An Implementation Blueprint for Enhancing Groundwater Recharge in the San Fernando Basin

Jingfen Sheng
John P. Wilson

University of Southern California GIS Research Laboratory
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Prepared for: Mountains Restoration Trust
3815 Old Topanga Canyon Road
Calabasas, California 91302

GIS research laboratory
Department of Geography
College of Letters, Arts, and Sciences
University of Southern California
Los Angeles, CA 90089-0255
www.usc.edu/dept/geography/gislab

Cover Photos:
Browns Canyon Creek (left), residential land use in the Browns Canyon Watershed (top right) (M. Antos), and a storm park infiltration facility (bottom right).

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Executive Summary

The purpose of this report is to analyze the potential of providing ground water recharge in the San Fernando Basin (SFB) using native water, including the identification of strategic plans for the recharge project. This report is prepared in accordance with the State's beneficial use of runoff. Currently, the City of Los Angeles beneficially uses a much smaller fraction of runoff - primarily through groundwater recharge spreading grounds in the SFB. This volume is contributed from hill and mountain areas, mostly outside the city jurisdictions. The mountain areas at the western end of the SFB produce large volumes of runoff during rainy seasons and therefore offer numerous opportunities to increase seasonal water storage, treatment and beneficial use of what is now storm runoff. The ability to beneficially use rainfall runoff depends on the seasonal storage capacity. Therefore, to meet these demands (which are typically nonexistent during rain events and low throughout the rainy season), the rainfall runoff would need to be stored and recharged to the groundwater for the beneficial use.

This report begins with briefing several types of structural measures proposed for groundwater recharge by various studies. They include water spreading, pits and shafts, dams and diversions, recharge wells, and natural openings. Some of these methods are still applicable for implementation in our focus area, but others may not be suitable due to various environmental and regulatory constraints.

Other than ideal hydrogeologic conditions for site location, engineering design, and construction of recharge facilities, many agencies and stakeholders are involved during various stages of the implementation plan. This report discusses the affected agencies and stakeholders by starting with water rights and the special role and power of the Upper Los Angeles River Area (ULARA) Watermaster in the ULARA. From there, the report endeavors to describe the almost dizzying array of programs and agencies that operate at the federal, state, and local levels. It concludes by talking about the role of the public at large – because agency proposed and/or approved recharge projects are not likely to be implemented if the public does not lend their support.

At the end, the report takes some of the findings from the Recharge Suitability Analysis by Swift et al. (2007) and provides an initial roadmap leading to the development of groundwater recharge implementation strategies in the study area. The key components of this implementation plan includes: the acquisition of the necessary approvals and permits; the location, design, and implementation of structural Best Management Practices (BMPs); the implementation of a long-term pollution constituents monitoring program; the designation of a groundwater recharge protection area; and some evaluation of the associated impacts and risks from the installation and operation of groundwater recharge BMPs. The strategic plan prepared in this report suggests how a multi-tiered approach needs to be adopted to identify problems and potential solutions for the groundwater recharge project.

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Introduction

The history of groundwater recharge in the San Fernando Valley (SFV) goes back to the 1920s when a drought hit southern California (Blevins and Mann, 1993). Aqueduct waters delivered from Owens River were spread to augment the stored groundwater. Shortly thereafter, the Tujunga Spreading Ground was established and used to spread waters in 1931-32. Groundwater recharge and extraction remained contentious issues and were the subject of numerous court decisions and administrative actions over the next following 50 years. Although the pumping rights was settled by the 1979 ULARA court judgment, new concerns surfaced in the year that followed the Judgement. Many wells in the SFB were found to contain contaminants above the action levels set by the California Department of Health Services (Blevins and Mann, 1993). Thus, both water groundwater quantity and quality became important for groundwater management.

This report is prepared in accordance with the State's beneficial use of runoff, which is one of the principle elements in the water management components of the Integrated Resources Plan (IRP) advocated by the City of Los Angeles Departments of Public Works (CLADPW) and the Los Angeles Department of Water and Power (LADWP) (CLADPW and LADWP, 2004). The IRP has a goal of beneficially using 50% of runoff. Currently, the City of Los Angeles beneficially uses a much smaller fraction – some 14,000 to 24,000 acre-feet per year (AF/Y) (4,500 to 7,800 million gallons per year (MG/Y)) of runoff - primarily through groundwater recharge spreading grounds in the SFB (LADPW, 2005). This volume is contributed from hill and mountain areas, mostly outside the city jurisdictions (ULARA Watermaster, 2006). The ability to beneficially use rainfall runoff depends on the seasonal storage capacity. Therefore, to meet these demands (which are typically nonexistent during rain events and low throughout the rainy season), the rainfall runoff would need to be stored until the demand occurs. The mountain areas at the western end of the SFB produce large volumes of runoff during rainy seasons and therefore offer numerous opportunities to increase seasonal water storage, treatment and beneficial use of what is now storm runoff (Swift et al., 2007).

In addition to the beneficial use of wet weather runoff, groundwater replenishment with native water provides a great alternative to the city's plan to use recycled water to recharge the SFB that was stalled due to the public's 'toilet to tap' outcry. In 1998, "Toilet to Tap" headlines helped fuel public opposition to the recycled water option. Environmental groups also campaigned against the recycled water groundwater recharge project, arguing that it would encourage growth and provide water for new homes (ESA, 2005). The concept of groundwater recharge using the native surface water overcomes the criticism labeled by the "Toilet to Tap" opponents and also provides a sustainable approach for groundwater storage.

The ULARA contributes groundwater to the San Fernando, Sylmar, Verdugo and Eagle Rock Groundwater Basins that underlie four Metropolitan Water District (MWD) of southern California members (the cities of Los Angeles, San Fernando, Burbank, and Glendale) and the Foothill Municipal Water District (Foothill MWD). Although its service area covers the Verdugo Basin, the Foothill MWD does not have pumping rights in the ULARA. A map of the groundwater basins surrounded by the ULARA is provided in Figure 1.

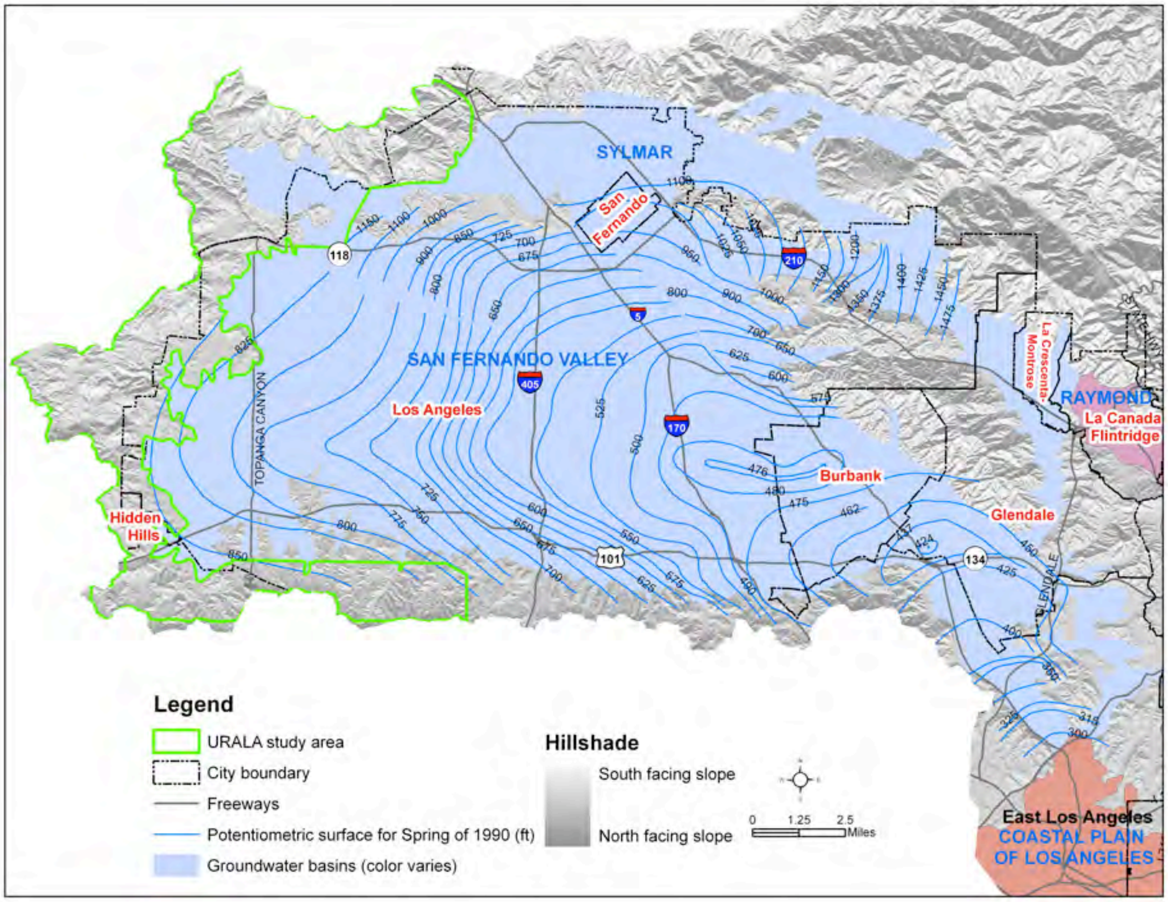

Figure 1. 1990 potentiometric surface in the SFB and adjacent areas

The SFB, the largest of the four basins within the ULARA, is an unconfined aquifer bordered by the Santa Monica Mountains to the south, the Simi Hills to the west, the Santa Susana Mountains to the northwest, and the San Gabriel Mountains and Verdugo Hills to the northeast. The primary inflows to the ULARA groundwater basins are imported water and precipitation runoff during the rainy season. Because the runoff is seasonal in nature, natural recharge is limited. Over the time period from the 1985-86 to the 2004-05 water years, rainfall varied between 6 to about 43 inches per year, with an average of about 18.6 inches per year (ULARA Watermaster, 2006).

