# Project 5

# Recycled Water Turnouts Project

# Supporting Documents

# PRELIMINARY ENGINEERING REPORT

## Groundwater Reliability Improvement Program Recycled Water Project

**FINAL**

Submitted to

WRD
*Water Replenishment District*
*of Southern California*

*Leadership in Affordable Water Independence*

CH2MHILL

in Association with

MWH

Carollo

Jörg Drewes, PhD

DR Consultants & Designers, Inc.

Somach Simmons & Dunn

BA, Inc.

February 2013

*Final Report*

# Preliminary Engineering Report for the GRIP Recycled Water Project

Prepared for

**Water Replenishment District of Southern California**

4040 Paramount Blvd.
Lakewood, CA 90712

February 2013

Prepared by

CH2MHILL

6 Hutton Centre Drive, Suite 700
Santa Ana, CA 92707

In Association With

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# Preliminary Engineering Report for the GRIP Recycled Water Project

Submitted to

## Water Replenishment District of Southern California

REGISTERED PROFESSIONAL ENGINEER
FRED SOROUSHIAN
No. C 37237
Exp. 6/30/14
CIVIL
STATE OF CALIFORNIA

F. Soroushian

February 2013

# Groundwater Reliability Improvement Program Recycled Water Project – Preliminary Engineering Report

PREPARED FOR: Jim McDavid/WRD

PREPARED BY: Don Bassett/MWH
Sarah Munger/MWH

SANITATION DISTRICTS REVIEWERS: Steve Highter/SANITATION DISTRICTS

CONSULTANT REVIEWERS: Fred Soroushian/CH2M HILL
Kim Wilson/CH2M HILL

DATE: February 18, 2013

## Executive Summary

The Water Replenishment District of Southern California (WRD), in coordination with the Sanitation Districts of Los Angeles County (Sanitation Districts), is developing the Groundwater Reliability Improvement Program (GRIP) Recycled Water Project as a part of WRD's Water Independence Now (WIN) strategy.

The overall goal of the GRIP Recycled Water Project is to offset the current use of imported water with recycled water for groundwater replenishment in the Central Basin. The GRIP Recycled Water Project evaluates recycled water supply sources, level of treatment, potential conveyance alignments, and type of recharge. The current effort is divided into several tasks, including the Alternatives Analysis Update Report, Preliminary Engineering Report, and Feasibility Study. Additionally, facilities planning and environmental assessment will be undertaken in connection with this project.

The previously submitted Alternatives Analysis Update Report formulated, analyzed and ranked alternative approaches to the treatment, conveyance and recharge of an additional 21,000 acre-feet per year (AFY) of recycled water for basin replenishment. The highest ranked alternatives from this evaluation form the basis for further technical elaboration as contained within this Preliminary Engineering Report (Report). This Report consists of six separate technical memoranda (TMs). A summary of the principle findings of each of these TMs follows.

### TM 2-1 Preliminary Engineering for Flow Equalization

Flows into the San Jose Creek Water Reclamation Plant (SJCWRP) vary over both the course of a day and over the progression of the year. The availability of recharge capacity at the Montebello Forebay Spreading Grounds (MFSG) also varies on a seasonal basis due to the preferential application of stormwater to the basins. The TM evaluates the means to mitigate the current seasonal variations in recharge capabilities and the daily flow variations found at the SJCWRP.

Storage can be used to mitigate seasonal variations in recharge capacity. Three methods of adding storage to the system are to: 1) construct large-scale storage, 2) add more spreading basin area or 3) augment existing recharge with injection wells. Both large-scale storage and additional spreading basin area require the procurement of land in a densely populated area and have a considerable cost associated with them. The use of injection wells is independent of spreading basin capacity and the impacts of storm flows. They also do not require as much land and are not as expensive. Typical injection wells characteristics suitable for this project are provided in the TM.

Daily flow variations within a treatment plant are influenced by the population and the geometry of the sewershed. Flow equalization can occur at any point during the treatment process, but is typically found following primary, secondary or tertiary treatment. Flow equalization of primary effluent typically requires a cover to mitigate odors and some sort of aeration or mixing to keep the solids suspended. Flow equalization of secondary effluent or tertiary effluent may not require a cover or substantial aeration/mixing. As a result, the cost for primary equalization is greater than that required for secondary or tertiary effluent. While primary flow equalization is under consideration as one means of process optimization at the SJCWRP, the TM focuses on secondary equalization in order to develop baseline costs for such a system. The TM provides the volume requirements and potential locations of secondary effluent flow equalization basins at the SJCWRP for the GRIP Recycled Water Project.

The flow equalization basin would be sized based on 20 percent of the daily influent water flow for the two feasible alternatives involving advanced treatment: Alternative 2 (advanced water treatment [AWT] Alternative) and Alternative 3 (Hybrid Alternative). The Hybrid Alternative would generate 10,000 AFY of AWT water, while the AWT Alternative would generate 21,000 AFY of AWT. The volume required in the flow equalization basin for the Hybrid Alternative is approximately 1.9 million gallons, and the volume required for the AWT Alternative is roughly 4.1 million gallons. Two locations for siting of the flow equalization basins are evaluated in the TM: a portion of land owned by the Los Angeles Department of Water and Power and US Army Corp of Engineers along the northwest boundary of the SJCWRP West, and undeveloped areas of the SJCWRP West. Both of these have also been identified as potential sites for the AWT facilities. The size of the AWT facilities, the expansion for the SJCWRP West and the size of the flow equalization basins would all have to be considered in determining the location of the flow equalization basins.

## TM 2-2 Preliminary Engineering for Treatment Alternatives

The Alternatives Analysis Update Report identified three feasible treatment alternatives for full-scale implementation: Tertiary, AWT and Hybrid. The TM presents preliminary engineering results, process schematics, design criteria, facility requirements and site layouts for these alternatives.

**Tertiary Alternative -** Up to 21,000 AFY of tertiary-treated recycled water from the SJCWRP would be delivered to the MFSG. The tertiary-treated recycled water currently being produced at the SJCWRP (using granular media filters) can be directly used for surface spreading. The current plant layout provides for additional tertiary facilities and no separate technical analysis was undertaken for this alternative.

**AWT Alternative -** Up to 21,000 AFY of advanced treated recycled water from the SJCWRP would be conveyed to the spreading grounds or potential injection well sites. The treatment processes consist of microfiltration/ultrafiltration (MF/UF), reverse osmosis (RO), and ultraviolet advanced oxidation process (UV-AOP). Consideration is also provided for the use of nanofiltration (NF) in lieu of RO should future requirements allow for such a conversion. Advantages of NF over RO include energy savings and less side-stream production. The 21,000 AFY advanced treated recycled water from the SJCWRP would be conveyed in a new dedicated pipeline to the injection sites. A detailed tabulation of design criteria is presented in the TM. Estimated footprint requirements for various treatment components are shown in Table ES-1 and the site plans for the AWT Alternative are presented in the TM.

**TABLE ES-1**
**Footprint for the AWT Alternative (21,000 AFY of AWT)**

| | **Footprint[a], sq-ft** |
|---|---|
| Flow Equalization Tank[b] | 31,900 (rectangular tank option; 130'x245') |
| MF/UF | 15,200 |
| Break tank | 1,800 |
| RO[c] | 23,000 |
| UV-AOP | 5,600 |
| Chemical Building | 15,000 |

Notes:

[a] All numbers are rounded to the nearest 100
[b] Per TM 2-1 Preliminary Engineering for Flow Equalization, GRIP Recycled Water Project
[c] Electrical room footprint is include in the RO facility footprint

**Hybrid Alternative –** In addition to the current recycled water flows, a minimum of 11,000 AFY of tertiary-treated recycled water from the SJCWRP would be delivered to the MFSG while producing up to 10,000 AFY of highly purified recycled water via AWT. The 10,000 AFY advanced treated recycled water from the SJCWRP would be conveyed in a new dedicated pipeline to the injection sites. Because the tertiary-treated water used for surface spreading is currently being produced via existing granular media filters, the treatment technologies evaluated for the Hybrid Alternative are limited to the AWT portion of the overall system. The AWT process train in the Hybrid Alternative is identical to the AWT Alternative and contains MF/UF, RO, UV-AOP, pretreatment and post treatment processes. The only difference between the two AWT facilities is the product capacity. Estimated footprint requirements for various treatment components are shown in Table ES-2 and the site plans for the Hybrid Alternative are presented in the TM.

**TABLE ES-2**
**Footprint of the Unit Treatment Processes for the Hybrid Alternative (10,000 AFY of AWT)**

| | **Footprint[a], sq-ft** |
|---|---|
| Flow Equalization Tank[b] | 15,000 (rectangular tank option; 100'x150') |
| MF/UF | 8,500 |
| Break tank | 1,000 |
| RO[c] | 16,500 |
| UVAOP | 3,600 |
| Chemical Building | 10,000 |

Notes:

[a] All numbers are rounded to the nearest 100
[b] Per TM 2-1 Preliminary Engineering for Flow Equalization, GRIP Recycled Water Project
[c] Electrical room footprint is include in the RO facility footprint

## TM 2-3 Preliminary Engineering for the AWT Conveyance Alignments

The Alternatives Analysis Update Report presented an evaluation of six potential pipeline alignments for the conveyance of AWT recycled water to the Montebello Forebay for recharge. After considering cost, route length, freeway and channel crossings, rights-of-way and easements, environmental permit issues, and existing utilities interference, the first and second highest ranking alternatives were determined to be the Parallel Alignment and the Durfee Avenue Alignment, respectively.

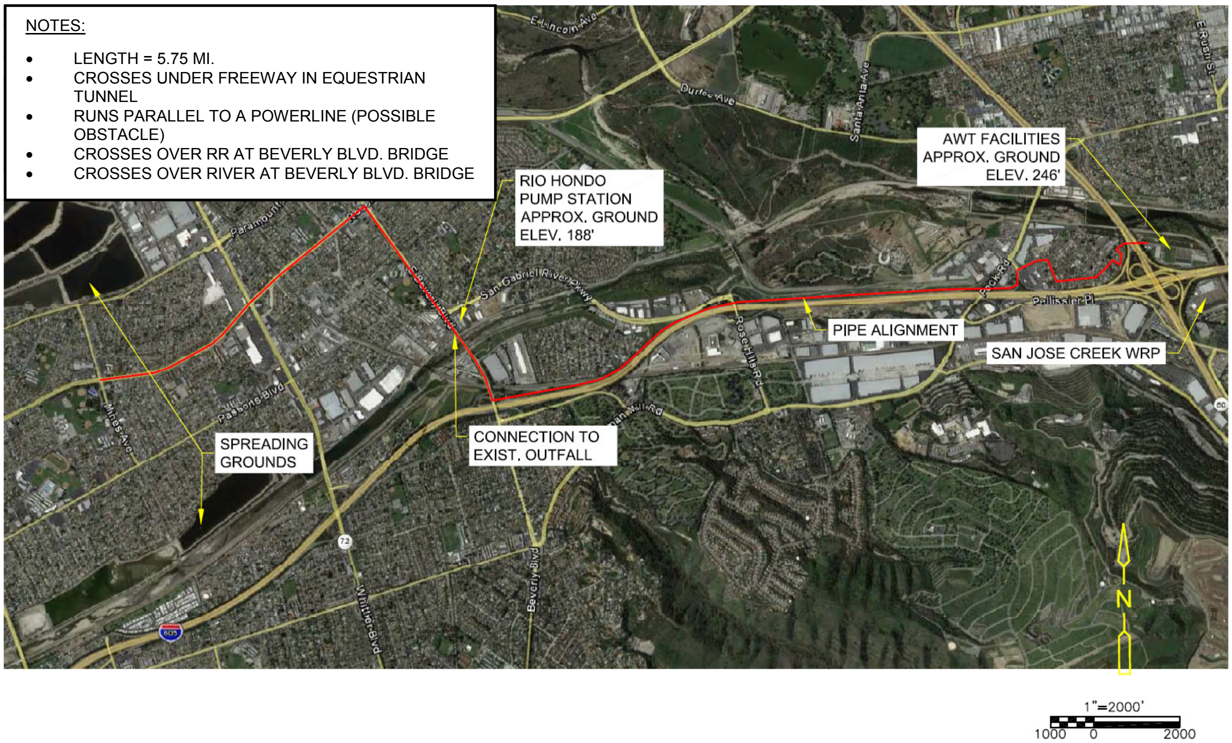
Paralleling the existing outfall is the most viable option for a new, dedicated AWT recycled water pipeline. This alignment would follow the existing SJCWRP effluent pipeline along the 605 Freeway south to Beverly Boulevard, using existing easements where possible, and then continue west along Beverly Boulevard to Rosemead Boulevard. At that point, the new pipeline would turn south and continue to Whittier Boulevard. An existing equestrian tunnel adjacent to the SJCWRP West offers a more convenient freeway crossing than that used for the existing outfall.

The second conveyance option for the new AWT pipeline would run westerly along Thienes Avenue to Durfee Avenue after crossing the unlined portion of the San Gabriel River just north of the SJCWRP West. The pipeline would cross under the 60 Freeway overpass, continuing along Durfee Avenue and turning south at Rosemead Boulevard, continuing to Whittier Boulevard. The river crossing would be a major challenge with this conveyance option and would need to be further investigated during detailed design to determine the extent of construction and right-of-way impacts.

Under both AWT pipeline alignment options, the AWT pipeline would extend along Rosemead Boulevard south of Whittier Boulevard to serve the injection wells that would be constructed along or near Rosemead Boulevard. At Beverly Boulevard, downstream of the Rio Hondo Pump Station, the AWT pipeline would tie into the existing outfall to allow spreading of the AWT recycled water in lieu of injection, providing operational flexibility in the event the injection wells are out of service.

The TM presents the preliminary engineering methodology, findings, and conclusions for the two AWT conveyance alignment alternatives. A preliminary plan and profile have been prepared for both of these AWT conveyance alignments and are presented in the TM appendices. Both the Parallel Alignment and Durfee Avenue Alignment are described in the TM and depicted on Figures ES-1 and ES-2.

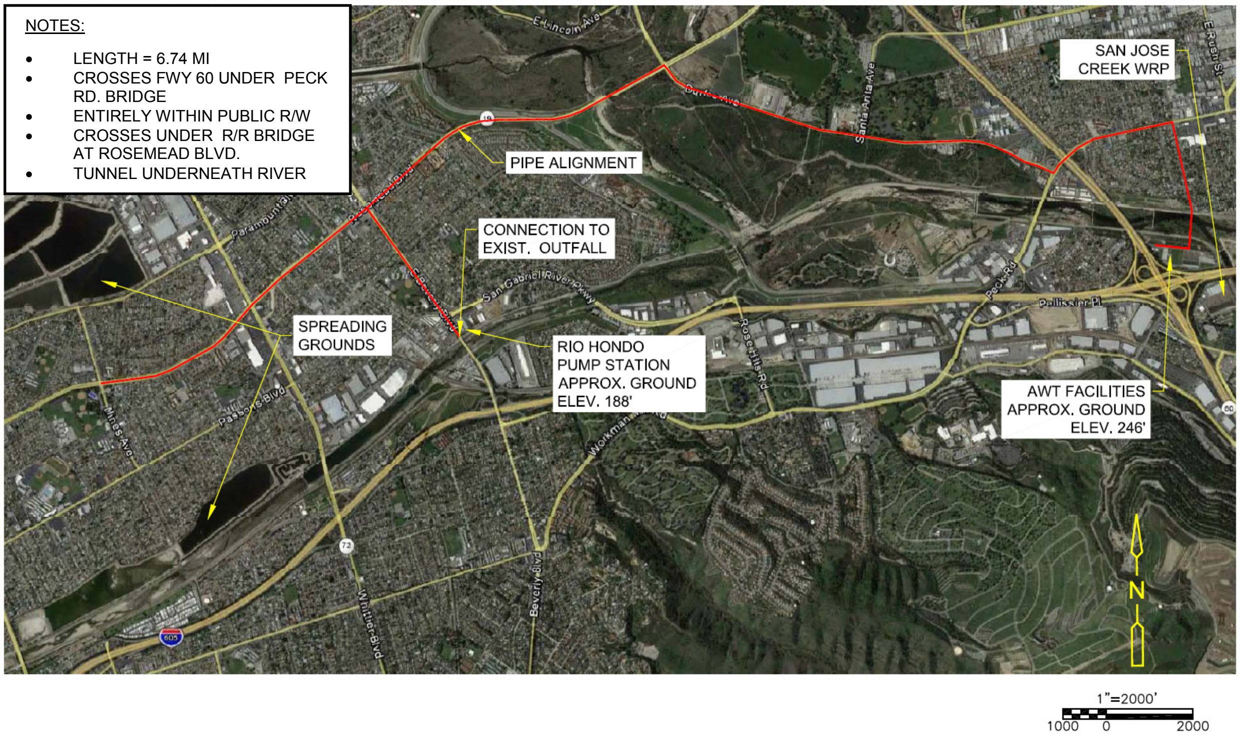
**FIGURE ES-1**
**Parallel Alignment**



NOTES:

- LENGTH = 5.75 MI.
- CROSSES UNDER FREEWAY IN EQUESTRIAN TUNNEL
- RUNS PARALLEL TO A POWERLINE (POSSIBLE OBSTACLE)
- CROSSES OVER RR AT BEVERLY BLVD. BRIDGE
- CROSSES OVER RIVER AT BEVERLY BLVD. BRIDGE

**FIGURE ES-2**
**Durfee Avenue Alignment**



NOTES:

- LENGTH = 6.74 MI
- CROSSES FWY 60 UNDER PECK RD. BRIDGE
- ENTIRELY WITHIN PUBLIC R/W
- CROSSES UNDER R/R BRIDGE AT ROSEMEAD BLVD.
- TUNNEL UNDERNEATH RIVER

## TM 2-4 Analysis of Recycled Water Supply Availability and Recharge Capabilities

In order to offset the current use of imported supplies with recycled water, there must be:

- A sufficient supply of recycled water available
- Adequate recharge capabilities to use the recycled water supply

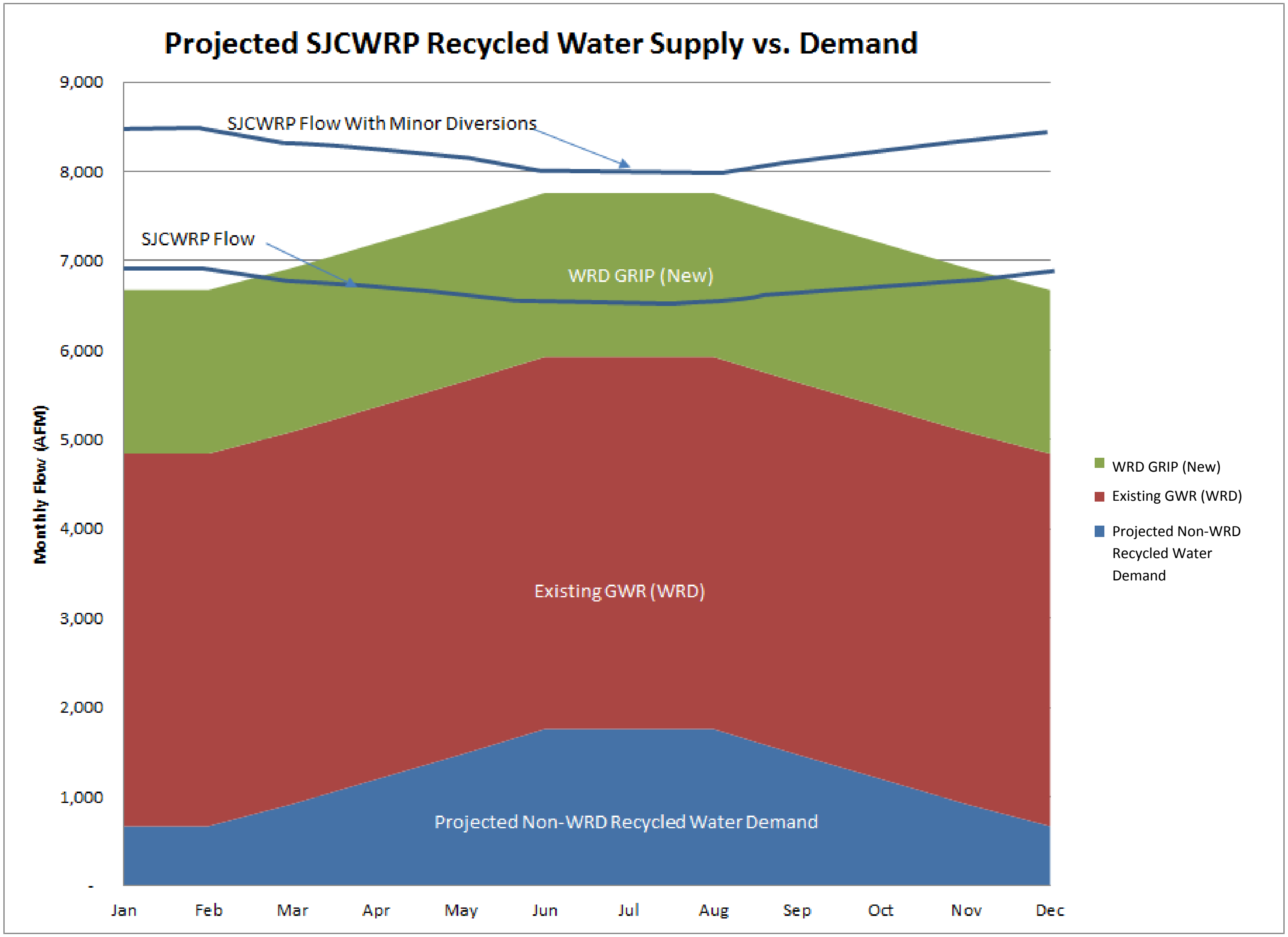
The supply sufficiency assessment is based upon using the SJCWRP as the only source. The available recycled water supply from this plant was calculated using recent data (2010 recycled water production figures) with the assumption that a number of improvements, referred to as minor diversions, would be implemented and thereby increase flows. The total available supply from the SJCWRP for the critical summer period is 7,966 acre-feet per month (AFM).

The total supply was compared to the existing and projected demands at the SJCWRP. This included the existing WRD baseline recycled water demand, projected non-WRD recycled water demands, and the new GRIP Recycled Water Project demands. The calculated total demand, also for the critical summer months, was 7,675 AFM. On this basis, the supply is sufficient to meet current, projected and new demands. The supply versus demand is graphically depicted on Figure ES-3. This analysis incorporates some degree of conservatism by using summer months (highest demand/lowest supply), and does not account for the replenishment contributions of effluent flows from the Whittier Narrows Water Reclamation Plant. These contributions effectively reduce the WRD baseline recycled water demand from the SJCWRP making additional supply available to other uses.

Assessment of the replenishment capabilities of the MFSG is based upon a spreading recharge capacity of 15,000 AFM. Stormwater application to the basins represents a competing use for basin capacity, and has preference in terms of recharge application. The analysis suggests that for a typical year, capacity would be available for recycled water recharge for the major portion of the year. For the periods of limited recharge availability due to stormwater application (i.e., 1-2 months of the year), additional recharge of recycled water would be required during those months that have recharge capacity availability (i.e., the other 10 months). On this basis, there is adequate recharge capacity to accommodate increased use of recycled water for replenishment via spreading at the MFSG. Based on the available information, a number of means were identified to improve recharge capabilities including improvements to the existing basins, a project to reduce the potential for groundwater mounding, and recharge augmentation by direct injection wells.

The analysis of supply sufficiency and recharge adequacy is based upon an average set of conditions using historic data to project future capabilities. Specific impacts of annual, monthly and daily variability in different parameters were not factored into the overall assessment. Supply may be impacted by actual future flows to the SJCWRP, the amount of additional flow that results from minor diversion improvements, and the growth experienced in non-WRD recycled water demands. The capacity of the MFSG to accept recycled water recharge is impacted by the highly variable and unpredictable amount of stormwater available in any given year and, as a result, is affected by operational considerations related to the acceptance of recycled water in conjunction with stormwater. Therefore, additional evaluation and testing would be necessary to establish the capacity gains from the proposed basin improvements and optimization of tertiary-treated recycled water in conjunction with stormwater. While theoretically the recycled water supply and spreading recharge capabilities are aligned for providing additional basin replenishment, very limited flexibility exists with this approach to deal with potential future variability.

**FIGURE ES-3**
**Projected SJCWRP Recycled Water Supply versus Demand**



Augmenting recharge capacity through injection wells improves reliability and allows recharge during wet periods when supply is available but spreading basin capacity may be limited. Use of injection for replenishment does, however, require a higher level of treatment. This advanced treatment is reflected in the AWT (21,000 AFY) and Hybrid (10,000 AFY) Alternatives. With the inclusion of capabilities for recharge via injection, both the Hybrid and AWT Alternatives provide the improved operational flexibility and increased recharge reliability needed. Both effectively allow for the increased use of recycled water for basin replenishment offsetting the needed for imported supplies. The Hybrid Alternative, however, provides the flexibility and reliability gains in a more cost-effective manner than the AWT Alternative while preserving the capabilities to expand advanced treatment capacity in the future. On this basis the Hybrid Alternative is the proposed approach for providing increased spreading and/or injection of AWT water at the Montebello Forebay.

## TM 2-5 Recharge at the MFSG by Spreading AWT Water

The objectives of the TM are to assess the impacts of spreading AWT recycled water at the MFSG and review regulatory compliance requirements for such an operation. Water quality impacts are evaluated in terms of:

- Pathogens
- Total Organic Carbon
- Nitrogen species
- Chemicals of Emerging Concern
- Heavy metals

Spreading of AWT water would only take place in the event that the injection wells are out of service and would occur for a short duration until the injection wells are again operational. The range of potential AWT flows to be recharged by spreading ranges from 10,000 AFY (Hybrid Alternative) to 21,000 AFY (AWT Alternative). In the assessment of potential groundwater effects, 21,000 AFY of AWT water is used to gage the maximum water quality impacts.

In the event that AWT water is being recharged via spreading at the MFSG, two options are considered:

- **Dedicated Spreading**
  *Dedicate specific spreading basins to function exclusively on recharging either AWT or tertiary-treated recycled water, keeping the recycled water supplies physically separate.*

- **Blended Spreading**
  *Blend the AWT and tertiary-treated recycled waters upstream of the spreading basins and recharge blended product water at the MFSG.*

Based upon the potential detrimental effects of dedicated spreading on soil aquifer treatment (SAT) performance, as well as the additional required facilities and special operational procedures needed for this approach, the option of dedicated spreading of 100 percent AWT water was eliminated from further consideration.

If recharge basins receive a blend of both tertiary-treated recycled water and AWT water, the AWT component of the blended water should not be higher than 75 percent to maintain the biological function of the recharge basins. Research has demonstrated that blends of AWT and tertiary-treated recycled waters, up to ratios of 75 percent AWT/ 25 percent tertiary-treated recycled water, have no adverse impacts on the continuous performance of SAT. As a result, none of the potential undesirable impacts associated with dedicated AWT spreading take place with the blended spreading option. The option of using a blend for recharge also avoids both the need for new facilities for dual, segregated recycled water distribution to spreading basins and the additional special operations that would be required during periods when dedicated spreading takes place.

Regulatory compliance is reviewed within the context of the most recent draft regulation published in November 2011. The use of a blend of AWT and tertiary-treated recycled water to provide the increased volume of 21,000 AFY in order to achieve an increase in the recycled water contribution for a currently permitted groundwater recharge project, such as the MFSG, should not be considered a treatment alternative under Section 60320.130 of the most recent groundwater recharge draft regulations, but rather an operational change that still requires a permit amendment. It is possible, however, that the California Department of Public Health may require a new permit, along with new permit conditions and increased monitoring requirements.

## TM 2-6 Preliminary Engineering Details of the Feasible Alternatives

The purpose of the TM is to provide a complete project description, additional technical information, including potential construction and operational impacts, needed by the Environmental Impact Report (EIR) consultant to complete the analysis of the three feasible alternatives as outlined in TMs 2-1 through 2-3. The EIR consultant will complete the environmental document in part based on this information.

**Tertiary Alternative -** This alternative would increase the amount of tertiary-treated recycled water discharged to the spreading grounds by an additional 21,000 AFY. Implementation is not anticipated to have any construction impacts and operations are expected to be similar to current operations.

**AWT Alternative -** This alternative enables WRD to offset the current use of imported water with 21,000 AFY of AWT recycled water for groundwater replenishment in the Central Basin via the Montebello Forebay. This alternative does require the construction of new AWT facilities, a new dedicated conveyance pipeline, and injection wells for recharge. Operational impacts include additional staff to operate the new treatment facilities, minimal noise and odor impacts during normal plant operations, and continuous consumption of energy and chemicals. The conveyance pipeline would be subsurface and require occasional inspection once every 5 to 10 years. New injection wells would be installed in below-grade pre-cast rectangular concrete vaults and would require routine maintenance once every couple of years. Approximately once a month the wells would be visually inspected.

**Hybrid Alternative -** The Hybrid Alternative is a combination of the Tertiary and AWT Alternatives, which allows WRD to offset the current use of imported water with a total of 21,000 AFY of both tertiary-treated and AWT recycled water for groundwater replenishment in the Central Basin via the Montebello Forebay. The Hybrid Alternative provides WRD the greatest degree of operational flexibility for spreading tertiary-treated recycled water and is therefore WRD’s proposed alternative. This alternative does require the construction of new AWT facilities, a new dedicated conveyance pipeline, and injection wells for recharge. Although the AWT facilities would be smaller and the number of injection wells for recharge would be less than that of the AWT Alternative above, the conveyance pipeline would be the same and overall construction impacts would be similar to those under the AWT Alternative. Staffing levels, noise impacts, odor impacts, and consumption of energy and chemicals are anticipated to be similar to or less than those presented under the AWT Alternative. Operational impacts related to conveyance and recharge would be the same as those presented under the AWT Alternative.

TECHNICAL MEMORANDUM 2-4

# Groundwater Reliability Improvement Program Recycled Water Project – Analysis of Recycled Water Supply Availability and Recharge Capabilities

| | |
|---|---|
| PREPARED FOR: | Jim McDavid/WRD |
| PREPARED BY: | Don Bassett/MWH<br>Sarah Munger/MWH |
| SANITATION DISTRICTS REVIEWERS: | Steven Highter/SANITATION DISTRICTS<br>Andrew Hall/SANITATION DISTRICTS |
| CONSULTANT REVIEWERS: | Fred Soroushian/CH2M HILL<br>Kim Wilson/CH2M HILL<br>Roger Stephenson/MWH |
| DATE: | November 26, 2012 |

## Executive Summary

In order to offset the current use of imported supplies with recycled water, there must be:

- A sufficient supply of recycled water available
- Adequate recharge capabilities to use the recycled water supply

The available supply assessment is based upon historic flow data for the San Jose Creek Water Reclamation Plant (SJCWRP). In order to augment current flows to this facility, a series of system improvements referred to as minor diversions are assumed to be implemented in the future. This same assumption is made in evaluating supply sufficiency. The critical period for supply is the summer period when SJCWRP flows are at their lowest and competing non-Water Replenishment District of Southern California (WRD) demands are at their highest. A summary of supply versus demand for the critical summer period indicates a demand of 7,675 AFM which can be met by the estimated supply of 7,966 AFM. The conclusion is, with the assumed minor diversion improvements, the SJCWRP supply would be able to meet maximum demand. This is a conservative assumption in that a portion of the flow from the Whittier Narrows Water Reclamation Plant (WNWRP) would also provide a supply of recycled water for basin replenishment.

Once the sufficiency of the supply is ascertained, the ability to use this additional volume of recycled water for replenishment must be confirmed. The recharge capacity of the Montebello Forebay Spreading Grounds (MFSG) by spreading is estimated at 15,000 AFM. Stormwater application to the basins represents a competing use for basin capacity, and has preference in terms of recharge application. The analysis suggests that for a typical year, capacity would be available for recycled water recharge for the major portion of the year. For the periods of limited recharge availability due to stormwater application (i.e., 1-2 months of the year), additional recharge of recycled water would be required during those months that have recharge capacity availability (i.e., the other 10 months). For

the extreme wet weather years (i.e., 1 year in 10), the recycled water recharge may be reduced for an extended period (i.e., 3 to 4 months). This higher volume of stormwater application would, however, likely offset the need for recycled water recharge during this period. Based on the available information, a number of means were identified to improve recharge capabilities including improvements to the existing basins, a project to reduce the potential for groundwater mounding and recharge augmentation by direct injection wells.

The analysis of supply sufficiency and recharge adequacy is based upon an averaged set of conditions using historic data to project future capabilities. Specific impacts of annual, monthly and daily variability in different parameters were not factored into the overall assessment. Supply may be impacted by actual future flows to the SJCWRP, the amount of additional flow that results from minor diversion improvements, and the growth experienced in non-WRD recycled water demands. The capacity of the MFSG to accept recycled water recharge is impacted by the highly variable and unpredictable amount of stormwater available in any given year and as a result is affected by operational considerations related to the acceptance of recycled water in conjunction with stormwater. While theoretically the recycled water supply and spreading recharge capabilities are aligned for providing additional basin replenishment, very limited flexibility exists with this approach to deal with potential future variability.

Augmenting recharge capacity through injection of advanced water treatment (AWT) recycled water improves reliability and allows recharge during wet periods when supply is available but spreading basin capacity may be limited. With the inclusion of capabilities for recharge via injection, both the Hybrid and AWT Alternatives identified in the *Groundwater Reliability Improvement Program (GRIP) Recycled Water Project Alternatives Analysis Update Report* provide improved operational flexibility and increased recharge reliability needed. Both effectively allow for the increased use of recycled water for basin replenishment offsetting the needed for imported supplies. The Hybrid Alternative, however, provides the flexibility and reliability gains in a more cost-effective manner than the AWT Alternative while preserving the capabilities to expand advanced treatment capacity in the future. On this basis the Hybrid Alternative is the preferred approach for providing increased spreading and/or injection of AWT water at the Montebello Forebay.

# 1.0 Background and Objectives

The mission of the WRD is: “To provide, protect and preserve high-quality groundwater through innovative, cost-effective and environmentally sensitive basin management practices for the benefit of residents and businesses of the Central and West Coast Basins.” This involves the monitoring and oversight of basin extraction, as well as replenishment, to ensure a reliable, high quality groundwater supply is available to residents within WRD’s service area. WRD’s Water Independence Now (WIN) strategy focuses on the reduction and elimination of imported supplies currently used for basin recharge. The goal of GRIP is to offset the current use of imported supplies by the increased use of recycled water for basin recharge.

In order to achieve the GRIP goal, there are two baseline conditions that must be satisfied:

1. There must be sufficient supply of recycled water available to replace imported supplies
2. There must be adequate recharge capabilities to fully utilize the recycle water supply for basin replenishment

This TM addresses the recycled water availability and recharge capabilities with respect to the feasible alternatives identified in TM 1-5, *Evaluation of Treatment and Conveyance Options*, *GRIP Alternatives*

*Analysis Update Report* (CH2M HILL, 2012a). One parameter of supply and recharge that adds a level of complexity to the analysis is seasonality. Both the supply availability and recharge capabilities are impacted by a variety of different factors that result in variability for both during the course of a year. In winter, the greatest volumes of recycled water are available, but this corresponds to periods with potential recharge limitations resulting from the application of stormwater to spreading grounds. In the summer, recharge capabilities are greatest, but supply availability, due to competing demands, can be lowest.

In the analysis of supply and recharge, the total volume of the groundwater basin relative to the annual recharge quantity, the impacts of climatic variability, and the regulations governing recycled water use favor review of data over an extended timeframe. For this TM, data used to assess supply availability and recharge capabilities typically extended over a 10-year period.

# 2.0 Recycled Water Supply Availability

There are currently multiple sources for groundwater replenishment to the basin. Using long-term averages, the major surface spreading replenishment sources relevant to this TM are summarized in Table 4-1.

TABLE 4-1
**Sources for Groundwater Basin Replenishment via Surface Spreading at the Montebello Forebay**

| Source | Estimated Annual Replenishment Amount (AFY) |
|---|---|
| Recharge – Stormwater | 57,000 |
| Recharge – Recycled Water | 50,000 |
| Recharge – Imported Water | 21,000 |

In order to continue with the current level of recycled water recharge (up to 50,000 AFY) and to increase the recycled water recharge by the current level of imported water recharge (21,000 AFY), the total recycled water supply availability in the future must be 71,000 AFY. This translates to approximately 6,000 acre-feet per month (AFM), although some degree of variability in monthly figures can be expected during the course of a year.

## 2.1 Assumptions

In the assessment of recycled water supply availability, three assumptions were made that impact the findings and results:

1. Source: The supply source is the SJCWRP. Alternative supply sources for recycled water were examined as part of TM 1-5, *Evaluation of Treatment and Conveyance Options*, *GRIP Alternatives Analysis Update Report* (CH2M HILL, 2012a), which concluded that the SJCWRP provides the best source of recycled water for future recharge. This is a conservative assumption in that a portion of the flow from the WNWRP also provides a degree of basin replenishment.
2. Availability: Recycled water production at the SJCWRP is well defined based upon historic data. There are, however, potential competing uses for recycled water from this facility that impact availability. Though significant prior commitments for recycled water have been made over the course of the plant's life, many of these commitments have not been exercised and there are no imminent projects that would result in significant future uses of recycled water beyond current

demands. For the purposes of analyzing supply availability from the SJCWRP, the current competing demands in addition to improvements identified for implementation within the next five years that would increase recycled water usage, were considered as projected future competing demands.

3. Minor Diversions – Supply Increase: There are a number of modifications and improvements to the existing conveyance system that would increase the volume of flow tributary to the SJCWRP. The improvements categorized as minor diversions would increase tributary flow to the SJCWRP by approximately 17,900 AFY (16.0 MGD). In this analysis, it is assumed that minor diversion improvements would be implemented and that the additional available recycled water flow generated from the added tributary flow to the SJCWRP is available for recharge.

## 2.2 Current Recycled Water Production

Current recycled water production from the SJCWRP is presented in Table 4-2 based upon 2010 flow figures. Review of plant flow information indicates that in terms of recycled water production, the data from 2010 constitutes a representative year. The "Summer Period" refers to the months of June, July and August. The "Winter Period" refers to the months of December, January and February. These reflect the high (winter) and low (summer) periods of production. Estimates of current recycled water summer and winter supply flows are calculated based on peaking factors of 0.97 and 1.03, respectively.

TABLE 4-2
**Estimated Current Recycled Water Production at the SJCWRP**

| Category | Production (MGD) | Production (AFM) |
|---|---|---|
| Current Available Recycled Water Supply | | |
| • Annual Average[a] | 72.0 | 6,721 |
| • Summer Period | 69.8 | 6,519 |
| • Winter Period | 74.2 | 6,923 |
| Minor Diversions - Additional Supply | | |
| • Annual Average[a] | 16.0 | 1,494 |
| • Summer Period | 15.5 | 1,447 |
| • Winter Period | 16.5 | 1,540 |
| Total Available Supply with Minor Diversions | | |
| • Annual Average[a] | 88.0 | 8,215 |
| • Summer Period | 85.3 | 7,966 |
| • Winter Period | 90.7 | 8,463 |

[a] Sanitation Districts Memorandum "Recycled Water Supply for GRIP – August 2010 Update" (August 23, 2010)

## 2.3 Competing Recycled Water Demands (non-WRD)

The assessment of supply adequacy for WRD basin recharge is based upon estimated SJCWRP recycled water production minus competing (i.e., non-WRD) demands. As previously outlined in Section 2-1, the competing demands are based upon current uses (entities and volumes) plus future demands identified that are likely to take place in the near term. These competing demands are presented in Table 4-3. The demands are based upon current uses and have a peaking factor applied to take into account diurnal variations. The peaking factors were provided by the Sanitation Districts based upon past actual usage and range from 0.5 to 2.0. For all agencies the average demands and peaking factors are higher for the summer period than they are for the winter period. As a result, the critical supply period is the peak summer months.

TABLE 4-3
Summary of Estimated SJCWRP Recycled Water Demands (non-WRD)

| Agency | Recycled Water Demand (AFY) | | | Recycled Water Demand (MGD) | | |
|---|---|---|---|---|---|---|
| | Average | Summer Period | Winter Period | Average | Summer Period | Winter Period |
| Central Basin MWD | 5,800 | 8,700 | 4,640 | 5.2 | 7.8 | 3.9 |
| Puente Hills Landfill | 1,500 | 2,600 | 1,000 | 1.3 | 2.3 | 0.9 |
| Rose Hills Memorial Park | 1,500 | 3,000 | 800 | 1.3 | 2.7 | 0.7 |
| California Country Club | 500 | 1,000 | 250 | 0.4 | 0.9 | 0.2 |
| City of Industry | 3,000 | 6,000 | 1,800 | 2.7 | 5.4 | 1.6 |
| TOTAL | 12,300 | 21,300 | 8,490 | 10.9 | 19.1 | 7.3 |

## 2.4 WRD Recycled Water Demand

The current WRD baseline recycled water demand is 50,000 AFY. To offset the current use of imported supplies, this demand would be increased by 21,000 AFY to a total of 71,000 AFY of recycled water. Three feasible alternatives have been identified in the *GRIP Alternatives Analysis Update Report* (CH2M HILL, 2012a):

1. Tertiary Alternative – adding 21,000 AFY of additional tertiary-treated recycled water
2. AWT Alternative – adding 21,000 AFY of AWT treated water
3. Hybrid Alternative – adding a combination of both tertiary-treated recycled water and AWT treated waters; 11,000 AFY of tertiary-treated recycled water and 10,000 AFY of AWT

Alternatives involving AWT would have a slightly higher recycled water demand due to the production of reverse osmosis (RO) concentrate and, therefore, would exhibit slightly higher demands (about 7 to 8 percent of the AWT flow). The RO concentrate flows are about 800 AFY and 1,600 AFY for the Hybrid (10,000 AFY AWT) and AWT (21,000 AFY AWT) alternatives, respectively. Therefore, the RO concentrate could represent up to a 2.5 percent increase in the total WRD recycled water demand in order to maintain the 71,000 AFY recycled water for MFSG recharge.

## 2.5 Findings and Conclusions

In order to assess the adequacy of the SJCWRP's recycled water supply versus projected demands, a "worst case" scenario was examined and is presented in Table 4-4. For this comparison, the minimum period for SJCWRP recycled water production (summer period) was used, along with the minimum period of additional recycled water (summer period) that would result from minor diversions. Adding these two figures together results in the "Total Supply Available" number. For the demand side of the equation, the maximum period of non-WRD recycled water demand (summer period) was added to the current WRD baseline demand and planned GRIP demand to create the "Total Demand" figure.

Subtracting the total demand from the total supply indicates the sufficiency of the supply as long as the product is a positive value.

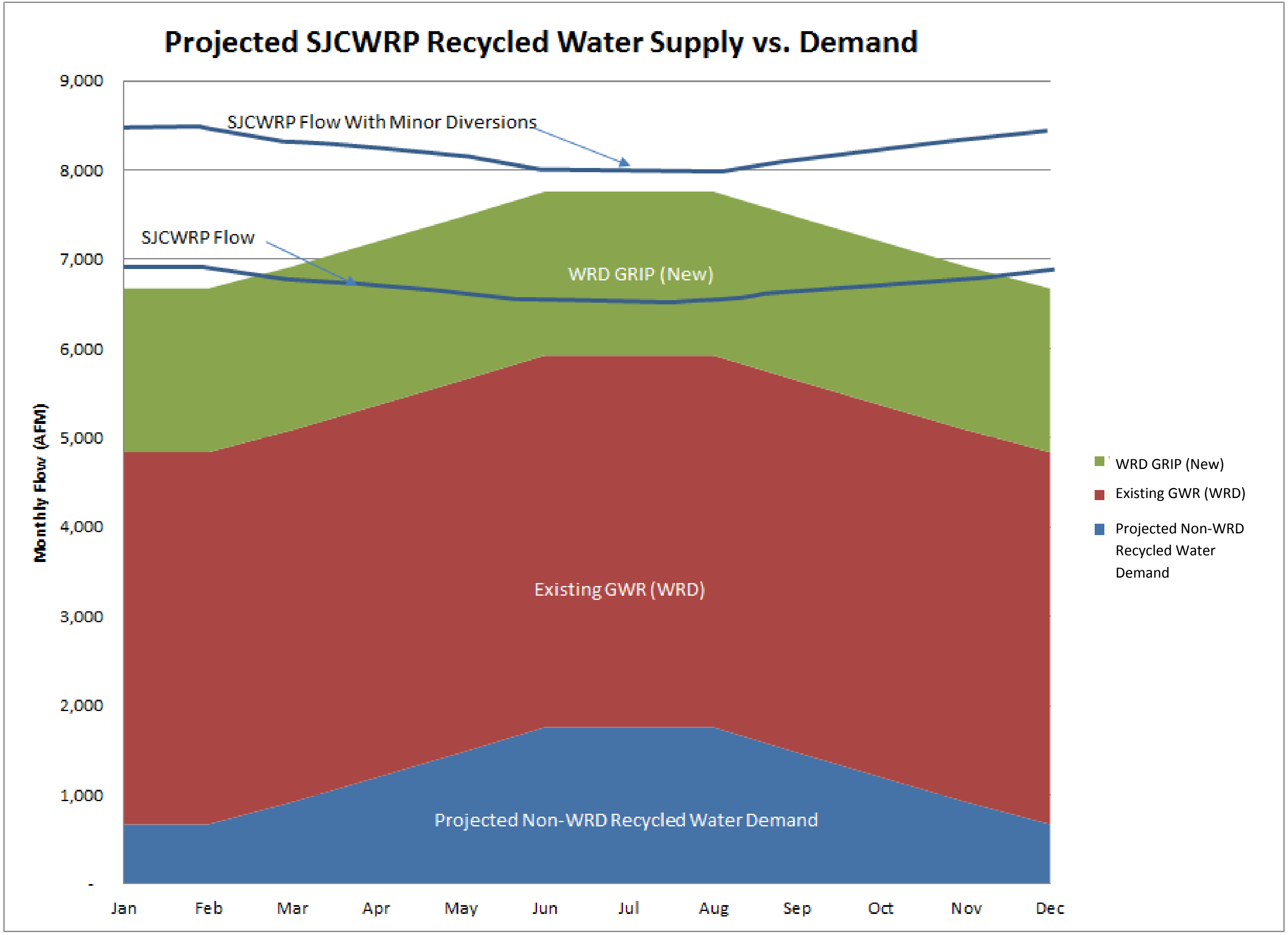
This analysis of the summer period represents a conservative approach to assessing supply availability. The WRD baseline recycled water demand of 50,000 AFY is assumed to be constant over the course of 12 months. In reality, the potential exists to increase the volume of baseline recharge during periods when non-WRD demands are lower. In addition, this approach assumes 100 percent of the WRD baseline demand is satisfied by the SJCWRP. While the SJCWRP is the primary source of recycled recharge, there is also a contribution from the WNWRP. Both of these factors effectively lower the WRD baseline recycled water demand from the SJCWRP during the peak demand periods thereby increasing the overall availability of the SJCWRP supply.

TABLE 4-4
Estimated Supply Versus Demand for the SJCWRP During the Summer Period

| Category | Recycled Water (AFM) | Recycled Water (MGD) |
|---|---|---|
| SUPPLY | | |
| • Available Recycled Water | 6,519 | 69.8 |
| • Additional Supply from Minor Diversions | 1,447 | 15.5 |
| • Total Supply Available | 7,966 | 85.3 |
| DEMAND | | |
| • Non-WRD Recycled Water Demand | 1,775 | 19.1 |
| • WRD Baseline Recycled Water Demand | 4,150 | 44.6 |
| • GRIP Demand (new) | 1,750 | 18.7 |
| • Total SJCWRP Demand | 7,675 | 82.4 |
| AVAILABLE RECYCLED WATER (Total Supply minus Total Demand) | 291 | 2.9 |

This information is graphically presented on Figure 4-1 across a full calendar year. The conclusion from both the tabulation and figure is that the supply of recycled water at the SJCWRP is adequate for the additional 21,000 AFY recharge envisioned as part of the GRIP effort, even during the minimum period of supply production and maximum period of competing demands.

FIGURE 4-1
Projected SJCWRP Recycled Water Supply versus Demand



# 3.0 Groundwater Recharge Capabilities

The assessment of the capability of the existing MFSG to accept additional recycled water involves the evaluation of a number of variables. From the perspective of an annual contribution of water to the underlying aquifer, the 21,000 AFY of additional recycled water is replacing the same volume as currently recharged using an imported supply. As such, there is no impact to the basin's overall storage capabilities. However, recycled water is produced on a fairly uniform basis, whereas imported water can be made available in greater quantities during periods when there is maximum available basin recharge capacity, such as summer months. The variability in basin availability for recycled water recharge is related to the basins' preferential application of stormwater based upon its availability. There is significant variability in stormwater available throughout the course of any given year, and over longer-terms durations (e.g., 10 years). It is therefore necessary to review the recharge capabilities of the basins to accept recycled water, taking into account the preferential competing application of stormwater.

## 3.1 Assumptions – Baseline Basin Recharge Capabilities and Needs

There are a number of factors that influence the short-term recharge capabilities of the MFSG. Looking at historic surface spreading at the MFSG, it was observed that on at least one occasion a monthly recharge rate of 60,000 AFM was achieved. There are also a few recorded instances when a rate of 45,000 AFM was attained, and numerous occurrences when 30,000 AFM was reached over the past 40 years. These capacities do not, however, incorporate time for basin draining and recovery maintenance, and, as such, these numbers do not represent a conservative value for sustainable capacity over extended durations. In the development of sustainable basin recharge capabilities, it is assumed:

- One-third of the basins are filling
- One-third of the basins are draining
- One-third of the basins are drying

Employing these assumptions, a sustainable, reliable recharge capacity for the MFSG basins is estimated at 15,000 AFM, as presented in the *Groundwater Basins Master Plan* (CH2M HILL, 2012b). This estimated value is based upon an analysis of historic records and merits verification.

As previously discussed, the total recharge capacity needed for WRD recycled water is 71,000 AFY. This consists of the current 50,000 AFY plus 21,000 AFY of additional recycled water to offset imported supplies. Assuming a uniform recharge rate, the 71,000 AFY of annual recharge translates to an approximate monthly requirement of 6,000 AFM of recharge.

## 3.2 Stormwater Recharge – Competing Use

As noted above, stormwater has preferential use of the basin recharge capacity over recycled water. The capacity of the basins to recharge recycled water is therefore a product of the basins' total capacity, minus that in use for stormwater recharge. In extended wet weather situations, there may be periods where all basins are in use for stormwater recharge and no capacity is available for recycled water recharge. Conversely, in dry summer months, the entire basin capacity may be available for recycled water.

## 3.3 Mounding - Potential Recharge Limitation

In addition to recharge limitations due to the preferential application of stormwater, long-term application of large quantities of any type of recharge water to the spreading basins may result in groundwater "mounding." When mounding occurs, the distance between the bottom of the percolation basin and the top surface, or hydraulic grade line, of the groundwater is reduced. This phenomenon can reduce the basin capacity for recharge with any water type: stormwater, recycled water, or imported.

## 3.4 Available Recharge Capacity

Determination of the available recharge capacity at the MFSG for recycled water is inherently challenging due to the competing, preferential application of stormwater and the associated high degree of unpredictability related to climatic conditions and subsequent stormwater volumes generated. Volumes of stormwater recharged on a monthly basis at the MFSG were examined over a 10-year period. Using the previously discussed sustainable, reliable capacity of 15,000 AFM for the basins, each of the months over that 10-year period were placed in one of three categories:

1. No Recycled Water Recharge – the monthly stormwater recharge was in excess of 15,000 AFM resulting in no capacity available for recycled water recharge.
2. Partial Recycled Water Recharge –the monthly stormwater recharge total is below 15,000 AFM indicating some capacity is available, but recharge is above 9,000 AFM indicating there is not a full 6,000 AFM available for recycled water recharge (6,000 AFM was calculated from a total of 71,000 AFY).
3. Full Recycled Water Recharge – the monthly total for stormwater is less than 9,000 AFM leaving in excess of 6,000 AFM for recycled water recharge.

Data for the past 10 years are presented in Table 4-5 and color coded per the above listed categories. For the majority of this timeframe, full or partial recharge would be available for recycled water flows using the criteria outlined above. This analysis is considered conservative in that the basins can operate for short durations at higher rates, and there is the potential to increase recycled water flows above the monthly average during periods where the basins are under loaded and supply is available. These data are also averaged for each month over the 10 years and are presented in Figure 4-2.

Using the 10-year average stormwater recharge volumes and the estimated 15,000 AFM capacity for the MFSG, a projected available basin recharge capacity beyond stormwater flows was calculated on a monthly basis. This is presented on Figure 4-3. On this figure a horizontal line (constant value - black) is provided for the necessary baseline recharge rate of 6,000 AFM that would be required to achieve a cumulative annual recycled water recharge quantity of 71,000 AFY. In addition, another line (varying value - red) is shown that plots the excess SJCWRP supply available for each month above and beyond the projected total demand for that same month (assuming minor diversions are implemented). This plot of supply above projected demand provides a perspective on the ability to increase recharge during months with available recharge capacity to compensate for those periods with restricted recharge capacity due to wet weather. For those months where the available recharge volumes (blue bars) exceed the 6,000 AFM baseline (black horizontal line) the opportunity exists to recharge beyond the baseline up to the available supply (red line). Conversely, in months where the blue bars are below the black line (January and February), limitations result in a recharge deficit that must be made up during the other 10 months if the cumulative annual recharge is to be achieved. Based upon actual values, the 10 months of potential additional or "excess" recharge capacity exceeds the two months of recharge deficit by 1,010 AF (Table 4-6). This indicates the available recharge capabilities for the MFSG are very close to the recycled water supply availability from the SJCWRP if spreading is the only means of replenishment employed.

This analysis suggests that during a typical year, capacity would be available for recycled water recharge for the major portion of the year. For the periods of limited recharge availability due to stormwater application (i.e., 1-2 months of the year), additional recharge of recycled water would be required during months with recharge availability. For the extreme wet weather years (i.e., 1 in 10 years), the recycled water recharge may be reduced for an extended period (i.e., 3 to 4 months). This higher volume of stormwater application would, however, likely offset the need for recycled water recharge during this period.

TABLE 4-5
Annual MFSG Recharge by Stormwater

| | YEARS – 2000-2010 (AFM) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **00/01** | **01/02** | **02/03** | **03/04** | **04/05** | **05/06** | **06/07** | **07/08** | **08/09** | **09/10** |
| **Oct** | 4,928 | - | - | - | 19,095 | 5,104 | - | - | 688 | 797 |
| **Nov** | - | 4,056 | 8,204 | 2,116 | 396 | - | - | 2,070 | 4,372 | - |
| **Dec** | - | 2,285 | 8,767 | 5,082 | 7,847 | 2,747 | - | 5,449 | 9,677 | 8,329 |
| **Jan** | 8,456 | 4,114 | - | 314 | 33,724 | 4,163 | 722 | 28,998 | 446 | 15,267 |
| **Feb** | 24,342 | 1,474 | 18,085 | 20,610 | 23,184 | 8,848 | 5,899 | 8,008 | 28,229 | 14,245 |
| **Mar** | 3,887 | 1,779 | 12,894 | 5,784 | 29,360 | 15,354 | 883 | 1,453 | - | 1,363 |
| **Apr** | 3,321 | 1,011 | 4,846 | 491 | 15,806 | 18,400 | 4,413 | 368 | - | 3,656 |
| **May** | - | 1,171 | 5,272 | - | 9,425 | 6,347 | 300 | 3,556 | - | - |
| **Jun** | 535 | 64 | 557 | 243 | 8,603 | 359 | - | - | - | - |
| **Jul** | - | 732 | 398 | 678 | 1,166 | 75 | 43 | 582 | 838 | - |
| **Aug** | - | 766 | 314 | - | 5 | - | - | 1,211 | - | - |
| **Sep** | - | 828 | - | - | 63 | - | 1,433 | 3,648 | - | - |

| | |
|---|---|
| 🟥 | Storm Flows ≥ 15,000 AFM – Basins not available for recycled water recharge |
| 🟨 | Storm Flows between 9,000 and 15,000 AFM – Basins not available for full 6,000 AFM recycled water recharge |
| 🟩 | Storm Flows ≤ 9,000 AFM – Basins available for full 6,000 AFM recycled water recharge |

The capacity of the MFSG to accept recycled water recharge is impacted by the highly variable and unpredictable amount of stormwater available in any given year and as a result is affected by operational considerations related to the acceptance of recycled water in conjunction with stormwater. Therefore, the availability of recharge capacity for recycled water during wet months does not necessarily ensure its application.

FIGURE 4-2

Monthly Stormwater Recharge Volumes (10-Year Average)

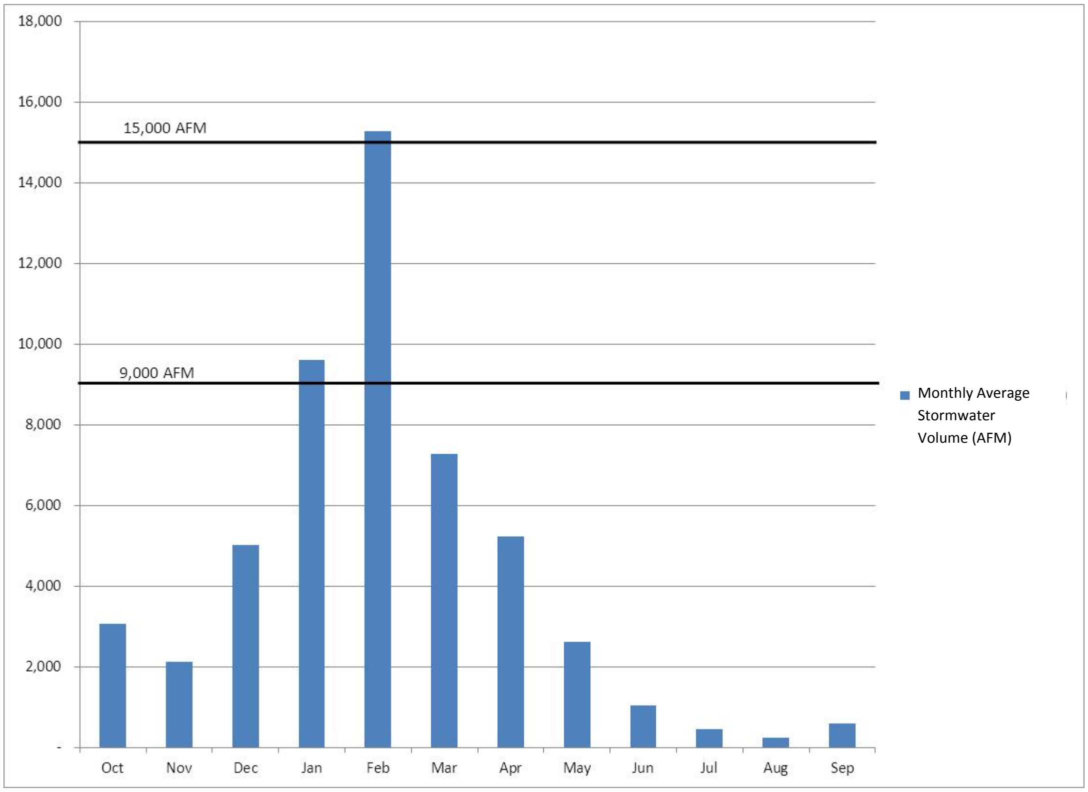


FIGURE 4-3

Estimated Monthly Recharge Volumes Available for Non-Stormwater Supplies (10-Year Average)

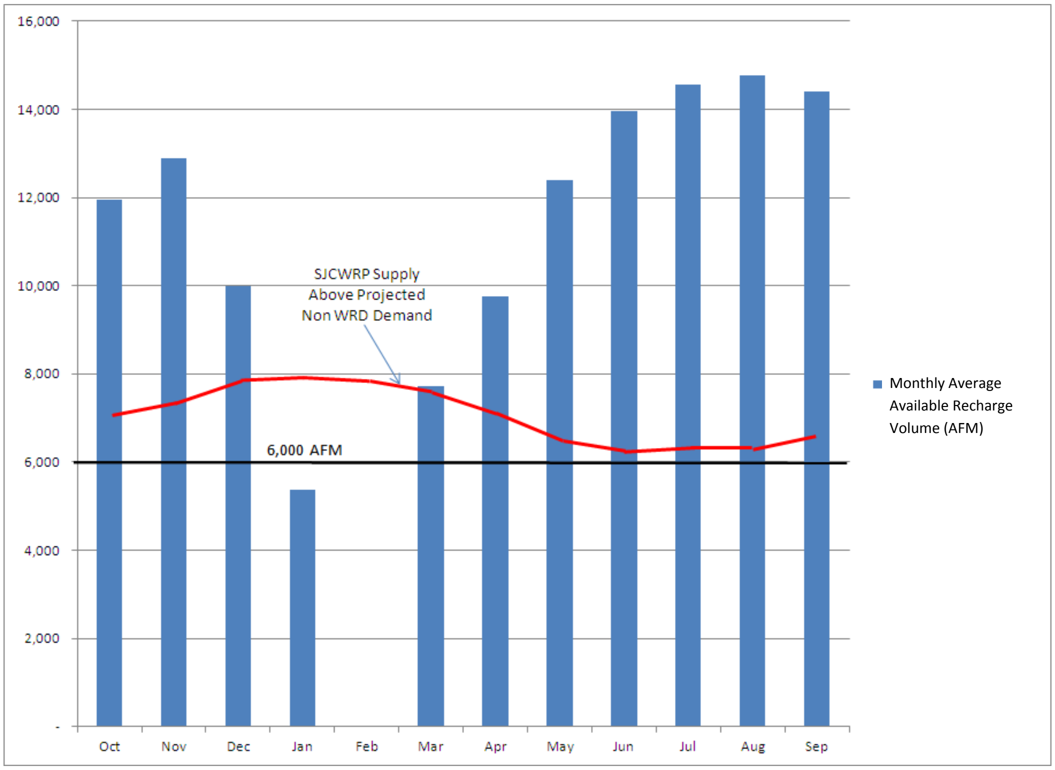


TABLE 4-6
Recharge Volumes – Monthly Excesses and Deficits

| Month | Excess (AF) | Deficit (AF) |
|---|---|---|
| October | 1,060 | --- |
| November | 1,400 | --- |
| December | 1,800 | --- |
| January | --- | 620 |
| February | --- | 6,000 |
| March | 1,400 | --- |
| April | 1,060 | --- |
| May | 530 | --- |
| June | 190 | --- |
| July | 190 | --- |
| August | 190 | --- |
| September | 530 | --- |
| **Annual Total** | 7,630 | 6,620 |

## 3.5 Recharge Capacity Enhancements

Three approaches were reviewed in terms of enhancing the current recharge capabilities of the MFSG, each of which is discussed separately:

1. Existing basin improvements
2. Groundwater mounding reduction
3. Direct injection wells

### 3.5.1 Existing Basin Improvements

Improvements to the existing basins can effectively increase the reliability of basin operations leading to additional capacity being available. This would ultimately result in the ability to recharge more recycled water. The County of Los Angeles Department of Public Works (LACDPW) has developed a listing of potential projects that could improve basin operations and capacity. These are listed in Table 4-7. Appendix A provides additional details on these proposed improvements.

TABLE 4-7
LACDPW Potential Recharge Basin Improvements[a]

| | Improvement | Benefit |
|---|---|---|
| 1 | San Gabriel River (SGR) Levee Improvement | Additional Reliability/Flexibility |
| 2 | San Gabriel Spreading Grounds Gate Replacement | Additional Capacity |
| 3 | Diversion Structure Across San Gabriel River Downstream of Zone 1 | Additional Capacity/Flexibility/Reliability |
| 4 | Acquire New Property – Dominguez Gap | Additional Capacity |
| 5 | Peck Spreading Basin Pump Station | Additional Flexibility |
| 6 | Increase Size of Rio Hondo Spreading Grounds Settling Basin | Additional Reliability |
| 7 | Facilities Master Planning | Additional Capacity/Flexibility/Reliability |
| 8 | New Rubber Dam at SGR Parkway (F-263) | Additional Capacity |
| 9 | New Rubber Dam at SGR Road 2 and Road 3 | Additional Capacity |
| 10 | Acquire Property Along LA River in Montebello Forebay | Additional Capacity |
| 11 | Replace Rio Hondo Radial Gates | Additional Capacity |

[a] Improvements currently underway are not included in this table

A decision relative to WRD's financial contribution to any of these improvements would be based upon a comparison of the additional capacity and flexibility gained versus the capital expenditure required. Analyses verifying potential capacity increases would be undertaken prior to decisions on joint financial participation.

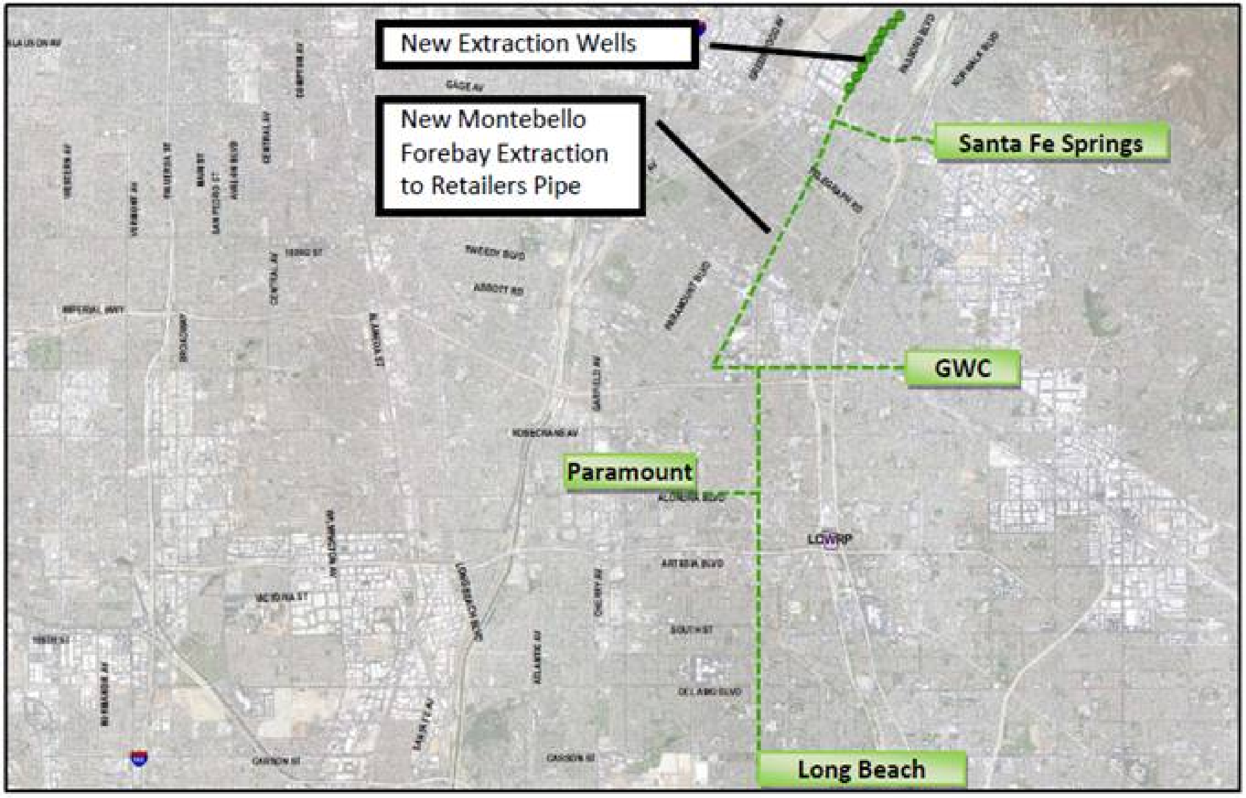
### 3.5.2 Groundwater Mounding Reduction

The reduction in potential groundwater mounding would also increase the available capacity of recharge basins. A project designated as "Central Basin Pipeline" would reduce groundwater levels in the immediate vicinity of the MFSG by pumping. The extracted groundwater would be reintroduced into the water distribution system. The project consists of new conveyance and production wells:

- Conveyance: Pipeline from new Montebello Forebay extraction wells to four retailers. MFSG to Junction 1 (12,300 feet, 36-inch), Junction 1 to Santa Fe Springs (11,000 feet, 14-inch), Junction 1 to Junction 2 (30,750 feet, 36-inch), Junction 2 to Golden State Water Company (15,000 feet, 16-inch), Junction 2 to Junction 3 (12,200 feet, 30-inch), Junction 3 to Paramount (8,500 feet, 16-inch), and Junction 3 to Long Beach (28,100 feet, 30-inch)
- Production Wells: Nine new extraction wells to provide 25,000 AFY of pumping shifted to the Montebello Forebay area from elsewhere in the Central Basin

The location of these facilities is depicted on Figure 4-4.

