East Raymond Basin Water Resources Plan

Appendix A – Review of Reference Documents

Prepared for: Cities of Arcadia and Sierra Madre
And the Los Angeles County Department of Public Works

FINAL DRAFT

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EAST RAYMOND BASIN WATER RESOURCES PLAN
APPENDIX A - REVIEW OF REFERENCE DOCUMENTS

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1.0 INTRODUCTION

Over the years, the Cities of Arcadia and Sierra Madre, along with the Los Angeles County of Public Works (LACDPW) and the U.S. Army Corps of Engineers (Corps) have conducted numerous studies in the East Raymond Basin (ERB) and the tributary watersheds. These studies have specifically focused on water system reliability, infrastructure rehabilitation and restoration of the Santa Anita Dam, Santa Anita Debris Dam, and associated spreading facilities. This report provides a summary and brief description of the documents relevant to the ERB's water resources. The information contained in the documents provides background related to development of additional ground water supplies through:

1. Rehabilitation and expansion of the existing spreading basins along the Santa Anita Creek.
2. Operational improvements to spreading basins along the Sierra Madre Creek
3. Potential for using injection wells to recharge water.
4. Consideration of importing water for artificial recharge.
5. In-lieu pumping.

In most cases, previous projects complement each other; others however, require some assessment to reconcile differences in findings and conclusions.

Documents and data relevant to the East Raymond Basin study have been provided by the Cities of Arcadia and Sierra Madre, the LACDPW, the Program Director, Steve Bucknam, and the United States Geological Survey (USGS). Documents have also been collected from the ERB

Project Team's (GEOSCIENCE Support Services, Inc., Stetson Engineers, URS Corporation, and Van Dell & Associates) previous work in the ERB.

Field reconnaissance of the Santa Anita Dam, Santa Anita Debris Dam, Santa Anita spreading grounds, Sierra Madre Dam and Sierra Madre spreading grounds was also conducted as part of the background review. During these field visits, valuable insights were gained as to understanding the operations, assets and constraints of the infrastructure. This knowledge was used extensively in the Hydrologic Analysis of the ERB Watersheds (Appendix C), and in the developement of Project Alternatives (Appendix G).

2.0 DOCUMENTS RELEVANT TO THE EAST RAYMOND BASIN

2.1 Raymond Basin

2.1.1 Conjunctive Use

GEOSCIENCE Support Services, Inc., 2005. Technical Memorandum – Raymond Basin Ground Water Flow Model Predictive Simulations. December 10, 2004.

A two layered ground water flow model constructed for the entire Raymond Basin is used to determine impacts from different conjunctive use options (i.e. in-lieu recharge, injection and spreading) for the storage of 75,000 acre-ft of water for Metropolitan Water District of Southern California. The movement of perchlorate within the basin, as a result of the additional stored water, was also evaluated.

GEOSCIENCE Support Services, Inc., 2004. Baseline Ground Water Assessment of the Raymond Basin. February 2, 2004.

Baseline evaluation including a comprehensive review of past documentation, and review and update of existing water facilities, infrastructure and systems. Work included collection and compilation of geohydrologic data, facilities information, and other background data. An extensive MS Access database was developed using the compiled data. Key basin management aspects were evaluated and recommendations made to improve the Basin's efficiency and management. Specific topics covered included an evaluation of the effects of the current long-term storage program on ground water levels, quality and storage; development of a basin-wide monitoring program outlining a monitoring network and monitoring protocol for the collection of geohydrologic data; and an investigation of existing conjunctive use within the Raymond Basin and development of a strategy for future conjunctive use and ground water storage opportunities.

CH2M Hill, 1991. Phase 2 Report Evaluation of Hydrogeologic Interconnection of Eastern And Western Units Raymond Basin. Prepared for the Cities of Arcadia and Sierra Madre. February 5, 1991.

This document evaluates the hydrologic connection between the eastern and western units of the Raymond Basin. The investigation builds on CH2M Hill's earlier work for the U.S Army Corps of Engineers and includes a description of the hydrogeology of the area, with ground water levels, hydrographs, storage estimates and production information. A model simulating different conjunctive use scenarios is also presented.

CH2M Hill, 1990. Phase 1 Raymond Basin California - First Technical Devil's Gate Multi-Use Project. Prepared for the City of Pasadena. January 26, 1990.

This report presents the hydrogeologic information that CH2M Hill used to develop its ground water model of the Raymond Basin. It provides detailed sections on the regional setting, hydrogeology, ground water quality, water systems, and institutions of the Raymond Basin, and offers a preliminary evaluation of several conjunctive use alternatives.

CH2M Hill, 1992. Phase 2 Raymond Basin, California - First Technical Assessment Devil's Gate Multi-Use Project. July 14, 1992.

This report presents the results of the ground water modeling of four conjunctive use concepts for the Raymond Basin. The discussion includes hydrogeologic properties, model calibration, water budgets, boundary conditions, and ground water storage. Institutional issues, water quality concerns and contaminant migration are also discussed in the context of the model as conclusions and recommendations are drawn.

2.1.2 Ground Water Management and Monitoring

California Department of Public Works, 1995. Bulletin No. 39-S; Ground Water Levels and Precipitation Records. Southern California Area Investigation - Groundwater for 1950, Los Angeles, San Gabriel, and Santa Ana River Basins, and Antelope Valley. April, 1955.

This publication summarizes ground water levels and precipitation for all of Southern California. It includes information from a precipitation station in Sierra Madre, and changes in ground water elevations for several wells in both the Raymond and Main San Gabriel Basins.

California Department of Water Resources, 1998. California Water Plan Update. Bulletin 160-98, Volume 2, Chapter 10. January, 1998.

This chapter draws conclusions of ways to meet California's water demands given current and potential water supplies. It breaks down some of this information by hydrologic subunit.

California Department of Water Resources, 1994. Bulletin 160-93; the California Water Plan Update. Chapter 4, Ground Water Supplies. October, 1994.

