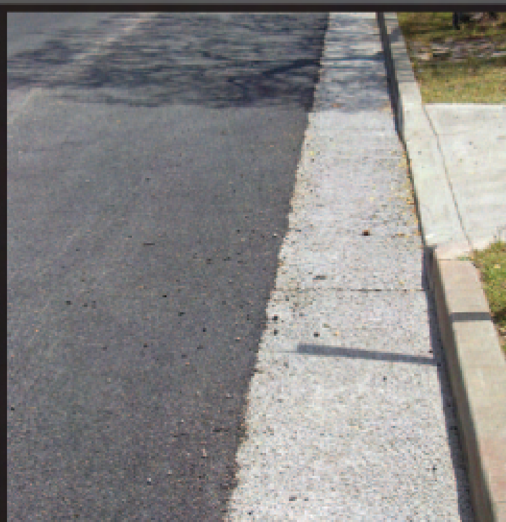



LOS ANGELES AND SAN GABRIEL RIVERS WATERSHED COUNCIL

# WATER AUGMENTATION STUDY | Research, Strategy, and Implementation Report


January 30, 2010

A Project of the Los Angeles & San Gabriel Rivers Watershed Council

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# ACKNOWLEDGEMENTS

*This report is dedicated to the memory of Dorothy Green (1929-2008) in recognition of her vision and hard work in initiating this study. We would also like to acknowledge the many individuals who participated in the Water Augmentation Study as Technical Advisory Committee members.*

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# WAS STUDY AND PARTNERS

The Los Angeles Basin Water Augmentation Study (WAS) is a long-term research project, initiated in 2000 and led by the Los Angeles & San Gabriel Rivers Watershed Council in partnership with local, state, and federal agencies and organizations, with major support from the federal Bureau of Reclamation. This study provides the basis determining the benefits and the practicality of implementing a broad-based approach to stormwater infiltration within the Los Angeles Region.

The following partners in the WAS have provided funding, cost-share, or in-kind services and many contributed valuable time as members of the Technical Advisory Committee (TAC)*:

- CALFED Bay-Delta Watershed Program
- California Department of Water Resources
- City of Long Beach Stormwater Management Division
- City of Los Angeles Bureau of Sanitation Watershed Protection Division*
- City of Los Angeles Bureau of Street Services
- City of Los Angeles Department of Water and Power*
- City of Santa Monica Environmental Programs Division*
- Los Angeles County Department of Public Works*
- Los Angeles Regional Water Quality Control Board*
- Metropolitan Water District of Southern California*
- Pomona College*
- State Water Resources Control Board
- TreePeople*
- University of California, Riverside*
- Upper Los Angeles River Area Watermaster*
- U.S. Department of the Interior, Bureau of Reclamation*
- Water Replenishment District of Southern California*

# EXECUTIVE SUMMARY

## ES.1. Introduction

The Los Angeles region and much of Southern California consistently face serious water supply threats from numerous factors, including increasing population, reliance on imported water, overuse of groundwater, and the consequences of climate change. In a region that experiences highly variable rainfall, periodic drought and climate change may exacerbate a system already operating on the edge with respect to water supply. In 2000, the Los Angeles & San Gabriel Rivers Watershed Council convened a workgroup of representatives from a variety of federal, state, and local agencies to discuss the potential benefits to water quality and supply from using stormwater runoff, as well as barriers associated with such use. The workgroup, which became the Water Augmentation Study Technical Advisory Committee (WAS TAC), developed the following long-term objectives (LASGRWC, 2002):

- Assess water quality implications of infiltrating urban runoff;
- Develop an understanding of the land use, soil, and hydrogeological factors in capturing and infiltrating runoff;
- Assess the effectiveness of various infiltration techniques, particularly in removing pollutants;
- Quantify the amount of stormwater that could realistically be captured and infiltrated;
- Develop a framework of social, economic, and institutional factors that must be addressed in order to create a program to implement widespread infiltration; and
- Develop a region-wide implementation plan to deploy infiltration devices in appropriate locations and settings, along with guidelines for sustainability.

The purpose of this report is to summarize the results of the long-term Water Augmentation Study and provide specific recommendations for a regional groundwater recharge strategy. The overall recommendation is to implement decentralized stormwater management practices to advance infiltration in existing and new development. Decentralized strategies are typically implemented at the neighborhood and parcel level to reestablish or mimic the natural hydrologic cycle by allowing rainfall to infiltrate for groundwater recharge. Decentralized strategies use various Best Management Practices (BMPs) to manage stormwater. BMPs can consist of a device, practice, or other method for removing, reducing, attenuating, or preventing stormwater runoff and associated pollutants from reaching receiving waters. The WAS has concluded that a broad-based, concerted expansion of recharge using stormwater should be a necessary component of the region's portfolio as water managers look to meet Los Angeles' water supply challenges.

## ES.2. The Effects Of Stormwater On Groundwater Quality

To evaluate the water quality impacts of infiltrating stormwater, the Water Augmentation Study was conceived as a multi-year study of several locations throughout the Los Angeles area *(Appendices A and B)*. During Phase I, a pilot study focused on monitoring water quality at two parcels equipped with infiltration structures through one wet season. During Phase II, the program was expanded in time and scope, adding four sites of varying land use and subsurface condition. Monitoring locations included two industrial sites, an elementary school, a commercial office building, a private residence and a public park. Monitoring systems included surface runoff sampling stations, groundwater wells and soil-pore water samplers (lysimeters) installed beneath the ground surface in the vadose zone. The monitoring program consisted of collecting runoff samples during storm events and post-storm samples from the lysimeters and monitoring wells.

Monitoring at these six sites revealed low concentrations of most constituents of concern in the stormwater run-off, suggesting that the risk of groundwater degradation from infiltration is relatively small. Monitoring results of the WAS indicate no evidence of groundwater quality degradation from the infiltration of stormwater. Trend analysis of data collected from 2000 to 2007 further suggested that groundwater quality at the six monitored sites was stable or improved for most constituents.

In conclusion, the study found no apparent trends to indicate that over the long-term, stormwater infiltration will negatively impact groundwater. At sites with shallow groundwater, stormwater infiltration resulted in water quality improvements for many constituents. At industrial sites, pre-treatment filtration methods effectively removed most constituents of concern prior to entering the subsurface infiltration system. The results of this study provide the basis for pursuing a decentralized stormwater management as a viable means for augmenting groundwater supplies in Southern California.

## ES.3. Modeling The Potential For Groundwater Augmentation

Another objective of the WAS is to quantify the amount of stormwater that can realistically be captured and infiltrated using decentralized techniques. The concept of capturing stormwater for groundwater infiltration is not new to the Los Angeles region. An average of 202,000 acre-feet of stormwater is captured for groundwater infiltration annually, 95% of which is from the upper watershed areas running off the national forests and open space areas (MWD, 2007). Not well-understood is how much precipitation infiltrates to groundwater through lawns, open space and other pervious surfaces, and what additional amount is available for capture from impervious surfaces.

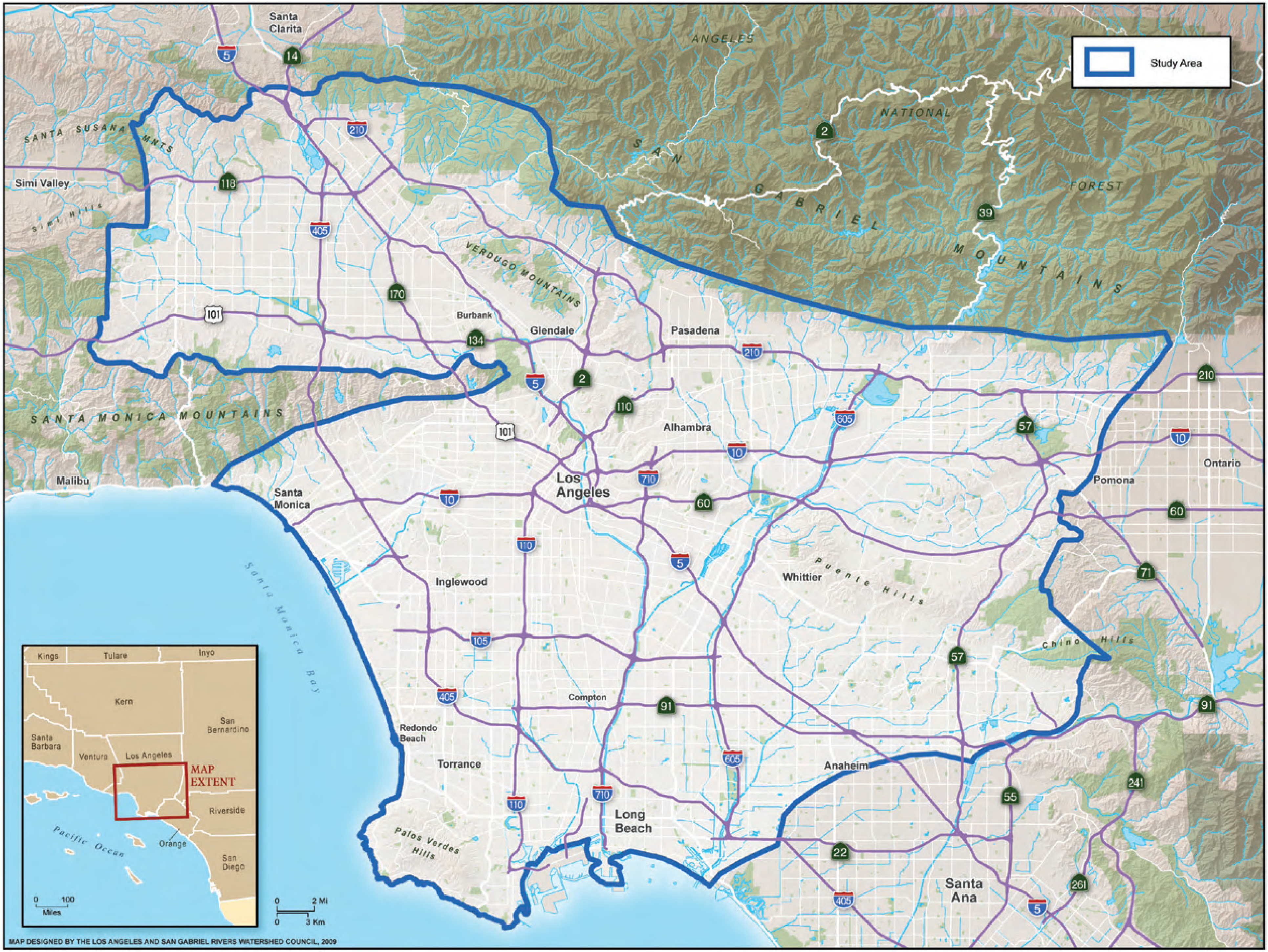
To estimate the current conditions of natural & unmanaged infiltration within the urban landscape, and the potential for intentional stormwater recharge, a geographic information system (GIS) based model, the Groundwater Augmentation Model (GWAM), was developed by the Bureau of Reclamation. The model estimates stormwater runoff and the potential for groundwater recharge focusing on the urbanized areas of Los Angeles County within the Los Angeles, San Gabriel, Dominguez Channel, and Santa Monica Bay watersheds *(Figure ES 1)*. The model provides an opportunity to examine approaches to addressing water supply and urban runoff issues through the capture of stormwater using alternative decentralized management scenarios.

The GWAM estimates that annually 16 percent of precipitation currently percolates to groundwater (about 194,000 acre-feet) in the Los Angeles Region, while 50 percent (approximately 601,000 acre-feet) becomes runoff that flows directly through the stormwater conveyance system to the ocean *(Appendix C)*. Implementing a regional decentralized stormwater management where the first ¾" of each rain storm is captured and directed for infiltration on all parcels could add up to 384,000 acre-feet bringing the estimated total to 578,000 acre-feet of recharge per year, on average, to the groundwater basins – enough water for 1.5 million people. This total does not factor the existing efforts to capture runoff into spreading basins, approximately another 202,000 acre-feet of water runoff from the upper natural watersheds outside the model area (MWD, 2007).

## ES.4. Valuing Stormwater Infiltration

There are multiple ways to value the benefits and costs of strategic decentralized stormwater management. Direct benefits of increasing groundwater recharge include reduced demand for imported water and therefore a reduction in associated costs and risks of over-reliance on an uncertain supply. Another direct benefit is the avoided cost of treatment when high runoff volumes breach wastewater conveyance systems and overwhelm wastewater treatment facilities. Strategic decentralized infiltration also diminishes the perennial need for enhancing storm drain system capacity. There are secondary direct benefits such as water conservation, reduced beach closures, new recreation and educational opportunities, community beautification, increased property values, and an

**Figure ES 1 - Water Augmentation Study Area**



enhancement of habitat, open space and ecosystem services. Indirect values associated with this approach include improvements in air quality, the creation of green jobs, and *multi-benefit* project collaborations that produce novel partnerships and cost-sharing opportunities.

Research conducted as part of the WAS found that, generally, decentralized systems can be cost-effective within the Los Angeles area. To address cost-effectiveness, the WAS determined the value of new water supplies by examining the cost of the current water supply and of imports that would avoided if local supplies were available. The value based on current supply cost is $695 per acre-foot as of January 1, 2009; this value increased to $811 per acre-foot in January 2010. The WAS used this cost as the replacement cost of water to be imported.

Consumer willingness to pay to avoid water shortages during dry years also has a value. The value of a stored supply of groundwater available for use during dry years ranges from $757 to $943 per acre-foot, depending on the usable storage volume available (Chesnutt et al, 2008; Cutter 2007). Perhaps more importantly, this stored water would provide a reliable supply of water and reduce risks regardless of the amount of rainfall in any given year.

Another important consideration when valuing infiltration BMP project costs and benefits, is the avoided cost that jurisdictions could realize from reducing stormwater requirements. A survey of stormwater quality costs conducted by the WAS found that the cost for treating the half-inch 24-hour event ranged from, $0.78 to $1.01 per gallon of stormwater runoff. If stormwater projects were capable of treating levels higher than a half-inch precipitation event, the avoided costs would be assumed to be greater than a dollar per gallon.

## ES.5. Summary Of The Findings

Based on the findings of the WAS research, decentralized stormwater management would provide a local and reliable supply of water that would not negatively impact groundwater quality. A decentralized approach could contribute up to 384,000 acre-feet of additional groundwater recharge annually if the first ¾" of each storm is infiltrated on all parcels, enough to provide water annually to approximately 1.5 million people. The value of this new water supply would be approximately $311 million, using the MWD Tier 2 rate for 2010. This economic valuation of infiltration excludes the water treatment benefit, which would significantly increase the economic benefit. The valuation also excludes costs for pumping and distribution of the new water supply which may lower the value of the overall supply.

Based on these findings, the WAS partnership moved forward on a demonstration project in a 24-single family residential home neighborhood in northeast San Fernando Valley to validate study findings. The multiple benefits of the project (water quality, water supply, costs, and additional benefits) are being tracked to provide data from before, during, and after installation, and will be reported in future addendums to this report.

## ES.6. Challenges And Recommendations

Challenges and recommendations of implementing decentralized stormwater management *(Figure ES 2)* fall into the following six categories that are described below: 1) institutional barriers, 2) existing development rules, 3) stormwater regulations, 4) groundwater management, 5) cost and funding, and 6) education and awareness.

**Institutional Barriers**

Implementation of a decentralized stormwater management will require changes at multiple levels of government. Therefore, governing bodies need to remain flexible and show a willingness to review and adopt new ideas. This will require support from the bottom to the top including government agencies, politicians, and the public. The ability to work across agency, municipal, and political boundaries will be essential to creating change. Cities should continue or initiate green teams or sustainability coordinators to work across departments.

**Existing Development Rules**

Over decades of urban growth, building codes, ordinances, and standards have evolved to ensure that the built environment is effective, efficient, and protects the public's health and safety. Many of these rules, however, were developed before stormwater runoff was known to impact surface water quality and codes were developed prior to understanding of the benefits of decentralized stormwater management methods. Standard plans and design standards, accessibility requirements, vehicle and fire codes, and vector control considerations all must be amended to enable decentralized stormwater management projects seeking to increase infiltration.

**Stormwater Regulations**

Stormwater Regulations are most often driven by water quality concerns and generally require treatment processes that do not provide multiple benefits. Most of the regulatory requirements to implement post-construction BMPs are part of the National Pollutant Discharge Elimination System's (NPDES) Municipal Stormwater Permit Program (MS4), which is intended for protection of beneficial uses of receiving waters. This federally-mandated regulation is administered at the county and city level through Standard Urban Stormwater Mitigation Plans (SUSMPs) that specify stormwater treatment requirements for particular development types. Stormwater regulations and permits should be written to give property owners incentives to go beyond basic SUSMP requirements to provide multiple benefits including augmenting water supply, improving habitat, and increasing recreation opportunities.

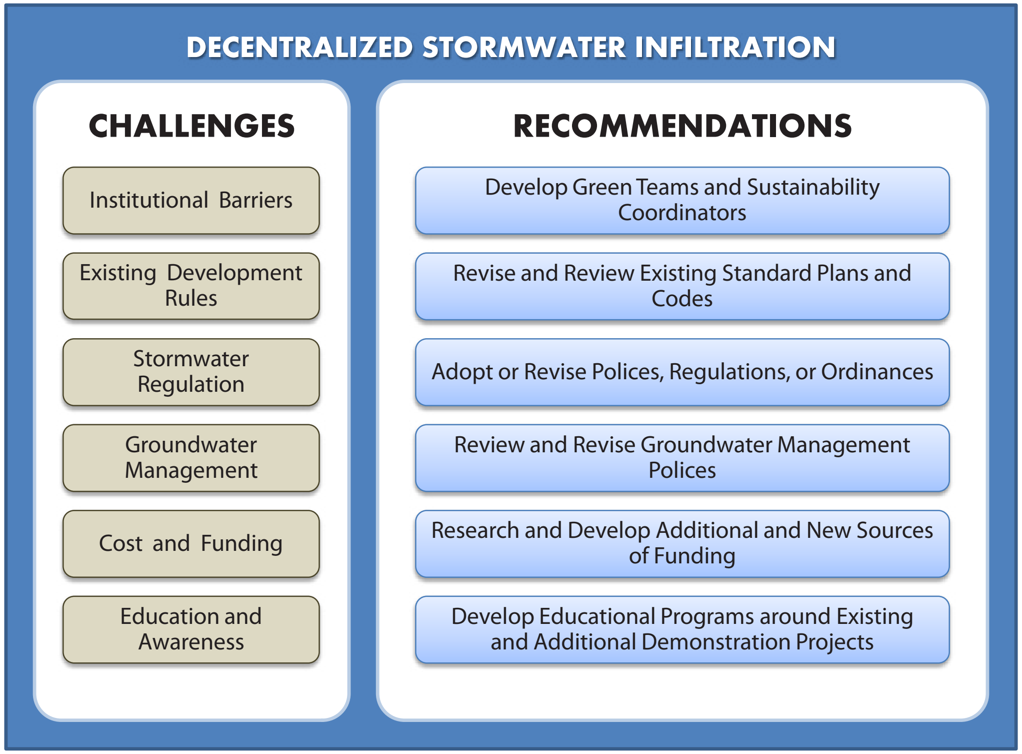
**Groundwater Management**

Within the Los Angeles region, management of many of the large groundwater basins is overseen by a municipal judge. Adjudication is a process by which all parties with a perceived claim on the water from the basin submit to a legal procedure to establish water rights and extraction rates and are subject to oversight, via a watermaster, by the courts. Adjudication can only be changed by the court, which means that for many groundwater basins, an increased amount of water available from decentralized recharge does not automatically allow for increased pumping. Judgements need to be changed to allow watermasters flexibility to consider stormwater infiltration amounts in managing extraction rates.

**Cost and Funding**

One objection to implementing decentralized stormwater management is the increased cost of construction. This objection is short-sighted in that it ignores many long term benefits, such as augmenting drinking water supplies. In addition, multiple methods to reduce implementation and installation costs and fund new projects are available – including

Figure ES 2 - Challenges and Recommendations



partnerships, fees, credits, rebates, grants and subsidies. Incorporating these BMPs into standard operating procedures, however, will require more local funding, likely coming from increased municipal stormwater permit fees. Other creative funding mechanisms should be studied and implemented if feasible.

**Education and Awareness**

A distributed network of sites that contribute increased infiltration for the region would require active participation and cooperation from both public agencies and private property owners. For a public-private infiltration strategy to succeed, public agencies and property owners need to better understand the goals of the strategy and maintenance requirements, including the need for long term maintenance and monitoring, and there needs to be a mechanism to educate new owners and tenants when properties change hands. Education and outreach around the results and recommendations of the Water Augmentation Study can ensure that implementation of stormwater recharge projects are a part of the local supply portfolio of water suppliers to help with demand and supply variations and to provide reliable supplies of water.

The recommendations provided in Section 6 of the report provide approaches to resolving the challenge in these six areas. Each recommendation is classified as to which entity should develop, study, or implement the recommendation: project proponents, governing bodies, or WAS partners.

## ES.7. Future Initiatives: Advancing Infiltration In Southern CA

For captured stormwater to become a reliable water supply in Southern California, techniques for infiltrating water must become the norm. Research in decentralized stormwater capture concurrent with planning, constructing and operating new stormwater facilities can identify and quantify innovative and efficient techniques unique to Southern California. The focus of future initiatives should address the four questions below.

- What are the best design, operation, and maintenance procedures?
- What are the multiple benefits and who receives the benefits of stormwater infiltration projects?
- What is the ultimate fate of each contaminant of concern found in stormwater runoff, and what effective mitigation alternatives exist?
- Where should future stormwater projects be located for maximum benefits?

Given the recommendations contained in this report for future research and policy changes, the WAS TAC should continue the partnership to achieve implementation of decentralized stormwater management as standard operating practice. The development of such a broad-based change in stormwater management will take a concerted effort over many years. In Southern California, restrictions on imported supplies combined with anticipated population growth and the impacts of climate change make this an opportune time for an investment in decentralized stormwater management with the ultimate goal of achieving sustainability with respect to water supplies for the Los Angeles region.