The total groundwater storage capacity of the SFB was estimated by the State Water Rights Board in the Report of the Referee to be approximately 3.2 million AF (CSWRB, 1962). A regulatory storage requirement of 360,000 AF was estimated for the SFB, taking into account normal wet-dry cycles, operational flexibility, and pumping based on the calculated safe yield. Despite the heavy rains of the 2004-05 water year, the storage volume at the end of water year 2004-05 was about 154,000 AF below the lower regulatory storage. Since 1980 the groundwater in storage declined at an average rate of 7,898 AF/Y (ULARA Watermaster, 2004). It was estimated that water levels in key wells have dropped 25 to 50 feet since 1985 (MWD, 2007). The probable causes of this decline include increased urbanization and runoff leaving the SFB, reduced artificial recharge, and continued heavy pumping. It was estimated that approximately 504,475 AF (the decline in storage since 1928) is available as additional storage capacity (ULARA Watermaster, 2006). Figure 2 provides a summary of the groundwater storage in the SFB from water year 1985-86 to 2004-05 (MWD, 2007).

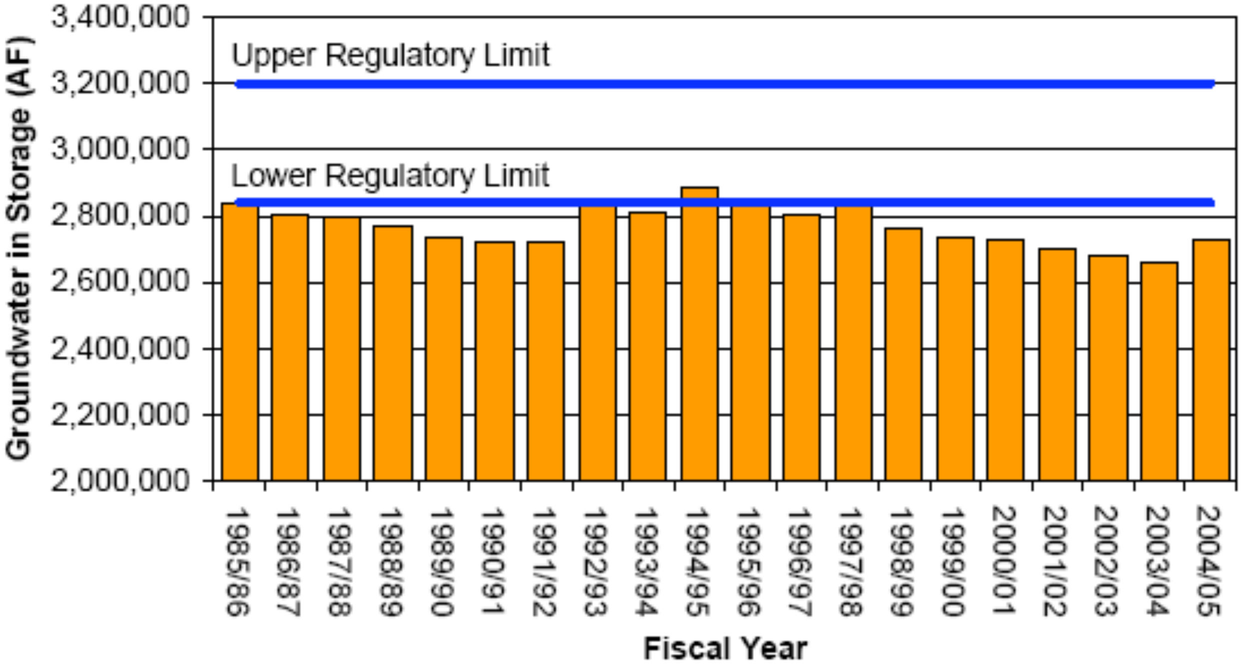

Figure 2. Historical groundwater storage estimates for the SFB (MWD, 2007)

Groundwater production in the ULARA Basins is constrained by the 1979 Final San Fernando Judgment (1979 Judgment) and the 1984 Sylmar Basin Stipulation (1984 Stipulation). Groundwater extraction from all four groundwater basins is limited by this adjudication and a court appointed Watermaster and Administrative Committee is established to administer the Court's rulings. An average production of 99,454 AF was pumped from the ULARA groundwater basins from the 1985 to the 2004 water years. During the 2004-05 water year a total of 77,995 AF were pumped from the ULARA groundwater basins. Approximately 94 percent of the total volume was pumped from municipal production wells with the remaining production from private wells (ULARA Watermaster, 2006). Most of these production wells are found in the eastern section of the SFB (Figure 3). The average production from the SFB was 88,370 AF from the 1985 to the 2004 water year (ULARA Watermaster, 2006).

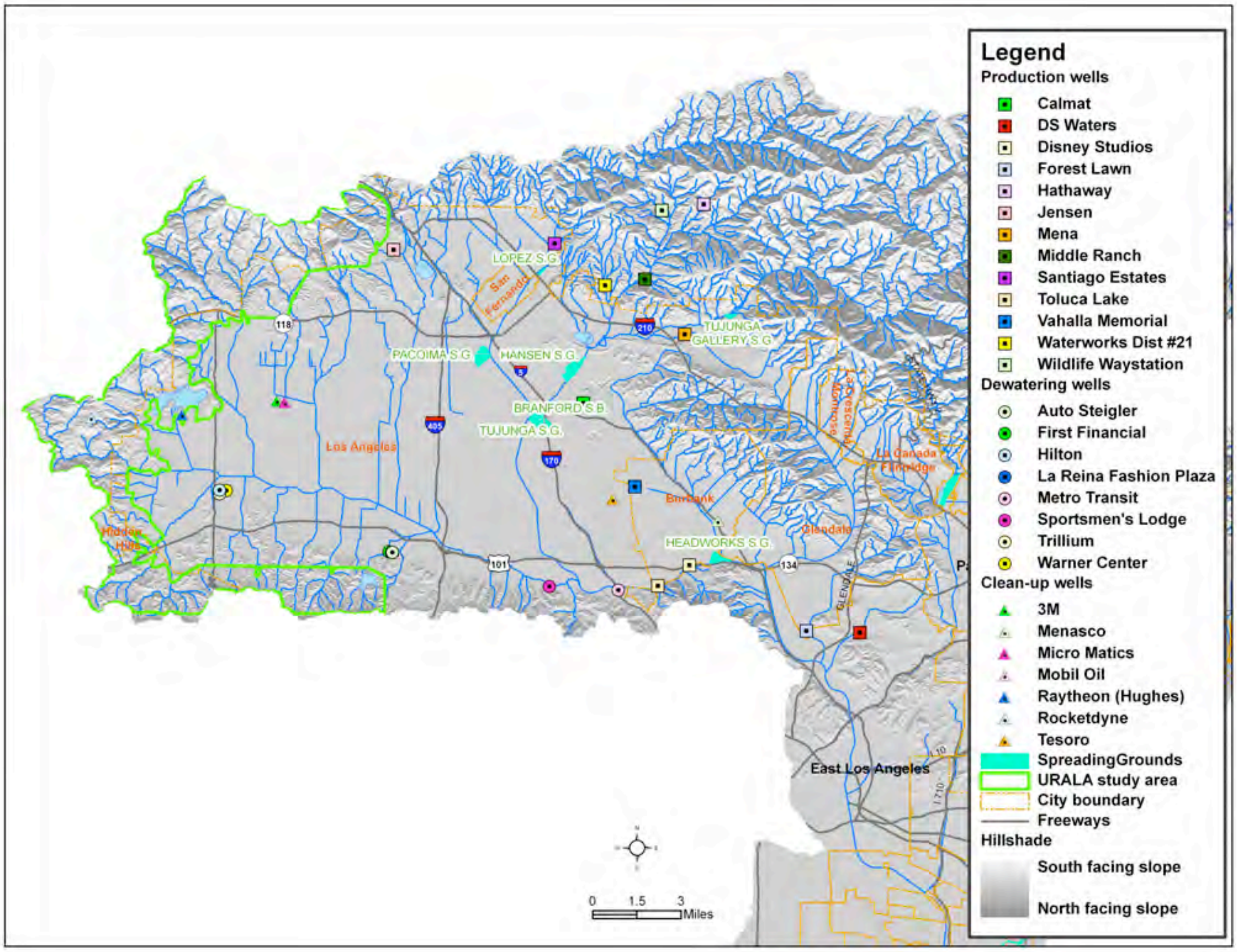

Figure 3. Production wells and spreading grounds in the SFB

Approximately 314 acres of recharge spreading basins (Figure 3) are located in or near the eastern half of the SFB with an estimated total capacity of approximately 104,000 AF/Y. Recharge spreading basins do not currently exist near the western boundary of the SFB. Water levels in the western and eastern halves of the SFB are shown in Figure 4.