This chapter discusses statewide ground water use and management of ground water resources. It briefly outlines all of the adjudicated basins in California.

California Department of Water Resources, 1945-1986. Watermaster Service in the Raymond Basin.

Each annual report summarizes purveyor activities in the Raymond Basin for the preceding year, including ground water extraction, surface water diversions and spreading, maps of wells, and hydrographs of key wells.

Raymond Basin Management Board, 1987-2002. Raymond Basin Watermaster Reports for 1986 to 2003.

Each annual report summarizes purveyor activities in the Raymond Basin for the preceding year, including ground water extraction and injection numbers, surface water diversions and spreading, changes in well status, maps of wells, and hydrographs of key wells.

California Department of Public Works, 1929. Bulletin No. 7; San Gabriel Investigation; Analysis and Conclusions. Report of the Division of Water Rights.

This bulletin delineates the amount of water which flows into the ocean from San Gabriel Canyon and attempts to find a method by which the supplies of the Basin could be better regulated and conserved. Information presented includes precipitation records, hydrology, percolation, and conservation methods.

California Department of Water Resources, 2003. California's Ground Water, Bulletin 118. Draft Individual Basin Descriptions. Raymond Groundwater Basin. Accessed online 7/20/04 at http://www.groundwater.water.ca.gov/bulletin118/update2003/index.cfm

This resource provides information on the hydrogeology of the Raymond Basin, including information on basin boundaries, ground water levels, quality, and storage, as well as recharge, monitoring data and well production characteristics. It also summarizes basin management structures.

2.1.3 Water Rights

Superior Court for the County of Los Angeles, 1984. Judgment in Superior Court Order No. Pasadena C-1323, City of Pasadena vs. City of Alhambra and other Defendants, March 26, 1984.

A copy of the Judgment as modified and restated on March 26, 1984.

Superior Court for the County of Los Angeles, 1984. Notice of Ruling on Motion Superior Court Order No. Pasadena C-1323, City of Pasadena vs. City of Alhambra and other Defendants, March 16, 1984.

This is a copy of the Notice of Ruling on motion of the Plaintiff City of Pasadena to Modify and Restate Judgment in Regard to Transfer of Rights and Establishment of a new Raymond Basin Management Board as Watermaster.

California Department of Public Works, 1954. Report of Referee on a Review of the Determination of the Safe Yield of the Raymond Basin Area, Los Angeles County, California. 109 p.

Determining the safe yield of the Raymond Basin is the focus of this legal report. It includes a ground water level contour map of the Raymond Basin from 1938 and changes in ground water levels through 1950. It also has several figures showing profiles of the water table over time. Findings in the report include:

- Total consumptive use decreased by about 1,100 acre-ft/yr between 1939 and 1949.
- Total dissolved solids concentrations appreciably increased between 1939 and 1949.
- Safe Yield is determined to be 30,770 acre-ft/yr for conditions existing during 1951-1952.

Superior Court for the County of Los Angeles, 1950. Superior Court Order No. Pasadena C-1323, City of Pasadena vs. City of Alhambra and other Defendants, October 6, 1950.

Motion by City of Sierra Madre for an order approving certain agreements made and entered on June 30, 1950, between the City of Sierra Madre and the City of Arcadia authorizing the City of Sierra Madre to salvage, spread, recover and recapture the waters not constituting the safe yield

of the Eastern unit. This document includes a copy of June 30, 1950 agreement, a copy of agreement dated December 12, 1950 between Los Angeles County Flood Control District and Sierra Madre pertaining to conservation of flood and storm waters of Santa Anita Wash, construction of headworks in Santa Anita Canyon and pipeline to carry diverted water for spreading.

Author Unknown, 1944. Amendment to Raymond Basin Area Water Exchange Agreement of 1943, April 4, 1944.

This Amendment the Raymond Basin Area Water Exchange Agreement of 1943 does the following:

- Adds to the list of parties in the Western Unit,
- Amends the first two paragraphs of Article VII, and
- Amends paragraph 2 of Article X.

Author Unknown, 1943. Raymond Basin Area Water Exchange Agreement of 1943, September 19, 1943.

This Agreement, made by and between the cities, districts, corporations and persons, for the purpose of:

- Settling the litigation (No. Pasadena C-1323) and making unnecessary further litigation,
- Stabilizing the extraction of water in Raymond basin to the safe yield, and
- Rendering water available to various parties to this agreement in order to secure the maximum beneficial use of the total supply available.

Superior Court for the County of Los Angeles, 1937. Superior Court Complaint to Quiet Title, for a Declaratory Decree, and for Injunction, No. Pasadena C-1323, City of Pasadena vs. City of Alhambra and other Defendants, September 22, 1937.

Copy of the Complaint by the City of Pasadena against said Defendants, requiring evidence of water rights to take and divert from the Raymond Underground Basin and Pasadena's assertion to the prior and paramount right to take and divert 14,600 acre-feet from Raymond Basin in each year.

Superior Court for the County of Los Angeles, 1930. Judgment and Decree in Superior Court Order No. Pasadena C-1323, City of Sierra Madre vs. City of Arcadia, April 21, 1930.

This is a copy of the Judgment and Decree pertaining to the Santa Anita Basin which stipulates that parties fully and finally settle all matters and issues related to said court action.

Superior Court for the County of Los Angeles, 1930. Stipulation for Judgment and Decree in Superior Court Order No. Pasadena C-1323, City of Sierra Madre vs. City of Arcadia, April 2, 1930.

This is a copy of the Stipulation for a Judgment and Decree pertaining to the Santa Anita Basin and waiver of any further legal action pertaining to this matter. Includes a description of the legal boundary of the Santa Anita underground water basin, territorial area of City of Sierra Madre, impounding of flood water in Santa Anita Canyon and export of water by City of Arcadia.