FIGURE 4-4
**Central Basin Pipeline Project for Groundwater Mounding Reduction in MFSG**



### 3.5.3 Direct Injection

Injection wells offer an additional avenue for basin recharge. This approach is not impacted by wet weather events and does not compete with stormwater for basin capacity. Recharge is available year round on a 24/7 basis.

The approach does require a higher water quality than that for recharge through percolation. The higher quality water would be produced by new AWT systems. These are the subject of other TMs, including TM 1-5. In addition to treatment, new, separate conveyance systems would be required for transport of AWT water from the SJCWRP to the injection well field. The location and construction of injection facilities would also be required. The wells used for injection are very similar to extraction wells, basically operating in reverse.

# 4.0 Conclusions

WRD is evaluating the use of recycled water to replace current imported supplies as part of the GRIP Recycled Water Project. Demonstrating the feasibility of this approach involves a variety of factors including the determination of *supply sufficiency* and *recharge adequacy*.

The supply sufficiency assessment was based upon the SJCWRP as the only source. The available recycled water supply from this plant was calculated using recent data (2010 recycled water production figures) with the assumption that a number of improvements, referred to as minor diversions, would be implemented and thereby increase flows. The total available supply from the SJCWRP for the critical summer period is 7,966 AFM.

The total supply was compared to the existing and projected demands at the SJCWRP. This included the existing WRD baseline recycled water demand, projected non-WRD recycled water demands, and the new GRIP demands. The calculated total demand, also for the critical summer months, was 7,675 AFM. On this basis, the supply is sufficient to meet current, projected and new demands. This analysis incorporates some degree of conservatism by using summer months (highest demand/lowest supply), and does not account for the replenishment contributions of effluent flows from the WNWRP. These contributions effectively reduce the WRD baseline recycled water demand from the SJCWRP making additional supply available to other uses.

Assessment of the replenishment capabilities of the MFSG is based upon a spreading recharge capacity of 15,000 AFM. Stormwater application to the basins represents a competing use for basin capacity, and has preference in terms of recharge application. The analysis suggests that for a typical year, capacity would be available for recycled water recharge for the major portion of the year. For the periods of limited recharge availability due to stormwater application (i.e., 1-2 months of the year), additional recharge of recycled water would be required during those months that have recharge capacity availability (i.e., the other 10 months). On this basis, there is adequate recharge capacity to accommodate increased use of recycled water for replenishment via spreading at the MFSG. Based on the available information, a number of means were identified to improve recharge capabilities including improvements to the existing basins, a project to reduce the potential for groundwater mounding, and recharge augmentation by direct injection wells.

The analysis of supply sufficiency and recharge adequacy is based upon an average set of conditions using historic data to project future capabilities. Specific impacts of annual, monthly and daily variability in different parameters were not factored into the overall assessment. Supply may be impacted by actual future flows to the SJCWRP, the amount of additional flow that results from minor diversion improvements, and the growth experienced in non-WRD recycled water demands. The capacity of the MFSG to accept recycled water recharge is impacted by the highly variable and unpredictable amount of stormwater available in any given year and, as a result, is affected by operational considerations related to the acceptance of recycled water in conjunction with stormwater. Therefore, additional evaluation and testing would be necessary to establish the capacity gains from the proposed basin improvements and optimization of tertiary-treated recycled water in conjunction with stormwater. While theoretically the recycled water supply and spreading recharge capabilities are aligned for providing additional basin replenishment, very limited flexibility exists with this approach to deal with potential future variability.

Augmenting recharge capacity through injection wells improves reliability and allows recharge during wet periods when supply is available but spreading basin capacity may be limited. Use of injection for replenishment does, however, require a higher level of treatment. This advanced treatment is reflected in the AWT (21,000 AFY) and Hybrid (10,000 AFY) Alternatives. With the inclusion of capabilities for recharge via injection, both the Hybrid and AWT Alternatives provide improved operational flexibility and increased recharge reliability needed. Both effectively allow for the increased use of recycled water for basin replenishment offsetting the needed for imported supplies. The Hybrid Alternative, however, provides the flexibility and reliability gains in a more cost-effective manner than the AWT Alternative while preserving the capabilities to expand advanced treatment capacity in the future. On this basis the Hybrid Alternative is the preferred approach for providing increased spreading and/or injection of AWT water at the Montebello Forebay.

# 5.0 References

CH2M HILL. 2012a. GRIP Alternatives Analysis Update Report. Final report prepared in October 2012.

CH2M HILL. 2012b. Groundwater Basins Master Plan. Draft report completed July 2012.

Sanitation Districts Memorandum. August 23, 2010. Recycled Water Supply for GRIP – August 2010 Update.

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WATER REPLENISHMENT DISTRICT OF SOUTHERN CALIFORNIA

SANITATION DISTRICTS OF LOS ANGELES COUNTY

U S G V M W D

# GRIP Alternatives Analysis
# Final Report

**Prepared by:**

RMC
Water and Environment

In Association with:
Nellor Environmental Consultants
Todd Engineers

**June 2011**

# Contents

# Tables

# Figures

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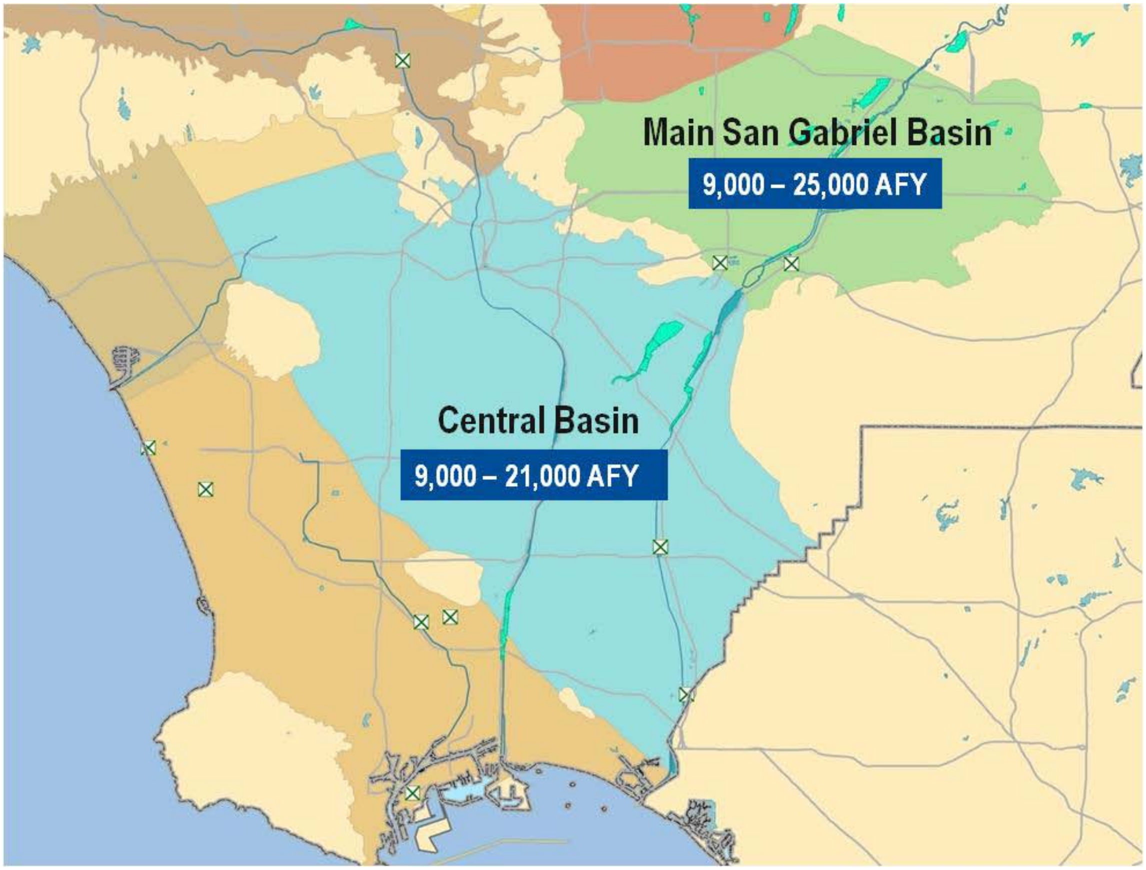
# 1 GRIP Alternatives Analysis Background

The reliability of traditional sources of water for replenishment in the Central and Main San Gabriel Groundwater Basins (Basins) is decreasing because of the combined effects of pumping, long-term drought, and climate change. To address this challenge, the Water Replenishment District of Southern California (WRD), the Upper San Gabriel Valley Municipal Water District (USGVMWD), and the Los Angeles County Sanitation Districts (LACSD) entered into a Joint Powers Authority (JPA) to explore alternatives for obtaining new or additional water sources for groundwater replenishment, referred to as the Groundwater Reliability Improvement Program (GRIP). To offset current Metropolitan Water District of Southern California (MWD) interruptible imported supplies that have historically been used to replenish the Basins, as shown in **Figure 1**, the following objectives for GRIP were established for this evaluation:

- Provide a minimum of 9,000 acre-feet per year (AFY) and up to 25,000 AFY of water to the Main San Gabriel Basin (MSG Basin) by 2020-2025
- Provide a minimum of 9,000 AFY and up to 21,000 AFY of water to the Central Basin by 2020-2025

**Figure 1: GRIP Supply Objectives**



GRIP includes this Alternatives Analysis (AA) that identifies and evaluates a number of alternatives to provide a long-term solution for needed groundwater replenishment in the Basins. The purpose of the AA is to provide information for ongoing technical, policy, and planning efforts and to provide a basis for subsequent California Environmental Quality Act/National Environmental Policy Act (CEQA/NEPA) and facilities planning activities related to decision-making for feasible GRIP alternatives.

# 2 Purpose of Final Report

The purpose of the GRIP AA Final Report (Final Report) is to develop and characterize potentially feasible GRIP project alternatives[1] using a sequential process of criteria and analysis that culminates in the development of GRIP supply portfolios. As a result, this Final Report provides the basis for six potentially feasible GRIP alternatives, including a no-project alternative, that can be carried forward to subsequent CEQA/NEPA and facilities planning work. The selection of potentially feasible alternatives is based on lifecycle values and recognizes that recycled water projects will be a necessary component of any successful GRIP supply portfolio. While the importance of other supply sources is acknowledged, the results of this Final Report focus on the recycled water components because other supply sources examined previously (e.g., stormwater projects) extend beyond the jurisdictional authority of the JPA, so only the portion of each portfolio made up of recycled water will be carried forward to the CEQA/NEPA and facilities planning process. Further development of non-recycled water supply sources is expected to be pursued as part of other planning efforts.

The information presented in this Final Report builds on the conceptual options identified in TM-1 (final version November 23, 2010) and the project options developed in TM-2 (final version November 10, 2010), by using them to create GRIP project alternatives (single projects) and then using those to build supply portfolios (multiple projects). These supply portfolios were originally developed in two draft documents: (1) as project alternatives in TM-3 and (2) as supply portfolios in TM-4. The Final Report combines the drafts for TM-3 and TM-4 into one stand-alone document. This Final Report also includes TM-1 and TM-2 as Appendices D and E, respectively.

## 2.1 Development of Supply Portfolios

This Final Report explains the overall process used to develop supply portfolios (i.e., the potentially feasible project alternatives) for the GRIP AA.

**Previous Documents:**

1. **Conceptual Options (Appendix D) -** Summarizes existing planning documents, regulatory issues, and legal issues relevant to the GRIP AA process
2. **Project Options (Appendix E) -** Identifies “supply” and “facility” project options from the existing documents in TM-1 that could potentially be used to meet the GRIP AA objectives

**This Document:**

3. **Baseline Conditions -** Constraints and assumptions regarding the Basins are defined and explained to establish the conceptual operating framework for the GRIP alternatives;[2]
4. **Screening Process -** The alternatives development process is described; this includes the previous preliminary screening, a subsequent second level screening, a third level screening process and finally a more detailed characterization using established evaluation criteria; the development of the evaluation criteria is also explained;
5. **Project Alternatives -** Twelve project alternatives are developed using the previously identified project options; these project alternatives are characterized using the evaluation criteria;
6. **Supply Portfolios -** The project alternatives are combined together into supply portfolios and are further investigated using the evaluation criteria;

---

[1] The phrase “project alternatives” is used to refer both to the single projects developed in Section 5 and the potentially feasible project alternatives characterized in Sections 7 and 8. The dual use of this phrase is intended to preserve continuity of terms with previous GRIP AA documents.

[2] Some of the more detailed aspects of the operations will be evaluated as part of the CEQA/NEPA effort and during facilities planning.

7. **Potentially Feasible Supply Portfolios –** Portfolios are characterized, including outstanding issues and next steps needed.

## 2.2 Reason for Portfolio Approach

The "portfolio approach" recognizes that a diverse combination of supply sources is preferred to achieve the GRIP objectives and that these supply combinations are best evaluated for cost-effectiveness and other criteria by integrating them over time. For this reason, the Water Evaluation and Planning (WEAP) model is used to integrate the various project alternatives, costs, energy, timing, and other information into supply portfolios that forecast supply over a 50-year lifecycle. In this way, true program costs and other quantitative measures can be compared.

The portfolio approach also provides more resolution on the assumptions and components of the various projects, and it provides more transparency in the analysis, as opposed to "bundling" the factors into single unit values. In addition, the portfolio approach shows the timing of supplies which in turn clarifies other factors of implementation (e.g., regulatory, institutional, etc.).

# 3 Groundwater Basin Constraints and Assumptions

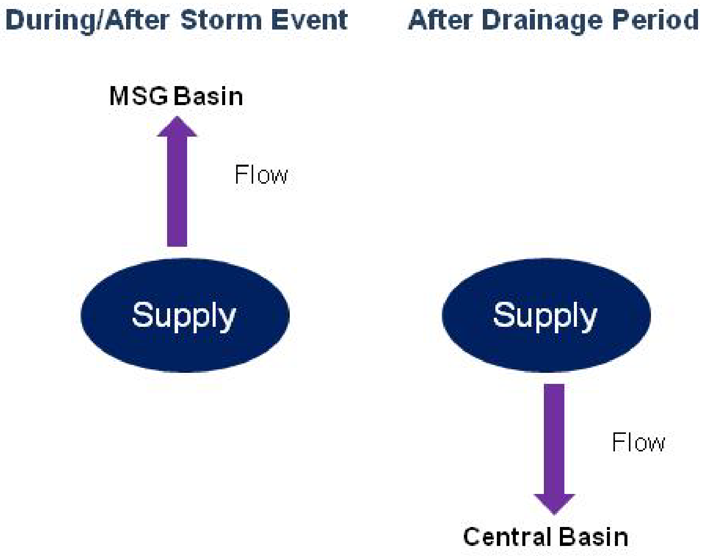
The following Basin constraints and assumptions are defined to establish the operating framework for development of the GRIP alternatives.

## 3.1 Basin Operations Under GRIP Alternatives

Under the alternatives developed for the GRIP project, existing spreading grounds and new injection wells in the MSG Basin and Central Basin could be used to recharge between 9,000 and 25,000 AFY of water in the MSG Basin and between 9,000 and 21,000 AFY of water in the Central Basin. The Santa Fe Spreading Grounds (SFSG) was assumed to be the recharge location in the MSG Basin due to its available percolation capacity. The Montebello Forebay Spreading Grounds (MFSG)[3] was assumed to be the recharge location in the Central Basin because of existing replenishment operations that are conducted with stormwater, imported water, and recycled water. Injection wells could also potentially be used to allow continuous operations in areas where confined conditions limit surface spreading, to increase recharge capacity in unconfined areas, or to increase operating flexibility in both Basins.

Following periods of heavy rainfall, stormwater runoff is plentiful, making year-round, continuous recharge of recycled water or other sources of water infeasible. Accordingly, it is assumed based on information provided by the WRD and Los Angeles County Department of Public Works (LACDPW) that the SFSG and MFSG can be operated in a flexible manner whereby the SFSG will be used preferentially following storms, receiving the flows that cannot be accepted at the MFSG (Johnson, 2010; Willardson, 2010). Once the MFSG basins begin to drain, recycled water flows would be preferentially directed back to these basins such that the goal of recharging up to the maximum of 25,000 AFY in the MSG Basin and 21,000 AFY in the Central Basin can be achieved. The analysis in this report was completed using monthly percolation data for the spreading grounds. Further investigation as part of a facilities plan is needed to assess the daily/weekly available capacities of the spreading basins and to optimize replenishment operations. This assumption is shown conceptually in **Figure 2**.

**Figure 2: Use of Both Basins to Provide Operational Flexibility**



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[3] The San Gabriel Spreading Grounds (SGSG) and the Rio Hondo Spreading Grounds (RHSG) are collectively known as the Montebello Forebay Spreading Grounds (MFSG).

## 3.2 Main San Gabriel Basin

This section summarizes existing hydrogeologic conditions, recharge operations, and sources of water supply in the MSG Basin.

The MSG Basin is hydrogeologically well suited for surface spreading or injection of replenishment water. The basin is mostly unconfined and highly permeable. More coarse-grained sands and gravels are found in the northern portion of the basin and along the San Gabriel River, while relatively more fine-grained alluvial layers alternate with coarse-grained units in the southern portion of the basin. These laterally continuous fine-grained units create semi-confined to confined conditions in the south, which limit opportunities for surface spreading.

On a regional scale, groundwater flows from the northern and eastern perimeters of the basin to the south and southwest toward the basin outlet to the Central Basin at Whittier Narrows. In the western portion of the basin, groundwater generally flows westward toward a major cone of depression caused by groundwater pumping in the southwestern quadrant of the basin.

The MSG Basin is currently managed under the Main San Gabriel Judgment (MSG Judgment) to maintain water levels in the Baldwin Park Key Well between 200 and 250 feet above mean sea level (MSL), referred to as the basin operating range. The operating safe yield for extraction and the available storage capacity for recharge vary from year to year based on the water level in the Key Well and other considerations.

The usable storage capacity in the operating range is approximately 400,000 AF (Superior Court of State of California for the County of Los Angeles, 1989). Between fiscal year (FY) 1999-00 and 2008-09, the operating safe yield averaged 205,000 AFY, and the available storage capacity for recharge averaged 250,000 AFY (MSGBW, 2010).

Groundwater production is typically greater than the safe yield, resulting in a replenishment obligation and providing the need for increased recharge. From 1999-00 to 2008-09, groundwater accounted for an average of 86 percent of the potable water supply in communities overlying the MSG Basin, with imported water and surface water diversions making up the remainder. Groundwater production from the MSG Basin has averaged about 250,000 AFY over the last ten years (FY 1999-00 to 2008-09) (MSGBW, 2010); indicating production has exceeded the safe yield by an average of 41,000 AFY.[4] Under the MSG Judgment, when groundwater pumping exceeds the operating safe yield, pumpers are assessed a replenishment fee by the Watermaster to fulfill replenishment requirements for the basin.

LACDPW operates 16 off-stream spreading facilities as well as in-stream facilities in the San Gabriel River that recharge local runoff and imported water to the MSG Basin. The off-stream facility with the highest recharge capacity is the SFSG. Historically, the SFSG has received both local runoff and imported water.

The total volume of water recharged in the MSG Basin varies from year to year, based on precipitation, conserved stormwater, and the availability of imported water, but has averaged about 153,000 AFY over the last 10 years (FY 1999-00 to 2008-09). On average, local runoff accounted for 73 percent of the recharge water, while imported water accounted for 27 percent (LACDPW, 2010).

Several issues must be considered when evaluating potential recycled water recharge projects in the MSG Basin, including:

- Basin adjudication
- Available percolation capacity
- Dilution water

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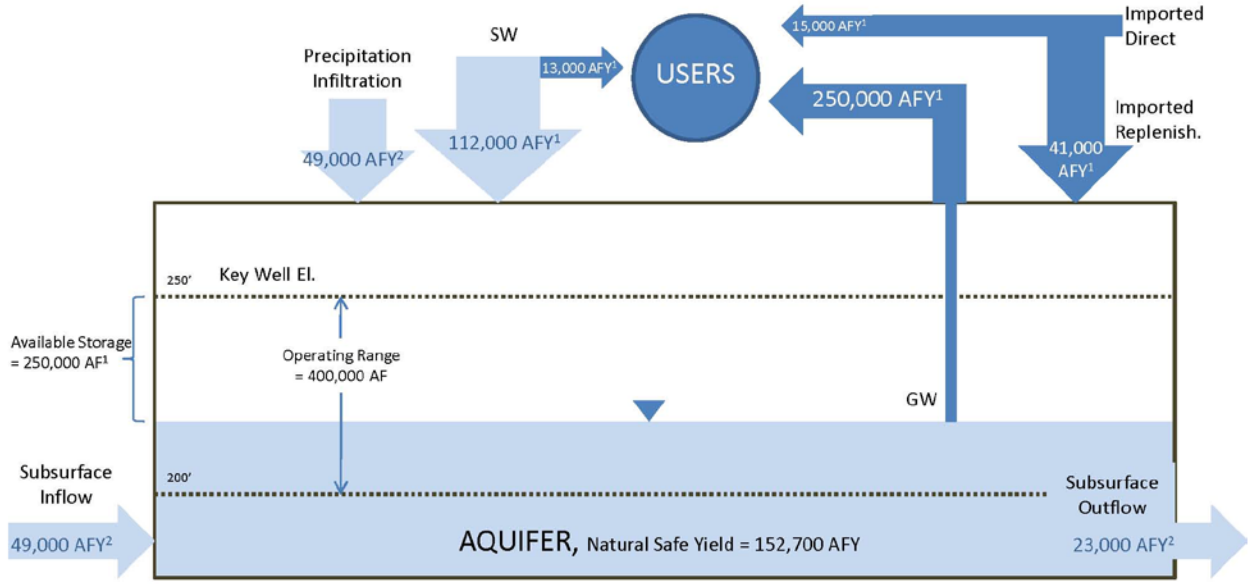
[4] This value for imported water differs from the GRIP objective of 25,000 AFY for the MSG Basin because it was set according to perceived tertiary recycled water supply limitations and not by replenishment demand.

- Residence time
- Mounding
- Water quality
- Injection wells
- Costs

These issues are discussed below. A schematic diagram of the MSG Basin water balance is shown in **Figure 3**.

**Figure 3: Main San Gabriel Basin Water Balance**



Notes:

1. Average values, 1999-2009, LACDPW data and reports and Watermaster reports
2. Average values, 1978-2003, GeoMatrix, Comprehensive Groundwater Model Report, July 2005

Several issues must be considered when evaluating potential recycled water recharge projects in the MSG Basin including the requirements of basin adjudication, available percolation capacity, dilution water, residence time, mounding, water quality, injection wells, and costs. These issues are discussed in further detail below.

### 3.2.1 Adjudication

The MSG Basin is an adjudicated basin. Accordingly, there is a specific court order that governs pumping rights, basin replenishment obligations, and other operating parameters, some with implications for GRIP alternatives.

In January 1973, the Judgment for the MSG Basin was recorded setting forth the basin's adjudicated water rights; developing the concept of Operating Safe Yield; establishing assessments to pay for administration, replenishment, and management; and creating the Watermaster. Since 1973, the MSG Basin judgment has been amended to allow for groundwater quality remediation and protection programs and the use of up to 30,000 AFY of recycled water for supplemental/replacement water. Under this amendment, up to 30,000 AFY of recycled water can be recharged in the basin. Currently, no recharge of recycled water is taking place. Additional amendments to the judgment are currently being proposed to allow more flexibility in the operation and management of the basin.

Specifically applicable to the GRIP alternatives, an amendment is being considered to remove the water level limit in the Key Well to allow recharge operations when the water level is above 250 ft MSL. Over the most recent ten year period for which there is data, water levels have risen above the 250 ft MSL level about 2 percent of the time. Our analysis assumes that judgment amendments will be implemented to allow recharge when water levels exceed 250 ft MSL in the Key Well.

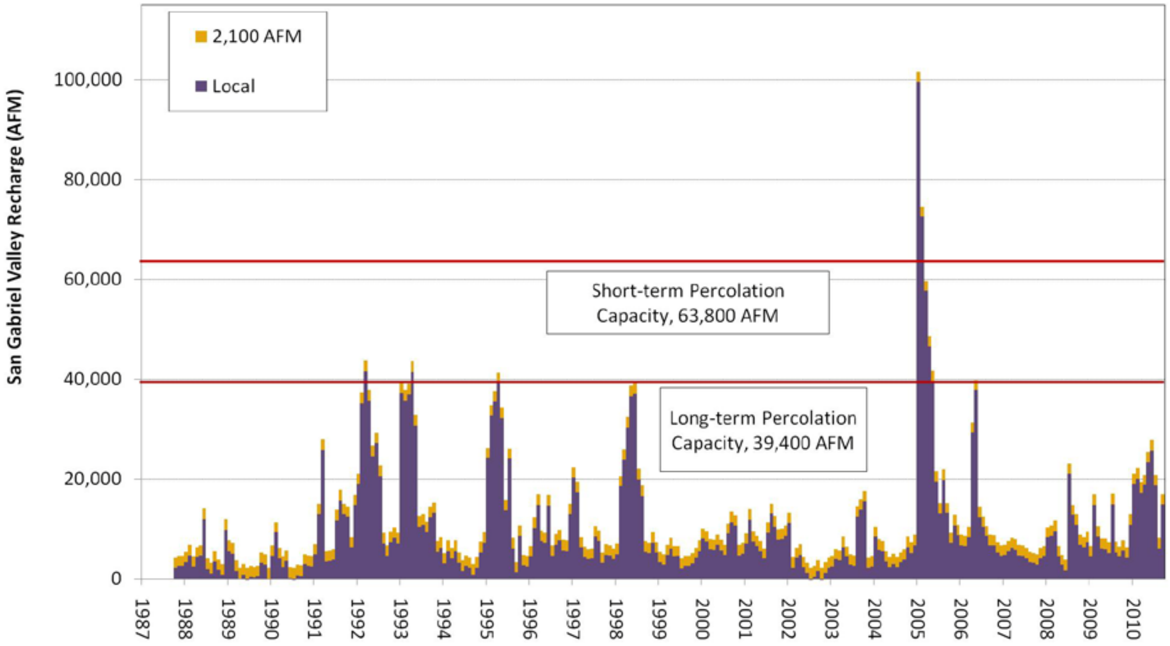
### 3.2.2 Available Recharge Capacity

#### MSG Basin Percolation Capacity

The use of existing spreading facilities offers the most readily accessible option for the recharge of additional water in the MSG Basin. This section discusses the current existing recharge capacity in the basin and the impacts of the GRIP alternatives.

The total short-term capacity and long-term recharge capacity of all the facilities in the MSG Basin are approximately 63,800 acre-feet per month (AFM) and 39,400 AFM, respectively (Stetson, 2007). Long-term capacity (i.e. more than 1 year) incorporates time needed to take facilities out of service for maintenance and vector control (due to standing water). Short-term capacity does not. **Figure 4** shows historical spreading in MSG Basin with imported water replaced with GRIP water assuming that sufficient blend water could be provided by local stormwater ("local" in figure). Based on the figure, the short-term recharge capacity of the basin has only been exceeded in two months over 23 years, or less than 1 percent of the time. Long-term percolation capacity was exceeded three times for a one-month period and one time for five consecutive months during the 23-year timeframe.

**Figure 4: Spreading in MSG Basin--Replacing Imported Water with GRIP Water (25,000 AFY; 2,100 AFM)**



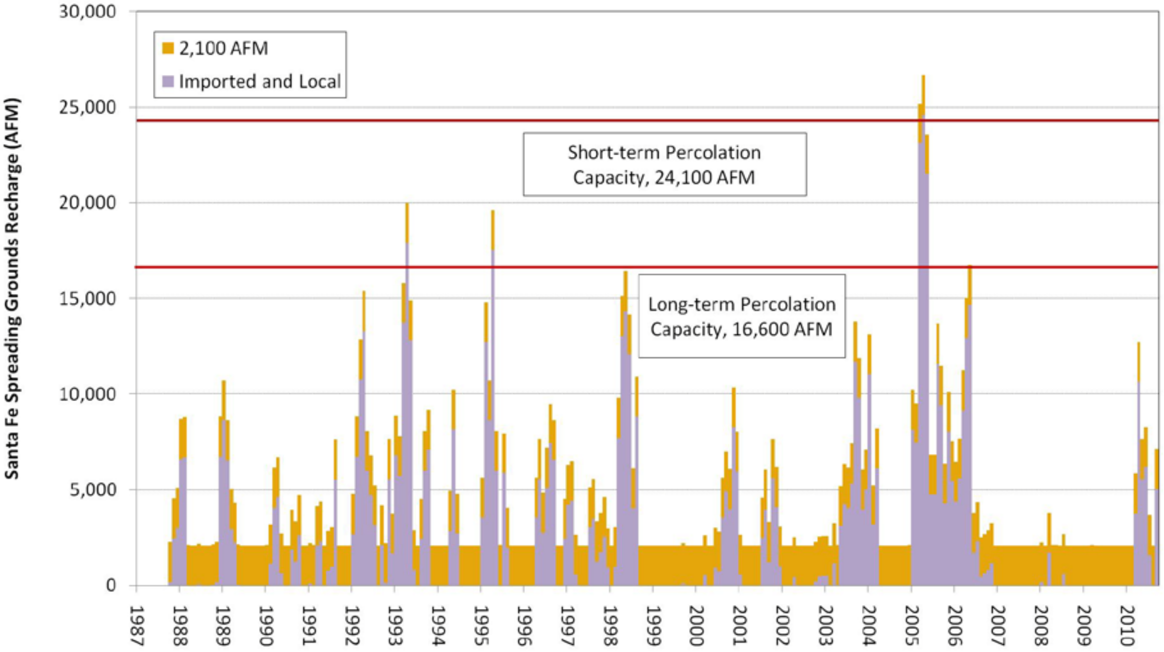
#### SFSG Percolation Capacity

The SFSG, the facility with the largest percolation capacity in the MSG Basin, has estimated short-term and long-term recharge capacities of 24,000 AFM and 17,000 AFM, respectively (Stetson, 2007). The LACDPW records the total acre-feet recharged by month at the SFSG but does not break out the individual amounts of imported and local water recharged. A location map of the SFSG is shown in **Figure 5**.

**Figure 5: SFSG Location Map**

**Figure 6** shows historical spreading, including combined imported and local stormwater in the SFSG relative to the short- and long-term recharge capacities. An additional 25,000 AFY (or 2,100 AFM) is added to the historical flows to illustrate how potential GRIP operations could impact the recharge capacity. Note that this figure represents a conservative scenario because it still contains imported water flows. Based on the values in the figure, the short-term recharge capacity of the SFSG would only be exceeded in two months out of 23 years, or less than 1 percent of the time.

**Figure 6: Spreading at the SFSG with GRIP Water (25,000 AFY; 2,100 AFM)**



Based on **Figure 6**, the SFSG has the capacity to recharge 25,000 AFY (2,100 AFM) of GRIP water in addition to stormwater and imported water (which is to be replaced by GRIP water). Moreover, the SFSG could potentially recharge the maximum GRIP flow of 46,000 AFY (3,833 AFM) more than 99 percent of the time, based on the short-term capacity and historical flows.

### 3.2.3 Dilution Water

This section presents a brief summary of existing regulatory requirements for groundwater recharge (GWR) dilution flows and explains the assumptions made about allowable recycled water contributions (RWCs) required for tertiary and advanced water treatment (AWT) recharge projects. This section also provides an estimate of available dilution flows at the SFSG and explains the assumptions made about how RWC could be implemented over time in the development of GRIP alternatives that use recycled water. Finally, this section includes a brief discussion of potential impacts to groundwater underflow to the Central Basin.

#### Regulatory Requirements

Regulatory constraints on recharge with recycled water must be considered for the MSG Basin, in particular the requirements governing new projects. For purposes of estimating the allowable volumes of recycled water and required dilution water, the requirements set forth in the California Department of Public Health (CDPH) August 2008 Draft Groundwater Recharge Regulations (Draft Recharge Regulations) have been applied (CDPH, 2008). These draft requirements may evolve as CDPH adopts final regulations to meet the December 31, 2013 deadline specified in Water Code Section 13562(a)(2). The Draft Recharge Regulations specify that a new project using tertiary-treated recycled water for recharge via spreading would have to start at an RWC of 20 percent or lower. The RWC is defined as quantity of recycled water applied at the GWR project divided by the sum of the recycled water and dilution water.

The Draft Recharge Regulations allow for projects to establish a higher RWC after the first year of operation provided that specific requirements are met. The most challenging are: (1) total organic carbon

(TOC) levels in the recycled water or in the recycled water after soil aquifer treatment (SAT) that are commensurate with the desired RWC[5]; and (2) that monitoring wells have a specified amount of recycled water.[6]

SAT involves percolation of recycled water through a recharge basin and subsequent extraction through recovery wells. SAT includes treatment in the vadose (unsaturated) zone of the underlying aquifer and storage within the saturated zone of the underlying aquifer. No information on SAT performance is available for the SFSG. If the SAT performance is comparable to that achieved in the MFSG, an established tertiary project could have an allowable RWC of 35 percent to 38 percent or higher (see discussion of MFSG SAT performance in Section 3.3.3). If SAT cannot attain the desired RWC, then the Draft Recharge Regulations allow for the use of AWT (reverse osmosis [RO] and advanced oxidation [AOP]) on that portion of the recycled water needing additional treatment to meet the TOC limit. The AOP must provide, at minimum, a level of treatment equivalent to a 1.2 log N-nitrosodimethylamine (NDMA) reduction and a 0.5 log 1.4-dioxane reduction. Other types of advanced treatment would have to be approved by CDPH under the Alternatives Section of the Draft Recharge Regulations, which allows for alternatives if they assure an equivalent level of public health protection.

For recycled water surface spreading projects with RO/AOP (AWT) applied to all recycled water for recharge, the Draft Recharge Regulations allow for a project’s initial maximum RWC to be up to 50 percent. The Draft Recharge Regulations require AWT for any type of injection project and allow the initial RWC to be up to 50 percent. For projects using AWT, the Draft Recharge Regulations allow for the initial RWC to be increased after the first years of operation using the same criteria described above for a tertiary project; however, the TOC achieved by AWT is not a limiting factor since it is typically less than 0.5 mg/L.

Compliance with the authorized RWC is determined based on the running monthly average RWC, which is the total volume of recycled water and dilution water applied for the preceding 60 months. For surface spreading and injection projects in operation less than 60 months, calculation of the running monthly average of RWC starts after 30 months of operation, based on the total volume of the recycled water and dilution water for the preceding months. So for startup, the compliance determination would begin after 30 months.

### RWC Assumptions

For the purposes of this analysis, allowable RWCs are assumed to increase over time for GWR projects as shown in **Figure 7**. For a CDPH-approved AWT project, it is assumed that the initial RWC would be 50 percent and that it could gradually be increased to 100 percent over ten years. For a tertiary project, it is assumed that the initial RWC would be 20 percent and that it could be increased to 50 percent over ten years.[7] It should be noted that these RWC assumptions would need to be re-evaluated as regulatory requirements evolve.

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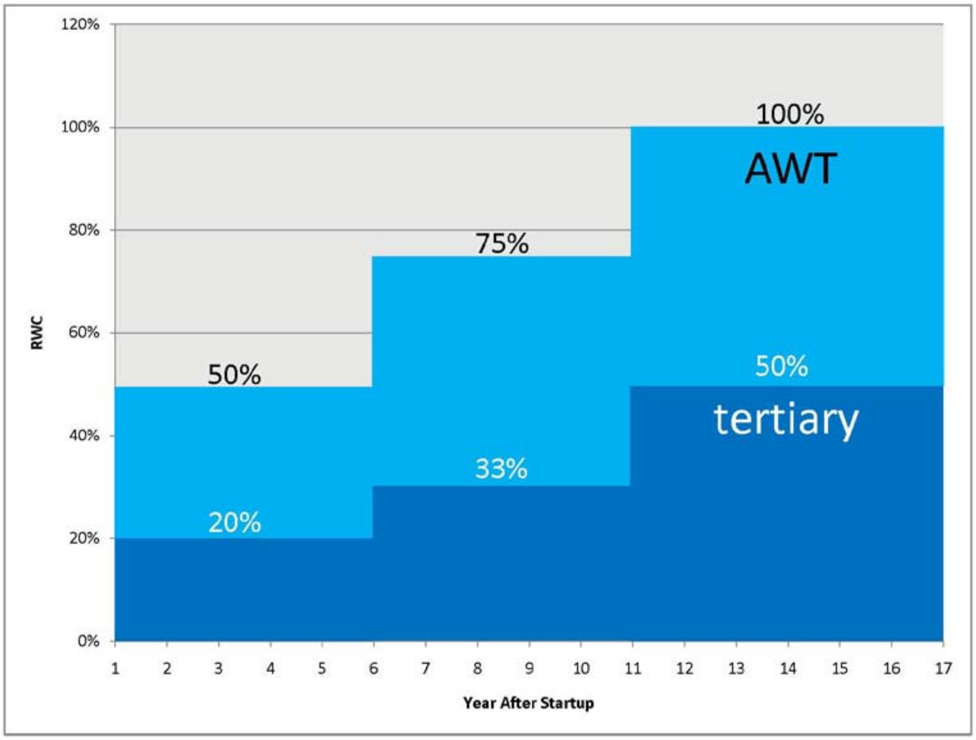
[5] To increase the RWC, the 20-week running average TOC cannot exceed 0.5 milligrams per liter (mg/L) ÷ $RWC_{proposed}$ based on the previous 52 consecutive weeks. This applies to the recycled water (no dilution allowed).

[6] For at least six months such that the fraction of the recycled water in a monitoring well equals a value of at least 0.5 multiplied by $RWC_{proposed}$; and for at least one year such that the fraction of the recycled water in a monitoring well equals a value of at least 0.8 multiplied by the permitted $RWC_{maximum}$.

[7] These assumptions were based on the analysis for the MFSG Combined RWC in Section 3.3.3.

Figure 7: Assumed RWCs for GWR Projects in the MSG Basin



Note: RWC assumptions will need to be re-evaluated as regulatory requirements evolve.

Using these assumptions, for a recycled water recharge volume of 25,000 AFY in the MSG Basin, an AWT project would require no dilution (blend) water after ten years while a tertiary project would require approximately 25,000 AFY of blend water after ten years.

## RWC Implementation

The following analysis presents the potential implementation of recycled water GWR projects at the SFSG, including the likelihood of having sufficient dilution flows. It assumes that projects in the MSG Basin would start up with a recycled water recharge volume of 9,000 AFY (the lower end of the range for the GRIP objectives). Historical data were assessed to determine if there is typically enough dilution water available at the SFSG to support GWR projects. RWC values are measured based on a 60-month rolling average as specified in Section 60320.041(a) of the Draft Recharge Regulations.

This analysis assumes that the GRIP recycled water recharge alternatives would move toward establishing a higher RWC after the first few years of operation as shown in **Figure 7**. The alternatives also assume that the recycled water portion would be fully expanded to 25,000 AFY by the year 2025.

To estimate the average available dilution flow for the SFSG, it is necessary to estimate the local stormwater contribution to the recharge operation. The average local stormwater and imported water recharged at the SFSG between 1992 and 2010 (60-month running average period) was 2,813 AFM, or 33,756 AFY (LACDPW, 2010). Using the average breakdown of local stormwater and imported water for the MSG Basin (73 percent is stormwater), 25,000 AFY of dilution flow is available on average.[8] This value is used in the dilution water discussions for AWT and tertiary projects below. Other potential dilution water sources such as groundwater underflow have not been identified at this time.

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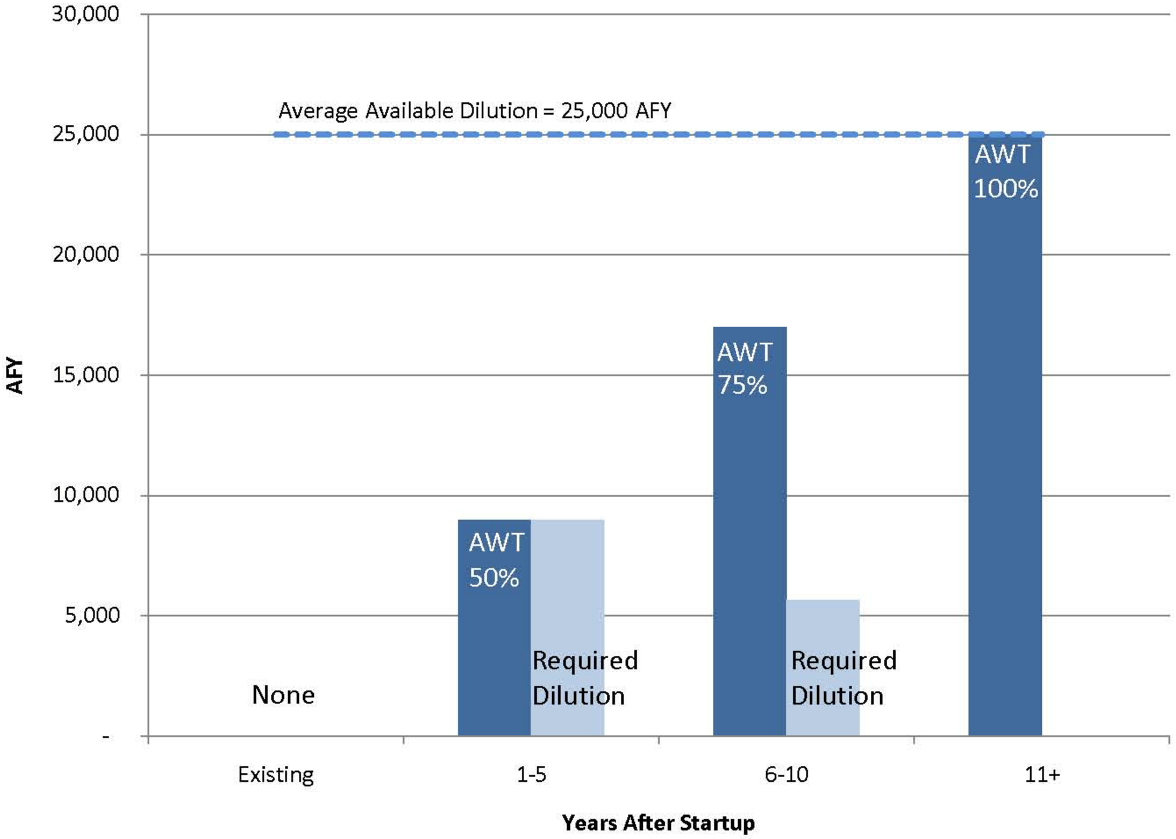
[8] It is a coincidence that the average available dilution flow to SFSG matches the GRIP objective for the MSG Basin.

## AWT Project

**Figure 8** shows the assumed implementation over time of a GWR project that uses AWT recycled water. The figure uses a start-up volume of 9,000 AFY of AWT water and an initial RWC of 50 percent based on **Figure 7**. The RWC and the volume of recycled water gradually increase over time until a 25,000 AFY project with a RWC of 100 percent is achieved after ten years. **Figure 8** indicates that, on average, there would be sufficient available stormwater dilution flow to implement the project; and after ten years, no dilution flow would be required.

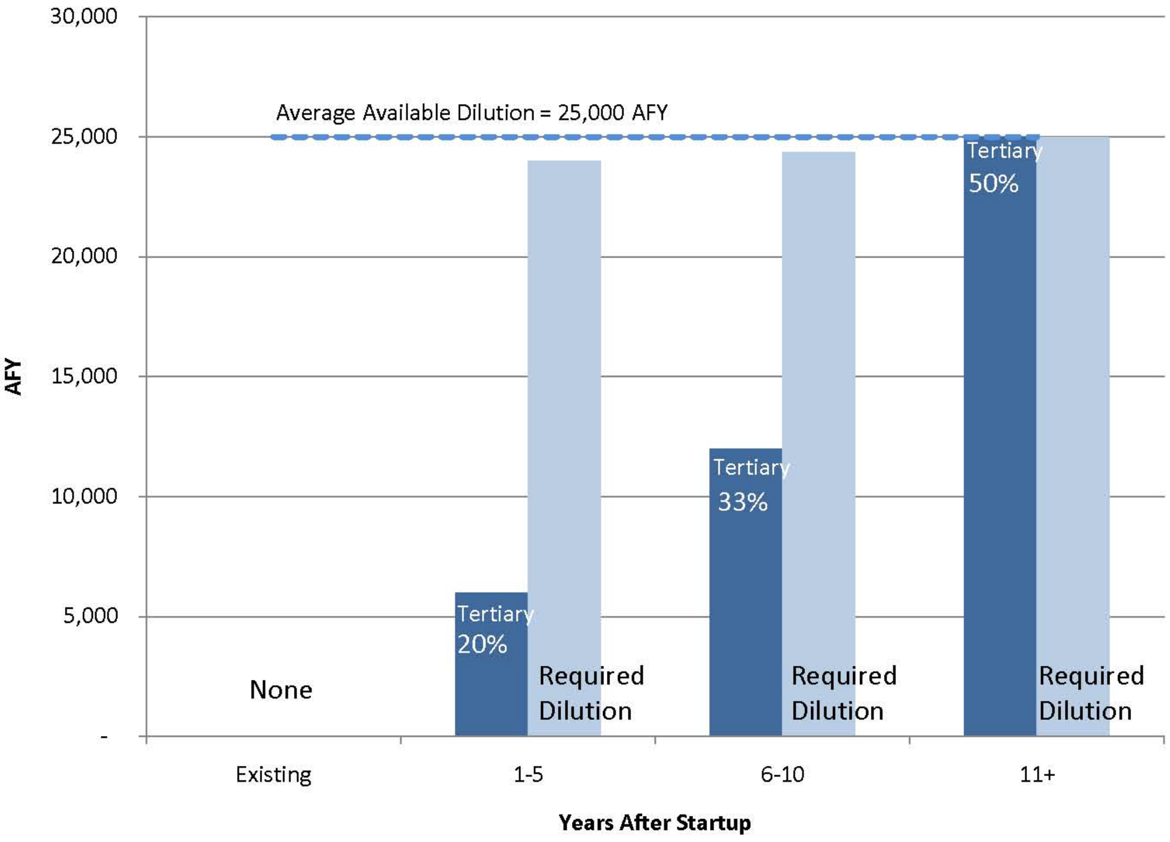
**Figure 8: Comparison of Available Stormwater Dilution Supply with a GWR Project with AWT at the SFSG (25,000 AFY)**



## Tertiary Project

**Figure 9** shows the assumed implementation over time of a GWR project that uses tertiary recycled water. The figure uses a start-up volume of 6,000 AFY of tertiary recycled water (below the lower range of the GRIP objectives) and an initial RWC of 20 percent based on **Figure 7**. The reason for this is that the average available dilution flow of 25,000 AFY is not sufficient to support a tertiary GWR project with an initial recycled water volume of 9,000 AFY and a RWC of 20 percent. The RWC gradually increases over time until a 25,000 AFY project with a RWC of 50 percent is achieved after ten years. **Figure 9** indicates that, on average, there would be sufficient available dilution flow to implement the project; though in some low rainfall years supplemental imported water may be required, as discussed in the next section.

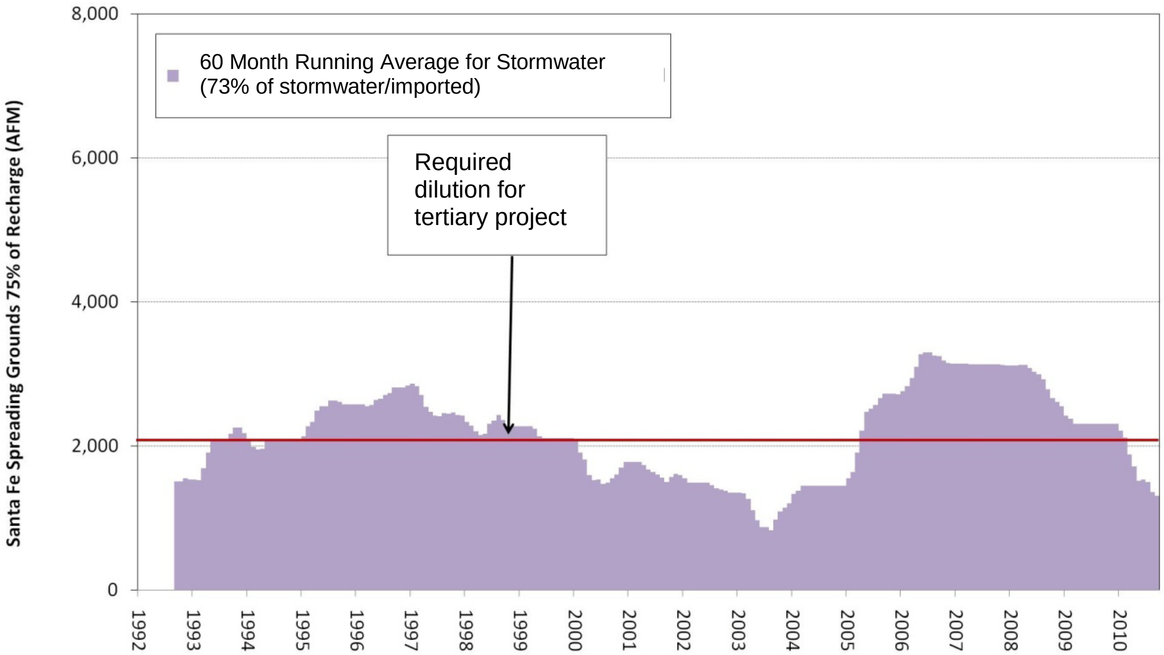
**Figure 9: Comparison of Available Stormwater Dilution Supply with a GWR Project with Tertiary at the SFSG (25,000 AFY)**



__Supplemental Imported Dilution Water for Tertiary Projects__

The required dilution flow for tertiary projects is close to the average available dilution flow of 25,000 AFY. Under actual operating conditions, there would be some 60-month periods when dilution flows would be less than average. Therefore, it is assumed that a GWR project using tertiary water would require the purchase of supplemental imported water in some low rainfall periods. **Figure 10** shows the values for local stormwater from LACDPW historical records with imported flows excluded (i.e., reduced by 27 percent). These values are then compared to the value of 25,000 AFY (2,100 AFM) that would be required for dilution flow under any of the implementation phases shown in **Figure 9**.

**Figure 10: 60-Month Running Average for Historical Stormwater Recharge at SFSG Compared to 25,000 AFY Dilution Requirement for a Tertiary Project**



Notes:

1. Average stormwater is assumed to be 73% of the combined total of local runoff and imported water from Figure 9.
2. These calculations do not include potential dilution water contributions from other storm/surface water replenishment operations in the MSG Basin (other than SFSG), rainfall infiltration, or groundwater underflow. Additional analysis is required to identify other potential dilution water sources.

**Figure 10** demonstrates that a tertiary GWR project would have to purchase between 10 and 1,200 AFM of supplemental imported water approximately 40 percent of the time. This calculates to an average of approximately 2,500 AFY. This amount of purchased imported water is included in the cost estimates for tertiary GWR projects at the SFSG.[9]

### Underflow to Central Basin

Another dilution consideration is that the MFSG, located down-gradient in the Central Basin, currently uses underflow from the MSG Basin as dilution water in determining the allowable RWC under the existing recharge permit. If subsurface flow through the Whittier Narrows contains a portion of recycled water from recharge operations in the MSG Basin, its status as dilution water may be called into question by the CDPH. This analysis assumes that there will be no impacts on the status of underflow used as dilution water in the Central Basin. Further investigation and coordination with CDPH will be necessary to confirm this assumption.

## 3.2.4 Residence Time

Based on the Draft Recharge Regulations, a recharge project must be located so that there is at least a six month underground residence time for the recycled water prior to extraction at a potable water supply well. For planning purposes in siting a groundwater recharge project, a project applicant can estimate

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[9] It may be possible to petition CDPH for a longer averaging period (e.g., 10 years) after a recharge project begins operation.

retention time using various methods approved by CDPH: (1) an intrinsic tracer study may be used to demonstrate a nine month minimum residence time; (2) a tracer study or numerical modeling may be used to demonstrate a 12 month residence time; or (3) analytical calculations (e.g., as Darcy's Law) may be used to demonstrate a 24 month residence time. Once the project is initiated, the six-month residence time must be demonstrated with an "added" tracer test approved by CDPH.

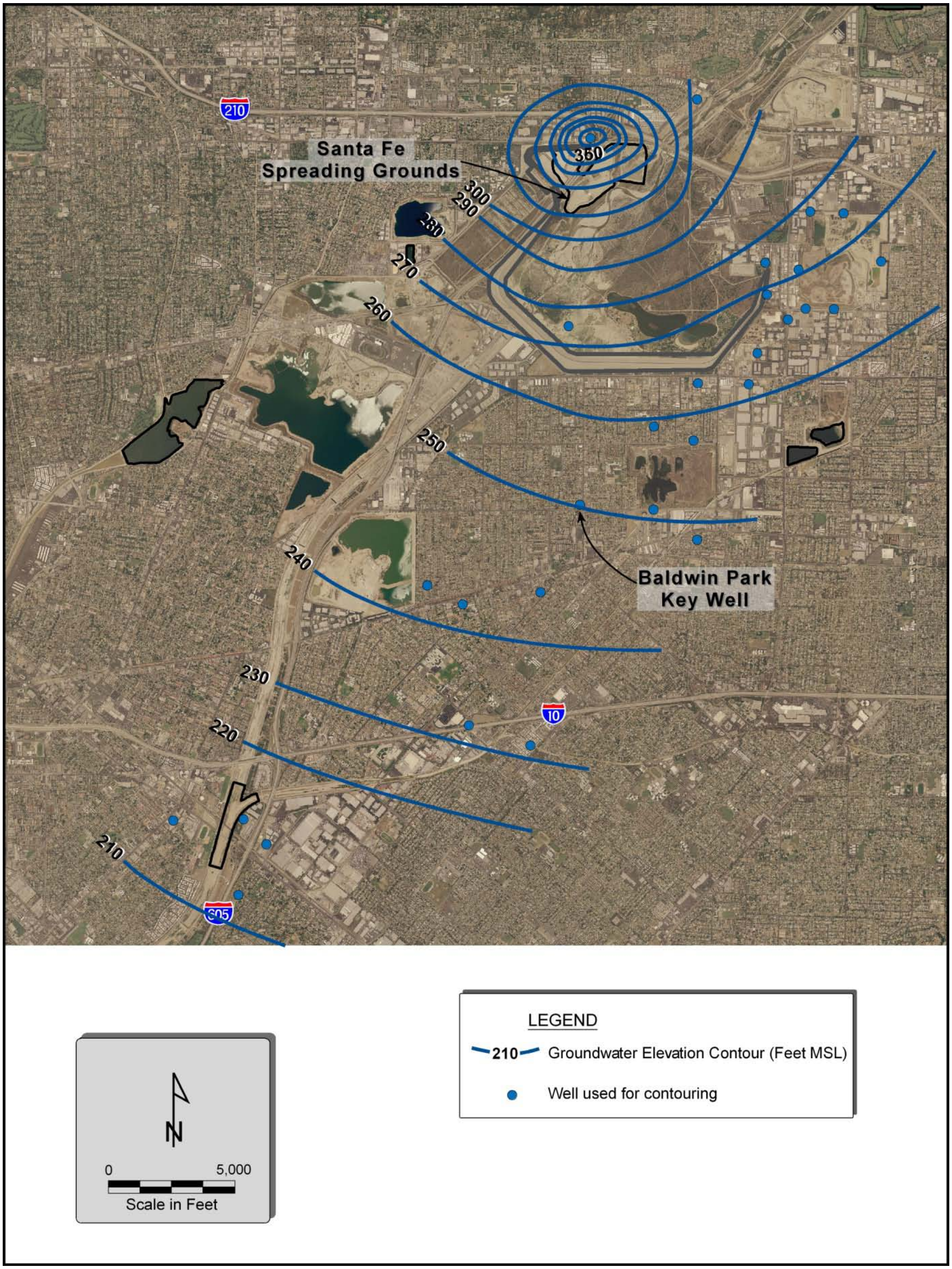
There are a few water supply wells located relatively close to the SFSG. It is assumed that any wells demonstrated to be within six months travel time from the recycled water recharge operation will be removed from service or reconfigured to meet the residence time requirement. Costs for removing, replacing, or modifying production wells are not included in Section 5, but they should be included in future cost estimates if it is determined that some wells fall within the six month boundary.

### 3.2.5 Mounding

Mounding caused by recharge operations has the potential to reduce percolation capacity if water levels rise to near the ground surface. Mounding may also alter groundwater flow directions affecting existing contamination plumes and remedial facilities, and may also impact other operations sensitive to increased groundwater levels.

Year-round recharge operations at the SFSG will result in groundwater mounding in the vicinity of the spreading grounds. Groundwater mounding in the vicinity of the SFSG has the potential to reduce recharge capacity and/or adversely affect gravel mining operations, landfills, other underground facilities, and contamination plumes. **Figure 11** shows a groundwater elevation contour map for Spring 2005. A total of 115,319 AF of water was spread in the SFSG in the water-year 2004-05 (October to September), the highest recharge volume since the spreading grounds have been in operation (LACDPW, 2010b). As shown on the figure, a groundwater mound formed around the spreading grounds.

Figure 11: Groundwater Elevation Contour Map, Spring 2005

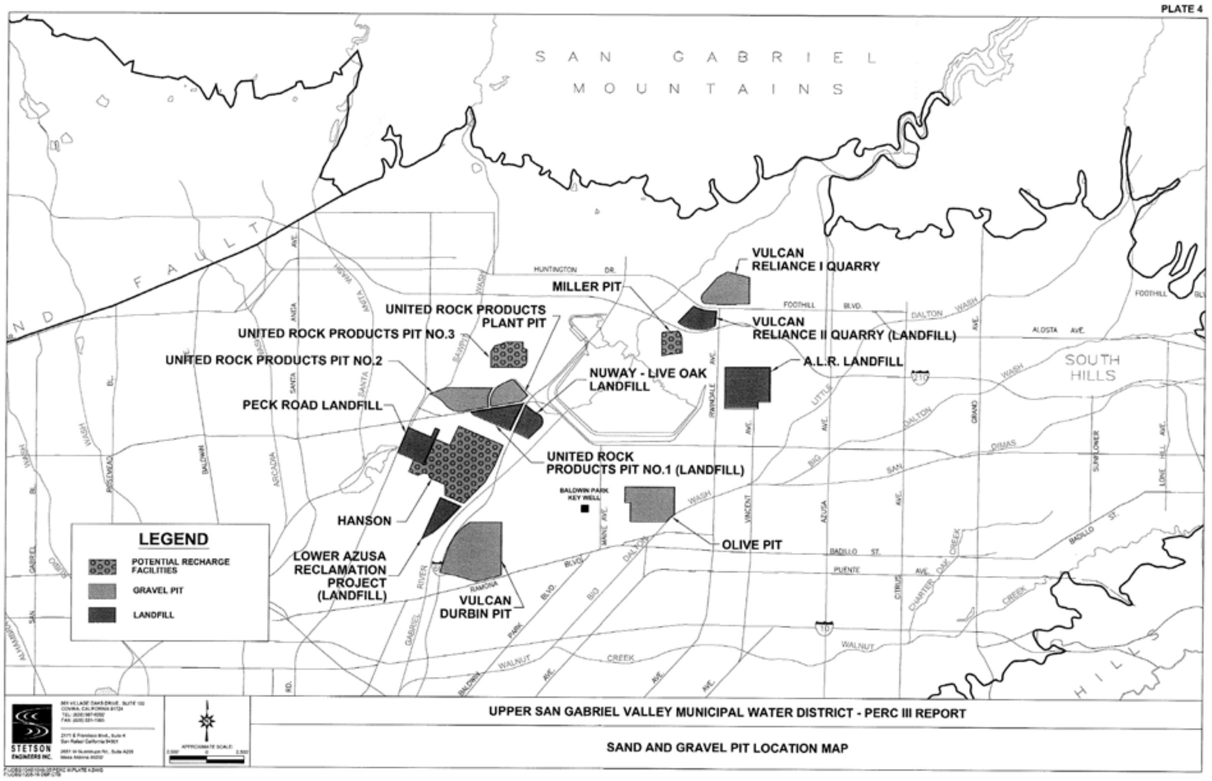


In accordance with the current MSG Basin Judgment, additional water cannot be recharged when the Key Well groundwater elevation exceeds 250 feet MSL. As shown in the figure, the water level in the Key Well was only slightly above 250 feet MSL in Spring 2005. For the purposes of this Alternatives Analysis, it is assumed that an amendment to the MSG Basin Judgment will be approved that will allow water levels to rise above 250 ft MSL.

Recharge capacity at the spreading facilities can be reduced if groundwater levels under the facilities rise too close to the bottom of the spreading basins. Based on the record of recharge and water levels near the SFSG, this is not anticipated to be a problem since even under the unusually high recharge conditions in 2005, there was still approximately 150 feet of unsaturated aquifer beneath the spreading grounds.

There are numerous active and inactive sand and gravel quarries in the San Gabriel Valley that may be impacted by a rise in groundwater levels. **Figure 12** shows the locations of quarries and landfills in the vicinity of the SFSG (Stetson, 2007). While some quarries currently conduct operations below the water table, others are dry pits. In addition, some of the quarry sites have been converted to inert waste landfills.

**Figure 12: Quarry and Landfill Locations**



## 3.2.6 Groundwater Quality

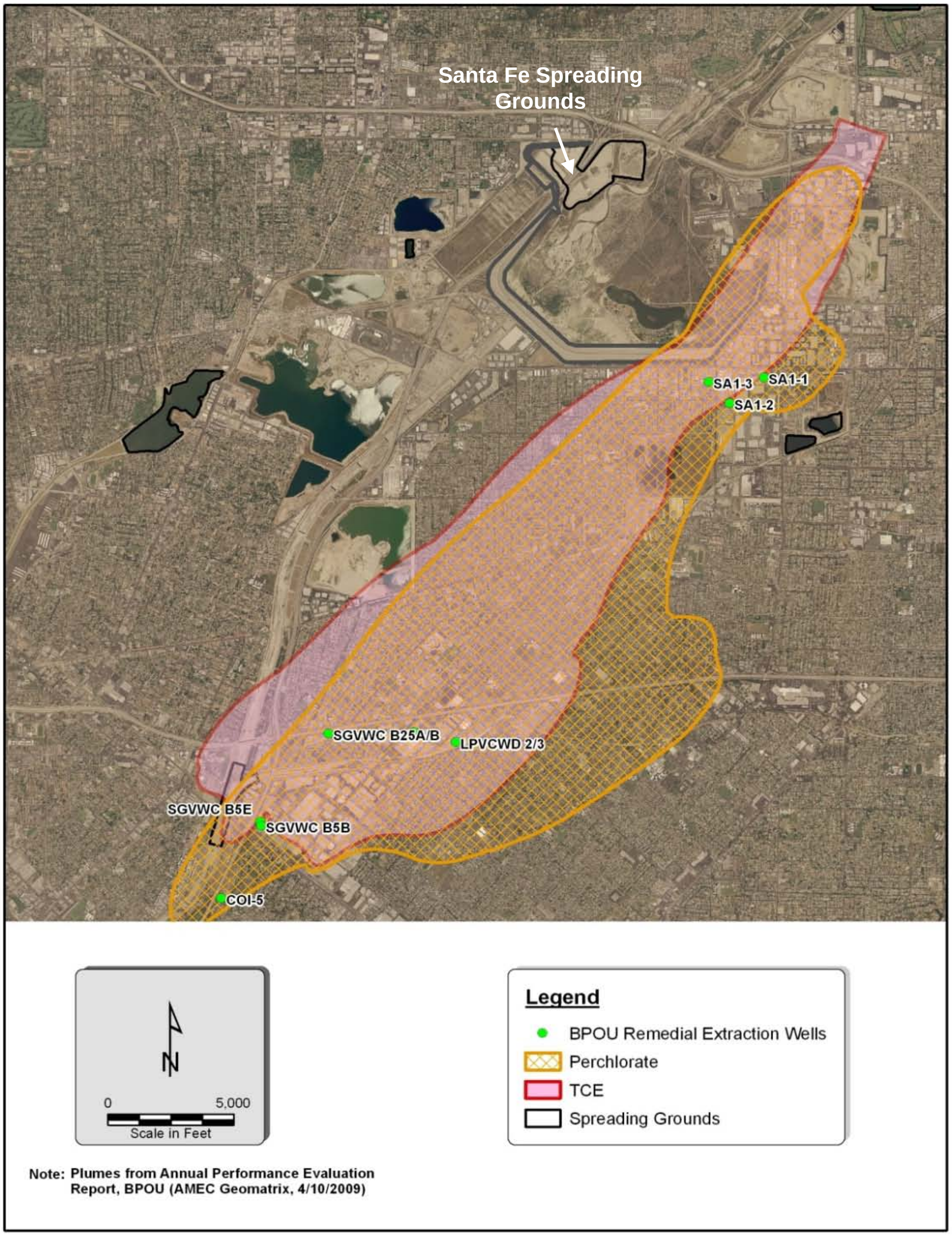
A replenishment project must satisfy the anti-degradation requirements in the SWRCB Recycled Water Policy (SWRCB, 2010) and therefore must consider potential impacts on existing contamination plumes and associated remedial activities (i.e., remedial extraction wells) as well as the dissolution of any naturally occurring contaminants.

While natural groundwater quality in the MSG Basin is good, groundwater quality has been impacted by anthropogenic releases of contaminants resulting in large contamination plumes and multiple areas of contamination regulated by the U.S. Environmental Protection Agency (USEPA) under the federal

Superfund program. These areas require remediation. Groundwater contaminated with volatile organic compounds (VOCs), nitrate, perchlorate, NDMA, 1,4-dioxane, 1,2,3-trichloropropane and tricholoroethylene (TCE) has been detected in the basin. The USEPA has defined several operable units (OU) or areas of contamination in the MSG Basin.

The Baldwin Park Operable Unit (BPOU) is located east of the SFSG and has the potential to be impacted by increased recharge and mounding at the SFSG. **Figure 13** shows the BPOU TCE and perchlorate plumes, BPOU remedial extraction wells, and the SFSG. Based on the location of the northern remedial extraction wells, year-round recharge operations may provide some benefit to the contaminated groundwater by decreasing concentrations through dilution and pushing the northern plume toward the remedial extraction wells. However, replenishment operations can also potentially raise groundwater levels, mobilizing known and potentially unknown basin contamination. Because of the magnitude of investments and potential for changes in basin operations to impact cleanups, there will need to be further consideration of potential impacts to existing contaminant plumes and contaminant dissolution in the MSG Basin as part of the facilities planning process.

**Figure 13: Baldwin Park Operating Unit Plumes**



Note: Plumes from Annual Performance Evaluation Report, BPOU (AMEC Geomatrix, 4/10/2009)

Any GWR project will have to conduct an anti-degradation analysis in conformance with the SWRCB Recycled Water Policy. For the use of tertiary recycled water for GWR, total dissolved solids (TDS) and nitrogen will be critical parameters, since tertiary recycled water contains higher concentrations than the blended imported water (a combination of State Water Project and Colorado River Water) used for replenishment. In determining the level of analysis needed to evaluate potential degradation, it will be necessary to identify the baseline assimilative capacity of the MSG Basin. The derivation of assimilative capacity will likely have to be undertaken by the project sponsors, with agreement from the Los Angeles

Regional Water Quality Control Board (RWQCB), as well as a review of how the project impacts the baseline assimilative capacity. Per the Recycled Water Policy, the anti-degradation analysis is less complex for a project that uses less than 10 percent of the assimilative capacity and more complicated if it uses more. The RWQCB may require this analysis for all regulated constituents detected in recycled water (i.e., comparing groundwater data to Basin Plan limits for regulated compounds such as maximum contaminant levels (MCLs) and mineral constituents) and/or for other constituents of interest. It is not clear how this would impact the maximum RWCs; however, it would also have to be factored into the development and implementation of the salt/nutrient management plan for the basin, also required as part of the Recycled Water Policy.

## 3.3 Central Basin

This section briefly summarizes existing hydrogeologic conditions, recharge operations, and sources of water supply in the Central Basin.

The Central Basin is a layered aquifer system with relatively coarse-grained aquifers alternating with more fine-grained confining units. These conditions limit surface spreading of replenishment water to selected areas of the basin where confining units are thin or absent, such as the Montebello and Los Angeles Forebays. Where confining units exist, injection wells are an alternate feasible means of recharge.

On a regional scale, groundwater flows from the northeast toward the southwest. Existing recharge operations in the Montebello Forebay result in a mounding of the water table and a radial groundwater flow pattern away from the spreading grounds.