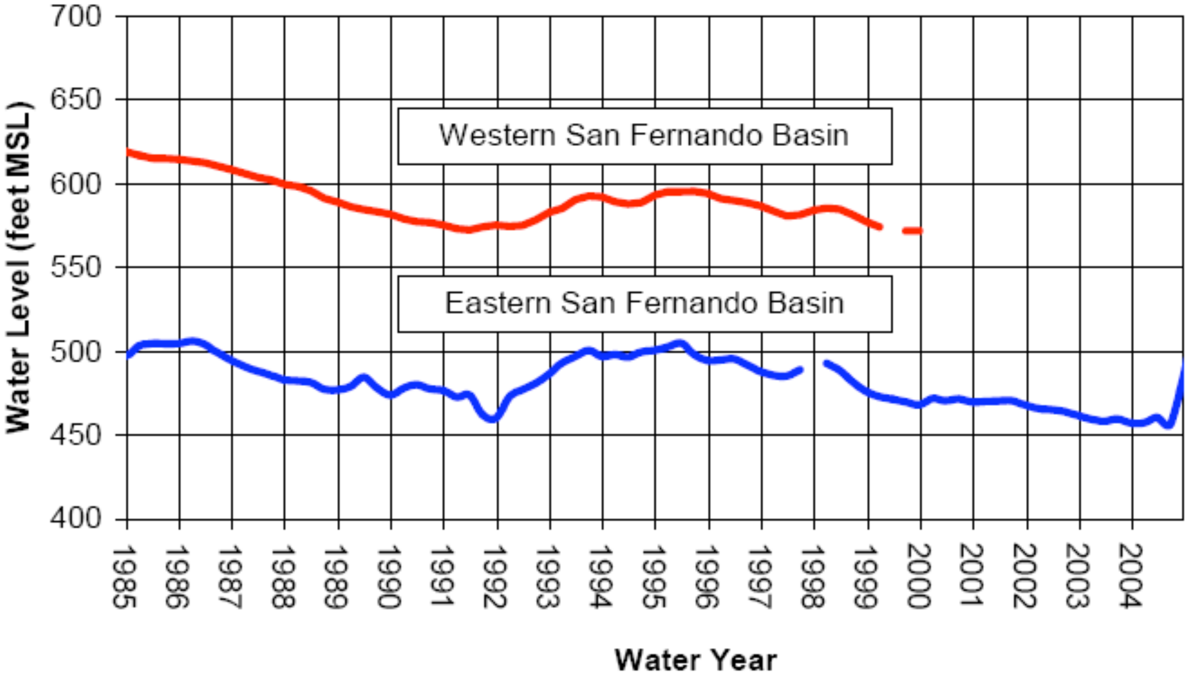

Figure 4. Historical water levels in the SFB (MWD, 2007)

Groundwater Recharge Methods

Groundwater recharge takes place in the forms of natural recharge, artificial recharge and incidental recharge (DWR, 2005). Natural recharge of groundwater takes place through natural infiltration of precipitation and stream flows to the aquifers. Water from precipitation and runoff infiltrates mainly along mountain fronts and in stream channels and also as direct underflow from faults and other openings in rocks. Artificial, intentional, or managed recharge is the process of adding water to an aquifer through human effort by building structures specifically for increasing recharge (DWR, 2005). These structures are called recharge basins, spreading basins or replenishment basins or areas. The goal of all managed recharge is to increase the rate of infiltration or percolation of surface water into the subsurface, and ultimately, into the saturated zone in the aquifer. Incidental recharge refers the percolation of water to an aquifer after the water has been withdrawn, diverted or received for delivery by a municipal provider for use within its service area. Seepage from reservoirs and from channels in which flow is prolonged by structural measures is the most common source of incidental recharge (Topper et al., 2004). A schematic diagram showing the various groundwater recharge methods is provided in Figure 5.

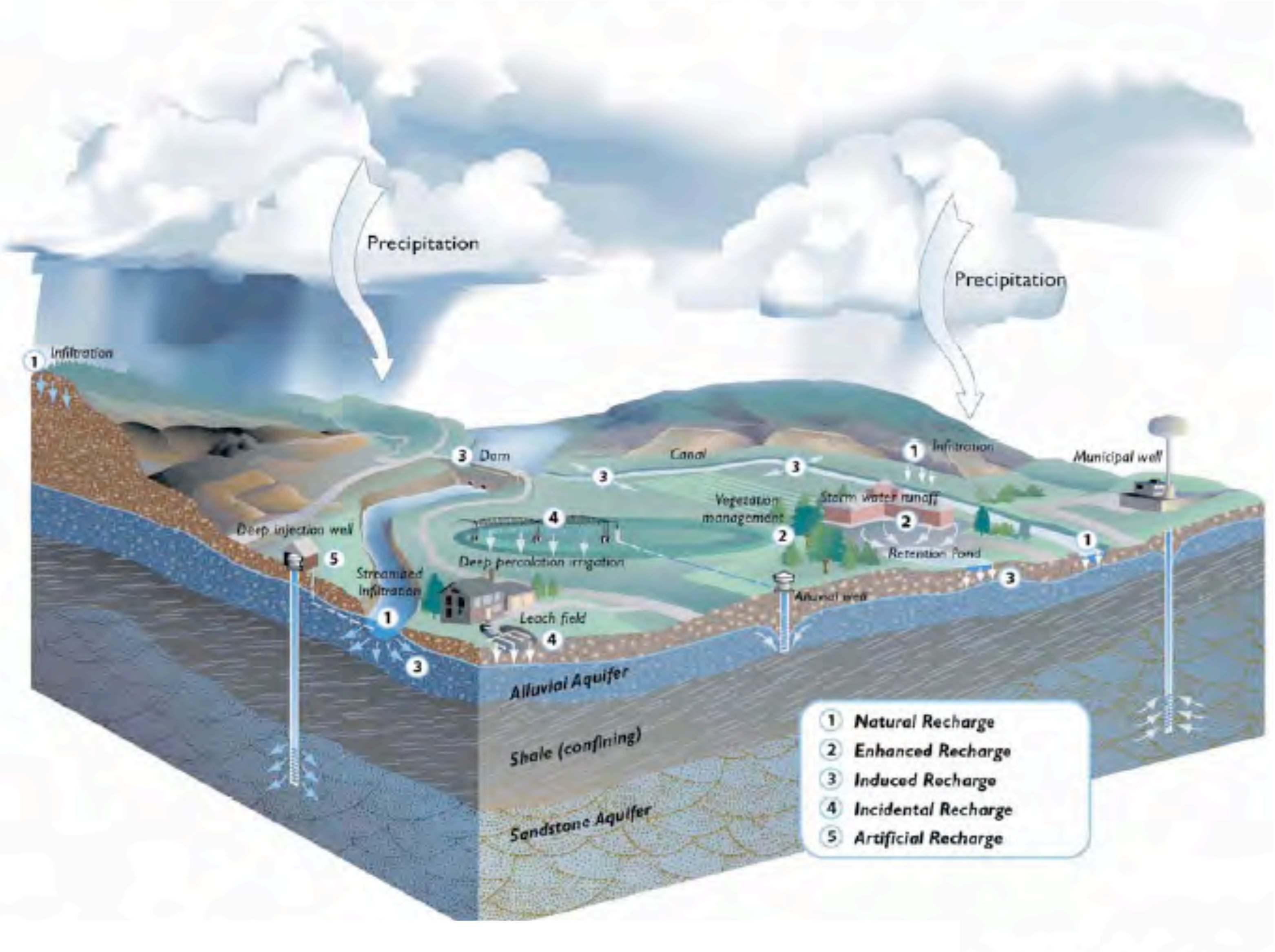

Figure 5. Schematic diagram showing groundwater recharge methods (Topper et al., 2004)

Several types of structural measures have been proposed for groundwater recharge (USDA-SCS, 1967). They include water spreading, pits and shafts, dams and diversions, recharge wells, and natural openings. Some of these methods are still applicable for implementation in our focus area, but others may not be suitable due to various environmental and regulatory constraints. The main features of these recharge options are discussed in the subsections that follows.

Water Spreading

Areas of deep sands, gravels, or cobbles are the most favorable for recharge by water spreading. The systems are usually similar to the systems constructed for irrigation or flooding. These systems minimize the disturbance of the affected landscape area where flooding is used. The water should be as clean as possible because the spreading of waters containing large quantities of fine sediment will reduce the infiltration rate and may overwhelm any beneficial effect of micro-organism activity. Infiltration rates may be improved by deep-rooted vegetation or by a surface cover of vegetative debris that is permitted to decompose under alternating wet and dry conditions (USDA-SCS, 1967). Surface spreading is the primary method used to replenish groundwater basins in the southern California (WRD, 2007).

Pits and Shafts

Pits or shafts will greatly increase infiltration if they reach into deep gravel beds or fractured cavernous or pervious rocks (USDA-SCS, 1967). Abandoned gravel pits, quarries or mines may be used so long as they extend into the aquifer or into cavernous rock formations. Underground infiltration basins may be constructed to achieve the same outcome (Sayre et al., 2006).

Dams and Diversions

Small inexpensive dams may be very effective in impounding streamflow long enough to let it enter large openings in or near the channel. Much of the runoff can be recharged to the groundwater basin in favorable locations. Diversions up to several miles in length may be constructed to direct storm runoff to large off-site openings. Such diversions can significantly attenuate the flood effects, especially flood peaks in impervious surface covered urban areas.

Recharge Wells

Recharge wells, often referred to as injection wells have been in use in almost every part of the U. S. in connection with irrigation, pumps and salt water intrusion control facilities. Wells or shafts are the only means of recharge where soils or substrata of very low permeability exist between the surface and the water table. They also may be installed to increase the volume of recharge along with other recharge facilities. In some cases, wells that normally are extracted during the dry and/or growing season are used for recharge during wet or surplus seasons.

Natural Openings

Natural openings in or near the stream channel in cavernous limestone and gypsum areas may be used instead of recharge wells. Some natural openings need little or no improvement or protection to maintain their efficiencies while others should be improved, protected, and maintained. Openings that need improvement should be cleaned out and provided with an effective trash guard or sediment removal strategy if necessary.

The choice of site and structural recharge facilities for groundwater recharge projects depend on a number of criteria. In addition to ideal hydrogeologic conditions, sites should be close to potential recharge water sources and groundwater production sites. Recharge sites should be down gradient from source waters and close to existing wells or pump facilities in order to minimize capital and operational costs. The recycled water quality, if any, should be such that it does not increase the levels of any regulated constituents above the specified limits or degrade the existing groundwater quality. That said, the design and construction of recharge facilities involves many agencies and stakeholders. The next section summarizes the types of concerns and issues that must be addressed in these types of projects.

Affected Agencies and Stakeholders

The discussion of affected agencies and stakeholders must start with a description of water rights and the special role and power of the ULARA Watermaster. From there, we will endeavor to describe the almost dizzying array of programs and agencies that operate at the federal, state, and local levels, and have some interest in water. We conclude by talking about the role of the public at large – because agency proposed and/or approved recharge projects are not likely to be implemented if the public does not lend their support.