2.2 East Raymond Basin

2.2.1 Conjunctive Use

2.2.1.1 Santa Anita Dam

Los Angeles County Department of Public Works, 2004. Proposed Santa Anita Dam Alternatives, July 2, 2004.

This is a schematic of three alternative designs currently under consideration by LADPW, including projected reservoir capacities and costs. Alternatives given include:

- Full buttress and spillway notch,
- Partial buttress and spillway notch, and
- Riser extension and spillway notch.

Montgomery Watson Harza, 2002. Options for Completion of 30 Percent Design Scheme, Santa Anita Dam Reanalysis Study. Letter report to the County of Los Angeles, Department of Public Works. July 24, 2002.

Montgomery Watson Harza (MWH) discusses an option for remediating Santa Anita Dam to address insufficient existing spillway capacity and seismic structural integrity consisting of a parapet wall and a notch on the crest of the dam and a concrete buttress against the downstream face of the dam. Optimization and cost benefit studies are required to select the height of the parapet (if any) vs. the depth of the notch and the height of the concrete buttress vs. the permanent operating level of the reservoir. MWH also notes that the State Division of Safety of Dams recently increased the Probable Maximum Flood (PMF) for the dam to 26,200 cubic feet per second (cfs).

Montgomery Watson Harza, 2002. Report – Supplemental Services for Santa Anita Dam Reanalysis Study, Tasks S-1 through S-6. Prepared for the Department of Public Works, County of Los Angeles (Contract No. 72193). February 6, 2002.

Montgomery Watson Harza (MWH) presents a supplemental concept for remediating Santa Anita Dam to address insufficient existing spillway capacity and seismic structural integrity. This concept consists of an ungated notch in the crest of the dam to pass the PMF without

overtopping the dam, and an ungated orifice (tunnel) through the dam that would restrict longer-term reservoir storage to elevation 1,270 feet above mean sea level (amsl). Additional analyses eventually showed that this concept would not reduce the seismic-induced stresses to an acceptable level, and the concept was abandoned.

Harza Consulting Engineers and Scientists, 2001. Report of Task 3 – Rehabilitation Alternatives, Santa Anita Dam Seismic Reanalysis and Spillway Modification Study. Prepared for the Los Angeles County Department of Public Works Water Resources Division. January 15, 2001.

Harza develops five different concepts for remediating inadequate spillway capacity for Santa Anita Dam and four different concepts for remediating inadequate seismic structural capacity. Harza recommends selection of a notch in the dam to increase spillway capacity in combination with either a downstream buttress (most preferred) or an upstream buttress.

Harza Consulting Engineers and Scientists, 2000. Existing Condition Assessment Report, Santa Anita Dam Seismic Reanalysis and Spillway Modification Study. Prepared for County of Los Angeles County Department of Public Works. April 3, 2000.

Harza reviews previous analyses of Santa Anita Dam and its current physical condition, and presents the results of updated analyses. The dam has insufficient spillway capacity for the PMF and insufficient structural strength for the stresses that would be induced during the Maximum Credible Earthquake event. Furthermore, the concrete used to construct the dam is slowly deteriorating due to alkali-aggregate reactivity.

2.2.1.2 Santa Anita Debris Dam

URS Corporation, 2004. Final Report – Santa Anita Debris Dam Spillway Relocation Concepts. Prepared for the County of Los Angles Department of Public Works. May 26, 2004.

URS presents a concept for relocating the existing spillway for Santa Anita Debris Dam from the center of the embankment to the bedrock left abutment. If the spillway structure can be founded on bedrock, and the intake tower is strengthened against seismic loads, the Division of Safety of Dams will favorably consider removing the current water conservation restriction on the dam.

Woodward-Clyde Consultants, 1998. Interim Report – Criteria and Assumptions for Analysis and Design of Four Debris Dams. Prepared for the Los Angeles County Department of Public Works. February 1998.

Woodward-Clyde Consultants (WCC) provides the criteria and assumptions that will be used to evaluate and design alternative remedial measures to improve the performance of four debris dams, including the Santa Anita debris dam, during a maximum credible earthquake event. The dams are restricted from storing water for conservation purposes until the remediation is performed and accepted by the State Division of Safety of Dams.

Woodward-Clyde Consultants, 1994. Final Report (Rev. 1) – Investigation and Analysis of Santa Anita Debris Dam, Los Angles County, California. Prepared for the Department of Public Works, County of Los Angeles. August 1994.

Woodward-Clyde Consultants (WCC) performed static stability and seismic performance analyses for the Santa Anita Debris Dam embankment, spillway walls, and intake tower utilizing updated (since 1955) seismic-induced ground motions. It was shown that the spillway and intake tower required structural strengthening for improved seismic performance, and that the dam embankment had the potential for seismic-induced settlement and lateral deformation. Concepts for remediation were developed, but the State Division of Safety of Dams (DSOD) rejected all proposals as long as the spillway passed over the embankment fill.

Los Angeles County Department of Public Works, 1985. Santa Anita Debris Dam, August 22, 1985.

This document provides a description of the history and construction details of the Santa Anita Debris Dam. It includes schematic cross-sections of the structure.

California Department of Water Resources, 1982. Flood Estimate and Spillway Analysis, Santa Anita Debris Dam. February 2, 1982.

The California Department of Water Resources, Division of Safety of Dams (DSOD) routinely verifies spillway design floods for dams under its jurisdiction, and compares the design flood for each dam against the flood associated with the Probable Maximum Precipitation (PMF) and the dam hazard rating. Although the DSOD's methodology differs from the methodology used by the Corps of Engineers for the original design (in 1955) of the spillway, it was shown that the

Corps' design flood of 38,000 cfs satisfied the DSOD's criteria for spillway capacity and freeboard.

U.S. Army Corps of Engineers, 1955. Hydrology for Santa Anita Wash Channels and Debris Basin (Design Memorandum No. 1). Prepared for the Los Angles County Drainage Area Flood Control project. October 1955.