The natural safe yield of the basin is 125,805 AFY (MWD, 2007). The historically utilized storage of the basin was 780,000 AF (WRD, 2010), while the available storage is approximately 300,000 AF (MWD, 2007). According to the basin adjudication, the allowable pumping allocation is 217,367 AFY.

Groundwater production from the Central Basin has averaged about 198,000 AFY for the last ten years (1999-00 to 2008-09), imported water deliveries for potable supply have averaged about 159,000 AFY, and recycled water used for non-potable purposes has averaged about 12,000 AFY (this does not include recycled water used for replenishment) (DWR, 2010a). There are no surface water diversions for potable or direct supply in the Central Basin.

Groundwater in the Central Basin is artificially recharged at the Montebello Forebay Spreading Grounds (MFSG) via surface spreading and at the Alamitos Gap Barrier Project via direct injection. There is also one conjunctive use water storage and recovery project in the City of Long Beach.

The Montebello Forebay recharge facilities consist of two off-stream spreading facilities operated by LACDPW, including the Rio Hondo Spreading Grounds (RHSG) and San Gabriel Spreading Grounds (SGSG) and several in-stream facilities in the San Gabriel River for replenishment[10] of recycled water, direct precipitation, local runoff, and imported water.[11] The volume of recharge varies significantly from year to year based on precipitation and availability of imported water, but has averaged 130,000 AFY over the period from 1999-00 to 2008-09, comprised of about 55,000 AFY of local runoff (43 percent), 31,000 AFY of imported water (24 percent)[12], and about 43,000 AFY of recycled water (33 percent) (LACDPW, 2010 and DWR, 2010). A location map for the MFSG is shown in **Figure 14**.

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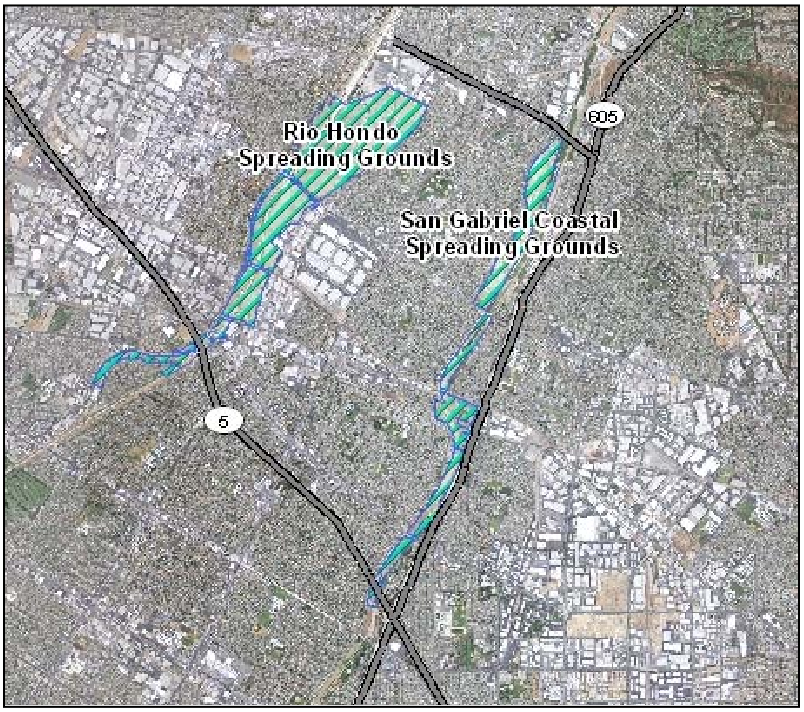
[10] Replenishment water does not include precipitation infiltration or groundwater underflow.

[11] The San Gabriel Spreading Grounds (SGSG) and the Rio Hondo Spreading Grounds (RHSG) are collectively known as the Montebello Forebay Spreading Grounds (MFSG).

[12] This value for imported water differs from the GRIP objective of 21,000 AFY for the Central Basin because a different averaging period was used in previous planning documents.

Figure 14: MFSG Location Map

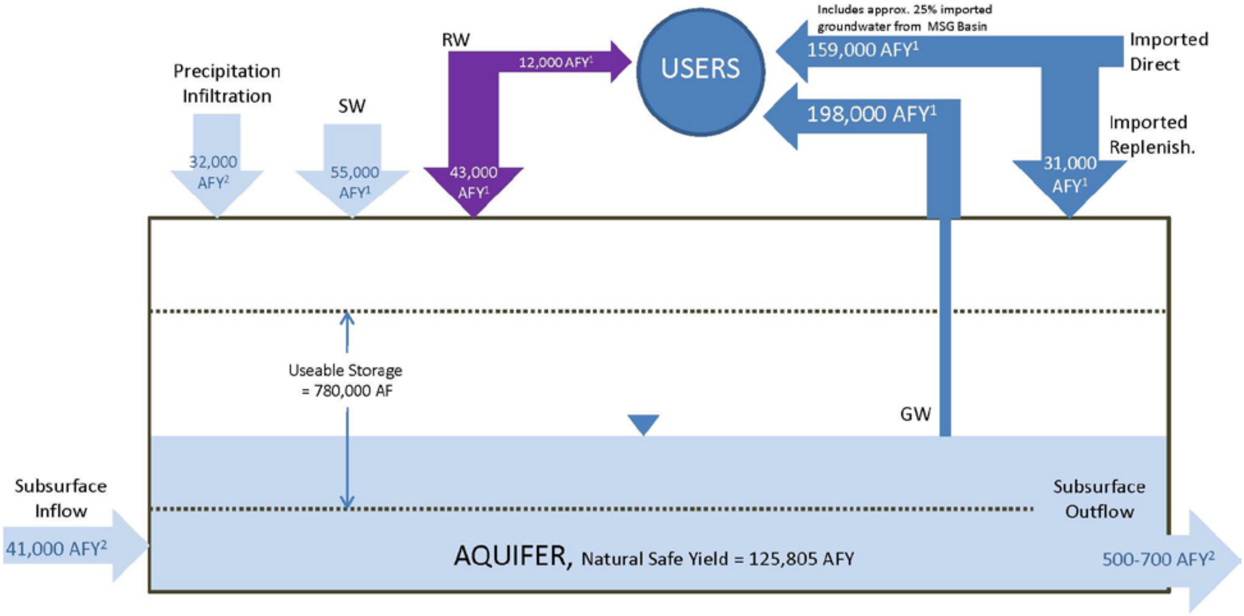


Several issues must be considered when evaluating potential recycled water recharge projects in the Central Basin, including:

- Basin adjudication
- Available percolation capacity
- Dilution water
- Residence time
- Mounding
- Water quality
- Injection wells
- Costs

For the Central Basin, these issues are discussed below. A schematic diagram of the Central Basin water balance is shown in **Figure 15**.

Figure 15: Central Basin Water Balance



Notes:

1. Average values, 1999-2009, LACDPW data and reports and Watermaster reports
2. Average values, 1971-2000, USGS, Water Resources Investigation Report 03-4065, 2003

### 3.3.1 Adjudication

The Central Basin is an adjudicated basin. Accordingly, there is a specific court order that governs pumping rights, basin replenishment obligations, and other operating parameters, some with implications for GRIP alternatives.

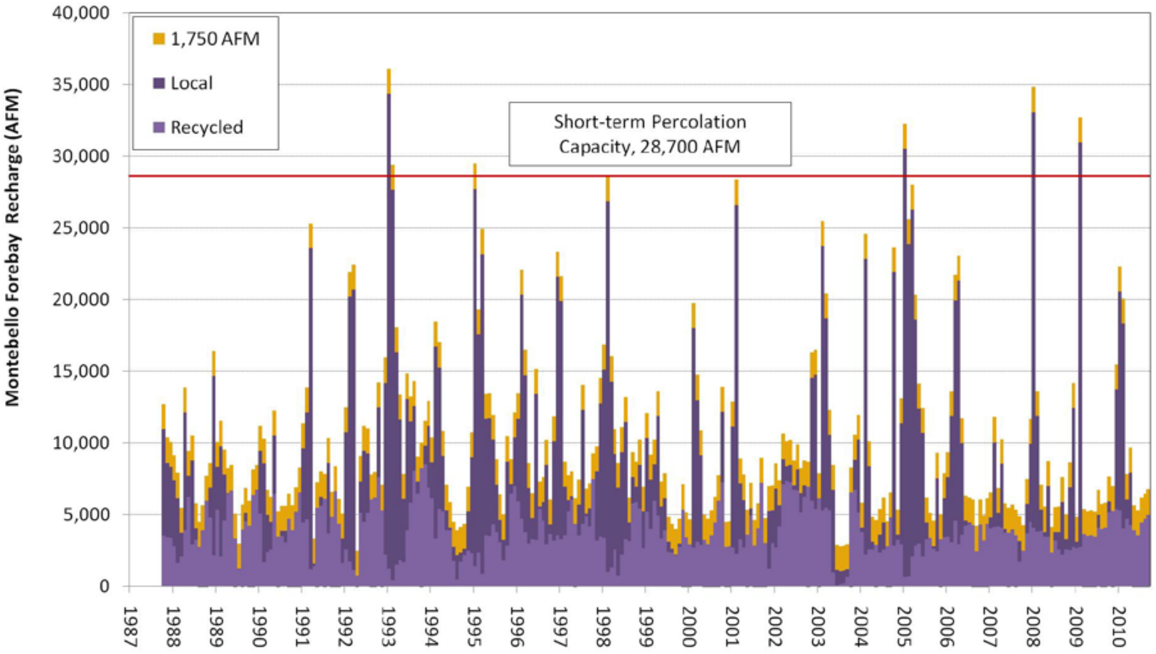
The Central Basin Judgment became effective in October 1966. According to the current judgment, the allowable pumping allocation is 217,367 AFY; and the judgment does not recognize the right to store water nor give pumpers the legal mechanism to pump more than their allocated right. Proposed judgment amendments for the Central Basin would allow greater flexibility in operation of the basin specifically related to storage and pumping needed to support the GRIP alternatives. However, the proposed amendments were opposed by a number of parties, and on July 7, 2010 the Los Angeles Superior Court ruled against the amendments proposed by WRD and other parties. Currently, there is uncertainty as to the next steps as there are major disagreements among some parties. Ultimately, amendments to the Central Basin Judgment may be necessary for some of the GRIP alternatives that include water augmentation projects (i.e., large recharge and recovery projects that exceed the current allowable pumping volumes) to be feasible.

### 3.3.2 Available Recharge Capacity

The use of existing spreading facilities offers the most readily accessible option for the recharge of additional water in the Central Basin. This section discusses the current existing recharge capacity in the basin and the impacts of the GRIP alternatives. The total short-term recharge capacity at the MFSG is approximately 29,000 AFM (LACDPW, 2010). The short-term capacity does not incorporate the time needed to take facilities out of service for maintenance and vector control.

**Figure 16** shows historical spreading at the MFSG relative to the short-term recharge capacity, with imported water removed (leaving only local stormwater and recycled water). Under the assumption that GRIP water would replace imported water, an additional 21,000 AFY (or 1,750 AFM) is added to the figure to illustrate how potential GRIP recharge alternatives could impact the recharge capacity. Based on Figure 16, the short-term recharge capacity of the spreading grounds has been exceeded in five months over the last 22 years, or 2 percent of the time.

**Figure 16: Spreading in Montebello Forebay Spreading Grounds Replacing Imported Water with 21,000 AFY of GRIP Water (1,750 AFM)**



Nonetheless, based on discussions with WRD and LACDPW (Johnson, 2010; Willardson, 2010), the MFSG are operated as stormwater/flood control facilities and the spreading ground intakes are open during and following storm events. As a result, following storm events, the basins fill with local runoff and there is typically no recharge capacity for recycled water for a week following each storm event. Unfortunately, weekly events when the basins are full are not necessarily captured in the monthly data presented in Figure 16. LACDPW estimated that in a typical rainfall year with 8 to 10 storms, the MFSG would be full 8 to 10 weeks. This means that in a normal rainfall year, the basins could be unavailable for GRIP water recharge 15 to 19 percent of the time. To address this limitation, LACDPW has suggested that the SFSG (MSG Basin) and MFSG (Central Basin) could be operated in a flexible manner, moving more recycled water preferentially up to the SFSG in wet periods and to the MFSG in dry periods, while maintaining the operational goal of up to 25,000 AFY and 21,000 AFY in the MSG Basin and Central Basin, respectively (this operating scenario is shown conceptually in Section 3.1).

### 3.3.3 Dilution Water

This section presents a brief summary of the dilution flow requirements for the existing GWR operation at the MFSG and explains the assumptions made about RWCs required for AWT and tertiary recharge projects that would supply recycled water beyond the amount authorized under the existing recharge project. This section also provides an estimate of available dilution flows at the MFSG and explains the assumptions made about how RWCs could be implemented over time in the development of GRIP alternatives that use recycled water.

## Dilution Flow Requirements for Existing Operations

In the Central Basin, recycled water has been successfully used as a source for groundwater recharge via spreading in the Montebello Forebay since 1962. Currently, disinfected tertiary recycled water used for replenishment in addition to engineered stormwater (local runoff and precipitation) and imported water at the spreading grounds. For the purpose of determining the allowable RWC, underflow from the MSG Basin is counted as dilution water. Based on this blend of water, the permit for the GWR project allows for a maximum of 35 percent recycled water to be used for replenishment using a 60-month running average for the total recharge in the MFSG.[13] The amount of recycled water recharged at the spreading grounds will vary from year to year depending on the availability of recycled water, dilution water, and the capacity of the spreading grounds, but overall averaged 43,000 AFY between 1999-00 and 2008-09.

If the existing project were to be modified to use additional tertiary-treated recycled water and increase the RWC above 35 percent, the permit would likely require modification to include provisions to conform to the 2008 Draft Recharge Regulations. A demonstration of TOC compliance is required in order to exceed the authorized RWC.[5]

WRD collected data as part of the 2009 permit amendment that authorized the 35 percent RWC based on a 60-month running average, which can be used to illustrate the potential SAT performance and concomitant $\text{RWC}_{\text{maximum}}$ using tertiary recycled water. Between May 2009 and October 2010 (75 weeks), WRD collected weekly TOC samples in groundwater monitoring wells. Although the results are considered preliminary, the maximum 20-week TOC average observed has varied between the two sets of spreading grounds: 1.3 milligrams per liter (mg/L) for the SGSG and 0.7 mg/L for the RHSG, with a combined average of 0.9 mg/L. These results represent TOC values from infiltrated recycled water, imported water, and stormwater that were recharged at various times over the 75-week period and thus are conservative estimates since TOC removal may be higher when only considering recycled water in the absence of the other replenishment sources. WRD will be performing an analysis in the near future that segregates TOC data into time periods when only recycled water was present, and it is expected that the 20-week average TOC values will be lower, thus allowing for a higher RWC.

CDPH is aware that the spreading grounds appear to have different SAT performances. If the permit were to be revised to allow the use of additional tertiary-treated recycled water, it is not clear if CDPH would establish individual RWCs for the SGSG and RHSG (similar to the approach used for the Chino Basin Groundwater Recharge Project), or continue to allow a combined RWC. Each scenario impacts the amount of additional tertiary-treated recycled water that can be recharged as shown below using the 75-week average TOC performance levels.

Recycled Water Contrib. (RWC) = 0.5 mg/L ÷ $\text{TOC}_{\text{max}}$

San Gabriel S.G. RWC = 0.5 mg/L ÷ 1.3 mg/L = 38 percent

Rio Hondo S.G. RWC = 0.5 mg/L ÷ 0.7 mg/L = 71 percent

Combined RWC = 0.5 mg/L ÷ 0.9 mg/L = 56 percent

The allowable RWCs could be potentially higher if (1) the WRD analysis discussed above establishes higher SAT performance for recycled water infiltration; or (2) CDPH allowed the use of Biodegradable Organic Carbon (BDOC) in lieu of TOC in the calculation. The use of BDOC would require approval of

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[13] The Montebello Forebay recharge permit was substantively revised in 1987 with amendments in 1991 and 2009. It does not include many of the provisions in the 2008 Draft Recharge Regulations.

an expert panel, which is expected to convene in 2011.[14] WRD has conducted additional research to document BDOC removal.

Another consideration is whether underflow from the MSG Basin containing recycled water will count as dilution water in the RWC calculation for Central Basin. CDPH currently allows underflow to be utilized as dilution water for the MFSG. Informal discussions regarding the use of groundwater containing recycled water as dilution water were held in 2008 as part of the CDPH Work Group convened to work on the Draft Recharge Regulations. For GRIP, the available volume of dilution water could be reduced for Central Basin if recycled water used in the MSG Basin for GWR disqualifies underflow from the MSG Basin to Central Basin as allowable dilution water for Central Basin. In addition, if individual RWCs are established for the RHSG and SGSG, then it would be necessary to derive a method for calculating the available dilution water contribution for each set of spreading grounds, including underflow. This analysis assumes that there will be no impacts to the status of underflow used as dilution water in the Central Basin.

In addition to using tertiary treated water for recharge via surface spreading, it would also be possible to recharge recycled water via injection wells which would require the entire recycled water stream to be treated using RO and AOP (or another CDPH approved AWT alternative). In the initial stages, recharge projects using injection wells could be required to blend dilution water above-ground before the recycled water is injected.

## RWC Assumptions

Currently, the MFSG in the Central Basin is permitted to recharge up to 35 percent tertiary-treated recycled water of the total recharge. As discussed above, preliminary 20-week average TOC data indicate that a RWC up to 56 percent may be allowed based on the combined spreading grounds' performance. For the purpose of this analysis, a maximum RWC of 50 percent for GWR projects with tertiary-treated recycled water was assumed based on the maximum RWC allowable under the Draft Recharge Regulations.

For the purposes of this analysis, allowable RWCs are assumed to increase over time for GWR projects with AWT and stay constant for GWR projects with tertiary, as shown in **Figure 17**. For an AWT project, it is assumed that the initial RWC would be 50 percent and that it could gradually be increased to 100 percent over ten years. For a tertiary project, it is assumed that the initial RWC of 35 percent for the existing project could be increased to 50 percent based on the analysis described above (or possibly as high as 56 percent for MFSG). It should be noted that these RWC assumptions would need to be re-evaluated as regulatory requirements evolve and additional monitoring data is collected.

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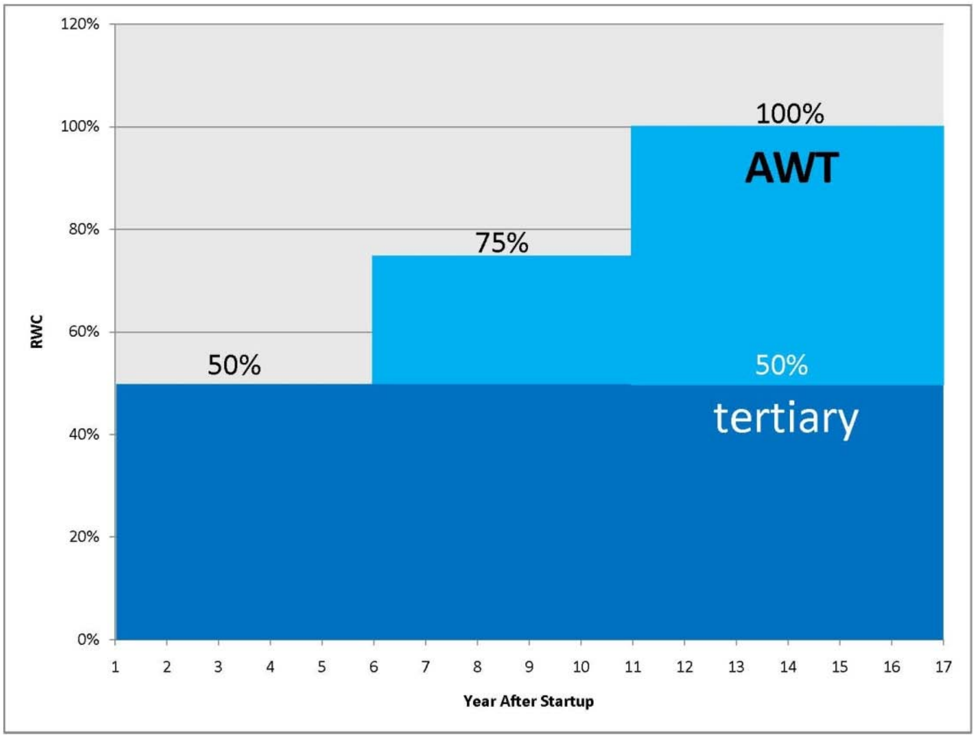
[14] Personal communication with Jeff Mosher, NWRI, December 14, 2010.

**Figure 17: Assumed RWCs for GWR Projects in the Central Basin**



Note: RWC assumptions will need to be re-evaluated as regulatory requirements are established by CDPH and the RWQCB.

Using these assumptions, for a recycled water recharge volume of 21,000 AFY in the Central Basin, an AWT project would require no blend water after ten years while a tertiary project would require approximately 21,000 AFY of blend water after ten years (in addition to blend requirements for the existing tertiary GWR operation).

It is important to note that for an AWT project, a methodology for calculating RWC compliance using two types of recycled water (AWT and tertiary) would have to be developed with CDPH and further consideration would have to be given regarding spreading basin operations/management to optimize TOC removal when infiltrating two types of recycled water.

## Available Dilution Flows

The following analysis is presented to demonstrate the likelihood of having sufficient dilution flows during the initial start-up of a new GWR project at the MFSG using AWT and tertiary recycled water. It assumes that projects in the Central Basin would start up with a recycled water recharge volume of 9,000 AFY (the lower end of the range for the GRIP Objectives) and a RWC of 50 percent for AWT or tertiary recycled water.

With the current permitted recycled water volume (50,000 AFY) and RWC (35 percent), it is assumed that average available dilution flows are approximately 93,000 [(50,000/0.35) – 50,000] AFY. This calculation assumes that all of the available dilution flow is required for the existing GWR operation at MFSG. Using the GRIP estimate of 21,000 AFY for average imported water recharged to the Central Basin, approximately 72,000 AFY is available, on average, from all other dilution flow sources.

For additional AWT or tertiary flows to be recharged, the allowable RWC must be increased above 35 percent for the existing tertiary recycled water that is replenished. Historical data were assessed to determine if there is typically enough dilution water available at the MFSG to support an expansion of the existing GWR project with AWT, assuming the RWC for tertiary GWR projects could be increased to 50 percent based on the analysis above.

## RWC Implementation

This analysis assumes that the GRIP recycled water recharge alternatives would progress toward establishing progressively higher RWCs for GWR projects with AWT as shown in **Figure 17**. The alternatives also assume that the recycled water portion would be expanded to 21,000 AFY by 2025.

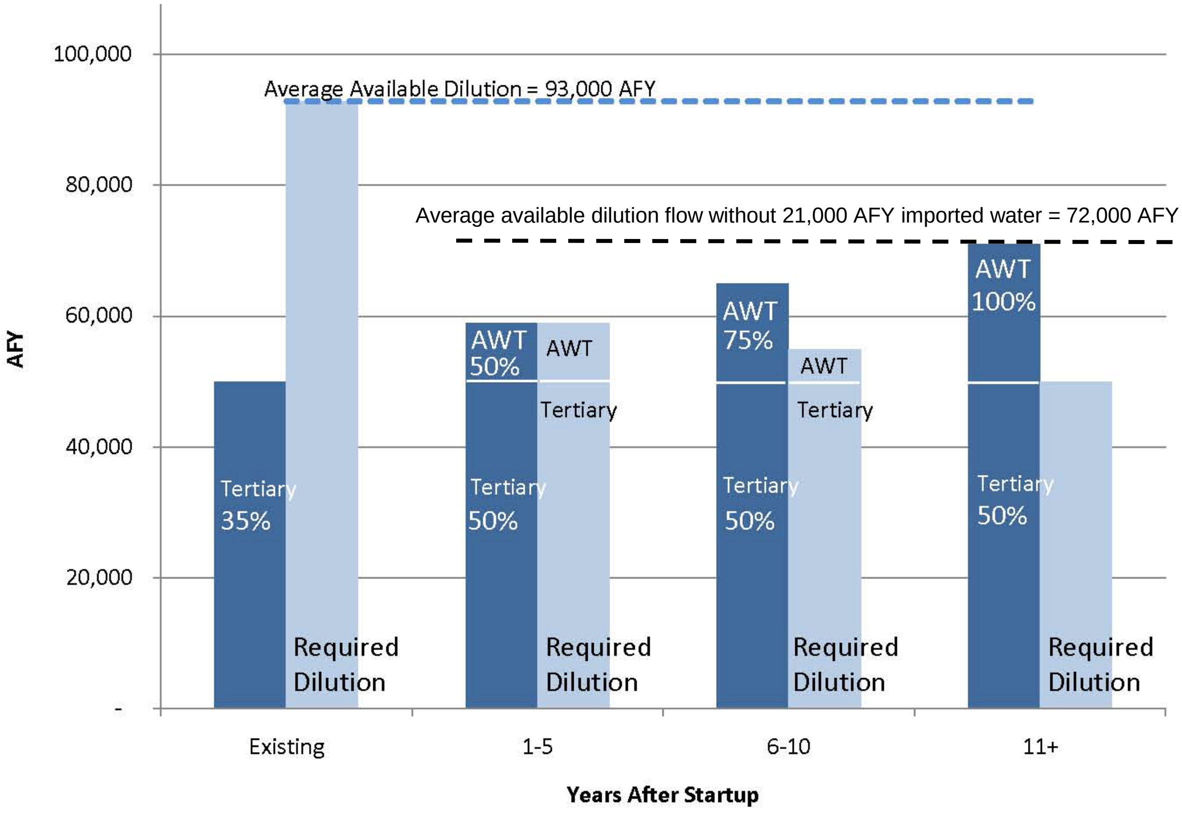
To determine the average available dilution flow for the MFSG, an estimate of the allowable dilution flows permitted for the existing recharge operation is needed. As calculated previously, the current GWR project is permitted for 50,000 AFY of tertiary recycled water at a 35 percent RWC. This is equivalent to approximately 93,000 AFY of average available dilution flow (or 72,000 AFY without imported water).

### AWT Project

**Figure 18** shows the assumed implementation over time of a GWR project that uses AWT recycled water, beginning with the existing 50,000 AFY (maximum) tertiary recharge project at the MFSG. Available dilution flows including imported water are shown for the existing project, and available dilution flows not including imported water are shown for future projects.

The figure uses a start-up AWT volume of 9,000 AFY and an initial RWC of 50 percent based on **Figure 17**. The RWC and the volume of recycled water gradually increase over time until a 21,000 AFY project is achieved after ten years. **Figure 18** indicates that, on average, there would be sufficient available dilution flow to implement the project during all phases.

**Figure 18: Comparison of Available Dilution Supply with an AWT GWR Project at the MFSG (21,000 AFY)**



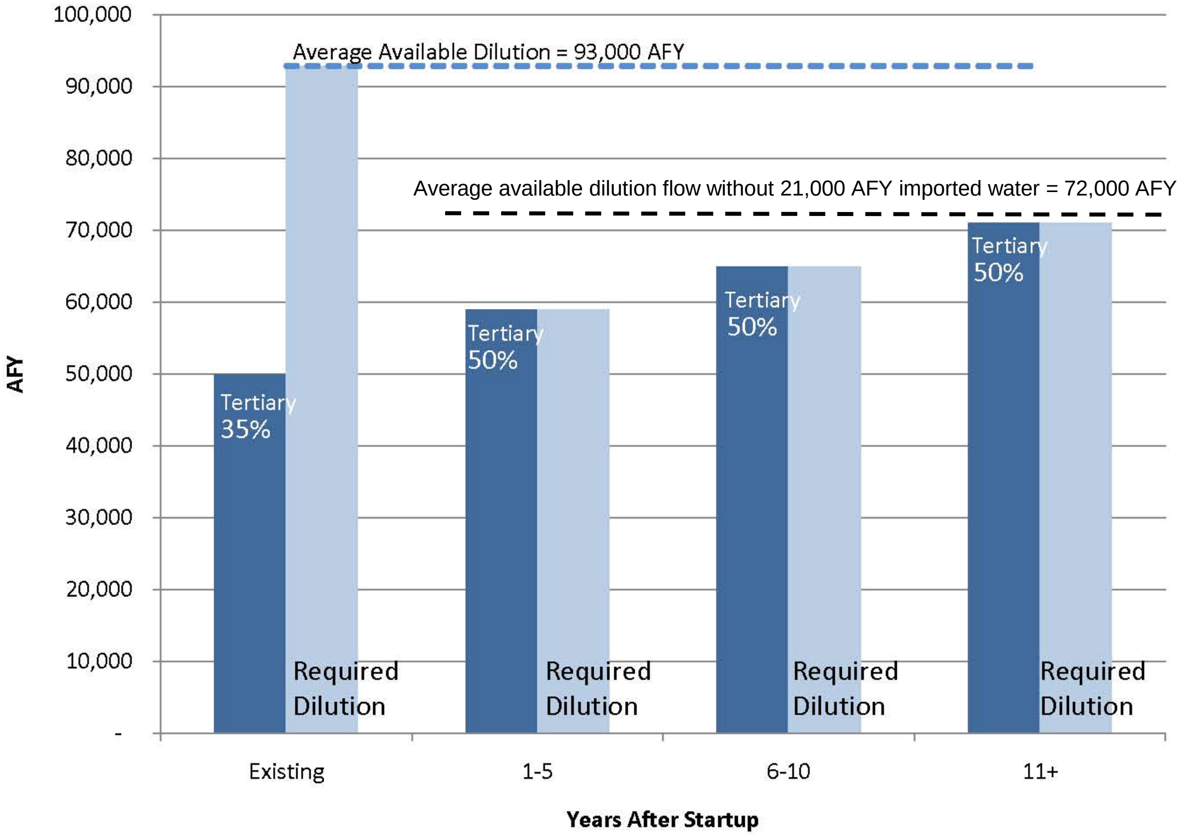
**Tertiary Project**

**Figure 19** shows the assumed implementation over time of a GWR project that uses tertiary recycled water. The tertiary project would be an expansion of the existing tertiary operation at MFSG. Available dilution flows including imported water are shown for the existing project, and available dilution flows not including imported water are shown for future projects.

The figure uses a start-up volume of 9,000 AFY of tertiary recycled water and an initial RWC of 50 percent, based on **Figure 17**. The volume of recycled water gradually increases over time until a 21,000 AFY project is achieved after ten years. **Figure 19** indicates that, on average, there would be sufficient available dilution flow to implement the project during most of the phases.

There could potentially be an issue during the final phase when required dilution approaches 71,000 AFY (close to the average available dilution of 72,000 AFY); however, for the purposes of this analysis it is assumed that adjustments to the allowable RWC up to 56 percent could be made at MFSG and that no additional imported water would need to be purchased for dilution.

**Figure 19: Comparison of Available Dilution Supply with a Tertiary GWR Project at the MFSG (21,000 AFY)**



## 3.3.4 Residence Time

Based on Draft Recharge Regulations, a GWR project must be located so that there is at least a six month underground residence time for the recycled water prior to extraction at a potable water supply well. For planning purposes in siting a groundwater recharge project, a project applicant can estimate retention time using a method approved by CDPH: (1) an intrinsic tracer study must be used to demonstrate a nine month minimum residence time; (2) a tracer study or numerical modeling can be used to demonstrate 12 months; or (3) analytical calculations (such as Darcy's Law) can be used to demonstrate 24 months residence time. Once the project is initiated, six months residence time must be demonstrated with an "added" tracer test.

Since the MFSG have been recharging recycled water since 1962, the issue of travel time to the nearest water supply wells has been addressed in numerous studies, including tracer tests conducted to estimate travel times to nearby water supply wells. Tracer tests demonstrated that two water supply wells were located within the six-month travel time from recycled water recharge basins, these wells were modified to seal off the upper screened intervals. This change allowed the wells to meet the travel time requirements, as demonstrated by subsequent tracer tests. It is not anticipated that the addition of 21,000 AFY of GRIP water will result in any additional wells falling within the six-month travel time, but additional analyses are required to verify.

### 3.3.5 Mounding

Mounding caused by recharge operations has the potential to reduce percolation capacity if water levels rise to near the ground surface. Mounding may also alter groundwater flow directions, affecting existing contamination plumes and remedial facilities and may impact other operations sensitive to increased groundwater levels.

Groundwater elevation contour maps are prepared by WRD for their annual Regional Groundwater Monitoring Reports for the Central and West Coast Basins. These maps show a relatively consistent mounding of the water table in the vicinity of the MFSG. While the Central Basin recharge operations are not limited by a Key Well elevation limit like the MSG Basin, elevated water levels near the MFSG do have the potential to reduce the unsaturated zone and percolation capacity. Records of water levels in shallow monitoring wells near the MFSG show water levels frequently rising to within 10 to 15 feet of the ground surface. This roughly corresponds to the depth of the basins, indicating that the unsaturated zone is reduced to the extent that percolation capacities are adversely impacted.

As discussed in Section 3.1, it is anticipated that the SFSG and MFSG can be operated flexibly in a manner such that the SFSG will be used preferentially following storms, receiving more of the recycled water flows. Once the MFSG basins begin to drain, recycled water flows would be directed back to these basins with the goal of meeting the maximum recharge goals of 25,000 AFY in the MSG Basin and 21,000 AFY in the Central Basin.

### 3.3.6 Groundwater Quality

A replenishment project must satisfy the anti-degradation requirements in the Recycled Water Policy, and therefore must consider potential impacts on existing contamination plumes and associated remedial activities (i.e., remedial extraction wells), as well as the dissolution of any naturally occurring contaminants.

The confined layering in the Central Basin has provided it with a greater degree of natural protection from surface releases of contaminants as compared to the MSG Basin. Overall, the groundwater in the Central Basin is of high quality and suitable for potable and non-potable uses without treatment. There is a shallow VOC plume, located southeast of the SGSG, associated with the former Omega Chemical Corporation parcel. However, it is not anticipated that the additional GRIP water will alter the already radial groundwater flow direction in the area enough to have a significant impact on the plume.

Any GWR project will have to conduct an anti-degradation analysis in conformance with the SWRCB Recycled Water Policy. For the use of tertiary recycled water for recharge, TDS and nitrogen will be critical parameters since tertiary recycled water contains higher concentrations than the imported water used for replenishment. In determining the level of analysis needed to evaluate potential degradation, it will be necessary to identify the baseline assimilative capacity of the Central Basin. The derivation of assimilative capacity will likely have to be undertaken by the project sponsors, with agreement from the

RWQCB, as well as a review of how a project impacts the baseline assimilative capacity. The anti-degradation analysis is less complex for a project that uses less than 10 percent of the assimilative capacity and more complicated if it uses more. The RWQCB may require this analysis for all regulated constituents detected in recycled water (i.e., comparing groundwater data to Basin Plan limits for regulated compounds, such as MCLs and mineral constituents) or other constituents of interest. It is not clear how this would impact the maximum RWCs; however, it would have to be factored into the development and implementation of the salt/nutrient management plan for the basin, also required as part of the Recycled Water Policy.  WRD is currently the development of this plan for the Central Basin.

## 3.4 Key Basin Assumptions for GRIP Alternatives Analysis

This section summarizes the key basin assumptions based on the analysis conducted in Section 3.

### Main San Gabriel Basin

- In the MSG Basin, the SFSG will be used for groundwater recharge due to available capacity
- The SFSG has the percolation capacity to recharge 25,000 AFY
- Percolation capacity at the SFSG will not be reduced by rising groundwater levels that could result from GRIP recharge activities
- Pending judgment amendments for the MSG Basin, when (or if) adopted, will allow groundwater recharge when water levels exceed 250-ft MSL in the Baldwin Park Key Well (this is currently not allowed under the existing adjudication)
- For recharge projects that use tertiary recycled water, the RWC requirement will be 20 percent at start-up, then 33 percent after five years, and then 50 percent after ten years
- For recharge projects that use AWT recycled water, the RWC requirement will be 50 percent at start-up, then 75 percent after five years, and then 100 percent after ten years
- GRIP alternatives that use recycled water will start in the year 2015 at 9,000 AFY and expand to 25,000 AFY by the year 2025
- For the tertiary recycled water projects, approximately 2,500 AFY of supplemental imported water would need to be purchased on average throughout the lifespan of the project
- Recycled water recharge projects in the MSG Basin will not impact the status of underflow used as dilution water in the Central Basin
- Any wells demonstrated to be within six months travel time from recycled water recharge will be removed from service, or modified
- To provide a conservative estimate, this analysis does not include groundwater underflow as dilution water as is currently allowed in the Central Basin

### Central Basin

- In the Central Basin, the MFSG will be used for groundwater recharge because of the existing spreading facility operation that has historically recharged recycled water
- In a normal rainfall year, the MFSG basins could be unavailable for GRIP alternative water recharge 15 to 20 percent of the time; therefore year-round, continuous recharge of water at MFSG is not feasible
- During and after heavy rainfall periods, the SFSG can receive flows that cannot be accepted at the MFSG; surplus water would be moved preferentially up to the SFSG in wet periods and to the MFSG in dry periods to make up for the time that MFSG is not available
- Pending Central Basin Judgment amendments would be necessary to implement GRIP alternatives that include water augmentation projects (i.e., large recharge and recovery projects that exceed the allowable pumping volumes under the current adjudication)

- Recycled water recharge projects in the MSG Basin will not impact the status of underflow used as dilution water in the Central Basin
- The RWC requirement will be increased from 35 percent to 50 percent for the existing recharge project that uses tertiary recycled water
- For recharge projects that use tertiary recycled water, the RWC requirement will be 50 percent at start-up and will remain at 50 percent, or potentially increase to 56 percent at MFSG
- For recharge projects that use AWT recycled water, the RWC requirement will be 50 percent at start-up, then 75 percent after five years, and then 100 percent after ten years
- GRIP alternatives that use recycled water will start in the year 2015 at 9,000 AFY and expand to 21,000 AFY by the year 2025
- For the tertiary recycled water projects, no supplemental imported water would need to be purchased for the lifespan of the project
- Additional recharged GRIP water will not alter the flow direction of the shallow VOC plume located southeast of the San Gabriel Spreading Grounds enough to have a significant impact

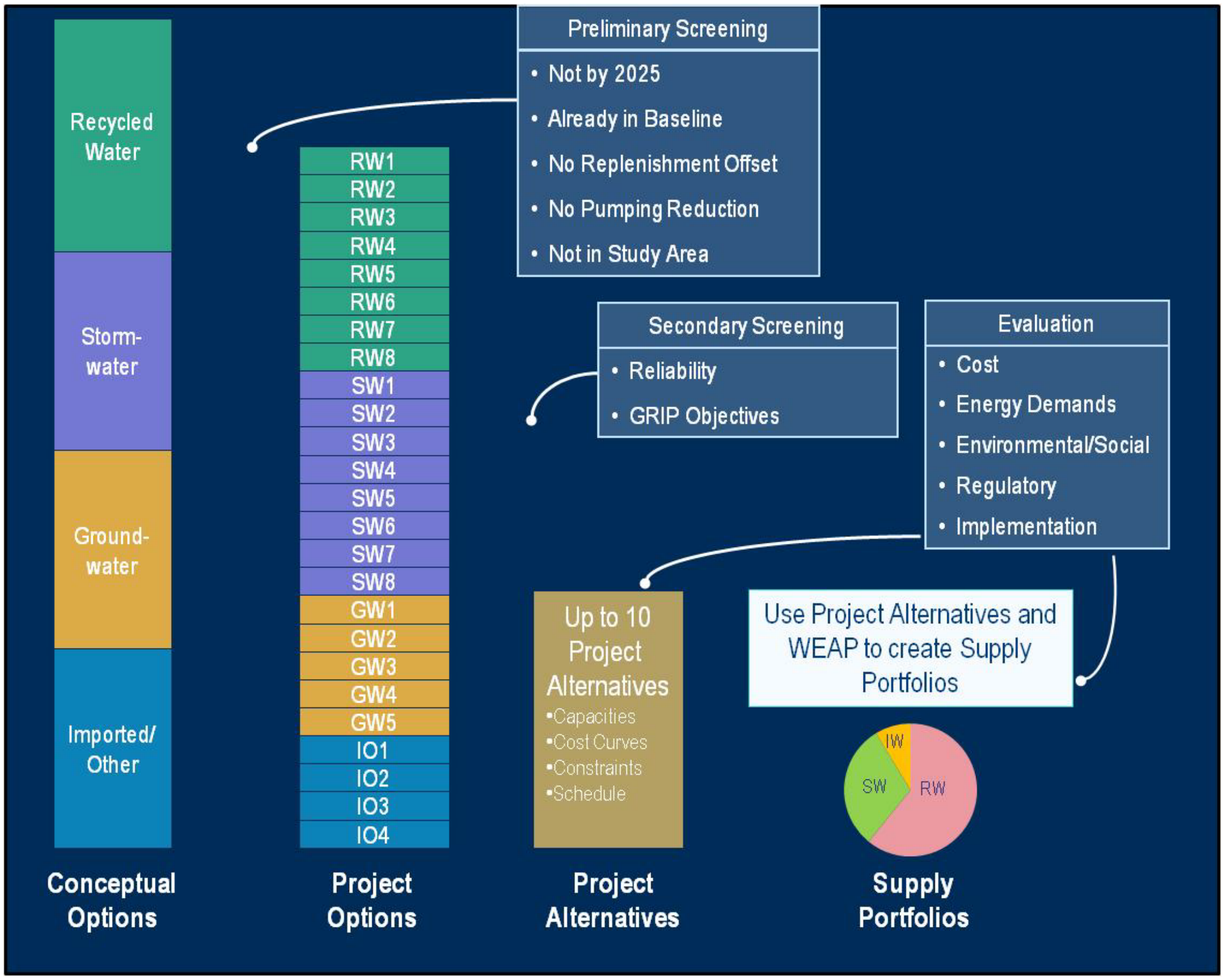
# 4 Overall Evaluation Process

This section explains the overall process used to develop supply portfolios for the GRIP AA. It builds off of the previous documents, which summarized existing planning documents, regulatory issues, and legal issues relevant to the GRIP AA process, and identified "supply" and "facility" project options that could potentially be used to meet the GRIP AA objectives. These documents are included as Appendix D and E, respectively.

The first step of the process was to identify potentially feasible alternatives from a large number of conceptual options through the systematic application of screening tools to create a more manageable number of preliminary project options that could meet the GRIP objectives. The next step was to apply another level of screening criteria to the preliminary options to identify project alternatives. Subsequently, the project alternatives were evaluated and characterized so that they could be combined together to create supply portfolios using the WEAP model. This process is described in more detail in **Figure 20** and in the sections below.

This section explains the first three steps of the process: (1) preliminary screening, (2) second level screening, and (3) development of project alternatives. Section 5 describes each of the project alternatives; Section 6 explains the process of developing supply portfolios; Section 7 defines the components of each supply portfolio, Section 8 characterizes the supply portfolios using the WEAP model and the evaluation criteria, and Section 9 provides recommendations and next steps.

**Figure 20: Development and Analysis Process for Supply Portfolios**



## 4.1 Preliminary Screening of Project Options

Conceptual options were identified during the collection of existing planning documents. The conceptual options were organized as broad categories, including stormwater, recycled water, imported and other waters, and groundwater. Using this information, more refined project options were developed as either "supply" or "facility" options. Supply options were divided into "direct" supplies that provide actual water (i.e., recycled water, imported water, desalination, stormwater) and "in-lieu" supplies that prevent groundwater from being pumped (i.e., conservation, non-potable reuse, desalination exchange). Facility options are projects that allow for a given supply option to provide replenishment water to the groundwater basin. These options may include conveyance, spreading grounds, and injection wells.

Once identified, all the conceptual options went through a preliminary screening process. Options were removed from further consideration if:

- They did not provide replenishment benefits inside the study area;[15]
- They could not be implemented by 2025;
- They were already part of the study area baseline;[16] or
- They did not offset imported replenishment water or groundwater pumping.

The supply and facility options that were eliminated during the preliminary screening process are listed in Appendix E, Tables 27 and 28. These tables provide a color coding to indicate the reason for screening out each option.

## 4.2 Second Level Screening of Project Options

After the preliminary screening process, the remaining options were further screened on the basis of reliability, cost, and ability to meet the objectives of GRIP. The following sections define the minimum requirements for reliability and describe the two layers of the Second Level Screening Process.

### 4.2.1 First Layer - Reliability

The first layer of the Second Level Screening Process is reliability. A minimum reliability requirement of 90 percent was established in order for a project to be eligible for further consideration. This means that supply would be available at least 90 percent of the time and that the facilities to recharge the water would be operational at least 90 percent of the time. The reliability assumptions for each project alternative are discussed below.

The options were then re-examined to determine whether they relied on unproven technology or other constraints, and therefore could not be assessed for reliability. The options that were removed from further consideration on this basis are identified in Appendix E.

### 4.2.2 Second Layer - GRIP Objectives

The second layer of the Second Level Screening Process involves a series of project-specific characteristics related to cost, availability, and potential to meet the GRIP objectives. The following project options were screened out: Los Angeles-Glendale Water Reclamation Plant (LAG), injection wells, conservation, and non-potable reuse. The basis for eliminating these options from further consideration is described in the following paragraphs.

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[15] "study area" is defined as the area overlying the MSG Basin, Central Basin, and West Coast Basin.

[16] Project options that were already committed to by the project proponent (i.e., design is underway and funding has been identified for construction) were removed.

## Los Angeles-Glendale Water Reclamation Plant

The recycled water supply options from LAG were removed from further consideration due to prohibitive cost, low yield, and proximity to the study area. In addition, based on discussions with the LADWP regarding the Recycled Water Master Planning process, it is anticipated that additional recycled water produced from LAG would be reserved for reuse within the City's service area.

## Injection Wells

The facility options considered include conveyance pipelines, spreading basins, and injection wells. While injection wells remain an option for future groundwater recharge projects, they are removed from the GRIP AA due to prohibitive costs and complex implementation.

Injection wells were removed from further consideration as a potential recharge option in the MSG Basin in order to take advantage of available percolation capacity in the existing spreading facilities. The use of spreading grounds is the preferred GRIP recharge option. Injection wells would also require blending facilities at or near the wellheads to meet the initial 50 percent dilution requirement, which adds significant complexity to a project.

Similarly, while injection wells are a potential recharge option in the Central Basin, given that there is available percolation capacity in existing spreading facilities in the MFSG, the use of spreading grounds is the preferred GRIP recharge option. Above-ground blending for the required dilution water makes injection wells more complicated to implement compared with spreading facilities, where dilution water can be averaged over 30 to 60 months. In addition, with respect to siting, the density of supply wells in the Central Basin may limit available injection well sites that will be able to meet the six-month residence time requirement.

The only project alternative for which injection wells are not screened out is the Metro Satellite project, which utilizes wells for groundwater recharge in the Los Angeles Forebay as part of Alternative B-3. Injection wells are appropriate for this project due to lack of proximity to existing spreading grounds.

It should be noted that injection wells may be necessary for more Project Alternatives if the operational flexibility gained from using both the Central Basin and MSG Basin cannot be achieved.

## Conservation and Non-Potable Reuse

Conservation and non-potable reuse (NPR) projects were originally considered as potential projects for the GRIP AA, but they are screened out from further consideration because it was determined that they do not meet the GRIP objectives. The details supporting this decision are explained in the following two sub-sections for the MSG Basin and Central Basin.

### Main San Gabriel Basin

Conservation and NPR are recognized as valuable parts of a successful water supply strategy in the MSG Basin, but they are not likely to completely offset demands for imported water.

The first reason for this is that water agencies will likely seek to maintain access to some direct delivery imported supply for diversification purposes. The MSG Basin imports approximately 15,000 AFY of MWD and State Water Project (SWP) water for direct delivery to users (Main San Gabriel Basin Watermaster, 2010). While in most instances, conservation or NPR would offset the most expensive water supply (treated MWD Tier 1 or Tier 2); in this particular case the amount of direct supply is low enough that the water agencies may seek to maintain this delivery to preserve access to the imported supply. This will allow them to maintain a diversified supply portfolio. For the purposes of the GRIP alternatives analysis, it is assumed that a minimum of approximately 15,000 AFY will be maintained for direct delivery of imported water. Using this assumption, conservation programs and/or NPR would not reduce the amount of direct deliveries.

The second reason is that conservation and NPR projects are not likely, by themselves, to produce sufficient demand reductions to completely replace imported replenishment water. Gross water demand in the MSG Basin is approximately 278,000 AFY according to the Main San Gabriel Basin Watermaster 2009-10 Annual Report. This is the summation of local direct and imported direct supplies, along with groundwater pumping. The minimum requirement for water efficiency imposed by Senate Bill (SB) 7x7 (20X2020) is a 5 percent reduction, or 13,900 AFY for the MSG Basin.[17]

While the GRIP objectives call for 25,000 AFY to be replaced by a new supply source, this value was set according to perceived tertiary recycled water supply limitations and not by replenishment demand, which is approximately 41,000 AFY (Main San Gabriel Basin Watermaster, 2010). Conservation or NPR programs would therefore have to reduce demand by 16,000 AFY [41,000 – 25,000] before they would begin to impact the need for 25,000 AFY of GRIP flow. For the purposes of the GRIP AA, it is assumed that a 5 percent reduction in total use (13,900 AFY) could be achieved with 90 percent reliability, but that additional conservation or NPR does not meet the reliability requirement. Therefore, conservation and NPR are recognized as feasible water resources projects, but they are assumed to only impact the "non-GRIP" portion of imported replenishment demands.

#### Central Basin

Conservation and NPR are also recognized as valuable parts of a successful water supply strategy in the Central Basin, but they are assumed to offset demands for more expensive imported Tier 1 or Tier 2 water rather than imported replenishment water or groundwater pumping.

Gross water demand in the Central Basin is approximately 349,400 AFY according to the 2010 Central Basin Annual Report (DWR, 2010a). This is the summation of local direct and imported direct supplies, along with groundwater pumping. The minimum requirement for water efficiency imposed by SB7x7 (20X2020) is a 5 percent reduction, or 17,500 AFY for the Central Basin.

The Central Basin imports approximately 190,000 AFY of water, 159,000 AFY for direct delivery and the remainder for replenishment. While the GRIP objectives call for 21,000 AFY of replenishment water to be replaced by a new supply source, this value was set according to a different averaging period than the value reported in Section 3.3, which was approximately 31,000 AFY (DWR, 2010a). Assuming that water supply agencies in the Central Basin would seek to maintain 10 percent access to direct delivery imported supplies for the diversification reasons mentioned above (approximately 16,000 AFY based on 159,000 AFY of direct delivery), conservation or NPR projects would therefore have to reduce demand by 169,000 AFY [190,000 – 21,000] before they would begin to impact the need for 21,000 AFY of GRIP flow. For the purposes of the GRIP AA, it is assumed that a 5 percent reduction (17,500 AFY) could be achieved with 90 percent reliability, but that additional conservation/NPR does not meet the reliability requirement. Therefore, conservation and NPR are recognized as feasible water resources projects, but they are assumed to impact demands for Tier 1 or Tier 2 imported water only and not imported replenishment water.

## 4.3 Development of Project Alternatives

After the Second Level Screening Process described above, Project Alternatives were developed that would later be combined together to create Supply Portfolios. These alternatives include:

A-1: Hyperion
A-2: JWPCP
B-1: San Jose Creek WRP AWT + Sewer Diversions
B-2: San Jose Creek WRP AWT + Los Coyotes WRP AWT + Sewer Diversions
B-3: San Jose Creek WRP AWT + Metro Satellite + Sewer Diversions
B-4: San Jose Creek WRP Tertiary + Sewer Diversions
C-1: Metropolitan Water District Tier 1 + Tier 2 Supply (Baseline or "No Project" Alternative)

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[17] SBx7-7 is the Water Conservation Act of 2009. It includes demand reduction requirements that promote the use of both demand management measures (conservation) and recycled water projects (NPR).

C-2: Non-MWD Imported Water
C-3: Desalination
D: Stormwater Projects

Two additional Project Alternatives were subsequently developed that are included in Section 5 under the "B" alternatives:

B-5: San Jose Creek WRP Tertiary + Los Coyotes WRP Tertiary
B-6: San Jose Creek WRP AWT and Tertiary Blend

Section 5 includes detailed descriptions of all Project Alternatives that were developed. The supply portfolio development process is described in Section 6 and the list of potentially feasible alternatives (supply portfolios) is presented in Section 7.

# 5 Project Alternatives

The following sections describe the Project Alternatives developed to meet the goals of the GRIP AA. These are divided into the general categories of regional recycled water, local recycled water, imported water and stormwater. Within each general category, some additional alternatives were developed. Cost Curves for each of the Project Alternatives that are used to develop Supply Portfolios are included in Appendix B. It should be noted that the flow rates indicated in this section are modified to create Supply Portfolios in subsequent sections.

Flow Potential: Central Basin = 21,000 AFY (18.8 million gallons per day (mgd)), MSG Basin = 25,000 AFY (22.3 mgd)

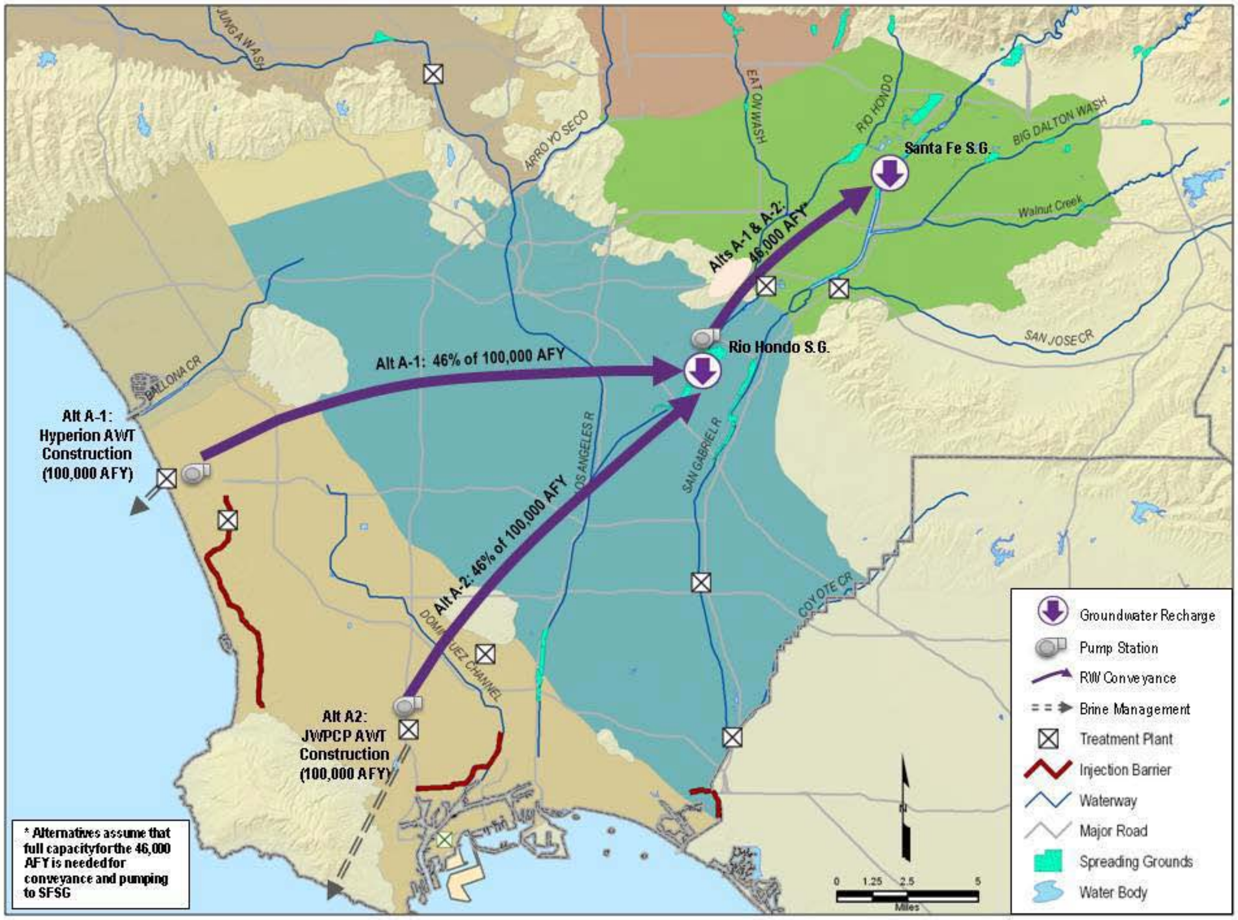
## 5.1 Regional Recycled Water Projects

The Regional Recycled Water alternatives involve the Partnership buying in to a portion of a larger recycled water project initiated by another entity or entities. Each of the projects described below is currently being developed on a concept level by other agencies. Regional Recycled Water projects are shown in **Figure 21** below and include:

**A-1**: Hyperion

**A-2**: JWPCP

Figure 21: Map of Regional Recycled Water Projects (“A” Alternatives)



## Alternative A-1: Hyperion

Description: This is a large regional project that would be implemented in partnership with LADWP, City of Los Angeles Bureau of Sanitation (LABOS), and others. It includes construction of new equalization (EQ) and AWT facilities at the Hyperion Treatment Plant (HTP) in the Playa del Rey area of Los Angeles with a total flow rate of 90 mgd (100,000 AFY) of AWT product water. AWT facilities include microfiltration, reverse osmosis, and advanced oxidation processes (MF/RO/AOP). It also includes a new pump station at HTP, a conveyance pipeline from HTP to the MFSG in the Central Basin, a second pump station, and a conveyance pipeline from the Central Basin to the SFSG in the MSG Basin. It is assumed that the project would include conveyance capacity for the full 46,000 AFY to SFSG to provide operational flexibility during and after storm events.

This alternative is based on a similar project included in LADWP's forthcoming Recycled Water Master Planning Document: Long Term Concept Report, which is anticipated in final draft form in 2011. The LADWP project includes the AWT treatment and the project components in the Central Basin, but it does not include the components in the MSG Basin. Therefore, the GRIP Partnership would buy into a portion of the treatment, pump station, conveyance, and groundwater recharge project (GWR) in the Central Basin and would assume full responsibility for project components that serve the MSG Basin. The buy-in portion is assumed to be proportional to flow rate and would therefore be equal to 46 percent (46,000 AFY of 100,000 AFY). It is assumed that the product water not used by GRIP would be delivered to other users and this use would require approval of the proposed CB and MSG Basin Judgment Amendments.

Reliability: The alternative is assumed to have a reliability of over 90 percent, based on the premise that each component of the treatment, pump station, conveyance, and GWR operations will be constructed with sufficient redundancy to provide over 95 percent of operational reliability. This redundancy is reflected in the cost estimates. To address percolation capacity limits at the spreading grounds, it is assumed that the SFSG and MFSG would be operated in a flexible manner, moving more recycled water preferentially up to the SFSG in wet periods and to the MFSG in dry periods, while maintaining an annual distribution of up to 25,000 AFY and 21,000 AFY in the MSG Basin and Central Basin, respectively.

*Note: This project alternative was eliminated from further consideration on the basis of timing.*

## A-2: JWPCP

Description: This is a large regional project that would be implemented in partnership with LACSD and others. It includes construction of new AWT facilities at JWPCP in Carson with a total flow rate of 90 mgd (100,000 AFY) of AWT product water. AWT facilities include MF/RO/AOP. It also includes a new pump station at JWPCP, a conveyance pipeline from JWPCP to the MFSG in the Central Basin, a second pump station, and a conveyance pipeline from the Central Basin to the SFSG in the MSG Basin.

This alternative is based on a similar project included in a forthcoming MWD/LACSD feasibility study which is anticipated in 2011. The LACSD project includes AWT treatment and a conveyance pipeline through the Central Basin and MSG Basin. The Partnership would buy into a portion of the treatment, pump station, conveyance, and GWR projects in both basins (as opposed to just the Central Basin conveyance as in A-1). The buy-in portion is assumed to be proportional to flow rate and would therefore be equal to approximately 46 percent of treatment and conveyance costs (46,000 AFY of 100,000 AFY) in the Central Basin and 46 percent (46,000 AFY of 100,000 AFY) in the MSG Basin. It is assumed that the project would include conveyance capacity for the full 46,000 AFY to SFSG to provide operational flexibility during and after storm events. It is also assumed that the product water not used by GRIP (above 46,000 AFY) would be delivered to other users and this use would require approval of the proposed CB and MSG Basin Judgment Amendments.

Variations on the project that utilize injection wells for GWR were examined, but were set aside for the reasons outlined in section 4.2.

Reliability: The A-2 alternative is assumed to have a reliability of over 90 percent, based on the premise that each component of the treatment, pump station, conveyance, and GWR operations will be constructed with sufficient redundancy to provide over 95 percent of operational reliability. This redundancy is reflected in the cost estimates. To address percolation capacity limits at the spreading grounds, it is assumed that the SFSG and MFSG would be operated in a flexible manner, moving more recycled water preferentially up to the SFSG in wet periods and to the MFSG in dry periods, while maintaining an annual distribution of up to 25,000 AFY and 21,000 AFY in the MSG Basin and Central Basin, respectively.

*Note: This project alternative was eliminated from further consideration on the basis of timing.*

## 5.2 Local Recycled Water Alternatives (San Jose Creek WRP - Centered)

The San Jose Creek Water Reclamation Plant (SJCWRP) is the basis for a series of alternatives due to its central location in the Study Area and the availability of recycled water from the plant. In this sense, the alternatives are considered to be "local" recycled water. Each of the following local recycled water alternative descriptions include some recycled water produced at the SJCWRP, and in each alternative it is necessary to supplement existing flows at the plant with upstream sewer diversions and/or with recycled water flows from another WRP.

These projects assume that 14,600 AFY of tertiary-treated effluent is available from SJCWRP based on the amount of un-contracted production flow at the plant (4,600 AFY) and the amount of flow contracted to USGVMWD and the San Gabriel Valley Municipal Water District (SGVMWD) that will be available for GRIP (10,000 AFY) (LACSD, 2008). Since the total amount of feed water required to produce 46,000 AFY of AWT water is 61,000 AFY, an additional 46,400 AFY is needed. Therefore, these alternatives also include a series of in-plant modifications for flow equalization and upstream sewer diversions to bring up to 46,400 AFY of additional influent flow to the SJCWRP. The plant modification and sewer diversion costs that have been examined are summarized in Appendix B.

Local recycled water supply alternatives are shown in **Table 1** and **Figure 22** and include:

**B-1**: San Jose Creek WRP (SJCWRP) AWT + Sewer Diversions
**B-2**: SJCWRP AWT + Los Coyotes WRP (LCWRP) AWT + Sewer Diversions
**B-3**: SJCWRP AWT + Metro Satellite + Sewer Diversions
**B-4**: SJCWRP Tertiary + Sewer Diversions

**Table 1: Local Recycled Water Alternatives ("B" Alternatives)**

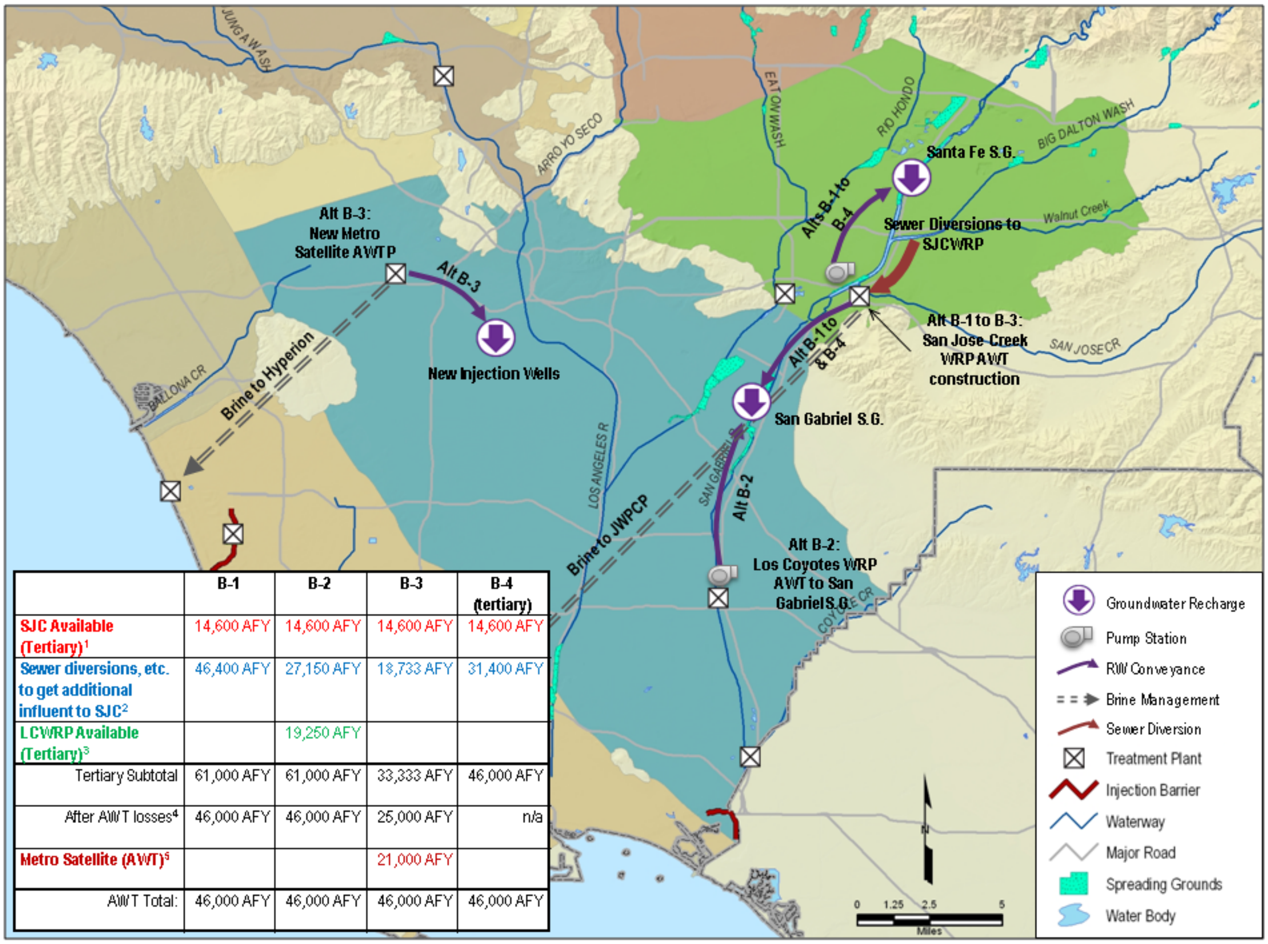
| Supplies | B-1 | B-2 | B-3 | B-4 |
|---|---|---|---|---|
| SJC Available (tertiary)[1] | 14,600 AFY | 14,600 AFY | 14,600 AFY | 14,600 AFY |
| Sewer Diversions & Plant Modifications to get additional influent to SJC[2] | 46,400 AFY | 27,150 AFY | 18,733 AFY | 31,400 AFY |
| LCWRP Available (tertiary)[3] | | 19,250 AFY | | |
| Tertiary Subtotal: | 61,000 AFY | 61,000 AFY | 33,333 AFY | 46,000 AFY |
| After AWT Losses[4]: | 46,000 AFY | 46,000 AFY | 25,000 AFY | n/a |
| Metro Satellite (AWT)[5] | | | 21,000 AFY | |
| AWT Total: | 46,000 AFY | 46,000 AFY | 46,000 AFY | 46,000 AFY |

Notes:
1. Calculated as un-contracted flows plus flows contracted to USGVMWD (4,600 AFY + 10,000 AFY = 14,600 AFY).
2. Diversions, plant modifications, etc. described in "Recycled Water Supply for GRIP – August 2010 Update", August 2010. In each alternative, these are used as needed to get the AWT flows up to 46,000 AFY.
3. Calculated as 2005-06 production flows minus contracted flows (31,350 AFY – 12,100 AFY = 19,250 AFY)
4. Assumes 75% recovery rate
5. Assumes Partnership would take 21,000 AFY of AWT water.