Water Rights

The ULARA Groundwater Basins are adjudicated and controlled by the 1979 Final San Fernando Judgment (1979 Judgment) and the 1984 Sylmar Basin Stipulation (1984 Stipulation). The Judgment distinguishes between the native safe yield (i.e. the portion of the safe yield derived from native waters) and the safe yield of imported waters (including return flows from imported water), and divides annual extraction rights based on whether it is native or imported water. This adjudication limits groundwater extraction from the ULARA groundwater basins and established a court appointed ULARA Watermaster to administer the Court’s rulings. The ULARA Watermaster oversees parties’ extraction and parties’ rights to native groundwater, imported return water, and stored waters in the ULARA groundwater basins.

The 1979 Judgment upheld the Pueblo Water Rights of the City of Los Angeles to all native water which starts out as precipitation within ULARA and all surface and groundwater underflows from the Sylmar and Verdugo groundwater basins (ULARA Watermaster, 2005). No other party has any right to such native waters. The Cities of Los Angeles, Glendale, and Burbank each has the right to extract from the SFB its imported return flows – that is, the amount of water that recharges the groundwater basin after being imported to the SFB from the Los Angeles Aqueduct or MWD. The City of Los Angeles can receive credit for and pump 20.8% of all delivered water (including reclaimed water) to the valley fill lands of the SFB; Glendale, 20%; Burbank, 20%; and the City of San Fernando no longer receives credit for imported return water in the SFB due to special credits provided in the 1984 Sylmar Basin Stimulation (ULARA Watermaster, 2006). Imported return flows that are not pumped in a given year by any of the cities can be accumulated as credit and pumped in later years as needed. Because the City of Los Angeles has rights to all of the water that normally recharges the Los Angeles River via runoff from precipitation, any water that is recharged purposely in the SFB also belongs to the City of Los Angeles (Mann, 1976).

The Cities of Los Angeles, Glendale, and Burbank each has the right to store water in the SFB by direct spreading of imported and reclaimed water or in lieu practices and each party has the right to pump equivalent amounts (ULARA Watermaster, 2006).

ULARA Watermaster

The ULARA Watermaster was authorized by the California Superior Court to enforce the provisions of the Judgment. It advises the parties or non-parties of the provisions of the Judgment and administers the Judgment of the California Superior Court. Because the Cities of Los Angeles, Glendale and Burbank each has the right to store water in the SFB by direct spreading of imported and reclaimed water or certain practices, the ULARA Watermaster oversees each party's storage and extraction volumes (ULARA Watermaster, 1998).

In addition to the ULARA Watermaster's responsibility to administer the Judgment, manage water rights, and ensure a safe yield, the ULARA Watermaster is also responsible for managing the groundwater quality of the basin. The Watermaster ensures that the objectives of the California Regional Water Quality Control Board (RWQCB) are met with regard to their anti-degradation policy for groundwater. Impacts associated with any proposed project involving groundwater spreading, storage, and extraction are therefore evaluated and monitored by the ULARA Watermaster.

The ULARA Watermaster can also coordinate with the RWQCB, California Department of Toxic Substance Control, U.S. Environmental Protection Agency (USEPA) and the California Department of Public Health (CDPH) to investigate sources or potential sources of groundwater contamination and to regulate surface water spreading to increase the water recharge to groundwater basins (ULARA Watermaster, 1998). The Watermaster must be notified of proposals to construct any facility to remove contaminants from groundwater produced from the SFB. A report should be prepared for the Watermaster regarding the facility specifications, treatment quantity and quality in these instances.

Federal Guidance and Oversight

Several federal agencies and their programs may impact the feasibility of different recharge options and should be considered when preparing new projects. The first is the Federal Clean Water Act. The National Pollution Discharge Elimination System (NPDES) permit program implemented with this legislation is intended to prevent and control the degradation of aquatic ecosystems. Pollutants cannot be discharged from a point source into navigable waters of the U.S. without a NPDES permit. This rule means that an NPDES permit would be required for any point source, for instance, the Boeing/Rocketdyne Santa Susana Field, to discharge water to ULARA watersheds in which spreading basins could be located.

The Safe Drinking Water Act (SDWA) administrated by the USEPA is the overarching legislation on water quality of potable drinking water supplies. The SDWA impacts recharge projects in terms of water quality since most groundwater recharge activities are intended to store water for potential public drinking water supplies. However, the purview of the SDWA requires water quality treatment for the source water both before and after storage. The SDWA's Underground Injection Control Program protects the native and surrounding waters in the aquifer. The applicability of different SDWA regulations depends largely on the source of the stored water.

If the stored water is surface water, the Surface Water Treatment Rule (SWTR) applies. The SWTR was published in the Federal Register by the USEPA on 29 June, 1989 and requires disinfection and filtration for all public water systems that use surface water or a source that is groundwater under the direct influence of surface water. Typically, this treatment requires aboveground storage during treatment with chlorine. USEPA's Disinfection By-products Rule is thus invoked due to the presence of disinfection products in the water at the time of recharge.

The 1973 Federal Endangered Species Act administrated by the U.S. Fish and Wildlife Service relies on scientists to determine whether species are "threatened" or "endangered" by the implementation of projects before agencies' approval of the project. Various endangered species are found in the SFB and the impact of the construction of devices should be considered as well as impacts from the device itself. For instance, certain noise levels may harass some species of concern. Early coordination between the local Fish and Wildlife Service office and biologists may help in getting construction and maintenance schedules approved.

In a similar vein, projects that involve modifications to existing surface storage and/or flood protection structures or new structures would warrant the involvement of the U.S. Army Corps of Engineers (USACE) and possibly the U.S. Bureau of Reclamation. The

USACE, which built and operates portions of several open channels in the area, is a desired partner in flood damage reduction projects and a necessary partner in any project that affects a Corps constructed flood control channel.

State Guidance and Oversight

The California Department of Water Resources (DWR), RWQCB, the State Water Resources Control Board, and the CDHS are the principal agencies responsible for regulating surface and groundwater resources at the state level.

The DWR manages the water resources of California in cooperation with other agencies, to benefit the State's people, and to protect, restore, and enhance natural and human environments. Any proposed project will comply with California Water Plan Update 2005 (Bulletin 160-05) to meet the State's future water needs (DWR, 2005). This is a useful reference, a living document integrating statewide and local planning initiatives, consistent with the California Water Code, and prepared with stakeholders input.

The DWR is also responsible for the Integrated Regional Water Management Grant Program (IRWMP) funded by Proposition 84, which provides significant funding opportunities to carry out groundwater recharge projects. The projects envisaged later in this report fit within the scope of the IRWMP in optimizing local water resources to reduce the reliance on imported water, protecting and improving groundwater and drinking water quality, and increasing watershed friendly recreational space, etc.

The RWQCB adopted the Los Angeles County's Standard Urban Storm Water Mitigation Plan (SUSMP), which is intended to address storm water pollution from new development and redevelopment by the private sector as well as equivalent public works projects. The countywide SUSMP require that BMPs be implemented to meet specific design standards to achieve specified water quality goals (LARWQCB, 2000).

SUSMP includes a limitation on the use of infiltration BMPs where there is potential for storm water to contaminate groundwater. This concern has also been expressed by the ULARA Watermaster. A limitation on the location of infiltration BMPs has been included in the City's Prescriptive Methods for SUSMP compliance to prohibit the implementation of infiltration BMPs in the SFB watershed. The SFB provides approximately 15% of the City's water supply and is an unconfined aquifer, which increases the likelihood of potential contamination. Implementation of these new regulations requires the Watershed Management Division (WMD) of the Los Angeles County Department of Public Works (LADPW) to review and approve certain categories of private and public development projects to comply with SUSMP requirements, determine pollution control system adequacy and appropriateness, and provide technical assistance to the public (LARWQCB, 2000).

CDPH is responsible for groundwater recharge and drinking water regulations. The primary maximum contaminant level for various constituents should comply with the

California Code of Regulations, Title 22, Chapter 15 Domestic Water Quality and Monitoring. Under the CDPH Draft Groundwater Recharge Criteria, no drinking water supply wells are allowed within a soil aquifer treatment zone defined by a distance of less than 500 feet and an underground retention time of 6 months from the point of recharge. Currently, if there are wells located near potential sites that supply domestic drinking water, an alternative source of domestic water supply or CDPH approved treatment mechanism must be provided to those users because of the construction of the BMP devices. The purchase of land or a conservation easement might be proposed if the acquisition is to protect the source water of the system from contamination and to ensure compliance with primary drinking water regulations. Public hearings, public workshops, focus groups, or meetings around the state will be conducted by CDPH to encourage the involvement and active input of the public and affected parties in the development and periodic updating of the source water protection program adopted pursuant to this requirement.

CDPH has also published draft regulations with specific criteria for groundwater recharge projects. CDPH has adopted the Safe Drinking Water and Toxic Enforcement Act of 1986 (25249.5-25249.13), and California SDWA as mandated by the California Health and Safety Code. It is required that the water delivered by public water systems of the state shall at all times be pure, wholesome, and potable. CDPH ensures appropriate water resource and quality data to meet the requirements of safe drinking water in coordination with the DWR. To prevent surface and groundwater contamination, new homes or new mobile home parks served by a septic tank/drain field system shall be on lots having minimum size limitations depending on whether they are within a low, medium or high pollution susceptibility area. The liquid capacity of all septic tanks shall confirm to the Los Angeles County Plumbing Code as determined by the number of bedrooms or apartment units or the number of fixture units.

State guidance and oversight may not end here because the impoundment of surface water during the rainy season and subsequent percolation to the groundwater may cause seasonal variation of the water table, resulting in a change in riparian habitats that are used to support a variety of species. An impact evaluation on the downstream habitat needs to be prepared in conjunction with the California Department of Fish and Game. If significant, the amount of induced recharge to off sites should be computed in order to determine a reduction in flooding or a reduced size of downstream channel.

Local Guidance and Oversight

Many of the federal and state requirements are replicated and occasionally augmented at the local level. This local input is often specified in plans and ordinances, such as the San Fernando Groundwater Quality Management Plan; the LADPW stormwater and runoff pollution control ordinance; regional, county, city land use general plans; and open space conservation plans.