# 1. INTRODUCTION

The Los Angeles Region and much of Southern California consistently face serious water supply threats from numerous factors, including increasing population, reliance on imported water, overuse of groundwater, and the consequences of climate change *(see sidebar)*. In a region that experiences highly variable rainfall, periodic drought and climate change have exacerbated a system already operating on the edge with respect to providing water.

The ability of the Los Angeles Region and much of Southern California, to maintain its already declining supply of imported water or to find additional sources from outside of the Los Angeles region is of critical concern.

New and creative ideas to manage, conserve, and enhance the region's water resources in a sustainable manner must be developed and implemented to improve water reliability in the region and avoid potentially catastrophic conditions for the region's human and wildlife populations. Increasing the reliability of local water supplies through conservation, infiltration for groundwater augmentation, water recycling and rainwater harvesting will be critical components of a long-range sustainability plan for Southern California. Among these is a water supply solution with great potential: decentralized management focusing on infiltration of stormwater and urban runoff.

## CLIMATE CHANGE

The effects of climate change are already being seen by current changes in runoff and precipitation (CA Dept. of Water Resources, 2008). Predictions for climatic change in the Los Angeles area suggest an increasing number of extreme heat events and modest declines in winter precipitation (Hayhoe et al., 2004). These findings are consistent with predictions for climate change from the National Oceanic and Atmospheric Administration (NOAA) that suggest California will experience only a slight decline in the total amount of precipitation, but that rainfall patterns will change dramatically with longer periods of no rain interrupted by a greater frequency of heavy rainfall events and a potential 25% decrease in the Sierra snowpack by 2050 (Le Comte, 2008).

This same report predicts an overall 40% reduction in annual runoff for the entire Southwest of the United States when comparing runoff data for 1900-1970 to those projected to occur 2041-2060 (Le Comte, 2008). This is consistent with findings regarding the impact of climate change on the supply of Colorado River water (MacDonald, 2007; Milly et al., 2008). One estimates that Colorado River flow is likely to decline by 10% to 30% over the next 30 to 50 years. It is also suggested that Lakes Mead and Powell have a 10% chance of losing their live storage capacity (the reservoir space from which water can be evacuated by gravity) as early as 2013 and a 50% chance by 2021 if current water allocations and management practices are not changed (Barnett & Pierce, 2008; Tanaka et al., 2006). Implementation of the available shortage management practices could greatly reduce the risk of losing the live storage however (Rajagopalan et al, 2009).

## 1.1 WATER AUGMENTATION STUDY TECHNICAL ADVISORY COMMITTEE

In 2000, the Los Angeles & San Gabriel Rivers Watershed Council convened a workgroup made up of representatives from a variety of federal, state, and local agencies to discuss the potential benefits and impacts of using stormwater runoff for infiltration and the barriers associated with such conservation. The workgroup, which became the WAS TAC, developed the following long-term objectives (LASGRWC 2002):

- Assess water quality implications of infiltrating urban runoff;
- Develop an understanding of the land use, soil, and hydrogeological factors in capturing and infiltrating runoff;
- Assess the effectiveness of various infiltration techniques, particularly in removing pollutants;
- Quantify the amount of stormwater that could be realistically captured and infiltrated;
- Develop a framework of social, economic, and institutional factors that must be addressed in order to create a program to implement widespread infiltration; and
- Develop a region-wide implementation plan to deploy infiltration devices in appropriate locations and settings, along with guidelines for sustainability.

The purpose of this report is to summarize the results of the long-term Water Augmentation Study and provide specific recommendations for a regional groundwater recharge strategy, implemented through decentralized stormwater management practices that encourage infiltration, capture, and reuse. Decentralized stormwater management strategies are very similar in meaning and intent to both low impact development and green infrastructure and these terms are often used interchangeably. In this report, we will primarily use the term decentralized stormwater management.

## 1.2 PURPOSE OF THIS REPORT

The purpose of this report is to summarize the results of the long-term Water Augmentation Study and provide specific recommendations for a regional groundwater recharge strategy. The concept of capturing stormwater for groundwater infiltration is not new to the Los Angeles region. An average of 202,000 acre-feet is currently captured annually at centralized spreading grounds, 95% of which is from the upper watershed areas running off the national forests and open space areas (MWD, 2007). Implementing a regional decentralized stormwater management approach, however, could provide an additional 384,000 acre-feet per year, on average, to the groundwater basins.

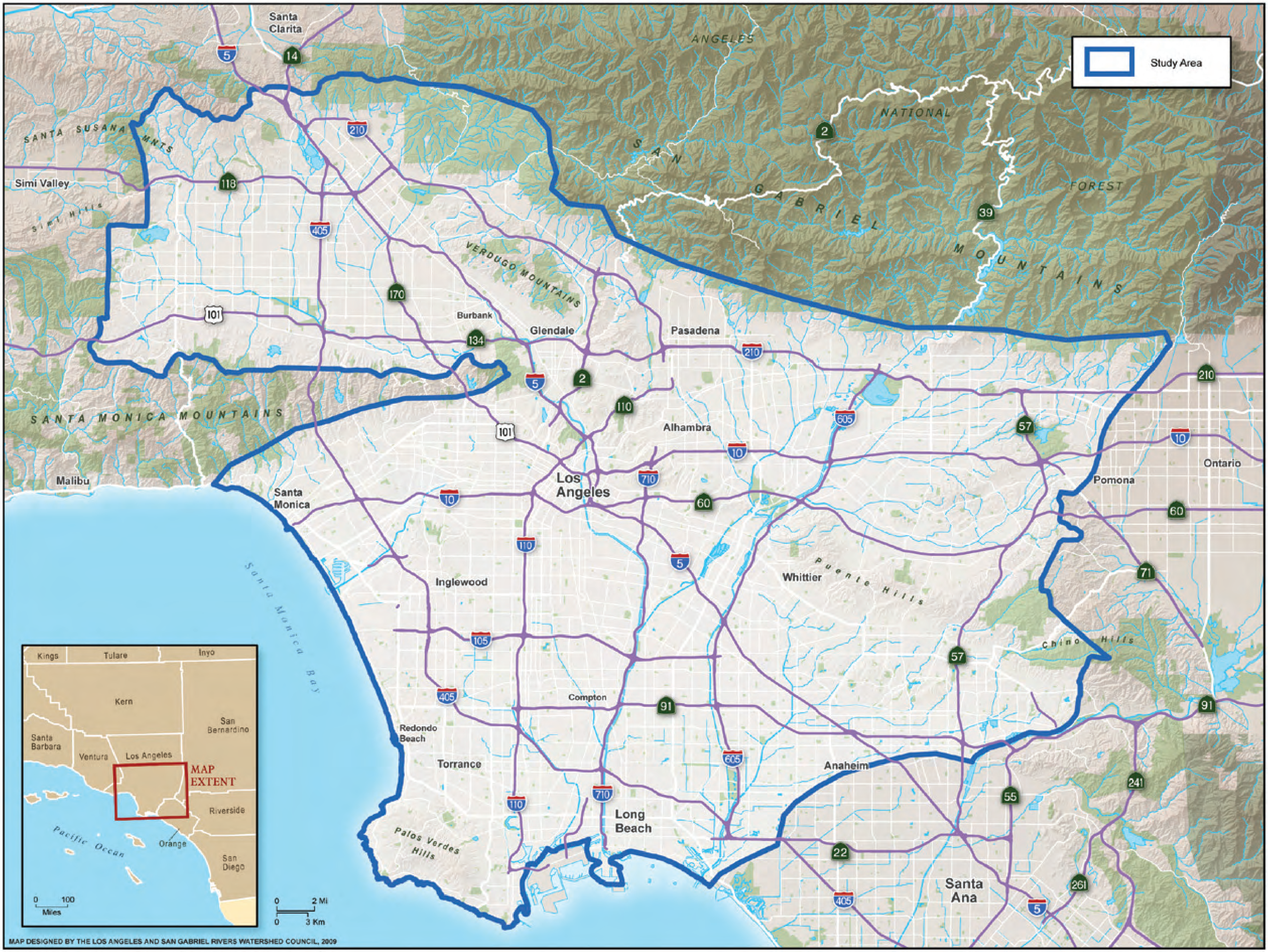
In recognition of the importance of groundwater and stormwater runoff to Southern California, this report evaluates the water quality, water supply, and cost implications of decentralized stormwater infiltration. While many of the findings and recommendations in this report can be applied to Southern California and similar arid regions, the emphasis of this report is on the Los Angeles Region, encompassing the coastal plains and valleys *(see sidebar and Figure 1)*.

The format of the report follows an initial summary and discussion of decentralized stormwater management strategies and the effects of stormwater infiltration on groundwater quality, as examined through the Water Augmentation Study (WAS). The report then identifies groundwater augmentation volumes that can potentially be realized from a

**STUDY AREA**

The focus of this report is on the Los Angeles Region (Figure 1) which encompasses the urbanized areas mostly within Los Angeles County that lie south and west of the mountains that separate the Los Angeles coastal plains and valleys from the drier desert regions. This boundary definition is different than the Los Angeles Metropolitan Area, which when used in this report refers to the greater urbanized regions of Los Angeles, Orange, Riverside, and San Bernardino Counties.

## Figure 1 - Water Augmentation Study Area



comprehensive infiltration management approach, followed by a discussion of costs and benefits of implementation.[1]

The last two sections of the report describe barriers and present recommendations intended to further the implementation of decentralized stormwater infiltration derived from the experiences of the WAS and its Technical Advisory Committee participants. Chapter 6 covers existing barriers ranging from regulations to awareness and strategies to overcome the barriers such as alternative funding and incentives and recommendations for new policies to encourage implementation of decentralized stormwater management. The final chapter focuses on identifying a program of research to answer remaining and new questions.

The long-term Water Augmentation Study demonstrates that infiltration of stormwater can provide multiple benefits, including reducing the most significant source of surface water quality impairment in urban areas and increasing the supply of groundwater available for use. The research and findings of this study seek to allay concerns about the potential impacts of stormwater infiltration on groundwater quality and to lay the foundation for new era of stormwater management aimed at providing a substantial water supply resource for Southern California and serving as a model throughout the arid West.

## 1.3 WATER AUGMENTATION STUDY METHODOLOGY

To identify the potential benefits of using stormwater runoff and address the barriers associated with such use the WAS TAC followed the steps outlined below. The methodology can be used by other agencies or departments to develop and implement decentralized stormwater management.

a. Facilitate Working Group: The Watershed Council assembled a technical advisory committee consisting of agencies, organizations, and academics representing multiple disciplines and missions including those managing and regulating stormwater, groundwater, recharge, local supply and imported supply. The TAC then directed and supported the Water Augmentation Study starting in 2000.

b. Develop Research Program: The WAS TAC developed a long term program of research, including monitoring, pilot and study phases, demonstration, and evaluation to ensure high quality and fidelity of the research.

c. Analyze and Report Research Results: Study results, including monitoring and economics data were analyzed to develop a list of lessons learned and next steps.

d. Demonstrate the Results in a Real-World Case Study: Based on the results and lessons learned from the study and related projects, the WAS TAC developed a real-world demonstration project.

e. Synthesize All Findings for Next Steps: Finally, this regional strategy document is an attempt by the WAS TAC set a road map for the path to changing standard operating procedures to include decentralized stormwater management where appropriate. Further research is still needed to answer or solve those questions not yet resolved by this study.

## 1.4 WATER SUPPLY AND QUALITY IN SOUTHERN CALIFORNIA

In the 1920s, when water managers started keeping data, approximately five percent of the annual precipitation within the Los Angeles Region ran off and flowed to the ocean. By the 2000s urbanization had increased to the point where runoff has increased to approximately 50 percent, on

1 More information can be found about each of these WAS components by reading reports posted on the website of the Los Angeles & San Gabriel Rivers Watershed Council website, *www.lasgrwc.org*.

average (Green, 2007; Appendix A. Groundwater Augmentation Model Demonstration Report). During this same time period, water managers in Southern California increased efforts that continue to this day to augment our limited local water supplies with imported water supplies.

Since 1913, the Los Angeles Metropolitan Area has relied on a mix of local and imported water supplies to meet its potable water and irrigation demands. This combination has allowed the region to grow and prosper, and in 2009 the County of Los Angeles ranked 24th in the world for Gross Domestic Product (GDP) compared to other cities and nations (Kyser, 2009).

Until the completion of the Los Angeles Aqueduct in 1913, most of Los Angeles relied on water from local aquifers, rivers, and streams. With the construction of the 233-mile aqueduct by the City of Los Angles to bring water from the Owens Valley, the potential for growth and economic development in the City of Los Angeles seemed limitless *(see sidebar)*. The creation of the Metropolitan Water District of Southern California (MWD) in 1928 to bring additional supplies of water from the Colorado River further expanded the development potential of Southern California. The growing statewide demand for water led to the approval and construction of the State Water Project in the 1960s, which brought new supplies from Northern California (Green, 2007). Despite the new imported water sources, expansive growth led to initial over-drafting of a once rich supply of groundwater (Johnson, 2005).

Depending on numerous seasonal factors, such as the amount of snow that falls in the Sierra Nevada Mountains, and periodic climate changes, such as drought in the Colorado River Basin, 30 to 60 percent of the Los Angeles Metropolitan Region's water is supplied by local groundwater, with an average annual reliance on groundwater of 40 percent (MWD, 2007). Currently, an average of about 202,000 acre-feet of water is recharged in the Los Angeles area each year[2] through more than 3,000 acres of spreading grounds, 95% of which is from the upper watershed areas running off the national forests and open space areas (MWD, 2007). Most of the spreading basins are supplied by annual runoff from the mountains and are located in areas where there is a good connection to the major aquifers *(Figure 2)*. When there is sufficient water, groundwater agencies may also spread imported water to supplement spreading operations. As a means of supplementing existing spreading operations, some agencies currently spread recycled water and others are using demonstration projects to evaluate the injection of recycled water into aquifers after additional treatment..

The deep and shallow aquifers found in the Los Angeles Region have large recharge capacities. The unused groundwater storage space available within San Fernando Valley, San Gabriel Valley, and Los Angeles County Coastal Plain is approximately 1.2 million acre-feet (MWD, 2007)[3].

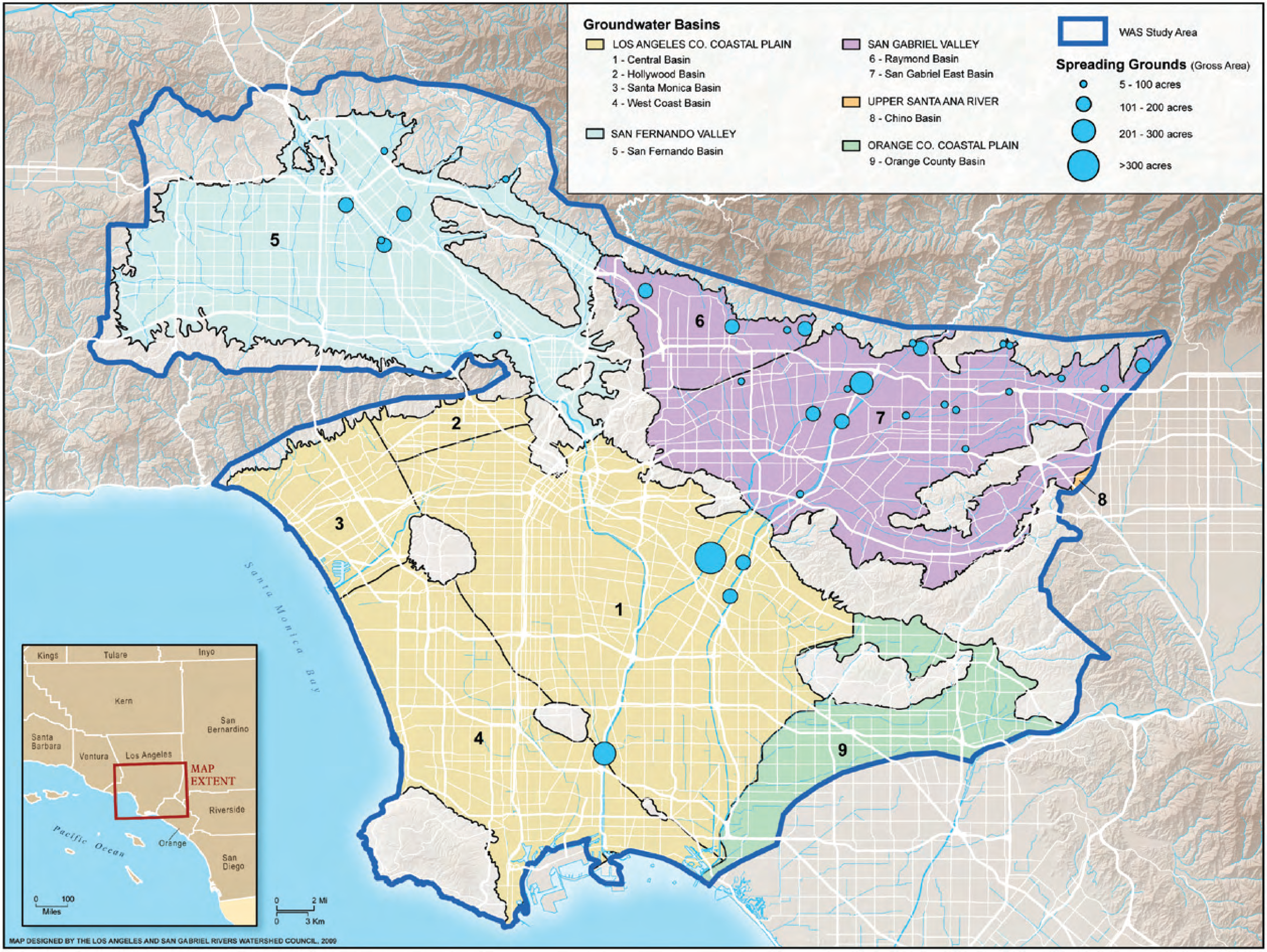
2 The range is from 170,000 to 444,000 acre-feet/year.

3 It is important to note that it may not be possible or advantageous to use all this space. Feasibility of using this storage space may be impacted by watermaster allocations of the storage space for long-term or short-term use, water quality issues, lack of overlying demand or other factors. For example, although there is more than 500,000 acre-feet of storage space available in the San Fernando Valley, use of this storage space would need to consider how the recharge would impact the remediation projects, water rights for the basin parties and exports from the basin. In addition, basin management decisions may dictate how much storage space is used.

## POPULATION GROWTH AND WATER USE

Despite recent declines in its growth rate (Connell, 2009), Los Angeles County is expected to grow from a 2008 population of 9.86 million (US Census Bureau, 2009) to an estimated 12.2 million by 2030 (SCAG, 2009). As of 2004 the per capita daily water use for the City of Los Angeles was just over 150 gallons (LA Dept. of Water and Power, 2005). In comparison the City of Long Beach reported 121 gallons per capita daily use in 2006 (LB Water Dept., 2006). Within the service area of the Metropolitan Water District, per capita daily use is projected to rise from 184 gallons in 2005 to 194 gallons in 2030 (MWD, 2005).

**Figure 2 - Groundwater Basins With Existing Spreading Basins Highlighted**



During times of surplus, imported water has historically been an important source of water for recharging Southern California's groundwater basins. As water imports become more restricted for environmental and regulatory reasons, scarcity of imported water for recharge will be a reality. Due to reductions in imported supplies many of the regional and local water suppliers have focused on alternative management strategies including efforts to meet future water demand using sustainable, local sources. The Los Angeles Department of Water and Power, for example, has implemented an aggressive water conservation campaign, enhanced stormwater capture, and increased use of recycled water for non-potable uses as well as groundwater recharge.

The Los Angeles Region needs to continue to grow its local water supply in a manner that is both reliable and sustainable to address fluctuations with imported water supplies. A region-wide effort to increase stormwater infiltration represents a dependable means to augment local groundwater supplies.

## 1.5 SURFACE WATER QUALITY IN SOUTHERN CALIFORNIA

The Water Augmentation Study and its demonstration projects focus on the infiltration of stormwater. Stormwater represents a much greater water volume than dry weather runoff, although infiltration techniques and recommendations nevertheless apply to dry weather flows as they do to stormwater. Stormwater runoff is generated by rainfall and snowmelt that runs off the land or impervious areas, picking up trash and pollutants along the way. It is then channeled through natural or manmade conveyance systems that eventually reach rivers and beaches. Dry weather runoff is generated during dry periods, generally from May through September, from anthropogenic sources such as over watering and sprinkler overspray, washing of cars and sidewalks, and other discharges not associated with a storm event. As with stormwater, dry weather runoff also travels across the built landscape, carrying pollutants to rivers and beaches.

As land is developed, the resulting large increase in impervious surface area increases the inputs of pollutants to our waters by increasing the quantity of stormwater that runs off urban surfaces into storm drains (Tiefenthaler & Schiff, 2003; EPA, 1999). The predominant land use in urbanized areas of Los Angeles is low-density residential, with the balance made up of high-density residential, industrial, commercial, institutional areas, all which have high levels of imperviousness (EPA, 2007). As urban runoff has increased in Los Angeles, water quality in the rivers and at the beaches has declined.

Within the area under the jurisdiction of the Los Angeles Regional Water Quality Control Board (LARWQCB) *(Figure 3)* there are 189 water bodies listed as impaired (LARWQCB, 2009), with typical impairments caused by constituents including bacteria, copper, cyanide, lead, zinc, trash, pH, nutrients, and toxicity. Stormwater and dry weather runoff continue to threaten aquatic life and public health. To address the impairments, approximately 92 *Total Maximum Daily Loads* (TMDLs) analytical units are being developed and implemented to improve water quality throughout the Los Angeles Region (LARWQCB, 2002).