Other alternatives added to the “B” alternatives (not shown in **Figure 22**) include:

- **B-5:** SJCWRP Tertiary + LCWRP Tertiary
- **B-6:** SJCWRP AWT and Tertiary Blend Alternative

Figure 22: Map of Local Recycled Water Portfolios (“B” Alternatives)



| | B-1 | B-2 | B-3 | B-4 (tertiary) |
|---|---|---|---|---|
| SJC Available (Tertiary)[1] | 14,600 AFY | 14,600 AFY | 14,600 AFY | 14,600 AFY |
| Sewer diversions, etc. to get additional influent to SJC[2] | 46,400 AFY | 27,150 AFY | 18,733 AFY | 31,400 AFY |
| LCWRP Available (Tertiary)[3] | | 19,250 AFY | | |
| Tertiary Subtotal | 61,000 AFY | 61,000 AFY | 33,333 AFY | 46,000 AFY |
| After AWT losses[4] | 46,000 AFY | 46,000 AFY | 25,000 AFY | n/a |
| Metro Satellite (AWT)[5] | | | 21,000 AFY | |
| AWT Total: | 46,000 AFY | 46,000 AFY | 46,000 AFY | 46,000 AFY |

## B-1: SJCWRP AWT + Sewer Diversions

Description: This is a recycled water alternative that would be implemented in partnership with LACSD and others. It includes construction of new AWT facilities at the SJCWRP, with a total flow rate of 41 mgd (46,000 AFY) of AWT product water. AWT facilities include MF/RO/AOP. It also includes a new pump station at SJCWRP, use of existing conveyance pipelines from SJCWRP to the MFSG in the Central Basin, a new conveyance pipeline from the SJCWRP to the SFSG in the MSG Basin, and brine concentrate management. This alternative also includes the sewer diversions described below.

It is assumed that the project would include conveyance capacity for the full 46,000 AFY to the MFSG and to the SFSG to provide operational flexibility during and after storm events.

Reliability: This alternative is assumed to have a reliability of over 90 percent, based on the premise that each component of the treatment, pump station, conveyance, and GWR operations will be constructed with sufficient redundancy to provide over 95 percent of operational reliability. This redundancy is reflected in the cost estimates. To address percolation capacity limits at the spreading grounds, it is assumed that the SFSG and MFSG would be operated in a flexible manner, moving more recycled water preferentially up to the SFSG in wet periods and to the MFSG in dry periods, while maintaining an annual distribution of up to 25,000 AFY and 21,000 AFY in the MSG Basin and Central Basin, respectively.

## B-2: SJCWRP AWT + LCWRP AWT

Description: This is a recycled water alternative that would be implemented in partnership with LACSD and others. It includes construction of new AWT facilities at the Los Coyotes Water Reclamation Plant (LCWRP) with a total flow rate of 13 mgd (14,400 AFY) of AWT product water. This flow represents the amount of product water generated from the un-contracted tertiary effluent available at LCWRP. The alternative also includes the construction of new AWT facilities at the SJCWRP with a total flow rate of 28 mgd (31,600 AFY) of AWT product water, for a combined total of 46,000 AFY between both WRPs. AWT facilities include MF/RO/AOP. The alternative includes a new pump station at LCWRP with a conveyance pipeline to the MFSG in the Central Basin, a new pump station at SJCWRP with a conveyance pipeline to the SFSG in the MSG Basin, the use of existing pipelines from the SJCWRP to the MFSG, and brine concentrate management.

This alternative assumes that 19,250 AFY of tertiary effluent is available from LCWRP based on the amount of un-contracted flow (LACSD, 2008). The amount of AWT water produced, 14,400 AFY, is not sufficient to satisfy the GRIP objective for the Central Basin of 21,000 AFY. Therefore, this alternative assumes that AWT at SJCWRP will supply 6,600 AFY of recycled water to the Central Basin in addition to supplying 25,000 AFY to the MSG Basin (a total AWT flow of 31,600 AFY). This alternative also includes 27,450 AFY of sewer diversions from Appendix B to bring the production capacity of the SJCWRP AWT facilities to 31,600 AFY (LACSD, 2008).

This alternative would not include conveyance capacity for 46,000 AFY to the SFSG and therefore would not have the same level of operational flexibility during and after storm events as the GRIP alternatives that do provide this additional capacity.

Reliability: The B-2 alternative is assumed to have a reliability of over 90 percent, based on the premise that each component of the treatment, pump station, and conveyance will be constructed with sufficient redundancy to provide over 95 percent of operational reliability. This redundancy is reflected in the cost estimates.

Percolation capacity limits and operations at the spreading grounds are more difficult to address. This alternative does not have the same operational flexibility as some other alternatives because it does not provide a means to move recycled water preferentially during wet and dry periods. This is an important disadvantage that is not captured in the evaluation criteria.

## B-3: SJCWRP AWT + Metro Satellite AWT

Description (MSG Basin Portion):

This is a recycled water project that would be implemented in partnership with LACSD, LABOS, LADWP and others. It includes construction of new AWT facilities at the SJCWRP with a total flow rate of 22.3 mgd (25,000 AFY) of AWT product water. The flow capacity for SJCWRP facilities is smaller because the Central Basin portion of the project would be accommodated by a new satellite treatment plant as described below. AWT facilities include MF/RO/AOP. This portion of the alternative also includes a new pump station at SJCWRP, a conveyance pipeline from SJCWRP to the SFSG in the MSG Basin, and brine concentrate management.

The MSG portion of this alternative assumes that 14,600 AFY of tertiary effluent is available from SJCWRP based on the amount of un-contracted production flow at the plant (4,600 AFY) and the amount of flow contracted to USGVMWD and the SGVMWD that will be available for GRIP (10,000 AFY) (LACSD, 2008). Since the total amount of feed water required to produce 25,000 AFY of AWT water is

33,000 AFY, an additional 18,400 AFY is needed. Therefore, this alternative includes 18,733 AFY of sewer diversions in Appendix B to bring the full production capacity of the SJCWRP AWT facilities to 25,000 AFY (LACSD, 2008).

Description (Central Basin Portion):

The Central Basin portion of this alternative includes construction of a new satellite treatment plant in the Los Angeles Metro area that uses membrane bioreactor technology (MBR) in addition to AWT facilities. The plant would be sized for a total flow rate of 44.6 mgd (50,000 AFY) of AWT product water. This project component also includes a conveyance pipeline and an injection well field for recharge into the aquifer in the Los Angeles Forebay area.

This project is based on a project concept in LADWP's Draft Long-Term Concept Report from the Recycled Water Master Plan, expected in 2011. Due to the relatively smaller size of the project conceived by LADWP (44.6 mgd/50,000 AFY), it is assumed that this alternative would only supply the Central Basin portion of GRIP (18.8 mgd/21,000 AFY).

The Partnership would buy into a portion of the project capital and O&M costs for treatment; the Partnership would also buy into a portion for pumping, conveyance, and GWR in Central Basin. The buy-in portion is assumed to be proportional to flow rate and would therefore be equal to approximately 42 percent (21,000 AFY of 50,000 AFY). It is assumed that the remaining product water would be delivered to other users and this use would require approval of the proposed CB and MSG Basin Judgment Amendments.

This alternative does not assume that the project would include conveyance capacity for the full 46,000 AFY to both MSG Basin and Central Basin since the spreading grounds at the Montebello Forebay are not used (the reason that operational flexibility was desired for other alternatives).

Reliability: The B-3 alternative is assumed to have a reliability of over 90 percent, based on the premise that each component of the treatment, pump station, conveyance, and GWR operations will be constructed with sufficient redundancy to provide over 95 percent of operational reliability. This redundancy is reflected in the cost estimates. It is assumed that the SFSG has a percolation capacity with greater than 90 percent reliability and that injection wells can recharge into the Los Angeles Forebay with 90 percent reliability.

*Note: This project alternative was eliminated from further consideration on the basis of timing.*

### B-4: SJCWRP Tertiary

Description: This is a recycled water alternative that utilizes tertiary-treated water for GWR instead of AWT water. It would provide tertiary-treated recycled water from the SJCWRP for recharge in Central Basin and MSG Basin. The alternative would be implemented in partnership with LACSD and others. It includes construction of a new pump station at SJCWRP, use of an existing conveyance pipeline from SJCWRP to the MFSG in the Central Basin, and a new conveyance pipeline from the SJCWRP to the SFSG in the MSG Basin.

This alternative assumes that 14,600 AFY of tertiary-treated effluent is available from SJCWRP based on the amount of un-contracted production flow at the plant (4,600 AFY) and the amount of flow contracted to USGVMWD and SGVMWD that will be available for GRIP (10,000 AFY) (LACSD, 2008). Since a total of 46,000 AFY of recycled water is required to meet the GRIP objectives, an additional 31,400 AFY is needed. Therefore, this alternative also includes some sewer diversions/flow equalization to allow the SJCWRP to produce a total of 46,000 AFY of tertiary recycled water.

It is assumed that the alternative would include conveyance capacity for the full 46,000 AFY to the MFSG and to the SFSG to provide operational flexibility during and after storm events.

Reliability: The B-4 alternative is assumed to have a reliability of over 90 percent, based on the premise that each component of the treatment, pump station, conveyance, and GWR operations will be constructed with sufficient redundancy to provide over 95 percent of operational reliability. This redundancy is reflected in the cost estimates. To address percolation capacity limits at the spreading grounds, it is assumed that the SFSG and MFSG would be operated in a flexible manner, moving more recycled water preferentially up to the SFSG in wet periods and to the MFSG in dry periods, while maintaining an annual distribution of up to 25,000 AFY and 21,000 AFY in the MSG Basin and Central Basin, respectively.

## B-5 SJCWRP Tertiary + LCWRP Tertiary

Description: This is a recycled water alternative that utilizes additional tertiary-treated water for GWR instead of AWT water. It would provide tertiary-treated recycled water from the SJCWRP for recharge in MSG Basin and would combine tertiary-treated recycled water from SJCWRP and LCWRP for recharge in the Central Basin. The alternative would be implemented in partnership with LACSD and others. It includes construction of a new pump station at SJCWRP and at LCWRP, use of an existing conveyance pipeline from SJCWRP to the MFSG in the Central Basin, a new conveyance pipeline from the SJCWRP to the SFSG in the MSG Basin, and a new conveyance pipeline from the LCWRP to the MFSG in the Central Basin.

This alternative also assumes that 19,250 AFY of tertiary-treated effluent is available from LCWRP based on the amount of un-contracted flow at the plant. Because this amount is not sufficient to recharge the full GRIP objective of 21,000 AFY in the Central Basin, a small amount of tertiary effluent from SJCWRP must be included (1,750 AFY).

This alternative assumes that 14,600 AFY of tertiary-treated effluent is available from SJCWRP based on the amount of un-contracted production flow at the plant (4,600 AFY) and the amount of flow contracted to USGVMWD and the San Gabriel Valley Municipal Water District (SGVMWD) that will be available for GRIP (10,000 AFY) (LACSD, 2008). Since a total of 46,000 AFY of recycled water would be required to meet the GRIP objectives, an additional 12,150 AFY (46,000 - 19,250 - 14,600) is needed. Therefore, this alternative also includes some sewer diversions/flow equalization to allow the SJCWRP to produce an additionally 12,150 AFY of tertiary recycled water.

Reliability: This alternative is assumed to have a reliability of over 90 percent, based on the premise that each component of the pump station, and conveyance will be constructed with sufficient redundancy to provide over 95 percent of operational reliability. This redundancy is reflected in the cost estimates.

Percolation capacity limits and operations at the spreading grounds are more difficult to address. This alternative would not include conveyance capacity for 46,000 AFY to the SFSG and therefore would not have the same level of operational flexibility during and after storm events as the GRIP alternatives that do provide this additional capacity. This is an important disadvantage that is not captured in the evaluation criteria.

## B-6 SJCWRP AWT and Tertiary Blend

Description: This is a recycled water alternative that utilizes a blend of AWT and tertiary-treated water from the SJCWRP for GWR. It combines the features of alternatives B-1 and B-4 and assumes a 50/50 split between AWT water and tertiary water. This split applies to the flow volume of each type of recycled water and the facilities needed to treat them. This alternative is fundamentally similar to alternative B-1 except that 23,000 AFY of AWT water would be produced and 23,000 AFY of tertiary would be produced, avoiding the need to provide AWT treatment for the full 46,000 AFY of product water (61,000 AFY feed water). The alternative would be implemented in partnership with LACSD and others. It includes construction of a new pump station at SJCWRP, use of an existing conveyance pipeline from SJCWRP to the MFSG in the Central Basin, and a new conveyance pipeline from the SJCWRP to the SFSG in the MSG Basin.

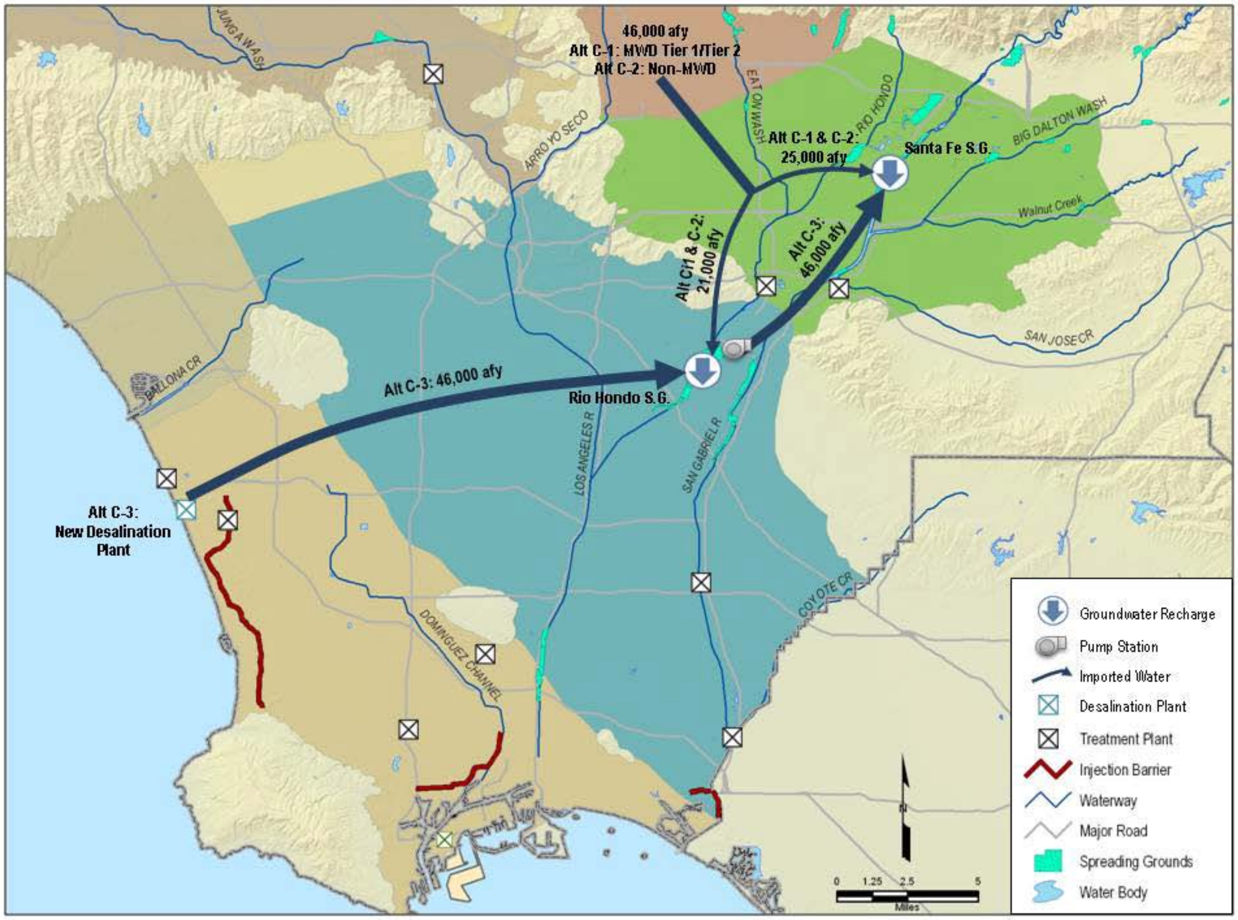
Reliability: This alternative is assumed to have a reliability of over 90 percent, based on the premise that each component of the treatment pump station, and conveyance will be constructed with sufficient redundancy to provide over 95 percent of operational reliability.

*Note: This project alternative was eliminated from further consideration on the basis of redundancy. The main components of this alternative are already captured by the B-1 and B-4 Project Alternatives.*

## 5.3 Imported Water

The C Alternatives involve imported water supplies that would be used to recharge the Basins. For these alternatives, MWD Tier1/Tier 2 water, non-MWD water, or desalinated seawater would be physically transferred to the existing spreading grounds with pumping and conveyance. Alternative C portfolios are shown in **Figure 23** below.

**Figure 23: Map of Imported Water Portfolios ("C" Alternatives)**



## C-1: MWD Tier1/Tier 2 Supply (Baseline or “No Project” Alternative)

Description: This alternative involves the continued use of MWD imported supply to meet replenishment needs. It is considered to be the “no project” alternative. WRD and USGVMWD would purchase additional Tier 1 and Tier 2 imported supplies from MWD. This alternative is the likely scenario if no project is implemented and is therefore considered to be the “no project” alternative. The alternative assumes that approximately 30 percent of the imported MWD water would be available as Tier 1 and that 70 percent would be available as Tier 2.

Reliability: This alternative is assumed to have a reliability of over 90 percent, based on the premise that MWD Tier1 and Tier 2 supplies are available and uninterruptible.

## C-2: Non-MWD Water

Description: This alternative would develop alternatives to supply non-MWD imported water that could be made available from non-SWP rights holders in areas with excess supply. These supplies would be generated outside of the region but would use existing SWP and MWD distribution infrastructure. The Partnership would purchase the capacity to “wheel” water through these systems. Since this water will likely be more available in winter months (off-peak demand), there should be minimal capacity constraints on the existing SWP and MWD infrastructure. However, given potential capacity constraints at the spreading grounds in winter, there may be a need to supply storage to ensure reliable supplies for spreading year-round.

Reliability: The C-2 alternative is assumed to have a reliability of over 90 percent, based on the premise that non-MWD supply can be made available and uninterruptible. The SWP and MWD distribution system constraints will be minimal given that this water will be wheeled in lieu of baseline SWP/MWD deliveries; however there will be additional costs of wheeling and distribution of non-SWP or -MWD waters through these systems. Also, both wet year and winter season normal year supplies that can’t be immediately used will be stored at underground water banks “up-system” from MSG and Central Basins.

*Note: This Project Alternative was eliminated from further consideration on the basis that non-MWD water supplies were significantly higher in cost compared to MWD Tier 1 and Tier 2 supplies.*

## C-3: Desalination

Description: This alternative would provide ocean desalination water directly for recharge in the Central Basin and MSG Basin. An “exchange” using desalinated water does not meet the GRIP Objectives because it would likely offset imported MWD Tier 1 water before it would offset replenishment water or groundwater pumping. At the present time, there are four planned ocean water desalination projects in the GRIP project area:

1. Long Beach Seawater Project, which would provide 10,000 AFY of water to meet local water demand by 2030;
2. Los Angeles Seawater Desalination Project, which is on hold, but as initially conceived would have provided 28,000 AFY of water to meet local water demand;
3. West Basin Seawater Desalination Project, which would potentially provide 20,000 AFY of water to meet local water demands by 2020 – the specifics of the projects are being evaluated as part of a Master Plan; and
4. MWD/West Basin Regional Desalination Project, which is intended to be a large regional ocean desalination effort that is intended to provide water to meet MWD’s regional water needs.

West Basin MWD and MWD in a joint partnership have just released an RFP for the Program Master Plan that addresses both West Basin's local project and MWD's regional project. The goal is to define alternative project sizes, site locations, process treatment requirements, distribution and conveyance requirements, and overall sequencing/phasing of the program development to meet local and regional near and long-term water demands, which potentially could include up to 100 mgd of water.

The City of Los Angeles Project (if re-activated), the Long Beach Project, and the West Basin Local Project would not be able to provide desalination water directly for recharge in Central Basin or MSG Basin or desalination water for exchange to use for recharge in Central Basin or MSG Basin since they are intended to only meet local water demands. The MWD/West Basin Regional Desalination Project, if determined to be feasible and if it could provide sufficient water for GRIP, is not expected to be able to provide water within the 2025 timeline because it will necessitate a complex planning and implementation effort.

This alternative assumes that a new desalination plant would be constructed for GRIP, with a total flow rate of 41 mgd (46,000 AFY) of desalination product water. The facilities include a new pump station at the desalination plant, a conveyance pipeline from the plant to the MFSG in the Central Basin, a second pump station, and a conveyance pipeline from the Central Basin to the SFSG in the MSG Basin. It is assumed that the project would include conveyance capacity for the full 46,000 AFY to SFSG to provide operational flexibility during and after storm events.

<u>Reliability</u>: The C-3 alternative is assumed to have a reliability of over 90 percent, based on the premise that each component of the treatment, pump station, conveyance, and GWR operations will be constructed with sufficient redundancy to provide over 95 percent of operational reliability. This redundancy is reflected in the cost estimates. To address percolation capacity limits at the spreading grounds, it is assumed that the SFSG and MFSG would be operated in a flexible manner, moving more recycled water preferentially up to the SFSG in wet periods and to the MFSG in dry periods, while maintaining an annual distribution of up to 25,000 AFY and 21,000 AFY in the MSG Basin and Central Basin, respectively.

*Note: This project alternative was eliminated from further consideration on the basis of timing and cost.*

## 5.4 Stormwater Projects

<u>Description:</u> This alternative includes several alternatives that would collectively provide additional stormwater percolation of 21,700 AFY into the Central Basin and 800 AFY into the MSG Basin. They generally involved the improvement of spreading grounds and/or strategic pumping of groundwater to capture greater volumes of stormwater flows. This alternative would be implemented in partnership with WRD, LACDPW, the City of Long Beach, and potentially other pumpers. Improvements can be made to existing spreading grounds to either expand the spreading grounds or increase percolation in order to capture surface water that is currently flowing to the ocean. The individual alternatives include:

- **Montebello Forebay Spreading Grounds Extraction and Stormwater Recharge (Legacy Project)**: This alternative consists of constructing a new well field in the Montebello Forebay that would extract approximately 23,000 AFY of groundwater and distribute the water in the Central Basin. The increased pumping would remove water in the Montebello Forebay where a subsurface groundwater mound currently exists. Lowering this mound would not only provide additional supplemental water for distribution, but also would induce increased infiltration of local stormwater. Five new groundwater extraction wells would be located in north-south transect between the SGSG and RHSG. Groundwater modeling indicates that the extraction will result in a long-term average increase in local stormwater recharge of 16,500 AFY (Montgomery Watson, 2001). The groundwater would be conveyed to users via pipeline and would provide an additional supplement that would partially replace the use of local groundwater.

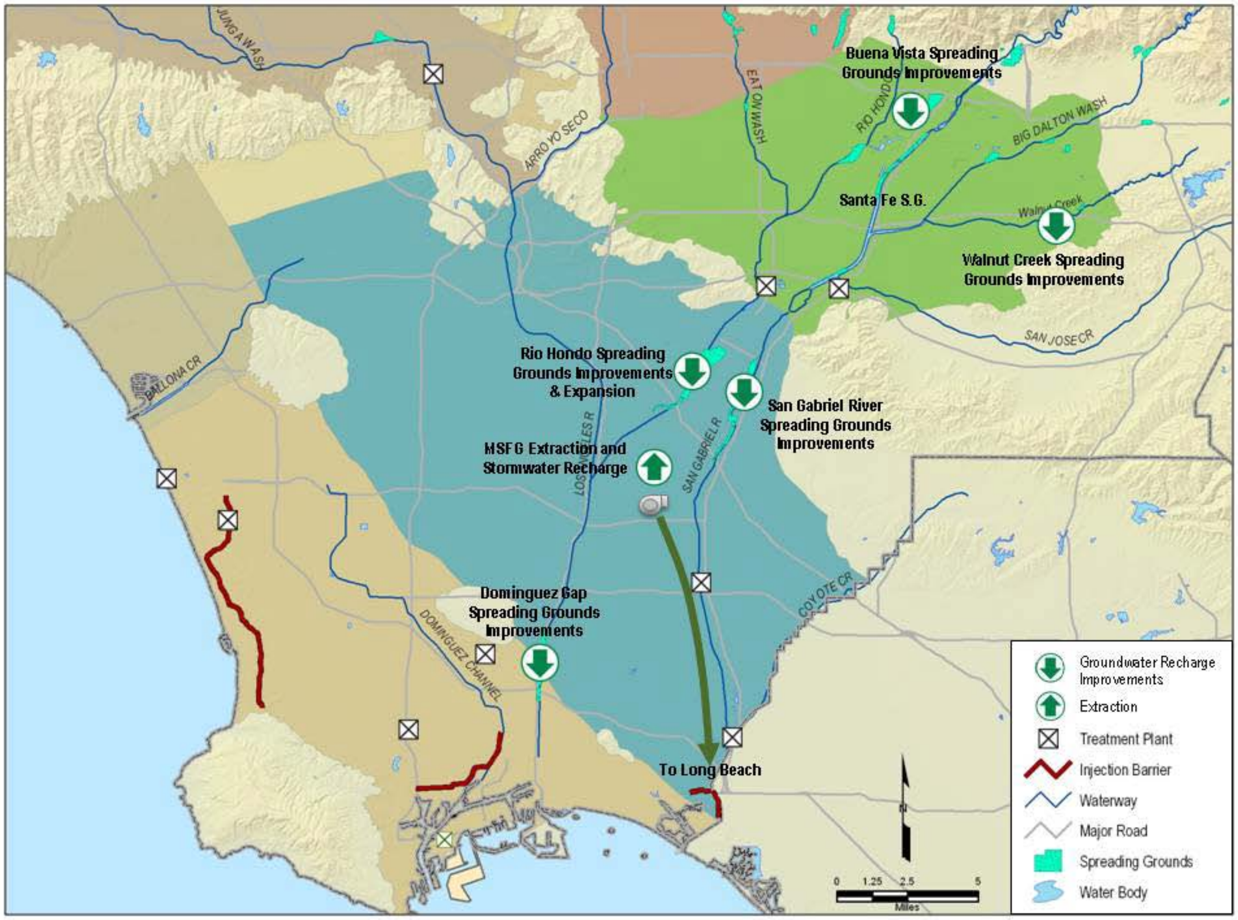
This alternative is based in part on the Montebello Forebay Groundwater Recharge Optimization Study (Montgomery Watson, 2001) and the Preliminary Plan for Groundwater Resources Development Program (WRD, 2000).

This alternative requires a new pipeline that must be constructed for conveyance of extracted groundwater from the Montebello Forebay to the City of Long Beach. This analysis also assumes that stormwater will be conveyed to spreading grounds using the existing surface water channels and spreading ground inlets.

- **Rio Hondo Spreading Grounds Expansion:** The RHSG in the Central Basin could be expanded into a nearby 23-acre parcel which would allow for the capture of an additional 4,200 AFY from the Rio Hondo. Installation of vertical drains in Basins 9W and 10W as a second phase of the alternative would also increase percolation, which is assumed to increase capture by 500 AFY. (A similar alternative is listed under for the Dominguez Gap Spreading Grounds).
- **Dominguez Gap Spreading Grounds Improvements**: These improvements would be designed to increase capture from the Los Angeles River by 500 AFY through the installation of vertical drains to optimize percolation.
- **Buena Vista Spreading Basin Improvements:** The removal of silt from the Buena Vista Spreading Basin in the MSG Basin could increase capture from the Buena Vista Channel (a tributary to the Rio Hondo River) by 500 AFY .
- **Walnut Creek Spreading Basin Improvements**: The removal of silt from the Walnut Creek Spreading Basin in the MSG Basin could increase capture from Walnut Creek (a tributary to the San Gabriel River) by 300 AFY.

Alternative D projects are shown in **Figure 24**.

**Figure 24: Map of Stormwater Alternatives ("D" Alternatives)**



Reliability: Stormwater reliability is highly variable on both a seasonal and an annual basis. The potential flows mentioned above are expected to be the average annual amounts that can be infiltrated into the basins. Overall, Alternative D is assumed to have a reliability of over 90 percent in the long-term since the estimated increased stormwater recharge is based on 13 years of stormwater data (1980 to 1993) representing both wet and dry years. Local stormwater not captured is currently lost to the ocean and unused. The pumping and conveyance facilities can be designed to increase reliability.

## 5.5 Third Level Screening Process

This subsection describes the subsequent screening process that occurred after the GRIP Project Alternatives were developed. Some of the project alternatives were screened out for:

1. Timing – Based on recent developments indicating that certain project alternatives would exceed the 2025 timetable for GRIP;
2. Cost – Based on information confirming that one or more project alternatives would not be as cost effective as a similar alternative; and
3. Redundancy – Based on the decision that two of the project alternatives (AWT and tertiary) sufficiently covered the elements of a third alternative (blend).

The Project Alternatives that were eliminated (after being developed) include the following:

- **HTP (A-1) -** This alternative is screened out due to timing. Recent developments in the LADWP Recycled Water Master Planning process indicate that a large recycled water project from HTP would not be implemented until after 2025.
- **JWPCP (A-2) -** This alternative is screened out due to timing. Recent developments in the planning efforts for a large, regional LACSD/MWD recycled water project from the JWPCP indicate that a project would not be implemented until after 2025.
- **Metro Satellite AWT (B-3) -** This alternative is screened out due to timing. Recent developments in the LADWP Recycled Water Master Planning process indicate that a large recycled water project from a Metro Satellite would not be implemented until after 2025.
- **SJCWRP AWT and Tertiary Blend (B-6) -** This alternative is screened out because the necessary components for this type of project are already sufficiently defined as part of the SJCWRP AWT and SJCWRP Tertiary alternatives.
- **Non-MWD Imported Water (C-2) -** This alternative is screened out because the projects had no discernable advantage over the MWD Tier 1 / Tier 2 Supply (“No Project” Alternative and the cost was always higher.
- **Desalination (C-3) -** This alternative is screened out due to timing and high cost. A preliminary analysis indicated that regulatory and permitting issues would push implementation of a desalination plant beyond 2025. In addition, the preliminary analysis indicated that the cost and energy consumption for desalination would not be cost competitive with other GRIP Project Alternatives.

# 6 Development of Supply Portfolios

This section describes the process of combining the remaining Project Alternatives (described in Section 5) into Supply Portfolios. The actual Supply Portfolios are described in Section 7.

## 6.1 Cost Analysis Using WEAP Model

The Water Evaluation and Planning (WEAP) model is a tool used for integrated water resources planning. WEAP uses databases of supply and demand information to drive the water balance of the system. Supplies and demands are represented as nodes in the model and can be linked together using defined rules and constraints to represent system limitations and operations (e.g., treatment facility and pipeline capacities). WEAP was used in this project to evaluate the feasibility of various combinations of recycled, imported, desalination and storm water supply projects in meeting the groundwater replenishment goals which are represented as demands in the model.

The WEAP model schematic and inputs are detailed in Appendix A and the cost curves are in Appendix B.

### WEAP Baseline and Portfolio Setup

The WEAP model was used to create a composite baseline for the MSG Basin and Central Basin that incorporates the basin constraints, available supplies for groundwater replenishment, and facility constraints described in this document. This baseline is equivalent to the “No Project” alternative. The assumptions used to characterize these components are described below.

#### Watershed Assumptions

In the WEAP model, precipitation falling within watersheds can contribute both to runoff and to groundwater infiltration. The Los Angeles River watershed and San Gabriel River watershed were broken down to the sub-watershed level to allow for varying river flow to the spreading grounds throughout each of the watersheds. Average precipitation taken from a representative Los Angeles County precipitation gage within each sub-watershed was applied. The watersheds that fall outside of the MSG Basin and Central Basin boundaries were not modeled; instead, river flow was input directly at the point where the main channel within the watershed enters the groundwater basin area. The sub-watersheds used in the WEAP model are listed in Appendix A.

Within the MSG Basin, an average of 49,000 AFY of precipitation infiltrates to the basin, while an average of 112,000 AFY of runoff is recharged via spreading basins. In the Central Basin, an average of 32,000 AFY of precipitation infiltrates to the basin, while an average of 55,000 AFY of runoff is recharged via spreading basins. These numbers in conjunction with LACSD recycled water data and United States Geological Survey (USGS) stream flow gages were used to calibrate the WEAP model to operate the natural surface water/groundwater system according to average climate conditions.

#### Groundwater Basin Assumptions

The MSG Basin and Central Basin were modeled according to the basin assumptions and characteristics described in Section 3, specifically basin capacities, basin yields, and subsurface inflows and outflows.

#### Spreading Ground Assumptions

Spreading grounds within the MSG Basin and Central Basin were included in the WEAP model, and were connected to the sub-watersheds from which they are recharged according to the LACDPW *Water Conservation Distribution System* (2008).

For those spreading grounds which receive imported water, the total average amount of imported water recharged to each basin as listed in Section 3 (41,000 AFY to MSG Basin and 31,000 AFY to Central Basin) was distributed according to each spreading basin’s total average annual recharge. For the Central

Basin spreading grounds, it was assumed that the average annual recycled water recharge volume of 43,000 AFY is distributed equally to the Rio Hondo and San Gabriel spreading grounds.

Imported water is currently recharged into the MSG Basin using six different spreading grounds, including the SFSG.[18] In this analysis, it is assumed that 25,000 AFY of imported water for GRIP would continue to be recharged under the current operational scheme (i.e., multiple spreading grounds) for the no project alternative; however, for other alternatives, it is assumed that imported water and other supply sources would be recharged entirely at the SFSG. As described in Section 3, the SFSG has percolation capacity sufficient to recharge 25,000 AFY of GRIP water (whether recycled, stormwater, or other sources of water).

### Supply Priority and Implementation Assumptions

Some supplies can be implemented earlier than others. The analysis assumes that imported water is used for recharge in the years before other projects can be implemented. It also assumes that the smaller stormwater projects (e.g., spreading ground improvements) can be implemented in five years. The analysis makes the judgment that cost-effectiveness and speed of implementation are sufficient reasons to include these smaller stormwater projects in all portfolios except the no-project portfolio.

The analysis goes on to assume that the tertiary recycled water projects can begin to be implemented by 2015, that the SJCWRP and LCWRP AWT projects can be implemented by 2020; and that the Montebello Forebay Spreading Grounds Extraction and Stormwater Recharge project ( “Legacy Project”) can be implemented by 2020.

## Cost Curves

The inputs for the WEAP model consist of cost curves, scheduling information, and capacity constraints for each project component. The cost curves may be found in Appendix B.

First, cost curves were developed to establish the relationships between unit cost and flow rate capacity, based on the source material for each of the Project Alternatives in Section 5. These cost curves were then used to develop annual cost curves that indicate the relationships between annual costs and flow rate capacity. The annual costs include both capital costs and operations and maintenance (O&M) costs. In some cases, specific capital costs are separated out further to provide clarity. Examples of unit and annual cost curves are shown below in **Figure 25** and **Figure 26**, respectively.[19]

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[18] Other spreading facilities used to recharge imported water in the MSGB include the Irwindale Spreading Basin/Manning Pit, Citrus S.G., Ben Lomond S.G., the San Gabriel River, and Valley Rubber Dams.

[19] These are “sample” cost curves that do not represent actual projects. The actual cost curves may be found in Appendix B.

**Figure 25: Example of Unit Cost Curve**

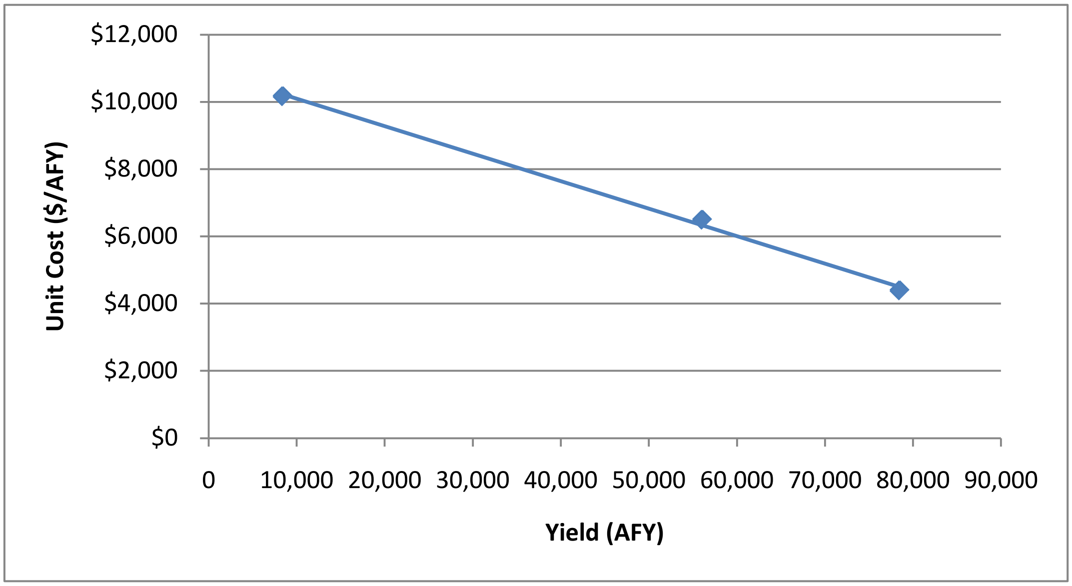
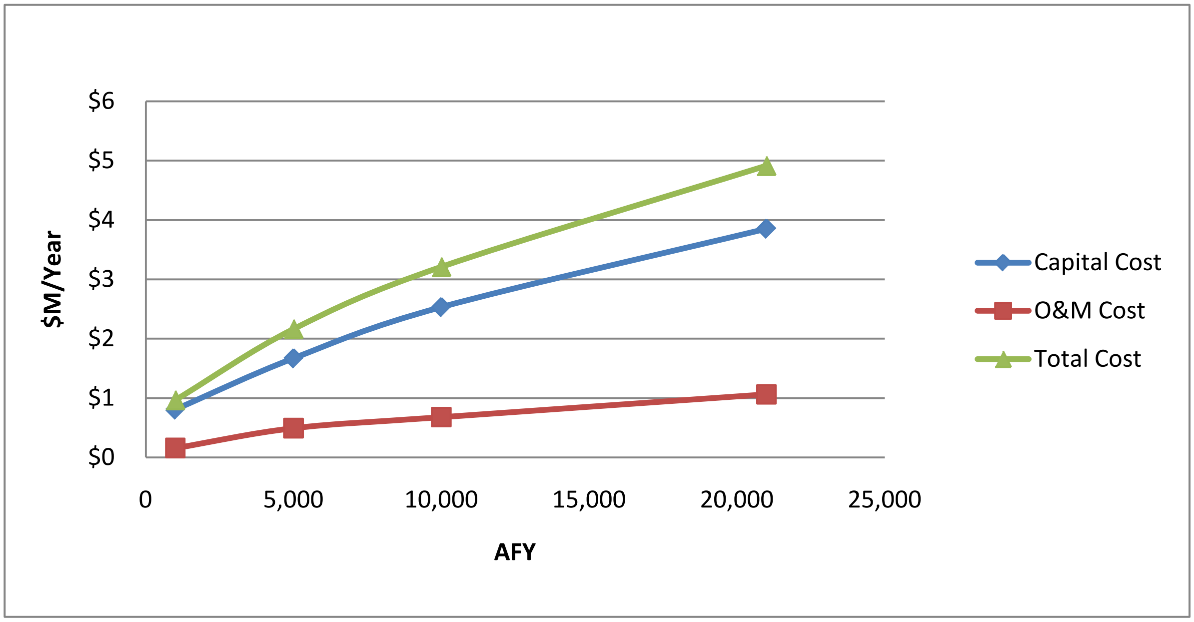


**Figure 26: Example of Annual Cost Curve**



These cost curves are used in the WEAP model to generate cost graphs for the various supply portfolios. The unit and annual cost curves for all of the project components are included in Appendix B.

The cost curves assume a general inflation rate of 2.5 percent and a finance rate of 5.5 percent. All costs are calculated in 2010 dollars using the Construction Cost Index (CCI) for Los Angeles area and assume that portfolio projects are implemented over varying lifespans depending on the supply component up to the year 2060. It is assumed that the cost estimates already include a contingency for both construction and O&M, and include mark up for engineering, construction management, legal, administration, and permitting. Costs are annualized using the financing rate and a period corresponding to the lifespan for each project (see Appendix B for details). For those projects where the lifespan is greater than 50 year life cycle, a salvage value is estimated according to the number of years remaining in the lifespan of the supply component. Specific cost curves were developed for the project components shown in **Table 2**.

**Table 2: Cost Curves Developed for GRIP**

| Project Component | Notes/Assumptions |
|---|---|
| All components | • Financing rate is 5.5% over a period determined by the lifespan for each project<br>• Inflation rate is 2.5%<br>• Capital costs assume 25% contingency and 15% for engineering, CM, legal, administration and permitting (unless otherwise noted)<br>• O&M costs assume a 25% contingency (unless otherwise noted) |
| Tier 1 and Tier 2 MWD Imported Water | • No water available at Replenishment Rate<br>• 30% treated Tier 1 and 70% treated Tier 2[1]<br>• Rate increases are projected for 50 years<br>• Two levels of pricing are estimated: Prices are based on MWD published rates up to 2012, then increase at one of two annual rates: 5.0% (low-range) or 7.5% (WRD projections based on average costs over the last 40 years)<br>• $104 per AF surcharge added for purchases made by WRD from CBMWD |
| Advanced Water Treatment | • Lifespan is 30 years<br>• Startup year is 2020<br>• Projects are re-built in 2050<br>• Salvage value in 2060 is included in lifecycle costs |
| Tertiary Purchase Price | • LACSD bases the price for tertiary recycled water on the 'Shared Savings Formula', which allows for the cost of capital expenditures to be deducted from the purchase price.<br>• Capital expenditures for GRIP AWT facilities are expected to be significantly higher than for tertiary facilities.<br>• Purchase price for AWT = $100/AF<br>• Purchase price for tertiary = $300/AF<br>• Escalation rate = 5% per year, based on 20-yr. historical average |
| Equalization | • Lifespan is 50 years<br>• Startup year is 2015 for tertiary and 2020 for AWT projects<br>• Unit cost of $4/gallon for below-grade<br>• Volume is assumed to be 20% of treatment capacity<br>• O&M costs are assumed equal to 0.5% of construction costs |
| Sewer Diversion and Plant Modification Construction Costs for SJC WRP | • Lifespan is 50 years<br>• Startup year is 2015 for tertiary and 2020 for AWT projects<br>• Contingencies and other markups included in values obtained from *Recycled Water Supply for GRIP*, LACSD TM, August 2010, Table 2<br>• Projects that include more than 26,600 AFY of tertiary product water or 19,950 AFY of AWT product water from SJCWRP will require more expensive sewer diversions (see Appendix B for details) |

| Project Component | Notes/Assumptions |
|---|---|
| Conveyance (including pipelines, pump stations, and purchase price for tertiary water) | • Startup year is 2015 for tertiary, and 2020 for AWT projects<br>• Assumes product water can flow by gravity using existing conveyance pipes between SJCWRP and MFSG<br>• Pump Station construction costs are based on the equation: 3.12*10^(0.7783*log(Q)+3,1951)<br>• Pump Station O&M costs estimated at 5% of annual construction costs, and pipeline O&M costs are estimated at 0.5% of annual construction costs<br>• Pipeline construction costs based on a unit cost of $25/in-dia/LF, assuming open-trench construction for pipelines less than 60" diameter<br>• Unit cost for electricity is assumed to be $0.12 per kWh |
| Stormwater - Spreading Ground Expansions | • Lifespan is 10 years<br>• Startup year is 2015<br>• All costs for capital and O&M are based on *Stormwater Issue Paper,* Metropolitan Water District, Draft, October 2010<br>• Contingencies and other markups included in values obtained from *Stormwater Issue Paper,* Metropolitan Water District, Draft, October 2010<br>• Potential supply from these projects is 5,200 AFY for the Central Basin and 800 AFY for the MSG Basin[2] |
| Stormwater – Legacy Project | • Lifespan is 30 years<br>• Startup year is 2020<br>• O&M costs for wells assumed at 1% of annual construction costs<br>• Costs for power to pump average $65/AF (2006 dollars)<br>• Salvage value included in lifecycle costs |

1. Tier 1 and Tier 2 split was determined by consensus at the GRIP Partnership meeting of January 11, 2011.
2. It should be noted that the total replenishment supply provided by the spreading ground expansions (6,000 AFY) would replace some of the additional AWT water made possible by sewer diversions and plant modifications at SJCWRP (if they are fully implemented to the maximum volume of 46,400 AFY). This supply would potentially be available from the SJCWRP for other projects. This assumes that the full sewer diversions/plant expansions are completed at SJCWRP and would make approximately 8,000 AFY of “extra” tertiary effluent available [6,000/0.75].

## Supply Graphs

The next step in the WEAP model was the development of supply graphs for each portfolio. These graphs indicate the AFY for each water supply source as they are implemented over time. Scheduling information, capacity constraints, and dilution flow requirements were obtained from the project alternative descriptions in Section 5 and they were adjusted within the WEAP model to meet the groundwater recharge objectives of GRIP.

An example of a supply graph is shown below in **Figure 27.**[20] In this example, imported water is used to meet the 21,000 AFY objective for the first five years, followed by the implementation of a stormwater project in 2015, and a recycled water project that begins a first phase in 2018, a second phase in 2023, and a third phase in 2028 (to allow for gradual increase in recycled water contribution over ten years). Each supply source is indicated by a different color bar and each year provides a total of 21,000 AFY. The actual supply graphs for all the portfolios are included in Appendix B.

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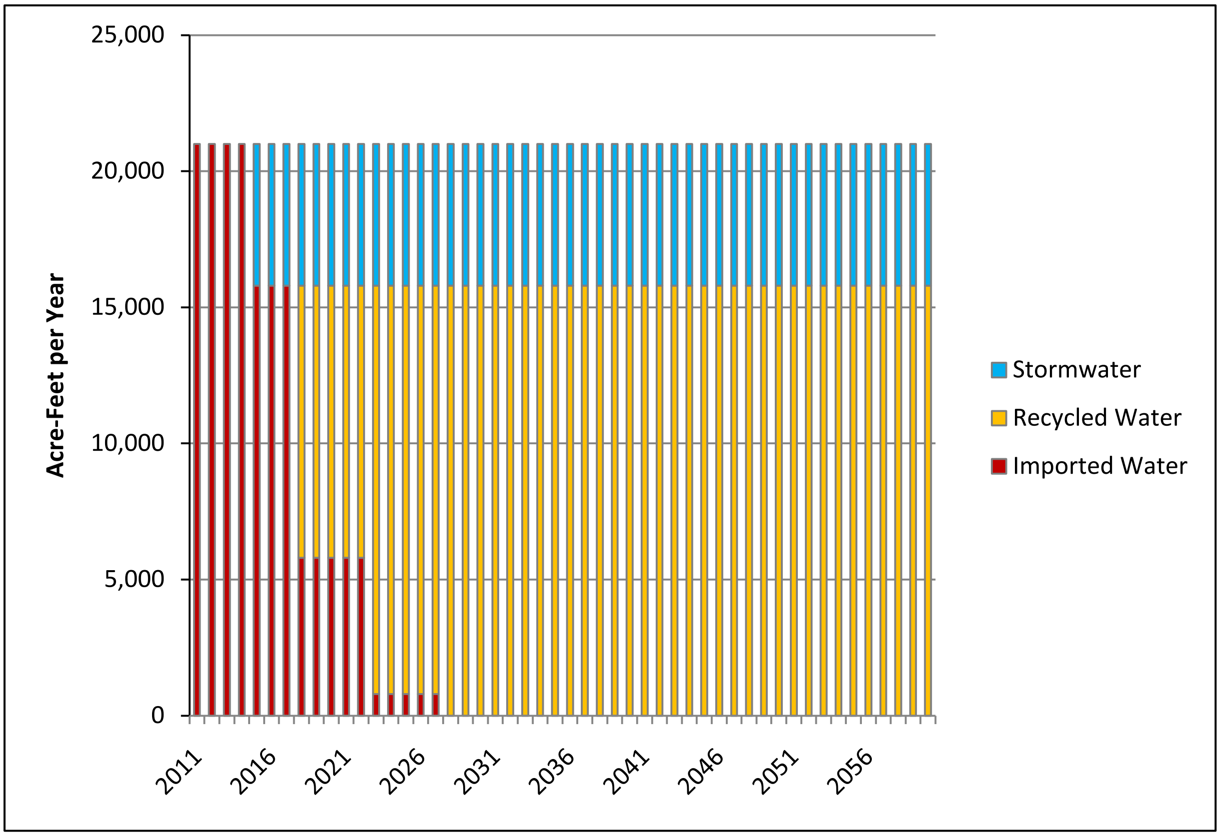
[20] This is a “sample” supply graph that does not represent an actual project. The actual supply graphs may be found in Appendix C.

Figure 27: Example of Portfolio Supply Graph



## Cost Graphs

Using the supply graphs and the cost curves, the WEAP model was then used to calculate the combined costs for each portfolio, including both construction and O&M costs. The costs are represented as annualized costs over a 50-year lifecycle up to the year 2060. Each annualized cost component is indicated by a different color bar, and the components are added together for a total annual cost.

An example of a cost graph is shown below in **Figure 28**.[21] In this example, five different projects are implemented over time, each contributing its own share of annualized costs. The actual cost graphs for all the portfolios are included in Appendix C.

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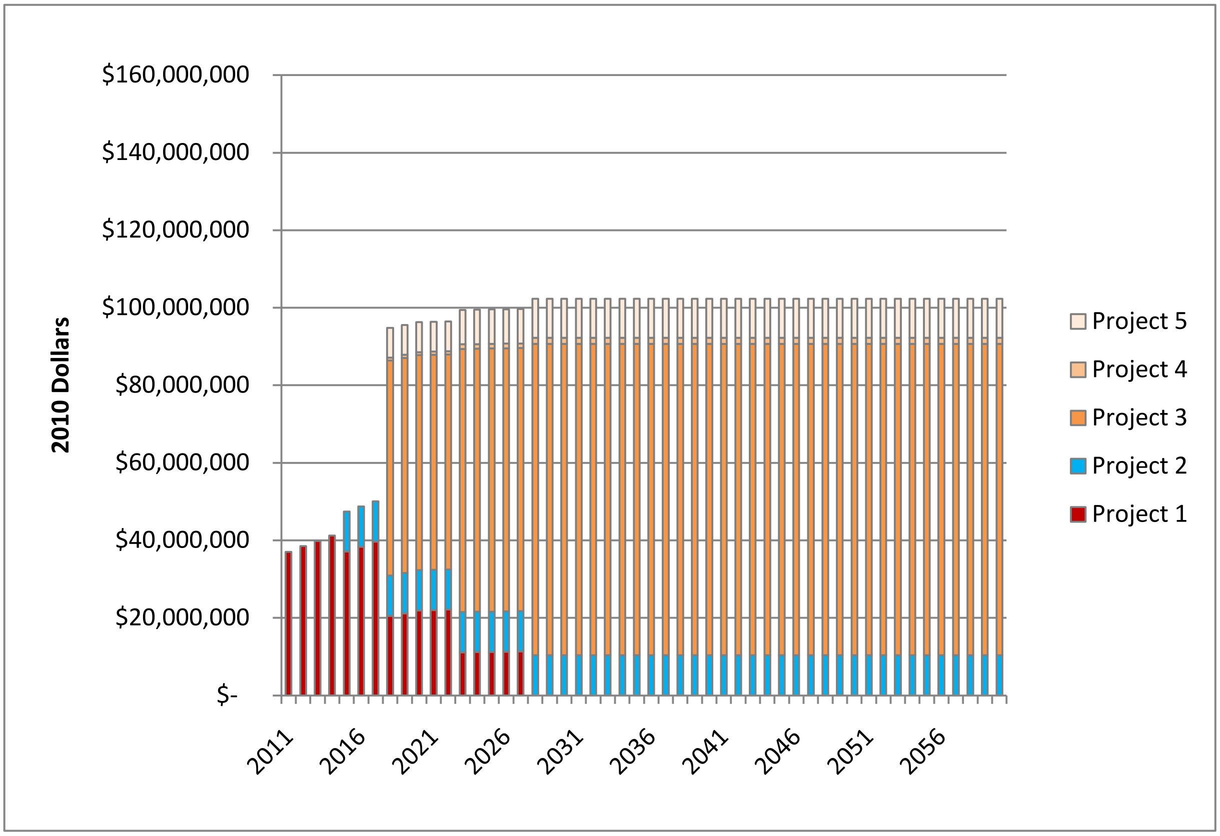
[21] These is a "sample" portfolio cost graph that does not represent an actual project. The actual portfolio cost graphs may be found in Appendix C.

Figure 28: Example of Portfolio Cost Graph



### Calculation of Net Present Value

The final step in the WEAP process is to bring the cost graph values back to single net present values (NPV) for each portfolio and use them to calculate unit cost values. These calculations are performed assuming a discount rate of 2.5 percent over the 50-year lifecycle. To calculate unit costs, the NPV was annualized at the general inflation rate (2.5 %) over 50 years and then divided by the annual yield of the portfolio (i.e., 46,000 AFY).

## 6.2 Evaluation Criteria

The five evaluation criteria that are used to compare the feasible alternatives are described below.

### Cost

For a portfolio lifecycle, cost is expressed as NPV and unit cost. The NPVs and unit costs are calculated in Appendix B. Lifecycle cost is calculated as the total cost of the portfolio over the 50 year lifecycle of the project, discounted by the inflation rate. Unit cost is calculated as the net present value of construction, O&M, and water purchases expressed as an equivalent annual cost per acre-foot in December 2010 dollars. Construction, O&M, and water purchase costs are obtained from various sources as described in Appendix B.

### Energy & $CO_2$ Emissions

Energy demand is expressed as total kWh for a portfolio lifecycle. It is calculated from combining the energy requirements for treatment and pumping. The calculations include the energy required for typical operation only and do not include raw material or construction activities.

The basis for treatment and conveyance energy calculations is summarized in **Table 3**. The calculations for energy demand are included in the cost curves in Appendix B.

**Table 3: Treatment and Conveyance Energy Values for GRIP Supply Sources**

| | Treatment (kWh/AF) | Conveyance (kWh/AF) | Reference |
|---|---|---|---|
| Imported – MWD Treated | 44 | 2,500[1] | WBMWD, 2007 |
| Recycled - AWT | 1,033 | [2] | GWRS, OCWD, 2008 |
| Recycled - Tertiary | 0 | [2] | Assumed since no net increase |
| Desalination | 3,275 | [2] | Monterey Bay Regional Water Supply Project, RMC, April 2010 |
| Recycled - Metro Satellite (MBR) | 2,767 | [2] | 1) Energy Audit of Full Scale MBR System, May 2010; A. Fenu et. al. 2) Hyperion Treatment Plant Opportunities TM, Feb. 2010. |

1. Conveyance energy intensity for MWD imported water are calculated using the average values for State Project Water and Colorado River Authority water (WBMWD, 2007).
2. Energy calculations for conveyance are based on the Hazen-Williams formula, using inputs for flow rate, total dynamic head, a pumping efficiency of 0.75 and a motor efficiency of 0.95. The calculations for conveyance energy are included with the cost estimates in Appendix B.

Using these assumptions and the supply graphs, annual values for energy demands were calculated for each portfolio. The portfolio graphs for annual energy demands are included in Appendix C. The graphs for annual energy demands were used to create a graph of total lifecycle energy demands for the various portfolios. The total lifecycle energy demands (in kWh) include all of the supply sources for each portfolio.

In addition to lifecycle energy demands, lifecycle carbon dioxide ($CO_2$) emissions were also calculated in order to indicate potential contributions with respect to climate change. These values were calculated by applying a factor of 0.724 lbs of $CO_2$ per kWh and converting to total tons of $CO_2$, based on the California Climate Action Registry, General Reporting Protocol, January 2009.[22]

## Environmental/Social

Environmental and social impacts are scored by considering the following questions. This part of the evaluation excludes energy, which is captured by the criterion above.

### Delta/Colorado River Demand

This criterion is included to acknowledge the impacts of GRIP projects on habitats in the Sacramento Bay-Delta and Colorado River. For the purposes of this analysis, projects that include more imported water are considered to have higher Delta/Colorado River demands and therefore greater impacts on Delta and Colorado River habitats.

### Basin TDS

This criterion is included to acknowledge the impacts of GRIP projects on local groundwater basin water quality. To compare portfolios on the basis of water quality impacts, the total dissolved solids (TDS) of

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[22] Climate Action Registry, General Reporting Protocol
http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html

the replenishment water is used as an indicator. The TDS concentration values used for various types of supply sources are summarized in **Table 4**.

**Table 4: TDS Concentration Values for GRIP Supply Sources**

| Supply Source | TDS Value | Reference |
|---|---|---|
| Recycled - AWT | 20 mg/l | LADWP, AWT Technical Assessment TM, Sept 2009 |
| LCWRP - Tertiary | 827 mg/l | LACSD, 20th Annual Status Report on Rec. Water FY 08-09 |
| SJCWRP - Tertiary | 617 mg/l | LACSD, 20th Annual Status Report on Rec. Water FY 08-09 |
| Imported – MWD[1] | 439 mg/l | MWDSC, UWMP, 2009 |
| Stormwater[2] | 271 mg/l | LACDPW, 2009-10 Stormwater Monitoring Report, 2009 |
| Desalination | 130 mg/l | Monterey Bay Regional Water Supply Project, RMC, 2010 |

1. Average of Colorado River Aqueduct (628 mg/l) and State Water Project (250 mg/l)
2. Average value for wet weather months

Using these assumptions and the supply graphs, the annual tons of TDS that are added to the basins was calculated for each portfolio, based on the volumes and TDS concentrations of the various supply sources. The portfolio graphs for annual tons of TDS are included in Appendix C.

### Construction Jobs

This criterion is included to acknowledge the benefits of GRIP projects on the local economy. To compare portfolios on this basis, construction job creation is used as an indicator. Using the *Estimated San Francisco Jobs Created by Capital Spending* document written by the Office of the City Administrator in San Francisco on February 25th, 2009, approximately 7.2 direct and indirect jobs are created for every million dollars in construction spending. This factor is used to estimate the number of temporary construction jobs for each portfolio.

## Regulatory/Institutional

Regulatory/Institutional criteria are expressed in quantitative terms, as described below.

### Permits

To develop a score that represents regulatory complexity, a table was created that lists many of the potential permits that will be necessary for each portfolio. The table is intended to include most, but not necessarily all, of the required permits. Potential permits are included for project components in both the Central Basin and MSG Basin. The regulatory permits/processes included in this assessment are:

- CEQA/NEPA documents
- California Water Code 1211 petition process (CWC 1211)
- Regional Water Quality Control Board/California Department of Public Health (RWQCB/CDPH)
    - Water Recycling Requirements (WRRs)
    - Waste Discharge Requirements (WDRs)
    - National Pollutant Discharge Elimination System permit (NPDES)
- United States Army Corps. of Engineers (USACE)
- Air Quality Management District (AQMD)
- Local construction permits and easements
- California Department of Fish and Game (CDFG) Streambed Alteration permit
- Tunnel excavation permit

- Occupational Safety and Health Administration (OSHA) tunnel authorization
- Coastal Commission permit

For additional detail on regulatory requirements and permitting, please refer to Appendix D and E.

### Potential Partners

To develop a score that represents institutional complexity, a table was created that lists many of the potential partners that will be necessary for each portfolio. The table is intended to include most, but not necessarily all, of the required partners. Potential partners are included for project components in both the Central Basin and MSG Basin. A score is given to each portfolio based on the number of potential partners that must be coordinated with over the 50-year lifecycle.

## Implementation

Implementation criteria are expressed in quantitative and qualitative terms, as described below.

### Time to First Phase

This criterion is included to acknowledge the benefits of implementing GRIP projects earlier rather than later, mainly from a reliability perspective. A portfolio that can start up earlier is considered superior because a more reliable replenishment supply can be provided sooner. The assumptions made about implementation time are shown in Table 2.

### Scalability

This criterion is included to acknowledge the benefits of the ability to scale back GRIP projects during implementation to accommodate changes and/or new projects alternatives. A portfolio that is more scalable is considered superior. The following assumptions are made about scalability:

- **Imported projects –** very easily scaled (take more or less from MWD)
- **Stormwater projects** (spreading ground improvements) – easily scaled
- **Treatment projects -** easily scaled
- **Stormwater** (Legacy Project) – easily scaled
- **Sewer diversion projects** – not easily scaled
- **Pipeline projects** – not easily scaled

A score is given to each portfolio based on the degree of scalability anticipated:

"++" high scalability (most favorable)
"+" medium scalability
"0" low scalability (least favorable)

# 7 Supply Portfolios

This section provides a tabulated summary of the Supply Portfolios that were created using the Project Alternatives from Section 5. These portfolios were intended to represent a broad range of project concepts, with each portfolio focusing on a different “main” supply source. Other supply sources are also included if they are (1) compatible, (2) cost-effective, and (3) able to be implemented earlier than the “main” supply source. Most of the “secondary” supply sources cannot provide enough water to meet the GRIP objectives on their own, or they are not cost-effective over time without combining them with other sources. The purpose of the portfolio analysis is to provide a better understanding of each portfolio and to identify any that should be eliminated from further consideration.

**Table 5** is provided below as a “quick reference” for the Supply Portfolios that are described with graphics and spreadsheets in Appendix C. The table specifies the name, the supply sources (with flow rates) for each basin, and key characteristics. It should be noted that the yields are different from the Project Alternative descriptions in Section 5 because one or more project alternatives are combined together to create these portfolios. In addition, the yields in this table represent the portfolios in the future, after the “main” supply source has been fully-developed. Supply sources that appear “early” in the portfolio lifecycle do not appear in the table.

The supply graphs that contain additional information for all the portfolios are included in Appendix C.

### Table 5: Supply Portfolio Descriptions

| Portfolio Name | Central Basin Components (AFY)[1,2] | MSG Basin Components (AFY)[1,2] | Key Characteristics |
|---|---|---|---|
| **Baseline / No Project** | Imported MWD (21,000)<br>**Total = 21,000** | Imported MWD (25,000)<br>**Total = 25,000** | • Assumes split[3] of Tier 1 (30%) and Tier 2 (70%) to achieve comparable reliability to other portfolios<br>• Costs are calculated assuming two different escalation rates of 5.0% and 7.5% per year to establish a range of costs |
| **SJC (AWT)** | AWT SJC (15,800)<br>S.G. projects[4] (5,200)<br>**Total = 21,000** | AWT SJC (24,200)<br>S.G. projects[5] (800)<br>**Total = 25,000** | • Recycled water operations phased according to dilution requirements in Section 3<br>• Sewer diversion projects are split according to RW usage<br>• Requires higher cost sewer diversions |
| **SJC + LC (AWT)** | AWT SJC (1,400)<br>AWT LC (14,400)<br>S.G. projects[4] (5,200)<br>**Total = 21,000** | AWT SJC (24,200)<br>S.G. projects[5] (800)<br>**Total = 25,000** | • Recycled water operations phased according to dilution requirements in Section 3<br>• Sewer diversion projects are split according to RW usage<br>• Requires higher cost sewer diversions |
| **SJC (Tertiary)** | Tertiary SJC (15,800)<br>S.G. projects[4] (5,200)<br>**Total = 21,000** | Tertiary SJC (21,700)<br>Imported MWD (2,500)<br>S.G. projects[5] (800)<br>**Total = 25,000** | • Recycled water operations phased according to dilution requirements in Section 3<br>• Sewer diversion projects are split according to RW usage<br>• An average of 2,500 AFY of imported dilution water is assumed for MSG Basin.<br>• Requires higher cost sewer diversions |
| **SJC + LC (Tertiary)** | Tertiary LC (15,800)<br>S.G. projects[4] (5,200)<br>**Total = 21,000** | Tertiary SJC (21,700)<br>Imported MWD (2,500)<br>S.G. projects[5] (800)<br>**Total = 25,000** | • Recycled water operations phased according to dilution requirements in Section 3<br>• Sewer diversion projects are split according to RW usage<br>• An average of 2,500 AFY of imported dilution water is assumed for MSG Basin.<br>• Does not require higher cost sewer diversions |
| **SJC (AWT) + Legacy Project** | Legacy Project (15,800)<br>S.G. projects[4] (5,200)<br>**Total = 21,000** | AWT SJC (24,200)<br>S.G. projects[5] (800)<br>**Total = 25,000** | • Recycled water operations phased according to dilution requirements in Section 3<br>• Sewer diversion projects are split according to RW usage<br>• Requires higher cost sewer diversions |

Notes:
1. The yields are different from the Project Alternative descriptions in Section 5 because one or more project alternatives are combined together to create the portfolios.
2. The yields in this table represent the portfolios in the future, after the “main” supply source has been fully-developed.
3. Tier 1 and Tier 2 split was determined by consensus at the GRIP Partnership progress meeting of January 11, 2011.
4. Includes Rio Hondo Spreading Grounds Expansion (4,700 AFY) and Dominguez Gap Spreading Grounds Improvements (500 AFY).
5. Includes Buena Vista Spreading Basin Improvements (500 AFY) and Walnut Creek Spreading Basin Improvements (300 AFY).
6. Appendix C contains the supply graphs that contain additional information for all the portfolios.

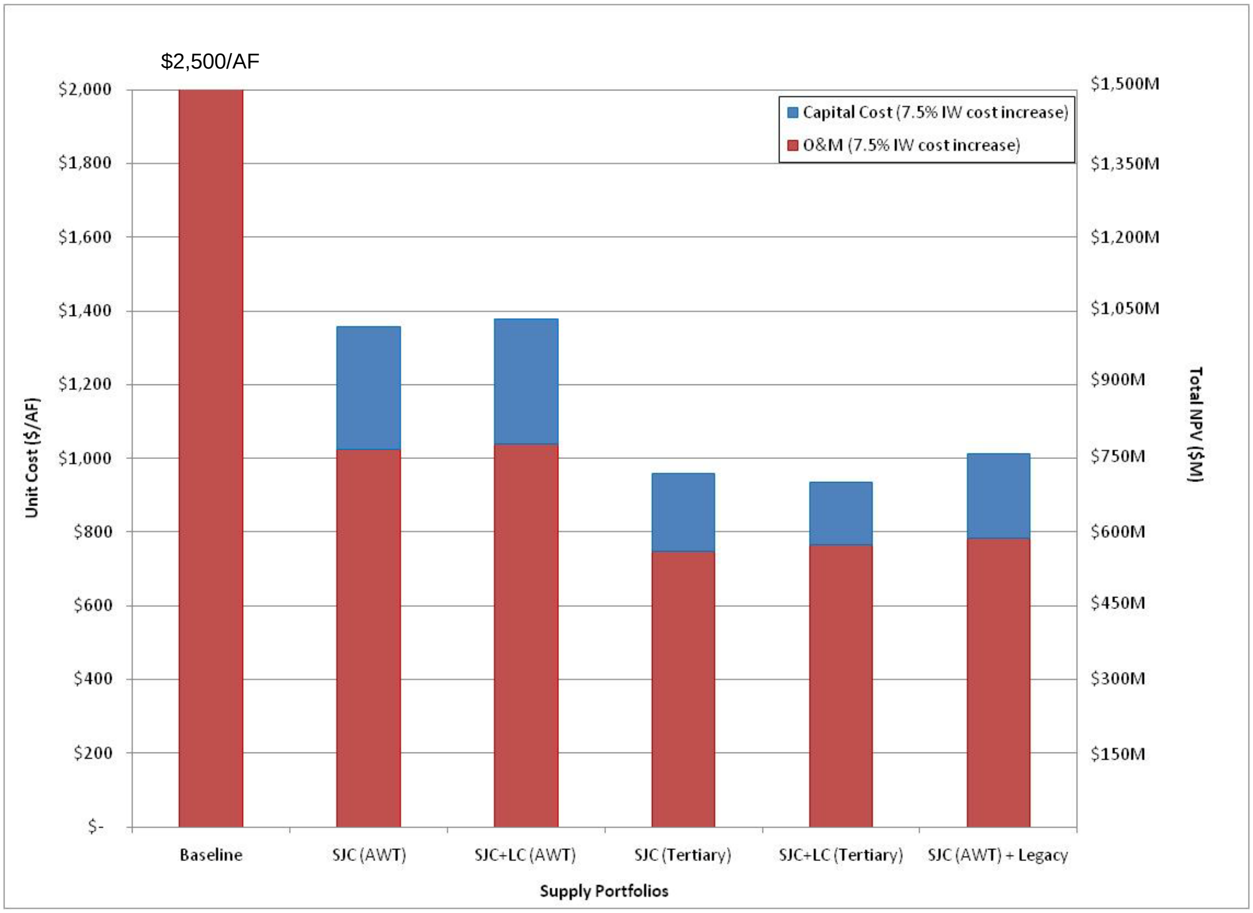
# 8 Evaluation Results

This section includes the analysis results of each portfolio for each of the criterion described in Section 7 and provides a comparative analysis of each portfolio. Evaluation results are broken out by basin in Appendix C.

## 8.1 Cost

The unit cost and net present values calculated in Appendix B were used to generate lifecycle values for cost as shown in **Figure 29.** The costs for the “Baseline” or “No Project” supply portfolio assume a 7.5 percent per year escalation rate for imported MWD Tier 1 and Tier 2 water. Appendix C includes a breakdown of unit costs and NPV by basin. Appendix C also includes an estimate for the “Baseline” or “Not Project” supply portfolio that assumes a 5.0 percent per year escalation rate for MWD imported water (in addition to the 7.5% escalation rate shown here).