The U.S. Army Corps of Engineers completed the design of the Santa Anita debris basin, a portion of the Santa Anita Wash channel, and the Sierra Madre Wash channel to accommodate the hydrologic conditions and run-off presented in this design memorandum. The spillway design flood of 38,000 cfs computed in 1955 remains the spillway design flood.

U.S. Army Corps of Engineers, 1955. General Design for Santa Anita Wash Channels and Debris Basin (Design Memorandum No. 2). Prepared for the Los Angles County Drainage Area Flood Control project. August 1955.

The U.S. Army Corps of Engineers completed the design of the Santa Anita debris basin, a portion of the Santa Anita Wash channel, and the Sierra Madre Wash channel in accordance with the criteria and specifications provided in this design memorandum. The facilities were constructed essentially as designed.

2.2.1.3 Santa Anita Wash

U.S. Army Corps of Engineers, 1999. Santa Anita Wash Section 206 Preliminary Restoration Plan. October 27, 1999.

The Cities of Arcadia and Sierra Madre co-sponsored this project to restore a riparian ecosystem in the Santa Anita Wash by establishing a hydrologic connection with the flood control channel, and regrading and revegetating 20 acres of land to mimic a healthy, natural wetlands system. The plan includes a low-flow meandering channel, in-channel terraces, and periodic inundation and flushing of the hydrologic system to mimic natural pulsed hydrology.

2.2.1.4 Santa Anita Spreading Grounds

Los Angeles County Department of Public Works, 2003. Percolation Optimization Investigation, Santa Anita Recharge Facility. Draft Final Report. November, 2003.

This facility report outlines percolation optimization and maintenance guidelines for the Santa Anita spreading grounds. Proposed guidelines for basin management include:

- Basin wetting cycles of no more than 6 days,
- Annual scraping of the clogging layer from the basin bottom, and
- Periodic ripping of the basin bottom to fluff the soil.

Planning Consultants Research, 1998. Santa Anita Spreading Grounds Enhancement and Mitigation Bank Study. Prepared for the County of Los Angeles Department of Public Works, December, 1998.

Data from biological and hydrogeological investigations are combined in the development of several alternatives for the Santa Anita spreading basins to improve present water recharge capacity and provide habitat as mitigation for other projects by LADPW. The findings of this report include the following:

- Ground water recharge rates are driven by water availability and not operations of the basins, so reducing capacity to increase mitigation potential would be feasible.
- The Santa Anita spreading grounds could be reconfigured to provide between 5.7 and 17.4 acres of oak/sycamore woodland habitat.
- The oak/sycamore woodland on the east side of the channel is of high value, and should be preserved in the basin habitat enhancement plan.
- The potential for wetland/riparian habitat mitigation is limited due to the lack of natural hydrologic conditions at the site.

Camp Dresser & McKee, Inc., 1998. Groundwater Recharge and Grounds Planning Assessment. Santa Anita Spreading Grounds, Los Angeles County, California. Prepared for Planning Consultants Research, August 4, 1998.

CDM conducted two short-term spreading tests at the Santa Anita spreading grounds, and

analyzed the results of these tests and other available data to assess the capabilities and limitations of the spreading grounds. This report summarizes their testing, analysis, conclusions, and recommendations, and four alternative use patterns are proposed. Findings in the report include:

- The grounds are capable of recharging more than the typical maximum delivery rate employed during normal spreading operations.
- The upper basins have higher infiltration rates than the lower basins.
- Substantial ground water mounding occurred in response to spreading.

GEOSCIENCE Support Services, 1997. City of Arcadia Water Infrastructure Restoration Study Task 5.7 - Santa Anita And Sierra Madre Watershed Hydrologic Models. Prepared for RBF Associates, July 31, 1997.

This report estimated the amount of recoverable water from the Santa Anita Watershed and the Sierra Madre Watershed through a simplified watershed model, analysis of the capacity of the existing Santa Anita and Sierra Madre spreading grounds, and recommendations for water conservation.

Vahabnezhad, Materials Engineering Division LACDPW, 1992. Santa Anita Spreading Grounds Modification Supplementary Subsurface Investigation. Prepared for Al Gribnau, Hydraulic/Water Conservation Division LACDPW. December 17, 1992.

This technical memorandum summarizes the results of a subsurface investigation at the Santa Anita spreading grounds. The field and laboratory investigations reported on include borehole lithologic logs, sieve analyses, and trench logs. Results include:

- The amount of fines in the subsurface sands ranges from 2.9% to 4.8%, but deposits of silts in the area of basin 5 contain 54% to 68% fines.
- In basins 4 and 5 a silty clay layer was encountered at 34-35 feet, with increasing clay content at 40-44 feet. The extent of this clay layer is unknown so it is impossible to estimate its effect on the overall permeability of the basin.
- A shallow silt layer was encountered in basin 5 at 18 inches. This layer appears capable of impeding seepage of water.
- The silt layer located in the 1991 report in basin 7 was not found.

2.2.1.5 Sierra Madre Spreading Grounds

GEOSCIENCE Support Services, 1997. City of Arcadia Water Infrastructure Restoration Study Task 5.7 - Santa Anita And Sierra Madre Watershed Hydrologic Models. Prepared for RBF Associates, July 31, 1997.

This report estimated the amount of recoverable water from the Santa Anita Watershed and the Sierra Madre Watershed through a simplified watershed model, analysis of the capacity of the existing Santa Anita and Sierra Madre spreading grounds, and recommendations for water conservation.

2.2.2 Water Supply

GEOSCIENCE Support Services, 2000. Evaluation of City of Sierra Madre Well Nos. 3, 4, 5 and 6 for Compliance with the Surface Water Treatment Rule. Prepared for the City of Sierra Madre. September 18, 2000.

This report provides important well information for four wells within the Raymond Basin, including the Drillers' Logs, monthly water quality coliform results, short review of local geohydrology, and discussion of surface to ground water connection in the City of Sierra Madre.