## 1.6 DECENTRALIZED STORMWATER MANAGEMENT

Stormwater infiltration practices are typically classified as either "centralized" or "decentralized" (sometimes called "distributed"). For the purpose of this study, centralized strategies in the Los Angeles Region are defined as large-scale projects that take runoff from offsite and upstream and provide flood protection and conservation of water resources through dams, wetlands, spreading basins, debris basins, and flood control channels. Centralized stormwater infiltration is successful in many regards, but this approach is unable to capture stormwater from the entire watershed, especially in a highly urbanized area such as Los Angeles. Increased urbanization and imperviousness shed additional amounts of rainfall from properties to the street and to the storm drain system, straining the existing flood control system, diminishing water quality, and reducing

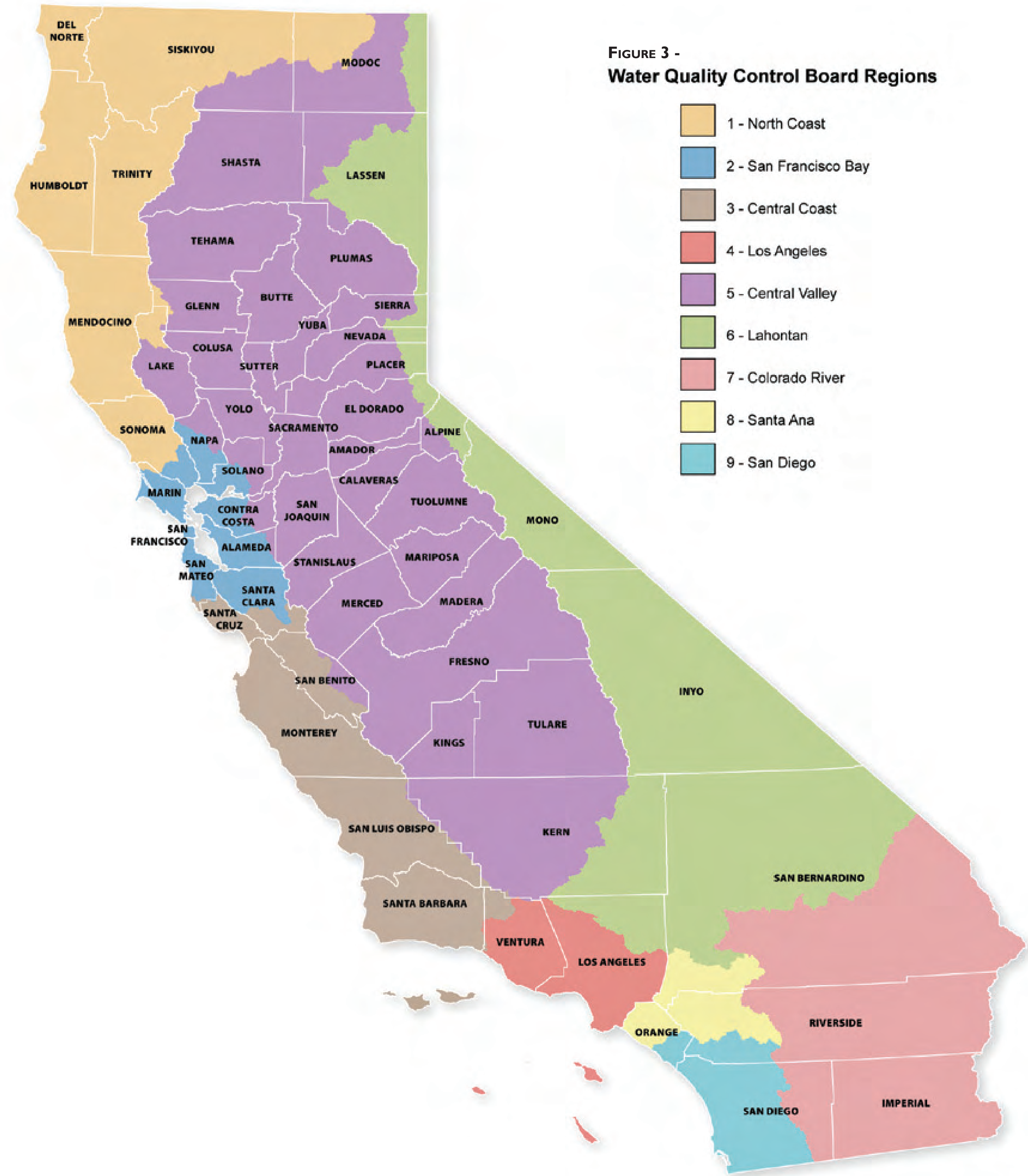


Figure 3 -
Water Quality Control Board Regions
1 - North Coast
2 - San Francisco Bay
3 - Central Coast
4 - Los Angeles
5 - Central Valley
6 - Lahontan
7 - Colorado River
8 - Santa Ana
9 - San Diego
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
YUBA
NEVADA
COLUSA
LAKE
SUTTER
PLACER
YOLO
EL DORADO
SONOMA
NAPA
SACRAMENTO
ALPINE
AMADOR
SOLANO
CALAVERAS
MARIN
CONTRA COSTA
SAN JOAQUIN
TUOLUMNE
MONO
SAN FRANCISCO
ALAMEDA
SAN MATEO
STANISLAUS
MARIPOSA
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
FRESNO
SAN BENITO
INYO
MONTEREY
TULARE
KINGS
KERN
SAN LUIS OBISPO
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL

natural recharge. New centralized opportunities are scarce in the Los Angeles region, where a largely built-out landscape makes it difficult and cost-prohibitive to acquire large tracts of land for centralized projects.

Decentralized strategies are implemented at the neighborhood and parcel level to reestablish or mimic the natural hydrologic cycle by allowing rainfall to infiltrate for groundwater recharge. Decentralized strategies manage stormwater using various Best Management Practices (BMPs) consisting of a device, practice, or other method for removing, reducing, attenuating, or preventing stormwater runoff and associated pollutants from reaching receiving waters. Rain gardens, porous pavement, dry wells, rain barrels, bio-swales, and infiltration trenches are all examples of stormwater BMPs. Other stormwater BMPs simply filter storm flows through a constructed system and then release treated runoff. Low impact development is another term for decentralized systems; we use the latter term here because of the association of low impact development with new urban construction, whereas our purpose here is to advance the implementation of infiltration in both existing and new urban development. Another term sometimes used is green infrastructure *(see sidebar)*.

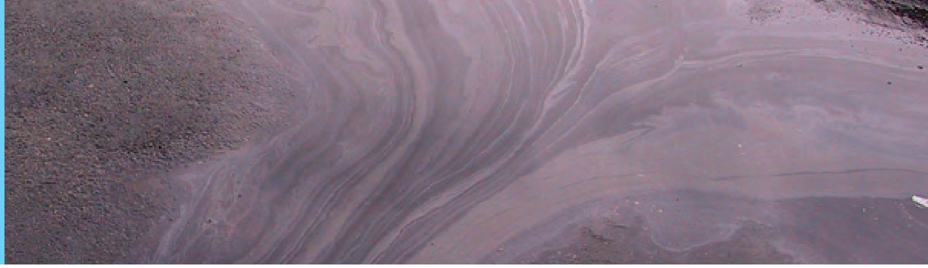
On average approximately 578,000 acre-feet of stormwater is discharged to the ocean within the Los Angeles Region annually *(Appendix A)*. Decentralized stormwater capture and infiltration techniques can provide a viable means of augmenting groundwater recharge and reducing the overall cost of managing urban runoff. By implementing decentralized treatment agencies can reduce the economic and environmental costs associated with acquiring large-scale parcels and converting them into centralized projects. The WAS has concluded that a broad-based, concerted expansion of recharge using stormwater should be a necessary component of the region's portfolio as water managers look to meet Los Angeles' water supply challenges.

## LOW IMPACT DEVELOPMENT AND GREEN INFRASTRUCTURE

The terms "Low Impact Development" (LID) and "Green Infrastructure" describe decentralized approaches to treat stormwater close to the source. LID is an approach to land development or re-development that mimics the natural hydrologic cycle of a site by preserving or recreating natural landscape features and minimizing imperviousness (EPA, Low Impact Development, 2009).

Green Infrastructure refers to technologies and practices that infiltrate, evapotranspire, capture and reuse stormwater to maintain or restore natural hydrologies (EPA, Managing Wet Weather with Green Infrastructure, 2009). For the purpose of this report, projects that use LID techniques or Green Infrastructure will be considered projects that contribute toward a decentralized infiltration strategy supported by the WAS.

# 2. THE EFFECTS OF STORMWATER ON GROUNDWATER QUALITY



The impacts of stormwater on surface water quality are well documented. The WAS TAC partners sought to assess a less documented process: the impacts of infiltrating stormwater on groundwater quality. The need to address this issue was identified as one of the key long-term objectives by the WAS TAC, in addition to evaluating the potential benefits of infiltrating stormwater. The WAS TAC formulated a long-term research plan to review potential groundwater impacts including a literature review and extensive monitoring of six locations throughout the Los Angeles Region *(Appendices A & B)*.

The EPA has identified urban stormwater runoff as a major source of surface water quality impairment. The EPA, through the research of the Nationwide Urban Runoff Program (NURP), has determined that major pollutants of concern from urban stormwater runoff include heavy metals, pathogens, pesticides, nutrients, organics, oxygen-demanding substances, and suspended solids. Although water quality constituents in urban areas can vary widely between locations, stormwater samples from 2,300 separate storm events collected at 81 sites in 22 different cities throughout the United States typically exhibited elevated heavy metals concentrations. Lead, cooper, and zinc were the most common heavy metals and were detected in 91 percent of the samples (EPA, 1983).

The Los Angeles County Department of Public Works (LACDPW) developed a region-wide comparison of constituent loads from different land uses (LACDPW, 2002). The LACDPW data were collected between 1994 and 2000 for compliance with LACDPW's 1996 National Pollutant Discharge Elimination System (NPDES) stormwater permit. The constituents included in the analysis are similar to those included in the WAS program, described below. Results indicate that commercial and industrial land uses typically have higher concentrations of metals than other land uses, which should be considered when evaluating infiltration locations.

Given the past history of groundwater pollution in Southern California[1], an investigation of stormwater infiltration on groundwater quality was necessary prior to making recommendations for increased stormwater infiltration through decentralized methods. The historic pollution has come from numerous sources including fertilizers, dairies, septic systems, seawater intrusion, industrial sources, and natural occurrences (MWD, 2007).

1 High nitrate and Total Dissolved Solids concentrations, along with volatile organic compounds (VOCs), naturally occurring iron and manganese, perchlorate, hexavalent chromium, sulfate, and methyl tert-butyl ether (MTBE).

**Figure 4 - WAS BMP Site Locations**


## 2.1 WATER AUGMENTATION STUDY METHODOLOGY

To evaluate the water quality impacts of infiltrating stormwater, the Water Augmentation Study was conceived as a multi-year study of several locations throughout the Los Angeles area *(Appendices A and B)*. During Phase I, a pilot study focused on monitoring surface and subsurface water quality at two parcels equipped with infiltration structures through one wet season. During Phase II, the program was expanded in time and scope, adding four sites of varying land use and subsurface condition. Upon completion of the study, the project locations included two industrial sites, an elementary school, a commercial office building, a private residence and a public park *(Figure 4 and 5)*. At the project sites, groundwater depth ranged from approximately 20 feet to 350 feet below ground surface and soil type varied from sand with gravel to interbedded sand, silt, and clay.

All project sites were retrofitted with various infiltration structures (ranging from simple landscaped swales to large-scale underground infiltration fields) and comprehensive monitoring systems. Monitoring systems included surface runoff sampling stations, groundwater wells and soil-pore water samplers (lysimeters) installed beneath the ground surface in the vadose zone. Lysimeters were installed at depths up to 70 feet below ground surface. Collectively, the six sites contained 12 runoff sample collection points, 17 lysimeters, and 10 wells.

The monitoring program consisted of collecting runoff samples during storm events and post-storm samples from the lysimeters and monitoring wells. During the 2001-2002 and 2002-2003 monitoring seasons, runoff samples were discrete grab samples collected during the early portion of the runoff event. For the remainder of the project, runoff samples were time-weighted composite samples collected at twenty-minute intervals during the initial portion of runoff, with volatile organics and bacteria collected as grab samples. Both types of surface samples are likely representative of the "first flush" concentration, which is likely greater than the whole-storm event mean concentration (EMC). Lysimeter

## Figure 5 - WAS Water Quality Monitoring Locations

### THE HALL HOUSE †

*LOS ANGELES, CA*

The front and rear lawns of the Hall House are bermed to collect, retain, and infiltrate runoff from the roof and other hardscape areas. In addition a drywell collects runoff conveyed to a trench drain in the driveway. A cistern collects 1/4 of roof runoff; the collected water is then used for irrigation.

### VETERANS PARK *

*LONG BEACH, CA*

The infiltration BMP was designed to intercept runoff from a 0.5-acre parking lot and adjoining sidewalks. Stormwater collection for the BMP system consists of catch basins positioned to intercept surface flow along existing flow lines at the edges of the parking lot. The discharge pipelines from the catch basins direct stormwater to a buried, concrete sand/oil interceptor, then to an underground infiltration gallery.

### BROADOUS ELEMENTARY SCHOOL *

*PACOIMA , CA*

The BMPs for the 7.4-acre site include a unit that treats stormwater, a subsurface infiltration system installed in the playground area of the school, and a vegetated system that slows, filters and safely channels stormwater through the campus.

### RECYCLED MATERIALS SORTING FACILITY *

*SUN VALLEY, CA*

The infiltration BMP was designed to intercept runoff from a 2.3-acre portion of the paved yard. The stormwater treatment system is a concrete detention/settling basin that discharges into a subsurface infiltration gallery. Runoff from a portion of the roof is directed to the underground infiltration gallery but does not undergo pretreatment.

### SCRAP METAL FACILITY *

*LOS ANGELES, CA*

The infiltration BMP at this site was designed to intercept runoff from a 0.85-acre portion of the site, pre-treat the collected stormwater to reduce the concentrations of sediment, oil and grease, and infiltrate the treated stormwater. The stormwater treatment system consists of a concrete detention/sedimentation basin that receives site runoff and discharges into a subsurface infiltration gallery.

### IMAX OFFICE *

*SANTA MONICA, CA*

A commercial office facility located in Santa Monica, this 3.5 acre site is equipped with two types of BMPs: a drywell receiving roof runoff and a landscaped area that receives parking lot runoff.

* photo by Suzanne Dallman † photo by TreePeople

samples were collected for a period of up to two days after a monitored storm event. At sites with shallow groundwater, monitoring well samples were collected within a few days of a storm event. At sites with deeper groundwater, monitoring well samples were collected periodically, but not in response to a storm. Background samples were collected from all monitoring wells before infiltration had occurred.

Sampling followed a documented Quality Assurance Program Plan and samples were sent to a state-certified laboratory for analysis. Collected water quality samples were analyzed for greater than 80 general constituents[1], including general minerals, metals, oil and grease, perchlorate, some pesticides, volatile and semi-volatile organic compounds, N-Nitrosodimethylamine, surfactants, and bacteria.

The monitoring goal was to sample at least two storm events at each site each year. Two locations, Broadous Elementary School and IMAX, were monitored during the 2001-02 winter; a residential location was added the following year and a total of three sites were monitored during 2002-03. Three additional monitoring locations – two industrial and one commercial/recreational site – were added prior to the 2003-04 winter. All six locations were monitored during the 2003-04 and 2004-05 seasons. A supplemental program of subsurface monitoring was conducted during 2005-06 and 2006-07 and included all sites except the Hall House, which does not have a groundwater well.

## 2.2 WAS MONITORING RESULTS

Monitoring conducted for the Los Angeles Basin Water Augmentation Study found no evidence of degradation of groundwater quality from the infiltration of stormwater. In general, runoff contained low concentrations of constituents of concerns (with the notable exception of metals) indicating that infiltration is unlikely to result in degradation of groundwater quality. Based on trend analysis of data collected from 2000 to 2007, groundwater quality at the six monitored sites was stable or improved for most constituents.

Water quality results were analyzed using statistical and non-statistical methods. Non-statistical methods included visual displays (graphs) of time- and depth-concentration data. Statistical methods included summary statistics and Mann-Kendal trend analysis. Trend analysis was performed for over 600 sets of data (each containing all analyses for one constituent at a single monitoring station) collected from 2000 to 2007. To test for trends, time-concentration charts were plotted at each monitoring location over the period of the monitoring program. Of the over 600 time-concentration charts, fewer than 80 trends were detected in the lysimeter and groundwater samples and 84 percent of these were negative trends where concentrations declined over time.

Monitoring was conducted during a variety of rainfall conditions. The study period included two of the driest years (2001-2002, 2006-2007) and the second wettest year (2004-2005) on record. In general, runoff contained low concentrations of constituents of concerns (with the notable exception of metals) indicating that infiltration is unlikely to degrade groundwater quality. At three project sites, pre-treatment was conducted[2] prior to infiltration to decrease the risk of groundwater impact.

Soil appears to be very effective in removing TSS and bacteria from stormwater. Bacterial indicators were found in stormwater samples at all locations except for at the Hall House. With the exception of one sample at Broadous School, bacteria were not detected or were at very low concentrations in soil-water and groundwater samples.

The concentration of metals tended to be higher in stormwater than in the subsurface samples. Metal concentrations in subsurface samples showed continued variability, but generally stable or decreasing concentrations.

1 The number is much larger when taking into account the numerous organic compounds and congeners.

2 Pre-treatment took the form of settling basins.

Exceptions include slightly increasing trends of copper and zinc in one lysimeter at the recycled materials site, which could be associated with infiltration of stormwater with relatively higher concentrations of these metals. A similar trend occurred in one lysimeter at the metal recycler. Numerous studies have observed effective removal of metals as runoff moves through soil (Weiss et al., 2008), sand filters, berms, and aquifers (Fuller, et al., 1994; Minton, 2005).

Most inorganic pollutants did not show clear trends or showed decreasing concentrations over the study period. Other studies (Weiss et al., 2008) have shown that concentrations of salts and some nutrients are not effectively reduced during infiltration. These constituents were generally present at low concentrations in runoff from the study sites, and negative groundwater impact was not observed.

Based on trend analysis, groundwater quality at monitored sites was stable or improved for most constituents of concern (LASGRWC, 2008). These findings are consistent with studies conducted around the world (Weiss, et al., 2008) indicating that the risk of degrading groundwater quality from properly conducted stormwater infiltration is relatively low.

Four increasing trends were detected in collected groundwater samples: chloride at the metal recycler site; and chloride, nitrate, and dissolved zinc at the municipal park. It is considered unlikely that any of these trends are the result of infiltration because runoff contained low concentrations of these constituents. Although not addressed in the WAS monitoring reports, trends in nitrate and chloride suggest that an expanded study in parks and agricultural areas where nutrients may be applied in large quantities may also be helpful.

The WAS study found no apparent trends to indicate that stormwater infiltration negatively impacted groundwater quality. At sites with shallow groundwater, groundwater quality showed improvements for many constituents, possibly due to dilution from infiltrating stormwater. At industrial sites, pre-treatment filtration methods seemed to be effective at removing most constituents prior to entering the subsurface infiltration system. Site characterization of surface and soil constituents at industrial sites, however, should be conducted prior to implementing infiltration strategies.

# 3. MODELING THE POTENTIAL FOR GROUNDWATER AUGMENTATION

Another objective of the WAS is to quantify the amount of stormwater that can be realistically captured and infiltrated using decentralized techniques. The concept of capturing stormwater for groundwater infiltration is not new to the Los Angeles region. An average of 202,000 acre-feet of stormwater is captured for groundwater infiltration annually at centralized spreading grounds, 95% of which is from the upper watershed areas running off the national forests and open space areas (MWD, 2007). Much of the increased runoff from urbanization and development, however, bypasses the centralized spreading grounds and flows to the ocean uncaptured and untreated.

To estimate the potential for stormwater recharge, the WAS partners participated in the development and application of geographic information systems (GIS) based model *(Appendix C)*. The Groundwater Augmentation Model (GWAM) was developed by the Bureau of Reclamation to quantify stormwater runoff and the potential for groundwater recharge focusing on the urbanized areas of Los Angeles County within the Los Angeles, San Gabriel, Dominguez Channel, and Santa Monica Bay watersheds. Not well-understood is how much precipitation infiltrates to groundwater through lawns, open space and other pervious surfaces, and what additional amount is available for capture from impervious surfaces.