**Figure 29: Unit Costs and NPV – 50 Year Lifecycle**



Note: It is important to note that these costs do not take into account any outside funding opportunities that are expected to be pursued from local, state, and federal sources.

Key findings from the unit cost and NPV evaluation are:

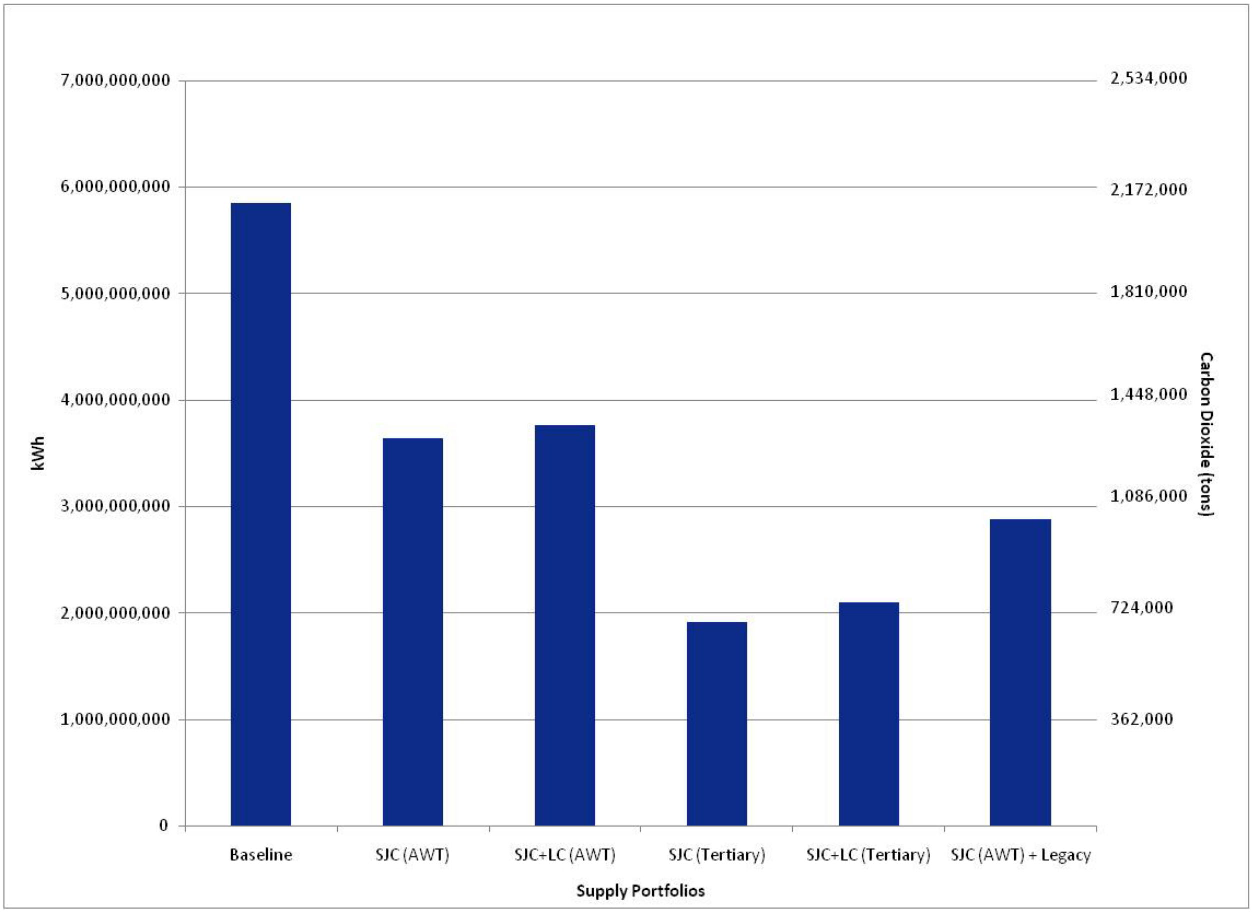
- All portfolios have lifecycle unit costs and NPV that are at least 45 percent lower than the costs for imported water (i.e., the “No Project” Portfolio), assuming a 7.5 percent per year escalation rate for imported water.

- AWT portfolio lifecycle costs are approximately 30 percent higher than the costs for tertiary portfolios.
- The lifecycle costs for tertiary portfolios could be lower if the purchase price for tertiary effluent is reduced. These estimates assume a price of $300/AF for tertiary projects and a price of $100/AF for AWT projects (for details see Appendix B).

## 8.2 Energy and $CO_2$ Emissions

The energy and $CO_2$ emissions calculated in Appendix C were used to generate lifecycle values as shown in **Figure 30.** Appendix C includes a breakdown of energy demands and $CO_2$ emissions by basin.

**Figure 30: Energy Demands and $CO_2$ Emissions – 50 Year Lifecycle**



Note: It is assumed that $CO_2$ emissions are equal to the WECC California eGRID Subregion $CO_2$ emission factor presented in Table C.2 of the California Climate Action Registry, General Reporting Protocol.

Key findings from the energy demands and $CO_2$ emissions evaluation are:

- Energy demands and $CO_2$ emissions are significantly higher for the No Project Portfolio due to pumping required for the conveyance of imported water
- $CO_2$ emission savings for AWT portfolios (approximately 40 percent) are equivalent to the emissions from approximately 125,000 cars in one year
- CO2 emission savings for tertiary portfolios (approximately 65 percent) are equivalent to the emissions from approximately 230,000 cars in one year

## 8.3 Environmental/Social

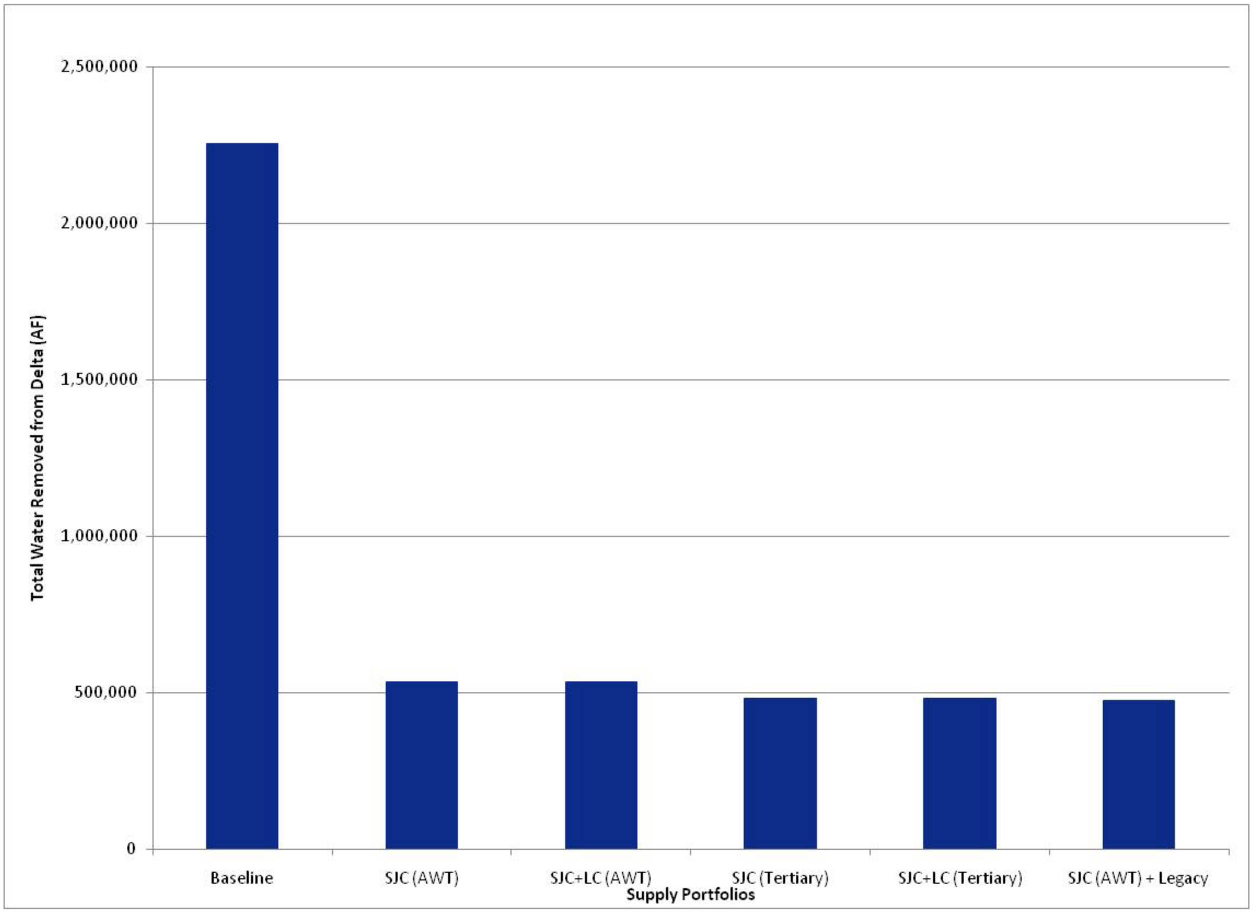
Environmental/Social criteria are expressed in quantitative terms as indicated below for:

- Potential Delta / Colorado River Demands
- Total Dissolved Solids
- Construction Jobs

### Potential Delta/Colorado River Demands

The total AF of Delta/Colorado River demands that could potentially be required for each portfolio over the 50-year lifecycle is shown in **Figure 31**. Appendix C includes a breakdown of potential Delta/Colorado River demands by basin.

**Figure 31: Potential Delta/Colorado River Demands – 50 Year Lifecycle**



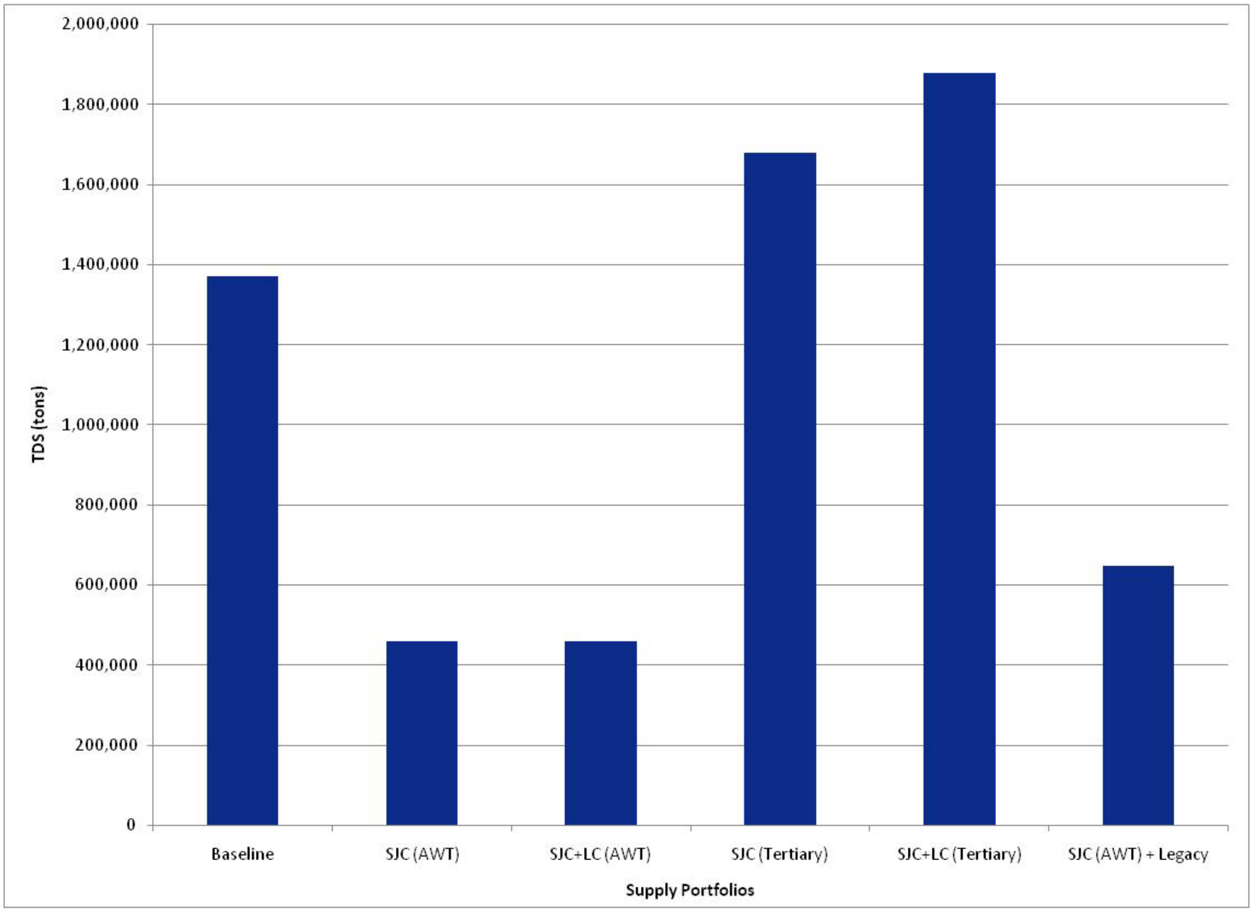
Key findings from the Delta/Colorado River demands evaluation are:

- All portfolios result in a reduction of demands of approximately 80 percent compared to the No Project portfolio.
- All portfolios require some imported water due to the phasing-in of GRIP projects over time and blending requirements for recycled water projects.

## Total Dissolved Solids

The total TDS over the 50-year lifecycle for the various portfolios is shown in **Figure 32**. Appendix C includes a breakdown of TDS loadings by basin.

**Figure 32: Total Dissolved Solids – 50 Year Lifecycle**



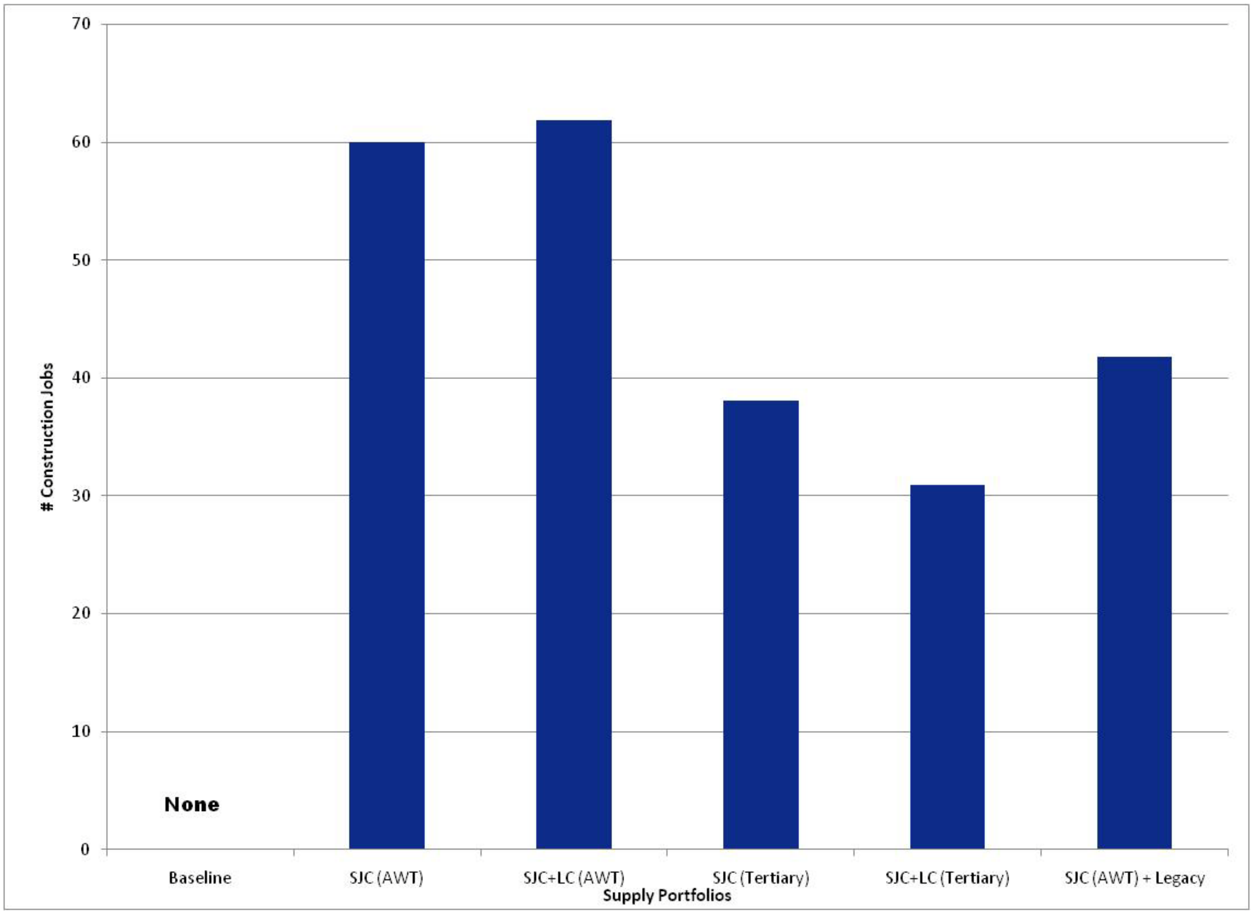
Key findings from the TDS loading evaluation are:

- AWT portfolios result in a TDS loading that is approximately 65 percent lower than the No Project portfolio.
- Tertiary portfolios result in a TDS loading that is approximately 20 to 35 percent higher than the No Project portfolio.
- The issue of TDS loading will need to be addressed in the salt and nutrient management planning process for the MSG Basin and Central Basin.
- If more tertiary recycled water is used for GRIP projects, it may be necessary to offset the increased TDS loading with AWT water or other water in order to get RWQCB approval.

### Construction Jobs

The estimated total construction jobs created over the 50-year lifecycle are shown for each portfolio in **Figure 33**. Appendix C includes a breakdown of jobs created by basin.

**Figure 33: Construction Jobs Created – 50 Year Lifecycle**



Key findings from the construction jobs evaluation are:

- Construction jobs constitute a benefit for larger projects with higher capital costs.
- AWT portfolios generate 40 to 50 percent more construction jobs than tertiary portfolios.

## 8.4 Regulatory/Institutional

The results scores for the regulatory/institutional criteria are discussed below and include:

- Permits
- Agency Coordination

### Permits

For each portfolio, a value is given to each portfolio based on the number of potential permits that must be obtained over the 50-year lifecycle as shown in **Table 6.** The key finding from the permit evaluation is that the number of permits is the same for each of the portfolios other than No Project.

**Table 6: Presumed Permits Needed**

| Permits | Baseline / No Project | SJC (AWT) | SJC+LC (AWT) | SJC (Tertiary) | SJC+LC (Tertiary) | SJC (AWT) + Legacy |
|---|---|---|---|---|---|---|
| CEQA/NEPA | | * | * | * | * | * |
| SWRCB - CWC 1211 | | * | * | * | * | * |
| RWQCB/CDPH - WRRs | | * | * | * | * | * |
| RWQCB/CDPH - WDRs | | * | * | * | * | * |
| USACE | | * | * | * | * | * |
| AQMD | | * | * | * | * | * |
| Construction/Easements | | * | * | * | * | * |
| CDFG Streambed Alteration | | * | * | * | * | * |
| **TOTAL** | **0** | **8** | **8** | **8** | **8** | **8** |

### Agency Coordination

To estimate institutional complexity, a score is given to each portfolio based on the number of potential partners that must be coordinated with over the 50-year lifecycle to show the required amount of agency coordination, as shown in **Table 7**. The key finding from the agency coordination evaluation is that the amount of coordination is roughly the same for each of the portfolios other than Baseline/No Project.

**Table 7: Agency Coordination**

| Agency | Baseline / No Project | SJC (AWT) | SJC+LC (AWT) | SJC (Tertiary) | SJC+LC (Tertiary) | SJC (AWT) + Legacy |
|---|---|---|---|---|---|---|
| WRD | * | * | * | * | * | * |
| LACSD | | * | * | * | * | * |
| USGVMWD | * | * | * | * | * | * |
| MWD | * | * | * | * | * | * |
| Central Basin MWD | * | * | * | * | * | * |
| LACDPW | | * | * | * | * | * |
| City of Long Beach | | | | | | * |
| **TOTAL** | **4** | **6** | **6** | **6** | **6** | **7** |

## 8.5 Implementation

The portfolio scoring for implementation criteria are discussed below and include:

- Time to First Phase
- Scalability

### Time to First Phase

The values assumed for each portfolio based on the time required to implement the first phase of the main project component, not including imported water or the smaller stormwater projects (which are included in all portfolios) are shown in **Table 8**. The key finding from the timing evaluation is that the number of years required to implement an AWT project is significantly higher than the time required to implement a tertiary project.

**Table 8: Time to First Phase for GRIP Portfolios**

| | Baseline / No Project | SJC (AWT) | SJC+LC (AWT) | SJC (Tertiary) | SJC+LC (Tertiary) | SJC (AWT) + Legacy |
|---|---|---|---|---|---|---|
| Years to First Phase | 0 | 10 | 10 | 5 | 5 | 10 |

## Scalability

The scalability scores given to each portfolio are shown in **Table 9**. As previously discussed, portfolios with no project components that are not easily scaled received a "most favorable" score, indicated by a "++" in the last row. Portfolios with one project component that is not easily scaled receive a "medium" score, indicated by a "+"; portfolios with two or more project components that are not easily scaled receive a "least favorable" score, indicated by "0". In the table columns a single asterisk (*) indicates that the portfolio includes this type of project for one basin. A double asterisk (**) indicates that the portfolio includes this type of project for both basins.

The key finding from the scalability evaluation is that, other than the No Project, the portfolios are not very scalable due to the need for conveyance pipelines and sewer diversions.

**Table 9: Scalability for GRIP Portfolios**

| | Baseline / No Project | SJC (AWT) | SJC+LC (AWT) | SJC (Tertiary) | SJC+LC (Tertiary) | SJC (AWT) + Legacy |
|---|---|---|---|---|---|---|
| Imported | ** | * | * | * | * | * |
| Stormwater - S.G. | | * | * | * | * | * |
| Treatment | | ** | * | | | * |
| Stormwater - Legacy | | | | | | * |
| Sewer Diversions | | ** | * | ** | | ** |
| Pipelines | | ** | ** | * | ** | ** |
| **Overall Score:** | **++** | **0** | **0** | **0** | **+** | **0** |

"*" indicates that the portfolio includes this type of project for one basin
"**" indicates that the portfolio includes this type of project for both basins

## 8.6 Evaluation

This section summarizes the evaluation criteria scores, combining cost findings from the WEAP model with the evaluation criteria. The updated evaluation criteria scores are shown in **Table 10**. Evaluation results are broken out by basin in Appendix C.

**Table 10: Potentially Feasible GRIP Project Alternatives**

| | Baseline / No Project | SJC (AWT) | SJC+LC[1] (AWT) | SJC (Tertiary) | SJC+LC[1] (Tertiary) | SJC (AWT) + Legacy |
|---|---|---|---|---|---|---|
| **Lifecycle Cost[2]** | | | | | | |
| Unit Cost ($/AF)[3] | 2,500 | 1,300 | 1,300 | 900 | 900 | 1,100 |
| NPV ($B) | 2.46 | 1.38 | 1.28 | 0.89 | 0.92 | 1.09 |
| **Energy** | | | | | | |
| Total Energy (MW) | 5.9 M | 3.6 M | 3.8 M | 1.9 M | 2.1 M | 2.9 M |
| $CO_2$ (tons) | 2.1 M | 1.3 M | 1.4 M | 0.7 M | 0.8 M | 1.0 M |
| **Environmental/Social** | | | | | | |
| Delta Demands (AF) | 2.3 M | 0.5M | 0.5 M | 0.5 M | 0.5 M | 0.5 M |
| Total TDS (tons) | 1.4 M | 0.5 M | 0.5 M | 1.7 M | 1.9 M | 0.6 M |
| Construction Jobs | 0 | 60 | 62 | 38 | 31 | 42 |
| **Regulatory/Institutional** | | | | | | |
| Permits | 0 | 8 | 8 | 8 | 8 | 8 |
| Partners | 4 | 6 | 6 | 6 | 6 | 7 |
| **Implementation** | | | | | | |
| Years to First Phase | 0 | 10 | 10 | 5 | 5 | 10 |
| Scalability | ++ | 0 | 0 | 0 | + | 0 |

Notes:

1. The SJC+LC supply portfolios do not provide the operational flexibility of other portfolios because the option to transfer flows to MSG Basin during and after storm events will not be available; this is an important disadvantage that is not captured in the evaluation criteria.
2. Lifecycle costs assume imported water costs escalate at 7.5% per year for Table 10; a range of values is shown in Appendix B that includes both 5.0% and 7.5% per year escalation rates.
3. Unit costs rounded to the nearest $100.

The key conclusions from the combined evaluation process are:

- There are pros and cons associated with each of the portfolios. There are none that can be eliminated at this level of analysis, given the assumptions used.
- For GRIP, the portfolios in **Table 10** are considered the Potentially Feasible GRIP Project Alternatives. The Legacy Project portion of the SJC (AWT) + Legacy Project alternative is considered outside the jurisdictional authority of the GRIP Partnership and is therefore acknowledged as a feasible alternative that will not be carried forward to CEQA/NEPA by the Partnership at this time. The SJC (AWT) + Legacy Project will be recommended for further evaluation by others.

# 9 Recommendations/Next Steps

This section provides recommendations for next steps in the GRIP project development. These recommendations are summarized in **Table 11**. The term "Project Alternative" is used for these final recommendations to provide consistency with the original name of the GRIP Alternatives Analysis.

**Table 11: Next Steps for Potentially Feasible GRIP Project Alternatives**

| Alternative | Portfolio Description | Outstanding Issues |
|---|---|---|
| Baseline / No Project | • blend of MWD Tier 1 and Tier 2 imported water<br>• small spreading ground improvements that allow capture of more stormwater | • MWD rate increases must be verified<br>• Split of Tier 1 and Tier 2 water must be verified |
| AWT (SJC) | • AWT recycled water produced at the SJC WRP<br>• small spreading ground improvements that allow capture of more stormwater | • public outreach is needed to provide feedback on specific treatment technologies<br>• need to track CDPH Groundwater Recharge Regulations<br>• need further investigation of soil aquifer treatment impacts<br>• need further evaluation of specific treatment technologies |
| AWT (SJC + LC) | • AWT recycled water produced at the SJC WRP<br>• AWT recycled water produced at the LC WRP<br>• small spreading ground improvements that allow capture of more stormwater | • significant lack of operational flexibility/redundancy<br>• must ensure operating reliability without the potential of storing stormwater in MSG Basin<br>• public outreach is needed to provide feedback on specific treatment technologies<br>• need to track CDPH Groundwater Recharge Regulations<br>• need further investigation of soil aquifer treatment impacts<br>• need further evaluation of specific treatment technologies |
| Tertiary (SJC) | • tertiary recycled water produced at the SJC WRP<br>• small spreading ground improvements that allow capture of more stormwater<br>• small amount of imported blend water for MSG Basin | • public outreach is needed to provide feedback on water quality concerns<br>• need to track CDPH Groundwater Recharge regulations<br>• must coordinate with salt and nutrient management efforts to address TDS impacts<br>• need further evaluation of specific treatment technology |
| Tertiary (SJC + LC) | • tertiary recycled water produced at the SJC WRP<br>• tertiary recycled water produced at the LC WRP<br>• small spreading ground improvements that allow capture of more stormwater<br>• small amount of imported blend water for MSG Basin | • significant lack of operational flexibility/redundancy<br>• must ensure operating reliability without the potential of storing stormwater in MSG Basin<br>• public outreach is needed to provide feedback on water quality concerns<br>• need to track CDPH Groundwater Recharge regulations<br>• must coordinate with salt and nutrient management efforts to address TDS impacts<br>• need further evaluation of specific treatment technology |

| Alternative | Portfolio Description | Outstanding Issues |
|---|---|---|
| SJC (AWT) + Legacy Project | • additional stormwater capture from percolation capacity created by new production wells<br>• AWT recycled water produced at the SJC WRP<br>• small spreading ground improvements that allow capture of more stormwater | • need partners with stormwater jurisdiction<br>• public outreach is needed to provide feedback on specific treatment technologies<br>• need to track CDPH Groundwater Recharge Regulations<br>• need further investigation of soil aquifer treatment impacts<br>• must ensure operator reliability<br>• need further evaluation of specific treatment technologies |

Additional research and investigation will be needed to consider the following in more detail.

- Specific treatment objectives should be established and specific advanced treatment and tertiary treatment technologies should be analyzed, such as membrane bioreactor (MBR), biological activated carbon (BAC), microfiltration (MF), nanofiltration (NF), ultrafiltration (UF), and reverse osmosis (RO).
- Various advanced oxidation technologies, including ultraviolet radiation (UV) and ozone, and product water stabilization technologies should also be analyzed to select the best combination for meeting the treatment objectives.
- Investigations of all treatment technologies should be accompanied by appropriate bench-scale and pilot-scale testing.
- For recycled water project components, an extensive analysis of regulatory requirements for dilution flows should be conducted.
    - determine the basis for RWC requirements (e.g., TOC, BDOC)
    - determine allowable flows that can be counted as blend water (e.g., underflow, infiltration, runoff)
    - determine the methodology for computing RWC (e.g., for MFSG, will both spreading grounds be averaged or computed separately)
- For all of the preferred alternatives, it is recommended that the ongoing review and approval process for the CDPH GWR Regulations be tracked.
- For all of the potentially feasible alternatives, it is recommended that extensive public and stakeholder outreach be conducted to assess the feasibility of project components with respect to public acceptance.

# References

California Climate Action Registry, 2009. General Reporting Protocol, Version 3.1. http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html. January.

CDPH, 2008. California Department of Public Health (CDPH), Groundwater Recharge Reuse Draft Regulations. August 5.

DWR, 2010a. Watermaster Service in the Central Basin Annual Reports 2000-01 to 2008-09. http://www.water.ca.gov/watermaster/.

Fairbanks Morse, 1988. Hydraulic Handbook: Fundamental Hydraulics and Data Useful in the Solution of Pump Application Problems, Thirteenth Edition; Fairbanks Morse Pump Corporation. p. 16.

Fenu, A., et al, 2010. Energy Audit of Full Scale MBR System. May.

GeoMatrix, 2005. Comprehensive Groundwater Model Report. July.

Hall, Andrew, 2010. Personal Communication with Andrew Hall, LACSD. December 15.

Johnson, Ted, WRD Chief Hydrogeologist, 2010. Personal Communications, November 12.

LACDPW, 2010b. Annual Hydrologic Reports. 1996 to 2008, and recent online data lacounty.gov/wrd/publication/.

Los Angeles County Sanitation Districts (LACSD), 2008. Water Reclamation Plant Contracted Flow Amounts Table, Los Angeles County Sanitation Districts.

LACSD, 2008. Water Conservation Distribution System.

LACSD, 2009. 20th Annual Status Report on Recycled Water FY 08-09.

LACSD, 2010. JWPCP Concept Level AWT & ZLD. November.

LACSD, 2010b. Recycled Water Supply for GRIP. August.

LADWP, 2010c. Cost Estimating Basis TM. December 2010 (Table 12)

LADWP, 2010d. Hyperion Treatment Plant Opportunities TM. February.

LADWP, 2010e. Terminal Island Water Reclamation Plant Opportunities TM. February.

Main San Gabriel Basin Watermaster, 2010. Annual and Five-Year Reports, 1972 to 2015.

Metropolitan Water District of Southern California (MWD), 2007. Status Report on the Use of Groundwater in the Service Area of the Metropolitan Water District of Southern California, Report 1308. September.

MWD, 2009. Regional Urban Water Management Plan. November.

MWD, 2010. IRP Stormwater/Urban Runoff Technical Workgroup Issue Paper.

MWD, 2010b. IRP Seawater Desalination Technical Workgroup Issue Paper.

Montgomery Waston. 2001. Montebello Forebay Groundwater Recharge Optimization Study. April.

MWH, 2009. GRIP Technical Memorandum 10 - OPCC and OM Costs. June.

OCWD, 2008. Groundwater Replenishment System Advanced Water Purification Facility and Green Acres - Monthly Report, OCWD, November.

RMC, 2010. Monterey Bay Regional Water Supply Project. April.

Sanks. Pumping Station Design. Figure 29.7.

Stetson Engineers, Inc., 2007. Potential Effective Recharge Capabilities (PERC) III. February 2007.

SWRCB, 2008. Draft Groundwater Recharge Reuse Regulations, August 2008.

Superior Court of the State of California for the County of Los Angeles, 1989. Amended Main San Gabriel Basin Judgment: Case #924128, Upper San Gabriel Valley Municipal Water District, plaintiff, vs. City of Alhambra, et al., Defendants. August 24, 1989 with amendments through February 1992.

Water Replenishment District of Southern California (WRD), 2000. Preliminary Plan for Groundwater Resources Development Program. May.

Water Replenishment District of Southern California (WRD), 2010. Annual Review of LVL Operating Costs.

Wilkinson, Robert C., 2007. Analysis of the Energy Intensity of Water Supplies for West Basin Municipal Water District.

Willardson, Ben, LACDPW Civil Engineer, 2010. Personal Communications, November 12.

# Appendices

This section contains a separate table of contents and five appendices:

- Appendix A: WEAP Model Schematic
- Appendix B: Cost Curves
- Appendix C: Portfolio Life Cycle Graphs
- Appendix D: Technical Memorandum 1: Review of Existing Documents and Regulations
- Appendix E: Technical Memorandum 2: Water Supply and Facility Options Evaluation

**Appendix A** contains a WEAP model schematic which is a screenshot of the WEAP model setup used for the GRIP alternatives analysis, and it is used strictly as an interface for accessing inputs and results. The locations of supply and demand nodes and the placement of links do not affect the results of the model. These inputs to WEAP align with with the cost curves and supplies described in Appendix B and Appendix C.

**Appendix B** contains the cost curves developed to calculate the costs of project components within each portfolio. The cost curves are organized by supply type and component (e.g., MWD imported, AWT treatment improvements, tertiary improvements, etc.) The assumptions used to generate the cost curves can be found at the end of the appendix.

**Appendix C** contains the detailed lifecycle information about each portfolio described in the TM including: supply breakdowns by year, energy use, TDS, capital costs and O&M costs. Each portfolio section begins with detailed information by year for each of the items described above organized within tables. Following this information are graphs summarizing supply breakdowns by year for each groundwater basin, cost information by portfolio supply component, TDS for each basin by supply component, and energy expenditure for each basin by supply. This appendix also contains portfolio summary information, including summary information by portfolio in table format and in chart format. Reference information specific to Appendix C can be found at the end of this section.

**Appendix D** contains a copy of Technical Memorandum 1: Review of Existing Documents and Regulations.

**Appendix E** contains a copy of Technical Memorandum 2: Water Supply and Facility Options Evaluation.

# Appendix Table of Contents

## Appendix A: WEAP Model Schematic and Inputs

## Appendix B: Cost Curves

## Appendix C: Portfolio Life Cycle Graphs

## Appendix D: Technical Memorandum 1

This appendix contains a table of contents within the document itself.

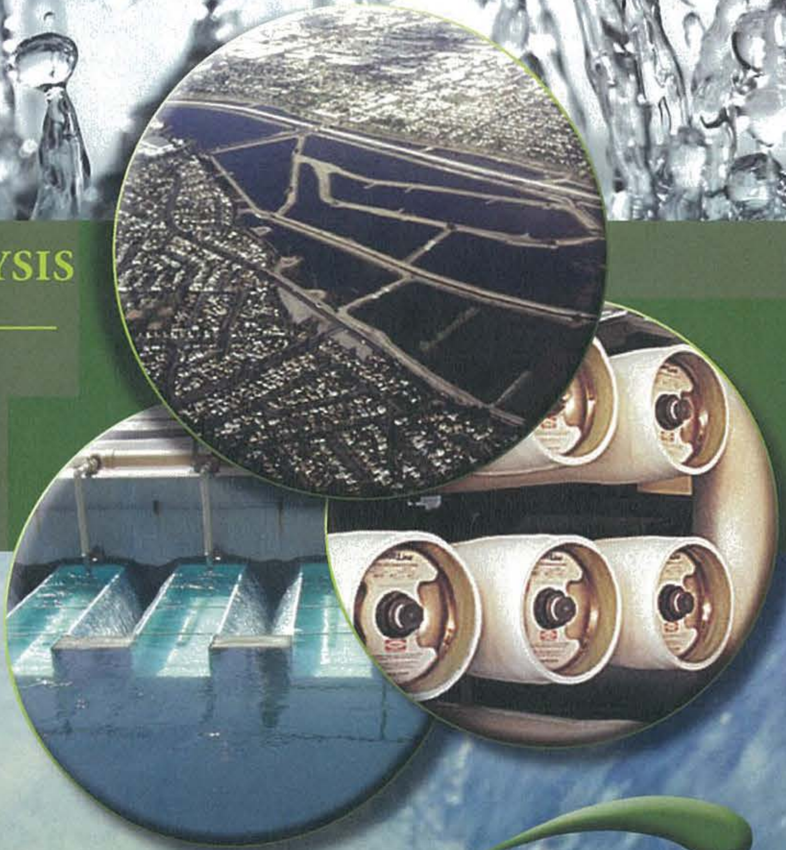
## Appendix E: Technical Memorandum 2

This appendix contains a table of contents within the document itself.

# ALTERNATIVES ANALYSIS UPDATE REPORT

## Groundwater Reliability Improvement Program Recycled Water Project

**FINAL**



Submitted to

**WRD**
*Water Replenishment District of Southern California*

*Leadership in Affordable Water Independence*

**CH2MHILL**

in Association with
MWH
Carollo
Jörg Drewes, PhD
DR Consultants & Designers, Inc.
Somach Simmons & Dunn
BA, Inc.

October 2012

*Final Report*

# Alternatives Analysis Update Report for the GRIP Recycled Water Project

Prepared for

**Water Replenishment District of Southern California**

4040 Paramount Blvd.
Lakewood, CA 90712

October 2012

REGISTERED PROFESSIONAL ENGINEER
FRED SOROUSHIAN
No. C 37237
Exp. 6/30/14
CIVIL
STATE OF CALIFORNIA

Prepared by

**CH2MHILL**

6 Hutton Centre Drive, Suite 700
Santa Ana, CA 92707

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*Final Report*

# Alternatives Analysis Update Report for the GRIP Recycled Water Project

Submitted to

**Water Replenishment District of Southern California**

October 2012

# Executive Summary

# Groundwater Reliability Improvement Program Recycled Water Project – Alternatives Analysis Update Report

| | |
|---|---|
| PREPARED FOR: | Jim McDavid/WRD |
| PREPARED BY: | Kim Wilson/CH2M HILL |
| SANITATION DISTRICTS REVIEWERS: | Steve Highter/SANITATION DISTRICTS<br>Andrew Hall/SANITATION DISTRICTS<br>Angela Chang/SANITATION DISTRICTS |
| CONSULTANT REVIEWERS: | Fred Soroushian/CH2M HILL<br>Don Bassett/MWH<br>Lauren Siniawer/MWH<br>Sarah Munger/MWH |
| DATE: | October 22, 2012 |

## Executive Summary

The Water Replenishment District of Southern California (WRD), in coordination with the Sanitation Districts of Los Angeles County (Sanitation Districts), is developing the Groundwater Reliability Improvement Program (GRIP) Recycled Water Project as a part of WRD's Water Independence Now (WIN) strategy.

The overall goal of the GRIP Recycled Water Project is to offset the current use of imported water with recycled water for groundwater replenishment in the Central Basin.

Specifically, the project's objectives are as follows:

- Provide a sustainable and reliable source of recycled water for groundwater basin replenishment via the Montebello Forebay.
- Implement a cost-effective and environmentally sound project.
- Protect the groundwater quality of the basin.
- Comply with pertinent regulatory requirements employing an institutionally feasible approach.
- Provide up to 21,000 acre-feet per year (AFY) of recycled water consistent with current and future needs within approximately 10 years.

The GRIP Recycled Water Project will evaluate recycled water supply sources, level of treatment, potential conveyance alignments, and type of recharge. The project is divided into several tasks, including the Alternatives Analysis Update Report, Preliminary Engineering Report, and Feasibility Study.

The Alternatives Analysis Update Report presented herein comprises seven technical memoranda (TMs), which WRD will rely upon to prepare a Facilities Plan and associated environmental impact assessment reports to meet State Revolving Fund (SRF) loan and California Environmental Quality Act (CEQA)/National Environmental Policy Act (NEPA) requirements, respectively. The highest ranked alternatives identified in the Alternatives Analysis Update Report will be carried forward into the feasible alternatives analysis during preliminary engineering. The Feasibility Study will be based upon the findings of the Preliminary Engineering Report and will be prepared to meet the requirements of the U.S. Bureau of Reclamation (USBR) Title XVI Water Recycling and Reuse Program.

A summary of each of the seven TMs included in this Alternatives Analysis Update Report follows.

## TM 1-1 Review and Summary of Existing Planning Documents

The Central Basin has been the subject of numerous studies over the years, addressing the challenges of groundwater supply reliability and availability problems that have occurred as a result of overpumping, drought, climate change, and decreased availability of imported water. The five studies listed below are particularly relevant to, and provide the basis for, the GRIP Recycled Water Project Alternatives Analysis Update Report.

**GRIP Conceptual Level Study Final Draft (Prepared by MWH in May 2009)** – This conceptual level study is made up of a series of 11 TMs that establish the requirements of a new GRIP Advanced Water Treatment Plant (AWTP) as well as options for conveying the product water from the AWTP to the Upper San Gabriel Valley Municipal Water District (USGVMWD) spreading basins and the Montebello Forebay Spreading Grounds (MFSG).

**GRIP Alternatives Analysis Final Report (Prepared by RMC in June 2011) –** This alternatives analysis report introduced a portfolio approach to develop and evaluate several viable alternatives for increasing recycled water recharge in the Montebello Forebay. The report identified six potentially feasible GRIP alternatives with the ultimate goal of providing up to 21,000 AFY of recycled water to the Central and West Coast Basins and up to 25,000 AFY of recycled water to the Main San Gabriel Basin (MSGB) by 2020/2025.

**Clearwater Program Draft Executive Summary (Prepared by the Sanitation Districts in January 2012) -** This document provides a concise summary of the Clearwater Program Draft Master Facilities Plan and the Clearwater Program Draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS). It provides a general overview of the Joint Outfall System (JOS) including the conveyance system, treatment facilities, and biosolids and effluent management systems. The summary addresses programmatic and project-specific needs of the JOS through the year 2050.

**Clearwater Program Draft Master Facilities Plan (Prepared by the Sanitation Districts in association with CH2M HILL and MWH in January 2012)** – This facilities planning study assesses alternatives for managing wastewater flows generated within the Joint Outfall System (JOS) through the year 2050. The analysis includes the conveyance system, treatment facilities, and biosolids and effluent management systems. This document provides background information on the areas around the San Jose Creek Water Reclamation Plant (SJCWRP) and the Los Coyotes Water Reclamation Plant (LCWRP), both of which are evaluated in the GRIP Recycled Water Project as preliminary supply options.

**Groundwater Basin Master Plan (Currently being prepared by CH2M HILL)** – This document is currently being developed. A review and summary will be added once the document is complete.

## TM 1-2 Review and Summary of Existing Regulations

There are several existing and potential regulations that may impact the alternatives identified as part of the GRIP Recycled Water Project. This TM focuses on the regulations that have been updated or modified since the completion of the GRIP Alternatives Analysis Final Report (RMC 2011). In general, the state and federal regulations have not changed. However, the new Groundwater Replenishment Reuse Draft Regulations (GRRDR) from the California Department of Public Health (CDPH) were released in November 2011.

Potential impacts to Groundwater Replenishment Reuse Projects (GRRPs) from these new draft regulations include general requirements, pathogenic microorganism control, nitrogen compound control, recycled water contribution (RWC), diluent water quantity and quality, total organic carbon (TOC) requirements, soil aquifer treatment (SAT) process requirements, and advanced treatment criteria.

## TM 1-3 Recycled Water Quality and Local Blend Water Source Availability

The objective of this TM is to provide supplemental information regarding recycled water quality from the SJCWRP and the availability of local blend water sources. As discussed in TM 1-5, the SJCWRP will serve as the supply source for the GRIP Recycled Water Project alternatives presented in this report. Additionally, the LCWRP was evaluated as a potential supply source in TM 1-5 and, through screening, was consequently eliminated.

The step feed anoxic (SFA) nitrification-denitrification (NDN) activated sludge system combined with the granular media filtration at the SJCWRP enhances organic, nitrogen, and solids removal performance and produces an effluent with an average total organic carbon (TOC) concentration less than 5 milligrams per liter (mg/L), total nitrogen (TN) concentration less than 10 mg/L, and total suspended solids (TSS) concentration less than 2.5 mg/L. The SJCWRP effluent is high quality and an ideal supply source for the GRIP Recycled Water Project.

Regarding the availability of local blend water sources for groundwater recharge, dilution sources include underflow from the MSGB, stormwater recharge, and precipitation recharge. The estimated available dilution quantities are 27,000 AFY, 57,000 AFY, and 7,000 AFY, respectively.

## TM 1-4 Analysis Methodology and Screening Criteria Definition

This TM establishes the analysis methodology, screening criteria definitions, and criteria weighting factors used in the evaluation of component options and system alternatives to identify and short-list potentially feasible alternatives for recharging the Central Basin via the Montebello Forebay with up to 21,000 AFY of recycled water. The analysis methodology takes into account four component areas (supply, treatment, conveyance, and recharge) and three levels of treatment (tertiary treatment, advanced water treatment [AWT], and a hybrid of the two).

The analysis methodology consists of the following two steps:

**Step 1** – Establish preliminary options by component area and apply evaluation criteria to determine viable options

**Step 2** – Establish viable alternatives from combinations of viable options from each of the four component areas and apply triple bottom line (TBL) evaluation criteria and the simple multiple-attribute rating technique (SMART) model to identify feasible alternatives

For each of the four component areas, a list of preliminary options and evaluation criteria was created collaboratively with WRD and the Sanitation Districts. The advantages and disadvantages of each option were discussed, and the options were evaluated based on a +/0/- designation to distinguish between advantage, neutral, and disadvantage of an option for a given criteria. The resulting viable options in each component area were then carried into Step 2 for the evaluation of system alternatives.

The TBL evaluation criteria, weighting factors, and scores for each alternative were developed in collaboration with WRD and the Sanitation Districts to compare viable alternatives in terms of their environmental, social, and economic impacts. Benefit scores were developed using the SMART model. The viable alternatives with the highest benefit score in each of the three treatment level categories are the recommended feasible alternatives to be further evaluated during preliminary engineering. Table ES-1 presents the TBL evaluation criteria, weights, and scoring characteristics.

The methodology for developing costs for each of the viable alternatives is also presented in this TM. Cost estimates for the viable alternatives were developed by calculating facility costs using a cost-estimating software system that included factoring in the costs for projects of similar type and size; and by obtaining budgetary-level equipment costs from equipment suppliers, when necessary. Cost estimates developed for this analysis provide a relative comparison of the alternatives and are considered order-of-magnitude estimates (Class 5) developed using a 30-year planning period and a 5-percent discount rate.

**TABLE ES-1**
**Triple Bottom Line Evaluation Criteria, Weights, and Scoring Characteristics**

| TBL Category | Evaluation Criteria | Weight | Elements of Scoring Assessment | Scoring Characteristics |
|---|---|---|---|---|
| Environmental (total weight = 10) | Construction and Operations Impacts | 2 | • Traffic impacts and commuter disruption<br>• Impacts to ecosystems<br>• Byproducts management | 5 – Least overall impacts from facilities construction and operations<br>3 – Low to minimum long-term impacts; moderate construction impacts<br>1 – Greatest potential for impacts with emphasis on long-term operations |
| | Water Quality | 4 | • Total dissolved solids (TDS)<br>• TOC<br>• Nutrients<br>• Trace contaminants | 5 – Consistently produces high water quality; greatest removals<br>3 – Very good water quality, but lower than highest level of removals<br>1 – Good water quality, but comparatively lower removals |
| | Sustainability | 4 | • Power requirements<br>• Greenhouse gas emissions<br>• Fixed resource consumption<br>• Space constraints, facilities footprint | 5 – Lowest in terms of power, greenhouse gases, consumption, and footprint<br>3 – Sustainable project; moderate resource/power consumption<br>1 – Sustainable project; comparatively higher in resource/power consumption |
| Social (total weight = 10) | Public Acceptability | 4 | • General public<br>• Basin pumpers<br>• Public agencies/public officials | 5 – Greatest likelihood of support from entire range of stakeholders<br>3 – Overall support for approach but reservations by limited number<br>1 – Some support but significant reservations by several stakeholders |
| | Institutional Feasibility | 3 | • Rights-of-way and easement procurement; railroad, freeway and river crossings<br>• Required reviews, permits and approvals<br>• Dependence on long-term, third party contracts for services | 5 – Easiest for procuring reviews/approvals/permits; limited third-party dependence<br>3 – Moderate for permits procurement; moderate dependence on third parties<br>1 – Potential for issues with permit procurement or high dependence on third parties |
| | Regulatory Compliance | 3 | • Compliance with existing regulations<br>• Future compliance<br>• Ease of permitting | 5 – Full compliance with existing regulations and potential future regulations<br>3 – Full compliance with existing regulations; good potential for future regulatory compliance<br>1 – Full compliance with existing; may have issues with future regulations |
| Economic (total weight = 10) | Life-Cycle Costs | 4 | • Capital<br>• Operation and maintenance | 5 – Lowest total life-cycle costs<br>3 – Mid-range life-cycle costs<br>1 – Highest total life-cycle costs |
| | Supply Reliability | 3 | • Seasonality of supply<br>• Potential variability | 5 – Highest certainty of supply source and recharge capabilities<br>3 – Some limitations of certainty of supply source and/or recharge capabilities<br>1 – Lowest relative certainty of supply source or recharge capabilities |
| | Operational Flexibility | 3 | • Ability to adjust to changing conditions including supply and recharge | 5 – Maximum flexibility to vary supply or recharge strategy<br>3 – Some ability to vary supply and/or recharge strategy<br>1 – Least flexibility to vary supply or recharge strategy |

## TM 1-5 Evaluation of Treatment and Conveyance Options

The alternatives analysis presented in this TM identifies preliminary options for each of the four component areas (supply, treatment, conveyance, and recharge). The analysis then discusses the viability of these options, develops viable alternatives, and applies the TBL evaluation criteria defined in TM 1-4 to short-list the most feasible alternatives to be further evaluated in preliminary engineering.

### Preliminary Options Assessment

The resulting viable options are summarized below for each of the four component areas.

**Supply** – Both the SJCWRP and LCWRP were identified as potential supply options. However, the SJCWRP was determined to be the most viable supply source for recycled water due to its proximity to the recharge locations, ability to flow by gravity to the basin, superior product water quality, and availability of supply.

**Treatment** – All three treatment levels (tertiary, AWT, and a hybrid using both tertiary and AWT) were identified as viable treatment options for full-scale implementation. In addition, several different AWT unit processes were considered in the development of a viable AWT treatment train. The following conventional and alternative AWT treatment trains were considered:

- AWT – Conventional:
    - Microfiltration/ultrafiltration (MF/UF), reverse osmosis (RO), ultraviolet advanced oxidation process (UV-AOP)
- AWT – Alternative:
    - MF/UF, nanofiltration (NF), UV-AOP
    - MF/UF, NF, Ozone-biologically activated carbon (BAC)
    - MF/UF, Ozone-BAC- granular activated carbon (GAC), UV-AOP

Although the AWT – Conventional treatment train option is the most viable option for full-scale implementation within the project timeframe, a number of AWT – Alternative options may merit consideration for pilot testing. The potential for significant operation and maintenance (O&M) cost savings with NF in lieu of RO due to NF's lower energy consumption and higher plant water recovery warrants further consideration of this technology and pilot testing to assess its performance. Ultimately, the full-scale design should allow for easy retrofit with NF in the future. In addition, pilot testing ozone-BAC for disinfection/advanced oxidation as part of the AWT should also be considered.

**Conveyance** – Both the existing outfall pipeline for tertiary water and a new, dedicated outfall pipeline for AWT water were determined to be viable conveyance options. Six potential alignments were evaluated for a new, dedicated AWT pipeline, three of which were viable. Paralleling the existing outfall was identified as the most viable option. However, additional detailed investigation is warranted to verify that construction of this alignment is practical and interference with existing utilities is avoided.

The second and third highest ranked approaches were the Durfee Avenue and Workman Mill Road Alignments, respectively. These are considered back-up approaches should the detailed examination of easements and rights-of-way, along with the assessment of potential interferences and crossings, result in the determination of severe limitations associated with the parallel alignment approach.

**Recharge** – Both spreading and injection were identified as viable recharge options. Tertiary and/or AWT recycled water could be introduced via surface spreading. Injection of AWT water would also be a viable option, considering the limitations of spreading with regard to spreading ground capacity and seasonality.

A project site map is presented on Figure ES-1 to show the relative location of the treatment facilities, spreading grounds, and potential injection well sites.

**FIGURE ES-1**
**Location of Injection Wells and Spreading Grounds Relative to AWTP at SJCWRP**

## Viable Alternatives Assessment

Six viable alternatives were developed using the viable options for each component area and evaluated using the TBL evaluation criteria. One feasible alternative was selected for each treatment level (tertiary, AWT, and hybrid). An overview of the analysis methodology and recommended feasible alternatives is presented on Figure ES-2, followed by a graphical representation of the SMART analysis results on Figure ES-3. The resulting three feasible alternatives with the highest benefit scores in each of the three treatment level categories are summarized below and will be carried forward into the feasible alternatives analysis during preliminary engineering.

**Tertiary (Feasible Alternative A)** – Tertiary recycled water (up to 21,000 AFY) from the SJCWRP is conveyed in the existing outfall pipeline to the MFSG.

**AWT (Feasible Alternative D)** – AWT recycled water (up to 21,000 AFY) from the SJCWRP is conveyed in a new, dedicated outfall pipeline to the MFSG and/or potential Montebello Forebay injection sites.

**Hybrid (Feasible Alternative F)** – A combination of tertiary and AWT recycled water from the SJCWRP are conveyed. Tertiary recycled water is conveyed in the existing outfall pipeline to the spreading grounds and AWT recycled water is conveyed in a new, dedicated outfall pipeline to the spreading grounds and/or potential injection sites. The quantities of tertiary and AWT recycled water may vary depending on the recharge capacity of the MFSG; however, this analysis assumes that the hybrid alternative uses 11,000 AFY of tertiary and 10,000 AFY of AWT recycled water to recharge the Montebello Forebay.

**FIGURE ES-2**
**GRIP Recycled Water Project Analysis Methodology Flow Diagram**

## GRIP RECYCLED WATER PROJECT FUNCTIONAL OBJECTIVES

- Provide a sustainable and reliable source of recycled water for groundwater basin replenishment via the Montebello Forebay
- Implement a cost-effective and environmentally sound project
- Protect the groundwater quality of the basin
- Comply with pertinent regulatory requirements employing an institutionally feasible approach
- Provide up to 21,000 acre-feet per year (AFY) of recycled water consistent with current and future needs within approximately 10 years

## PRELIMINARY OPTIONS

### SUPPLY

- SJCWRP
- LCWRP

### TREATMENT

- Tertiary
- AWT
- Hybrid (Tertiary + AWT)

### CONVEYANCE

- Combined Pipeline (use of existing)
- Dedicated/Separate Pipelines

### RECHARGE

- Spreading
- Injection

## PRELIMINARY OPTIONS EVALUATION CRITERIA

### EVALUATION CRITERIA

- Availability of supply
- Quality of supply
- Distance to recharge
- Pumping required
- Site availability for new facilities
- Consistency with long-term plans
- Ability to achieve regulatory compliance
- Institutional feasibility
- Time/schedule to implement

### EVALUATION CRITERIA

- Water quality suitability for recharge
- Ability to permit
- Cost of treatment
- Operational familiarity
- Demonstrated performance
- Institutional feasibility
- Time/schedule to implement
- Environmental impact

### EVALUATION CRITERIA

- Costs
- Operational flexibility
- Recycled water utilization
- Potential for optimizing operations
- Project flexibility
- Institutional feasibility

### EVALUATION CRITERIA

- Cost for new facilities
- Availability/seasonality
- Ability to permit
- Institutional feasibility
- Water quality requirements
- Operational flexibility

## VIABLE OPTIONS

### SUPPLY

- SJCWRP

### TREATMENT

- Tertiary
- AWT (Conventional)
- Hybrid (Tertiary + AWT)

### CONVEYANCE

- Dedicated Pipeline Route
  - Parallel Existing Outfall
  - New Alignment

### RECHARGE

- Spreading
- Injection

## VIABLE ALTERNATIVES

| ALT | SUPPLY | TREATMENT | CONVEYANCE | RECHARGE |
|---|---|---|---|---|
| A | SJCWRP | Tertiary | No New Pipeline | Spreading |
| B | SJCWRP | AWT (Conventional) | No New Pipeline | Spreading |
| C | SJCWRP | AWT (Conventional) | Dedicated/Existing Align | Injection |
| D | SJCWRP | AWT (Conventional) | Dedicated/Existing Align | Injection/Spreading |
| E | SJCWRP | Hybrid (Tertiary/AWT) | Dedicated/Existing Align | Injection |
| F | SJCWRP | Hybrid (Tertiary/AWT) | Dedicated/Existing Align | Injection/Spreading |

## VIABLE ALTERNATIVES EVALUATION CRITERIA

- Triple Bottom Line (TBL) Cost/Benefit Analysis:
  - Environmental
  - Social
  - Economic
- Criteria Development and Application
- SMART Decision Tool

## FEASIBLE ALTERNATIVES

| ALT | SUPPLY | TREATMENT | CONVEYANCE | RECHARGE |
|---|---|---|---|---|
| A | SJCWRP | Tertiary | No New Pipeline | Spreading |
| D | SJCWRP | AWT (Conventional) | Dedicated/Existing Alignment | Injection/Spreading |
| F | SJCWRP | Hybrid (Tertiary + AWT) | Dedicated/Existing Alignment | Injection/Spreading |

**FIGURE ES-3**
**SMART Analysis Results**

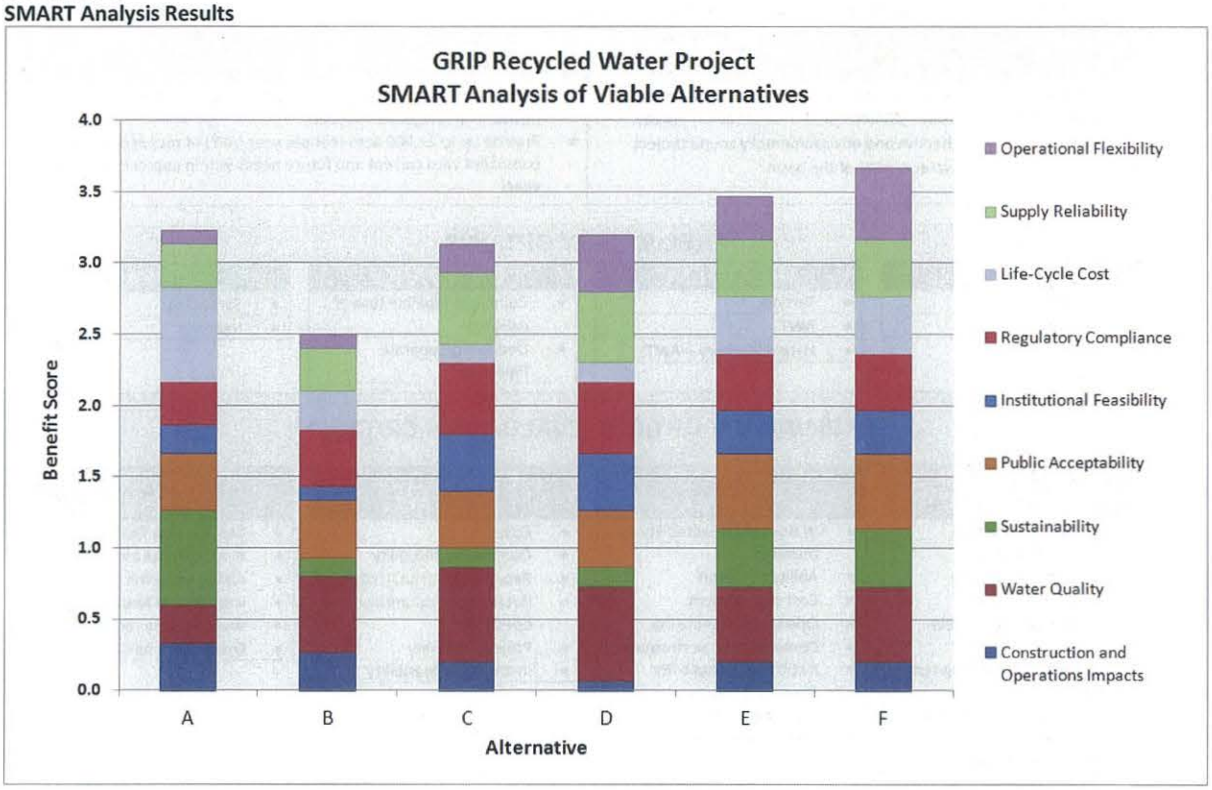


Table ES-2 presents the preliminary cost opinion for the viable alternatives, based on the cost development methodology described in TM 1-4.

**TABLE ES-2**
**Preliminary Cost Opinion for Viable Alternatives**

| | A<br>Tertiary, Spreading | B<br>AWT, Spreading | C<br>AWT, Injection | D<br>AWT, Spreading/ Injection | E<br>Hybrid, Injection | F<br>Hybrid, Spreading/ Injection |
|---|---|---|---|---|---|---|
| Present Value of Capital Cost[1] ($) | 1,749,000 | 184,655,000 | 246,664,000 | 246,664,000 | 142,092,000 | 142,092,000 |
| Present Value of O&M Cost[2] ($) | 180,759,000 | 532,058,000 | 532,058,000 | 532,058,000 | 348,045,000 | 348,045,000 |
| Total Present Value[3] ($) | 182,508,000 | 716,713,000 | 778,722,000 | 778,722,000 | 490,137,000 | 490,137,000 |

Notes:

[1] Capital costs include construction of treatment and conveyance facilities, injection, and flow equalization. Sewer connection fees and flow diversion costs are also included. The costs for improvements to the MFSG are not included in this cost estimate. Estimate assumes a 20 percent markup for engineering, legal, and administrative fees and a 20 percent contingency.

[2] O&M costs include facilities O&M, recycled water purchase, and sewer surcharge fee. Present value is based on 30 years at 5 percent bond (interest) rate and a general inflation rate of 3 percent. Present value of recycled water purchase costs are based on an annual escalation rate of 4 percent.

[3] For comparison purposes only, cost assumes all capital financed at 5 percent for 30 years and does not include revenue from users or potential subsidies.

## TM 1-6 Evaluation of Brine Management Options

Several RO concentrate disposal alternatives are considered in this TM. Direct concentrate discharge and direct discharge with concentrate volume reduction are the two primary methods described and evaluated.

Both zero liquid discharge (ZLD) technologies and deep well injection (DWI) were considered, but neither proved to be a viable option for AWTP brine management. Despite meeting the high water recovery, ZLD is typically cost prohibitive, operationally complex, and only employed where there is no access to sewer or surface water for discharge. DWI is characterized with a high risk of aquifer contamination (particularly in seismic zones), implementation uncertainties, and reduced water recovery.

Direct sewer discharge with ultimate ocean disposal is an established and well-accepted concentrate disposal method, and the least complex option with no additional infrastructure required. However, it is costly and results in reduced water recovery. Reduction of concentrate volume prior to ultimate disposal is a compromise solution to reduce sewer discharge and treatment fees, lower loading impact on the downstream treatment facility, and increase water recovery.

The following two concentrate disposal options are considered within this TM:

- Direct concentrate discharge into the Sanitation Districts sewer system
- Sanitation Districts Joint Outfall System (JOS) sewer discharge with one of the following concentrate volume reduction technologies:
    - Direct third-stage RO
    - Third-stage RO with pelletized softening pretreatment
    - High-efficiency RO (HERO)
    - Seeded precipitation and recycle RO (SPARRO)

Operating and maintaining a third-stage RO process is very similar to operating and maintaining a primary RO system, with no additional skill or pretreatment required. Therefore, an integrated direct third-stage RO process was selected for further evaluation. The remaining three concentrate volume reduction technologies were excluded from further evaluation due to lack of sufficient track record, high cost and complexity, the need for significant amounts of chemicals, the fact that an excessive amount of solids needing disposal would be produced, or a combination of these factors.

There are currently two AWT product flow scenarios under consideration for the AWT at the SJCWRP: 10,000 AFY and 21,000 AFY. Costs for brine management for these scenarios, with and without volume reduction, are summarized in Table ES-3.

Implementation of sewer discharge with direct third-stage RO offers reduced overall costs for each flow scenario, and it is therefore the recommended disposal option. The lower cost of the sewer discharge with the direct third-stage RO option is primarily driven by a reduction in sewer connection fees as a result of increased water recovery via the third stage.

**TABLE ES-3**
**Preliminary Cost Opinion for Brine Management Options**

| | 10,000 AFY AWT | | 21,000 AFY AWT | |
|---|---|---|---|---|
| | **Direct Sewer Discharge** | **Volume Reduction via Third-Stage RO** | **Direct Sewer Discharge** | **Volume Reduction via Third-Stage RO** |
| Capital Cost ($) | 98,059,000 | 93,140,000 | 178,379,000 | 167,663,000 |
| Annual O&M Cost ($/yr) | 7,620,000 | 7,176,000 | 16,002,000 | 15,055,000 |
| Life-Cycle Costs ($) | 215,197,000 | 203,453,000 | 424,369,000 | 399,095,000 |

## TM 1-7 Impacts of Increased Use of Tertiary Effluent for Recharge on Groundwater Quality and Recycled Water Content

This TM addresses potential groundwater quality and implementation impacts of increasing the amount of tertiary recycled water for recharge from a baseline of 50,000 AFY to 71,000 AFY by recharging an additional 21,000 AFY. The tertiary effluent is currently applied by surface spreading in the MFSG, where percolation of this water through the vadose and saturated zone of the aquifer results in water quality improvements.

The increase in the RWC will have regulatory implications because the maximum TOC concentration allowed in percolated water is directly linked to the RWC. Considering the currently recognized 35 percent RWC at the MFSG, the maximum TOC concentration currently allowed in percolated water is 1.43 mg/L.

The removal efficiency of SAT for pathogens is not expected to be affected or compromised by increasing the annual recharge volume using tertiary treated effluent. Because TOC attenuation is primarily based on biological processes of the indigenous microbial consortium present in SAT facilities, an increase in recharge volume of tertiary treated effluent from 50,000 AFY to 71,000 AFY is not expected to compromise the removal efficiency of SAT. This is supported through findings of a monitoring study conducted by WRD over 75 weeks at the MFSG during which 100 percent recycled water was applied, resulting in average TOC concentrations in the groundwater of 0.91 mg/L. These findings suggest that an increase of the RWC using tertiary treated effluent from the current 50,000 AFY (RWC of 35 percent) to 71,000 AFY (RWC of 44 percent) at the point of compliance is not expected to result in any noticeable increase in the TOC concentration.

Given the long-term operational experience at the MFSG and demonstrated SAT performance, the Regional Water Quality Control Board (RWQCB) and CDPH will likely be open to consider demonstrating the viability of a higher RWC while maintaining a water quality that is protective of public health. The water quality parameters to be considered during this performance monitoring phase are likely demonstrating that a higher RWC (a) does not exceed a maximum TOC concentration of 1.25 mg/L (RWC of 40 percent) and 1.14 mg/L (RWC of 44 percent) at the point of compliance, (b) continues to achieve more than 90 percent removal of select performance chemicals of emerging concern (CEC) indicator compounds, and (c) meets all regulated chemical limits for groundwater recharge projects. Based on past experience, it is likely that the RWQCB or CDPH will require some additional monitoring for at least a 75-week period demonstrating proper performance before a higher RWC is granted through a permit amendment.