RBF Associates, 1999. Cities of Arcadia and Sierra Madre Los Angeles County, California – Water Infrastructure Restoration Projects Preliminary Design Report. Prepared for the U.S Army Corps of Engineers, Los Angeles District. March 31, 1999.

This is the final report to address the water system infrastructure of the Cities of Arcadia and Sierra Madre. The principal objectives of this feasibility phase are to identify existing site conditions for design, determine standard design plans and specifications, and document the selected improvement projects for design with a preliminary report.

GEOSCIENCE Support Services, 1999. United States Army Corps of Engineers, Cities of Arcadia and Sierra Madre Water Infrastructure and Design Projects 30 Percent Completion Tasks 5.6 and 5.8 - Geohydrologic Investigation of the Orange Grove and St. Joseph Plants. Prepared for U.S Army Corps of Engineers, and the Cities of Sierra Madre and Arcadia. March 31, 1999.

This report was prepared to provide the information necessary to develop preliminary design specifications for two new water supply wells, one of which is in the Raymond Ground Water Basin. The report includes the results of ground water modeling of predicted drawdown, and the capacity of the aquifers in the region.

Dames & Moore, 1998. Assessment of History and Nature of Flutter Wheel Springs, City of Sierra Madre. Prepared for City of Sierra Madre, April 16, 1998.

This report documents the identity and nature of two springs in Sierra Madre that have been historically referred to as the Flutter Wheel Springs. It includes a review of historical information, published technical reports, existing data and field testing of various hydrogeological, meteorological and water quality parameters, and assessment of potential for surface water impacts.

RBF Associates, 1997. Cities of Arcadia and Sierra Madre Water Infrastructure Restoration Special Study Los Angeles County, Los Angeles - Final Special Study Report Volume I - Prepared for the U.S Army Corps of Engineers, Los Angeles District. August, 1997.

This report describes water system performance and vulnerability to earthquake-induced damage for the Cities of Arcadia and Sierra Madre. The evaluation includes discussion of the water purveyors, system improvements, conservation, potential for increased water storage, use of reclaimed water, dam modifications, spreading grounds, local ground water basin operations, and the development of an emergency response system.

RBF Associates, 1997. Cities of Arcadia And Sierra Madre Water Infrastructure Restoration Special Study Los Angeles County, California - Final Special Study Report Volume II Technical Appendices. Prepared for the U.S Army Corps of Engineers, Los Angeles District. August, 1997.

This volume contains Appendices A through H of the Water Infrastructure Study, consisting of methodologies, cost estimates, economics, environmental evaluation, real estate, public coordination, leak detection audit, and hydrology.

GEOSCIENCE Support Services, 1997. City of Arcadia Water Infrastructure Restoration Study - Phase II Task 5.3, 5.5.1, 5.7.1, and 5.7.2. Prepared for RBF Associates, July 31, 1997.

This document is GEOSCIENCE's contribution to a larger preliminary study to evaluate the ability of the City of Arcadia water supply and distribution system to withstand a major earthquake. The purpose of the study was to identify the problems, solutions and governmental responsibilities in providing a dependable water supply. This phase encompasses the review of ground water reports and facilities.

GEOSCIENCE Support Services, 1997. Air Problem and Decrease in Specific Capacity City of Arcadia Chapman Well. Prepared for the City of Arcadia. July 7, 1997.

This report troubleshoots a specific capacity decrease in a City of Arcadia well in the Raymond Basin.

Perliter and Ingalsbe, 1996. City of Sierra Madre Basic Water System Description and Analyses. Prepared for the City of Sierra Madre. January 18, 1996.

This report describes the City of Sierra Madre's water supply and distribution system, including: water supply from four wells, artificial recharge, and rights to "salvage water"; pipelines, pump stations, and reservoirs; and an evaluation of sources for individual pressure zones in the distribution system. Further engineering investigations which would be of benefit for the water system are also identified.

2.2.3 Potential Pipelines

Stetson Engineers Inc., 1980. Letter to Don Owen & Associates, July 1, 1980.

This letter discusses alternatives to meet supplemental water requirements of San Gabriel Valley Municipal Water District (SGVMWD). It includes a brief description of the water supply situation, water supply projections and requirements, supplemental requirements, and discussion of alternatives to overproduction by use of supplemental water connection for the Cities of Alhambra, Azusa, Monterey Park and Sierra Madre.

Stetson Engineers Inc., 1972. Progress Statement Concerning Deliberations Between City of Sierra Madre and San Gabriel Valley Municipal Water District, September 5, 1972.

This report is a progress statement on deliberations concerning means of supplying supplemental water to the City of Sierra Madre via construction of new imported water pipeline from San Gabriel Valley Municipal Water District to the City of Sierra Madre. It includes information on possible exchanges with Raymond Basin interests, agreement for transport of water by Metropolitan, drilling a well in Main Basin and pipeline to Sierra Madre, and possible extension of SGVMWD pipeline to Sierra Madre.

2.2.4 Safe Yield

California Department of Water Resources, 1959. Report of Watermaster Service on Determinations of Credit for Water Salvaged by the City of Sierra Madre.

This report determines the amount of water creditable to the City of Sierra Madre from spreading of "salvaged" Santa Anita Creek water. It discusses corrections incidental to the delivery of water to spreading grounds, the increase in subsurface outflow from the Santa Anita Subarea due to spreading, and the portion of water spread by the City of Sierra Madre that should be assigned to the safe yield of the Santa Anita Subarea. Findings of the report include the following:

- The measurements of flow into and out of the Sierra Madre spreading grounds is accurately recorded.
- Losses from evaporation, transpiration and soil moisture replenishment are estimated to be about 1% of the total water spread, and may be eliminated from further determinations of the amount of water actually spread by Sierra Madre.