The GWAM was specifically designed to show the potential increase in groundwater recharge given certain hypothetical infrastructure changes within the Los Angeles Region *(Figure 6)*. The model area consists of only the urbanized portions of Los Angeles Region watersheds and excludes the mountainous areas because of the limited amount of groundwater infiltration possible on the steep slopes. The runoff from the mountains is recharged in centralized spreading basins and therefore not included in the model. The model calculates a soil moisture budget using soil

FIGURE 6 - GWAM MODELED AREA

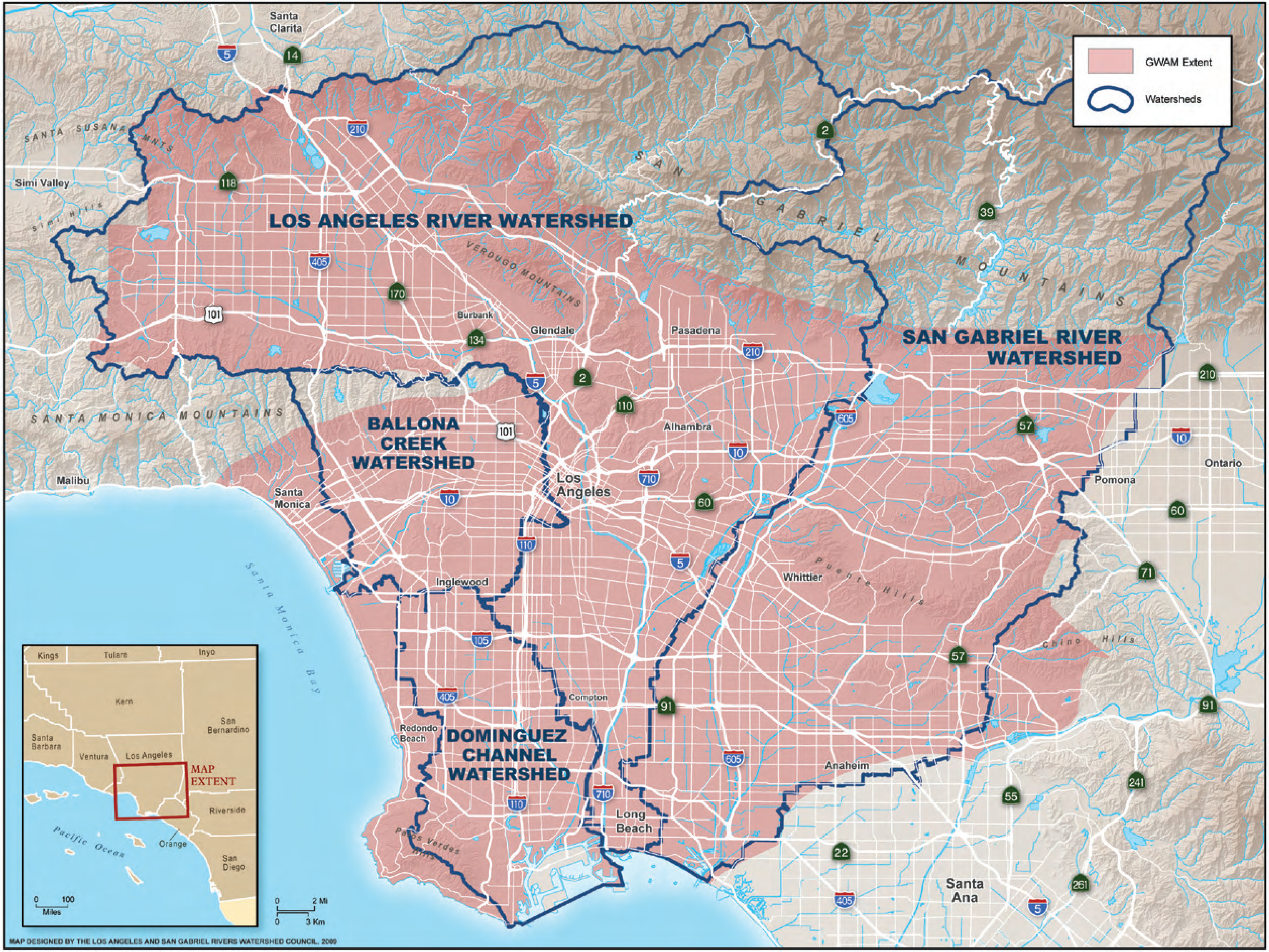


**Figure 7 - GWAM Process Diagram**

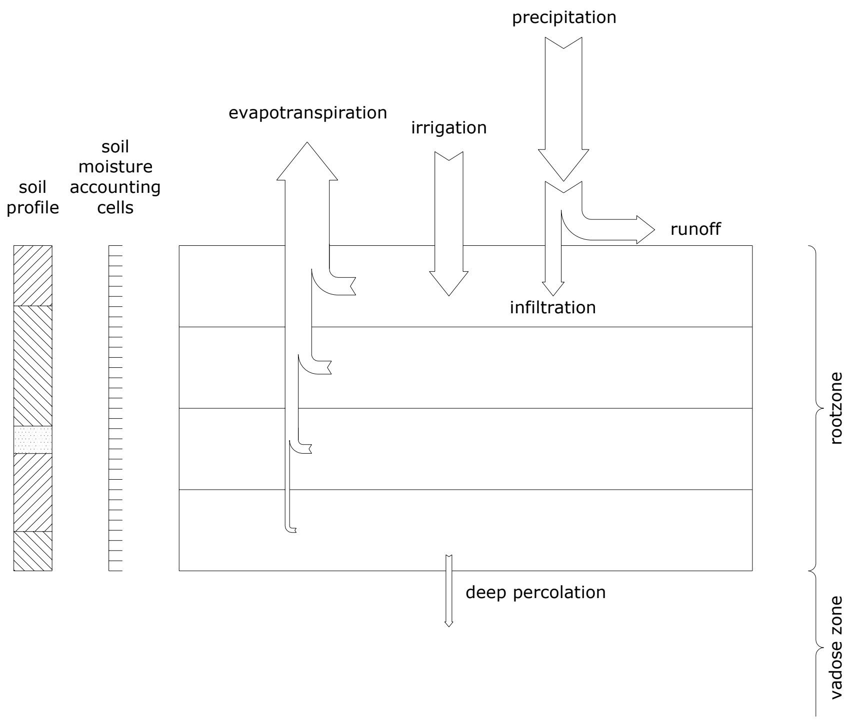



**Table I - Generalized GWAM Process Calculations**

| | |
|---|---|
| INFILTRATION | = Precipitation – Bare Surface & Canopy Evaporation – Runoff |
| | Where:<br>*Infiltration*<br>Is the volume of water (acre feet) entering into the root zone.<br>*Precipitation*<br>Is hourly precipitation data from a fifty year record, in inches.<br>*Bare Surface & Canopy Evaporation*<br>Is the volume of water intercepted and/or evaporated before it can become runoff or infiltration<br>*Runoff*<br>Is runoff predicted by the model using the SCS curve number procedure. |
| DEEP PERCOLATION | = Previous Soil Moisture + Infiltration + Irrigation – Evapotranspiration |
| | Where:<br>*Deep Percolation*<br>Is the volume of water predicted to infiltrate past the root zone and into the vadose zone.<br>*Previous Soil Moisture*<br>Is the soil moisture from each previous daily time step in the model.<br>*Infiltration*<br>Is as described above.<br>*Irrigation*<br>Is applied water to fulfill deficits in soil moisture.<br>*Evapotranspiration*<br>Is calculated within the model from california irrigation management system data, and processed using accepted methods. |

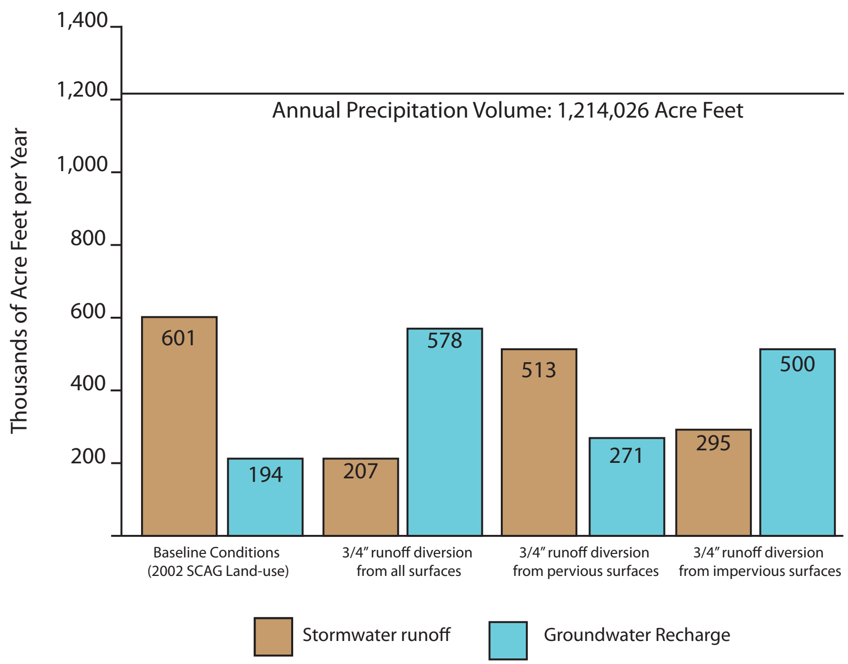
properties, land cover, slope and daily precipitation. The GWAM predicts the amount of runoff, infiltration, and deep percolation through the root zone (groundwater recharge) under current conditions and the potential for increasing groundwater recharge if BMPs are employed to increase permeability or infiltration *(Figure 7 and Table 1)* (Bureau of Reclamation, 2007). The model provides an opportunity to examine multiple benefit approaches to water supply and urban runoff issues using a variety of techniques to capture and treat stormwater using alternative decentralized management scenarios.

As a planning tool, the GWAM models the fate of precipitation in a given study area and depicts the likely infiltration or deep percolation generated on a selected area during a precipitation event. The dynamics of runoff and infiltration in the model can be altered with user-selected diversions of runoff to infiltration. This allows the model to consider efforts to diminish runoff volume by retaining water as a potential recharge source.

The model is a useful tool to determine which areas offer the best potential for recharge efforts or which types of infiltration systems are more appropriate to particular areas within the Los Angeles Region. Because the model does not account for subsurface geologic features or groundwater movement, augmentations to groundwater available for later pumping cannot be estimated from the model output. Additional groundwater modeling is called for to make these estimates, and GWAM is capable of contributing output to select groundwater models for such an effort.

The GWAM model allows a user to divert rainfall, based on percent volume or absolute depth (inches), from impervious and pervious land uses to infiltration devices that either infiltrate through the root zone (e.g., bioswales) or directly below the root zone (e.g., infiltration trenches). Users may select either a predefined area for analysis – such as a watershed, sub-watershed, or groundwater basin -- or define their own area by uploading a GIS coverage. The GWAM forecasts that substantial amounts of groundwater recharge can be realized through a comprehensive implementation of distributed stormwater infiltration.

**Figure 8 - GWAM Volume Estimates**




The model estimates that annually 16 percent of precipitation currently percolates to groundwater (about 194,000 acre-feet) in the Los Angeles Region, while 50 percent (approximately 601,000 acre-feet) becomes runoff that flows directly through the stormwater conveyance system to the ocean *(Figure 8)*. Implementing a regional decentralized stormwater management where the first ¾" of each rain storm is captured and directed for infiltration on all parcels could add up to 384,000 acre-feet bringing the estimated total to 578,000 acre-feet of recharge per year, on average, to the groundwater basins – enough water for 1.5 million people. This total does not factor the existing efforts to capture runoff into spreading basins, approximately another 202,000 acre-feet of water runoff from the upper natural watersheds outside the model area (MWD, 2007).

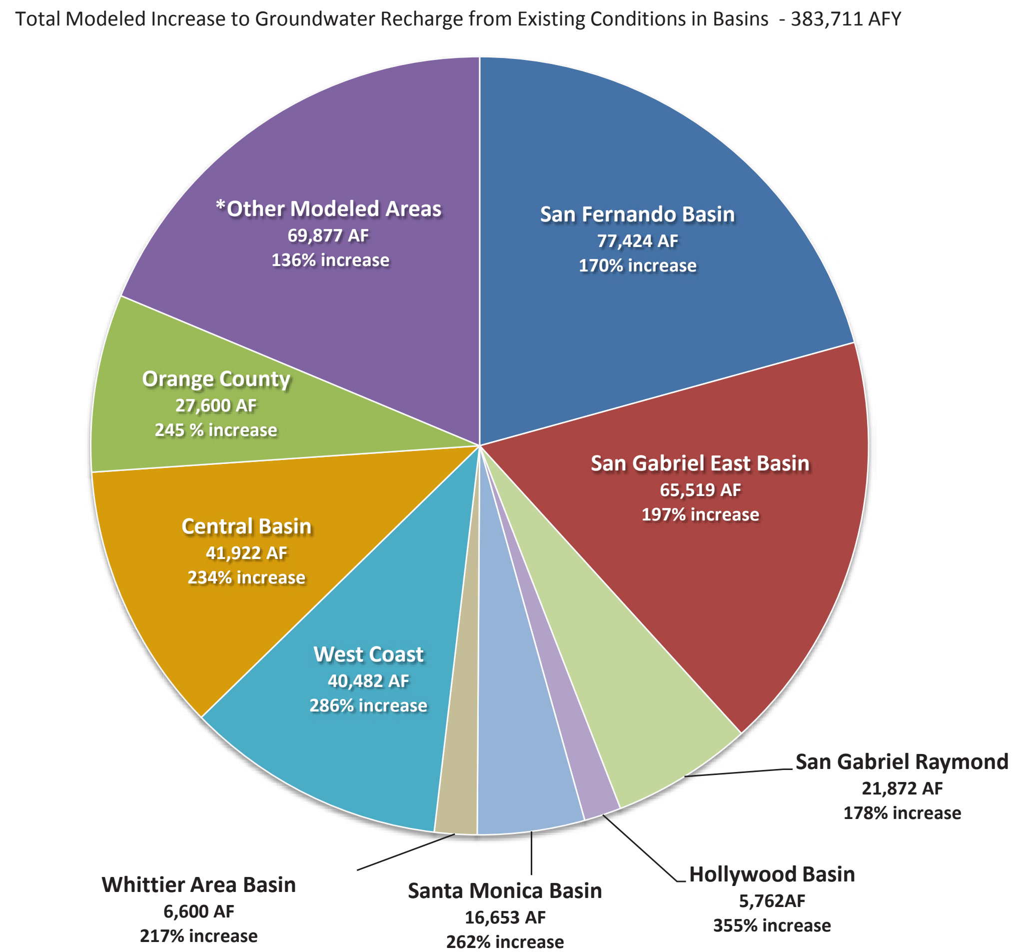
The GWAM is a planning tool and as such has limitations. The general findings of the model are sound; however, as in all models, the exactness of the numerical output can mask some of the uncertainties in the model input assumptions. For example, the precipitation values are modeled using Thiessen polygons generated from weather station locations. Because of this purely geometric approach, the precipitation values may not account for all the topographic or spatial variation of precipitation across the study area.

The GWAM does not perform channel routing and cannot make an assessment of infiltration from streams. Runoff from one polygon is not calculated as run-on in the next down-shed polygon, which could lead to underestimations of infiltration in some areas. However, considering that BMPs would be implemented on specific land parcels for the purpose of increasing infiltration from those parcels then it is likely that GWAM is predicting conservative infiltration values for consideration in planning studies.

The results from modeling full implementation of the SUSMP policy[1] requirement in the Los Angeles Region, in which development projects must treat the first three-quarter inch of rainfall, demonstrate the potential for up to 48 percent of precipitation to recharge groundwater (approximately 578,000 acre-feet per year), with a net reduction of stormwater runoff (approximately 207,000 acre-feet a year compared to approximately 601,000 acre-feet of runoff prior to the diversions). The full potential for groundwater recharge will vary depending on the type of infiltration system used and whether the water passes through the root zone (increasing the loss due to evapotranspiration) or if it enters below the root zone. Regardless of the variability, the GWAM results demonstrate a substantial amount of groundwater recharge potential from a systematic approach of decentralized stormwater management *(Appendix C)*.

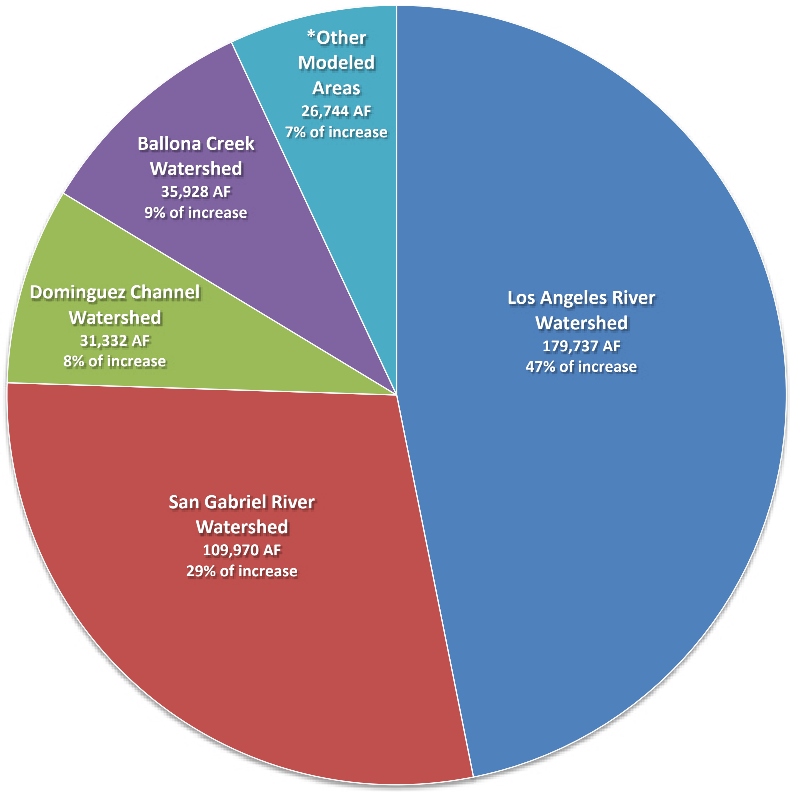
There is significant recharge capacity in both the deep and shallow aquifers of the Los Angeles area *(see Ch 1, Figure 2)*. These aquifers have an estimated capacity of 1.2 million-acre-feet (MWD, 2007) and a broad-based strategy to increase infiltration in the region would move the region closer to capitalizing on available storage. The GWAM model provides a big picture view of areas and land uses that provide locations conducive to infiltration. Therefore, the GWAM model was run to compare the groundwater basins and the watersheds to provide the differences that exist due to the characteristics of the areas, such as land uses and precipitation and to determine those areas that have greater capacity for stormwater infiltration. In terms of relative volume increase per acre, during a modeling scenario where ¾" of precipitation is diverted from all land-uses to recharge, the largest projected increase over existing conditions would occur in the Raymond Basin *(Figure 9)*. The GWAM projects an increase from 0.3 to 1.3 acre-feet per acre within Raymond

FIGURE 9 - GWAM RESULTS FOR TOTAL GROUNDWATER RECHARGE BY GROUNDWATER BASIN FOR ¾" STORM




1 SUSMP standards apply to particular new and redevelopment projects that require building/ development permits and are administered by the municipalities approving the projects. The SUSMP standard is a National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit requirement as required by the State Water Quality Control Board and US EPA.

**Figure 10 - GWAM Results For Total Groundwater Recharge By Watersheds For ¾" Storm**




Total Modeled Increase to Groundwater Recharge from Existing Conditions in Watersheds - 383,711 AFY

Basin. The relatively small size of the Basin, however, limits the total volume of increase to groundwater recharge to 21,872 acre-feet per year. In contrast, infiltration in the Central Basin could increase from 0.16 to 0.62 acre-feet per acre; factoring in the size of this basin, the largest within the WAS area, the annual increased volume of groundwater recharge would be around 81,200 acre-feet. Based on their location and total amount of impervious surface, and regardless of their size, the Rio Hondo, Coyote Creek, Ballona Creek and Dominguez Channel watersheds would potentially each yield between 30,000 and 35,000 additional acre-feet to the groundwater aquifers if all parcels diverted the three-quarter inch storm *(Figure 10)*.

The second largest groundwater basin after Central Basin is the San Fernando Basin. At 169,000 acres, it deep percolates only 45,500 AFY in existing conditions. With a diversion of ¾" of runoff from both pervious and impervious land-uses the deep percolation would increase to nearly 123,000 AFY, or a 170% increase. In baseline conditions the San Fernando Basin receives 0.26 acre feet per acre of potential recharge, and in the diversion scenario this number increases to 0.72. For another project, a scenario calling for a 100% diversion from high-density residential land was performed in the San Fernando Basin. That land-use accounts for 42% of the area of the Basin, and in this diversion scenario 0.93 acre feet per acre of potential deep percolation was generated, or an increase of 66,700 AFY.

As with any model, collection of additional site-specific information will be necessary for accurate identification of suitable sites. With further refinement of input data parameters and integration with other surface and groundwater models, such as the Los Angeles County Structural BMP Prioritization and Analysis Tool model (SBPAT) (Geosyntec, 2006), which takes into account water quality benefits, and the USGS Modular Three-Dimensional Groundwater Flow Model (MODFLOW) (Harbaugh, 2000) the GWAM will be valuable in the determination of priority locations, types, and potential benefits of infiltration strategies. For example, the drainage area of an infiltration BMP, specified by SBPAT to improve surface water quality, could be input into GWAM to estimate the volume of water

**Figure 11 - Soil Types & Infiltration Rates**

that could be infiltrated with the installation of the BMP. In addition GWAM could evaluate changes in infiltration from climate change by using the precipitation records from years that match the predicted precipitation amounts within the more accepted climate models.

A clear pattern for potentially increasing infiltration of stormwater to groundwater emerged in this analysis. Sub-watersheds located near or originating in the foothills infiltrate a larger volume of water per area, and convert a greater percentage of precipitation to groundwater. The soils underlying the areas of the study are one of the main variables in determining infiltration capacity. The sub-watersheds and basins with higher capacity had soils with higher infiltration rates *(Figure 11)*. Soil infiltration increases as the size of the soil particles increases, so those areas with Soil Class A (Sand) have the greatest potential for infiltration while those areas dominated by clay soils have a lower capacity (Class D).

# 4. VALUING STORMWATER INFILTRATION

There are multiple ways to value the benefits and costs of strategic decentralized stormwater managment. Direct benefits of increasing groundwater recharge include the reduced demand for imported water and therefore a reduction in associated costs and risks of over-reliance on an uncertain supply. Another direct benefit is the avoided cost of treatment when high runoff volumes breach wastewater conveyance systems and overwhelm wastewater treatment facilities.

Strategic decentralized stormwater infiltration also diminishes the perennial need for enhancing storm drain system capacity. Other secondary direct benefits include water conservation, reduced beach closures, new recreation and educational opportunities, community beautification, increased property values, and an enhancement of habitat, open space and ecosystem services. Indirect values associated with this approach include improvements in air quality, the creation of green jobs, and multi-benefit project collaborations that produce novel partnerships and cost-sharing opportunities (Chesnutt et al., 2008).

## 4.1 WAS RESEARCH

Research conducted as part of the WAS found that, generally, decentralized systems can be cost-effective within the Los Angeles area. Los Angeles has long relied on large, centralized spreading basins to recharge groundwater aquifers because of the economies of scale these projects offered for construction and maintenance costs. The current high cost of land in the region however, coupled with potential resistance from communities concerned about expansion of spreading basins and corresponding removal of habitat and recreational opportunities, call into question reliance on typical centralized strategies going forward.