TECHNICAL MEMORANDUM 1-5

# Groundwater Reliability Improvement Program Recycled Water Project – Evaluation of Treatment and Conveyance Options

| | |
|---|---|
| PREPARED FOR: | Jim McDavid/WRD |
| PREPARED BY: | Kim Wilson/CH2M HILL<br>Ufuk Erdal/CH2M HILL<br>Don Bassett/MWH<br>Tony Perez/DR CONSULTANTS<br>Andrew Salveson/CAROLLO |
| SANITATION DISTRICTS REVIEWERS: | Steve Highter/SANITATION DISTRICTS<br>Andrew Hall/SANITATION DISTRICTS<br>Angela Chang/SANITATION DISTRICTS |
| CONSULTANT REVIEWERS: | Jim Lozier/CH2M HILL<br>Larry Schimmoller/CH2M HILL<br>Fred Soroushian/CH2M HILL<br>Lauren Siniawer/MWH<br>Sarah Munger/MWH |
| DATE: | October 22, 2012 |

## Executive Summary

The objectives of this technical memorandum (TM) are to present preliminary options for each of the four component areas (supply, treatment, conveyance, and recharge); discuss the viability of those options and the status and application of viable technologies; and develop viable alternatives and apply the triple bottom line (TBL) evaluation criteria defined in TM 1-4 to short-list the feasible alternatives to be further evaluated in preliminary engineering.

For each of the four component areas, a list of preliminary options and evaluation criteria was identified collaboratively with the Water Replenishment District of Southern California (WRD) and the Sanitation Districts of Los Angeles County (Sanitation Districts). The resulting viable options in each component area were then combined to create a list of viable alternatives.

The TBL evaluation criteria, weighting factors, and scores for each alternative were developed in collaboration with WRD and the Sanitation Districts to compare viable alternatives in terms of their environmental, social, and economic impacts. Benefit scores were developed using the Simple Multiple Attribute Rating Technique (SMART) model. The analysis resulted in short-listing the most feasible alternatives for increasing groundwater recharge at the Montebello Forebay. Each alternative had the highest benefit score in its respective treatment level category: all tertiary, all advanced water treatment (AWT), and a hybrid (a combination of tertiary and AWT). Costs for each of the viable alternatives are also presented in this TM. An overview of the analysis methodology as well as the recommended feasible alternatives is graphically presented on Figure 5-1.

**FIGURE 5-1**
**GRIP Recycled Water Project Analysis Methodology Flow Diagram**

## GRIP RECYCLED WATER PROJECT FUNCTIONAL OBJECTIVES

- Provide a sustainable and reliable source of recycled water for groundwater basin replenishment via the Montebello Forebay
- Implement a cost-effective and environmentally sound project
- Protect the groundwater quality of the basin
- Comply with pertinent regulatory requirements employing an institutionally feasible approach
- Provide up to 21,000 acre-feet per year (AFY) of recycled water consistent with current and future needs within approximately 10 years

## PRELIMINARY OPTIONS

| SUPPLY | TREATMENT | CONVEYANCE | RECHARGE |
|---|---|---|---|
| • SJCWRP | • Tertiary | • Combined Pipeline (use of existing) | • Spreading |
| • LCWRP | • AWT | • Dedicated/Separate Pipelines | • Injection |
| | • Hybrid (Tertiary + AWT) | | |

## PRELIMINARY OPTIONS EVALUATION CRITERIA

| EVALUATION CRITERIA | EVALUATION CRITERIA | EVALUATION CRITERIA | EVALUATION CRITERIA |
|---|---|---|---|
| • Availability of supply<br>• Quality of supply<br>• Distance to recharge<br>• Pumping required<br>• Site availability for new facilities<br>• Consistency with long-term plans<br>• Ability to achieve regulatory compliance<br>• Institutional feasibility<br>• Time/schedule to implement | • Water quality suitability for recharge<br>• Ability to permit<br>• Cost of treatment<br>• Operational familiarity<br>• Demonstrated performance<br>• Institutional feasibility<br>• Time/schedule to implement<br>• Environmental impact | • Costs<br>• Operational flexibility<br>• Recycled water utilization<br>• Potential for optimizing operations<br>• Project flexibility<br>• Institutional feasibility | • Cost for new facilities<br>• Availability/seasonality<br>• Ability to permit<br>• Institutional feasibility<br>• Water quality requirements<br>• Operational flexibility |

## VIABLE OPTIONS

| SUPPLY | TREATMENT | CONVEYANCE | RECHARGE |
|---|---|---|---|
| • SJCWRP | • Tertiary | - Dedicated Pipeline Route | • Spreading |
| | • AWT (Conventional) | • Parallel Existing Outfall | • Injection |
| | • Hybrid (Tertiary + AWT) | • New Alignment | |

## VIABLE ALTERNATIVES

| ALT | SUPPLY | TREATMENT | CONVEYANCE | RECHARGE |
|---|---|---|---|---|
| A | SJCWRP | Tertiary | No New Pipeline | Spreading |
| B | SJCWRP | AWT (Conventional) | No New Pipeline | Spreading |
| C | SJCWRP | AWT (Conventional) | Dedicated/Existing Align | Injection |
| D | SJCWRP | AWT (Conventional) | Dedicated/Existing Align | Injection/Spreading |
| E | SJCWRP | Hybrid (Tertiary/AWT) | Dedicated/Existing Align | Injection |
| F | SJCWRP | Hybrid (Tertiary/AWT) | Dedicated/Existing Align | Injection/Spreading |

## VIABLE ALTERNATIVES EVALUATION CRITERIA

- Triple Bottom Line (TBL) Cost/Benefit Analysis:
  - Environmental
  - Social
  - Economic
- Criteria Development and Application
- SMART Decision Tool

## FEASIBLE ALTERNATIVES

| ALT | SUPPLY | TREATMENT | CONVEYANCE | RECHARGE |
|---|---|---|---|---|
| A | SJCWRP | Tertiary | No New Pipeline | Spreading |
| D | SJCWRP | AWT (Conventional) | Dedicated/Existing Alignment | Injection/Spreading |
| F | SJCWRP | Hybrid (Tertiary + AWT) | Dedicated/Existing Alignment | Injection/Spreading |

## Preliminary Options Assessment

The resulting viable options for each of the component areas are summarized herein.

**Supply** – The San Jose Creek Water Reclamation Plant (SJCWRP) and the Los Coyotes Water Reclamation Plant (LCWRP) were identified as potential supply options. However, the SJCWRP was selected as the source of supply of recycled water because of its proximity to the recharge locations, the ability to leverage flow by gravity to the basin, its superior product water quality, and the availability of adequate supply.

**Treatment** – Both tertiary and conventional AWT were identified as viable treatment options for full scale implementation because each has a demonstrated and proven performance and either one can be approved, permitted, and implemented within the project timeframe. In addition, the assessment included consideration of a "hybrid" approach which would allow a combination of tertiary and conventional AWT to be used.

Regarding alternative AWT technologies, the potential for significant operation and maintenance (O&M) cost savings with nanofiltration (NF) in lieu of reverse osmosis (RO) due to lower energy consumption and higher product water recovery from less brine production warrants further consideration as a pilot demonstration. Ultimately, the full scale design will allow for easy retrofitting with NF in the future. In addition, consideration should be given to the possible testing of ozone-biologically activated carbon (BAC) for disinfection/advanced oxidation as part of the AWT pilot demonstration.

**Conveyance** – Both the existing outfall pipeline for tertiary water and a new, dedicated outfall pipeline for AWT water were determined to be viable conveyance options. Six potential alignments were evaluated for the new, dedicated AWT pipeline. Paralleling the existing outfall was identified as the most viable option. However, additional detailed investigation is warranted to ensure construction within this alignment is practical and interference with existing utilities is avoided.

The second and third ranked approaches, the Durfee Avenue and Workman Mill Road alignments, are considered as back-up alignments should the detailed examination of easements and rights-of-way, along with the assessment of potential interferences and crossings, result in the determination of severe limitations associated with the alignment that parallels the existing outfall.

**Recharge** – Both spreading and injection were identified as viable recharge options. Tertiary and/or AWT water could be introduced via surface spreading. Injection of AWT water would also be a viable option, considering the limitations of spreading with regard to spreading ground capacity and seasonality.

## Viable Alternatives Assessment

Six viable alternatives were developed using the viable options from each component area and evaluated using the TBL evaluation criteria and SMART model. The three feasible alternatives resulting from that assessment are summarized herein and will be carried forward into the feasible alternatives analysis during preliminary engineering.

**Feasible Alternative A** – Tertiary recycled water from the SJCWRP is conveyed in the existing outfall pipeline to the Montebello Forebay Spreading Grounds (MFSG).

**Feasible Alternative D** – AWT recycled water from the SJCWRP is conveyed in a new, dedicated outfall pipeline to the MFSG and/or potential Montebello Forebay injection sites.

**Feasible Alternative F –** A combination of tertiary and AWT recycled water from the SJCWRP is conveyed to the MFSG and/or potential Montebello Forebay injection sites. The quantities of tertiary and AWT recycled water may vary depending on the recharge capacity of the MFSG.

# 1.0 Background and Objectives

WRD, in coordination with the Sanitation Districts, is developing the Groundwater Reliability Improvement Program (GRIP) Recycled Water Project as a part of WRD's Water Independence Now (WIN) strategy.

The overall goal of the GRIP Recycled Water Project is to offset the current use of imported water with recycled water for groundwater replenishment in the Central Basin.

The project's objectives are as follows:

- Provide a sustainable and reliable source of recycled water for groundwater basin replenishment via the Montebello Forebay.
- Implement a cost-effective and environmentally sound project.
- Protect the groundwater quality of the basin.
- Comply with pertinent regulatory requirements employing an institutionally feasible approach.
- Provide up to 21,000 acre-feet per year (AFY) of recycled water consistent with current and future needs within approximately 10 years.

The GRIP Recycled Water Project will evaluate recycled water supply sources, level of treatment, potential conveyance alignments, and type of recharge.

The project is divided into several tasks, including the following:

- Alternatives Analysis Update Report
- Preliminary Engineering Report
- Feasibility Study

This TM is to be included in the Alternatives Analysis Update Report, the purpose of which is to further develop the recycled water components of the potentially feasible water supply portfolios presented in Table 11 of the GRIP Alternatives Analysis Final Report (RMC 2011). The objectives of this TM are to present the options, current status and application of viable technologies; cost analysis and non-monetary comparison of the viable alternatives; results of the TBL analysis of the viable project alternatives; and a fully supported recommendation for a range of potential alternatives "that could feasibly accomplish most of the basic objectives of the project," as required by the California Environmental Quality Act (CEQA). The National Environmental Policy Act (NEPA) has similar requirements. This TM presents a detailed analysis of alternatives based on the methodology and screening criteria presented and defined in TM 1-4.

# 2.0 Methodology for Alternatives Development and Evaluation

As described in TM 1-4, the analysis methodology is broken down into multiple sequential steps:

- Identify functional component areas
- Develop preliminary options for each component area
- Screen preliminary options using evaluation criteria – results in viable options
- Combine viable options for each component area into comprehensive system approaches – results in viable alternatives
- Screen viable alternatives by applying TBL Evaluation Criteria and SMART model – results in feasible alternatives

## 2.1 Evaluation of Preliminary Options for Each Component Area to Determine Viable Alternatives

For each of the four component areas, a list of preliminary options and evaluation criteria was identified collaboratively with WRD and the Sanitation Districts. The advantages and disadvantages of each option were discussed, and the options were evaluated based on a +/0/- designation to distinguish between advantage, neutral, and disadvantage of an option for a given criteria. The resulting viable options in each component area were then carried into the evaluation of system alternatives.

## 2.2 Evaluation of Viable Alternatives to Identify Feasible Alternatives

The TBL evaluation criteria, weighting factors, and scores for each alternative were developed in collaboration with WRD and the Sanitation Districts to compare viable alternatives in terms of their environmental, social, and economic impacts. Benefit scores were developed using the Simple Multi-Attribute Rating Technique (SMART) model. The viable alternatives with the highest benefit score in each of the three treatment level categories became the recommended feasible alternatives to be further evaluated during preliminary engineering.

The TBL evaluation criteria, weighting factors, and scoring characteristics are summarized in Table 19 at the end of this TM.

## 2.3 Cost Estimate

The preliminary cost opinion for each of the viable alternatives is also presented in this TM. Cost estimates for the viable alternatives were developed by calculating facility costs using a cost-estimating software system that included factoring the costs for projects of similar type and size and, when necessary, by obtaining budgetary-level equipment costs from equipment suppliers. Costs estimates developed for this analysis provide a relative comparison of the alternatives and are considered order-of-magnitude estimates (Class 5) developed using a 30-year planning period and a 5 percent discount rate.

# 3.0 Preliminary Options Assessment

Preliminary options for each of the four component areas are listed in Table 5-1.

**TABLE 5-1**
**Summary of Preliminary Options by Component Area**

| Supply | Treatment | Conveyance | Recharge |
|---|---|---|---|
| San Jose Creek WRP | Tertiary | Combined Conveyance: One pipeline (existing) | Spreading |
| Los Coyotes WRP | AWT | Separate Conveyance: Dedicated pipelines (one new) | Injection |
| | Hybrid (Tertiary + AWT) | | |

For each component area, the preliminary options are described and comparatively assessed. Lower ranking options are eliminated from further consideration. The basis for elimination is identified. Higher ranking options are carried forward in the analysis and are described as viable options.

The options are scored against the previously discussed parameters and rated on a scale of plus, zero, and minus, where:

| | |
|---|---|
| + | Rated superior with respect to other component area options for a specific parameter |
| 0 | Rated neutral with respect to other component area options for a specific parameter |
| - | Rated inferior with respect to other component area options for a specific parameter |

The screening parameters are used as a measure of an individual component area option's relative merits in comparison to other options in that area, and scored accordingly. The scores are summed to develop a total score for each option.

## 3.1 Supply Options Assessment

### 3.1.1 Supply – Preliminary Options

The preliminary assessment identified two recycled water supply options based primarily on availability and quality of source water, relative distance to the MFSG and the need to pump. The recycled water supply preliminary options include treated wastewater from the SJCWRP and the LCWRP. Both plants are designed for and operate in a biological nitrogen removal mode to reduce nitrogen. Tertiary filtration and disinfection systems are provided at both plants as well.

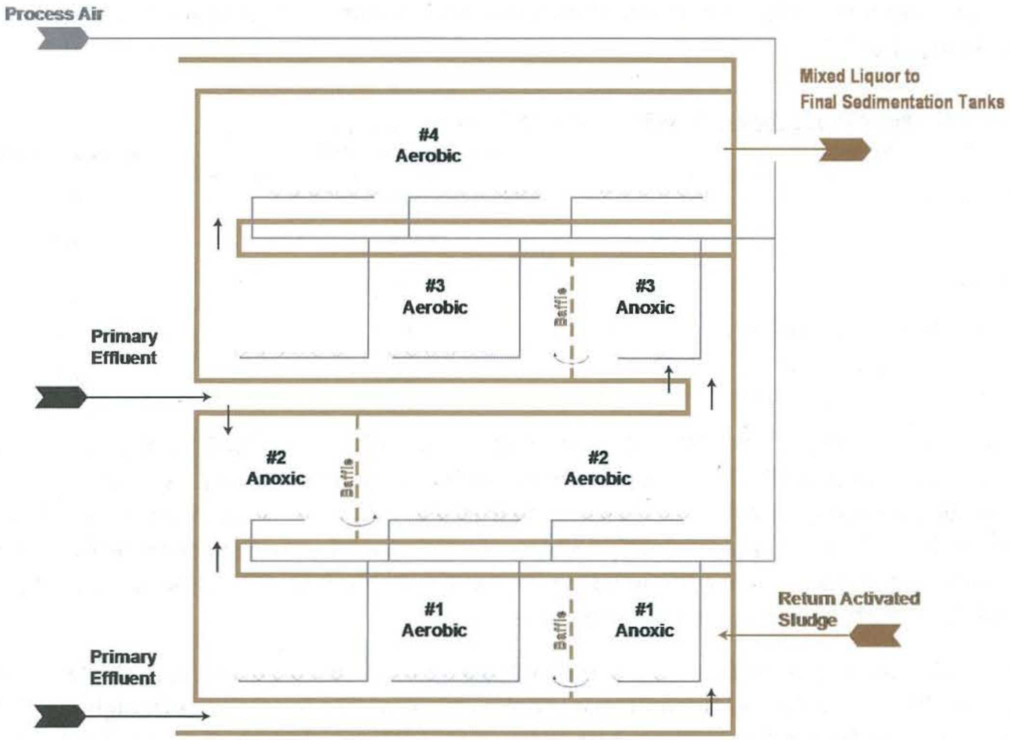
#### San Jose Creek Water Reclamation Plant

The SJCWRP is located at 1965 Workman Mill Road on a 51-acre site within unincorporated Los Angeles County, next to the city of Whittier. The SJCWRP is split by Interstate (I-) 605 into two independent, but hydraulically interconnected, plants. The east plant (SJCWRP East) discharges to both the San Gabriel River and San Jose Creek (tributary to the San Gabriel River), while the west plant (SJCWRP West) discharges only to the San Gabriel River. The overall site is bound by San Jose Creek to the north, State Route (SR-) 60 to the south, Workman Mill Road to the east, and the San Gabriel River to the west. Easements owned by the city of Los Angeles, the Los Angeles Department of Water and Power, and the state of California run along the northern side of the property. Land uses surrounding the plant consist mostly of low-density residential areas, intermixed with an industrial area to the west and open recreational space to the east. The GRIP Conceptual Level Study (MWH 2009) Technical Memorandum 8 identified four contiguous parcels of land adjacent to the northwest boundary of SJCWRP as a potential site for a new AWT facility. Two of the parcels are owned by the Los Angeles Department of Water and Power; two are owned by the US Army Corps of Engineers. The total area of all four is 7.6 acres. Use of this land would require long-term agreements with current users. Current uses and easements may provide some restrictions to use. Undeveloped areas at SJCWRP West are also being evaluated as a potential location for an AWT facility. Both the Los Angeles Department of Water and Power and the US

Army Corp of Engineer properties, as well as undeveloped areas of SJCWRP West are being evaluated for siting a new AWT facility and supporting systems.

The SJCWRP started operation in 1971 as a conventional secondary treatment, activated sludge plant. In 1978, it was upgraded with the addition of filters to a tertiary facility. The combined permitted capacity of the SJCWRP is 100.0 million gallons per day (MGD) (62.5 at SJCWRP East and 37.5 and SJCWRP West). The activated sludge process was converted from a conventional step-feed nitrification process to a step feed anoxic (SFA) configuration in 2004. As depicted on Figure 5-2, the settled wastewater is split into three anoxic zones. The SFA configuration enhances nitrogen removal performance and produces a secondary effluent with total nitrogen (TN) of less than 10 milligrams per liter (mg/L). In 2010, the plants treated a combined average daily flow of 77.0 MGD.

**FIGURE 5-2**
**Step Feed Anoxic Configuration Used at SJCWRP and LCWRP**



Step Feed NDN Process Schematic

## Los Coyotes Water Reclamation Plant

The LCWRP is located at 16515 Piuma Avenue on a 34-acre site within the city of Cerritos. The treatment facilities occupy the lower southwest corner of the site. The remaining 20 acres are leased to the city of Cerritos for use as the Iron-Wood Nine Golf Course. There is limited land available to accommodate the addition of the AWT facilities in the immediate vicinity of the plant. The land that is currently used for the Iron-Wood Nine Golf Course is not available for the siting of above ground treatment facilities. The LCWRP is bound by Southern California Edison property to the north, SR-91 to the south, I-605 to the east, and the San Gabriel River to the west. Land uses surrounding the LCWRP consist of light industrial areas to the north and south, and residential areas to the east and west. Caruthers Park is located immediately west of the LCWRP.

The LCWRP was commissioned in 1970 with an initial capacity of 12.5 MGD. The LCWRP originally consisted of primary and secondary treatment with conventional activated sludge and was upgraded to tertiary treatment in 1978. In 2008, the activated sludge process was converted to the SFA configuration (Figure 5-2). The SFA configuration enhances nitrogen removal performance and produces a secondary effluent with total nitrogen (TN) of less than 10 mg/L. The current permitted capacity of the LCWRP is 37.5 MGD. In 2010, the plant treated an average daily flow of 26.8 MGD.

### 3.1.2 Supply – Preliminary Options Assessment

The recycled water quality is significantly different at the two WRPs. The water quality at the SJCWRP is superior to that of the LCWRP in terms of total dissolved solids (TDS), total organic carbon (TOC), average total hardness, and alkalinity. TDS, TOC and TN are relevant in terms of regulated water quality parameters for groundwater recharge in MFSG. In addition, if advanced membrane treatment is under consideration, lower TDS reduces RO feed pressure and lower TOC can reduce membrane fouling and reduces ozone and other oxidant demand. A snapshot comparison of effluent water quality at each WRP is presented in Table 5-2.

**TABLE 5-2**
**Comparison of Effluent Water Quality at SJCWRP and LCWRP (2010)**

| Parameter | San Jose Creek WRP | Los Coyotes WRP |
|---|---|---|
| Average TDS, mg/L | 570 | 840 |
| TOC, mg/L | 4.5-5.5 | 6-8 |
| Average TN, mg/L | <10 | <10 |
| Average Total Hardness, mg/L CaCO3 | 200 | 290 |
| Average Alkalinity, mg/L as CaCO3 | 110 | 210 |

With respect to proximity to potential recharge locations at MFSG, the SJCWRP is approximately 4.5 miles from MFSG; the LCWRP is 12 to 16 miles from MFSG. In addition, conveyance from the SJCWRP does not require pumping. Conversely, conveyance from the LCWRP to MFSG requires pumping with a total dynamic head (TDH) of approximately 180 feet, as estimated by the Sanitation Districts. Reducing the pipeline length and eliminating the need for pumping with the SJCWRP option significantly reduces capital and O&M costs associated with conveyance.

In terms of available recycled water supply, the SJCWRP has a larger treatment capacity (100.0 MGD) than the LCWRP (37.5 MGD) and currently has more water available for reuse. Although the LCWRP appears to have a sufficient supply of product water, approximately 8 MGD of recycled water is anticipated to be allocated to the Leo J. Vander Lans (LVL) treatment facility. As a result, the LCWRP will not have sufficient recycled water available to meet the GRIP Recycled Water Project flow of 21,000 AFY.

Table 5-3 presents criteria scoring for recycled water supply options based on the established evaluation criteria defined in TM 1-4.

**TABLE 5-3**
**Summary of Scoring Results for Supply Options**

| Criteria | San Jose Creek WRP | Los Coyotes WRP |
|---|---|---|
| Availability of Supply | + | - |
| Quality of Supply | + | 0 |

**TABLE 5-3**
**Summary of Scoring Results for Supply Options**

| Criteria | San Jose Creek WRP | Los Coyotes WRP |
|---|---|---|
| Distance to Recharge | 0 | - |
| Pumping Required | + | - |
| Site Availability for New Facilities | + | 0 |
| Consistency with Long-Term Plans | + | 0 |
| Ability to Achieve Regulatory Compliance | 0 | 0 |
| Institutional Feasibility | + | 0 |
| Time/Schedule to Implement | 0 | - |
| **Score** | **6** | **-4** |
| **Rank** | **1** | **2** |

### 3.1.3 Supply - Preliminary Option Eliminated

One preliminary supply option was eliminated from further consideration based upon the assessment performed – LCWRP. This supply option was eliminated principally on the basis of:

- Distance from recharge
- Requirement for pumping (versus gravity flow)
- Lower quality water
- Limited and potentially insufficient supply quantity

These limitations would impact the cost and utility of recharge systems.

### 3.1.4 Supply – Viable Option

One preliminary supply option was carried forward for further evaluation – SJCWRP. It is now termed a viable option.

## 3.2 Treatment Options Assessment

### 3.2.1 Treatment – Preliminary Options

Three levels of treatment were considered for the production of 21,000 AFY of recharge using recycled water for basin replenishment via the MFSG. The treatment levels include:

- Tertiary treatment
- AWT
- Hybrid (Tertiary + AWT)

#### Tertiary Treatment

Following the activated sludge treatment at the WRPs, there is a tertiary treatment step prior to effluent discharge or reuse. This tertiary treatment step involves a number of processes, including:

- Pre-filtration chemical conditioning
- Filtration
- Disinfection
- Post-disinfection treatment

The chemical conditioning is undertaken to enhance the filterability of the secondary effluent. Polymers are added to improve characteristics through coagulation and flocculation of the solids. Following conditioning, down-flow granular media gravity filters are employed for solids and pathogen removal. Disinfection is by way of chlorination. To minimize the formation of disinfection byproducts, the Sanitation Districts use a two stage chlorination process employing both free chlorine and monochloramine. Following disinfection, residual amounts of chlorine are removed by chemical addition for the flows directly discharged to the waterways. The product water is often referred to as Title 22 water, in that it meets requirements for tertiary-treated recycled water as set forth in Title 22 of the California Code of Regulations. Requirements are established for both solids content and bacteriological properties. The WRP's National Pollutant Discharge Elimination System (NPDES) and Title 22 permit requirements establish a median number of total coliform bacteria as measured over a seven-day period that cannot be exceeded as a most probable number (MPN) of 2.2 per 100 milliliters (mL). The tertiary-treated water via granular media filtration is required to meet Title 22 turbidity requirements as follows:

- Average of 2 NTU within 24-hr period
- 5 NTU not more than 5 percent of the time during 24-hr period
- Less than 10 NTU at all times

Because the tertiary-treated water can be directly used for surface spreading without further treatment, the treatment technologies described in this TM will only cover AWT technologies.

### AWT Treatment

Although other technologies may be feasible, currently microfiltration/ultrafiltration (MF/UF), reverse osmosis (RO,) and ultraviolet light based advanced oxidation process (UV-AOP) is the only Full Advanced Treatment (FAT) scheme recognized by the California Department of Public Health (CDPH) for Groundwater Replenishment Reuse Projects (GRRPs) as currently outlined in the Groundwater Replenishment Reuse Draft Regulations.

MF/UF provides solids and pathogen removal and adequate pretreatment for RO. RO greatly removes nitrogen, dissolved organics (i.e., TOC and trace organic constituents), dissolved salts (TDS), and inorganic material (e.g., arsenic) and further removes pathogens from water. UV-AOP inactivates pathogens and oxidizes trace organic contaminants in the RO permeate (e.g., N-nitrosodimethylamine [NDMA], 1,4-Dioxane).

### Hybrid (Tertiary + AWT)

The hybrid approach combines treatment of a portion of the 21,000 AFY using tertiary (11,000 AFY) and the remainder of the 21,000 AFY using AWT (10,000 AFY). The quantities may vary as the hydraulic spreading capacity of the MFSG is determined; however, this analysis assumes that the hybrid alternative uses 11,000 AFY of tertiary and 10,000 AFY of AWT recycled water to recharge the Montebello Forebay.

Tertiary-treated water would be conveyed in the existing outfall pipeline to the spreading grounds, and AWT water would be conveyed in a new, dedicated outfall pipeline to either the spreading grounds or injection sites. Although this approach may result in high capital and O&M costs due to inclusion of AWT, require additional labor to operate and maintain the new AWT facilities and new conveyance system, and require skilled operation, this approach offers improved water quality compared to tertiary-treated water alone. It also offers operational flexibility by allowing recycled water to be used for recharge year round; in terms of recharge capabilities tertiary treated water may be used for surface spreading only during periods when spreading basin capacity is available, while AWT water may be used throughout the year for surface spreading and/or injection.

### 3.2.2 Treatment – Preliminary Options Assessment

The advantages and disadvantages for all three treatment levels are presented in Table 5-4.

**TABLE 5-4**
**Advantages and Disadvantages of Treatment Level Options**

| Treatment Level Option | Advantages | Disadvantages |
|---|---|---|
| Tertiary | • No investment is needed for additional treatment facilities<br>• No additional treatment facilities to operate and maintain (no impact on treatment O&M cost including labor)<br>• No new outfall pipeline is required | • Lower quality water quality (high TN, TOC) compared to AWT<br>• Requires detailed evaluation to estimate how much tertiary treated water can be applied for spreading considering additional treatment provided by the soil aquifer treatment system<br>• Spreading grounds may not be available during wet period when basins are at capacity with stormwater runoff and/or precipitation. |
| AWT | • Very high quality water (very low TN, TOC, TDS)<br>• Up to 100 percent recycled water can be used for recharge (minimize or eliminates the need for dilution water once the facility has been in operation for a certain period of time and has been in compliance with permit requirements)<br>• With injection wells, the recycled water can be used year round (ensure use of AWT at full-capacity)<br>• Injection of AWT water will improve the salt and nutrient levels in the basin, providing a reduction in basin-wide TDS and nutrients | • Highest capital and O&M cost amongst the options<br>• Requires new outfall pipeline to convey advanced treated water<br>• Requires additional labor to operate and maintain the new AWT facilities and new conveyance system<br>• Requires skilled operation |
| Hybrid (Tertiary + AWT) | • Improved water quality compared to tertiary treated water alone<br>• Provides flexibility, ensures recycled water use year round in a cost effective manner (dry seasons mostly tertiary treated water via surface spreading, year round AWT via surface spreading or injection)<br>• Reduced O&M costs | • High capital and O&M cost due to inclusion of AWT<br>• Requires additional labor to operate and maintain the new AWT facilities and new conveyance system |

Table 5-5 summarizes scoring results for these treatment options based upon established evaluation criteria defined in TM 1-4.

**TABLE 5-5**
**Summary of Scoring – Treatment Preliminary Options**

| Criteria | Tertiary | AWT | Hybrid (Tertiary + AWT) |
|---|---|---|---|
| Water Quality Suitability for Recharge | 0 | + | + |
| Ability to Permit | + | + | + |
| Cost of Treatment | + | - | 0 |
| Operational Familiarity | + | + | + |
| Demonstrated Performance | + | + | + |
| Institutional Feasibility | 0 | + | + |
| Time/ Schedule to Implement | + | 0 | 0 |
| Environmental Impact | 0 | 0 | 0 |
| **Score** | **5** | **5** | **5** |
| **Rank** | **1 (tie)** | **1 (tie)** | **1 (tie)** |

### 3.2.3 Treatment – Viable Options

All three treatment level options were carried forward for further evaluation:

- Tertiary
- AWT
- Hybrid (Tertiary + AWT)

In terms of water quality, all options produce high-quality product water, with the AWT providing the best, followed by the Hybrid and the Tertiary. All are judged equally in terms of their ability to permit. The Tertiary option has the lowest implementation and operations costs, followed by the Hybrid; the AWT option is the most expensive. With respect to operational familiarity, all are rated the same based upon staff familiarity. Similarly, all options have demonstrated performance capabilities under similar conditions. The institutional feasibility ratings reflect the expectations established by recent projects that provide high levels of treatment for recharge. The Tertiary option is ranked highest for time/schedule to implement since it has the least new facilities involved; the Hybrid and AWT are slightly lower. All options are rated the same with regard to environmental impacts associated with construction and operations. In summary, while the options have different individual scores, the overall cumulative scores and rankings are the same.

### 3.2.4 AWT – Conventional vs. Alternative

The viable AWT treatment option was further evaluated to determine the viability of conventional vs. alternative AWT treatment trains. The conventional and alternative AWT treatment trains have both similar and different process elements associated with them. This section provides an overview of the different AWT processes as follows:

- AWT – Conventional:
  - MF/UF, RO, UV-AOP
- AWT – Alternative:
  - MF/UF, NF, UV-AOP

  - MF/UF, NF, Ozone-BAC
  - MF/UF, Ozone-BAC-granular activated carbon (GAC), UV-AOP

As discussed in Section 3.2.1, although other technologies may be feasible, currently MF/UF, RO, and UV-AOP is the only FAT scheme recognized by the CDPH for GRRPs. With respect to AWT treatment options, this process is referenced as the AWT – Conventional option.

The conventional AWT process is energy intensive, requires a high capital investment, and generates considerable amount of RO concentrate requiring disposal. In recent years, research has been intensified to develop new options to reduce capital and O&M costs of AWT facilities. These processes are referenced as the AWT – Alternative options. Although limited pilot testing data shows promise, performance and equivalency of these processes to FAT needs to be demonstrated.

### AWT Unit Processes

MF/UF is a barrier for solids and is a universally accepted pretreatment step for RO and NF. In addition, MF/UF provides an extra barrier for pathogens which is required by the new Groundwater Replenishment Reuse Draft Regulations (November 2011). Therefore, MF/UF is included as the first step for all treatment train options discussed.

RO may be replaced with NF or ozone-BAC-GAC to meet the TOC, virus, and protozoa requirements of the AWT. Finally, the combination of ozone-BAC may be used to replace UV-AOP and provide disinfection and advanced oxidation.

#### MF/UF

The MF/UF system is an integral part of an AWT facility and serves the following two main purposes: (1) to minimize fouling of the downstream RO process through the removal of particulate matter in the influent and (2) to provide a barrier to the passage of pathogenic microorganisms, including bacteria and protozoa.

The MF/UF is a pressure or vacuum driven separation process that typically employs membranes to provide a barrier to the passage of solids (i.e., turbidity, suspended solids) and pathogenic microorganisms, including bacteria and protozoa. The MF pore sizes range from approximately 0.1 – 0.2 micron (nominally 0.1 micron) and the UF pore sizes range from 0.01 – 0.05 micron (nominally 0.01 micron). Despite the pore size differences, both systems produce a virtually solids-free effluent with a turbidity of usually less than 0.1 NTU without chemical addition for particle coagulation. As a result, MF and UF systems are both qualified by the CDPH as an AWT unit process.

MF/UF systems are designed to filter small suspended solids and particles. Larger size suspended solids, if allowed to enter the fiber bundle, can cause fiber damage (including breakage) and accumulate, leading to a buildup of solids. As a result, MF/UF systems employ self-cleaning strainers with a screen size of 500 micron or less to prevent the entry of larger particulates into the membrane modules. In addition, feed water chloramination is usually necessary as a pretreatment to protect both MF/UF and RO membranes against biological fouling.

MF/UF can be divided into two broad categories based on the side of the membrane the driving force for filtration is applied to:

- Pressurized (pressure applied to the feed side)
- Immersed or submerged (vacuum applied to the permeate side)

In both types of systems, membrane fibers are bundled in groups of several thousand and potted in a resin on both ends to form a module, with tens to hundreds of modules coupled together to form a system.

In pressurized systems, the modules are housed in a pressure vessel. Feed water is pressurized and applied to the feed side of the membranes in the module. Typical operating pressures range from 3 to 40 pounds per square inch (psi) depending on the product and operating conditions for that specific supplier.

With submerged systems, the modules are placed into an open-to-atmosphere tank filled with feed water. A vacuum is applied to the filtrate side of the membranes to pull the treated water through the fibers. Because the feed water is contained in an open basin, the pressure differential across the fibers is limited to a maximum of 13 psi, assuming 1 to 2 feet of head above the top of the membrane modules. Normally, a vacuum of approximately -3 to -12 psi is applied at the bore or lumen of the fibers via pump suction, although this vacuum can be provided via a siphon where the permeate flows to a receiving tank at a lower elevation. Figure 5-3 shows pictures of pressurized and submerged MF installations.

**FIGURE 5-3**
**Pressurized (left) and Submerged (right) MF Installations**

Advantages and disadvantages of pressurized and submerged membranes are presented in Table 5-6.

**TABLE 5-6**
**Advantages and Disadvantages of MF/UF Treatment Process Options**

| MF/UF Option | Advantages | Disadvantages |
|---|---|---|
| Pressurized MF/UF | • Smaller footprint for small capacity facilities<br>• One set of pumps (feed pumps) is needed<br>• Easy to construct<br>• Easy to access the membranes for repair and maintenance<br>• Lower unit chemical use for cleaning | • Usually operates with higher pressures than submerged<br>• May not be cost effective for plant capacities exceeding 20 MGD<br>• Higher unit energy consumption |
| Submerged MF/UF | • Typically operates with lower pressures than pressurized systems which reduce O&M cost<br>• Smaller footprint for larger capacity facilities<br>• Usually cost effective for plant capacities exceeding 20 MGD<br>• Uses similar membranes as membrane bioreactors (MBR) | • More difficult to access the membranes for repair and maintenance (requires draining of the tank )<br>• Increased height requirement for above ground installations<br>• Two pumps may be required for above ground installations |

Although each system has some advantages and disadvantages, the CDPH equally qualifies both systems as a component of AWT for GRRPs. Both systems will be considered for the Preliminary Engineering Report. The selection of the MF/UF system (pressurized vs. submerged) will be made as a part of the facilities design.

### Reverse Osmosis

RO is a pressure-driven membrane separation process in which dissolved organic and inorganic compounds (such as TOC, nutrients, or TDS) and pathogens are removed from the solution by forcing the water through a semi-permeable membrane under a higher pressure than the osmotic pressure of the solution. The United States Environmental Protection Agency (USEPA) has classified RO as a best available technology (BAT) for removal of many of the contaminants listed under Phases II, III, and V of the Amendments to the 1986 Safe Drinking Water Act (SDWA). Currently, RO is the only recognized technology by the CDPH to reduce TOC, nitrogen and TDS (if needed) in GRRPs using FAT.

The amount of energy required to drive feed water through the membrane depends on the permeability of the polyamide rejecting layer and on the osmotic pressure of the feed water (AWWARF 1996). The most common type of RO membrane module used is the spiral-wound configuration. Individual RO membrane elements are housed in cylindrical pressure vessels. Feed and concentrate flow through the feed–side channels in a straight path parallel to the direction of the permeate collection tube. Water penetrates the membrane and is collected in the center permeate tube. The remaining water passes the element and exits through the concentrate outlet of the pressure vessel. Typically, six or seven elements are housed in series in a pressure vessel in which the concentrate from one element serves as the feed to the next element in series.

RO systems in reuse applications are generally designed for 85 percent recovery. Typical operating RO pressure in reuse applications is between 120 and 300 psi depending upon feed TDS content, operating temperature, and age of the membrane elements.

In addition to treatment by MF/UF, the RO feed must be chemically conditioned using an antiscalant chemical for scale control. The feed may also require acidification to reduce pH depending upon calcium, alkalinity, and phosphate levels in the feedwater. Cartridge filters are installed to retain any solids that might be present in the MF filtrate, especially those introduced through construction or maintenance activities.

Figure 5-4 shows a picture of a full-scale RO train.

**FIGURE 5-4**
**RO Pressure Vessels**

The advantages and disadvantages of RO are discussed in Table 5-7.

**TABLE 5-7**
**Advantages and Disadvantages of RO Treatment Process Compared to Alternative Treatment Processes**

| Advantages | Disadvantages |
|---|---|
| • Recognized by the CDPH as a FAT component in GRRPs<br>• Can be permitted and implemented within the project timeframe<br>• Proven performance with excellent track record and operating experience<br>• Produces very high water quality with low TOC, TN, TDS, and other soluble compounds present in the effluent<br>• Provides greater removal of NDMA and 1,4 dioxane<br>• RO permeate has high UV transmission (UVT), reducing capital and O&M cost of the UV-AOP facilities<br>• Provides significant removals of UV light and hydroxyl radical scavengers (e.g., alkalinity or iron), improving performance and reducing O&M costs of UV-AOP | • Higher energy requirement<br>• Generates a greater volume of concentrate requiring further treatment/disposal<br>• RO permeate requires stabilization |

## Nanofiltration (NF)

Like RO, NF is a pressure driven membrane separation process. Historically, NF has been used as an alternative to lime softening for reducing the level of calcium and magnesium in hard waters (membrane softening) and for removal of natural organic matter (TOC) from ground and surface waters. More recently, bench and pilot studies have demonstrated that NF membranes can provide high removal efficiencies for TOC and constituents of emerging concern (CEC) from secondary effluent at lower operating pressures than RO (75 to 125 psi). NF can also allow for higher overall recovery (Mansell 2011). Because of its low inorganic ion rejection, NF provides little if any removal of nitrogen compounds.

NF is currently not recognized by the CDPH as a FAT component.

As in RO systems, NF elements are configured identically to those of RO (spiral wound) and utilize similar pressure vessels and hydraulic arrays. Feedwater pretreatment requirements (i.e., silt density index, turbidity, and scale control) are the same; however, because NF concentrates scaling ions to a lesser degree than RO, antiscalant and acid requirements are lower when operated at a similar recovery.

The advantages and disadvantages of NF are discussed in Table 5-8.

**TABLE 5-8**
**Advantages and Disadvantages of NF**

| Advantages | Disadvantages |
|---|---|
| • Lower energy requirement<br>• Very little or no requirement for product water stabilization<br>• Higher water recoveries and reduced concentrate volumes<br>• Allows passage of some prevalent scaling ions, such as silica, which makes volume reduction of the concentrate easier and less expensive<br>• Can be retrofitted into the existing RO facilities with some modifications (e.g., feed pump de-staging) | • Not recognized by the CDPH as a FAT component in GRRPs<br>• Not likely to be permitted and implemented within the project timeframe<br>• No full-scale operating experience in reuse projects<br>• Lower removal of TN, NDMA, and 1,4 dioxane compared to RO<br>• Lower UVT in NF permeate, increasing capital and O&M cost of the UV-AOP<br>• Not effective for removing UV light and hydroxyl radical scavengers that reduce UV-AOP performance and increase O&M cost |

## Ozone-BAC-GAC (for TOC removal)

Use of ozone-BAC-GAC in lieu of RO will eliminate the generation of a RO concentrate waste stream, which can be difficult and costly to dispose. Although not practiced in California, indirect potable reuse (IPR) treatment schemes that utilize ozone-BAC-GAC have been implemented in other areas of the country where RO is not considered necessary to address treated water requirements (such as low TDS effluents). For example, at the Upper Occoquan Sewage Authority in northern Virginia, a GAC-based treatment process has successfully been used for flows into a potable water reservoir for more than 30 years. More recently, IPR projects have been implemented in Gwinnett County, Georgia (UF, ozone, BAC, ozone) and Loudoun County, Virginia (MBR, GAC, UV).

In the Ozone-BAC-GAC process, ozone partially oxidizes organic matter present in secondary effluent, making it more readily biodegradable. The ozonated effluent then passes through a GAC bed. Initially, most of the removal occurs through physical adsorption on the GAC media, while bacteria introduced into the bed through the feedwater (or through artificially seeding) become acclimated. Removal by adsorption gradually decreases due to acclimation of microorganisms and saturation of adsorption sites, and biological assimilation and transformation of the organics becomes the dominant removal mechanism. After the ozone-BAC process, GAC is used to provide additional TOC removal via adsorption. Saturated GAC needs regeneration or replacement to restore treatment efficiency.

Although recent pilot studies have shown promising results, the major uncertainties with the use of ozone-BAC-GAC are its ability to produce treated water that can meet the 0.5 mg/L TOC limit for direct injection and the lack of reliable performance data to size and cost treatment facilities.

Figure 5-5 shows a picture of an ozone contactor.

**FIGURE 5-5**
**Ozone Contactor**

The advantages and disadvantages of Ozone-BAC-GAC are discussed in Table 5-9.

**TABLE 5-9**
**Advantages and Disadvantages of Ozone-BAC-GAC Treatment Process**

| Advantages | Disadvantages |
|---|---|
| • No requirement for water stabilization<br>• No liquid waste stream (concentrate) requiring disposal<br>• Lower life-cycle costs than RO based trains<br>• Lower power requirements and greenhouse gas emissions | • Not recognized by the CDPH as a FAT component in GRRPs<br>• Difficulty in being permitted and implemented within the project timeframe<br>• No track record and lack of full-scale operating experience in reuse projects<br>• Complex operation and maintenance<br>• Requires periodic replacement and disposal of spent GAC<br>• Not effective for removing TN and TDS<br>• Process performance for removal of TOC, NDMA, and 1,4 dioxane is not established<br>• Lower UVT in the effluent increases capital and O&M cost of UV-AOP<br>• Not effective for removing UV light and hydroxyl radical scavengers that reduces UV-AOP performance or increases O&M cost |

## UV-AOP

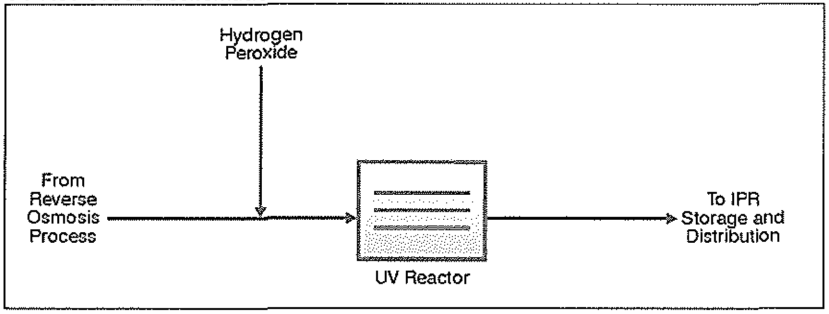
Two primary classes of micro pollutants that are now of public concern and scientific interest are pharmaceuticals and potential endocrine disrupting compounds. AOPs are powerful treatment barriers to such trace pollutants as well as pathogens (WRRF 2012a). The AOP process uses strong oxidants to degrade pollutants. The most common oxidizing radical is the hydroxyl radical (•OH) since it has the highest oxidation potential as compared to ozone ($O_3$), hydrogen peroxide ($H_2O_2$) and chlorine dioxide ($ClO_2$) (WRRF 2012a).

In wastewater reclamation processes, AOP is typically employed following RO, similar to the systems at the Orange County Water District or the West Basin Municipal Water District. In the post-RO mode of operation, the AOP universally implemented at full-scale is the UV plus $H_2O_2$ process. However, there is a growing interest and a subsequent body of research on alternative AOPs and the use of these AOPs in different places in the reclamation process (WRRF 2012a, WRRF 2012b).

The hydroxyl radical is described as a non-selective oxidant and displays high reaction rates with organic and inorganic species present in natural waters. Because of the non-selective nature of this oxidant, the hydroxyl radical will react not only with target pollutants of choice, but also with inherent species present in water. Rosenfeldt and Linden (2007) note that once the hydroxyl radical is created, it will quickly react with natural organic matter (NOM), carbonate species (both $HCO_3^-$ and $CO_3^{2-}$), any other organic compounds in the water, and even $H_2O_2$ in AOP applications that utilize the oxidant. The consumption of •OH through these ever-present compounds in water is called scavenging. Understanding this parameter is important to the design of robust AOPs because it inhibits the oxidation of the target pollutants in water. Due to the purified nature of RO permeate, there is little scavenging of •OH in post-RO AOP applications, assuming that RO permeate stabilization compounds are added after the AOP process.

Figure 5-6 shows a schematic of the UV AOP process. For this process, the $H_2O_2$ is injected upstream of the UV reactor at the desired dose. A portion of the $H_2O_2$ is then converted to the hydroxyl radical in the UV reactor, where oxidation of the contaminants occurs.

**FIGURE 5-6**
**UV-AOP Process Schematic**



For this evaluation, the UV-AOP system would be sized to provide approximately 1.4-log reduction of NDMA which is also efficient to meet 0.5 log reduction of 1,4-dioxane. To meet these targets, a UV dose of 500 millijoules per square centimeter (mJ/cm2) or more and a $H_2O_2$ dose of 3-5 mg/L are required. There are several viable manufacturers of UV-AOP systems, including Trojan, WEDECO, Calgon, and Engineered Treatment Systems (ETS). This analysis is based upon the use of UV reactors from Trojan, because these provide a more conservative cost estimate approach. However, the layouts used for space allocation were based on the Calgon's UV reactors because these require a slightly larger footprint.

The advantages and disadvantages of the UV-AOP unit treatment process are presented in Table 5-10.

**TABLE 5-10**
**Advantages and Disadvantages of UV-AOP Treatment Process**

| Advantages | Disadvantages |
|---|---|
| • Proven technology<br>• Reliable effluent quality<br>• Short reactor detention time and small reactor footprints<br>• Provides two mechanisms for transformation of organic chemicals: direct photolysis and hydroxyl radical oxidation<br>• Recognized by the CDPH as a FAT process | • High energy requirements as a result of high UV doses<br>• The need to store and inject $H_2O_2$<br>• High capital cost |

## Ozone and BAC (for disinfection and CEC removal)

Ozone ($O_3$), an unstable gas, is produced when oxygen ($O_2$) molecules are dissociated by an energy source into oxygen atoms and collide with an oxygen molecule. Ozone is a very strong oxidant and virucide and is used to disinfect both water and wastewater. The mechanisms of disinfection using ozone include:

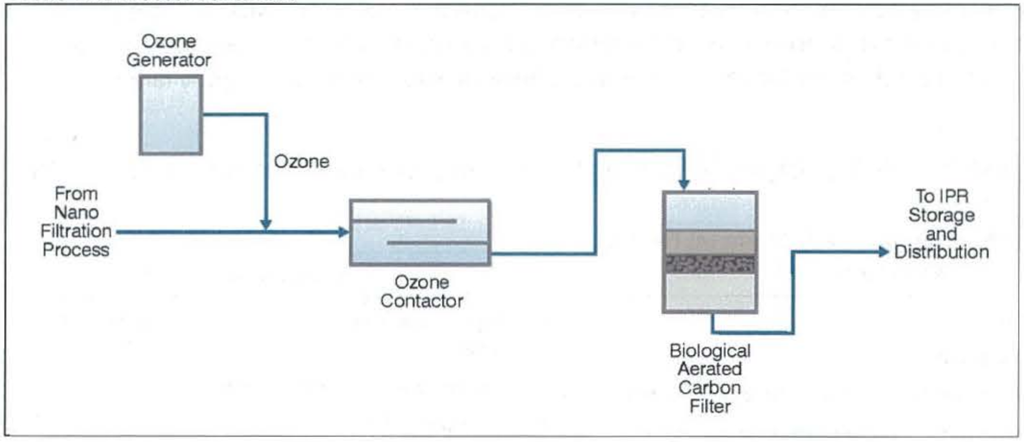
- Direct oxidation/destruction of the cell wall with leakage of cellular constituents outside of the cell
- Reactions with radical by-products of ozone decomposition
- Damage to the constituents of the nucleic acids (purines and pyrimidines)

BAC is a filter where a biological colony is allowed to develop. The organisms in the filter degrade and remove organic material from the water. It has been found that ozone use ahead of filtration aids the BAC process by increasing the concentration of available biodegradable organic matter.

Ozone alone has been shown to destroy pollutants, CECs, and pathogens in conventional filtered secondary effluent at low-ozone dose values (WRRF 2012a). Research (Stantec 2011) has also shown that ozone can create trace levels of byproducts, including aldehydes, bromates, and even nitrosamines (including NDMA). When followed by biologically active filters, these by products have been shown to be removed below detectable levels (Stantec 2011). Additional benefits include the significant reduction of TOC (typically 20 to 70 percent) through this combined process. The use of BAC is optimal on a filtered wastewater effluent, in which the biology would have the ability to provide substantial treatment. The use of BAC following ozone on RO permeate would likely have little value due to the purified and nutrient free water quality. To our knowledge, no post-RO testing of ozone-BAC has been performed.

Figure 5-7 shows a schematic of the Ozone-BAC process. For this process, the ozone is injected upstream of the ozone contact basin either via direct or side stream injection at the desired dose. The ozonation water then goes to a contactor which is sized for a desired contact time (≤5 minutes) to achieve required pathogen kill and pollutant destruction. From the ozone contact basin the water then flows to a BAC filter.

**FIGURE 5-7**
**Ozone-BAC Process Schematic**



Similar to the UV-AOP, the ozone-BAC system would be designed to provide 1.2-log reduction of NDMA and 0.5 log reduction of 1,4-dioxane. To meet this target, an ozone dose of 1-3 mg/L is recommended. There are several viable technology options for $O_3$ system, including systems from APT Water and WEDECO. The BAC would be designed with single media at a loading rate of 6 gallons per minute per square foot (gpm/ft$^2$) and an empty bed contact time of 5 minutes.

The advantages and disadvantages of the ozone-BAC treatment process are presented in Table 5-11.

**TABLE 5-11**
**Advantages and Disadvantages of Ozone-BAC Treatment Process**

| Advantages | Disadvantages |
|---|---|
| • Uses ozone to oxidize organic material and inactivate pathogens<br>• BAC is used for removal of organic material<br>• Low capital cost | • No proven track record and lacks full-scale operating experience in reuse applications<br>• $O_3$ may generate byproducts, including NDMA; BAC needed to remove these byproducts<br>• Not recognized by the CDPH as a FAT unit process for GRRPs and requires testing to prove equivalency<br>• Significant time may be required for biology to be acclimated to target pollutants<br>• Requires storage of liquid oxygen on-site<br>• Requires periodic replacement and disposal of the spent carbon |

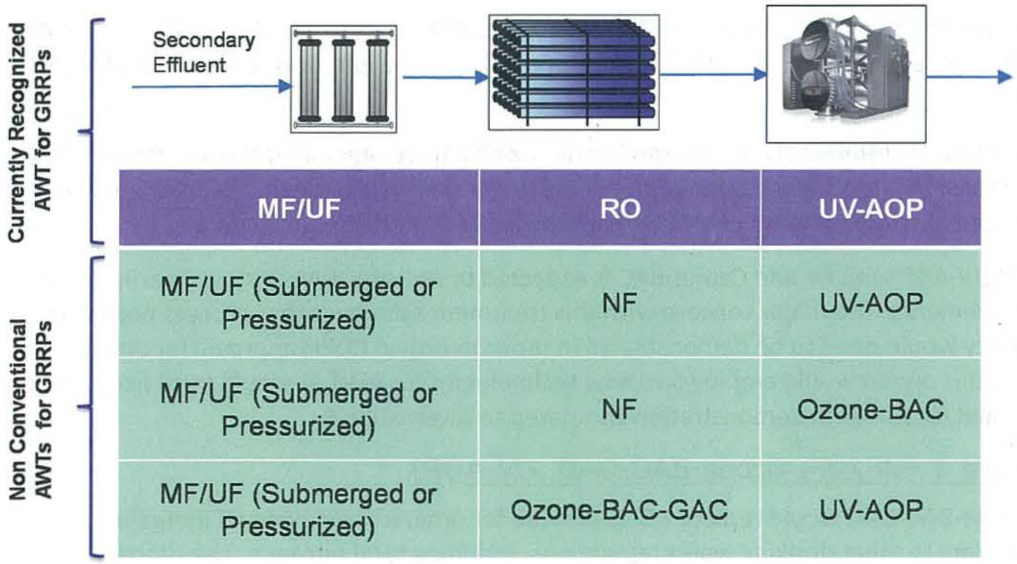
## AWT Treatment Train Options

Process components presented previously are coupled to form an AWT process train as shown on Figure 5-8. The MF/UF, RO, UV-AOP train is referred to as AWT – Conventional. Three alternative AWT process train options are also illustrated on Figure 5-8. The AWT – Alternative treatment train options evaluated include:

- MF/UF, NF, UV-AOP
- MF/UF, NF, Ozone-BAC
- MF/UF, Ozone-BAC-GAC, UV-AOP

These alternative AWT process trains are not recognized by the CDPH for GRRPs as currently outlined in the Groundwater Replenishment Reuse Draft Regulations and will require equivalency testing to show their effectiveness and efficiency compared to the conventional AWT.

**FIGURE 5-8**
**AWT Conventional and Alternative Treatment Train Options**



| | | | |
|---|---|---|---|
| Currently Recognized AWT for GRRPs | MF/UF | RO | UV-AOP |
| Non Conventional AWTs for GRRPs | MF/UF (Submerged or Pressurized) | NF | UV-AOP |
| | MF/UF (Submerged or Pressurized) | NF | Ozone-BAC |
| | MF/UF (Submerged or Pressurized) | Ozone-BAC-GAC | UV-AOP |

## AWT – Conventional (MF/UF, RO, UV-AOP)

Secondary effluent from the SJCWRP would most likely serve as the feed water to the AWT. The MF/UF would employ self-cleaning strainers with a screen size of 500 micron or less to prevent the entry of larger particulates into the membrane modules. Feed water chloramination would be implemented as a pretreatment to protect both MF/UF and RO membranes against biological fouling. The treated flow (filtrate) from MF/UF would enter a break tank to provide a continuous supply of feed to RO as well as filtrate for MF/UF backwash and cleaning. Antiscalant would be continuously dosed to the RO feed for scale control (low alkalinity and calcium content of feed may not require acid addition). RO permeate would be routed to the UV-AOP process. Hydrogen peroxide would continuously be dosed to the RO permeate prior to UV to generate hydroxyl radical for advanced oxidation.

Because RO removes nearly all of the alkalinity and calcium, the RO permeate would be aggressive and have an acidic pH and negative Langelier Saturation Index (<-4.5). Post treatment (decarbonation and chemical addition) would be required to stabilize the water before injection.

The backwash waste generated from the MF/UF would be conveyed to the head of the WRP for re-treatment. For the purpose of this analysis, it was assumed that the RO concentrate would be discharged into the sewer either directly or following a concentrate volume reduction process. An evaluation of the brine management options is discussed in TM 1-6.

## AWT – Alternative 1 (MF/UF, NF, UV-AOP)

In this option, NF would replace RO to provide similar treatment capability at a reduced O&M cost, due to significantly lower operating pressure. This treatment train would resemble the previous one. However, this scheme would require very little or no post treatment for water stabilization due to the higher levels of calcium and alkalinity in the NF permeate and higher permeate pH. In addition, NF would allow greater passage of scaling ions, especially silica, which would make volume reduction of the concentrate easier and less expensive. The major concern with this treatment scheme, as discussed before, is that process performance and FAT equivalency would need to be demonstrated in order to obtain CDPH approval for direct injection.

## AWT – Alternative 2 (MF/UF, NF, Ozone BAC)

In this option, NF would replace RO (similar to Alternative 1) and Ozone-BAC would replace the UV-AOP process. Pretreatment requirements for MF/UF in this option would be identical to those required in conventional AWT.

Ozone would be dosed to disinfect the water and further oxidize trace organics left over after NF. BAC would serve as a polishing step to remove organics in the water. Periodic backwash of BAC would be required to eliminate excessive growth of microorganisms in the filter bed.

Replacing RO and UV-AOP with NF and Ozone-BAC is expected to reduce O&M costs, primarily due to lower power requirements. The major concern with this treatment scheme is that process performance and FAT equivalency would need to be demonstrated in order to obtain CDPH approval for direct injection. Because this option would employ two new technologies for AWT, it would most likely require extensive testing and longer-term demonstration compared to Alternative 1.

## AWT – Alternative 3 (MF/UF, Ozone-BAC-GAC, UV-AOP)

In this option, Ozone-BAC-GAC would replace RO to provide for organics removal and inorganic constituents necessary to meet drinking water regulations, including total nitrogen. The process substitution would eliminate costs associated with concentrate disposal and treated water stabilization.

The MF/UF step would be unchanged; however, the need for other aspects of RO feedwater pretreatment (i.e., cartridge filtration and antiscalant addition) would be eliminated. Ozone would be dosed prior to the BAC filters that contain granular activated carbon as filter media. Ozone would oxidize the organic material present in the MF filtrate into a more bioavailable form which would then be biologically degraded by microorganisms residing in BAC. GAC would adsorb residual dissolved organic material remaining in the BAC effluent (polishing) in order to achieve the desired treated water TOC goal of 0.5 mg/L.

The UV-AOP would provide advanced oxidation and disinfection. UV transmittance in UV-AOP feed from the MF/UF, Ozone-BAC-GAC process would be expected to be lower than the NF or RO treated water which could increase both capital and O&M costs of the UV-AOP for this option.

The major concern with this treatment scheme is that process performance and FAT equivalency would need to be demonstrated in order to obtain CDPH approval for direct injection. Because this option would employ a non-membrane based new technology for AWT, it would most likely require extensive testing and longer-term demonstration compared to Alternative 1.

### Evaluation of AWT Treatment Train Options

Table 5-12 summarizes scoring results for these AWT treatment options based upon established evaluation criteria defined in TM 1-4.

Conventional AWT was determined to be the most viable AWT treatment option. All three alternative AWT treatment options were eliminated from further consideration based upon the assessment performed. These AWT – Alternative treatment options were eliminated principally on the basis of:

- Uncertainty in the ability to permit
- The lack of comparable operating systems achieving consistent effluent quality
- The schedule impacts related to permitting and extensive testing and demonstration likely to be required

**TABLE 5-12**
**Summary of Scoring – AWT Treatment Preliminary Options**

| Criteria | AWT - Conventional | AWT - Alternative | | |
|---|---|---|---|---|
| | MF/UF, RO, UV-AOP | MF/UF, NF, UV-AOP | MF/UF, NF, ozone-BAC | MF/UF, ozone-BAC-GAC, UV-AOP |
| Water Quality Suitability for Recharge | + | 0 | 0 | 0 |
| Ability to Permit | + | 0 | - | - |
| Cost of Treatment | - | + | + | 0 |
| Operational Familiarity | + | + | 0 | 0 |
| Demonstrated Performance | + | 0 | - | - |
| Institutional Feasibility | + | 0 | 0 | 0 |
| Time/Schedule to Implement | + | 0 | - | - |
| Environmental Impact | 0 | 0 | 0 | 0 |
| **Score** | **5** | **2** | **-2** | **-4** |
| **Rank** | **1** | **2** | **3** | **4** |

Although the AWT – Conventional treatment train option was the most viable option for full-scale implementation within the project timeframe, some of the AWT – Alternative options discussed may merit consideration for pilot testing. The potential for significant O&M cost savings with NF in lieu of RO due to NF's lower energy consumption and higher plant water recovery warrants further consideration of this technology and pilot testing to demonstrate its performance efficiency and reliability. Ultimately, the full-scale design should allow for easy retrofit with NF in the future. In addition, pilot testing ozone-BAC for disinfection/advanced oxidation as part of the AWT should also be considered.

## 3.3 Conveyance Options Assessment

### 3.3.1 Conveyance - Preliminary Options

Conveyance is required to transport recycled water from the location of treatment (SJCWRP) to the location of recharge (Montebello Forebay). Two preliminary options were considered:

- Existing Pipeline – Combine Conveyance
- New Pipeline – Separate Conveyance

Currently, tertiary effluent from the SJCWRP is conveyed through an outfall pipeline that varies in diameter from 54 to 72 inches. The existing outfall pipeline travels from the plant, southerly alongside the San Gabriel River to where it discharges to the lined portion of the San Gabriel River. A turnout, located approximately 4.4 miles from the SJCWRP, is used to divert tertiary treated flows to the San Gabriel spreading basins for recharge at the Montebello Forebay. Use of this line would preclude the need for any significant or additional conveyance related construction. Use of the existing single conveyance would, however, require the blending of tertiary flows with any planned AWT flows. Blending flows would limit the recharge option to spreading and eliminate the potential for injection of high quality AWT product water into the Montebello Forebay.

The construction of a new pipeline would allow for separate, dedicated conveyance of tertiary flows and any AWT product water flows. This separation would allow for the use of both spreading basins (tertiary or AWT flows) and injection wells (AWT only) for recharge in the future. Construction of a new pipeline would necessitate additional capital investment. The construction of any new pipeline would require acquisition of additional rights-of-way, including permanent easements, temporary construction easements, encroachment permits, and possibly permanent rights-of-way.

### 3.3.2 Conveyance - Preliminary Options Assessment

The advantages and disadvantages for the existing and new pipeline conveyance options are presented in Table 5-13.

**TABLE 5-13**
**Advantages and Disadvantages of Conveyance Options**

| Conveyance Option | Advantages | Disadvantages |
|---|---|---|
| Existing Pipeline - Combined Conveyance | • Lowest capital investing<br>• Maximum use of existing facilities<br>• Operational familiarity | • Limited recharge flexibility |
| New Pipeline - Separate Conveyance | • Operational flexibility<br>• Best use of AWT product water | • Capital investment<br>• Complexity of construction; easements |

The two preliminary options of Existing Pipeline (Combined Conveyance) and New Pipeline (Separate Conveyance) were evaluated based upon established evaluation criteria. Table 5-14 summarizes scoring results for the conveyance options.

**TABLE 5-14**
**Summary of Scoring Results for Conveyance Options**

| Criteria | Existing Pipeline - Combined Conveyance | New Pipeline - Separate Conveyance |
|---|---|---|
| Costs | + | - |
| Operational Flexibility | - | + |
| Recycled Water Utilization | 0 | + |
| Potential for Optimizing Operations | 0 | + |
| Project Flexibility | - | + |
| Institutional Feasibility | - | 0 |
| **Score** | **-2** | **+3** |
| **Rank** | **2** | **1** |

### 3.3.3 Conveyance – Viable Options

Both options were carried forward for further evaluation; the existing pipeline could convey tertiary treated water and the new dedicated pipeline could convey AWT water. These approaches are now termed viable options.

#### New Pipeline – Potential Alignments

Six potential alignments for conveying AWT water from SJCWRP to the Montebello Forebay were examined for the New Pipeline – Separate Conveyance option. Each of the potential alignments described herein present different routes between SJCWRP and Rosemead Boulevard south of Whittier Boulevard. From there, each of the six potential alignments will extend along Rosemead Boulevard south of Whittier Boulevard to serve the injection wells along Rosemead Boulevard. The new AWT pipeline would also tie in to the existing outfall at Beverly Boulevard, immediately downstream of the Rio Hondo Pump Station, for recharging the Rio Hondo Spreading Grounds and the San Gabriel Spreading Grounds.

The six different alignments reviewed were:

1. Parallel Alignment
2. West Levee Alignment
3. Durfee Avenue Alignment
4. Workman Mill Road Alignment
5. Railroad Alignment
6. City Streets Alignment

Each of the alignments is described in the sections following and depicted on Figures 5-9 through 5-14.

**1. Parallel Alignment** – This pipeline alignment would follow the existing Sanitation Districts' outfall pipeline along I-605. The pipeline would start at the SJCWRP West and would require a crossing under SR-60. The pipeline would follow I-605 south to Beverly Boulevard, where it would turn west. The pipeline would continue west along Beverly Boulevard to Rosemead Boulevard, at which point it would turn south and terminate at Whittier Boulevard where it could serve the injection wells, and/or the San

Gabriel and Rio Hondo Spreading Grounds. The length of this alignment would be approximately 4.75 miles.

**2. West Levee Alignment** – This pipeline alignment would exit the SJCWRP West and cross the San Gabriel River. The pipeline would then run southwest in the west levee of the river until the Whittier Narrows Dam, at which point the pipeline would go around the Dam along Fairway Drive to the San Gabriel River Parkway. The pipeline would continue southwest along the San Gabriel River Parkway to Beverly Boulevard. The pipeline would continue west along Beverly Boulevard to Rosemead Boulevard, at which point it would turn south and terminate at Whittier Boulevard where it could serve the injection wells, and/or the San Gabriel and Rio Hondo Spreading Grounds. The length of this alignment would be approximately 4.70 miles. This alignment would require crossing a river and SR-60, as well as substantial coordination with the Los Angeles Department of Water and Power (LADWP), the U.S. Army Corps of Engineers (USACE), and the U.S. Fish and Wildlife Service (USFWS).

**3. Durfee Avenue Alignment** – This pipeline alignment would exit the SJCWRP West and cross the San Gabriel River. The pipeline would run westerly along Thienes Avenue to Durfee Avenue, where the pipeline would turn south. Durfee Avenue turns into Peck Road, where the pipeline would continue southerly underneath the SR-60 overpass. After crossing underneath the freeway, the pipeline would turn west at Durfee Avenue and travel approximately 1.6 miles along Durfee Avenue to Rosemead Boulevard. The pipeline would turn south at Rosemead Boulevard, and continue south to terminate at Whittier Boulevard, where it could serve the injection wells and/or the San Gabriel and Rio Hondo Spreading Grounds. The length of this alignment would be approximately 5.10 miles. This alignment would require a river crossing, but would avoid crossing the freeway. This alignment also would avoid permitting and/or rights-of-way issues with LADWP, USACE, and USFWS.

**4. Workman Mill Road Alignment** – This pipeline alignment would exit the SJCWRP West along the southeast side of the plant, and cross both SR-60 and I-605 to Workman Mill Road. The pipeline would traverse Workman Mill Road to Crossroads Parkway South. The pipeline would turn southwest onto Crossroads Parkway South to Workman Mill Road. The pipeline would continue southwest along Workman Mill Road to Pioneer Boulevard, where it would turn west onto Pioneer Boulevard to Beverly Boulevard. The pipeline would continue northwest along Beverly Boulevard, where it would again cross the I-605 and the San Gabriel River. The pipeline would continue northwest along Beverly Boulevard to Rosemead Boulevard, at which point it would turn south and terminate at Whittier Boulevard, where it could serve the injection wells and/or the San Gabriel and Rio Hondo Spreading Grounds. The length of this alignment would be approximately 5.70 miles. This alignment would require crossing a river and crossing under SR-60, I-605, and railroad tracks. It would also require coordination with LADWP, USACE, and USFWS.