The San Fernando Groundwater Quality Management Plan is a basin wide plan developed by the LADPW in July 1983 through a cooperative agreement with the Southern California Association of Governments. The plan, with funding from the State Water Resources Control Board and USEPA under the 208 Grant Program (Blevins and Mann, 1993) seeks to protect and upgrade the quality of the stored water in the SFB. The Plan recommends systematic installation of sanitary sewers in designated areas throughout the SFB in order to eliminate existing commercial and industrial discharge of wastewater to the groundwater basin. The State-mandated Underground Storage Tank Program headed by the City of Los Angeles Fire Department focuses on the detection of leaks from underground tanks, the monitoring and removal of gasoline, and their related constituents from the soils. If groundwater contamination is suspected, the problem is directed to the Los Angeles Regional Water Quality Control Board (LARWQCB).

The Los Angeles Department of Water and Power (LADWP), in coordination with other agencies, performs various remedial investigations followed by appropriate actions. These actions include water quality monitoring of groundwater contaminant plumes, management of production well operations, operation of groundwater treatment facilities, and necessary capital improvements.

The IRP supports the neighborhood recharge that involves installing recharge facilities in portions of vacant urban lots, abandoned alleys, and city parklands, where the soil is highly permeable (CLADPW and LADWP, 2004). This option involves installing underground storage devices (such as a honeycomb shaped device, but without the lining which would prevent infiltration). The IRP also proposed the regional recharge option which focuses on large scale projects to capture and infiltrate runoff from large areas within the city. Certain portions of our study area meet the criteria described in the plan and might therefore comprise potentially feasible projects.

Rising groundwater associated with groundwater recharge can be addressed by installing de-watering wells on appropriate land lots according to the Department of Building and Safety (DBS) ordinances. The wells should be designed to activate at a groundwater level that will prevent the groundwater from rising above predetermined levels on the geologic cross-sections. Discharging non-contaminated groundwater produced by dewatering activities may require a NPDES permit from the RWQCB. In order to improve the on-site natural infiltration of storm runoff, permeable asphalt may be a paving option that can be explored with the DBS and Safety and Bureau of Street Services.

The WMD of the LADPW manages the discharge of pollutants from private property developments. Preventing these pollutants from entering the stormwater discharge system can be accomplished by installing and maintaining post-construction treatment control BMPs on qualified projects. Selection, implementation and financing of effective BMPs are facilited by the BMP Task Force under the Watershed Management Division through data gathering, analysis and exchange, stakeholder coordination, and outreach. The discharge, deposit or disposal of any stormwater and/or runoff to the storm drain system and/or receiving waters within any unincorporated area covered by the NPDES municipal stormwater permit need to confirm with the Los Angeles County Stormwater

Ordinance (Ord. 98-0021 §1 (part), 1998.), also known as the "stormwater and runoff pollution control ordinance of the County of Los Angeles Title 12 Environmental Protection Chapter 12.80". It requires that:

> All industrial and commercial facilities shall implement BMPs to the maximum extent practicable. Minimum BMPs applicable to all industrial and commercial facilities include, but are not limited to: A. Termination of all nonstormwater discharge to the storm drain system that is not specifically authorized by a NPDES permit; B. Exercising general good housekeeping practices; C. Incorporating regular scheduled preventive maintenance into operations; D. Maintaining spill prevention and control procedures; E. Implementing soil erosion control; F. Posting on-site private storm drains to indicate that they are not to receive liquid or solid wastes;G. Implementing regular cleaning of the on-site private storm drain system; and H. Insuring that stormwater runoff is directed away from operating, processing, fueling, cleaning and storage areas. (Ord. 98-0021 § 1 (part), 1998.)

The State of California required cities and counties to adopt general plan conservation and open space elements by 1973 (Government Code Section 65302). Planning departments such as the Los Angeles County Department of Regional Planning, City of Los Angeles Department of City Planning, County of Ventura Planning Division, and the City of Calabasas Planning and Environmental Programs Division have developed corresponding general plans incorporating land use and open space conservation elements. Land uses promoting groundwater recharge should comply with general plan provisions.

Many local agencies are also involved in managing and protecting parkland and open space resources. Some of the parkland in the study area is under the jurisdiction of the State and the Santa Monica Mountains Conservancy. Los Angeles and Ventura Counties own the parkland adjacent to Chatsworth Reservoir. And a half-mile length of Browns Canyon above the confluence with Devil Canyon is part of an undeveloped park under the jurisdiction of the City of Los Angeles.

Public At Large

Ultimately, the public at large may have as much or more impact on the feasibility of some proposed plans as the aforementioned federal, state, and local agencies. Clearly, a groundwater recharge project with native water is different from the recharge project with reclaimed and recycled water, since the latter is likely to be of more concern to the public. Acceptance and participation of the public ensures the success of the project, particularly these aimed at source water protection. A public hearing may be necessary or required prior to making a final determination on the public heath and safety aspects of any project. Until more definitive criteria are adopted, proposals to recharge groundwater by either surface spreading or injection will be evaluated on a case-by-case basis.

case basis. Public education and outreach, such as interviews with residents, focus groups, fact sheets, television and newspaper articles, endorsements by scientific panels and citizen advisory panels, and taste tests may be considered if necessary. Unlike projects that recharge groundwater using recycled water, the public education program for the interventions envisaged in this report should focus on the involvement and participation of the public in pollution prevention, source recharge area protection, infiltration friendly and good housekeeping practices. Prior to construction, the community should be educated on the purpose and potential impact of the project. Prior knowledge can avoid confusion and unnecessary public reaction (Currier and Moeller, 2000).

Based on the results revealed in the Recharge Suitability Analysis, guidance and oversight from federal, state and local agencies, several recharge projects are recommended and illustrated in the following section. They are: on-site natural infiltration in the catchments of Browns Canyon, Devil Canyon, Mormon Canyon, Ybarra Canyon, and Topanga Canyon, structural infiltration BMP facilities in Aliso Canyon Wash Park, along Falls Creek, a major tributary to Browns Canyon and at the Browns Canyon outlet, and reuse of Chatsworth Reservoir for temporary water impoundment.

Possible Implementation Strategies

This section takes some of the findings from the Recharge Suitability Analysis (Swift et al., 2007) and provides an initial roadmap leading to the development of groundwater recharge strategies in the study area.

The key components of any implementation plan will include: the acquisition of the necessary approvals and permits; the location, design, and implementation of structural BMPs; the implementation of a long-term pollution constituents monitoring program; the designation of a groundwater recharge protection area; and some evaluation of the associated impacts and risks from the installation and operation of groundwater recharge BMPs. The key features of these components are highlighted in the subsections that follow.

Acquisition of Approvals and Permits

Groundwater recharge projects involve various parties, stakeholders and government agencies as discussed in the previous section. Identifying the approval and permitting requirements early will accelerate project planning and development and help facilitate the selection of BMPs that will minimize any adverse impacts. For example, a BMP that will impact existing trees at a site should be considered for a redesign to avoid such impact because the permitting means that impacted trees will have to be replaced at a five to one ratio. This type of problem can be avoided by installing small footprint BMPs or by choosing sites that minimize the impact on existing trees. The various agencies whose mandates and programs that may be impacted by groundwater recharge projects are listed in the section of regulatory and environmental agencies.

Location, Design, and Implementation of Structural BMPs

The Recharge Suitability Analysis results reported by Swift et al. (2007) highlighted Aliso Canyon, Browns Canyon, and the upland areas draining into Chatsworth Reservoir as favorable locations for installing BMPs and increasing the recharge of stormwater runoff. The text and diagram that follow take this analysis a step further and describes the types of BMPs that might be installed.

Aliso Canyon Wash Park

Aliso Canyon is mostly comprised of parkland owned by the City of Los Angeles. The parkland is approximately 2.5 miles long by 0.2 miles wide and flanked by housing on the adjacent hills. This park is part of Porter Ranch, but basically is an undeveloped open space with limited maintenance. The park supports equestrian recreation as a rider trail trickles through the park. The natural stream channel that flows through this park in Aliso Canyon terminates at the Aliso right-of-way debris basin above the 118 freeway (Figure 6). The lower canyon above the 118 freeway, received substantial quantities of urban runoff from numerous concrete stormwater spillways and irrigated, hillside erosion-control plots (Figure 7). These structures typically form isolated pools immediately downstream from each input. Conductivity always exceeded 2500 µS/cm, and sulfate, chlorine, total dissolved solids, iron, manganese and fluorine levels often exceed California's Maximum Concentration Level (MCL) (DHS, 2003). By installing an infiltration BMP facility in coordination with the downstream right-of-way debris basin, stormwater from hillside concrete lots could be collected and percolated into the groundwater on the open park land, which takes advantage of the community/neighborhood groundwater recharge proposed by the IRP (CLADPW and LADWP, 2004). Such recharge facilities under parklands, parking lots, abandoned alleys, etc. will help prevent the uncontaminated runoff from ever entering the storm drains or channels. This option involves installing underground storage capabilities while still maintaining a safe area above ground for human activity. The runoff would be pumped or flow by gravity to the site where it would be collected temporarily until it is able to infiltrate (CLADPW and LADWP, 2004). A favorable water bearing geologic formation is present along Aliso Canyon area shaded in green in Figure 7.