To address cost-effectiveness, the WAS determined the value of new water supplies by examining the cost of the current water supply and of imports that would avoided if local supplies were available. The value based on current supply cost is $695 per acre-foot as of January 1, 2009; this value increased to $811 per acre-foot in January 2010[1] (Chesnutt et al., 2008). The WAS used this cost as the replacement cost of water to be imported.

Consumer willingness to pay to avoid water shortages during dry years also has a value. The value of a stored supply of groundwater available for use during dry years ranges from $757 to $943 per acre-foot, depending on the usable storage volume available (Chesnutt et al., 2008; Cutter 2007). Perhaps more importantly, this stored water would provide a reliable supply of water and reduce risks regardless of the amount of rainfall in any given year.

Another important consideration in valuing infiltration BMP project costs and benefits is the avoided cost that jurisdictions could realize from reducing stormwater requirements. A survey of stormwater quality costs conducted by the WAS found that the cost for treating the half-inch 24-hour event[2] ranged from, $0.78 to $1.01 per gallon of stormwater runoff. This means that the total amount of avoided cost for treatment of a half-inch stormwater is nearly a dollar per gallon (Chesnutt, 2006). If stormwater projects were capable of treating levels higher than a half-inch precipitation event, the avoided costs would be greater (Chesnutt et al., 2008).

1 The cost of The Metropolitan Water District of Southern California Full Service Tier 2 Supply Rate as of 1/1/2009, Available at: *http://www.mwdh2o.com/mwdh2o/pages/finance/finance_03.html*

## 4.2 RELATED RESEARCH

Researchers at the University of California, Riverside have documented that an incentive-based approach to decentralized stormwater management can be a viable means of increasing groundwater recharge projects. Considering factors such as the cost of land and construction and maintenance costs, researchers concluded that a system whereby land owners would be paid to implement small-scale stormwater infiltration systems would be more economical and effective than reliance on centralized infiltration basins (Baerenklau et al., 2008; Cutter 2007). The main driving factor for the reduced cost is that this approach does not rely on land acquisition.

Other studies have also shown the use of decentralized approaches to be a cost-effective. A literature review of Low Impact Development (LID) design systems found these systems tend to be less expensive than conventional systems[3] to install, and in most cases less expensive to maintain (MacMullan and Reich, 2007). This finding is consistent with analysis by federal and state regulatory agencies regarding the implementation and life costing of LID systems (Ackerman & Stein, 2008; US EPA, 2007). This analysis is especially true when LID systems are sized to treat the lower intensity storm events that result in the highest percent concentration of pollutants typically found in urban stormwater runoff (Tiefenthaler & Schiff, 2003). Treating lower intensity storms is the strategy

2 It should be noted that the water quality treatment requirements are typically ¾ inch to 1 inch within Los Angeles County.

3 Conventional systems range from structural end-of-pipe solutions to diversion to sewers.

preferred by both the EPA and the California State Water Quality Control Board under the NPDES stormwater discharge requirements.

Development of a decentralized stormwater infiltration management approach has the multiple effects of providing groundwater recharge, reducing pollutant runoff, reducing stormwater management construction and implementation costs, and meeting state and federal regulatory water quality requirements.

# 5. FINDINGS AND DEMONSTRATION OF THE WATER AUGMENTATION STUDY

Based on the findings of the WAS research, a decentralized stormwater infiltration strategy would provide a local and reliable supply of water that would not negatively impact groundwater quality. A decentralized approach could provide an additional 384,000 acre-feet to achieve a total of 578,000 acre-feet of groundwater recharge annually if the first ¾" of each storm was infiltrated on all parcels. This is enough water supply for approximately 1.5 million people. As many development projects are already required to treat the first ¾" of each storm this seems like a feasible opportunity. In some locations the infiltrated water may not be available for pumping for later use. At these locations, stormwater could be captured for either reuse on-site or diverted and infiltrated in other locations. The value of this new water supply would be approximately $311 million annually, using the MWD Tier 2 rate for 2010. This economic valuation of infiltration excludes the water treatment benefit, which would significantly increase the economic benefit. The valuation also excludes costs for pumping and distribution of the new water supply which may lower the value of the overall supply.

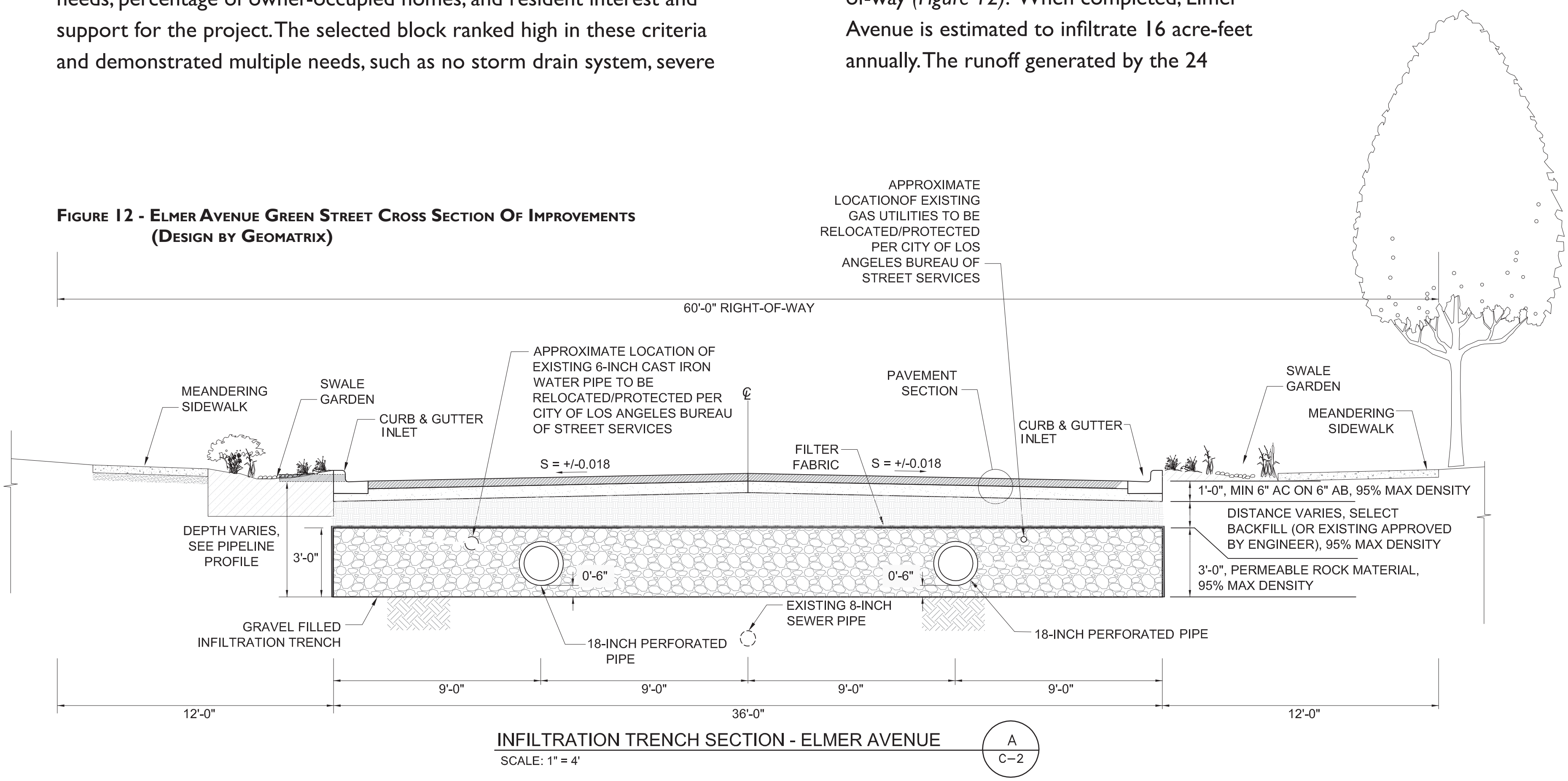
Implementing the recommendations of this report to increase infiltration through installation of BMPs requires changes in policy for development, redevelopment, and retrofit of existing properties. Modifications to development codes, standards, permits and incentives can ensure that new developments or larger redevelopments preserve or enhance the amount of water they infiltrate. Retrofitting existing properties poses a significantly more complex challenge, which has been the focus of the demonstration phase of the WAS.

## 5.1. ELMER AVENUE NEIGHBORHOOD RETROFIT DEMONSTRATION PROJECT

Based on the findings of this study, the WAS partnership moved forward on a demonstration project in a 24-single family residential home neighborhood in northeast San Fernando Valley to validate study findings. The Elmer Avenue Neighborhood Retrofit Demonstration Project (Elmer Avenue) focuses on a block of 24 single-family residences in Sun Valley, a Los Angeles neighborhood located in the northeast San Fernando Valley. The site was chosen after an extensive selection process that evaluated neighborhoods based on more than 80 criteria including underlying groundwater basins, zoning, unmet drainage needs, street improvement needs, percentage of owner-occupied homes, and resident interest and support for the project. The selected block ranked high in these criteria and demonstrated multiple needs, such as no storm drain system, severe flooding, an absence of sidewalks and no street lighting, which could be addressed through project improvements to enhance the neighborhood while meeting groundwater recharge objectives.

Elmer Avenue receives run-on from approximately 40 acres of upstream residential area causing flooding with most storms. The project was designed to treat the volumes produced by these 40 acres during an approximate two-year storm by conveying stormwater to a large infiltration gallery underneath the street right-of-way *(Figure 12)*. When completed, Elmer Avenue is estimated to infiltrate 16 acre-feet annually. The runoff generated by the 24

**Figure 12 - Elmer Avenue Green Street Cross Section Of Improvements (Design by Geomatrix)**

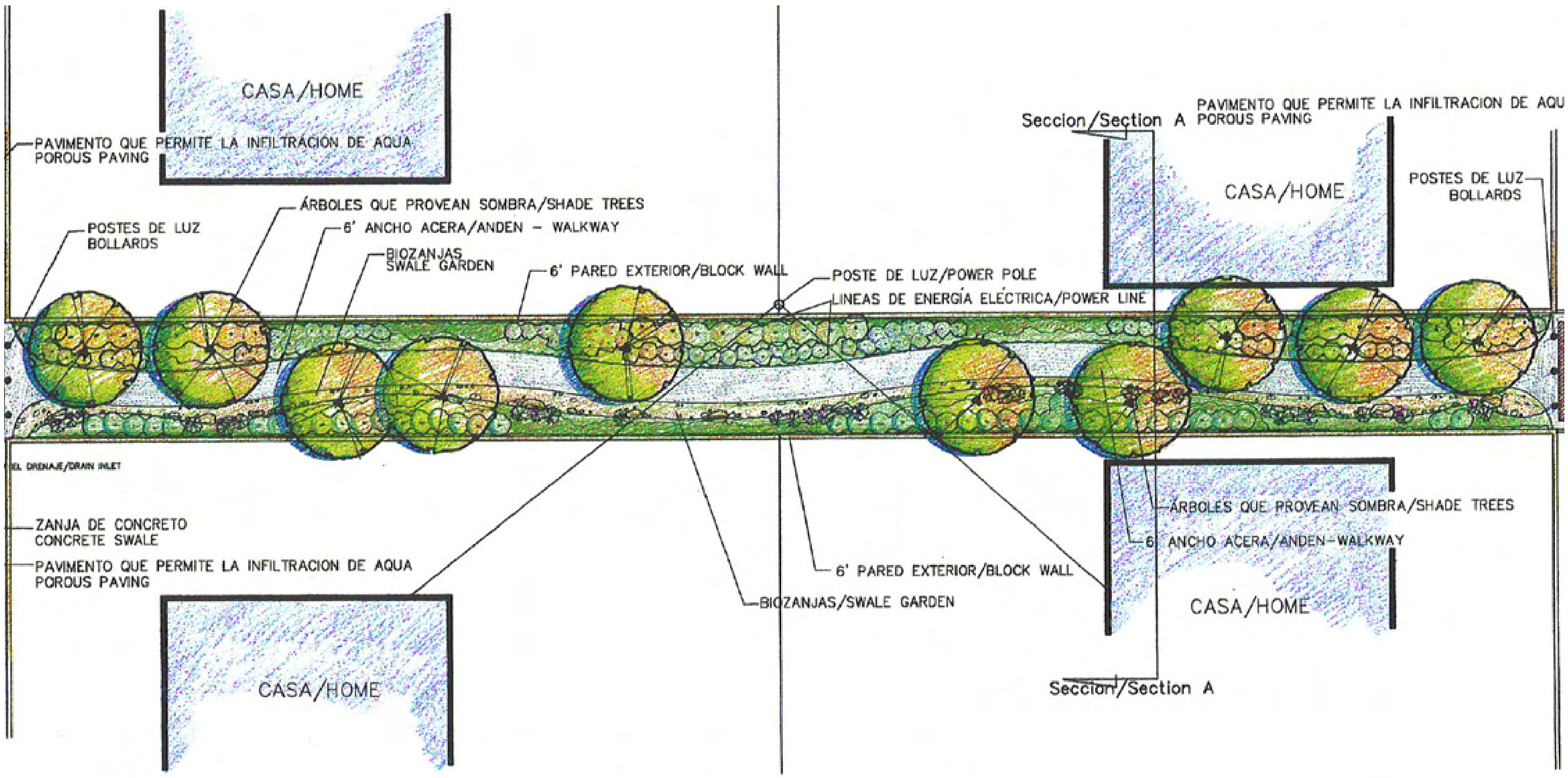


residences on Elmer Avenue will be treated in bio-swales in the parkway portion of newly installed sidewalks. In addition, improvements will be installed on private property to reduce runoff through porous pavers, rain gardens, rain barrels, and native plantings that reduce water demand. The project includes monitoring the quality and quantity of water supplied to the infiltration gallery and through the bio-swales. Behavioral changes pertaining to water usage will be evaluated, and the lessons learned from the outreach, design, construction, maintenance, and implementation will be documented to increase the success of future projects.

A proposed phase II of the Elmer Avenue project will retrofit an alleyway, or paseo *(Figure 13)*, at the southern end of the block to treat an additional 20 acres of runoff, for a total of 60 acres to be managed through decentralized stormwater management. The Elmer Paseo will add durable, permeable surfaces for walking and a bio-swale adjacent to the pathway, improving walkability and safety while increasing the infiltration benefits of the project.

Pre- and post-construction monitoring of the demonstration project will provide additional data regarding the feasibility of decentralized infiltration for groundwater recharge. The multiple benefits of the project (water quality, water supply, costs, and additional benefits) are being tracked to provide data from before, during, and after installation, and will be reported in future addendums to this report.

**Figure 13 - Proposed Phase II Elmer Avenue Alley Retrofit**



# 6. CHALLENGES AND RECOMMENDATIONS

This section moves from a description of the WAS results and findings to a discussion of the lessons learned and challenges surrounding implementation of a decentralized stormwater management approach within the Los Angeles Region. Challenges and recommendations fall into the following categories: 1) institutional barriers 2) existing development rules, 3) stormwater regulations, 4) groundwater management, 5) cost and funding, and 6) education and awareness.

It is unlikely that a purely regulatory approach will be successful in the implementation of a systematic decentralized stormwater infiltration strategy (Ringquist, 1993, 1995). Rather, the development of decentralized systems for stormwater capture and recharge will require novel and strategic approaches to overcome barriers. The strategies and recommendations that follow provide an approach to improving water quality, increasing groundwater recharge and producing multiple benefits through a decentralized stormwater strategy. Implementing these recommendations will result in the added benefit of creating an encouraging environment for developers and private landowners to incorporate distributed infiltration systems on their properties and in their projects.

The recommendations in this chapter are directed to three groups that should develop, study, or implement them: project proponents, governing bodies, and WAS partners. Project proponents are those individuals, organizations, developers, or cities developing projects, specifically urban retrofit and redevelopment but also referring to new development. Recommendations to project proponents are project specific, but they may be addressed by governing bodies' policies or regulations. Governing body is a broad term applying to local, county, regional, state, and federal governmental agencies that develop, modify, or adopt policies and regulations. The recommendations directed at WAS partners are those items that the partnership proposes to address by working with project proponents, governing bodies and all other required parties. While written specifically for the Water Augmentation Study partnership, these recommendations could apply to any similar partnership undertaken with similar goals to advance decentralized stormwater infiltration for groundwater augmentation.

## 6.1 INSTITUTIONAL BARRIERS

Implementation of decentralized stormwater management will require changes at multiple levels of government. Municipalities and agencies will have to review existing policies, plans, and regulations for conflicts. Many existing practices, from approvals at planning counters to maintenance at parks may require modification. Therefore, governing bodies need to remain flexible and show a willingness to review and adopt new ideas. This will require support from the bottom to the top including government agencies, politicians, and the public. The political will to change must be in place at the same time that agencies seek changes. The ability to work across agency, municipal, and political boundaries will be essential to creating change and implementation of the recommendations provided in the sub-sections below. Many of the recommendations in the sub-sections refer to increased coordination amongst multiple disciplines. Many cities have initiated this process through green teams or sustainability coordinators within departments that meet and discuss new sustainable approaches.

Recommendations:

- Governing Bodies: Develop cross department "green teams" or sustainability coordinators to review and incorporate decentralized approaches to stormwater management.

- WAS Partners: Provide assistance to governing bodies regarding effective strategies for decentralized stormwater mangaement that focus on integration across departments and agencies.

## 6.2 EXISTING DEVELOPMENT RULES

Over decades of urban growth, building codes, ordinances, and standards have evolved to ensure that the built environment is effective, efficient, and protects the public's health and safety. Many of these rules, however, were developed before stormwater runoff was known to impact surface water quality and codes were developed prior to understanding of the benefits of decentralized stormwater management methods. Standard plans and design standards, accessibility requirements, vehicle and fire codes, and vector control considerations all must be amended to enable decentralized stormwater management projects seeking to increase infiltration.

The Center for Watershed Protection, a non-profit organization located in Maryland, has found that implementation of alternative stormwater management projects that encourage infiltration are typically stymied by or conflict with municipal rules that fall under the categories of Zoning and Planning, Subdivisions, Flood Control, Street Designs, Building and Fire Codes, and Landscaping (CWP, 2008). Additional barriers that fall into this category include accessibility, vehicle codes, and vector control and are addressed below.

Recommendations:

- WAS Partners: Convene a panel or working group for LID review of standard plans and updates to existing development rules within the Los Angeles region and study examples from the City and County of Los Angeles.

### 6.2.1 STANDARD PLANS AND DESIGN STANDARDS

Municipalities rely on rules and standard plans for infrastructure improvements, which can reduce the flexibility needed for innovative stormwater infiltration projects. Standard plans provide guidance and can reduce time in approvals for public and private projects. For example, many municipalities have rules that require downspouts and drainages to be directed to impervious surfaces reducing the ability to use infiltration techniques. Standard plans include details on the types of catch basins, sidewalks, curbs, and gutters that can be installed on both private and public projects. There are currently few standard plans that incorporate infiltration techniques, such as parkways with bio-swales. Until decentralized or LID strategies are incorporated into standard plans, a city will require additional review and time for plans that include infiltration elements, resulting in increased costs for builders. Additional time, and related expenses, should be built into any project until standard plans are updated.

Recommendations:

- Governing Bodies: Incorporate LID design standards into standard plan development for both private developers and municipal agencies.

### 6.2.2 ACCESSIBILITY

Accessibility for persons with disabilities is required under federal law by the Americans with Disabilities Act (ADA). Requirements and design standards for access may diverge from designs that seek to maximize pervious areas and infiltrate stormwater. Narrow interpretation of ADA design guidelines can restrict the number and type of water infiltration strategies that can be demonstrated and tested. The ADA guidelines include details for types of walkway surfaces, edges and slopes against walkways, and curvatures of pathways. For example, the slope of the rain garden and the sidewalk curvature and width along Elmer Avenue had to be modified in ways that reduced capacity for infiltration of water or planting of trees *(see sidebar)*.

As stormwater projects begin to use the public right-of-ways for infiltration areas, such as bio-swales, methods to ensure accessible routes and adequate space for infiltration must be evaluated on a case-by-case basis if no standard plans exist.

Recommendations:

- Project Proponents: Include access consultants in the design of demonstration projects.
- Governing Bodies: Evaluate standard plans to account for universal access in projects with stormwater infiltration elements.

**ELMER AVENUE STREETSCAPE**

The Elmer Avenue project includes modifications to the standard parkway, which typically includes a planter area and sidewalk. The parkway along Elmer calls for bio-swales that are at a different grade to the adjacent sidewalk and curb. In addition, the plans called for a meandering sidewalk feature.

These elements required review and modification to ensure that they meet the guidelines of the American Disabilities Act for access. Many permutations were evaluated looking at similar plans in other cities and comparing them to the examples provided by the ADA guidelines. Extensive outreach to experts in the field and to other agencies and municipalities regarding the designs had to be undertaken to ensure compliance with the intent of the ADA guidelines.

### FIRE AND VEHICLE CODES IN SEATTLE, WA AND KENTWOOD, MI

The Seattle "Street-Edge-Alternative" (SEA) Streets program has overcome some fire code barriers. These projects succeeded in using alternative materials in street retrofits while simultaneously accommodating emergency access. One design consideration was to include sidewalks rated for fire truck access so that street width could be reduced.

Another example of new materials accommodating for fire truck and safety access comes from Kentwood, Michigan (Low Impact Development Center, 2009). A type of permeable paver was field tested with a 30-ton fire truck, which operated its ladder during the test. This test led to the approval of the GEOBLOCK© system for use in the city's fire lanes.