**5. Railroad Alignment** – This pipeline alignment would exit the SJCWRP West along the southeast side of the plant, and cross both SR-60 and I-605 to Workman Mill Road. The pipeline would continue south along Workman Mill Road to the railroad rights-of-way. The pipeline would then travel southerly, parallel to the railroad tracks, crossing I-605 again to Beverly Boulevard. The pipeline would continue northwest along Beverly Boulevard, crossing the San Gabriel River, and would then turn south onto Rosemead Boulevard. The pipeline would continue southerly along Rosemead Boulevard and terminate at Whittier Boulevard, where it could serve the injection wells and/or the San Gabriel and Rio Hondo Spreading Grounds. The length of this alignment would be approximately 4.90 miles. This alignment would require crossing a river and crossing under SR-60 and I-605. It would also require coordination with LADWP, USACE, and USFWS.

**6. City Streets Alignment** – This pipeline alignment would exit SJCWRP West along the south side of the plant and cross SR-60. The pipeline would then use residential city streets to Rooks Road. The pipeline would travel southwesterly along Rooks Road to the east levee of the river. The pipeline would then travel along the east levee to the San Gabriel River Parkway. The pipeline would continue southwest along the San Gabriel River Parkway to Beverly Boulevard. The pipeline then would continue northwest along Beverly Boulevard to Rosemead Boulevard, at which point it would turn south and terminate at Whittier Boulevard, where it could serve the injection wells and/or the San Gabriel and Rio Hondo Spreading Grounds. The length of this alignment would be approximately 4.80 miles. This alignment would require crossing SR-60, and substantial coordination with LADWP, USACE, and USFWS.

**FIGURE 5-9**
**AWT Pipeline Alignment Option No. 1 - Parallel Alignment**

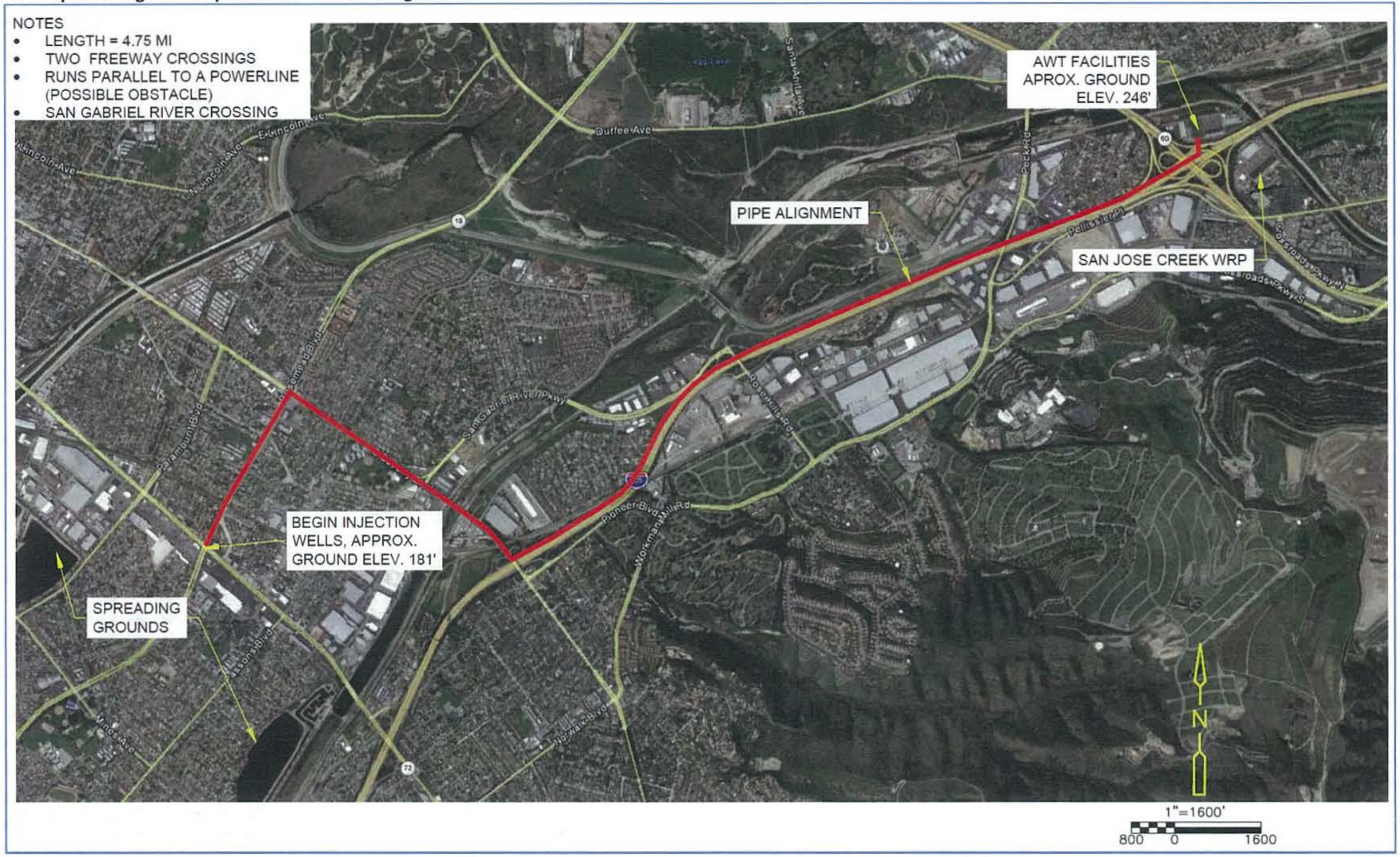
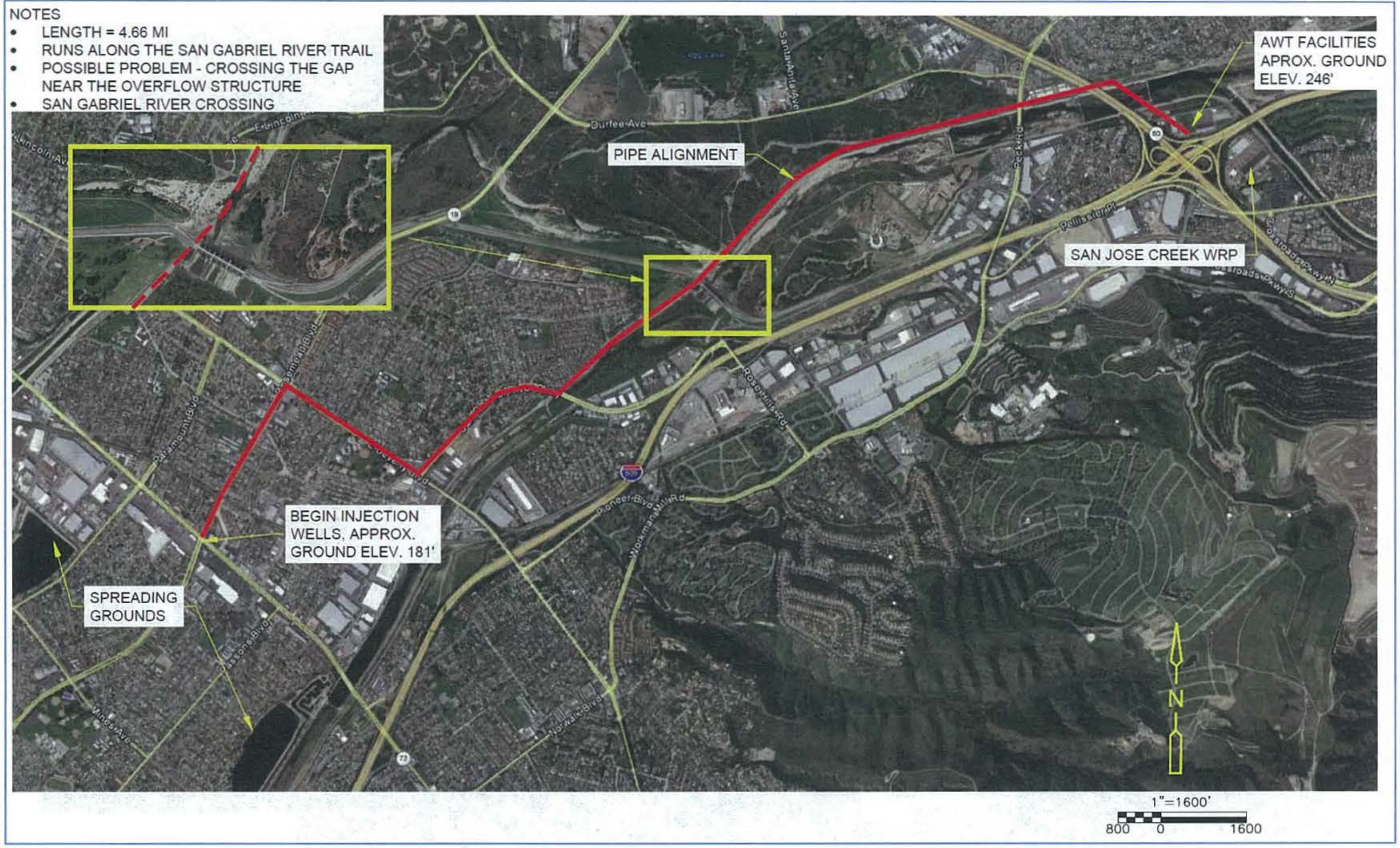


**FIGURE 5-10**
**AWT Pipeline Alignment Option No. 2 - West Levee Alignment**



NOTES
- LENGTH = 4.66 MI
- RUNS ALONG THE SAN GABRIEL RIVER TRAIL
- POSSIBLE PROBLEM - CROSSING THE GAP NEAR THE OVERFLOW STRUCTURE
- SAN GABRIEL RIVER CROSSING

AWT FACILITIES APROX. GROUND ELEV. 246'

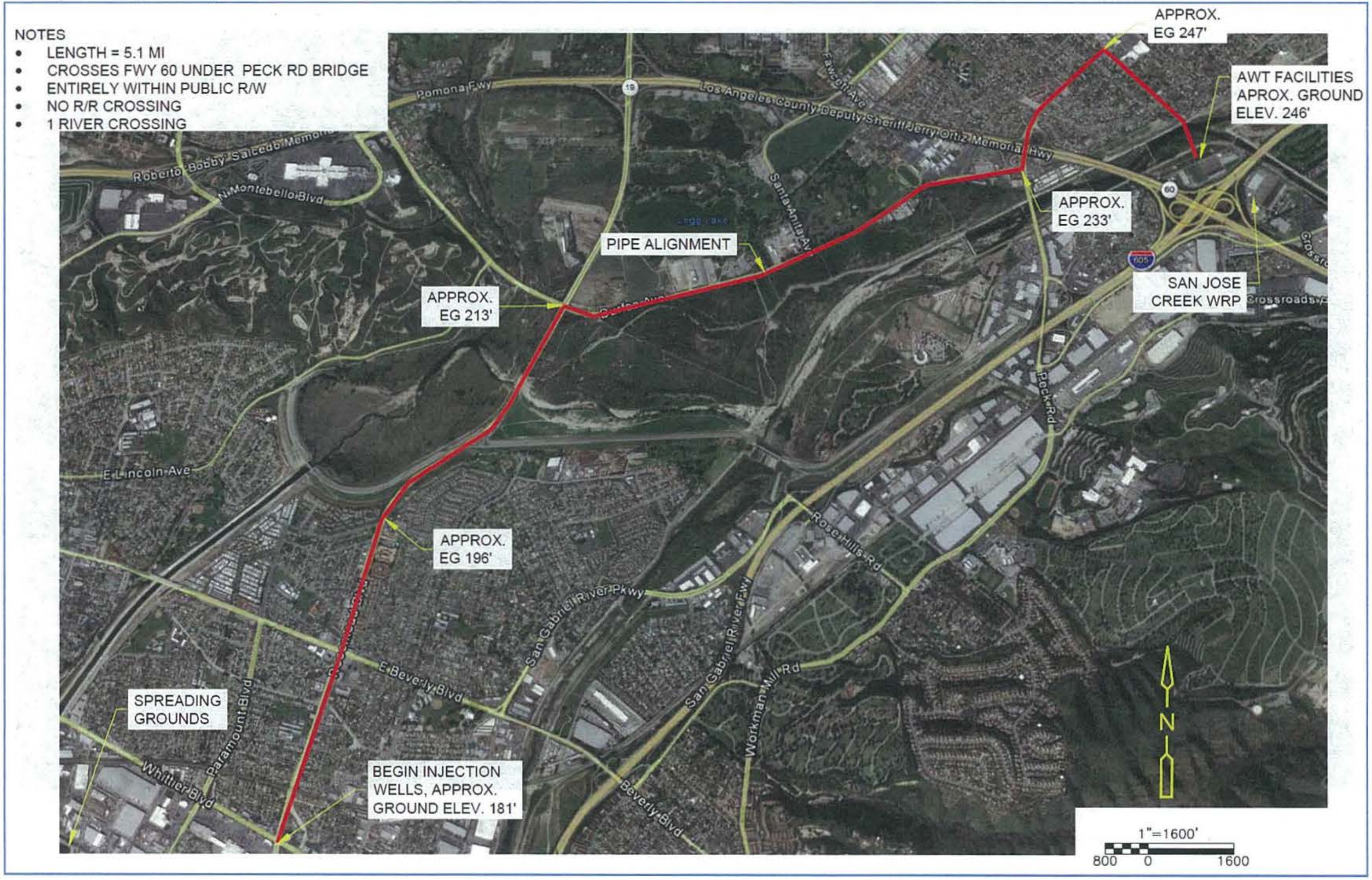
PIPE ALIGNMENT

SAN JOSE CREEK WRP

BEGIN INJECTION WELLS, APPROX. GROUND ELEV. 181'

SPREADING GROUNDS

**FIGURE 5-11**
**AWT Pipeline Alignment Option No. 3 - Durfee Avenue Alignment**



NOTES
- LENGTH = 5.1 MI
- CROSSES FWY 60 UNDER PECK RD BRIDGE
- ENTIRELY WITHIN PUBLIC R/W
- NO R/R CROSSING
- 1 RIVER CROSSING

APPROX. EG 247'

AWT FACILITIES APROX. GROUND ELEV. 246'

APPROX. EG 233'

SAN JOSE CREEK WRP

PIPE ALIGNMENT

APPROX. EG 213'

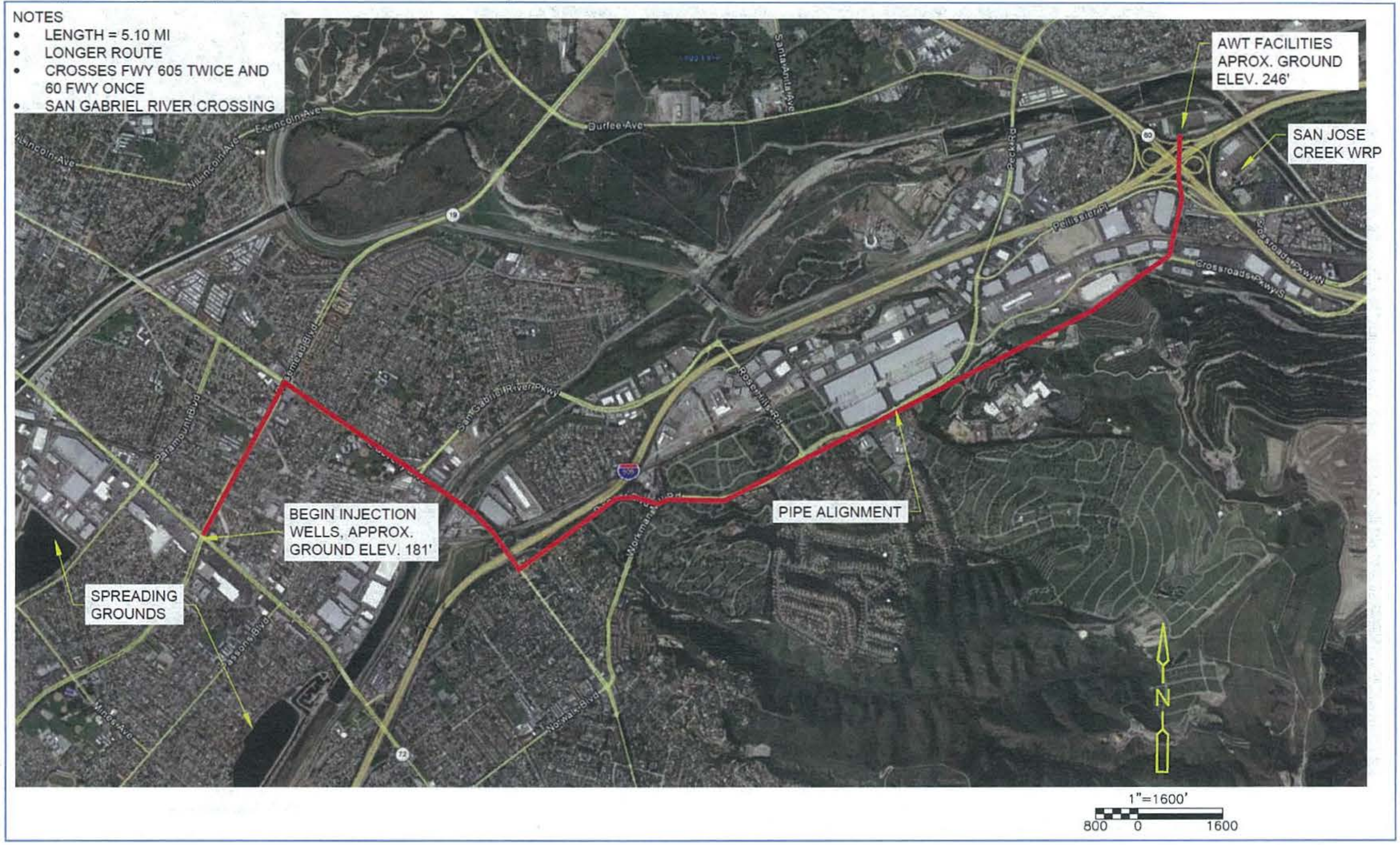
APPROX. EG 196'

SPREADING GROUNDS

BEGIN INJECTION WELLS, APPROX. GROUND ELEV. 181'

1"=1600'

**FIGURE 5-12**
**AWT Pipeline Alignment Option No. 4 - Workman Mill Road Alignment**



NOTES
- LENGTH = 5.10 MI
- LONGER ROUTE
- CROSSES FWY 605 TWICE AND 60 FWY ONCE
- SAN GABRIEL RIVER CROSSING

AWT FACILITIES APROX. GROUND ELEV. 246'

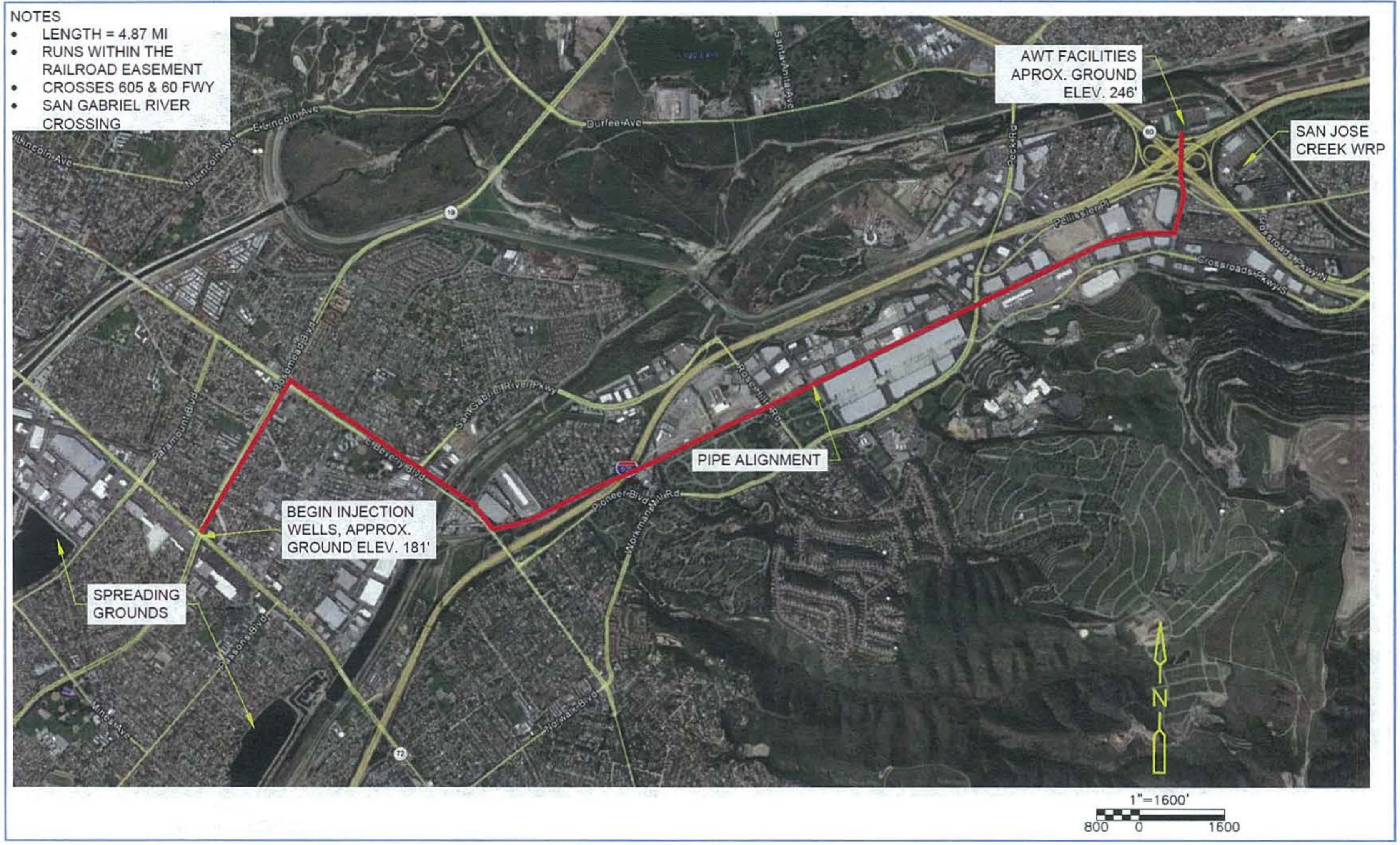
SAN JOSE CREEK WRP

BEGIN INJECTION WELLS, APPROX. GROUND ELEV. 181'

PIPE ALIGNMENT

SPREADING GROUNDS

**FIGURE 5-13**
**AWT Pipeline Alignment Option No. 5 - Railroad Alignment**



NOTES
- LENGTH = 4.87 MI
- RUNS WITHIN THE RAILROAD EASEMENT
- CROSSES 605 & 60 FWY
- SAN GABRIEL RIVER CROSSING

AWT FACILITIES APROX. GROUND ELEV. 246'

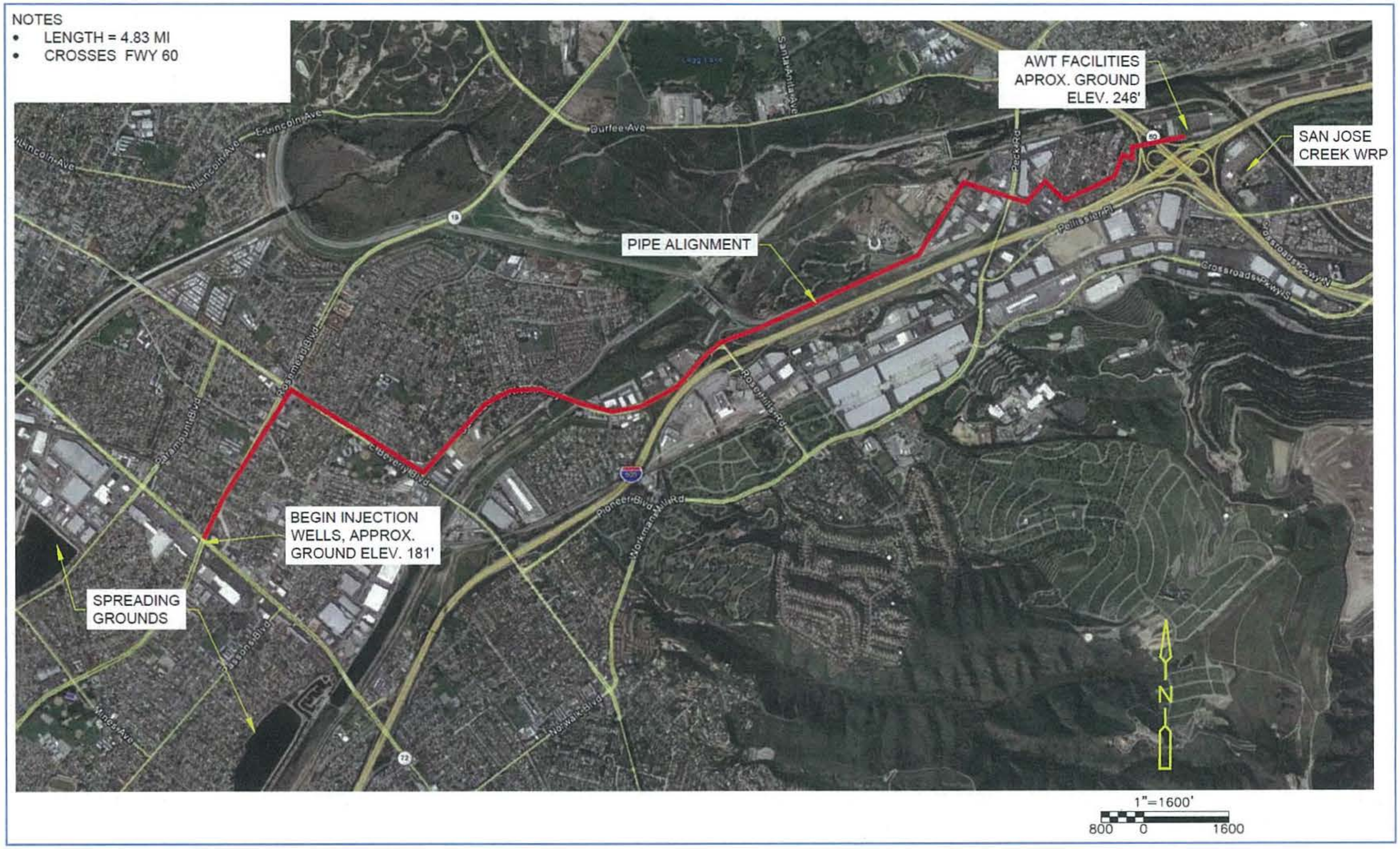
SAN JOSE CREEK WRP

PIPE ALIGNMENT

BEGIN INJECTION WELLS, APPROX. GROUND ELEV. 181'

SPREADING GROUNDS

**FIGURE 5-14**
**AWT Pipeline Alignment Option No. 6 - City Streets Alignment**



NOTES
- LENGTH = 4.83 MI
- CROSSES FWY 60

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The advantages and disadvantages of each potential alignment are presented in Table 5-15.

**TABLE 5-15**
**Advantages and Disadvantages of New Dedicated AWT Pipeline Alignment Options**

| Option | AWT Pipeline Alignment | Advantages | Disadvantages |
|---|---|---|---|
| **1** | Parallel Alignment | • Relatively low cost<br>• Relatively short length<br>• Relatively minor permitting issues<br>• Relatively minor utility interference | • Complicated freeway crossing |
| **2** | West Levee Alignment | • Relatively short length | • Significant rights-of-way and permitting issues<br>• Significant environmental issues<br>• High cost |
| **3** | Durfee Avenue Alignment | • Favorable river/freeway/railroad crossings | • Public disruption due to building in public streets |
| **4** | Workman Mill Road Alignment | • Relatively minor permitting issues | • Public disruption due to building in public streets |
| **5** | Railroad Alignment | • Relatively minor environmental permitting issues | • Significant permitting issues with railroad<br>• Significant rights-of-way issues |
| **6** | City Streets Alignment | • Moderate length | • Public disruption due to building in public streets<br>• Significant rights-of-way and permitting issues<br>• Significant environmental issues<br>• Significant utilities interference<br>• High cost |

Table 5-16 summarizes scoring results for the new pipeline potential alignments.

**TABLE 5-16**
**Summary of Scoring Results for New Dedicated AWT Pipeline Alignment Options**

| Criteria | Options | | | | | |
|---|---|---|---|---|---|---|
| | 1 (Parallel) | 2 (W. Levee) | 3 (Durfee) | 4 (Workman) | 5 (Railroad) | 6 (City Streets) |
| Cost | + | - | 0 | 0 | 0 | - |
| Route Length | + | + | 0 | - | 0 | 0 |
| Freeway/Channel/Railroad Crossings | 0 | 0 | + | 0 | - | 0 |
| Rights-of-Way/Easements/Approvals | 0 | - | 0 | 0 | - | - |
| Environmental Permit Issues | + | - | 0 | + | + | - |
| Existing Utilities Interference | + | 0 | 0 | 0 | 0 | - |
| Score | **4** | **-2** | **1** | **0** | **-1** | **-4** |
| **Rank** | **1** | **5** | **2** | **3** | **4** | **6** |

Based on the information currently available on all the potential alignments for a new pipeline between the SJCWRP and the Montebello Forebay, the best approach is to use an alignment parallel to the existing LACSD outfall pipeline. Therefore, the Parallel Alignment will be carried forward as the primary approach. Prior to a final determination, however, additional detailed investigation is warranted to ensure construction of this alignment is practical.

The second and third highest ranking alignments are the Durfee Avenue and Workman Mill Road Alignments, respectively. These alignments are considered as back-up approaches should the detailed examination of easements and rights-of-way, along with assessment of potential interferences and crossings, result in the determination of severe limitations associated with the Parallel Alignment.

## 3.4 Recharge Options Assessment

### 3.4.1 Recharge - Preliminary Options

Two means of recharging recycled water via the Montebello Forebay were identified:

- Surface spreading
- Direct injection

#### Spreading

Groundwater is currently artificially recharged at the Montebello Forebay via surface spreading. There are two off-stream spreading facilities adjacent to the river operated by the Los Angeles County Department of Public Works (LADPW). These are the Rio Hondo Spreading Grounds and the San Gabriel Spreading Grounds, as shown on Figure 5-15, collectively referred to as the Montebello Forebay Spreading Grounds. There also are in-stream facilities used for recharge by spreading. The volume of annual recharge (recycled water and stormwater) varies depending upon precipitation, local runoff, and imported supplies availability.

The capacities of the spreading basins to physically accept additional tertiary water for recharge requires additional analysis, and third party operation of the spreading basins poses a potential challenge in guaranteeing a "firm" spreading capacity. As demonstrated in the 2011 GRIP Alternatives Analysis Report, the short-term recharge capacity of the spreading grounds has been exceeded in five months over the last 22 years, or 2 percent of the time. This, however, reflects large scale deliveries of imported supplies over short duration periods when the basins are close to 100 percent available for spreading operations and as such differs from the relatively constant supply of recycled water. Furthermore, following storm events, the basins fill with local runoff, and there is typically no recharge capacity for recycled water for a week following each storm event. In a normal rainfall year, the basins could be unavailable for GRIP water recharge 15 to 19 percent of the time; therefore, year-round, continuous recharge of water at the MFSG via surface spreading is not feasible (RMC 2011).

The option to spread recycled water for groundwater recharge is an option for both tertiary treated and AWT water. However, it should be noted that long-term spreading of AWT water may lead to detrimental impacts on the biological treatment capabilities of soil columns in spreading basins.

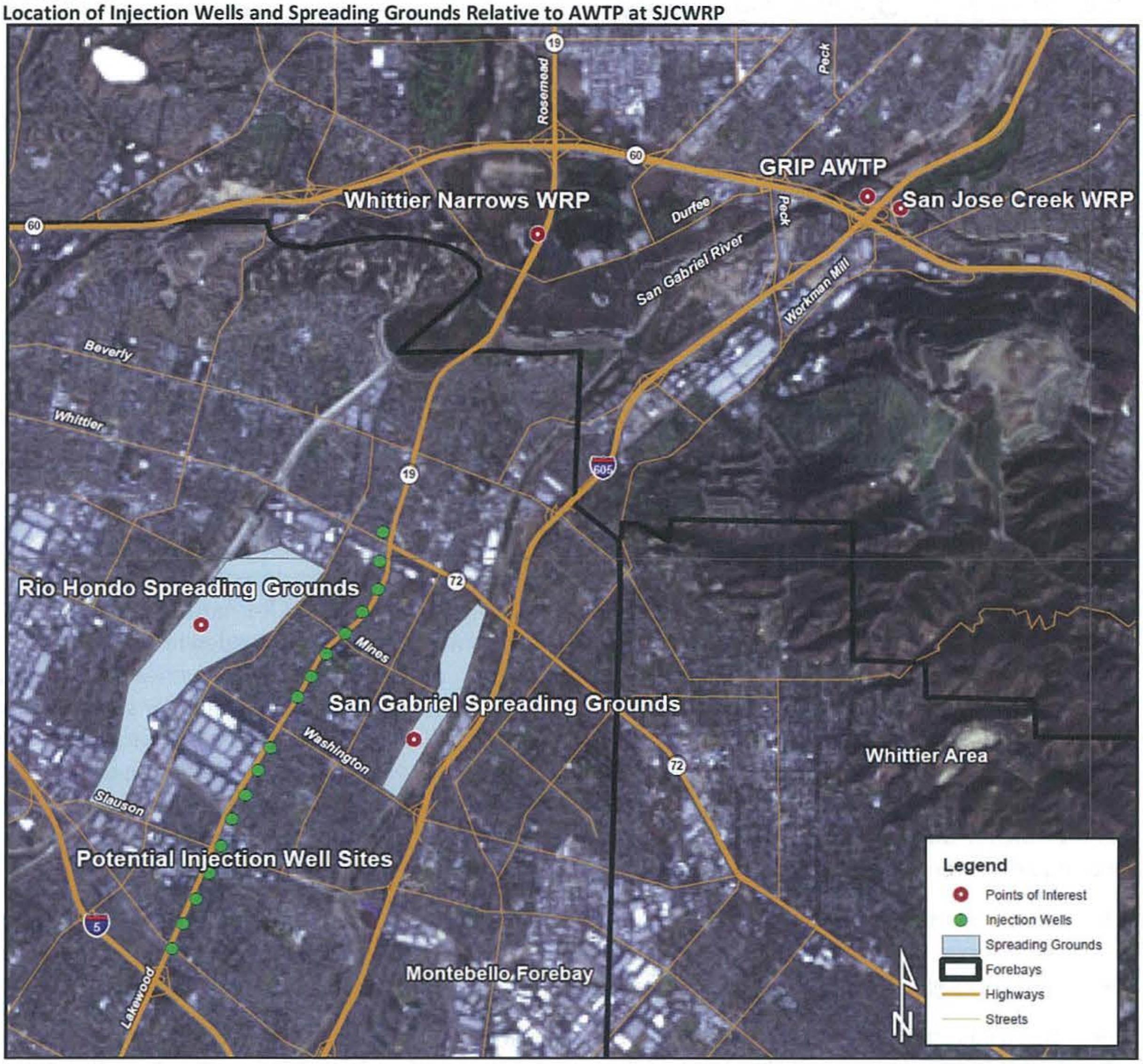
Further evaluation of the available supply, potential constraints, and recharge capabilities of the spreading basins will be necessary during preliminary engineering.

#### Injection

No direct injection currently takes place at the Montebello Forebay. The ability to inject and the appropriate location of injection facilities were investigated in connection with the Groundwater Basins Master Plan (GBMP) undertaken for WRD. The GBMP identified over a dozen potential injection sites along Rosemead Boulevard at Whittier Boulevard, as shown on Figure 5-15. The capacity of the injection wells was assumed to be approximately 2 to 2.5 MGD per well. One of the major advantages of direct injection is that injection wells can be used to allow continuous operations in areas where confined conditions limit or prohibit surface spreading. This, in turn, would increase recharge capacity in unconfined areas and increase operating flexibility in the basin.

The option to inject recycled water for groundwater recharge is only an option for AWT water, not for tertiary treated water. The reason for this is because injection requires a high level of treatment prior to recharge.

**FIGURE 5-15**
**Location of Injection Wells and Spreading Grounds Relative to AWTP at SJCWRP**



## 3.4.2 Recharge – Preliminary Options Assessment

The advantages and disadvantages for both preliminary options for recharge are presented in Table 5-17.

**TABLE 5-17**
**Advantages and Disadvantages of Recharge Options**

| Recharge Option | Advantages | Disadvantages |
|---|---|---|
| Spreading | • Existing facilities in-place<br>• Low impact/energy<br>• Additional SAT provided | • Seasonal limitations<br>• Dependent on third party for operations<br>• Requires more land/improvements to accommodate added capacity |

**TABLE 5-17**
**Advantages and Disadvantages of Recharge Options**

| Recharge Option | Advantages | Disadvantages |
|---|---|---|
| Injection | • Can be operated continuously; no seasonality<br>• Can be used in aquifer water level depressions caused by pumping drawdown<br>• Easy to increase capacity because no additional land is required | • High capital for construction<br>• Increased energy consumption for operations<br>• Requires higher level of treatment |

Table 5-18 summarizes scoring results for recharge options based upon established evaluation criteria defined in TM 1-4.

**TABLE 5-18**
**Summary of Scoring Results for Recharge Options**

| Criteria | Spreading | Injection |
|---|---|---|
| Cost for New Facilities | + | - |
| Availability/Seasonality | - | + |
| Ability to Permit | 0 | 0 |
| Institutional Feasibility | 0 | + |
| Water Quality Requirements | + | - |
| Operational Flexibility | - | + |
| **Score** | **0** | **1** |
| **Rank** | **2** | **1** |

### 3.4.3 Recharge – Viable Options

Both options were carried forward for further consideration. In the case of surface spreading, either tertiary treated or AWT treated water can be applied. In the case of direct injection, only AWT water can be used. These approaches are now termed viable options.

# 4.0 Viable Alternatives Assessment

## 4.1 Viable Alternatives

Component area options are the building blocks for comprehensive, system-wide alternatives. Individual viable options from each of the component areas are combined into viable alternatives. While there are various permutations, the viable alternatives created are logical in terms of functionality, reasonable with respect to achieving goals, and practical as they apply to compatibility. Each of these viable alternatives is listed in Table 5-19 and illustrated graphically on Figure 5-16.

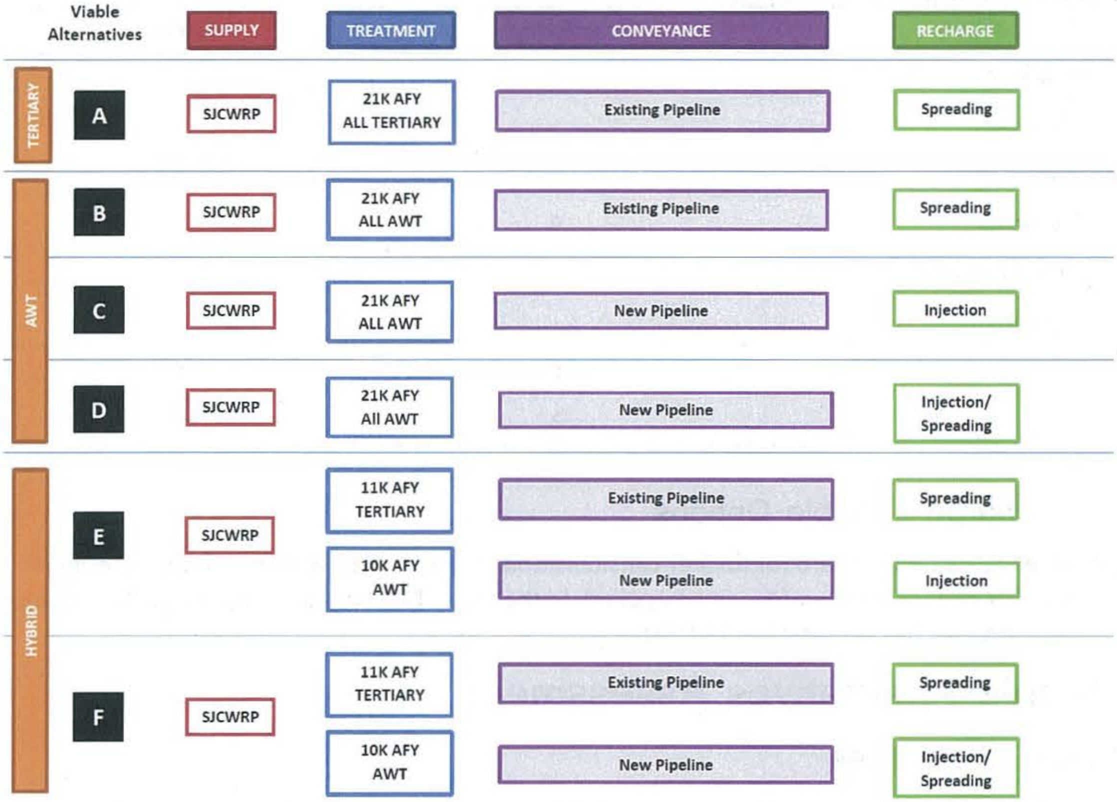
**TABLE 5-19**
**Summary of Viable (Preliminary) Alternatives**

| Alternative | Supply | Treatment | Conveyance | Recharge |
|---|---|---|---|---|
| A | San Jose Creek WRP | Tertiary | Existing pipeline: Combined Conveyance | Spreading |
| B | San Jose Creek WRP | AWT Conventional | Existing pipeline: Combined Conveyance | Spreading |
| C | San Jose Creek WRP | AWT Conventional | New Pipeline: Separate Conveyance | Injection |

**TABLE 5-19**
**Summary of Viable (Preliminary) Alternatives**

| Alternative | Supply | Treatment | Conveyance | Recharge |
|---|---|---|---|---|
| D | San Jose Creek WRP | AWT Conventional | New Pipeline: Separate Conveyance | Injection/ Spreading |
| E | San Jose Creek WRP | Hybrid (Tertiary + AWT Conventional) | New Pipeline: Separate Conveyance | Injection |
| F | San Jose Creek WRP | Hybrid (Tertiary + AWT Conventional) | New Pipeline: Separate Conveyance | Injection/ Spreading |

**FIGURE 5-16**
**Summary of Viable Alternatives for Further Evaluation Using TBL Criteria and SMART Model**



|  | Viable Alternatives | SUPPLY | TREATMENT | CONVEYANCE | RECHARGE |
|---|---|---|---|---|---|
| TERTIARY | A | SJCWRP | 21K AFY ALL TERTIARY | Existing Pipeline | Spreading |
| AWT | B | SJCWRP | 21K AFY ALL AWT | Existing Pipeline | Spreading |
|  | C | SJCWRP | 21K AFY ALL AWT | New Pipeline | Injection |
|  | D | SJCWRP | 21K AFY All AWT | New Pipeline | Injection/ Spreading |
| HYBRID | E | SJCWRP | 11K AFY TERTIARY | Existing Pipeline | Spreading |
|  |  |  | 10K AFY AWT | New Pipeline | Injection |
|  | F | SJCWRP | 11K AFY TERTIARY | Existing Pipeline | Spreading |
|  |  |  | 10K AFY AWT | New Pipeline | Injection/ Spreading |

## 4.2 Viable Alternatives Assessment

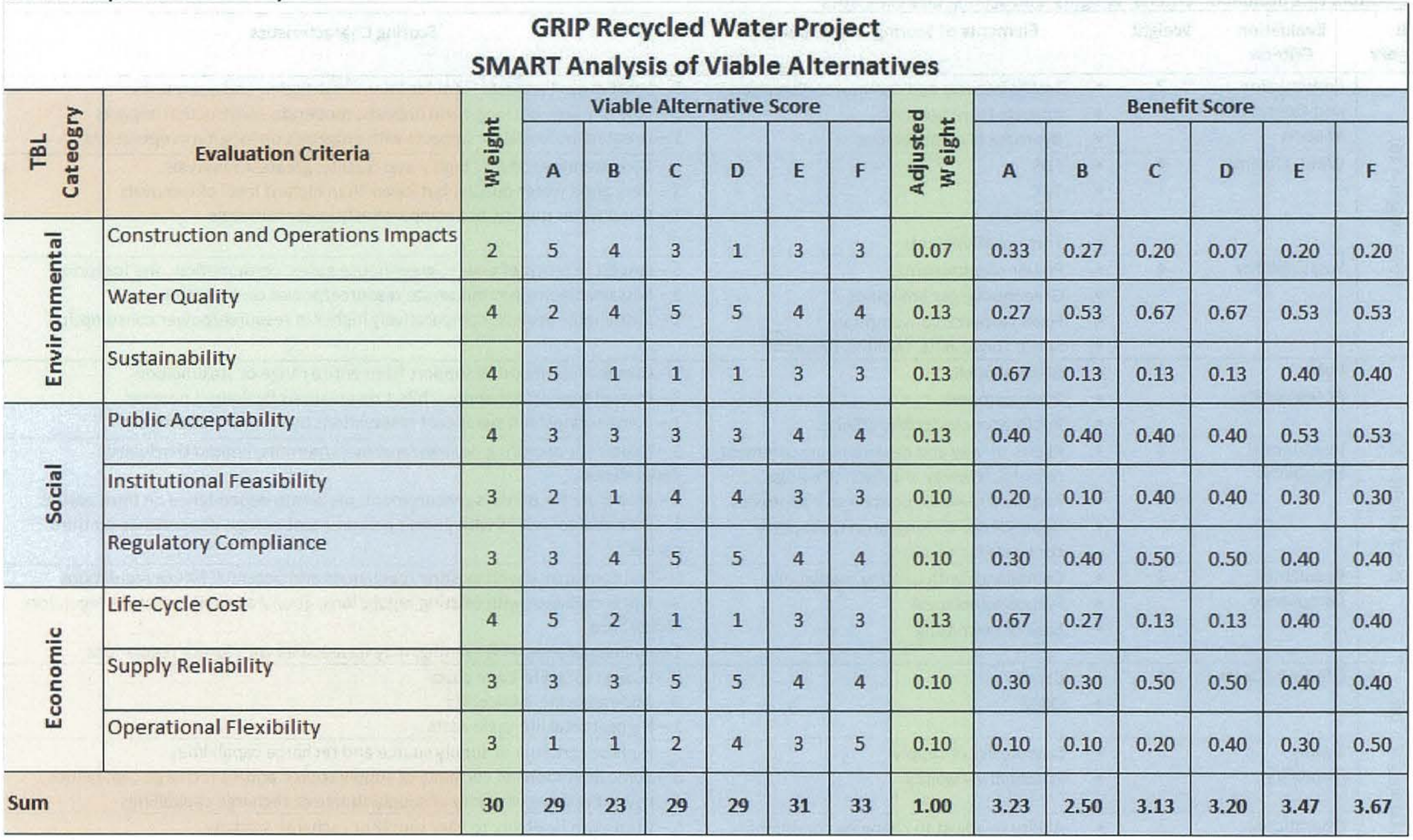
Each of the viable alternatives was comparatively evaluated based on the TBL evaluation criteria developed in collaboration with WRD and the Sanitation Districts for consideration of environmental, social, and economic impacts. Each alternative was assigned a score from 1 to 5, with 5 being the most favorable approach. The TBL evaluation criteria, weighting factors, and scoring characteristics are summarized in Table 5-20.

Once the criteria and weighting factors were determined, the scores for all the viable alternatives were entered into the SMART model, along with all criteria weights, to generate a total benefit score for each alternative. The results of the SMART analysis are presented on Figure 5-17 and illustrated graphically on Figure 5-18.

**TABLE 5-20**
**Triple Bottom Line Evaluation Criteria, Weights, and Scoring Characteristics**

| TBL Category | Evaluation Criteria | Weight | Elements of Scoring Assessment | Scoring Characteristics |
|---|---|---|---|---|
| **Environmental** (total weight = 10) | Construction and Operations Impacts | 2 | • Traffic impacts and commuter disruption<br>• Impacts to ecosystems<br>• Byproducts management | 5 – Least overall impacts from facilities construction and operations<br>3 – Low to minimum long-term impacts; moderate construction impacts<br>1 – Greatest potential for impacts with emphasis on long-term operations |
| | Water Quality | 4 | • TDS<br>• TOC<br>• Nutrients<br>• Trace contaminants | 5 – Consistently produces high water quality; greatest removals<br>3 – Very good water quality, but lower than highest level of removals<br>1 – Good water quality, but comparatively lower removals |
| | Sustainability | 4 | • Power requirements<br>• Greenhouse gas emissions<br>• Fixed resource consumption<br>• Space constraints, facilities footprint | 5 – Lowest in terms of power, greenhouse gases, consumption, and footprint<br>3 – Sustainable project; moderate resource/power consumption<br>1 – Sustainable project; comparatively higher in resource/power consumption |
| **Social** (total weight = 10) | Public Acceptability | 4 | • General public<br>• Basin pumpers<br>• Public agencies/public officials | 5 – Greatest likelihood of support from entire range of stakeholders<br>3 – Overall support for approach but reservations by limited number<br>1 – Some support but significant reservations by several stakeholders |
| | Institutional Feasibility | 3 | • Rights-of-way and easement procurement, railroad, freeway and river crossings<br>• Required reviews, permits and approvals<br>• Dependence on long-term third-party contracts for services | 5 – Easiest for procuring reviews/approvals/permits; limited third-party dependence<br>3 – Moderate for permits procurement; moderate dependence on third parties<br>1 – Potential for issues with permit procurement or high dependence on third parties |
| | Regulatory Compliance | 3 | • Compliance with existing regulations<br>• Future compliance<br>• Ease of permitting | 5 – Full compliance with existing regulations and potential future regulations<br>3 – Full compliance with existing regulations; good potential for future regulatory compliance<br>1 – Full compliance with existing; may have issues with future regulations |
| **Economic** (total weight = 10) | Life-Cycle Costs | 4 | • Capital<br>• O&M | 5 – Lowest total life-cycle costs<br>3 – Mid-range life-cycle costs<br>1 – Highest total life-cycle costs |
| | Supply Reliability | 3 | • Seasonality of supply<br>• Potential variability | 5 – Highest certainty of supply source and recharge capabilities<br>3 – Some limitations of certainty of supply source and/or recharge capabilities<br>1 – Lowest relative certainty of supply source or recharge capabilities |
| | Operational Flexibility | 3 | • Ability to adjust to changing conditions including supply and recharge | 5 – Maximum flexibility to vary supply or recharge strategy<br>3 – Some ability to vary supply and/or recharge strategy<br>1 – Least flexibility to vary supply or recharge strategy |

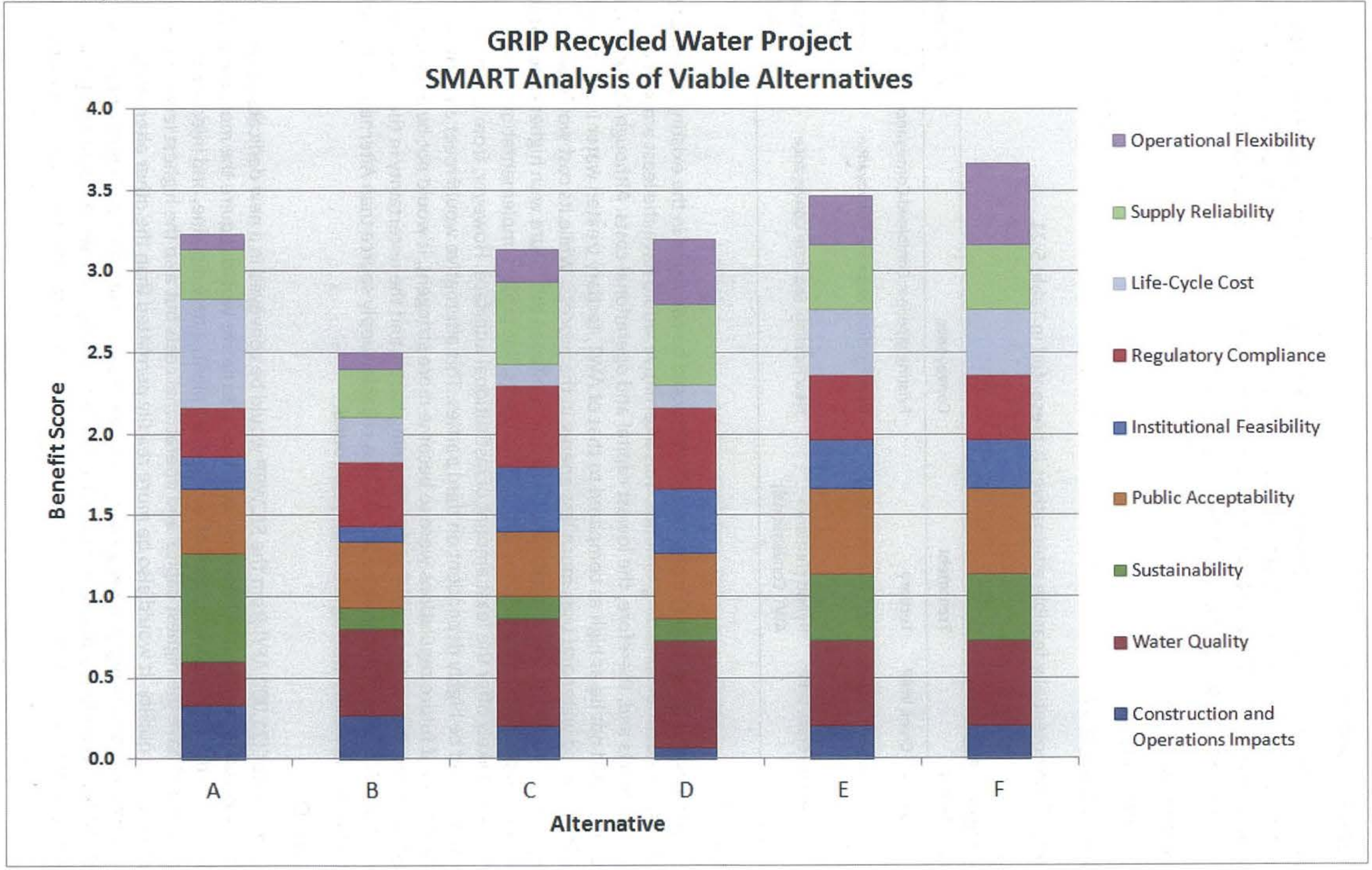
**FIGURE 5-17**
**SMART Analysis Results Summary**



**GRIP Recycled Water Project**
**SMART Analysis of Viable Alternatives**

| TBL Category | Evaluation Criteria | Weight | Viable Alternative Score | | | | | | Adjusted Weight | Benefit Score | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | | A | B | C | D | E | F |
| Environmental | Construction and Operations Impacts | 2 | 5 | 4 | 3 | 1 | 3 | 3 | 0.07 | 0.33 | 0.27 | 0.20 | 0.07 | 0.20 | 0.20 |
| | Water Quality | 4 | 2 | 4 | 5 | 5 | 4 | 4 | 0.13 | 0.27 | 0.53 | 0.67 | 0.67 | 0.53 | 0.53 |
| | Sustainability | 4 | 5 | 1 | 1 | 1 | 3 | 3 | 0.13 | 0.67 | 0.13 | 0.13 | 0.13 | 0.40 | 0.40 |
| Social | Public Acceptability | 4 | 3 | 3 | 3 | 3 | 4 | 4 | 0.13 | 0.40 | 0.40 | 0.40 | 0.40 | 0.53 | 0.53 |
| | Institutional Feasibility | 3 | 2 | 1 | 4 | 4 | 3 | 3 | 0.10 | 0.20 | 0.10 | 0.40 | 0.40 | 0.30 | 0.30 |
| | Regulatory Compliance | 3 | 3 | 4 | 5 | 5 | 4 | 4 | 0.10 | 0.30 | 0.40 | 0.50 | 0.50 | 0.40 | 0.40 |
| Economic | Life-Cycle Cost | 4 | 5 | 2 | 1 | 1 | 3 | 3 | 0.13 | 0.67 | 0.27 | 0.13 | 0.13 | 0.40 | 0.40 |
| | Supply Reliability | 3 | 3 | 3 | 5 | 5 | 4 | 4 | 0.10 | 0.30 | 0.30 | 0.50 | 0.50 | 0.40 | 0.40 |
| | Operational Flexibility | 3 | 1 | 1 | 2 | 4 | 3 | 5 | 0.10 | 0.10 | 0.10 | 0.20 | 0.40 | 0.30 | 0.50 |
| **Sum** | | **30** | **29** | **23** | **29** | **29** | **31** | **33** | **1.00** | **3.23** | **2.50** | **3.13** | **3.20** | **3.47** | **3.67** |

**FIGURE 5-18**
**SMART Analysis Results Illustration**



## 4.3 Feasible Alternatives

The analysis resulted in three potentially feasible alternatives, representing those viable alternatives with the highest benefit score in each of the three treatment level categories: all tertiary, all AWT, and a hybrid of tertiary and AWT. The following three viable alternatives will be carried forward into the feasible alternatives analysis during preliminary engineering:

- Tertiary – Alternative A
- AWT – Alternative D
- Hybrid – Alternative F

A summary of the potentially feasible alternatives is presented in Table 5-21.

**TABLE 5-21**
**Summary of Feasible Alternatives**

| Alternative | Supply | Treatment | Conveyance | Recharge |
|---|---|---|---|---|
| A | San Jose Creek WRP | Tertiary | Existing pipeline: Combined Conveyance | Spreading |
| D | San Jose Creek WRP | AWT (Conventional) | New Pipeline: Separate Conveyance | Injection/ Spreading |
| F | San Jose Creek WRP | Hybrid (Tertiary + AWT Conventional) | New Pipeline: Separate Conveyance | Injection/ Spreading |

### Alternative A

Tertiary recycled water (21,000 AFY) from the SJCWRP would be conveyed in the existing pipeline to the Rio Hondo and San Gabriel Spreading Grounds. This alternative would have the least amount of construction impacts and, therefore, the lowest capital and operational costs. Although the product water quality would not be as high as compared to that of AWT, tertiary treated water is still considered good quality recycled water and uses much less energy in the process. While its cost would be very attractive to basin pumpers, public acceptance could be limited in the future with higher expectations to see advanced treatment in comparison to other IPR projects. For project implementation, this alternative would likely offer the least amount of institutional interface. However, from an operational standpoint, it would be highly dependent on third parties. This alternative would meet all current requirements, but, if future regulations were to become more stringent, it would not be as easily permitted as others. Due to the nature of the spreading basins and the uncertainty in the available capacity of the basins, this alternative could be a less reliable supply source than Alternatives D and F, which would offer flexibility with injection all year round.

### Alternative D

AWT recycled water (21,000 AFY) from the SJCWRP would be conveyed in a new dedicated pipeline to the spreading grounds or potential injection sites. This alternative would require the most construction of any alternative due to the construction of a new AWT plant, a new pipeline, and injection wells; therefore, it would have the highest capital and operational costs but also the highest level of treatment and resultant water quality. It would also be more readily permitted than the other alternatives. However, it would have the highest energy usage and chemical consumption and could encounter greater challenges in achieving public acceptability due to the high costs, which could also be of concern to pumpers and rate payers. This alternative would also require construction permitting but would be independent of third-party operations. It would also offer supply reliability and operational flexibility with the ability to inject all AWT recycled water year round.

### Alternative F

This alternative is a combination of Alternatives A and D and assumes that both tertiary (11,000 AFY) and AWT (10,000 AFY) recycled water from the SJCWRP would be conveyed to the spreading grounds or potential injection sites. This hybrid approach would offer greater flexibility and a cost that would fall between that of the other two feasible alternatives. Tertiary water would be conveyed in the existing pipeline to the spreading grounds. AWT water would be conveyed in a new dedicated pipeline to the spreading grounds and/or potential injection sites. This alternative would require construction of a new AWT plant, a new pipeline, and injection wells. It is a hybrid of treatment and resultant water quality; therefore, it would require approximately half the energy usage and chemical consumption compared to Alternative D. This alternative would straddle quality and cost when it comes to public acceptability. It would require construction permitting but would be less dependent than Alternative A on third-party operations. For future permitting, regulatory compliance for Alternative F would be more feasible than Alternative A, but less than Alternative D. Alternative F would require smaller-scale AWT facilities and injection wells (the pipeline would be the same size for full AWT or the hybrid option). The mix of treatment levels and recharge options would allow for improved operational flexibility.

## 5.0 Cost Summary

The cost estimates developed for this analysis provide a relative comparison of the alternatives and are considered order-of-magnitude estimates. An order-of-magnitude cost estimate is an approximate estimate made without detailed engineering data. The Association for the Advancement of Cost Engineering (AACE) International defines order-of-magnitude costs as *Class 5* cost estimates without detailed engineering data. Examples of order-of-magnitude costs include an estimate from cost capacity curves, an estimate using scale-up or scale-down factors, and an approximate ratio estimate. The estimates shown, and any resulting conclusions on project financial or economic feasibility or funding requirements, have been prepared to guide project evaluation and implementation from the information available at the time of cost estimation. The expected accuracy ranges for a Class 5 cost estimate are -15 to -30 percent on the low side and +20 to +50 percent on the high side. The final costs of the project and resulting feasibility will depend on actual labor and material costs, competitive market conditions, actual site conditions, final project scope, implementation schedule, continuity of personnel and engineering, and other variables.

Table 5-22 presents the cost summary for viable alternatives based on the cost development methodology described in TM 1-4.

**TABLE 5-22**
**Preliminary Cost Opinion for Viable Alternatives**

| | A<br>Tertiary, Spreading | B<br>AWT, Spreading | C<br>AWT, Injection | D<br>AWT, Spreading/ Injection | E<br>Hybrid, Injection | F<br>Hybrid, Spreading/ Injection |
|---|---|---|---|---|---|---|
| **Capital Cost ($)** | | | | | | |
| AWT Product Capacity (AFY) | 0 | 21,000 | 21,000 | 21,000 | 10,000 | 10,000 |
| AWT Product Capacity (MGD) | 0 | 18.8 | 18.8 | 18.8 | 8.9 | 8.9 |
| Pretreatment[1] | 0 | 1,250,000 | 1,250,000 | 1,250,000 | 1,030,000 | 1,030,000 |

**TABLE 5-22**
**Preliminary Cost Opinion for Viable Alternatives**

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| | **Tertiary, Spreading** | **AWT, Spreading** | **AWT, Injection** | **AWT, Spreading/ Injection** | **Hybrid, Injection** | **Hybrid, Spreading/ Injection** |
| MF[2] | 0 | 37,820,000 | 37,820,000 | 37,820,000 | 19,170,000 | 19,170,000 |
| RO | 0 | 40,663,000 | 40,663,000 | 40,663,000 | 21,770,000 | 21,770,000 |
| UV-AOP | 0 | 15,090,000 | 15,090,000 | 15,090,000 | 8,800,000 | 8,800,000 |
| Post Treatment[3] | 0 | 1,150,000 | 1,150,000 | 1,150,000 | 990,000 | 990,000 |
| Flow Equalization[5] | 0 | 9,000,000 | 9,000,000 | 9,000,000 | 4,520,000 | 4,520,000 |
| **Total Treatment Cost[4] ($)** | 0 | 104,973,000 | 104,973,000 | 104,973,000 | 56,280,000 | 56,280,000 |
| Engineering, Legal and Administrative Fees (20%) | 0 | 20,995,000 | 20,995,000 | 20,995,000 | 11,256,000 | 11,256,000 |
| Contingency (20%) | 0 | 20,995,000 | 20,995,000 | 20,995,000 | 11,256,000 | 11,256,000 |
| **Total Treatment Cost with Engineering Fees and Project Contingency ($)** | 0 | 146,963,000 | 146,963,000 | 146,963,000 | 78,792,000 | 78,792,000 |
| Sewer Connection Fee[9] | 0 | 20,422,000 | 20,422,000 | 20,422,000 | 9,695,000 | 9,695,000 |
| Flow Diversion | 1,600,000 | 1,600,000 | 1,600,000 | 1,600,000 | 1,600,000 | 1,600,000 |
| **Total Capital Cost ($)** | 1,600,000 | 168,985,000 | 168,985,000 | 168,985,000 | 90,087,000 | 90,087,000 |
| Other (Optional) Project Cost Items[6] | | | | | | |
| Conveyance[7] | 0 | 0 | 16,533,000 | 16,533,000 | 16,533,000 | 16,533,000 |
| Injection[8] | 0 | 0 | 24,000,000 | 24,000,000 | 12,000,000 | 12,000,000 |
| **Subtotal for Optional Project Cost Items ($)** | 0 | 0 | 40,533,000 | 40,533,000 | 28,533,000 | 28,533,000 |
| Engineering, Legal and Administrative Fees (20%) | 0 | 0 | 8,107,000 | 8,107,000 | 5,707,000 | 5,707,000 |
| Contingency (20%) | 0 | 0 | 8,107,000 | 8,107,000 | 5,707,000 | 5,707,000 |
| **Total Optional Project Cost with Engineering Fees and Project Contingency ($)** | 0 | 0 | 56,747,000 | 56,747,000 | 39,947,000 | 39,947,000 |
| **Total Capital Cost ($)** | 1,600,000 | 168,985,000 | 225,732,000 | 225,732,000 | 130,034,000 | 130,034,000 |
| **Total Capital Cost with Escalation to Midpoint of Construction (Year 2015) ($)** | 1,749,000 | 184,655,000 | 246,664,000 | 246,664,000 | 142,092,000 | 142,092,000 |
| **Present Value of Capital Cost[11] ($)** | 1,749,000 | 184,655,000 | 246,664,000 | 246,664,000 | 142,092,000 | 142,092,000 |
| **O&M Costs** | | | | | | |
| Annual O&M Cost for Facilities[12] ($/yr) | 0 | 16,695,000 | 16,695,000 | 16,695,000 | 7,950,000 | 7,950,000 |
| **Total Annual O&M Cost for AWT Facility ($/yr)** | 0 | 16,695,000 | 16,695,000 | 16,695,000 | 7,950,000 | 7,950,000 |

**TABLE 5-22**
**Preliminary Cost Opinion for Viable Alternatives**

| | A Tertiary, Spreading | B AWT, Spreading | C AWT, Injection | D AWT, Spreading/ Injection | E Hybrid, Injection | F Hybrid, Spreading/ Injection |
|---|---|---|---|---|---|---|
| **Present Value of O&M Cost for AWT Facility[11] ($)** | 0 | 445,440,000 | 445,440,000 | 445,440,000 | 212,115,000 | 212,115,000 |
| Present Value of Recycled Water Purchase[10,11] ($) | 180,759,000 | 86,618,000 | 86,618,000 | 86,618,000 | 135,930,000 | 135,930,000 |
| **Present Value of O&M Cost[11] ($)** | 180,759,000 | 532,058,000 | 532,058,000 | 532,058,000 | 348,045,000 | 348,045,000 |
| **Total Present Value[11] ($)** | 182,508,000 | 716,713,000 | 778,722,000 | 778,722,000 | 490,137,000 | 490,137,000 |

Notes:

[1] Pretreatment includes feed water monochloramination to protect MF and RO membranes against biological fouling.
[2] Includes costs of strainers and break tank.
[3] Post treatment is achieved via liquid calcium chloride and caustic addition.
[4] AWT treatment capacity was estimated based on a 0.8 on-line factor.
[5] Reflects approximately 2.1-MG and 4.4-MG covered concrete tanks for 10,000 and 21,000 AFY cases, respectively. The flow equalization tank is sized to store 20 percent of the AWT influent flow per the *GRIP Conceptual Level Study* (MWH, 2009). The construction cost is for a concrete tank with a concrete cover.
[6] The cost for improvements to the MFSG is not included in this cost estimate.
[7] Conveyance cost for the 42" RCP represents the higher estimate between the Parallel Alignment and Durfee Avenue Alignment options.
[8] Cost of each injection well with a 2.0 MGD capacity is $2.0 million. The total number of wells for 21,000-AFY and 10,000-AFY cases are 12 and 6, respectively.
[9] Calculated using formulas provided by the Sanitation Districts. The cost does not account for brine volume reduction.
[10] As of October 2012, the recycled water purchase ceiling rate and floor rate is $270/AF and $81/AF, respectively. The present value for recycled water purchase cost is based on an annual Sanitation Districts recycled water escalation rate of 4 percent.
[11] Bond (interest) rate of 5 percent over a period of 30 years and a general inflation rate of 3 percent was used to calculate present value. Present value calculated assuming midpoint of construction in 2015, with facility operations beginning in 2017.
[12] Includes calcium chloride and hydrogen peroxide costs of approximately $70/AF in addition to $725/AF for the treatment facilities. Costs associated with the sewer surcharge fee are included in the O&M costs for the treatment facilities.

# 6.0 Conclusion

The analysis presented herein assessed the viability of options in each of the four component areas: supply, treatment, conveyance, and recharge. The following is a summary of the viable options for each of the component areas, and the resulting viable and feasible alternatives.

## Viable Supply Option – SJCWRP

The SJCWRP was determined to be the most viable source of supply for recycled water because of its proximity to the recharge locations, ability to flow by gravity to the basin, superior product water quality, and availability of supply.