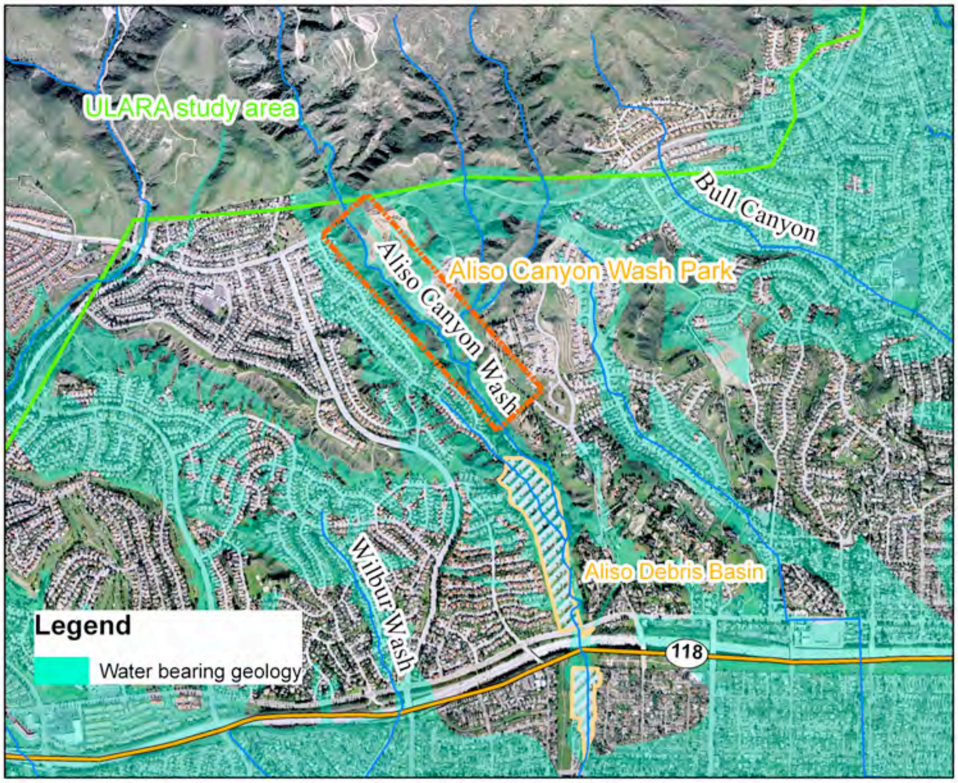

Figure 6. Aliso Canyon Wash viewed on 2005 aerial image

Figure 7. Hillside modifications along Aliso Canyon Wash Park

Browns Canyon

Geologically speaking, Browns Canyon is comprised predominantly of alluvial and the underlying Saugus formation ("sandstone"), which consists of loose to moderately dense sand and silty sand layers with interbeds of silt and clay (Yerkes and Campbell, 2005). Much of the upper canyon and some tributaries appeared to be relatively uninfluenced by human activity. But some upstream canyon catchments are heavily paved and developed as residential lots (Figure 8). Several sections of flowing stream were used as horse trails, and several horse pastures were immediately adjacent to the stream. Some flood control emplacements and pipes of unknown purpose were located in the lower canyon (Miles, 2007).

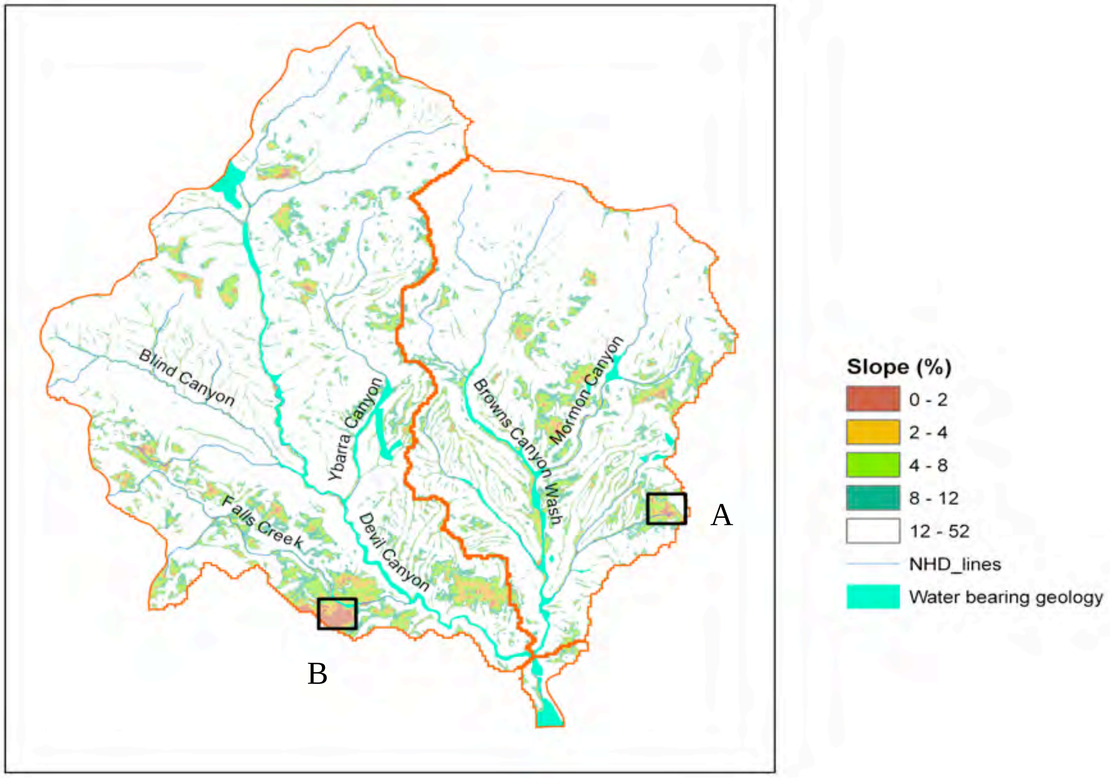

Figure 8. The Browns Canyon and Devil Canyon catchments. Inset boxes A and B are two large residential areas in the Browns and Devil Canyon Catchments, respectively.

More than 500 residential lots are located at the upstream canyon that contributes to Browns Canyon (Figure 9A). In the Devil Canyon catchment, Falls Creek passes through a large residential lot and receives a substantiate amount of urban storm water from the residential lots (Figure 9B). Impervious pavement and roofs reduce the runoff infiltration and increase first-flush storm water. The stream below the residential lots receives urban runoff with low sulfate and conductivity and high nitrate concentrations. Infiltration basin and trenches could be used to increase recharge in these areas so long as the slope were relatively modest (0-8%), high infiltration rate, and the upslope drainage areas relatively small (5-50 acres) (Boutiette and Duerring, 1994). Favorable water bearing geologic formation is also present along tributary canyons (Figure 8).

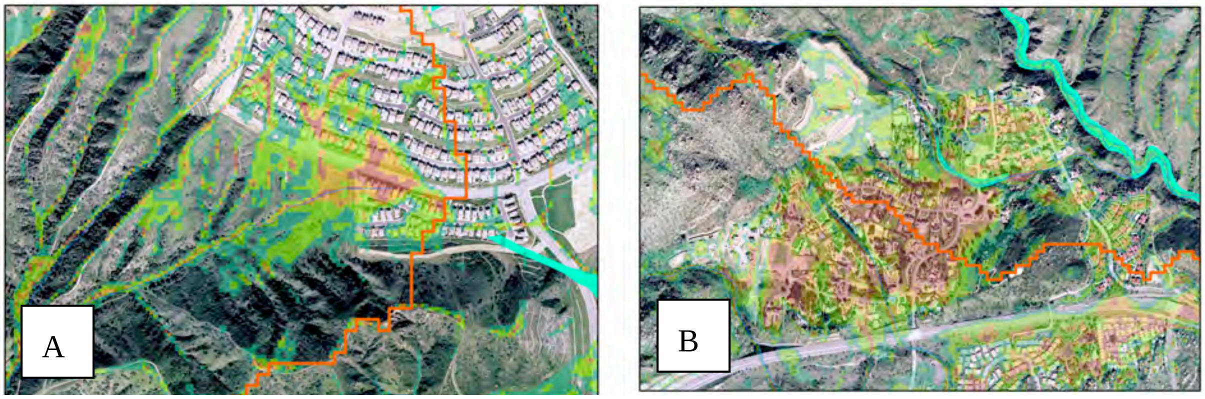

Figure 9. Residential areas along (A) a tributary in Browns Canyon; and (B) Falls Creek

Open land exists at the confluence of Browns Canyon and Devil Canyon and is suitable for an extended/dry detention basin or wet pond (Figure 10A). A relatively small but constant base flow is present at the confluence during dry weather conditions (Figure 10B), which would be necessary to maintain a low-flow channel in the infiltration basin or wet pond. California Department of Transportations (Caltrans) has successfully constructed and maintained such BMPs at various sites in southern California (Caltrans, 2004) (Figure 11). Stormwater collects in the basins and the outlet allows water to drain slowly, while sediment and other particulate forms of pollutants settle out. At full capacity, the basin will be designed to drain in 24-72 hours to prevent mosquito production and allow for capture of subsequent storms. The basin will generally remain dry except immediately following storms and the detention period thereafter. When maintenance thresholds are reached, accumulated sediment is removed, characterized, and disposed of appropriately.

Figure 10. (A) Browns Canyon under the 118 freeway overpass; and (B) A hybrid portion of Browns Canyon where the natural creek channel becomes a concretized box channel

Figure 11. An extended infiltration basin that was constructed by Caltrans, San Diego County

Chatsworth Reservoir

The Recharge Suitability Analysis showed that the upper canyons that drain into Chatsworth Reservoir were characterized of high surface runoff production. Collection and storage of the surface water off the stream should be considered before the surface runoff reaches the channel and flushes down the concrete box channel. Chatsworth Reservoir provides an opportunity for temporary storage of the native water that runs off the surrounding hills. Chatsworth Reservoir used to serve as a water-storage facility for the LADWP, but the reservoir is no longer for this purpose because the Chatsworth Dam, an older earthen facility, was determined to be unsafe in 1969. The structure was considered to be unable to withstand a major earthquake. No water has since been stored in Chatsworth Reservoir, with all runoff passed directly through the outlet. LADWP however, is considering a long term plan to restore Chatsworth Reservoir for water supply impoundment in the City of Los Angeles Integrated Resources Plan.

> …A regional approach would include the use of out-of-service reservoirs for seasonal storage. Conversion of the out-of-service Chatsworth reservoir is one option for storing the wet weather runoff. The total volume available in the Chatsworth Reservoir is 10,600 acre-feet (3,500 million gallons). ……Using the Chatsworth reservoir would require the runoff to be diverted to it, which would require a collection system, pumping stations, and treatment either before storage or before the beneficial use (CLADPW and LADWP, 2004).