- The portion of the water spread by Sierra Madre that should be credited to the normal supply of the Santa Anita Subarea is determined as the additional amount of percolation that would have occurred if there had been no diversion, based on an empirically determined percolation rate versus stream flow curve for Santa Anita Creek.
- The increased subsurface outflow from the Santa Anita Subarea that can be attributed to Sierra Madre's spreading activities is linearly proportional to the amount of water stored in the basin.

Raymond Basin Management Board, 2000. Draft Report on Eastern Unit Water Resources, July 11, 2000.

This report provides a review of existing safe yield calculations in the Eastern Unit. Alternatives to current water rights accounting procedures for the City of Sierra Madre (decreed right production first) are proposed. The following findings are proposed:

- The Decreed Rights in the unit are appropriate and not in need of re-determination.
- Watermaster's calculations for percolation and spreading in the County's basins have properly and adequately accounted for the portion of the flows of Santa Anita Creek that are a part of the safe yield of the Eastern Unit of the Raymond Basin.
- Watermaster does not object to the export of water from the Raymond Basin by parties to the Judgment. Watermaster does not object to the export of water from one unit of the basin to any other unit of the basin.
- Nothing in the Judgment precludes the City of Sierra Madre from drilling a well in the Western Unit for the purpose of accessing its long-term storage account there.
- The City of Sierra Madre's salvage activities in the Eastern Unit are a long-term storage operation and should be administered in the same way as long-term storage accounts in the Western Unit, with the exception of water loss and costs.
- The City of Arcadia may store water in the Eastern Unit in a long-term storage account if it so chooses.
- The proposed projects in the Eastern Unit to enhance spreading and restore habitat will be of benefit to the Eastern Unit of the Raymond Basin.

2.2.5 Water Rights

Raymond Basin Management Board, 2000. Draft Report on Eastern Unit Water Resources, July 11, 2000.

This report discusses re-determination of safe yield in Eastern Unit, accounting for first duty of waters of Santa Anita Creek, export of water from the Eastern Unit and the Raymond Basin, storage of salvage water in the Western Unit of the basin, accounting of Sierra Madre's groundwater production, exchange of water with the City of Arcadia, and methods for the City of Sierra Madre to access its Western Unit long-term storage account.

Littleworth, Arthur L. Esq., 1998. Report on Santa Anita Creek Project, December 4, 1998.

This memorandum from Arthur L Littleworth, Esq. to Michael H Miller, Esq. (City Attorney - City of Arcadia) including Introduction, Rights of the Parties, Requirements for the Joint Project, Other Possible Approaches.

Harbicht, Robert C., Mayor City of Arcadia, 1998. Letter Pertaining to the Santa Anita Creek Study, March 23, 1998.

This letter from the Mayor or the City of Arcadia to Senator Diane Feinstein requests the Senator's support for the environmental mitigation project called the Santa Anita Creek Study and requests this project be added to the Energy and Water Subcommittee Appropriations Request for fiscal year 1999. Includes project description attachment and location map.

State Water Resources Control Board, 1991. Order Revising Declaration of Fully Appropriated Stream System, August 22, 1991.

This is copy of the order revising declaration of fully appropriated stream system and addition of the San Gabriel River Watershed to its list.

Stetson Engineers Inc., 1991. Letter to State Water Resources Control Board, Division of Water Rights. Prepared for Main San Gabriel Basin Watermaster, May 1, 1991.

This letter informs the Division of Water Rights that Main Basin Watermaster is in support of the amendment to Water Right Order 89-25, adding the San Gabriel River Watershed to Exhibit A of

said Order and that Watermaster concurs that the San Gabriel River Watershed is a fully appropriated stream system.

Best, Best & Krieger, Law offices of; 1982. Memorandum of Understanding Pertaining to the Long Beach Judgment, May 13, 1982.

This Memorandum of Understanding among the Board of Water Commissioners of the City of Long Beach, the Central Basin Municipal Water District, the City of Compton, the Upper San Gabriel Valley Municipal Water District, and the Main San Gabriel Basin Watermaster provides information pertaining to cooperation during possible supplemental water shortages, payment in lieu of surface water delivery of make-up water and reclaimed water credits.

State Water Resources Control Board, Division of Water Rights, 1973. Report of Licensee for 1970, 1971 & 1972. Prepared for City of Sierra Madre, March 2, 1973.

This Report of Licensee describes the quantity of water diverted and used by the City of Sierra Madre under License No. 8738 for calendar years 1970, 1971 and 1972.

State Water Resources Control Board, Division of Water Rights, 1973. Report of Licensee for 1970, 1971 & 1972. Prepared for City of Sierra Madre, March 2, 1973.

This Report of Licensee describes the quantity of water diverted and used by the City of Sierra Madre under License No. 9810 for calendar years 1970, 1971 and 1972.

State Water Resources Control Board, Division of Water Rights, 1973. Supplemental Report to Progress Report by Licensee for 1972. Prepared for City of Sierra Madre, March 2, 1973.

This Supplemental Report to Progress Report by Licensee describes information on water use practices by the City of Sierra Madre under License No. 8738 for calendar year 1972.

State Water Resources Control Board, Division of Water Rights, 1971. License for Diversion and Use of Water No. 9810, City of Sierra Madre, April 14, 1971.

This License allows the City of Sierra Madre to divert 3,000 acre-feet/yr from Santa Anita Canyon for purposes of underground storage by spreading at a maximum rate of 25 cfs.

State Water Resources Control Board, Division of Water Rights, 1967. License for Diversion and Use of Water No. 8738, City of Sierra Madre, May 5, 1967.

This License allows the City of Sierra Madre to divert 1,500 acre-feet/yr from Santa Anita Canyon for purposes of underground storage by spreading at a maximum rate of 30 cfs.

Superior Court for the County of Los Angeles, 1961. Final Order of Condemnation, Los Angeles County Flood Control District vs. Unknown Defendant, April 11, 1961.

This is a copy of the Final Order of Condemnation for two parcels (with legal descriptions of said parcels) acquired by the Flood Control District.

