urban and storm water runoff for beneficial uses. The EWMPs are developed through collaborative approaches between permittees within the watershed. The vision for development of the EWMPs is to utilize a multi-pollutant approach that maximizes 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. The EWMPs determine the network of control measures, or BMPs, that will achieve required pollutant reductions while also providing multiple benefits to the community and leveraging sustainable green infrastructure practices.

Achieving the stormwater capture values identified in the EWMPs will be accomplished by a range of watershed control measures, which are strategies and BMPs implemented to address applicable stormwater quality regulations. Some of these watershed control measures will also provide water supply benefits through groundwater recharge or direct use. Other BMPs may improve water quality of runoff prior to discharging to receiving water or infiltrating as perched groundwater. Regional projects are described in the EWMPs as “centralized facilities located near the downstream ends of large drainage areas, typically treating 10s to 100s of acres.” (Draft Upper LA River EWMP, June 2015). In addition, distributed, or decentralized, BMPs include the network of LID and green streets as part of the EWMP implementation strategy. EWMPs are subject to a two-year update cycle pursuant to the adaptive management provisions of the MS4 Permit.

Some of the modeling assumptions for the LA Basin Study were similar to the EWMPs. The screening analysis conducted for the LA Basin Study used similar

GIS criteria such as: parcel ownership, land use, parcel size, and proximity to a 36-inch storm drain or open channel.

4.4.2. Greater LA Water Collaborative

A coalition of agency partners, including the LADWP, LASAN, and the LACFCD joined to form the Greater LA Water Collaborative (formerly known as the Multi-Agency Collaborative). The vision of the partnership is to craft integrated solutions to achieve climate-resiliency and be better protected from flooding and drought. TreePeople, local non-profit organization, is intimately involved with this Collaborative to maximize the benefits between the agencies for this unique partnership. The Collaborative's StormCatcher Project is currently retrofitting up to ten homes with cisterns and rain gardens to demonstrate how residents can help the region secure a climate-resilient future by capturing stormwater at home. The StormCatcher Project features advanced cisterns, equipped with cloud-based monitoring and controls to optimize system performance in real time. The StormCatcher Project is an example of how government agencies can partner with the public to meet goals for water sustainability.

The activities undertaken by the Greater LA Water Collaborative have been captured in the LA Basin Study analysis. The LA Basin Study's modeling approach for LID assumes that LID implementation would be implemented basin wide. The implementation percentages were taken from the Task 3.2 Report for different land uses. The Stormwater Policies and Green Infrastructure Programs assume an increase in residential implementation rates, as those programs encourage homeowners to willingly implement LID on their properties.

4.4.3. Greater Los Angeles County Integrated Regional Water Management Plan

The Greater Los Angeles County (GLAC) Integrated Regional Water Management (IRWM) Region covers an area that serves approximately 10 million residents, portions of four counties, 84 cities, and hundreds of agencies and districts. The first GLAC IRWM Plan was first prepared in 2006 and the most recent update was completed in 2013. The 2013 update, *The Greater Los Angeles County Integrated Regional Water Management Plan, 2013 Update,* provides a water supply targets and, most importantly, a regional framework that ensures agencies across the region who have varying responsibilities when it comes to water coordinate their planning efforts to maximize project benefits and minimize costs.

The GLAC Region is divided into five sub-regions for ease of governance and maximizing stakeholder participation:

- Lower San Gabriel and Los Angeles Rivers
- North Santa Monica Bay
- South Bay
- Upper Los Angeles River
- Upper San Gabriel and Rio Hondo Rivers

The GLAC Region maintains a website at www.lawaterplan.org to facilitate the accessibility of the IRWM Plan information to stakeholders. A database of related projects called Opti is maintained by regional participants with projects classified by primary benefits of water supply/groundwater, water quality, habitat/open space/recreation, and flood. There are roughly 135 water supply/groundwater projects currently listed. As part of future LA Basin Study concept implementation, a review of the GLAC project list should be conducted to identify potential opportunities for collaboration and cost sharing.