### 6.2.3 VEHICLE CODES

The California Vehicle Code includes street sizing standards. The size standards mandate width, which prevents reduction of impervious surfaces to increase the amount of space for stormwater capture. Most municipalities refer to the California Vehicle Code for standards but some have developed their own guidelines or adopted revised codes to allow for innovative designs.

In other states, many municipalities have found that street widths can be safely reduced in size or modified in designs to allow for stormwater infiltration practices while accommodating vehicles safely. Numerous examples exist within and outside the state of California. The Cities of San Diego and Santa Rosa design standards call for reduced street widths to 30 feet in low volume residential neighborhoods that include parking on both sides and two-way traffic, allowing increased area for infiltration in the public right-of-way.

In residential areas, reducing street widths and adding curb bump-outs with inlets to stormwater infiltration areas has a positive effect on neighborhood livability. These streetscape changes lead to traffic calming, encourage bicycling, and help to create a more walkable environment.

Recommendations:

- Governing Bodies: Develop criteria and standards for reduced street widths in low volume residential neighborhoods to facilitate stormwater infiltration and incorporate street width modifications into design guidelines and standard plans.

### 6.2.4 FIRE CODES

Requirements for emergency vehicle access can conflict with measures to reduce impervious surfaces. Local fire officials look to the International Fire Code (IFC) as adopted by California for guidance, although local ordinances often allow fire officials discretion regarding access requirements for emergency vehicles. The code is a guidance document that allows some flexibility but many infiltration techniques such as pervious concrete and block pavers are unfamiliar to local officials, who may lack confidence in the pavers' structural integrity.

Examples of decentralized stormwater management techniques integrated with fire codes exist in some other states, counties, and cities *(see sidebar)*. Sharing information about alternative methods for stormwater management in use in other jurisdictions is critical to shifting local codes to allow use of innovative techniques.

Recommendations:

- Project Proponents: Involve local fire agencies in demonstration projects that utilize new and innovative products and materials.
- Governing Bodies: Develop code guidance and acceptable materials to support Low Impact Development methods and update standard plans for fire lanes, street widths, and private driveways.

### 6.2.5 VECTOR CONTROL

Many diseases are carried to and between humans by mosquitoes and other animals. An animal that carries disease to humans is termed a "vector," and vector control is a public health function of cities and special districts or agencies. Vector control officials are concerned that LID stormwater treatment practices that rely on infiltration may lead to standing water, which can serve as a breeding ground for mosquitoes. Solutions to potential vector control problems include working with vector control agencies early in the process to agree upon design criteria and establish schedules for maintenance of infiltration techniques such as swales, dry wells, and ponds. Vector control agencies should be included in discussions of locations for inspection, maintenance, and design plan reviews.

Recommendations:

- Project Proponents: Consult with vector control officials during design of demonstration projects.
- Governing Bodies: Develop new standard plans and accepted stormwater infiltration design guidelines based on consultation with vector control officials.

## 6.3 STORMWATER REGULATIONS

Stormwater regulations are most often driven by water quality concerns and generally require treatment processes that do not provide multiple benefits. Most of the regulatory requirements to implement post-construction BMPs are part of the National Pollutant Discharge Elimination System's (NPDES) Municipal Stormwater Permit Program (MS4), which is intended for protection of beneficial uses of receiving waters. This federally-mandated regulation is administered at the county and city level through Standard Urban Stormwater Mitigation Plans (SUSMPs) that specify stormwater treatment requirements for particular development types. Property owners have little incentive to comply with infiltration requirements beyond the bare minimum.

Permitted types of infiltration BMPs and specifications regarding their siting also warrant close examination. In the Los Angeles area, established guidelines from both county and city agencies restrict infiltration in areas where proximity to groundwater, presence of underground storage tanks, and pre-existing contaminated soils or groundwater are concerns. It is important to ensure that these limitations do not affect other infiltration opportunities. Stormwater regulations and permits should be written to give property owners incentives to go beyond basic SUSMP requirements to provide multiple benefits including augmenting water supply, improving habitat, and increasing recreation opportunities.

### 6.3.1 PERMITS

Beginning with its recent issuance of the NPDES permit for Ventura County, the Los Angeles Regional Water Quality Control Board now requires infiltration strategies. This encouraging trend is anticipated to continue with the issuance of the renewed Los Angeles County NPDES permit, anticipated to be developed in 2010. To support this shift in stormwater management thinking, LID manuals and guidelines have been developed by the counties of Ventura, San Diego, and Los Angeles to encourage effective and innovative methods that both comply with stormwater permits and increase infiltration opportunities and related benefits (LARWQCB, 2009) and help them achieve permit compliance.

Recommendations:

- Governing Bodies: Revise stormwater permits, including general construction permits and MS4 permits, to recommend infiltration BMPs as the primary approach to managing stormwater.

- WAS Partners: Continue to support research that quantifies the benefits of infiltration practices and the effects of bioremediation of stormwater to further improve BMP design and implementation.

### 6.3.2 ORDINANCES

Municipal ordinances can be highly effective at requiring alternative stormwater design approaches, from increasing infiltration, to utilizing specific LID techniques. By implementing ordinances, cities and counties can have an effective mechanism for enforcement and long-term reliability (Chau, 2009).

The County of Los Angeles has adopted a LID ordinance and the City of Los Angeles has drafted a similar ordinance that will encourage infiltration as the leading strategy for treatment of stormwater. Many municipalities have Green Building Ordinances that provide points or credits for on-site stormwater treatment in development projects to document that projects are achieving environmental benefits. Similarly the new Sustainable Sites Initiative[1] will provide points for on-site stormwater infiltration in park and landscape projects. In addition, the state of California has adopted a Model Landscape Ordinance, which requires the landscape elements of new or redeveloped projects over 2500 square feet to conserve water and use sustainable runoff management techniques, including infiltration.

1 Led by the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center and the US Botanic Garden

Recommendations:

- Governing Bodies: Adopt Low Impact Development (LID) ordinances that are grounded in scientific research and encourage the use of proven best management practices. Preference should be given to LID ordinances that require developers to mimic natural (or pre-development) hydrologic processes and that prioritize infiltration BMPs above treat and release BMPs.

- Governing Bodies: Adopt ordinances with comprehensive green development practices by incorporating elements of LID, Model Landscape, and Green Building ordinances in combination with voluntary rating systems such as LEED (Leadership in Energy and Environmental Design) and Sustainable Sites Initiative to provide mechanisms to support and encourage infiltration.

- WAS Partners: Continue to support research into appropriate locations and types of decentralized strategies to encourage in ordinances.

## 6.4 GROUNDWATER MANAGEMENT

Within the Los Angeles region, management of many of the large groundwater basins is specified in existing adjudications. Adjudication is a process by which all parties with a perceived claim on the water from the basin participate in a court approved process to establish water rights and extraction rates which are subject to oversight by courts which typically appoint a watermaster. Adjudications can typically only be changed through a legal process with court approval.

An increase in stormwater infiltration and groundwater recharge does not necessarily provide an equal increase in the amount a party with water pumping rights can withdraw. For many adjudicated groundwater basins, an increased amount of water available from decentralized recharge does not automatically allow for increased pumping. Depending on the specifications in the adjudication documents a court may need to be petitioned with supporting evidence to change the adjudicated amounts.

Implementation of stormwater infiltration BMPs raises the question of which party receives credit for the water captured *(Table 2)*. For example, if a party stores additional supplies in Raymond Basin, that party receives credit toward pumping rights *(see sidebar)*. However, in the San Fernando Basin, runoff captured by the cities of Burbank or Glendale is nevertheless owned by the City of Los Angeles. In Main San Gabriel, Central and West Coast Basins, runoff capture is used to sustain the pumping yield of the basins and pumping rights are allocated based upon this yield.

Changes in adjudication take many years to implement, and discussion of how additional storage in local basins will be allocated is contentious. Additional research into the quantity of water available for later withdrawal from particular BMPs is needed to ensure the quantity of infiltrated water can be extracted at a later time and that any credits developed for stormwater BMPs have a standard process and known quantity. Thereafter, basin managers, groundwater producers and interested parties will have the necessary information to make decisions regarding increasing pumping rights, managing storage and adjusting basin rules accordingly.

Recommendations:

- Governing Bodies: Support the establishment of conjunctive use policies for groundwater basins that will encourage localized stormwater recharge and use by providing credits for recharge from the implementation of stormwater BMPs.
- Governing Bodies/Project Proponents: Develop strategic plans for locations of decentralized stormwater BMPs.
- WAS Partners: Collaborate on research to calculate the water supply benefit of decentralized stormwater BMPs with regional water providers, retail water agencies, groundwater basin managers, and other stakeholder agencies.

## 6.5 COSTS AND FUNDING

One objection to implementing decentralized stormwater management is the increased cost of construction. This objection, while valid, is shortsighted in that it ignores many long-term benefits, such as augmenting drinking water supplies. In addition, multiple methods are available to reduce implementation and installation costs and fund new projects – including partnerships, fees, credits, grants, rebates subsidies, and innovative programs such as bidding incentives. The practical and political feasibility of many of these mechanisms will determine which efforts will be most promising. A significant challenge is lack of funds for maintenance of projects over the long term. Causes include inadequate stormwater fees or an inability to apply bond or other funding sources toward maintenance. Incorporating these BMPs into standard operating procedures, however, will require more local funding, likely

### STORMWATER MANAGEMENT IN THE RAYMOND BASIN

The Raymond Basin is an adjudicated groundwater basin located within the northwestern San Gabriel Valley. The Raymond Basin was adjudicated in 1944 by the Los Angeles County Superior Court. The Raymond Basin Management Board has administered and enforced the provisions of the Judgment since 1984. The Raymond Basin safe yield, which is based upon native recharge and returns from use alone, was defined as 30,622 acre-feet per year in 1955.

In addition to their adjudicated rights, basin parties also receive additional pumping rights equal to 80 percent of the stormwater that they spread in spreading basins. An average of about 9,500 acre-feet per year of stormwater is currently spread in the Raymond Basin. Because of these additional rights, basin parties have actually pumped an average of 33,000 acre-feet per year since 1985, an 8 percent increase above their adjudicated rights.

**Table 2 - Effects of Existing Adjudication Rules on the Change in Groundwater Production as a Result of Enhanced Stormwater Recharge**

| BASIN | CHANGE IN GROUNDWATER PRODUCTION ALLOWANCE | CHANGE IN RECYCLED WATER RECHARGE | CHANGE IN IMPORTED WATER DEMAND | COMMENTS |
|---|---|---|---|---|
| **Raymond** | Increase | No Net Change | Decrease | • Credit given for enhanced stormwater. |
| **San Fernando** | Increase | No Net Change | Decrease | • Increased groundwater levels would allow for increased production through the utilization of existing stored water credits. No direct credit currently given for enhanced stormwater.<br>• May reduce the risk of declining groundwater levels, thereby offsetting potential increases in imported water demands.<br>• When the safe yield calculation is revisited, increased groundwater levels would lead to an increase in the safe yield for increased production. |
| **West Coast** | No Net Change | No Net Change | No Net Change | • No credit currently given for enhanced stormwater.<br>• May reduce the risk of declining groundwater levels, thereby offsetting potential increases in imported water demands. |
| **Central** | Likely Increase | Increase | Decrease | • No credit currently given for enhanced stormwater, but used by WRD to replenish the basin in support of the adjudicated pumping rights.<br>• May reduce the risk of declining groundwater levels, thereby offsetting potential increases in imported water demands.<br>• Increased stormwater capture results in both an increase in the ability to spread additional recycled water (due to blending needs) and a reduction in imported water need to meet that blend requirement. |
| **Orange County** | Likely Increase | Increase | Decrease | • Credit given for enhanced stormwater.<br>• Enhanced stormwater would likely increase BPP[1], which would increase groundwater production.<br>• Increased stormwater capture results in both an increase in the ability to spread additional recycled water (due to blending needs) and a reduction in imported water need to meet that blend requirement. |
| **Main San Gabriel** | Likely Increase | No Net Change | Decrease | • Enhanced stormwater would likely increase OSY[2], which would increase groundwater production. |
| **Chino** | Increase | Increase | Decrease | • Credit given for enhanced stormwater.<br>• Increased stormwater capture results in both an increase in the ability to spread additional recycled water (due to blending needs) and a reduction in imported water need to meet that blend requirement. |

Source: MWD-IRP Technical Workgroup (2009 )Stormwater/Urban Runoff Issue Paper

1. BPP is the Basin Production Percentage, where the production over the BPP incurs costs
2. OSY is the Operational Safe Yield, where excess production is subject to payment for imported supplemental water to recharge the basin.

coming from increased municipal stormwater permit fees. Other creative funding mechanisms should be studied and implemented if feasible.

### 6.5.1 LACK OF MAINTENANCE FUNDS

City, county, state, and federal governments frequently face budget shortfalls that threaten to eliminate routine maintenance from their accounts. Maintenance in the public right-of-way has traditionally fallen upon governmental agencies; however, distributed stormwater infiltration systems have the opportunity to utilize untapped community resources if projects achieve community buy-in early on. An effective mechanism to ensure projects are maintained is to involve residents in design and implementation, fostering interest and a sense of responsibility.

The success of fostering a vested interest in the success of a neighborhood retrofit has been demonstrated in city projects from Seattle, Portland, Tucson, to the Elmer Avenue Neighborhood Retrofit project in Sun Valley, California. The challenge is to maintain that interest over time and through changes in home ownership and tenancy. For homeowners who hire someone to do their landscape maintenance, the challenge is to find gardeners that understand these systems. This emerging job market is reflected in the development of "green gardener" training programs[2].

Recommendations:

- Project Proponents: Involve residents and landowners in the design and implementation process of distributed infiltration systems and train them to care for swales, rain gardens, or other BMPs.

- Governing Bodies: Train gardeners in the maintenance of native and climate-appropriate landscapes along with the operation and maintenance of distributed stormwater management systems.

2 The City of Los Angeles held its first Green Gardener training program in December 2009.

### 6.5.2 FUNDING PARTNERSHIPS – MULTIPLE BENEFIT PROJECTS

The State of California increasingly recognizes the importance of and supports integrated planning efforts. Multi-benefit projects have been a hallmark of watershed management plans, especially those funded by the state and federal government. The development of multi-benefit projects is called for in the Water Augmentation Study, local watershed plans and various Integrated Resource Planning processes.

In 2002 the voters in California adopted Proposition 50: Water Quality, Supply and Safe Drinking Water Projects, which amended state law to establish Integrated Regional Water Management Plans (IRWMPs). The proposition called for the sale of bonds to provide for planning and implementation funds for regions that form partnerships and create IRWMPs. Partners in the process include water and waste water agencies, federal and state resource agencies, land owners, tribes, utilities, municipalities, businesses, and nonprofit organizations. The Greater Los Angeles County Region, encompassing the watersheds of Los Angeles, San Gabriel, and Santa Monica Bay, received funding for planning and was awarded and is receiving $25 million for project implementation as of 2009.

An early local example of a multi-benefit project is demonstrated by the Broadous Elementary School Infiltration Project completed in 2001 and highlighted in Table 1 as a WAS monitoring site. A large infiltration BMP was installed on site to collect runoff from a 305,000-square-foot drainage area. The nonprofit TreePeople managed the project, which was funded by LADWP, the Los Angeles Unified School District (LAUSD) and other partners. The project not only reduced onsite flooding issues but also improved the campus, making it a more attractive space to learn and play.

Other examples include recreational facilities retrofitted with infiltration facilities. The Los Angeles County Department of Public Works led the effort on Sun Valley Park, which combined a large infiltration basin with a soccer field, upgraded ball fields, new lighting and interpretive panels.

Funding includes state grants for recreational enhancements and local flood control dollars.

Similarly, the City of Downey's Discovery Park includes an infiltration basin under a new athletic field *(Figure 14)*. Additional opportunities throughout the region include modifying existing facilities such as spreading grounds to accommodate recreational or educational uses. As evidenced in the Elmer Avenue project, the benefit of partnerships with multiple organizations, to help develop community engagement plans cannot be understated and can be utilized as a significant strategy for future implementation.

**Figure 14 - Discovery Park Infiltration System**

Recommendations:

- Project Proponents: Coordinate with other agencies, groups, and community organizations to develop projects that share common goals and provide multiple benefits.
- Governing Bodies: Participate in and encourage the implementation of multi-benefit, multi-partner projects developed through watershed management planning efforts and Integrated Regional Water Management Plans.
- WAS Partners: Convene a working group to facilitate and highlight the multiple benefits of decentralized stormwater mangement approaches.

### 6.5.3 STORMWATER FEES AND REBATES

Fees can serve as an incentive, especially if fee waivers are available for implementing stormwater infiltration above and beyond regulatory requirements. For example, if a development does not provide for infiltration at a pre-determined level, such as exceeding pre-development or pre-project runoff volume, an assessment can be levied. These funds can then be used for purchasing lands for infiltration or for paying incentives to other landowners to install infiltration systems.

Many communities currently have a stormwater fee in place to cover maintenance costs for storm drain infrastructure. Some of the fees are tied to impervious area of a property and can be recalculated if changes in the impervious area are made, thereby providing an incentive to property owners to reduce stormwater runoff through a rebate. Such a program can apply to both new development and existing developments but it remains to be seen if the relatively small cost of the fees compared to capital costs can provide the impetus for property owners to increase infiltration on their properties. In a national comparison of stormwater fees, the City of Los Angeles ranks among the lowest 10 cities with a rate of $1.92 per month collected through city utility fees. Neighboring Santa

Monica charges $10 per month, while the highest rate nationally is found in Portland, Oregon, at about $17 per month.

Rebates or reductions in stormwater parcel assessment fees can also encourage adoption of LID approaches to reduce runoff and increase infiltration. Both the City and County of Los Angeles are considering increasing parcel stormwater assessment fees while also providing a mechanism for rebates to those parcels that implement LID approaches to reduce runoff and increase infiltration.

In-lieu fee systems can be used to provide funding for larger centralized systems or regional facilities, particularly in highly developed areas that do not have available land or site conditions that allow for infiltration. An in-lieu fee system might provide an additional mechanism to ensure all parcels can address stormwater either on- or offsite.

Recommendations:

- Governing Bodies: Review and increase stormwater fees where needed and implement an incentive and or rebate system to encourage existing and new developers to reduce the amount of stormwater running off their property.
- Governing Bodies: Establish or expand in-lieu fee systems for projects that do not or cannot meet infiltration requirements on site.
- WAS Partners: Research application of in-lieu fees.

### 6.5.4 TRADABLE CREDITS

There may also be opportunities for the development of a trading system to reward landowners who exceed infiltration requirements by allowing them to sell water quality or water supply credits to utilities and developers who are unable to meet infiltration requirements. Regulations would require some level of treatment of runoff from all sites, but full infiltration capacity may be difficult to achieve in all locations. Through the identification of priority areas, a web-based system may provide the means for the establishment of a trading scheme to enhance the net infiltration capacity on a watershed basis. Stormwater marketplaces have been tested in Cincinnati and evaluated in Portland, and the Defenders of Wildlife have partnered on a conservation registry[3] to facilitate credit trading. This is an approach that warrants further research.

Recommendations:

- WAS Partners: Conduct research and prepare a white paper on the applicability of tradable water quality credits and implications to water supply within the Los Angeles Region to determine if improvements in water quality could be achieved through this mechanism.

### 6.5.5 SUBSIDIES FOR DECENTRALIZED PROGRAMS

Subsidies or cost tradeoffs for infiltration projects should be provided by those agencies receiving the water quality or supply benefits. In some cases benefits may be reductions in import or supply needs and therefore local and regional water providers may offer subsidies for stormwater recharge. For example, MWD currently provides up to $250 per acre-foot under its Local Resources Program (LRP) for singular large projects, such as desalters and recycled water, where the water supply benefit is clearly established.

Water providers may apply unit incentives for cost effective BMPs that provide an additional benefit to conservation or regional water supplies. For example, items such as low-flow toilets, artificial turf, and high efficiency clothes washers are often targeted for incentives (e.g. Burbank Water and Power currently offers a $100 rebate for qualifying clothes washers and a $75 rebate for a qualifying dishwasher). These credits are typically intended to be correlative with the water supply benefit and do not necessarily

3 See www.conservationregistry.org

cover a significant portion of the cost. In addition, these types of incentives are often provided by the local water retail agency where there is a direct relationship with the customer, which allows for more efficient monitoring and controls.

For larger stormwater recharge projects or for regional implementation of BMPs, a unit incentive per acre-foot of yield may be provided by the local water agency or regional providers when the water supply benefit is clearly established. For incentives and credits to be disbursed knowledge of those agencies and groundwater basins receiving benefits must be determined and agreed upon.

Recommendations:

- Governing Bodies: Support development of subsidy program by water providers and water quality mangers to encourage customers to pursue on-site infiltration projects as a means of providing groundwater recharge for future use.
- WAS Partners: Research and develop a process for receiving credits based on the calculations of modeling locations for yields and returns from distributed BMPs.

### 6.5.6 BIDDING FOR INCENTIVES

Regulatory approaches can have an impact on new development, but within a built environment, such as the Los Angeles region, implementing BMPs on private, developed properties may be a key strategy for widespread infiltration. Cutter, et al. (2008), Baerenklau et al. (2008), and Thurston et al. (2008) have proposed placing stormwater BMPs on private parcels by first inviting landowners to submit proposed BMP designs and costs to a local stormwater authority, essentially entering into a bidding process. The stormwater authority would then fund the bids that offer the best combination of low cost and water supply and quality benefits. Because only the low-cost, high-value bids would be funded, landowners would have an incentive to select the most cost-effective BMP designs for their property and keep their costs down.

Thurston et al. (2008) describes the implementation of a bidding pilot project where the homeowner selects a rain garden or rain barrel design for their property and states the required payment to implement the proposed design. The proposed designs were evaluated using an Environmental Benefits Index and the designs with the highest benefit per dollar were chosen for construction. Thurston et al. (2008) found that the environmental benefits per dollar were significant.