State of California Department of Water Resources, 1959. Report of Watermaster Service on Determinations of Credit for Water Salvaged by the City of Sierra Madre in the San Anita Subarea, Raymond Basin Los Angeles County, California, August 1959.

This report presents the findings of the Watermaster in regard to the amount of water to be credited to the City of Sierra Madre as water "salvaged" by the City's spreading operation in the Eastern unit. Includes information on spreading facilities, metering and gaging stations, and factors in determination of salvaged water.

Superior Court for the County of Los Angeles, 1893. Baldwin, E.G. vs. City of Sierra Madre, June 17, 1893.

This is a copy of a court decree finding in favor of City of Sierra Madre as the owner of the North East quarter of the North West quarter of Section 16, Township 1 North, Range 11 West, San Bernardino Base and Meridian lines, and also owns the waters rising or flowing in or flowing out of the tunnel jointly constructed on said lands.

Bangham, W.O., Date Unknown. Proposal by Arcadia and Sierra Madre to Prepare East Raymond Basin Resources Plan. Prepared for Raymond Basin Management Board.

This memorandum lists tasks to be accomplished by or under the direction of the Board, including:

- Make a re-determination of the safe yield of the Eastern Unit,
- Review the water rights and licenses in the Eastern Unit,

- Preparation of East Raymond Basin Water Resources Plan,
- Amending the Judgment, and
- Board involvement in any plan to enhance spreading in the Eastern Unit.

City of Long Beach, et al. vs. San Gabriel Valley Water Company, et al., Los Angeles County Superior Court No. 722647, (unsigned document).

This Stipulation for Judgment outlines the resolution for division of the water supply of the San Gabriel River System between Upper Area and Lower Area.

Trager, Susan M., Law offices of; Date Unknown. Report on Obligation of the City of Sierra Madre Water Resources. Prepared for unknown.

A report presenting an inventory of the City of Sierra Madre's water resources, including summary of water resources and obligations, rights under the Raymond Basin Judgment, and rights to purchase State Project Water through the San Gabriel Valley Municipal Water District.

Trager, Susan M., Law offices of; Date Unknown. Report on Obligation of the City of Sierra Madre to Others Regarding Water Resources. Prepared for unknown.

This report presents the obligations of the City of Sierra Madre to others regarding water resources. It includes obligations to maintain certain groundwater elevations in the Raymond Basin pursuant to the Raymond Basin Judgment, Arcadia's option or first right of refusal regarding 6.00 cfs if surface flows are not used by the City of Sierra Madre and reporting obligations.

Trager, Susan M., Law offices of; Date Unknown. Summary of Judgments Governing Sierra Madre's Use of Water Resources; Chronology of Raymond Basin Adjudications; and History and Geologic Setting of the Tunnels. Prepared for unknown.

This report presents a summary of court actions for City of Sierra Madre vs. City of Arcadia and City of Pasadena vs. City of Alhambra, decreed surface water right, decreed right in groundwater, chronology of the Raymond Basin Adjudications, and history and geologic setting of the tunnels.

2.2.6 Earthquake Hazards

Harza/LRB, 1996. Ground Motion Estimate for the Arcadia and Sierra Madre Area. Prepared for Robert Bein, William Frost & Associates, July 26, 1996.

This letter report presents the results of an earthquake ground motion estimate for a single, representative location in the cities of Arcadia and Sierra Madre. The location chosen by RBF was the intersection of Foothill Boulevard and Rodeo Dr. in Arcadia; ground shaking hazard for that site was calculated using both probabilistic and deterministic methods. Findings from this study were:

- The peak ground acceleration with a 10% probability of exceedance in 50 years (475 year return period) is 0.64g.
- The highest site accelerations would be from a M7.2 earthquake on the Sierra Madre fault zone; these accelerations are from 0.66g (50th percentile) to 1.02g (84th percentile).

3.0 REVIEW OF KEY STUDIES – SANTA ANITA SPREADING GROUNDS

Three key studies of the Santa Anita spreading grounds were reviewed and compared to estimate the potential for additional surface water that could be added to the existing spreading grounds. The three reports were prepared individually by Los Angeles County Department of Public Works (LACDPW, 1992), Camp Dresser McKee (CDM, 1998), and GEOSCIENCE Support Services, Inc. (GEOSCIENCE, 1997).

3.1 LACDPW (1992) Report

In December 1992, LACDPW issued a memorandum titled "Santa Anita Spreading Grounds Modification – Supplementary Subsurface Investigations." The memorandum summarizes exploration performed to verify the nature of subsurface soils beneath the Santa Anita spreading grounds. The subsurface exploration consisted of installing five borings, two piezometers, and six trenches. Sieve analyses were conducted on selected soil samples. Soils encountered were generally 40 to 60 feet of well-graded sand with tightly packed oversized boulders. Estimated permeability from the sieve analyses of soil from basins 4, 5, and 7 indicated high permeability soils. Clay layers that may impede water infiltration were identified at 35 feet beneath basins 4 and 5 and at 45 feet in boring B-2 adjacent basins 5 and 6. Infiltration at basin 5 may also be impacted by a silt layer at a depth of approximately 18 inches. Except for local occurrences and at basin 5, no shallow surface soils were identified that might impede infiltration. Bedrock (a silty sand, SM) was reported at approximately 35 feet in boring 5 (basin 10) and at 125 feet in boring B-1 (adjacent basins 11 and 12). CDM (1998) presents a geologic cross section using lithology from the five LACDPW borings, but does not indicate that these silty sand units are bedrock.

3.2 GEOSCIENCE (1997) Report

In July 1997, GEOSCIENCE completed a hydrologic model of the Santa Anita watershed for a City of Arcadia water infrastructure restoration study. Objectives of the study included estimating the amount of recoverable water from the Santa Anita watershed and estimating the capacity of the existing Santa Anita spreading grounds.