4.4.4. Greenways to Rivers Arterial Stormwater System

The Greenways to Rivers Arterial Stormwater System (GRASS) Vision Plan was developed for the City of Los Angeles Department of Public Works Bureau of Sanitation (LASAN) in 2013. The project establishes a method to implement appropriate LID infrastructure within the upper LA River watershed, while addressing the issue of park poverty. The GRASS project focuses on existing streets with wide corridors, bike routes, bus routes, and existing storm drains, which make up a Regional Green Network. Two priority areas were identified that connects major destinations like schools, parks, and civic institutions. The two priority areas were overlapped with a series of five classes to identify appropriate locations for stormwater infiltration, capture and reuse, and treatment BMPs.

The City will use the GRASS Vision Plan as a planning document to ultimately reduce pollutant loads in the LA River while addressing regional park poverty with a system of greenways throughout Greater Los Angeles. The LA Basin Study assumes implementation of BMPs throughout all transportation corridors within the watershed. The ratio of implementation for transportation land uses were taken from the Task 3.2 Report of the LA Basin Study. Thus, the areas and stormwater capture volumes identified in the GRASS represent a portion of the stormwater capture volume identified in the LA Basin Study.

4.4.5. Los Angeles River Ecosystem Restoration Feasibility Study

The USACE Los Angeles District and its local sponsor, the City of Los Angeles, developed a plan for restoring the ARBOR (Area with Restoration Benefits and Opportunities for Revitalization) study area. The 11-mile ARBOR reach of the

Los Angeles River extends from approximately Griffith Park to downtown Los Angeles.

The Recommended Plan of the Los Angeles River Ecosystem Restoration Feasibility Study is the Locally Preferred Plan, referred to as Alternative 20 or RIVER (Riparian Integration via Varied Ecological Reintroduction). Certification of the Final Integrated Feasibility Report and approval of the proposed Project by the City of Los Angeles is expected in early 2016. Alternative 20 is divided into eight reaches that would restore a total of 719 acres.

In addition to removal of invasive species throughout the project footprint, Alternative 20 includes numerous restoration features specific to each reach including establishment of riparian corridors, daylighting of streams, establishing freshwater marshes, widening of the channel, and removing portions of the concrete channel and converting it to soft bottom. Associated with these restoration features are opportunities for stormwater harvesting to establish and sustain habitat as well as the potential for stormwater infiltration. Some of these features are included in the various project groups of the LA Basin Study.
For example widening the channel and converting to soft bottom is part of the Stormwater Conveyance Systems and the Regional Impact Programs project groups.

4.4.6. Stormwater Capture Master Plan

The Stormwater Capture Master Plan (SCMP) was completed in August 2015 for the Los Angeles Department of Water and Power (LADWP). The SCMP is the latest major component of LADWP's initiative to increase the local water supply through a multi-pronged approach that includes stormwater capture, water conservation, recycled water, and groundwater remediation. The SCMP focuses on stormwater capture as an important element of LADWP's overall plan to enhance water supply. Stormwater capture for water supply is identified in the SCMP in terms of existing capture in centralized facilities, such as spreading grounds, as well as potential capture in centralized facilities and distributed BMPs, including infiltration and direct use storage facilities. Existing and potential recharge was categorized by geophysical obstacles and opportunities and aquifer class. The annual capture volume was broken down by aquifer and between distributed capture and centralized capture.

The SCMP evaluated existing stormwater capture facilities and projects, quantified the maximum stormwater capture potential, developed feasible stormwater capture alternatives, and provided potential strategies to increase stormwater capture. The SCMP identified an annual stormwater capture by year 2099 under a conservative and aggressive scenario. In addition, the SCMP evaluated the multi-beneficial aspects of increasing stormwater capture, including groundwater recharge, increased water conservation, potential open space alternatives, improved downstream water quality, and peak flow attenuation in downstream channels, creeks, and streams such as the Los Angeles River. The Master Plan also includes recommendations on stormwater capture projects, programs, policies, incentives, and ordinances throughout the entire City of Los Angeles.