Reopening of Chatsworth Reservoir would definitely improve the native water collection during the rainy season and hence improve the groundwater recharge. However, the feasibility of reuse Chatsworth Reservoir needs to be investigated regarding its stability and dam safety. As an alternative, small lot size surface water impoundments might be appropriate for storing direct surface water running off the hillslopes, which would cause much less impact on the reservoir stability. Again the feasibility of this plan needs to be further evaluated in terms of reservoir safety. The nearby Sage Ranch is a seismically-active area with several faults that extend from Chatsworth Reservoir, up Woolsey Canyon, and westward into the Burro Flats area. The best known of these faults, the Santa Susana Fault, is largely responsible for the rapid uplift of the Santa Susana Mountains and Simi Hills.

Pollution Constituents Monitoring Program

A big issue that may affect the viability of some infiltration options is the risk associated with unknown contaminants. BMPs or pretreatment devices may need to be installed upstream of the recharge basins. The treatment method could be as simple as a trash and solids removal device or as complex as a filtration device depending on the quality of runoff. All installations should meet site-specific requirements. Permanent storm water infiltration basins shall not be constructed in areas having high pollution susceptibility. Miles (2007) found urban runoff that exceeded California's MCL for various constituents at multiple monitoring sites in the study area. Land use development, stormwater discharge and wastewater disposal practices that have impact on surface and groundwater quality should be closely monitored in the upstream catchments before infiltration projects are planned and/or implemented.

The Santa Susana Field Laboratory (SSFL) discharges stormwater runoff into Dayton Canyon and Bell Canyon, both located in the study area (Boeing, 2006b). The september 2005 Topanga Fire burned approximately 70% of the SSFL (2000 acres) and destroyed many of the BMPs that controlled runoff from the site, with the copper, lead, dioxin and nitrate levels exceeding the EPA MCL at monitoring sites located in Bell Canyon (Boeing, 2006b). The highest copper and lead concentrations occurred during storm flow events in January 2006, and Boeing concluded that the erosion of soils and ash following the Topanga Wildfire was the most probable cause. The highest dioxin concentrations occurred immediately following the Topanga Wildfire, and decreased as BMPs were rebuilt and improved (Boeing, 2006b).

Monitoring each BMP system is essential to evaluate the performance of each system based on removal efficiency, effectiveness, maintenance, and cost. The monitoring program should provide details of the frequency, location, and reporting of water quality for canyons and streams highlighted in this report and the Recharge Suitability Analysis report prepared by Swift et al. (2007). Responsible jurisdictions or committees may propose a plan to take water samples and provide data to assess water quality and determine the requirements of BMPs.

Designation of a Groundwater Recharge Protection Area

> Recharge area protection includes keeping groundwater recharge areas from being paved over or otherwise developed and guarding the recharge areas so they do not become contaminated. Protection of recharge areas, whether natural or man-made, is necessary if the quantity and quality of

> groundwater in the aquifer are to be maintained. Existing and potential recharge areas must be protected so that they remain functional and they are not contaminated with chemical or microbial constituents. Zoning can play a major role in recharge area protection by amending land-use practices so that existing recharge sites are retained as recharge areas (DWR, 2005).

Protection of recharge areas consists of two components: (1) preventing the areas from being concretized by urban infrastructure, which leads to the impermeable land surface and reduces the infiltration; and (2) preventing chemical or microbial contamination that would require expensive treatment before the water could be delivered for potable, agricultural, or industrial purposes. The State promotes additional protection of recharge areas by implementing a series of recommendations suggested in the California Water Plan Update (DWR, 2005).

The Recharge Suitability Analysis shows the greatest infiltration capacity occurs in the catchments draining Browns, Devil, Mormon and Ybarra Canyons. The rainy season (Nov through March) infiltration is estimated to be 12-18 inches based on the 30-year average precipitation data and was denoted as very suitable area for natural infiltration (Swift et al, 2007). Much of the upper canyon and some tributaries appeared to be relatively uninfluenced by human activity. But some large residential lots appear in the high infiltration sites. Illegal dumping is very common along the roadside, and on several occasions bags of household garbage have been spotted near flowing streams. Several sections of flowing streams are used as horse trails. Horse feces were routinely observed within the streams (Miles, 2007).

Due to the potential risk of new developments in the high infiltration rate zones, protection of the infiltration area to ensure natural infiltration of runoff to subsurface soil is recommended. Pavement of potential infiltration areas should be strictly controlled. Infiltration BMPs are suggested to be installed at sites where urban runoff comes off the hillside and flows to the surface stream. Infiltration basins have high pollutant removal efficiency and can also help recharge the groundwater, thus restoring low flows to stream systems.

Other Considerations

Damages caused by groundwater may be identified, but the portion of the damages created by recharge may not always be easily ascertained. These might include the raising of water tables or increasing pore pressures in earth materials. This in turn may cause wet basements, ineffective filter fields and septic tanks, unstable foundations, earth slides, or affect water quality for non-agricultural purposes. Hillslope areas are prone to landslides in the study area, which may be caused or increased by groundwater recharge. Landslides or earth flows could cause damage to roads, buildings and other structures. Areas that are designated as liquefaction and landslide prone areas during a strong earthquake should be investigated to determine the influence of the groundwater recharge sites on these areas and vice versa.

Groundwater problems may be associated with seasonal high water tables or fluctuating water tables associated with flood events. Locally, the problem may have been analyzed and the source of the groundwater determined. Records, newspaper accounts, or affected residents often can relate the occurrence of damaging groundwater with past events and developments or with certain recurring events, such as storms of a given intensity or duration. It may be the geologist's responsibility to substantiate or disprove these analyses and determine whether the preliminary investigation appears to warrant a detailed study. These examples demonstrate how a multi-tiered approach might be used to identify problems and potential solutions.

Conclusions

Groundwater recharge using the native water from the upper Los Angeles River Area is a great opportunity for maximizing beneficial use of runoff as opposed to flushing much of the stormwater runoff into the ocean. This region has one of the most effective flood control systems in the world that protect people and their properties from the impact of flash flooding. Stormwaters that historically recharged local groundwater basins are now discharged into the ocean as quickly as possible from impermeable surfaces through concrete lined channels, making this region even more dependent on imported water supplies. As many projects to use reclaimed water for potable purposes fail, augmentation of the imported water supply with native sources is becoming more attractive than ever.

Permeable soils, high infiltration rates, surplus rainy weather water, and limited development in ULARA ensure the physical feasibility of native recharge of the groundwater basin. This implementation plan has provided guidance for implementing solutions including identification of options for groundwater recharge projects and description of the coordination of recharge activities with state, local and federal agencies. Based on the overview of physical and technical feasibility, existing plans, programs and institutional structures, the following bullets summarize the abovementioned recommendations and general principles that should be followed to maximize the likelihood of success.

- **Integration into existing water management plans and programs, versus establishing individual water quality and quantity protection and monitoring programs**

Many existing water management plans and programs involve groundwater quality monitoring and improvement, such as Los Angeles County’s SUSMP, the San Fernando Groundwater Quality Management Plan, and the City of Los Angeles IRP. The objectives of recharge projects are more likely to be achieved if they are incorporated into existing projects and programs that are supported by individual agencies and jurisdictions. Many agencies and jurisdictions increasingly acknowledge the value of collaboration with nonprofits (like Mountains Restoration Trust (MRT)) and other stakeholders in the planning, design, implementation, funding, monitoring and maintenance of integrated projects.

- **Involvement of land use decision makers**

Land use decisions have the potential to affect the water recharge strategies utilized in the plan, as land use can affect population growth, watershed surface pavement and surface water quality. The implementation of stormwater BMPs projects may require acquisition of land which could change existing uses and may warrant consideration of modifications to land use policies and practices. In developed areas, the land use decision makers are primarily the cities and counties along with private land owners. The National Park Service and California State Parks have responsibility for the conservation and preservation of nationally and regionally significant open spaces. All of these agencies and jurisdictions should be involved as participants at stakeholder workshops.

- **Data Management**

The collection, management, and utilization of data are essential elements to creating a feasible and sustainable plan. There currently exists a need for additional data on water quality and quantity during the rainy season. This is especially important for determining the size and scale of the recharge facilities taking into account seasonal and annual variation of water storage and maintenance. Some federal, state, local and community agencies and organizations have been conducting monitoring of surface water quality in the region for years, but there has been no systematic monitoring and sampling in the ULARA. Monitoring at a finer temporal and spatial scale is required to characterize the impact of vegetation and atmospheric factors such as evaporation and transpiration on the spatio-temporal pattern and magnitude of storm runoff across the study area.

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References

Blevins, M. L., and Mann, Jr. J. F. 1993. *Management of Upper Los Angeles River area (ULARA) ground water contamination. Proceedings of the 19th Biennial Ground Water Conference*. Edited by J. J. DeVries and J.Woled. Water Resources Center Report No. 84. September 13-14, Sacramento, California.

Boeing, 2006a. *Annual NPDES Discharge Monitoring Report Compliance File CI-6027*. Canoga Park, CA, Santa Susana Field Laboratory.

Boeing, 2006b. *1st Quarter 2006 NPDES Discharge Monitoring Report Submittal-Santa Susana Field Laboratory Compliance File CI-6027*. Canoga Park, CA, Santa Susana Field Laboratory.

Boutiette, L.N., and Duerring, C.L., 1994. *Massachusetts Nonpoint Source Management Manual, The Megamanual: A Guidance Document for Municipal Officials, Massachusetts Department of Environmental Protection*, Office of Watershed Management, Nonpoint Source Program, Boston, MA.

California State Water Rights Board (CSWRB). 1962. *Report of Referee*, The City of Los Angeles vs. City of San Fernando et al.

Caltrans, 2004. *BMP Retrofit Pilot Studies (Technical Information)*. October 2004. http://www.dot.ca.gov/hq/env/stormwater/ongoing/pilot_studies/index.htm#bmps.

CLADPW - Bureau of Sanitation and LADWP, 2004. *City of Los Angeles Integrated Resources Plan Facilities Plan (IRP) Volume 3: Runoff Management*. Prepared by: CH: CDM, A Joint Venture.