The amount of recoverable water (surface runoff and underground percolation) for the Santa Anita watershed was estimated using a watershed model based on historic daily precipitation between 1950 and 1995. The measuring point for the watershed model was the Santa Anita diversion structure located in the Arcadia Wilderness Park. The model utilized variables for precipitation, soil properties, evapotranspiration, infiltration, percolation, and vegetation interception. The amount of recoverable water in the Santa Anita watershed was found to vary widely from year to year with a range of 8 to 19,236 acre-ft and a mean of 4,513 acre-ft. Capture of water at the Santa Anita diversion structure can be routed to both the Santa Anita and Sierra Madre spreading grounds.

GEOSCIENCE estimated the capacity of the existing spreading basins from personal communications from LACDPW staff (E. Gerlitz, 1996). The maximum flow rate into the Santa Anita spreading grounds was estimated at 15 cfs. The maximum percolation rate was estimated at approximately 5 cfs.

3.3 CDM (1998) Report

In August 1998, CDM completed infiltration testing of the Santa Anita Spreading grounds. The testing is described in their report titled “Groundwater Recharge and Grounds Planning Assessment”. The purpose of the testing was to evaluate the recharge potential of the existing facilities. CDM conducted two infiltration tests in late 1997. Test 1 included the upper basins

(0 to 6). Test 2 utilized the upper basins, but targeted the lower basins (7 to 12). During both tests, ground water elevations were measured in two observation wells, OB-1 and OB-2S.

For interpretation of the subsurface conditions, CDM presented a geologic cross section using the borings and wells installed by LACDPW (1992). At the surface, the cross section shows poorly-graded gravel and sand varying in thickness from approximately 10 to 50 feet. This course-grained unit is underlain by silty sand and clayey sand deposits, interpreted as bedrock by LACDPW (1992) at borings B-1 (adjacent basin 12) and B-5 (adjacent basins 10 and 11). CDM does not discuss these fine-grained units as bedrock, but suggests they could be "acting as an impedance to the downward migration of recharge water." CDM notes bedrock has been reported at 195 feet at boring B-1 although LACDPW (1992) indicated bedrock at boring B-1 is at a depth of 125 feet. CDM also indicated bedrock in the surrounding area (to the west) is up to 600 feet deep.

During the 1997 infiltration testing, water was added to basins for generally 1 day and allowed to infiltrate. While water was added to basins, ground water levels rose rapidly in the two monitoring wells indicating substantial recharge mounding develops during water spreading. Based on ground water level trends, mounding beneath the basins would occur within 2 to 3 days of continuous addition of water spreading. Recovery of ground water levels to pre-test conditions was estimated by CDM to be 6 days. CDM estimated infiltration rates from falling head conditions by dividing the decrease in basin surface water depth by the time for the depth to change. The following table lists the infiltration rates estimated from the two tests.

Summary of Santa Anita Spreading Grounds Infiltration Rates (As Estimated by CDM, 1998)

Basin Number	CDM Test Number	Days of Water in a Basin	Infiltration Rate [ft/day]
0	2	5.0	0.5
1	2	4.5	5.3
2	1	2.0	5.5
3	1	1.6	4.6
4	1	1.6	4.3
5	1	1.4	6.2
6	2	1.8	5.4
7	2	1.5	4.1
8	2	3.0	3.8
9	2	3.4	0.6
10	2	4.0	6.6
11	2	3.8	3.3
12	2	2.0	2.0

CDM used these infiltration rates and various operating scenarios to estimate the recharge capacity of the Santa Anita spreading grounds. Using the test infiltration rates, CDM estimated up to 1,400 acre-ft could be recharged over six months with alternating use of the even then odd numbered basins. The estimate assumes a basin is used for four days of spreading followed by six days of being idle. CDM felt this estimate could be increased to 1,780 acre-ft over six months if mounding eliminated by alternating basins produced an estimated 30% increase in infiltration rates. From a historical perspective, the mean annual historical spreading (water years 1979-80 to 1996-97) is 540 acre-ft over approximately 14 spreading events from November to May. The highest historic annual input has been 1,186 acre-ft.

CDM made other estimates based on assumptions of quicker mound dissipation (four days rather than six) to estimate that perhaps a 50% increase in recharge is feasible by an increase in the number of recharge cycles. With these assumptions, CDM estimated 1,790 acre-ft could be

percolated over six months with twenty-two 8-day cycles of alternating use of every other even numbered basin. With the same assumptions and a 30% increase in infiltration rates due to less mounding, CDM estimated 2,200 acre-ft could be percolated over six months through alternating use of every other even numbered basin.

3.4 Evaluation

Comparison of the LACDPW (1992), GEOSCIENCE (1997), and CDM (1998) studies shows that recoverable water exists on average in the Santa Anita watershed above what has been historically infiltrated (540 acre-ft per year) and above the infiltration capacity of the existing Santa Anita spread grounds. Depending on the alternatives and validity of assumptions made by CDM, the infiltration capacity of the existing Santa Anita spreading grounds ranges from 1,400 to 2,200 acre-ft per year during a November to May operation period. Based on GEOSCIENCE watershed modeling, 4,513 acre-ft may be available on average at the Santa Anita diversion structure, approximately twice the available maximum recharge capacity estimated by CDM for the Santa Anita spreading grounds and eight times the historical average. It must be noted, however, that as precipitation in southern California can be highly variable, the range of recoverable water may vary annually from 8 to 19,236 acre-ft.

Based on a review of the three documents, the following recommendations can be made:

- Better define the bedrock geometry and lithologic definition in the area of the Santa Anita spreading grounds, through a program of soil coring, multi-depth monitoring well construction, and slug testing.

- Refine the infiltration capacity of existing facilities by evaluating recharge mound formation and dissipation for a period of time greater than that conducted during the 1997 infiltration testing. A future infiltration test may seek to induce and measure the intersection of the mound with the basin bottom.