Cutter et al. (2008) examines a similar bidding system in the Los Angeles area for commercial and industrial properties. In their proposed system, landowners would submit proposed infiltration BMP designs and costs and a stormwater agency would pick the bids with the greatest infiltration of runoff and most water supply benefit per dollar. The maintenance of the BMPs would be ensured by the same covenant agreements that often cover required BMPs on new development. The study found that this decentralized, incentive-based system would be less expensive per acre-foot of runoff infiltrated than centralized infiltration approaches that require land purchases.

A simplified version of decentralized BMP installation, such as Portland, Oregon's residential downspout disconnect program, may have merit in the Los Angeles Region. The City of Los Angeles is piloting such a program, which it is calling the Rainwater Harvesting Program, in select locations within the city[4].

Recommendations:

- WAS Partners: Research and evaluate future bidding approaches within the Los Angeles Region.
- WAS Partners: Monitor and evaluate the results of the Rainwater Harvesting downspout disconnect program in Los Angeles.

4 This effort is funded by a grant from the Santa Monica Bay Restoration Commission.

## 6.6 EDUCATION AND AWARENESS

A distributed network of sites that contribute increased infiltration for the region will require active participation and cooperation from both public agencies and private property owners. For a public-private infiltration strategy to succeed, public agencies and property owners need to better understand the goals of the strategy and maintenance requirements, including the need for long term maintenance and monitoring; and there needs to be a mechanism to educate new owners and tenants when tenancy changes.

In recent years, the general public has become more aware of the costs of California's unsustainable water system which relies on importing and exporting water across the state. In June 2008, the California Governor declared that California was in a drought and directed water managers to take steps to improve coordination, water efficiency, and conservation. Subsequent conservation mandates implemented by local water agencies have resulted in reductions in water use by residents and there are indications residents, developers, and community groups have begun to seek out more sustainable landscapes that are drought-tolerant and reduce the need for wasteful watering practices. Education and outreach around the results and recommendations of the Water Augmentation Study can ensure that implementation of stormwater recharge projects are a part of the local supply portfolio of water suppliers to help with demand and supply variations and to provide reliable supplies of water.

### 6.6.1 INCREASING AWARENESS

The drought has also increased interest in rainwater harvesting technologies such as cisterns and rain barrels, as well as in the use of LID BMPs such as bioswales and rain gardens that take advantage of rainwater for use in landscapes. Demonstration sites across the Los Angeles region have also contributed to increased awareness of sustainable stormwater management alternatives that can easily be transposed to private properties and the public right-of-way.

Designing projects that capture and infiltrate stormwater requires collaboration from partners in a wide variety of disciplines – from architects, engineers and landscape architects, to planners, contractors and developers. It is crucial that these disciplines work together for multi-benefit projects to be successful and function effectively. The conventional approach often seen in cities around the country, where disparate disciplines operate in separate silos, leads to inefficient solutions that do not maximize the services a site can offer in terms of capturing, treating and infiltrating rainfall. If an architect is not conscious of the need for landscape areas to treat stormwater, the approaches available to landscape architects and engineers will be limited. Similarly, if the value associated with treating stormwater and providing supply is not taken into account, a developer may overlook that value in final design. A conscious effort to reach out to all those involved in the design and construction process will increase awareness and encourage a holistic design process and help reduce inefficiencies.

Recommendations:

- Governing Bodies/WAS Partners: Develop new or incorporate into existing public education campaigns at the city, county, and water agency level programs that explain the need for stormwater management alternatives and encourage stormwater infiltration, capture and reuse.
- WAS Partners: Present findings of the WAS to water district boards and other relevant parties.
- WAS Partners: Organize decentralized infiltration technical workshop/conference.

### 6.6.2 PROPERTY OWNER CONSENT AND COOPERATION

A distributed network of sites that contribute increased infiltration for the region would require active participation and cooperation from private property owners. For a public-private infiltration strategy to succeed, the following considerations will need to be addressed for any onsite BMPs: maintenance, change of property, and access agreements.

#### *Maintenance*

Once in place, many of the proposed BMPs require little additional maintenance beyond typical landscape care or occasional cleaning. Careful choice of the plant palette will also minimize gardening chores. However, some BMPs may need additional servicing and public agencies may want to perform the maintenance in order to guarantee the BMP is operating with maximum efficiency. A written maintenance agreement will need to be signed by the property owner to clarify who is to perform the maintenance.

The Seattle Public Utility Commission has developed a "Care and Maintenance Manual for Natural Drainage Systems" that outlines responsibilities of public entities and homeowners. The pamphlet gives care tips, states who is responsible for various tasks, and provides contact information for assistance or questions. A care and maintenance manual for the Elmer Avenue Neighborhood Retrofit is under development and can be used as a template for local projects.

Recommendations:

- Project Proponents: Identify and implement incentive programs for property owner BMP maintenance in LID ordinances in order to increase accountability and performance.
- Governing Bodies/Project Proponents: Provide owners and operators with clear care and maintenance instructions, developed for each appropriate audience, for each BMP or program, including a monthly checklist of maintenance needs.
- WAS Partners: Develop appropriate care and maintenance procedures for BMPs utilizing Elmer Avenue as a case study.
- WAS Partners/Govering Bodies: Identify and develop incentive programs incentive programs for property owner BMP maintenance in LID ordinances in order to increase accountability and performance.

### *Change Of Property Ownership and Tenancy*

If decentralized stormwater management is widely adopted there must be a protection of the investment in the installed BMPs. If they are installed on private property, property owners will need to require transfer the BMPs and their maintenance obligations to new owners and tenants as a condition of property transfer. This potential restriction of property rights could meet resistance and much work needs to be done to determine appropriate and equitable land use restrictions.

Recommendations:

- Project Proponents: Develop maintenance agreements that take into account the appropriate life expectancy of various BMPs.
- Project Proponents: Plan programs and BMP placement to minimize future restrictions of building additions and other likely property improvements, to the extent possible.
- WAS Partners: Work with local agencies to determine how to incorporate BMP chain of custody into property deeds.

### *Access Agreements Or Easements For Maintenance Or Monitoring*

Agreements are necessary between the project managing entity and the property owner to allow access for inspection, maintenance and monitoring. A number of municipalities around the country have developed maintenance and access agreements for stormwater BMPs on private property; their efforts can be referenced for development of similar public-private agreements in the Southern California region.

Recommendations:

- WAS Partners: Review existing LID-related access agreements, such as from Abermarle County, Virginia; Montgomery, Maryland; Cambria, Pennsylvania; and Oak Creek, Wisconsin, to develop recommendations as to how municipalities and utilities can modify existing easement access requirements to include necessary inspection, maintenance and monitoring of stormwater BMPs.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# 7. FUTURE INITIATIVES FOR WATER AUGMENTATION

Since 2000, the WAS partnership has identified and implemented a crucial research and demonstration study on the costs, benefits, and feasibility of stormwater infiltration for the Los Angeles Region as described in the previous sections. This unique partnership between local water supply, wastewater and public works agencies, regulators, and state and federal water agencies allows each partner to contribute its own funding and perspectives to the scientific evaluation of the feasibility of promoting infiltration without impacting groundwater quality. By working together, each agency has multiplied its contributions to successfully implement a study that would have been difficult for any to do individually.

For captured stormwater to become a reliable water supply in Southern California, techniques for infiltrating and valuing the benefits must become the norm. Research in decentralized stormwater capture, concurrent with planning, constructing, and operating new stormwater facilities, can identify and quantify innovative and efficient techniques unique to Southern California. Developing future stormwater infiltration projects and studying the results will allow us to advance the science and engineering of stormwater capture technologies and answer outstanding questions. Although the exact value of water supply benefit from each project is difficult to ascertain, general estimates can be calculated. Water quality, flood protection, and open space benefits are other variables that require more research. Questions such as optimal location and sizing of infiltration BMPs, the type and use of vegetation in BMPs, and BMP overflow design still remain. Through continued funding of stormwater research and future stormwater projects, techniques necessary for widespread adoption of decentralized stormwater management will emerge for Southern California.

The focus of future research initiatives should address the four questions below:

- What are the best design, operation, and maintenance procedures?
- What are the multiple benefits and who receives the benefits of stormwater infiltration projects?
- What is the ultimate fate of each contaminant of concern found in stormwater runoff, and what effective mitigation alternatives exist?
- Where should future stormwater projects be sited for maximum benefits?

Many of the recommendations contained in this document rely on governmental organizations or project proponents to make changes based on the information presented in the report or tested approaches ready to be fully adopted. Given the recommendations for future research and policy changes, the WAS TAC should continue the partnership to achieve implementation of decentralized stormwater management as standard operating practice. The development of such a broad-based change in stormwater management will take a concerted effort over many years. In Southern California, restrictions on imported supplies combined with anticipated population growth and the impacts of climate change make this an opportune time for an investment in decentralized stormwater management with the ultimate goal of achieving sustainability with respect to water supplies for the Los Angeles region.

## 7.1 STORMWATER INFILTRATION DESIGN, OPERATION, AND MAINTENANCE PROCEDURES

For widespread implementation of decentralized stormwater management projects there must be clear standards and approved plans for public and private projects. Those projects will require clear operation and maintenance procedures. The development of successful design, operation, and management of these systems relies on cross sharing of information between various, engineers, planners, departments, and agencies within the Los Angeles region. Based on the knowledge gained from the previous WAS pilot projects and the development of the Elmer Avenue Neighborhood Retrofit. This effort will range from increasing the awareness of the alternative stormwater management techniques to municipalities, developing maintenance manuals, to long term maintenance and responsibilities for the BMPs.

Specific Tasks Include:

- Develop a working group of engineers, planners, designers, and other parties involved in design of infrastructure design to propose LID approaches for inclusion in standard plans.
- Develop a white paper incorporating stormwater infiltration into complete street designs.
- Develop maintenance and training materials for the Elmer Avenue project.
- Monitor the maintenance and effectiveness of the Elmer Avenue Neighborhood Retrofit.
- Review approaches and develop recommendations for approaches to maintenance of public and private BMPs including those types of incentives and responsible agencies/groups.
- Develop best approaches to encompassing BMP maintenance and access for perpetuity.

Desired Outcomes:

- Adopted standard plans that encourage stormwater infiltration and balance infrastructure needs.
- Stormwater infiltration practices incorporated into complete street designs.
- Successfully maintained BMPs throughout the Los Angeles Region.

## 7.2 DETERMINING THE VALUE OF BENEFITS AND COSTS

Establishing a widespread, distributed network of infiltration projects in Southern California will necessitate a paradigm shift away from traditional project planning and governance. As with the Elmer Avenue Neighborhood Retrofit Demonstration Project, such projects frequently receive funding from a variety of local, state and federal sources. Multi-benefit projects are attractive to multiple funding partners, which effectively reduces the individual cost burden to provide each benefit. Many agencies have funds to cover capital costs but may struggle with the ensuing maintenance responsibilities due to a restrictive maintenance budget. Therefore, a clear understanding of the distribution of the multiple benefits provided by such projects is needed. The readily identifiable benefit from infiltration projects are increased groundwater supply. Water quality improvements and other benefits from recreation or restoration however, may actually be of a higher monetary value. Therefore, this section discusses water supply benefits and additional benefits, both of which are equally important.

### 7.2.1 WATER SUPPLY BENEFITS

While infiltration of stormwater is technically feasible, the specific impacts to the groundwater level, operating yield and basin losses have not been evaluated. Research is needed to better define the specific benefits of increased infiltration in each groundwater basin and the feasibility of storing and extracting stormwater (on a near continuous basis) in groundwater basins. This can be accomplished through the identification and study of various pilot projects and modeling. The results from these studies and models can then be used to quantify costs and benefits of recharge to optimize partnerships and to understand regional challenges. The GWAM developed for the WAS provides the initial information on areas to focus research through the selection of pilot projects by evaluating the types of land use, groundwater basins, or municipalities with high infiltration potential.

Specific Tasks Include:

- Identify feasible implementation alternatives for each groundwater basin (e.g. 25 percent of all residential parcels or 75 percent of all public parks) based on scenario runs of the GWAM

- Evaluate the impacts to groundwater level, yield and losses as a result of implementation of each alternative strategy assuming existing pumping patterns and increased yield scenarios using existing groundwater models or investigational tools such as applying GWAM outputs to groundwater models.

- Develop a model to quantify the relationship between capture and production, to quantify water supply component costs and benefits.

- Model on a per-basin scale, the effect of increased active stormwater recharge on production yield.

- Determine a business case and an accurate cost/benefit analysis for providing regional incentives and rebates based on the study of various pilot projects including the facilities required to extract.

- Identify effective methods to encourage enhanced stormwater recharge/use partnerships that educate the public on the benefits and uses of stormwater, including the relationship between stormwater quality and drinking water supply.

Water supply benefits and costs must include comparisons for imported supplies with the marginal operations and maintenance (O&M) cost of groundwater pumping and disinfection, to the construction and O&M costs of new groundwater production wells, pipelines, and treatment systems. Determining the full cost of supplying water will require the project proponent and the water supply agency to work collaboratively throughout project development and implementation.

Desired Outcomes:

- Development of a clear approach to allocation of water supply benefits based on expected yield calculations.

- List of priorities and locations based on land uses, subwatershed, or basins to initiate infiltration BMPs for groundwater recharge.

### 7.2.2 ADDITIONAL BENEFITS

Infiltration projects typically provide multiple benefits. These multiple benefits almost always include water supply, water quality, and flood protection, however there are many other benefits that may or may not be associated with a particular project. The water supply benefit is the best understood, however more research is still needed to improve current estimates. Much less understood are the water quality, flood protection, open space, and other benefits that may be accrued. More research is needed to estimate additional benefits typically termed "ecosystem values" or "nature's services" which go beyond easily monetized values. Much research is still required to determine approaches and actual values of infiltration projects that maximize these more difficult to monetize benefits. Additional values to be evaluated include, but are not limited to:

- Flood protection
- Water quality
- Transportation
- Reduced greenhouse gas emissions
- Ecosystem restoration
- Heat island effect
- Reduced energy use
- Air quality improvements
- Creation of recreation spaces
- Habitat function
- Carbon sequestration

Each of these benefits may need considerable research to develop monetized values. However if truly multi-beneficial projects are to continue, the individual beneficiaries need to fund the costs proportionally to the accrued benefits.

Specific Tasks Include:

- Develop metrics for measuring non-water supply benefits for comparison purposes between projects.
- Monitor and assess existing or new WAS-type projects.
- Evaluate economic valuation techniques and develop approaches for allocating a project's benefits among water quality and water supply agencies.

Desired Outcomes:

- Project benefits can be clearly identified and valued.
- Multiple partners contribute to the development of new stormwater infiltration projects in proportion to benefits received.
- Ecosystem values or services are recognized and valued as project benefits.

## 7.3 IDENTIFYING THE FATE OF POLLUTANTS

In agreement with several national studies cited in this report, results of the WAS monitoring efforts determined that infiltrating stormwater into the groundwater aquifers effectively removes most contaminants commonly found in urban runoff. During the process of filtration and bioremediation, various constituents of concern of stormwater are removed as it travels through vegetated areas and/or infiltrates through the vadose zone to groundwater.

Further research and field investigations are necessary to determine the extent and the ultimate fate of all potential pollutants of concern at varying concentrations to determine the most effective way of treating stormwater. Published research (Weiss et al., 2008) indicates that infiltration will likely not be effective in removing salts and some nutrients. These constituents typically were detected at low concentrations at the WAS sites. Sufficient information about the accumulation of pollutants at the surface layer of soils as well as the bioaccumulation of pollutants within vegetation is still lacking. With an increased understanding of the ultimate fate of pollutants of concern, improved mitigation measures for treatment and maintenance will be developed.

Specific Tasks Include:

- Evaluate existing and new infiltration projects to determine the role of various infiltration treatment approaches including bio-remediation and larger scale restoration efforts for effectiveness.
- Monitor existing sites and the Elmer Avenue project over the long term to evaluate the fate of pollutants and relationship to various soils, plants, and pollutant sources.
- Characterize the fate and transport of nutrients and salts at parks and agricultural sites where nutrients are applied in large quantities.

Desired Outcomes:

- Better understanding of fate of pollutants and relationship to specific plants, soils, and design strategies.
- Development of design and specification materials for best locations and types of habitats/plants for use in swales or treatment trains prior to infiltration.

## 7.4 SITING DECENTRALIZED INFILTRATION STRATEGIES

While the WAS efforts found that decentralized stormwater management can be cost-effective and successful in providing recharge, the approach to locating BMPs is often complex. Both decentralized and centralized locations will be needed to handle runoff from existing developments and new developments. In particular situations decentralized on-site management of stormwater may not be realistic because of hydrogeologic conditions, the presence of subsurface contamination, or the high cost of retrofit. Conversely, centralized BMPs might not be economically feasible if land costs are high. Finding ideal locations for both centralized and decentralized BMPs requires an understanding of the best physical locations for infiltration and accessible recharged water and economic feasibility.

### 7.4.1 INFILTRATION LOCATIONS

Finding the best locations for infiltration BMPs can be tied to the specific tasks described in 7.2.1 to document the water supply benefits. The GWAM output can be used to develop a better understanding of potential landuse areas with better recharge capability. For a location to be effective however, it needs to have direct connection to an accessible aquifer. Therefore, ensuring that available information regarding infiltration, recharge, and extraction are current is essential.

Basin-specific designs for recharge and direct use will ensure implementation of effective projects. A project in one area may produce better results than the same project in another area, and additional research is needed to develop specific methods of analysis to predict water extraction reliability of specific BMPs for discrete areas within the Los Angeles region.

Specific Tasks Include:

- Update sub-surface, landuse, surface water, and future pumping maps.
- Develop an approach to ranking the various surface and sub-surface conditions for best infiltration locations.
- Apply and develop additional modeling efforts as needed to identify key areas to implement decentralized stormwater projects.

Desired Outcomes:

- Map of the best locations within the Los Angeles region for infiltration BMPs based on surface and sub-surface features and pumping capability for various decentralized stormwater management scenarios.

### 7.4.2 ECONOMIC INCENTIVES FOR INFILTRATION PLACEMENT

Infiltration in Los Angeles has largely taken advantage of natural locations for centralized stormwater capture, such as pervious foothill and river bottom areas. The WAS monitoring projects and Elmer Avenue Neighborhood Retrofit Project have studies capturing runoff on site or within the public right-of-way.

Opportunities to retrofit streets for stormwater capture and place centralized infiltration are likely to be geographically scattered: cost-effective for the areas where they can be implemented but available only in portions of the Los Angeles area. As stated previously, the Los Angeles Region needs additional decentralized strategies to capture and manage runoff in the areas not covered by these solutions.

A project consisting of several well-designed randomized experiments should be launched to examine options for increasing infiltration opportunities through incentives and analyze which models best suit the needs of different Los Angeles areas. Incentives for installation of residential infiltration technologies in cities such as Eugene, Oregon; Austin, Texas; and Cincinnati, Ohio show promising results (Thurston et al., 2008). Residential incentive programs often subsidize all or a portion of the cost of installation of BMPs such as rain barrels, rain gardens, or downspout redirection to pervious areas. The City of Los Angeles is currently conducting a pilot program for residential BMPs that offers eligible applicants no-cost downspout redirection to a rain garden or a rain barrel. This program is an encouraging step for the city, and it is necessary to continue the momentum by exploring a variety of subsidy options such as free giveaways and partial subsidies to determine which options most cost-effectively spur infiltration.

Commercial and industrial properties must also be considered for placement of infiltration systems. The average size and high proportion of impervious surfaces typical to these land uses means that there is a high runoff capture potential as well as economies of scale in BMP construction. Cutter et. al., (2008) shows that infiltration retrofits of larger commercial and industrial properties are likely to be less expensive than common centralized runoff management infrastructure if the centralized projects necessitate acquisition of land. Retrofits of commercial and industrial properties however, should be targeted toward smaller storms and properties where retrofit costs are lower than average. Because these retrofits must be targeted, incentive-based policies that are aimed at identifying low-cost retrofits are a necessary component of these retrofits. Some commercial and industrial properties may be suitable for infiltrating runoff from the surrounding neighborhood or region. In particular, big box stores have large parking lot areas that could be retrofitted to infiltrate large quantities of stormwater.

Publicly-owned lands also offer opportunities for advancing a broad-based infiltration strategy for the region. The advantage of siting infiltration BMPs on publicly-owned parcels is that in many cases this strategy would not require land acquisition. In a largely built-out region, publicly-owned lands also often represent some of the largest of existing parcels. A technical report prepared by Community Conservancy International (2008) found that within the County of Los Angeles there are over 10,000 publicly-owned "opportunity parcels" that could serve as sites for distributed and regional water quality improvement and runoff reduction BMPs. Within these sites, a net average of 15,000 acres of existing public lands are suitable for "Green Solution Projects" that could potentially meet the following criteria: convert paved, impervious areas to pervious lands; retrofit existing pervious areas to effectively capture, clean and reduce runoff; and create multi-benefits sites, such as parks, recreation, habitat, and other open space opportunities. These encouraging findings warrant further investigation into implementation of infiltration retrofits on public lands.

Specific Tasks Include:

- Identify which large properties are suitably located near large storm drains or channels and whether it would be feasible to retrofit them to capture significant stormwater volumes.
- Develop alternative incentive-based retrofit strategies for commercial and industrial properties based on pilot projects, including analysis of bidding, and give-aways for rainwater capture.
- Evaluate alternative management strategies such as land leases, retirement of development rights, trading of water quality rights, purchase of easements, and floodplain acquisition.
- Evaluate use of public lands versus private lands for cost effectiveness of stormwater infiltration based valuation of water supply, water quality, and multiple benefits.

Desired Outcomes:

- Understanding of those economic approaches that are successful at facilitating change and implementation of a decentralized stormwater BMPs.
- Establishment of a program to incentivize those properties and landowners with the best economic reasons to have BMPs located on their property.

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# GLOSSARY

**24-HOUR STORM**
Amount of precipitation, typically recorded in inches, received during a period of 24 hours once measurable rain begins to fall.