The SCMP assigned groundwater basins to category A, B, or C depending on its combined appropriateness for infiltration, and BMP sizes were increased proportionally for more desirable and/or less constrained areas. The LA Basin Study took a similar approach by modeling a higher capture depth and shorter drawdown time for areas within the Los Angeles River and San Gabriel River watersheds, and a lower capture depth and longer drawdown time for other watersheds with groundwater basins that are less conducive for recharge. Also, the breakdown of BMPs assigned to Local Solution concepts was consistent with the distributions assumed in the SCMP. This was used to compute weighted averages of program costs. The costs for Local Solutions developed for the LA Basin Study were derived from unit costs estimated in the SCMP, and adjusted for a 50-year analysis period instead of 100-year in the SCMP.

Although the Study Team and LADWP went to great lengths to ensure many of the approaches and strategies considered in the LA Basin Study are similar to those of the SCMP, there were some key differences in the modeling approach and the respective study methodologies which resulted in differences in the total amount of stormwater conservation and subsequently, the cost per acre foot. The reasons for departure in methodologies owe to differences between study objectives and study areas. These differences are outlined in Appendix C, Section 3.

4.4.7. Water LA Program Collaborative

The Water LA Program Collaborative engages local government, non-profit partners, community-based organizations, neighborhood groups and local businesses in an ongoing collective effort to capture, conserve, and reuse water. The Water LA pilot program, developed in 2013 by a local non-profit The River Project, retrofitted 24 properties and developed accessible standard plans and guidance for urban acupuncture on private residential properties. Urban acupuncture strategies include rain tanks, rain grading, parkway basins, permeable surfaces, greywater systems, infiltration trenches, and native landscapes. The program also addressed conflicting codes and policies, and established the Water LA Program Collaborative to facilitate regional uptake and stewardship of these climate adaptive strategies. The second phase, launching in 2016 in partnership with The River Project, GLAC IRWM, LADWP, LACFCD, and LASAN, plans to retrofit 100 properties and 1,000 parkway basins in climate-vulnerable communities, infiltrating 170 AFY of stormwater into groundwater basins, conserving 35 AFY of potable water, and providing myriad multiple benefits.

The activities taken by the Water LA Program have been captured in the LA Basin Study analysis. The LA Basin Study's modeling approach for LID assumes that LID implementation would be implemented basin wide. The implementation percentages were taken from the Task 3.2 Report for different land uses. The stormwater policies and green infrastructure management solutions assume an increase in residential implementation rates, as programs such as Water LA encourage homeowners to willingly implement LID on their properties.

4.5. Future Concept Considerations

The concepts studied in this report 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 best professional 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. Site-specific projects across the 12 various project groups should not be compared "head-to-head" to one another; should this still be required, a more detailed analysis between the site-specific projects would be warranted.

Should any future iteration be undertaken to reassess certain concepts, altering the assumptions such as implementation rates, changes in land use, site identification criteria, actual site availability, etc. will alter the stormwater conservation benefits and costs. For example, should the site selection criteria for the Regional Stormwater Capture project group or the implementation rates of the LID project group be changed, higher or lower stormwater conservation volumes would most likely be modeled. At the time of this report's publication, the LA Basin Study explored 12 various project groups based upon reasonable assumptions to better inform the region on its potential options for enhancing climate resiliency of the local water supply.

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Managing Water in the West

Los Angeles Basin Stormwater Conservation Study

Task 5 Infrastructure and Operations Concepts Appendices

U.S. Department of the Interior
Bureau of Reclamation

County of Los Angeles
Department of Public Works

Los Angeles County
Flood Control District

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Appendix A: Concept Development and Technical Analysis Spreadsheets

See separate excel file:

- *"LA Basin Study - Task 5_Appendix A (Final_20151212).xlsx"*

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Appendix B: Project Group Fact Sheets

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Appendix C: Modeling Approach and Assumptions

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Appendix D: Project Group Cost Estimates

See separate excel files:

- *"Appendix D Local and Management Costs.xlsx"*
- *"Appendix D Regional 1 Costs.xlsx"*
- *"Appendix D Regional 2 Costs.xlsx"*
- *"Appendix D Regional 3 Costs.xlsx"*
- *"Appendix D Storage 3 Costs.xlsx"*

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Appendix E: LACFCD Dam Hydrology and Cost Estimates

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