Currier, B., and Moeller, G.L., 2000. *Lessons Learned: The Caltrans Storm Water Best Management Practice Retrofit Pilot Study*. Storm Water Program CSUS Office of Water Programs 7801 Folsom Boulevard, Suite 102, Sacramento, CA 95826

Department of Health Services (DHS), 2003. *Maximum Contaminant Levels: Title 22, California Code of Regulations; Division 4, Environmental Health; Chapter 15 Domestic Water Quality and Monitoring*, California Department of Health Services.

DWR, 2005. *California Water Plan Update. Chapter 15 Volume 2: Resource Management Strategies*. http://www.waterplan.water.ca.gov/docs/cwpu2005/vol2/v2ch15.pdf

Environmental Science Associates (ESA), 2005. *Analysis of Developing and Implementing a Groundwater Recharge Reuse Project in the Antelope Valley*. Reviewed by J. Crook. Submitted to: County Sanitation District No. 20 of Los Angeles County http://www.lacsd.org/civica/filebank/blobdload.asp?BlobID=2171

LADPW, 2005. *Los Angeles County Annual Hydrologic Reports, 1996-2005.* http://dpw.lacounty.gov/wrd/report/

LARWQCB, 2000. *Standard Urban Storm Water Mitigation Plan (SUSMP).* http://www.swrcb.ca.gov/rwqcb4/html/programs/stormwater/susmp/susmp_details.html

Mann, Jr. J. F., 1976. *Pueblo Water Rights of the City of Los Angeles. California Geology*. December, 267-272. California Division of Mines and Geology.

Miles, J. W., 2007. *Water Quality and Land Use in Western SFB Canyons and Tributary Streams*. Master Thesis. California State University, Northridge.

MWD, 2007. *Groundwater Assessment Study: Status Report on the Use of Groundwater in the Service Area of the Metropolitan Water District of Southern California, Chapter IV Groundwater Basin Reports San Fernando Valley Basins - Upper Los Angeles River Area Basins*. Report Number 1308.

Sayre, J. M., Devinny, J. S. and Wilson, J.P., 2006. *Green Visions Plan for 21st Century Southern California: A Guide for Habitat Conservation, Watershed Health, and Recreational Open Space. 11. Best Management Practices (BMPs) for the treatment of stormwater runoff.* University of Southern California GIS Research Laboratory and Center for Sustainable Cities, Los Angeles, California

Swift J., Antos M., Wilson J.P., and Sheng, J., 2007. *Upper Los Angeles River Area Recharge Suitability Analysis*. Los Angeles, California: University of Southern California GIS Research Laboratory Technical Report No. 6.

Topper, R., Barkmann, P.E., Bird, D., and Sares, M.A., 2004. *Colorado Geological Survey Department of Natural Resources, Artificial Recharge of Ground Water in Colorado – A statewide Assessment*. Colorado Geological Survey Division of Minerals and Geology Department of Natural Resources Denver, Colorado. http://geosurvey.state.co.us/portals/0/ARExecSum%20for%20web.pdf

ULARA Watermaster, 1998, *Watermaster Service in the Upper Los Angeles River Area: Policies and Procedures*. Upper Los Angeles River Area Watermaster, City of Los Angeles, vs. City of San Fernando, et al. Case No. 650079-County of Los Angeles. February 10,1998

ULARA Watermaster, 2004, *Watermaster Service in the Upper Los Angeles River Area, 2002-03 Water Year, October1, 2002-September 30, 2003*. Upper Los Angeles River Area Watermaster, City of Los Angeles, vs. City of San Fernando, et al. Case No. 650079-County of Los Angeles. May 2004

ULARA Watermaster, 2005, *Watermaster Service in the Upper Los Angeles River Area, 2003-04 Water Year, October1, 2003-September 30, 2004*. Upper Los Angeles River Area Watermaster, City of Los Angeles, vs. City of San Fernando, et al. Case No. 650079

County of Los Angeles. May 2005.

ULARA Watermaster, 2006, *Watermaster Service in the Upper Los Angeles River Area, 2004-05 Water Year, October1, 2004-September 30*, 2005. Upper Los Angeles River Area Watermaster, City of Los Angeles, vs. City of San Fernando, et al. Case No. 650079-County of Los Angeles. May 2006

U.S.Department of Agriculture (USDA), Soil Conservation Service (SCS) Engineering Division., 1967. *Ground water Recharge*. Technical Release No.36. Geology. http://www.info.usda.gov/CED/ftp/CED/tr36.pdf

Water Replenishment District of Southern California (WRD), 2007. *Regional Groundwater Monitoring Report Water Year 2005-2006*. Central and West Coast Basins Los Angeles County, California.

Yerkes, R. F., and Campbell, R.H., 2005. *Preliminary Geologic Map of the Los Angeles 30' x 60' Quadrangle, Southern California*. USGS. a. C.GSUS. Department of the Interior.

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List of Terms

Abbreviation	Term	Description
BMPs	Best Management Practices	Any method for controlling, removing, preventing, or reducing pollution.
CDPH	California Department of Public Health	The CDPH goals are to improve access to quality public health services, to improve health outcomes, and to reduce health care costs through prevention with services such as disease screenings and vaccinations, and patient safety initiatives. http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/default.aspx
CLADPW	City of Los Angeles Department of Public Works	The Department of Public Works, the City's third largest Department, is responsible for construction, renovation, and the operation of City facilities and infrastructure. The Department builds the City streets, installs its sewers, constructs storm drains as well as public buildings and service facilities.
DBS	Department of Building and Safety	The Los Angeles Department of Building and Safety is responsible for investigating code violations on existing single family residential, commercial, industrial and vacant buildings inside the City of Los Angeles.
IRP	City of Los Angeles Integrated Resources Plan	The IRP is an inaugural visionary process for stakeholder-based integrated water resources planning. The IRP incorporates the values of Los Angeles communities into infrastructure planning and integrates planning for wastewater, recycled water and stormwater.
IRWMP	Integrated Regional Water Management Plan	The IRWMP was developed for the Greater Los Angeles County regions, funded by Proposition 50, Chapter 8, provides about $380 million for competitive grants for projects to protect communities from drought, protect and improve water quality, and improve local water security by reducing dependence on imported water.
LADPW	Los Angeles County Department of Public Works	Responsible for the construction and operation of Los Angeles County's roads, building safety, sewerage, and flood control (http://dpw.lacounty.gov/PRG/DeptOverview/index.cfm).
LADWP	Los Angeles Department of Water and Power	The LADWP, the nation's largest municipal utility, serving the water and electricity needs of the City of Los Angeles
LARWQCB	Los Angeles Regional Water Quality Control Board	The Los Angeles Regional Water Quality Control Board (LARWQCB) protects ground and surface water quality in the Los Angeles Region, including the coastal watersheds of Los Angeles and Ventura Counties, along with very small portions of Kern and Santa Barbara Counties.
MCL	California's Mean Concentration Level	The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
MRT	Mountains Restoration Trust	A California Public Benefit Nonprofit Organization committed to preserving, protecting and enhancing the natural resources of the Santa Monica Mountains in the County of Los Angeles, California (http://mountainstrust.org/).
MWD	Metropolitan Water District of Southern California	MWD is a consortium of 26 cities and water district that provides drinking water to nearly 18 million people in parts of Los Angeles, Orange, San Diego, Riverside, San Bernardino and Ventura counties.
NPDES	National Pollution Discharge Elimination System	On July 15, 1996, the Los Angeles Regional Water Quality Control Board issued a national pollutant discharge elimination system (NPDES) permit to the 85 incorporated cities and

Abbreviation	Term	Description
		the county within Los Angeles County. NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States
RWQCB	California Regional Water Quality Control Board	There are nine Regional Water Quality Controls Boards (RWQCB) within the state of California. The RWQCB have authority to conduct, order, and oversee investigation and cleanup where discharges of waste cause, or threaten to cause, discharges to waters of the state that could cause, or threaten to cause, pollution or nuisance, including impacts to public health and the environment.
SDWA	USEPA Safe Drinking Water Act (SDWA)	The Safe Drinking Water Act (SDWA), which celebrates its 30th anniversary on December 16, 2004, is the main federal law that ensures the quality of Americans' drinking water. Under SDWA, EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers who implement those standards. http://www.epa.gov/safewater/sdwa/index.html
SFB	San Fernando Basin	The San Fernando Groundwater Basin was adjudicated in 1979, and includes the water-bearding sediments beneath the San Fernando Valley, the Tujunga Valley, Browns Canyon, and the alluvial areas surrounding the Verdugo Mountains near La Crescent and Eagle Rock.
SFV	San Fernando Valley	The San Fernando Valley is bounded by the Santa Susana Mountains to the northwest, the Simi Hills to the west, the Santa Monica Mountains to the south, the Verdugo Mountains to the east, and the San Gabriel Mountains to the northeast. http://en.wikipedia.org/wiki/San_Fernando_Valley
SUSMP	Standard Urban Storm Water Mitigation Plan	The SUSMP is a plan that designates best management practices (BMPs) that must be used in specified categories of development projects. The County submitted SUSMP, but the Regional Water Board approved the SUSMP only after making revisions. The Executive Officer issued the revised SUSMP on March 8, 2000.
SWTR	Surface Water Treatment Rule	The SWTR was published in the Federal Register by the Environmental Protection Agency on June 29, 1989. This rule contains provisions that require disinfection and filtration for all public water systems that use surface water or a source that is ground water under the direct influence of surface water.
ULARA	Upper Los Angeles River Area	Basins located within the Los Angeles River Watershed in Los Angeles County, including San Fernando, Sylmar, Verdugo and Eagle Rock Basins (http://mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/PDFs/SanFernandoValleyBasins/UpperLARiverAreaBasins.pdf)
USACE	US Army Corps of Engineers - Los Angeles District	The Los Angeles District provides civil works and military engineering support to Southern California, Nevada, Arizona, and parts of Utah. It provides services include planning, designing, building and operating water resources and other civil works projects.
WMD	Watershed Management Division	WMD of the LADPW implements watershed management countywide to improve the overall quality of life for residents of Los Angeles County.