**ACRE-FOOT**
A measure of volume: the amount of water contained in one acre, one foot deep. One acre-foot is the equivalent of 325,851.43 US gallons.

**BIOREMEDIATION**
Using biological organisms to return a site to its natural condition after it has been exposed to contamination.

**BEST MANAGEMENT PRACTICES (BMP)**
BMPs can consist of a device, practice, or other method for removing, reducing, retarding, or preventing stormwater runoff and associated pollutants from reaching receiving waters.

A Proprietary BMP system is a manufactured device in which stormwater receives treatment before being discharged to another BMP or to the receiving water. This is a broad category of BMPs with a variety of pollutant removal mechanisms and varying pollutant removal efficiencies. (North Carolina Department of Environment, Health and Natural Resources, "Stormwater BMP Manual", July 2007).

**BUILT-OUT LANDSCAPES**
A term used to describe a portion of the earth that has been completely developed with infrastructure and structures. Associated landscaping is included. No undisturbed land remains in the described area.

**CAPTURE AND REUSE OF PRECIPITATION (DIRECT REUSE OF CAPTURED PRECIPITATION)**
Capture and Reuse encompasses a wide variety of water storage techniques designed to "capture" precipitation, hold it for a period of time, and reuse the water for irrigation or other non-potable applications. This is different than capturing precipitation for infiltration to groundwater to allow later pumping for water supply.

**COMPLETE STREETS**
Complete streets are designed and operated to enable safe access for all users. Pedestrians, bicyclists, motorists, and public transportation users of all ages and abilities are able to safely move along and across a complete street. (National Complete Streets Coalition, *www.completestreets.org*, visited October 26, 2009).

**CONJUNCTIVE USE**
Active management of aquifer systems as an underground reservoir. During wet years, when more surface water is available, surface water is stored underground by recharging the aquifers with surplus surface water. During dry years, the stored water is available in the aquifer system to supplement or replace diminished surface water supplies. Conjunctive use is an effective tool for increasing the overall water supply. (DWR, *http://www.cd.water.ca.gov/groundwater/conjunctiveuse.cfm*, visited 10/22/2009).

**CENTRALIZED VS. DECENTRALIZED (DISTRIBUTED) INFILTRATION**
A centralized system for infiltration captures the runoff from impervious surfaces once it is in the infrastructural drainage network, relying on spreading basins and unlined streams to handle as much volume as possible. A decentralized system instead seeks many small, localized infiltration opportunities to diminish the flow volume that ends up in the infrastructural drainage network. LID, addressed below and within this document expresses decentralized infiltration as one of its keystone principles.

**DRYWELL**
An excavated pit filled with clean stone typically 3 to 12 feet deep that is usually designed to collect and store stormwater from rooftops or other relatively "clean" runoff. Runoff enters the dry well through an inflow pipe (such as a roof gutter downspout) and from surface infiltration. The water then infiltrates down through the subsoil rather than running over land. (Graphic from: *http://www.seagrant.sunysb.edu*, visited October 28, 2009).

**ECOSYSTEM SERVICES**

A blanket term for all the features of an ecosystem that benefit human life, which can include water supply, clean air, recreation opportunities, food, etc.

**EVAPOTRANSPIRATION**

The process of liquid water converted to water vapor through direct evaporation from bodies of water, the land surface or in the upper soil layers, or through transpiration from vegetation. Root uptake is a separate measure of soil-moisture removed by vegetation for sustenance and growth.

**GREEN INFRASTRUCTURE**

Green infrastructure is an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly. Green Infrastructure management approaches and technologies infiltrate, evapotranspire, capture and reuse stormwater to maintain or restore natural hydrologies. (US EPA, *http://cfpub.epa.gov/npdes/home.cfm?program_id=298*, visited 10/22/2009).

**GROUNDWATER AUGMENTATION**

The recharge of groundwater which can occur from infiltration of various water sources through soil or direct recharge to the depth of the aquifer. Sources of water can include stormwater, imported water, or reclaimed water.

**GROUNDWATER INJECTION WELLS**

An Injection well is a device that places fluid deep underground into porous rock formations, such as sandstone or limestone, or into or below the shallow soil layer. These fluids may be water, wastewater, brine (salt water), or water mixed with chemicals. (EPA, Underground Injection Control Program, *http://www.epa.gov/safewater/uic/basicinformation.html*, visited October 26, 2009).

**GEOHYDROLOGIC CONCEPTS**

Precipitation that falls towards the surface can be intercepted by vegetation and man-made objects. Of the precipitation that hits the surface of the Earth, some directly evaporates, some infiltrates and some runs-off. Infiltration is precipitation that enters the soils, while runoff is water that stays on the surface and moves off downhill under the force of gravity (in most inhabited landscapes frozen precipitation eventually does one of these things).

Once water infiltrates it migrates downwards under the forces of gravity. Some of this water is captured in the first few feet of soil (the root zone) by nearby vegetation and used for plant growth, termed root-uptake. The downward migration of water in and past the root zone is limited by the size of the pores between the soil particles; larger pores involve faster movement, smaller pores constrain the movement. Hydraulic conductivity is a measure of how easily water can move through a particular soil, with high values implying faster movement.

This region of the soils, where air occupies most of the pore space, is called the vadose zone (or unsaturated zone), and while infiltrated precipitation is moving downwards through this zone that water is called soil moisture. At some depth, the downward flow of soil moisture will be stopped because the pores between the soil particles are filled with water. This is called the zone of saturation. The boundary between vadose zone and saturated zone is called the water table. All water within the pore spaces in the zone of saturation is called groundwater.

Regions of the subsurface that contain water are called aquifers. Unconfined aquifers have unrestricted downward migration of water from the vadose zone. Confined aquifers have a restricting geologic or soil layer that either blocks, or tightly constrains the flow into or out of the aquifer. A Groundwater Basin is "an alluvial aquifer or a stacked series of alluvial aquifers with reasonably well-defined boundaries in a lateral direction and having a definable bottom" (California Department of Water Resources, *http://www.water.ca.gov/groundwater/groundwater_glossary.cfm*, visited 10/22/09).

In the extent of the Water Augmentation Study there are many groundwater basins, the two largest being the West Basin on the inland portion of the Coastal Plain, and the San Fernando Basin, which underlies most of the San Fernando Valley (see Figure 3 on page 15).

**HYDRODYNAMIC SEPARATORS**
Hydrodynamic separators are flow-through structures with a settling or separation unit to remove sediments and other pollutants that are widely used in storm water treatment. (United States Environmental Protection Agency. Washington, DC. "Storm Water Technology Fact Sheet: Hydrodynamic Separators." September 1999. Document No. EPA 832-F-99-017).

**INTEGRATED REGIONAL WATER MANAGEMENT PLAN (IRWMP)**
An IRMWP is a comprehensive planning document to encourage regional strategies for management of water resources. An IRWMP should investigate a broad spectrum of management strategies, identify the benefits of integrating water management strategies, and identify priorities for implementing projects and programs. (DWR, via Regional Water Authority).

**LIFE-CYCLE COST**
The National Institute of Standards and Technology (NIST) Handbook 135, 1995 edition, defines Life Cycle Cost (LCC) as "the total discounted dollar cost of owning, operating, maintaining, and disposing of a building or a building system" over a period of time. Life Cycle Cost Analysis (LCCA) is an economic evaluation technique that determines the total cost of owning and operating a facility over its lifetime of use.

**LOS ANGELES BASIN**
The Los Angeles Basin is the coastal sediment-filled plain located between the peninsular and transverse ranges of southern California, and contains downtown Los Angeles as well as its southern and southeastern suburbs (both in Los Angeles and Orange counties). It is approximately 35 miles long and 15 miles wide, bounded on the north by the Santa Monica Mountains and Puente Hills, and on the east and south by the Santa Ana Mountains and San Joaquin Hills. The Palos Verdes Peninsula, formerly an island, marks the outer edge of the basin along the coast. (Wikipedia, visited 10/26/2009) (Graphic source: USGS, *http://pubs.usgs.gov/fs/2002/fs086-02/images/my_attngrbbr.jpg*, visited October 29, 2009).

**LOW IMPACT DEVELOPMENT**
Low Impact Development methods mimic the predevelopment site hydrology by using site design techniques that store, infiltrate, evaporate, and detain runoff. This helps to reduce off-site runoff and ensure adequate groundwater recharge. Since every aspect of site development affects the hydrologic response of the site, LID control techniques focus mainly on site hydrology. (National LID Manual, Prince Georges County, MD, 1999).

**LYSIMETER**
A lysimeter is a device placed in the ground to collect soil moisture that is migrating downward through the vadose zone. Water samples can be drawn up to the surface for analysis.

**MANN-KENDALL TEST**
Mann-Kendall statistical tests are non-parametric tests for the detection of trend in a time series.

**MS4 PERMITS**
Polluted stormwater runoff is commonly transported through Municipal Separate Storm Sewer Systems (MS4s), from which it is often discharged untreated into local waterbodies. To prevent harmful pollutants from being washed or dumped into an MS4, operators must obtain a NPDES permit and develop a stormwater management program. (EPA, *http://cfpub.epa.gov/npdes/stormwater/munic.cfm*, visited 10/23/2009).

**MTBE**
Methyl tertiary-butyl ether - MTBE is a chemical compound that is manufactured by the chemical reaction of methanol and isobutylene, and is almost exclusively used as a fuel additive in motor gasoline. It is one of a group of chemicals commonly known as "oxygenates" because they raise the oxygen content of gasoline. At room temperature, MTBE is a volatile, flammable and colorless liquid that dissolves rather easily in water. (EPA, *http://www.epa.gov/MTBE/faq.htm*, visited 10/22/09).

**MULTIPLE BENEFIT APPROACH**
Multiple Benefit Projects are those that meet multiple goals such as reduced flooding, increased water supply, enhanced recreational opportunities and wildlife habitat, and reduced stormwater pollution.

**METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA (MWD)**
The MWD is a consortium of 26 cities and water districts that provides drinking water to nearly 19 million people in parts of Los Angeles, Orange, San Diego, Riverside, San Bernardino and Ventura counties. (MWD, www.mwdh2o.com, visited 10/22/2009).

**NATIONWIDE URBAN RUNOFF PROGRAM**
The Nationwide Urban Runoff Program (NURP) is a research project conducted by the US Environmental Protection Agency (EPA) between 1979 and 1983. It was the first comprehensive study of urban stormwater pollution across the United States. (EPA NURP Final Report, via wikipedia).

**NDMA**
N-nitrosodimethylamine – a pollutant generated by certain industrial processes, and is linked to sites which had rocket fuel present.

**NATIONAL POLLUTION DISCHARGE ELIMINATION SYSTEM (NPDES)**
Authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. (EPA, *http://cfpub.epa.gov/NPDES/*, visited 10//22/2009).

**PARKWAY**
This is the commonly grassy or vegetated strip of land that runs between the curb and the sidewalk in most suburban development.

**PERCHLORATE**
Perchlorate is both a naturally occurring and man-made chemical. Perchlorate is used to manufacture fireworks, explosives, flares and rocket propellant. (EPA, *http://www.epa.gov/ogwdw000/contaminants/unregulated/perchlorate.html*, visited 10/22/09).

**PLANT PALETTE**
A list of plants chosen by a designer for use in a project. Traditionally selected for appearance, more frequently and in relation to this document the palette contains native or drought-tolerant plants appropriate to the needs of rain gardens and bioremediation swales.

**RAINWATER HARVESTING**
Collecting and storing rain for use in irrigation. This is normally used to describe small-scale projects like a residential rain barrel or cistern.

**RECLAIMED WATER**
Reclaimed water is treated wastewater and can be used for irrigation and other nonpotable uses to extend water supplies. (Southwest Florida Water Management District, *http://www.swfwmd.state.fl.us/conservation/reclaimed/*, visited 10/23/2009)

**RUNOFF**
Runoff is a generalized term for any water that flows across the land surface and in streams. This water can originate as precipitation, or from a tap (irrigation, car washes, etc), or from a point-source discharge location (water treatment plant, pumping at a construction site, etc). In this document, three descriptions are used to differentiate the sources of the water within runoff.

> **Dry-Weather Runoff** is generated by a variety of sources, such as over-spray from landscaping and car washes, discharge from water reclamation plants, and imported water that is sent seasonally to spreading grounds located throughout the watershed. This water makes its way through the storm-drain system, or is discharged directly into streams. (SCCWRP)
>
> **Stormwater Runoff** (Or Wet-Weather Runoff) is generated by rainfall and snowmelt that runs off the landscape.
>
> **Urban Runoff** is used herein to describe all the flows that leave the urban extent of Los Angeles, including both dry-weather flows and storm flows.

**RUN-ON**
This term is used to describe runoff flows that enter an area of interest. For instance, a green street project might need to manage the run-on from adjacent land, rather than just the precipitation falling on it.

**SOUTHERN CALIFORNIA ASSOCIATION OF GOVERNMENTS**
The designated Metropolitan Planning Organization for the region, and is mandated by the federal government to research and draw up plans for transportation, growth management, hazardous waste management, and air quality. (SCAG, *http://www.scag.ca.gov/about.htm*, visited 10/22/09).

**SPREADING GROUNDS**
Infiltration basins are designed to capture a storm water runoff volume, hold this volume and infiltrate it into the ground over a period of days. Infiltration basins are almost always placed beside stormflow conveyances, and are designed to only intercept a certain volume of runoff. Any excess volume will bypass the basin in the storm drain. The basin may or may not be lined with plants. Vegetated infiltration systems help to prevent migration of pollutants and the roots of the vegetation can increase the permeability of the soils, thereby increasing the efficiency of the basin. Infiltration basins are typically not designed to retain a permanent pool volume. Their main purpose is to simply transform a surface water flow into a ground water flow and to remove pollutants through mechanisms such as filtration, adsorption and biological conversion as the water percolates through the underlying soil. (EPA, 1999, Urban Storm Water Best Management Practices Report).

**STREAM DAYLIGHTING**
To return a stream, which has been redirected by development into a culvert or underground pipe, to a more natural state.

**SUBSURFACE INFILTRATION GALLERY**
This is an underground area in which water can be held until it filters into the soil. These systems are used below streets or parks to capture runoff from the nearby storm-drains.

**STANDARD URBAN STORMWATER MITIGATION PLAN (SUSMP)**
SUSMP standards apply to particular new and redevelopment projects that require building/development permits and are administered by the municipalities approving the projects. The SUSMP standard is a National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit requirement as required by the State Water Quality Control Board and US EPA.

**THIESSEN POLYGONS**
Polygons whose boundaries define the area that is closest to each point relative to all other points in a set.

**TOTAL MAXIMUM DAILY LOADS (TMDL)**
TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet water quality standards.

**TOTAL DISSOLVED SOLIDS (TDS)**
An expression for the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular suspended form.

**VOLATILE ORGANIC COMPOUNDS**
Volatile organic compounds are compounds that have a high vapor pressure and low water solubility. Many VOCs are human-made chemicals that are used and produced in the manufacture of paints, pharmaceuticals, and refrigerants. VOCs typically are industrial solvents, such as trichloroethylene; fuel oxygenates, such as methyl tert-butyl ether (MTBE); or by-products produced by chlorination in water treatment, such as chloroform. VOCs are often components of petroleum fuels, hydraulic fluids, paint thinners, and dry cleaning agents. VOCs are common ground-water contaminants. (USGS, *http://toxics.usgs.gov/definitions/vocs.html*, visited 10/23/2009).

**WATER IMPAIRMENT**
There are regulatory limits for water quality set by Federal and State agencies. When a water body or stream has pollutants in excess of these regulatory limits, it is termed an impaired water body. The Clean Water Act requires the reporting of these impaired bodies, and the resulting list is called the 303d list. This section code, 303d, has become shorthand to describe impaired water bodies.

**WATERSHED MANAGEMENT PLANS**
The goal of watershed management is to plan and work toward an environmentally and economically healthy watershed that benefits all who have a stake in it.

# APPENDICES

*(The appendices are available on the enclosed CD - see inside back cover)*

A. LOS ANGELES BASIN WATER AUGMENTATION STUDY PHASE II FINAL REPORT

B. LOS ANGELES BASIN WATER AUGMENTATION STUDY PHASE II MONITORING REPORT UPDATE

C. GROUNDWATER AUGMENTATION MODEL DEMONSTRATION REPORT

# PHOTO CREDITS

COVER *(from top left to bottom right)*:

**Brookside Park Parking Lot BMP -** Pasadena, CA
*Photo courtesy of Drew Ready*

**Parking Lot Swale -** Downey, CA
*Photo courtesy of Gerry Greene*

**Gutter with Permeable Paving -** Santa Monica, CA
*Photo courtesy of Rebecca Drayse*

**Lysimeter Sampling -** Broadous Elementary School
*Photo courtesy of Suzanne Dallman*

INSIDE:

Pg 11 - **Los Angeles Aqueduct**
*Photo courtesy of Aquafornia.com*

Pg 15 - **Parking Lot Swale -** Downey, CA
*Photo courtesy of Gerry Greene*

Pg 16 - **Lysimeter Sampling -** Broadous Elementary School
*Photo courtesy of Suzanne Dallman*

Pg 23 - **Pacoima Spreading Grounds -** Los Angeles, CA
*Photo courtesy of Los Angeles Dept. of Water and Power*

Pg 31 - **Parking Lot Infiltration BMP -** Downey, CA
*Photo courtesy of Edward Belden*

Pg 34 - **Elmer Avenue Neighborhood Retrofit -** Sun Valley, CA
*Photo courtesy of Edward Belden*

Pg 39 - **Vista Hermosa Park -** Los Angeles, CA
*Photo courtesy of Edward Belden*

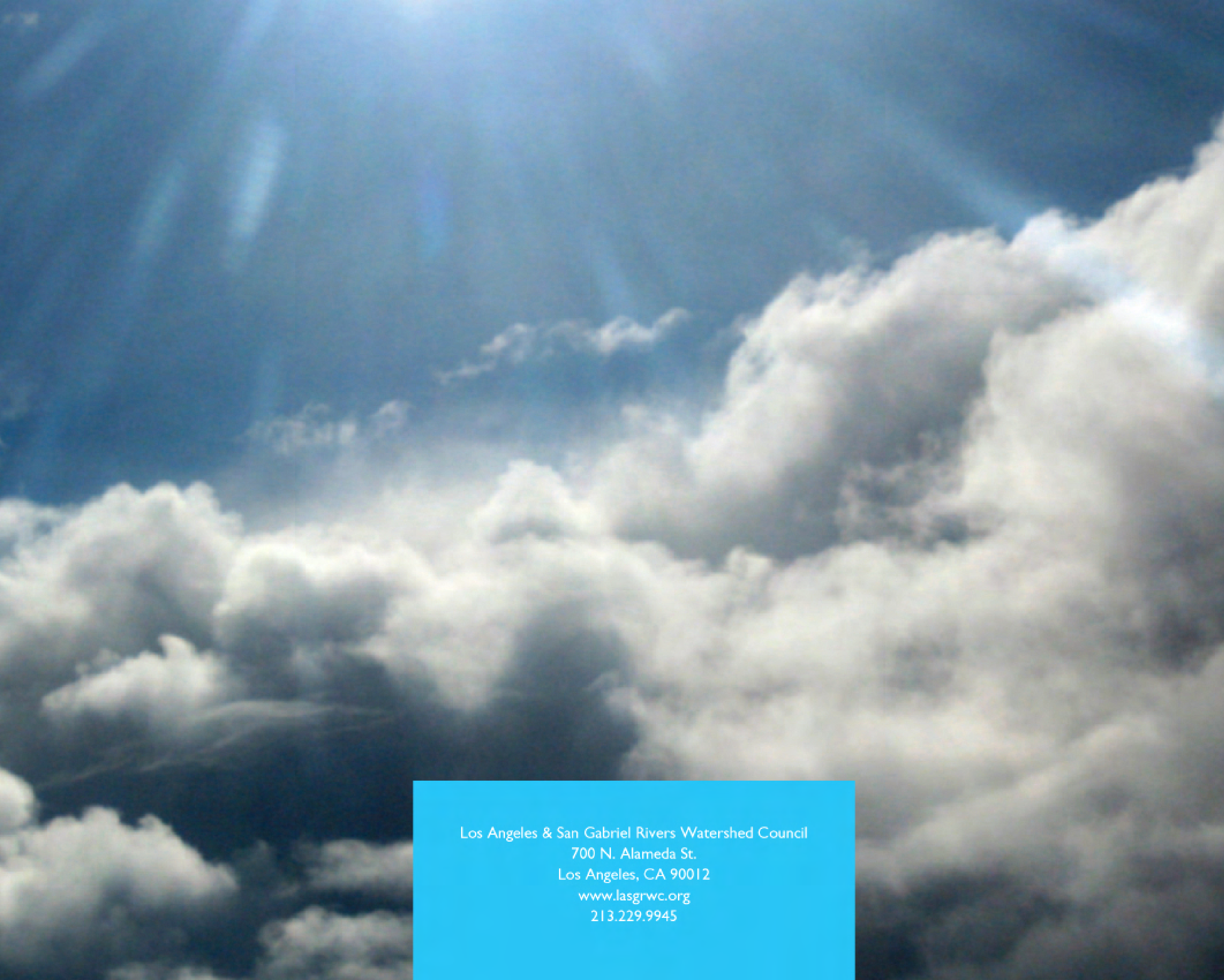
Pg 41 - **Elmer Avenue Neighborhood Retrofit -** Sun Valley, CA
*Photo courtesy of Michael Antos*

Pg 42 - **SEA Street Neighborhood Retrofit -** Seattle, WA
*Photo courtesy of Rebecca Drayse*

Pg 45 - **Brookside Park Parking Lot BMP -** Pasadena, CA
*Photo courtesy of Drew Ready*

Pg 48 - **Discovery Park Infiltration System -** Downey, CA
*Photo courtesy of Gerry Greene*

Pg 55 - **Bio-Swale -** Lone Pine, CA
*Photo courtesy of Edward Belden*



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