## Viable Treatment Options – Tertiary, AWT (Conventional), and Hybrid

All three treatment levels (tertiary, AWT, and a hybrid using both tertiary and AWT) were determined to be viable treatment options for full-scale implementation. In addition, several different AWT unit processes were considered in the development of a viable AWT treatment train. The following conventional and alternative AWT treatment trains were considered:

- AWT – Conventional:

  - MF/UF, RO, UV-AOP
- AWT – Alternative:
  - MF/UF, NF, UV-AOP
  - MF/UF, NF, Ozone-BAC
  - MF/UF, Ozone-BAC- GAC, UV-AOP

Although the AWT – Conventional treatment train option was determined to be the most viable option for full-scale implementation within the project timeframe, a number of AWT – Alternative options may merit consideration for pilot testing. The potential for significant O&M cost savings with NF in lieu of RO due to NF's lower energy consumption and higher plant water recovery warrants further consideration and pilot testing to assess the technology's performance. Ultimately, the full-scale design should allow for easy retrofit with NF in the future. In addition, pilot testing ozone-BAC for disinfection/advanced oxidation as part of the AWT should be considered.

### Viable Conveyance Options - Existing Pipeline and New Dedicated Pipeline

Both the existing outfall pipeline for tertiary water and new dedicated pipeline for AWT water were determined to be viable conveyance options. Six potential alignments were evaluated for the new dedicated AWT pipeline, and three alignments were determined to be viable. Based on the information currently available on all the potential alignments for a new pipeline between the SJCWRP and the Montebello Forebay, the best option is to use an alignment parallel to the existing outfall pipeline. Therefore, the Parallel Alignment will be carried forward as the primary option. Prior to a final determination, however, additional detailed investigation is warranted to ensure construction of this alignment is practical and interference with existing utilities is avoided.

The second and third highest ranking alignments are the Durfee Avenue and Workman Mill Road Alignments, respectively. These are considered as back-up options should the detailed examination of easements and rights-of-way, along with assessment of potential interferences and crossings, result in the determination of severe limitations associated with the Parallel Alignment.

### Viable Recharge Options - Spreading and Injection

Both spreading and injection were determined to be viable recharge options. In the case of surface spreading, either tertiary treated or AWT treated water can be applied. In the case of direct injection, only AWT water can be used.

### Viable Alternatives Assessment

Six viable alternatives were developed from a number of combinations of the viable options in each component area and evaluated using the TBL evaluation criteria and SMART model. The analysis resulted in three potentially feasible alternatives, representing those viable alternatives with the highest benefit score in each of the three treatment level categories: all tertiary, all AWT, and a hybrid of tertiary and AWT. The resulting three feasible alternatives are summarized herein and will be carried forward into the feasible alternatives analysis during preliminary engineering.

**Tertiary (Feasible Alternative A) –** Tertiary recycled water (up to 21,000 AFY) from the SJCWRP is conveyed in the existing outfall pipeline to the MFSG.

**AWT (Feasible Alternative D) –** AWT recycled water (up to 21,000 AFY) from the SJCWRP is conveyed in a new, dedicated outfall pipeline to the MFSG and/or potential Montebello Forebay injection sites.

**Hybrid (Feasible Alternative F) –** A combination of tertiary and AWT recycled water from the SJCWRP are conveyed. Tertiary recycled water is conveyed in the existing outfall pipeline to the spreading grounds, and AWT recycled water is conveyed in a new, dedicated pipeline to the spreading grounds and/or potential injection sites. The quantities of tertiary and AWT recycled water may vary depending on the recharge capacity of the MFSG; however, this analysis assumes that the hybrid alternative uses 11,000 AFY of tertiary and 10,000 AFY of AWT recycled water to recharge the Montebello Forebay. This flow split was to provide a midpoint between the AWT and tertiary alternatives.

# 7.0 References

American Waterworks Association Research Foundation (AWWARF) (1996). Water Treatment Membrane Processes.

California Department of Public Health (CDPH). (2011, November 21). Groundwater Replenishment Reuse Draft Regulations. Sacramento, CA.

Mansell, Bruce (2011, February). Groundwater Reliability Improvement Program Collaborative Membrane Project Final Report. Sanitation Districts of Los Angeles County.

MWH. (2009). Groundwater Reliability Improvement Program Conceptual Level Study.

Rosenfeldt, E.J. and K.G. Linden (2004) "Degradation of endocrine disrupting chemicals bisphenol A, ethinyl estradiol, and estradiol during UV photolysis and advanced oxidation processes," Environmental Science and Technology, vol.38, no.20, pp. 5476-5483.

RMC. (2011). GRIP Alternatives Analysis Final Report. June 2011.

Stantec. (2011). Indirect Potable Reuse: Reno-Stead WRF Pilot Test. Presentation to the Nevada Department of Environmental Protection.

U.S. Environmental Protection Agency (USEPA). (1986). Quality Criteria for Water. USEPA 440/5-86-001. Office of Water Regulations and Standards, Washington D.C.

WateReuse Research Foundation (WRRF). (2012a). Project 02-009 – Innovative Treatment Technologies for Reclaimed Water.

WateReuse Research Foundation (WRRF) (2012b). Project 11-02 – Equivalency of Advanced Treatment Trains for Potable Reuse. (Project underway.)

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October 2012

# Analysis of the Energy Intensity of Water Supplies for West Basin Municipal Water District

March, 2007

Robert C. Wilkinson, Ph.D.

## Note to Readers

This report for West Basin Municipal Water District is an update and revision of an analysis and report by Robert Wilkinson, Fawzi Karajeh, and Julie Mottin (Hannah) conducted in April 2005. The earlier report, *Water Sources "Powering" Southern California: Imported Water, Recycled Water, Ground Water, and Desalinated Water*, was undertaken with support from the California Department of Water Resources, and it examined the energy intensity of water supply sources for both West Basin and Central Basin Municipal Water Districts. This analysis focuses exclusively on West Basin, and it includes new data for ocean desalination based on new engineering developments that have occurred over the past year and a half.

## Principal Investigator: Robert C. Wilkinson, Ph.D.

Dr. Wilkinson is Director of the Water Policy Program at the Donald Bren School of Environmental Science and Management, and Lecturer in the Environmental Studies Program, at the University of California, Santa Barbara. His teaching, research, and consulting focuses on water policy, climate change, and environmental policy issues. Dr. Wilkinson advises private sector entities and government agencies in the U.S. and internationally. He currently served on the public advisory committee for California's 2005 State Water Plan, and he represented the University of California on the Governor's Task Force on Desalination.
Contact: wilkinson@es.ucsb.edu

### West Basin Municipal Water District

**Contact:** Richard Nagel, General Manager
West Basin Municipal Water District
17140 South Avalon Boulevard, Suite 210
Carson, CA 90746
(310) 217 2411 phone, (310) 217-2414 fax
richn@westbasin.org

West Basin Municipal Water District www.westbasin.org

# Overview

Southern California relies on imported and local water supplies for both potable and non-potable uses. Imported water travels great distances and over significant elevation gains through both the California State Water Project (SWP) and Colorado River Aqueduct (CRA) before arriving in Southern California, consuming a large amount of energy in the process. Local sources of water often require less energy to provide a sustainable supply of water. Three water source alternatives which are found or produced locally and could reduce the amount of imported water are desalinated ocean water, groundwater, and recycled water. Groundwater and recycled water are significantly less energy intensive than imports, while ocean desalination is getting close to the energy intensity of imports.

Energy requirements vary considerably between these four water sources. All water sources require pumping, treatment, and distribution. Differences in energy requirements arise from the varying processes needed to produce water to meet appropriate standards. This study examines the energy needed to complete each process for the waters supplied by West Basin Municipal Water District (West Basin).

Specific elements of energy inputs examined in this study for each water source are as follows:

- Energy required to **import water** includes three processes: pumping California SWP and CRA supplies to water providers; treating water to applicable standards; and distributing it to customers.
- **Desalination of ocean water** includes three basic processes: 1) pumping water from the ocean or intermediate source (e.g. a powerplant) to the desalination plant; 2) pre-treating and then desalting water including discharge of concentrate; and 3) distributing water from the desalination plant to customers.
- **Groundwater** usage requires energy for three processes: pumping groundwater from local aquifers to treatment facilities; treating water to applicable standards; and distributing water from the treatment plant to customers. Additional injection energy is sometimes needed for groundwater replenishment.
- Energy required to **recycle water** includes three processes: pumping water from secondary treatment plants to tertiary treatment plants; tertiary treatment of the water, and distributing water from the treatment plant to customers.

The energy intensity results of this study are summarized in the table on the following page. They indicate that recycled water is among the least energy-intensive supply options available, followed by groundwater that is naturally recharged and recharged with recycled water. Imported water and ocean desalination are the most energy intensive water supply options in California. East Branch State Water Project water is close in energy intensity to desalination figures based on current technology, and at some points along the system, SWP supplies exceed estimated ocean desalination energy intensity. The following table identifies energy inputs to each of the water supplies including estimated energy requirements for desalination. Details describing the West Basin system operations are included in the water source sections. Note that the Title 22 recycled water energy figure reflects only the *marginal* energy required to treat secondary effluent wastewater which has been processed to meet legal discharge requirements, along with the energy to convey it to user

## Energy Intensity of Water Supplies for West Basin Municipal Water District

| | af/yr | Percentage of Total Source Type | kWh/af Conveyance Pumping | kWh/af MWD Treatment | kWh/af Recycled Treatment | kWh/af Groundwater Pumping | kWh/af Groundwater Treatment | kWh/af Desalination | kWh/af WBMWD Distribution | Total kWh/af | Total kWh/year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Imported Deliveries** | | | | | | | | | | | |
| State Water Project (SWP) [1] | 57,559 | 43% | 3,000 | 44 | NA | NA | NA | NA | 0 | 3,044 | 175,209,596 |
| Colorado River Aqueduct (CRA) [1] (other that replenishment water) | 76,300 | 57% | 2,000 | 44 | NA | NA | NA | NA | 0 | 2,044 | 155,957,200 |
| **Groundwater**[2] | | | | | | | | | | | |
| natural recharge | 19,720 | 40% | NA | NA | NA | 350 | 0 | NA | 0 | 350 | 6,902,030 |
| replenished with (injected) SWP water [1] | 9,367 | 19% | 3,000 | 44 | NA | 350 | 0 | NA | 0 | 3,394 | 31,791,598 |
| replenished with (injected) CRA water [1] | 11,831 | 24% | 2,000 | 44 | NA | 350 | 0 | NA | 0 | 2,394 | 28,323,432 |
| replenished with (injected) recycled water | 8,381 | 17% | 205 | 0 | 790 | 350 | 0 | NA | 220 | 1,565 | 13,116,278 |
| **Recycled Water** | | | | | | | | | | | |
| West Basin Treatment, Title 22 | 21,506 | 60% | 205 | NA | 0 | NA | NA | NA | 285 | 490 | 10,537,940 |
| West Basin Treatment, RO | 14,337 | 40% | 205 | NA | 790 | NA | NA | NA | 285 | 1,280 | 18,351,360 |
| | 35,843 | | | | | | | | | | |
| **Ocean Desalination** | 20,000 | 100% | 200 | NA | NA | NA | NA | 3,027 | 460 | 3,687 | 82,588,800 |

Notes:

NA Not applicable

[1] Imported water based on percentage of CRA and SWP water MWD received, averaged over an 11-year period. Note that the figures for imports do not include an accounting for system losses due to evaporation and other factors. These losses clearly exist, and an estimate of 5% or more may be reasonable. The figures for imports above should therefore be understood to be conservative (that is, the actual energy intensity is in fact higher for imported supplies than indicated by the figures).

[2] Groundwater values include entire basin, West Basin service area covers approximately 86% of the basin. Groundwater values are specific to aquifer characteristics, including depth, within the basin.

# Energy Intensity of Water

Water treatment and delivery systems in California, including extraction of "raw water" supplies from natural sources, conveyance, treatment and distribution, end-use, and wastewater collection and treatment, account for one of the largest energy uses in the state.[1] The California Energy Commission estimated in its 2005 Integrated Energy Policy Report that approximately 19% of California's electricity is used for water related purposes including delivery, end-uses, and wastewater treatment.[2] The total energy embodied in a unit of water (that is, the amount of energy required to transport, treat, and process a given amount of water) varies with location, source, and use within the state. In many areas, the energy intensity may increase in the future due to limits on water resource extraction, and regulatory requirements for water quality, and other factors.[3] Technology improvements may offset this trend to some extent.

> ***Energy intensity*** is the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location.

## The Water-Energy Nexus

Water and energy systems are interconnected in several important ways in California. Water systems both provide energy – through hydropower – and consume large amounts of energy, mainly through pumping. Critical elements of California's water infrastructure are highly energy-intensive. Moving large quantities of water long distances and over significant elevation gains, treating and distributing it within the state's communities and rural areas, using it for various purposes, and treating the resulting wastewater, accounts for one of the largest uses of electrical energy in the state.[4]

Improving the efficiency with which water is used provides an important opportunity to increase related energy efficiency. (*"Efficiency"* as used here describes the useful work or service provided by a given amount of water.) Significant potential economic as well as environmental benefits can be cost-effectively achieved in the energy sector through efficiency improvements in the state's water systems and through shifting to less energy intensive local sources. The California Public Utilities Commission is currently planning to include water efficiency improvements as a means of achieving energy efficiency benefits for the state.[5]

## Overview of Energy Inputs to Water Systems

There are four principle energy elements in water systems:

1. primary water extraction and supply delivery (imported and local)
2. treatment and distribution within service areas
3. on-site water pumping, treatment, and thermal inputs (heating and cooling)

4. wastewater collection, treatment, and discharge

Pumping water in each of these four stages is energy-intensive. Other important components of embedded energy in water include groundwater pumping, treatment and pressurization of water supply systems, treatment and thermal energy (heating and cooling) applications at the point of end-use, and wastewater pumping and treatment.[6]

***1. Primary water extraction and supply delivery***

Moving water from near sea-level in the Sacramento-San Joaquin Delta to the San Joaquin-Tulare Lake Basin, the Central Coast, and Southern California, and from the Colorado River to metropolitan Southern California, is highly energy intensive. Approximately 3,236 kWh is required to pump one acre-foot of SWP water to the end of the East Branch in Southern California, and 2,580 kWh for the West Branch. About 2,000 kWh is required to pump one acre foot of water through the CRA to southern California.[7] Groundwater pumping also requires significant amounts of energy depending on the depth of the source. (Data on groundwater is incomplete and difficult to obtain because California does not systematically manage groundwater resources.)

***2. Treatment and distribution within service areas***

Within local service areas, water is treated, pumped, and pressurized for distribution. Local conditions and sources determine both the treatment requirements and the energy required for pumping and pressurization.

***3. On-site water pumping, treatment, and thermal inputs***

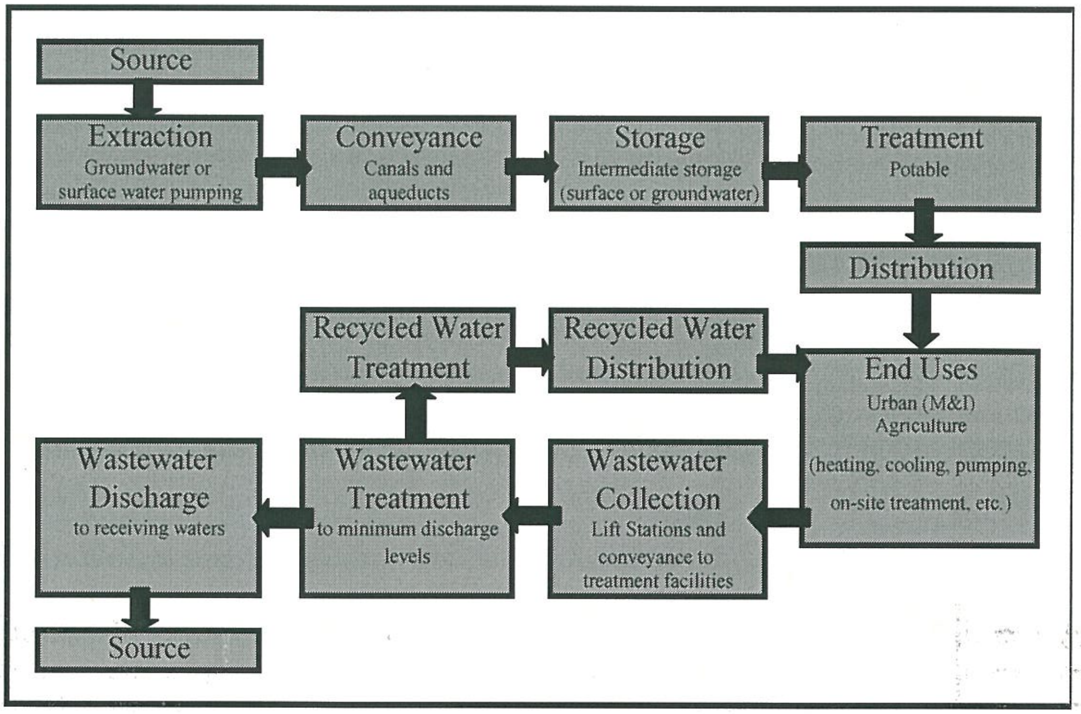
Individual water users use energy to further treat water supplies (e.g. softeners, filters, etc.), circulate and pressurize water supplies (e.g. building circulation pumps), and heat and cool water for various purposes.

***4. Wastewater collection, treatment, and discharge***

Finally, wastewater is collected and treated by a wastewater authority (unless a septic system or other alternative is being used). Wastewater is often pumped to treatment facilities where gravity flow is not possible, and standard treatment processes require energy for pumping, aeration, and other processes. (In cases where water is reclaimed and re-used, the calculation of total energy intensity is adjusted to account for wastewater as a *source* of water supply. The energy intensity generally includes the additional energy for treatment processes beyond the level required for wastewater discharge, plus distribution.)

The simplified flow chart below illustrates the steps in the water system process. A spreadsheet computer model is available to allow cumulative calculations of the energy inputs embedded at each stage of the process. This methodology is consistent with that applied by the California Energy Commission in its analysis of the energy intensity of water.

## Simplified Flow Diagram of Energy Inputs to Water Systems



Source: Robert Wilkinson, UCSB[8]

## Calculating Energy Intensity

Total energy intensity, or the amount of energy required to facilitate the use of a given amount of water in a specific location, may be calculated by accounting for the summing the energy requirements for the following factors:

- imported supplies
- local supplies
- regional distribution
- treatment
- local distribution
- on-site thermal (heating or cooling)
- on-site pumping
- wastewater collection
- wastewater treatment

Water pumping, and specifically the long-distance transport of water in conveyance systems, is a major element of California's total demand for electricity as noted above. Water use (based on embedded energy) is the next largest consumer of electricity in a typical Southern California home after refrigerators and air conditioners. Electricity required to support water service in the typical home in Southern California is estimated at between 14% to 19% of total residential energy demand.[9] If air conditioning is not a factor the figure is even higher. Nearly three quarters of this energy demand is for pumping imported water.

### Interbasin Transfers

Some of California's water systems are uniquely energy-intensive, relative to national averages, due to the pumping requirements of major conveyance systems which move large volumes of water long distances and over thousands of feet in elevation lift. Some of the interbasin transfer systems (systems that move water from one watershed to another) are net energy producers, such as the San Francisco and Los Angeles aqueducts. Others, such as the SWP and the CRA require large amounts of electrical energy to convey water. On *average*, approximately 3,000 kWh is necessary to pump one AF of SWP water to southern California,[10] and 2,000 kWh is required to pump one AF of water through the CRA to southern California.[11]

Total energy savings for reducing the full embedded energy of *marginal* (e.g. imported) supplies of water used indoors in Southern California is estimated at about 3,500 kWh/af.[12] Conveyance over long distances and over mountain ranges accounts for this high marginal energy intensity. In addition to avoiding the energy and other costs of pumping additional water supplies, there are environmental benefits through reduced extractions from stressed ecosystems such as the delta.

## Imported Water: The State Water Project and the Colorado River Aqueduct

Water diversion, conveyance, and storage systems developed in California in the 20th century are remarkable engineering accomplishments. These water works move millions of AF of water around the state annually. The state's 1,200-plus reservoirs have a total storage capacity of more than 42.7 million acre feet (maf).[13] West Basin receives imported water from Northern California through the State Water Project and Colorado River water via the Colorado River Aqueduct. The Metropolitan Water District of Southern California delivers both of these imported water supplies to the West Basin.

**California's Major Interbasin Water Projects**

## The State Water Project

The State Water Project (SWP) is a state-owned system. It was built and is managed by the California Department of Water Resources (DWR). The SWP provides supplemental water for agricultural and urban uses.[14] SWP facilities include 28 dams and reservoirs, 22 pumping and generating plants, and nearly 660 miles of aqueducts.[15] Lake Oroville on the Feather River, the project's largest storage facility, has a total capacity of about 3.5 maf.[16] Oroville Dam is the tallest and one of the largest earth-fill dams in the United States.[17]

Water is pumped out of the delta for the SWP at two locations. In the northern Delta, Barker Slough Pumping Plant diverts water for delivery to Napa and Solano counties through the North Bay

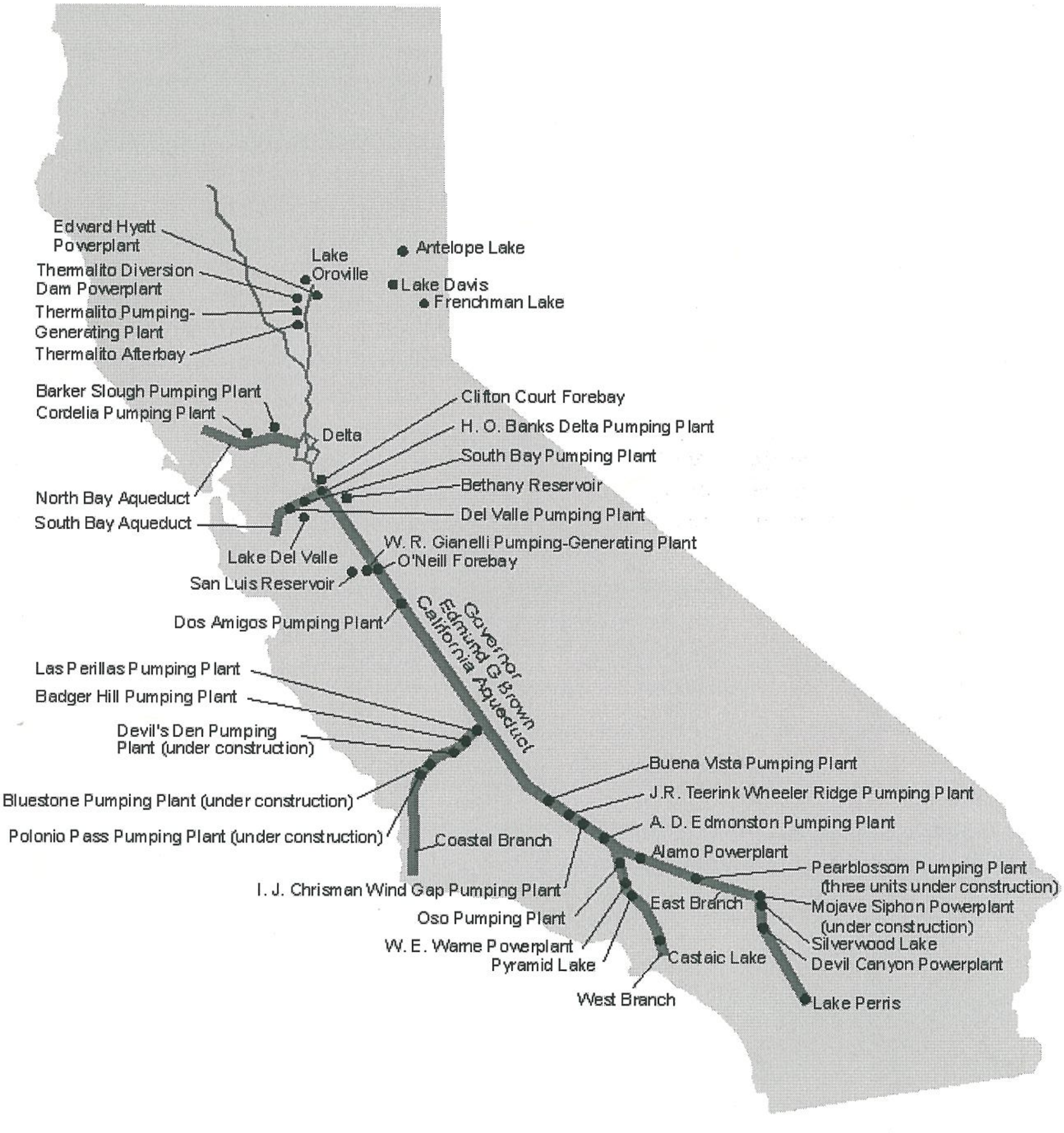
Aqueduct.[18] Further south at the Clifton Court Forebay, water is pumped into Bethany Reservoir by the Banks Pumping Plant. From Bethany Reservoir, the majority of the water is conveyed south in the 444-mile-long Governor Edmund G. Brown California Aqueduct to agricultural users in the San Joaquin Valley and to urban users in Southern California. The South Bay Pumping Plant also lifts water from the Bethany Reservoir into the South Bay Aqueduct. [19]

The State Water Project is the largest consumer of electrical energy in the state, requiring an average of 5,000 GWh per year.[20] The energy required to operate the SWP is provided by a combination of DWR's own hydroelectric and other generation plants and power purchased from other utilities. The project's eight hydroelectric power plants, including three pumping-generating plants, and a coal-fired plant produce enough electricity in a normal year to supply about two-thirds of the project's necessary power.

Energy requirements would be considerably higher if the SWP was delivering full contract volumes of water. The project delivered an average of approximately 2.0 mafy, or half its contracted volumes, throughout the 1980s and 1990s.[21] Since 2000 the volumes of imported water have generally increased.

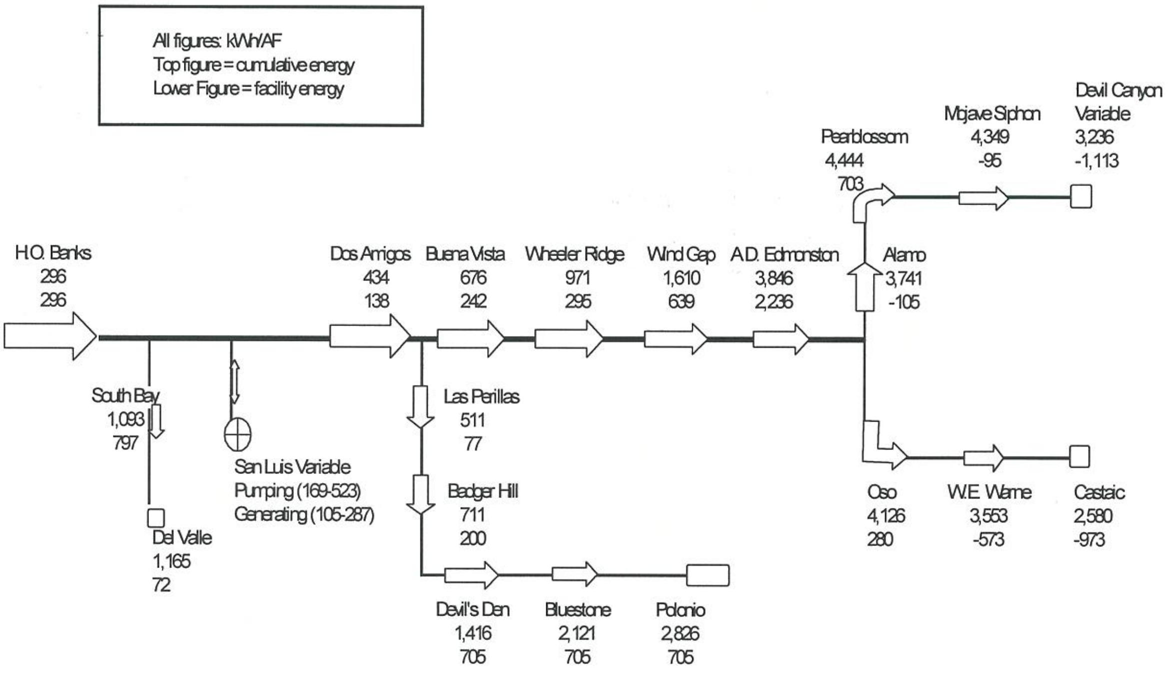
The following map indicates the location of the pumping and power generation facilities on the SWP.

## Names and Locations of Primary State Water Delivery Facilities



The following schematic shows each individual pumping unit on the State Water Project, along with data for both the individual and cumulative energy required to deliver an AF of water to that point in the system. Note that the figures include energy recovery in the system, but they do not account for losses due to evaporation and other factors. These losses may be in the range of 5% or more. While more study of this issue is in order, it is important to observe that the energy intensity numbers are conservative (e.g. low) in that they assume that all of the water originally pumped from the delta reaches the ends of the system without loss.

**State Water Project**
**Kilowatt-Hours per Acre Foot Pumped**
(Includes Transmission Losses)



Source: Wilkinson, based on data from: California Department of Water Resources, State Water Project Analysis Office, Division of Operations and Maintenance, *Bulletin 132-97*, 4/25/97.

## The Colorado River Aqueduct

Significant volumes of water are imported to the Los Angeles Basin and San Diego in Southern California from the Colorado River via the Colorado River Aqueduct (CRA). The aqueduct was built by the Metropolitan Water District of Southern California (MWD). Though MWD's allotment of the Colorado River water is 550,000 afy, it has historically extracted as much as 1.3 mafy through a combination of waste reduction arrangements with Imperial Irrigation District (IID) (adding about 106,000 afy) and by using "surplus" water.[22] The Colorado River water supplies require about 2,000 kWh/af for conveyance to the Los Angeles basin.

The Colorado River Aqueduct extends 242 miles from Lake Havasu on the Colorado River to its terminal reservoir, Lake Mathews, near Riverside. The CRA was completed in 1941 and expanded in 1961 to a capacity of more than 1 MAF per year. Five pumping plants lift the water 1,616 feet, over several mountain ranges, to southern California. To pump an average of 1.2 maf of water per year into the Los Angeles basin requires approximately 2,400 GWh of energy for the CRA's five pumping plants.[23] On average, the energy required to import Colorado River water is about 2,000 kWh/AF. The aqueduct was designed to carry a flow of 1,605 cfs (with the capacity for an additional 15%).

The sequence for CRA pumping is as follows: The Whitsett Pumping Plant elevates water from Lake Havasu 291 feet out of the Colorado River basin. At "mile 2," Gene pumping plant elevates water 303 feet to Iron Mountain pumping plant at mile 69, which then boosts the water another 144 feet. The last two pumping plants provide the highest lifts - Eagle Mountain, at mile 110, lifts the water 438 feet, and Hinds Pumping Plant, located at mile 126, lifts the water 441 feet.[24]

MWD has recently improved the system's energy efficiency. The average energy requirement for the CRA was reduced from approximately 2,100 kWh /af to about 2,000 kWh /af "through the increase in unit efficiencies provided through an energy efficiency program." The energy required to pump each acre foot of water through the CRA is essentially constant, regardless of the total annual volume of water pumped. This is due to the 8-pump design at each pumping plant. The average pumping energy efficiency does not vary with the number of pumps operated, and MWD states that the same 2,000 kWh/af estimate is appropriate for both the "Maximum Delivery Case" and the "Minimum Delivery Case."[25]

It appears that there are limited opportunities to shift pumping off of peak times on the CRA. Due to the relatively steep grade of the CRA, limited active water storage, and transit times between plants, the system does not generally lend itself to shifting pumping loads from on-peak to off-peak. Under the Minimum Delivery Case, the reduced annual water deliveries would not necessarily bring a reduction in annual peak load, since an 8-pump flow may still need to be maintained in certain months.

Electricity to run the CRA pumps is provided by power from hydroelectric projects on the Colorado River as well as off-peak power purchased from a number of utilities. The Metropolitan Water District has contractual hydroelectric rights on the Colorado River to "more than 20 percent of the firm energy and contingent capacity of the Hoover power plant and 50 percent of the energy and capacity of the Parker power plant."[26] Energy purchased from utilities makes up approximately 25 percent of the remaining energy needed to power the Colorado River Aqueduct.[27]

## Minimizing the Need for Inter-Basin Transfers

For over 100 years, California has sought to transfer water from one watershed for use in another. The practice has caused a number of problems. As of 2001, California law requires that the state examine ways to "*minimize the need to import water from other hydrologic regions*" and report on these approaches in the official State Water Plan.[28] A new focus and priority has been placed on developing *local* water supply sources, including efficiency, reuse, recharge, and desalination. The law directs the Department of Water Resources as follows:[29]

> The department, as a part of the preparation of the department's Bulletin 160-03, shall include in the California Water Plan a report on the development of regional and local water projects within each hydrologic region of the state, as described in the department's Bulletin 160-98, to improve water supplies to meet municipal, agricultural, and environmental water needs and *minimize the need to import water from other hydrologic regions.*

(Note that Bulletin 160-03 became Bulletin 160-05 due to a slip in the completion schedule.)

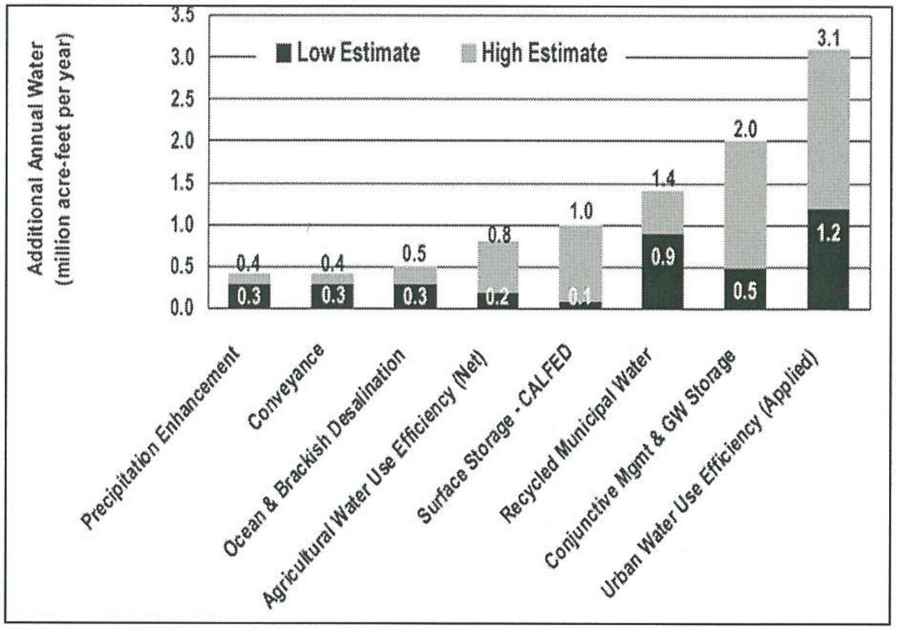
The legislation set forth the range of local supply options to be considered:

> The report shall include, but is not limited to, regional and local water projects that use technologies for desalting brackish groundwater and ocean water, reclaiming water for use within the community generating the water to be reclaimed, the construction of improved potable water treatment facilities so that water from sources determined to be unsuitable can be used, and the construction of dual water systems and brine lines, particularly in connection with new developments and when replacing water piping in developed or redeveloped areas.

This law calls for a thorough consideration in the state's official water planning process of work that is already going on in various areas of the state. The significance of the legislation is that for the first time, local supply development is designated as a priority in order to minimize inter-basin transfers.

The Department of Water Resources State Water Plan (Bulletin 160-05) reflects this new direction for the state in its projection of water supply options for the next quarter century. The following graph clearly indicates the importance of local water supplies from various sources in the future.

**California State Water Plan 2005**
**Water Management and Supply Options for the Next 25 Years**



Source: *California Water Plan Update 2005.*[30]

## Energy Requirements for Treatment of State Water Project and the Colorado River Aqueduct Supplies

Imported SWP and CRA supplies require an estimated 44 kWh/af for treatment before it enters the local distribution systems. Water pressure from MWD's system is sufficient to move supplies through the West Basin distribution system without requiring additional pressure.

# Groundwater and Recycled Water at West Basin MWD

Nearly half of the water used in the service area of the Metropolitan Water District of Southern California (from Ventura to Mexico) is secured from *local* sources, and the percentage of total supplies provided by local sources is growing steadily.[31] This figure is up from approximately one-third of the supply provided by local resources in the mid-1990s.[32] MWD has encouraged local supply development through support for recycling, groundwater recovery, conservation, groundwater storage, and most recently, ocean desalination.

Groundwater and recycled water are important and growing supply sources for West Basin. Water flows through natural hydrologic cycles continuously. The water we use today has made the journey many times. In water recycling programs, water is treated and re-used for various purposes including recharging groundwater aquifers. The treatment processes essentially short-circuit the longer-term process of natural evaporation and precipitation. In cities around the world water is used and then returned to natural water systems where it flows along to more users down stream. It is often used again and again before it flows to the ocean or to a terminal salt sink.

## Groundwater at West Basin MWD

Groundwater reservoirs in West Basin are replenished with four water sources; natural recharge, SWP supplies, CRA supplies, and recycled water supplies. The largest portion (approximately 40%) of groundwater supplies is derived from natural recharge. The energy associated with recovering this naturally recharged supply is estimated at 350 kWh/af for groundwater pumping.

Imported water, from both the SWP and CRA, is injected into the groundwater supply in West Basin. The imported water remains at sufficient pressure for injection, so no additional energy is required. The energy requirements for importing water are significant, however, primarily due to the energy associated with importing the water from northern California and the Colorado River. The imported water also passes through MWD's treatment plant, incurring additional energy requirements. The total energy intensity for West Basin's imported water used for recharge of groundwater storage from the SWP is 3,394 kWh/af and from the CRA is 2,394 kWh/af.

Recycled water is also used to recharge groundwater in the basin. West Basin replenishes groundwater by injecting RO treated recycled water from the West Basin Water Recycling Facility (WBWRF). The total energy use is 1,565 kWh/af. Details for the recycled water energy are described in the next section.

## Recycled Water at West Basin MWD

Many cities in California are using advanced processes and filtering technology to treat wastewater so it can be re-used for irrigation, industry, and other purposes. In response to increasing demands for water, limitations on imported water supplies, and the threat of drought, West Basin has developed state-of-the-art regional water recycling programs. Water is increasingly being used more than once within systems at both the end-use level and at the municipal level. This is because scarce water resources (and wastewater discharges) are increasing in cost and because cost-effective technologies and techniques for re-using water have been developed that meet health and safety requirements. At the end-use, water is recycled within processes such as cooling towers and industrial processes prior to entering the wastewater system. Once-through systems are increasingly being replaced by re-use technologies. At the municipal level, water re-use has become a significant source of supplies for both landscape irrigation and for commercial and industrial processes. MWD of Southern California is supporting 33 recycling programs in which treated wastewater is used for non-potable purposes. [33]

West Basin provides customers with recycled water used for municipal, commercial and industrial applications. Approximately 27,000 AF of recycled water is annually distributed to more than 210 sites in the South Bay. These sites use recycled water for a wide range of non-potable applications. Based in El Segundo, California, the WBWRF is among the largest projects of its kind in the nation, producing five qualities of recycled water with the capacity at full build-out to recycle 100,000 AF per year of wastewater from the Los Angeles Hyperion Treatment Plant.

In 1998, West Basin began to construct the nation's only regional high-purity water treatment facility, the Carson Regional Water Recycling Facility (CRWRF). A pipeline stretching through five South Bay communities connects the CRWRP to West Basin's El Segundo facility. At the CRWRF, West Basin ultra-purifies the recycled water it gets from the El Segundo facility. From the CRWRF, West Basin uses service lines to transport two types of purified water to the BP Refinery in Carson. The West Basin expansion also includes a new disposal pipeline to carry brine reject water from the CRWRF to a Los Angeles County Sanitation District's outfall.

In order to provide perspective on the energy requirements for the WBWRF, two water qualities and associated energy intensity are presented. "Title 22" water, produced by a gravity filter treatment system, requires conveyance pumping energy from Hyperion to WBWRF at 205 kWh/af. The water flows through the filters via gravity, thus no additional energy is required for treatment. The final energy requirement is 285 kWh/af for distribution with a total energy requirement of 490 kWh/af. This is the lowest grade of recycled water that WBWRF produces. Contrasting the Title 22 water, WBWRF produces RO water with a total energy requirement of 1,280 kWh/af. This includes 205 kWh/af for conveyance from Hyperion, 790 kWh/af for treatment with RO, and 285 kWh/af for distribution.

More than 210 South Bay sites use 9 billion gallons of West Basin's recycled water for applications including irrigation, industrial processes, indirect potable uses, and seawater barrier injection. West Basin has been successful in changing the perception of recycled water from merely a conservation tool with minimal applications to a cost-effective business tool that can reduce costs and improve reliability.

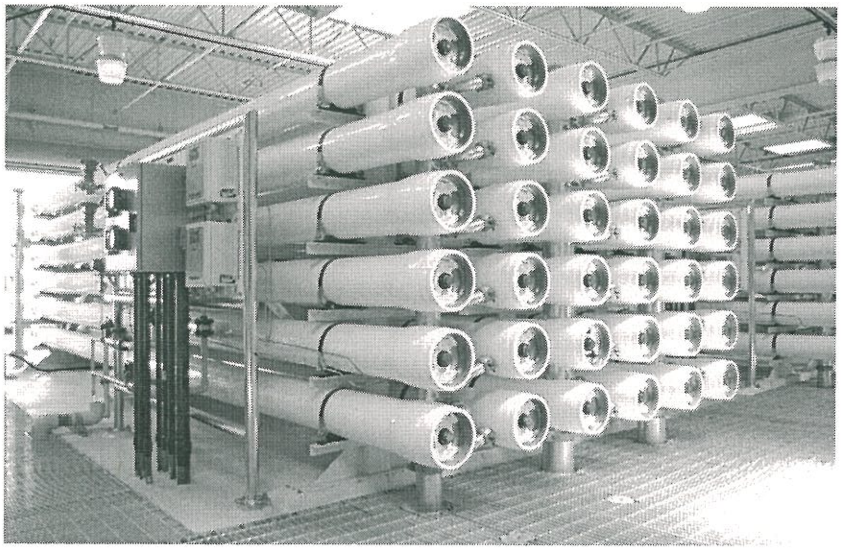
Local oil refineries are major customers for West Basin's recycled water. The Chevron Refinery in El Segundo, the Exxon-Mobile refinery in Torrance, and the BP refinery in Carson use recycled water for cooling towers and in the boiler feed systems.

## Ocean Water Desalination Development

Desalination technologies are in use around the world. A number of approaches work well and produce high quality water. Many workable and proven technology options are available to remove salt from water. During World War Two, desalination technology was developed as a water source for military operations.[34] Grand plans for nuclear-driven desalination systems in California were drawn up after the war, but they were never implemented due to cost and feasibility problems.

Desalination techniques range from distillation to "reverse osmosis" (RO) technologies. Current applications around the world are dominated by the "multistage flash distillation" process (at about 44% of the world's applications), and RO, (at about 42%).[35] Other desalting technologies include electrodialysis (6%), vapor compression (4%), multi-effect distillation (4%), and membrane softening (2%) to remove salts.[36] All of the ocean desalination projects currently in place or proposed for municipal water supply in California employ RO technology.

**Reverse Osmosis Membranes**



A recent inventory of desalination facilities world-wide indicated that as of the beginning of 1998, a total of 12,451 desalting units with a total capacity of 6.72 afy[37] had been installed or contracted worldwide.[38] (Note that *capacity* does not indicate actual operation.) Non-seawater desalination plants have a capacity 7,620 af/d[39], whereas the seawater desalination plant capacity reached 10,781af/d.[40]

Desalination systems are being used in over 100 countries, but 10 countries are responsible for 75 percent of the capacity.[41] Almost half of the desalting capacity is used to desalt seawater in the Middle East and North Africa. Saudi Arabia ranks first in total capacity (about 24 percent of the world's capacity) followed by the United Arab Emirates and Kuwait, with most of the capacity being made up of seawater desalting units that use the distillation process.[42]

The salinity of ocean water varies, with the average generally exceeding 30 grams per liter (g/l).[43] The Pacific Ocean is 34-38 g/l, the Atlantic Ocean averages about 35 g/l, and the Persian Gulf is 45 g/l. Brackish water drops to 0.5 to 3.0 g/l.[44] Potable water salt levels should be below 0.5 g/l.

Reducing salt levels from over 30 g/l to 0.5 g/l and lower (drinking water standards) using existing technologies requires considerable amounts of energy, either for thermal processes or for the pressure to drive water through extremely fine filters such as RO, or for some combination of thermal and pressure processes. Recent improvements in energy efficiency have reduced the amount of thermal and pumping energy required for the various processes, but high energy intensity is still an issue. The energy required is in part a function of the degree of salinity and the temperature of the water.

West Basin is in the process of developing plans to construct an ocean desalinating plant. Estimated energy requirements have been calculated by Gerry Filteau of Separation Processes, Inc for each step in the process.[45] The values presented for desalination are based on his work. Since the proposed plant will tap the source water at the power plant, there is no ocean intake pumping required. The source water is estimated to require 200 kWh/af this energy will bring ocean water from the power plant to the desalination system, approximately one quarter of a mile in distance. Pre-treatment of the source water is estimated at 341 kWh/af. This figure includes microfiltration and transfer to the RO units via a 5-10 micron cartridge filter. The RO process requires 2,686 kWh/af if operated at the most energy-efficient level. A slightly less efficient but more cost-effective level of operation would require 2,900 kWh/af, or 214 kWh/af additional energy input according to Filteau. Finally, an estimated 460 kWh/af is required to deliver the product water to the distribution system, including elevation gain, conveyance over distance, and pressurization to 90 psi. No additional energy is required to discharge the brine, as it flows back to the ocean outfall line by gravity.

The energy intensity figures presented here for desalination are lower than previous estimates. This is mainly due to improved membrane technologies, efficiency improvements for high pressure pumps, and pressure recovery systems. It should be noted that the figures provided here are based on engineering estimates, not on actual plant operations.

The total energy required to desalinate the ocean water, including each of the steps above, is estimated to be 3,687 kWh/af. If the energy intensity is increased slightly to improve cost-effectiveness, the total figure increases to 3,901 kWh/af.

# Summary

This study examined the energy intensity of imported and local water supplies (ocean water, groundwater, and recycled water) for both potable and non-potable uses for West Basin. All water sources require pumping, treatment, and distribution. Differences in energy requirements arise from varying pumping, treatment, and distribution processes needed to produce water to meet appropriate standards for different uses.

The key findings of this study are: 1) the marginal energy required to treat and deliver recycled water is among the *least* energy intensive supply options available, 2) naturally recharged groundwater is low in energy intensity, though replenishment with imported water is not, and 3) current ocean desalination technology is getting close to the level of energy intensity of imported supplies.

Further refinement of the data in this study, such as applying an agency's own energy values, may provide a more accurate basis for decision-making tailored to a unique water system. The information presented, however, provides a reasonable basis for water managers to explore energy (and cost) benefits of increased use of local water sources, and it indicates that desalination of ocean water is getting close to the energy intensity of existing supplies.

# Sources

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[1] Water systems account for roughly 7% of California's electricity use: See Wilkinson, Robert C., 2000. Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency.

[2] California Energy Commission, 2005. *Integrated Energy Policy Report*, November 2005, CEC-100-2005-007-CMF.

[3] Franklin Burton, in a recent study for the Electric Power Research Institute (EPRI), includes the following elements in water systems: "Water systems involve the transportation of water from its source(s) of treatment plants, storage facilities, and the customer. Currently, most of the electricity used is for pumping; comparatively little is used in treatment. For most surface sources, treatment is required consisting usually of chemical addition, coagulation and settling, followed by filtration and disinfection. In the case of groundwater (well) systems, the treatment may consist only of disinfection with chlorine. In the future, however, implementation of new drinking water regulations will increase the use of higher energy consuming processes, such as ozone and membrane filtration." Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities.* (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.3-1.

[4] Wilkinson, Robert C., 2000. *Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency.

[5] California Public Utilities Commission, Order Instituting Rulemaking Regarding to Examine the Commission's post-2005 Energy Efficiency Policies, Programs, Evaluation, Measurement and Verification, and Related Issues, Rulemaking 06-04-010 (Filed April 13, 2006)

[6] An AF of water is the volume of water that would cover one acre to a depth of one foot. An AF equals 325,851 gallons, or 43,560 cubic feet, or 1233.65 cubic meters.

[7] Metropolitan Water District of Southern California, *Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations*, 1996, p.5.

[8] This schematic, based on the original analysis by Wilkinson (2000) has been refined and improved with input from Gary Wolff, Gary Klein, William Kost, and others. It is the basic approach reflected in the CEC IEPR and other analyses.

[9] QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency*, Report for the Southern California Edison Company, p. 24.

[10] Figures cited are *net* energy requirements (gross energy for pumping minus energy recovered through generation).

[11] Metropolitan Water District of Southern California, *Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations*, 1996, p.5.

[12] Wilkinson, Robert C., 2000. *Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency.

[13] California Department of Finance. California Statistical Abstract. Tables G-2, "Gross Capacities of Reservoirs by Hydrographic Region," and G-3 "Major Dams and Reservoirs of California." January 2001. (http://www.dof.ca.gov/html/fs_data/stat-abs/toc.htm)

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[14] "The SWP, managed by the Department of Water Resources, is the largest state-built, multi-purpose water project in the country. Approximately 19 million of California's 32 million residents receive at least part of their water from the SWP. SWP water irrigates approximately 600,000 acres of farmland. The SWP was designed and built to deliver water, control floods, generate power, provide recreational opportunities, and enhance habitats for fish and wildlife." California Department of Water Resources, *Management of the California State Water Project.* Bulletin 132-96. p.xix.

[15] California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.p.xix.

[16] Three small reservoirs upstream of Lake Oroville — Lake Davis, Frenchman Lake, and Antelope Lake — are also SWP facilities. California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.

[17] California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96. Power is generated at the Oroville Dam as water is released down the Feather River, which flows into the Sacramento River, through the Sacramento-San Joaquin Delta, and to the ocean through the San Francisco Bay.

[18] The North Bay Aqueduct was completed in 1988. (California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.)

[19] The South Bay Aqueduct provided initial deliveries for Alameda and Santa Clara counties in 1962 and has been fully operational since 1965. (California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.)

[20] Carrie Anderson, 1999, "Energy Use in the Supply, Use and Disposal of Water in California", Process Energy Group, Energy Efficiency Division, California Energy Commission, p.1.

[21] Average deliveries for 1980-89 were just under 2.0 mafy, deliveries for 1990-99 were just over 2.0 mafy. There is disagreement regarding the ability of the SWP to deliver the roughly 4.2 mafy that has been contracted for.

[22] According to MWD, "Metropolitan's annual dependable supply from the Colorado River is approximately 656,000 AF -- about 550,000 AF of entitlement and at least 106,000 AF obtained through a conservation program Metropolitan funds in the Imperial Irrigation District in the southeast corner of the state. However, Metropolitan has been allowed to take up to 1.3 maf of river water a year by diverting either surplus water or the unused portions of other agencies' apportionments." Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[23] Metropolitan Water District of Southern California, 1999, http://www.mwd.dst.ca.us/pr/powres/summ.htm.

[24] The five pumping plants each have nine pumps. The plants are designed for a maximum flow of 225 cubic feet per second (cfs). The CRA is designed to operate at full capacity with eight pumps in operation at each plant (1800 cfs). The ninth pump operates as a spare to facilitating maintenance, emergency operations, and repairs. Metropolitan Water District of Southern California, 1999, Colorado River Aqueduct: http://aqueduct.mwd.dst.ca.us/areas/desert.htm, 08/01/99.

[25] Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, p.5.

[26] Metropolitan Water District of Southern California, 1999, "Summary of Metropolitan's Power Operation". February, 1999, p.1, http://aqueduct.mwd.dst.ca.us/areas/desert.htm.

[27] Metropolitan Water District of Southern California, 1999, http://www.mwd.dst.ca.us/pr/powres/summ.htm. MWD provides further important system information as follows: Metropolitan owns and operates 305 miles of 230 kV transmission lines from the Mead Substation in southern Nevada. The transmission system is used to deliver power from Hoover and Parker to the CRA pumps. Additionally, Mead is the primary interconnection point for Metropolitan's economy energy purchases. Metropolitan's transmission system is interconnected with several utilities at multiple

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interconnection points. Metropolitan's CRA lies within Edison's control area. Resources for the load are contractually integrated with Edison's system pursuant to a Service and Interchange Agreement (Agreement), which terminates in 2017. Hoover and Parker resources provide spinning reserves and ramping capability, as well as peaking capacity and energy to Edison, thereby displacing higher cost alternative resources. Edison, in turn, provides Metropolitan with exchange energy, replacement capacity, supplemental power, dynamic control and use of Edison's transmission system.

[28] SB 672, Machado, 2001. California Water Plan: Urban Water Management Plans. (The law amended Section 10620 of, and adds Section 10013 to, the Water Code) September 2001.

[29] SEC. 2. Section 10013 to the Water Code, 10013. (a) SB 672, Machado. California Water Plan: Urban Water Management Plans. September 2001, (Emphasis added.)

[30] California Department of Water Resources, 2005. California Water Plan Update 2005. Bulletin 160-05, California Department of Water Resources, Sacramento, CA.

[31] Metropolitan Water District of Southern California, 2000. *The Regional Urban Water Management Plan for the Metropolitan Water District of Southern California*, p.A.2-3.

[32] "About 1.36 maf per year (34 percent) of the region's average supply is developed locally using groundwater basins and surface reservoirs and diversions to capture natural runoff." Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, Vol.1, p.1-2.

[33] MWD estimates that reclaimed water will ultimately produce 190,000 AF of water annually. Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[34] Buros notes that "American government, through creation and funding of the Office of Saline Water (OSW) in the early 1960s and its successor organizations like the Office of Water Research and echnology (OWRT), made one of the most concentrated efforts to develop the desalting industry. The American government actively funded research and development for over 30 years, spending about $300 million in the process. This money helped to provide much of the basic investigation of the different technologies for desalting sea and brackish waters." Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts, p.5. This very useful summary is available at http://www.ida.bm/PDFS/Publications/ABCs.pdf

[35] Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts, p.5. This very useful summary is available at http://www.ida.bm/PDFS/Publications/ABCs.pdf See also; Buros et al.1980. *The USAID Desalination Manual.* Produced by CH2M HILL International for the U.S. Agency for International Development.

[36] Wangnick,Klaus.1998 *IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association; and Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts, p.5.

[37] Desalination systems with a unit size of 100 m3/d or more. Figures in original cited as 6,000 mgd.

[38] Wangnick Consulting GMBH (http://www.wangnick.com) maintains a permanent desalting plants inventory and publishes the results biennially in co-operation with the International Desalination Association, as the IDA Worldwide Desalting Plants Inventory Report. Thus far, fifteen reports have been published, with the latest report having data through the end of 1997; and see Wangnick,Klaus.*1998 IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association. The data cited are as of December 31, 1997.

[39] Cited in original as 9,400,000 m3/d.

[40] Wangnick,Klaus.*1998 IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association. (Cited in original in m3d (13,300,000 m3/d).

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[41] Wangnick,Klaus.1998 *IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association; and Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts. The United States ranks second in over-all capacity (16 %) with most of the capacity in the RO process used to treat brackish water. The largest plant, at Yuma, Arizona, is not in use.

[42] Wangnick,Klaus.1998. *IDA Worldwide Desalting Plants Inventory Report No.15.* Produced by Wangnick Consulting for International Desalination Association; and Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts.

[43] Salinity levels referenced in metric units.

[44] OTV. 1999. "Desalinating seawater." Memotechnique, Planete Technical Section, No. 31 (February), p.1; and Gleick, Peter H. 2000. *The World's Water: 2000-2001*, Island Press, Covelo, p.94.

[45] Gerry Filteau, Separation Processes, Inc., 2386 Faraday Ave., Suite 100, Calsbad, CA 92008, www.spi-engineering.com

# California Climate Action Registry
# General Reporting Protocol

## Reporting Entity-Wide Greenhouse Gas Emissions

Version 3.1 | January 2009

Thus, regional/power pool emission factors for electricity consumption can be used to determine emissions based on electricity consumed. If you can obtain verified emission factors specific to the supplier of your electricity, you are encouraged to use those factors in calculating your indirect emissions from electricity generation. If your electricity provider reports an electricity delivery metric under the California Registry's Power/Utility Protocol, you may use this factor to determine your emissions, as it is more accurate than the default regional factor. Utility-specific emission factors are available in the Members-Only section of the California Registry website and through your utility's Power/Utility Protocol report in CARROT.

This Protocol provides power pool-based carbon dioxide, methane, and nitrous oxide emission factors from the U.S. EPA's eGRID database (see Figure III.6.1), which are provided in Appendix C, Table C.2. These are updated in the Protocol and the California Registry's reporting tool, CARROT, as often as they are updated by eGRID.

To look up your eGRID subregion using your zip code, please visit U.S. EPA's "Power Profiler" tool at www.epa.gov/cleanenergy/energy-and-you/how-clean.html.

Fuel used to generate electricity varies from year to year, so emission factors also fluctuate. When possible, you should use emission factors that correspond to the calendar year of data you are reporting. CO$_2$, CH$_4$, and N$_2$O emission factors for historical years are available in Appendix E. If emission factors are not available for the year you are reporting, use the most recently published figures.

### U.S. EPA Emissions and Generation Resource Integrated Database (eGRID)

The Emissions & Generation Resource Integrated Database (eGRID) provides information on the air quality attributes of almost all the electric power generated in the United States. eGRID provides search options, including information for individual power plants, generating companies, states, and regions of the power grid. eGRID integrates 24 different federal data sources on power plants and power companies, from three different federal agencies: EPA, the Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). Emissions data from EPA are combined with generation data from EIA to produce values like pounds per megawatt-hour (lbs/MWh) of emissions, which allows direct comparison of the environmental attributes of electricity generation. eGRID also provides aggregated data to facilitate comparison by company, state or power grid region. eGRID's data encompasses more than 4,700 power plants and nearly 2,000 generating companies. eGRID also documents power flows and industry structural changes. www.epa.gov/cleanenergy/egrid/index.htm.

**Figure III.6.1 eGRID Subregions**

Source: eGRID2007 Version 1.1, December 2008 (Year 2005 data).

# Project 6

# Goldsworthy Desalter Expansion Project

## Supporting Documents

*Final Report*

# Feasibility Study for the Expansion of Robert W. Goldsworthy Desalter

Prepared for

**Water Replenishment**
**District of Southern California**

CH2MHILL.

1000 Wilshire Boulevard
Suite 2100
Los Angeles, CA 90017

**October 2012**

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## Water Replenishment District of Southern California

October 2012

REGISTERED PROFESSIONAL ENGINEER
DENNIS M. SMITH
No. 25053
Exp. 12/31/13
CIVIL
STATE OF CALIFORNIA
10/26/12

**CH2MHILL®**
1000 Wilshire Boulevard
Suite 2100
Los Angeles, CA 90017

SECTION 1

# Introductory Information

## 1.1 Project Background and Objectives

The Water Replenishment District of Southern California (WRD) is a special district established in 1959 under the California Water Code. WRD manages the groundwater resources of the Central Basin and West Coast Basin that serve as a potable water source for about four million people over a service area that covers 420 square miles in southern Los Angeles County. WRD is responsible for maintaining adequate groundwater supplies, preventing seawater intrusion into the underground groundwater aquifers, and protecting groundwater quality against contamination.

WRD owns the Robert W. Goldsworthy Desalter (Desalter) that is located in the City of Torrance in southern Los Angeles County. The Desalter was constructed in 2002, and is currently being operated and maintained by City of Torrance personnel under contract with WRD. The Desalter represents an effort to create a locally sustainable groundwater supply that will eliminate dependence on imported water and accelerate the remediation of a plume of brackish (high chloride) groundwater that was formed by seawater intrusion into the groundwater basins, and was trapped inland when the seawater intrusion barriers were placed into operation.

The Goldsworthy Desalter is capable of producing 2.5 million gallons per day (mgd) of potable water by extracting brackish groundwater and treating it through a desalination treatment system employing the reverse osmosis (RO) process. The Desalter treatment system is a traditional brackish groundwater treatment system for southern California. A portion of the extracted groundwater delivered to the desalination treatment system is bypassed around the main RO treatment process and is then re-blended with the RO permeate to produce a final blended treated water that is pumped into the City of Torrance water distribution system for potable use. The Desalter was originally designed and constructed to easily accommodate expansion to an ultimate blended treated water capacity of 5 mgd.

The purpose of this study is to evaluate the feasibility of expanding the existing Desalter to its ultimate blended treated water capacity by drilling of one or two new wells in the immediate vicinity of the Desalter where high chloride brackish groundwater is available, construction of delivery pipelines from the new wells to the existing Desalter, and install membrane modules and appurtenant equipment to increase the existing facility production capacity. The study will also evaluate the feasibility of constructing a desalination facility with a final blended treated water capacity of 5 mgd at other locations within the City of Torrance, which will include the drilling of two or more high chloride groundwater wells, pipelines from the new wells to the new desalters, construction of a new 5 desalination treatment facility and treated water pumping facilities to pump the treated water to the City of Torrance potable water distribution system.

Brackish groundwater pumped from Madrona Well No. 2 is the source of supply for the existing Goldsworthy Desalter. The Madrona Well No. 2 currently produces groundwater with a chloride concentration of about 680 mg/L that is below the minimum chloride concentration of 1,000 mg/L that is required to qualify for a pumping rights exemption. A new source of groundwater is required for the Desalter to produce the quantity of groundwater needed for an expanded facility to produce 5 mgd of blended treated water. In addition, it is desirable that the source of supply for the expanded Desalter be brackish groundwater with a chloride concentration significantly higher than 1,000 mg/L for the life of the project so that pumping rights may potentially be exempt. The project study will therefore evaluate several new well locations within the project area to provide sufficient high chloride groundwater as a supply source for alternatives to expand the desalter to produce 5 mgd of blended treated water.

In addition to the "no project" alternative, the project study will evaluate the following expansion options for the desalination facilities:

- Expansion of the existing Goldsworthy Desalter to 5 mgd
- Construction of a new 5 mgd desalter at the City of Torrance Elm Street site
- Construction of a 5 mgd desalter at the City of Torrance Well No. 7 or Well No. 8 site

The Elm Street site is currently empty. The site encompasses approximately two acres and is located in a residential neighborhood. Although approximately one-half of the site may be reserved for future park like environment, approximately one acre could be available for construction of a desalter. The City of Torrance water distribution system in the immediate area was sized to accommodate the combined yield from two former wells with a production capacity of approximately 5,000 gpm.

The City of Torrance Well No. 7 site has a reservoir, well and booster pump station. The well and booster pump station are housed in separate buildings. The reservoir can be demolished to make room for the new brackish groundwater treatment facility. The water distribution system in the vicinity of the site was designed to accommodate the combined production of two groundwater wells (Well No. 7 and Well No. 8) with a combined maximum groundwater production rate of approximately 5,000 gpm. The site is located in a predominantly industrial/commercial area of the City of Torrance. The entire facility is intact and operational, including the booster pump station and well pumping equipment. The site area is approximately 0.32 acres.

The City of Torrance Well No. 8 site is available for the new brackish ground water treatment facility. Although a groundwater well was drilled on the site, it was not equipped. The site encompasses approximately 0.47 acres, and is locate approximately 700 feet southeast of the Well No. 7 site.

## 1.2 Study Report Requirements

The project is receiving Federal funding from the United States Department of Interior, Bureau of Reclamation's (BOR's) WaterSMART program. The BOR's Title XVI program is an important part of the WaterSMART program. The study report has been structured to comply with the BOR's Title XVI feasibility report requirements to preserve current and future project Federal funding, and includes the following sections:

Section 1: Introductory Information

Section 2: Statement of Problems and Needs

Section 3: Water Reclamation and Reuse Opportunities

Section 4: Description of Alternatives

Section 5: Economic Analysis

Section 6: Selection of Proposed Project

Section 7: Environmental Consideration and Potential Effects

Section 8: Legal and Institutional Requirements

Section 9: Financial Capability of the Sponsor

Section 10: Research Needs

# 2.2 Desalter Groundwater Quality Objective

## 2.2.1 Introduction

Treatment at the Goldsworthy Desalter consists of chemical pre-dosing, cartridge filtration, single pass reverse osmosis (RO), decarbonation, and product water pumping into the City of Torrance potable water distribution system. A portion of the pumped groundwater delivered to the Desalter is bypassed around the RO process and re-blended with the RO product water to produce final blended product water. The blend ratio at the facility targets a Total Dissolved Solid (TDS) concentration of less than 500 mg/L and a Chloride concentration of less than 250 mg/L.

The Desalter is part of a regional strategy to mitigate the high salinity plume trapped in the WCB. As such, WRD was granted a pumping exemption from WCB groundwater pumping and replenishment charges if the chloride concentration in the extracted groundwater is maintained at 1,000 mg/L, or more. Unfortunately, the chloride concentration of Madrona Well No. 2 has declined over time, with the pumped groundwater chloride concentration now being about 660 mg/L. WRD has lost its pumping exemption as a result of the chloride concentration decrease.

Additional groundwater pumping will be necessary to expand the existing Goldsworthy Desalter capacity to the target 5 million gallons per day (mgd) of blended product water. There are two options to increase the quantity and the quality of groundwater pumped to the Desalter. The first option includes rehabilitating the Madrona Well No. 2 to improve production and increase the chloride concentration, plus the drilling of a second new groundwater production well. The second option involves the drilling of two or more new groundwater production wells to achieve the groundwater production and chloride concentration targets. Both of those options will increase the operational cost of the Goldsworthy Desalter as the groundwater chloride concentration increases. As the pumped groundwater chloride concentration increases, the:

1. Amount of water that can be bypassed around the treatment system decreases in order to maintain targeted Total Dissolved Solids (TDS) or chloride concentrations in the Desalter blended product water.
2. The feed pressure of the RO treatment process increases due to both a higher feed water osmotic pressure and a higher permeate flow requirement (higher membrane flux or flow per unit area).
3. The amount of pretreatment chemical dosing and the amount of RO cleaning chemical increase as the capacity of the RO increases.
4. The amount of sequestering agent decreases as the volume of the bypass water decreases, although this is lessened by the assumption that the manganese levels increase in the desalter feed with increasing chloride concentrations.

The above-described effects can be seen clearly by comparing **Figure 2-2** and **Figure 2-3** on the following page.

The impacts on the Goldsworthy Desalter operating costs for groundwater chloride concentrations of 660 mg/L (existing baseline), 1,400 mg/L, 1,800 mg/L, and 2,400 mg/L were examined. The existing Madrona Well No. 2 chloride concentration has degraded significantly over the last 10 years; therefore, chloride concentration values larger than 1,000 mg/L were analyzed to provide a buffer to allow for possible future decreases in the pumped groundwater chloride concentration.

**Figure 2-2**
Goldsworthy Desalter Process Flow Diagram with Existing Chloride Feed Concentration
(5 Year Membrane Age, 5 mgd Blended Treated Water)

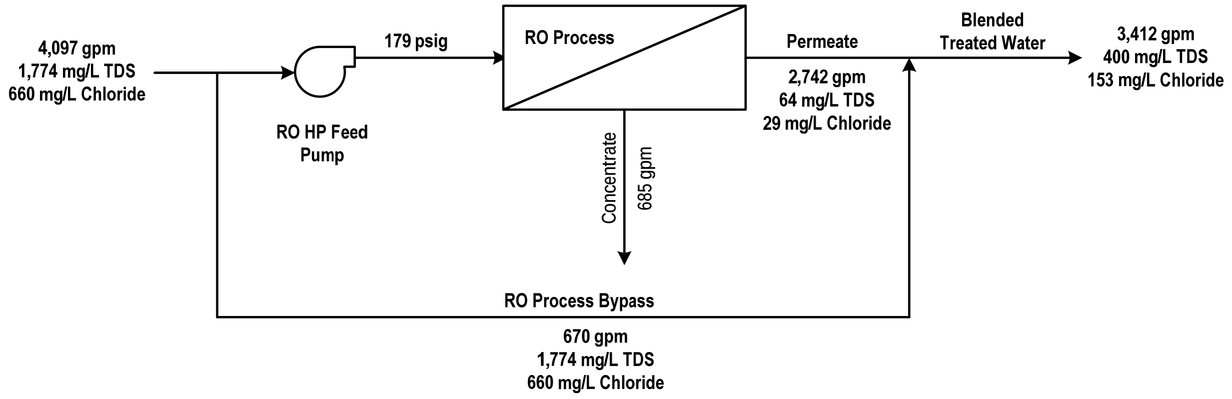
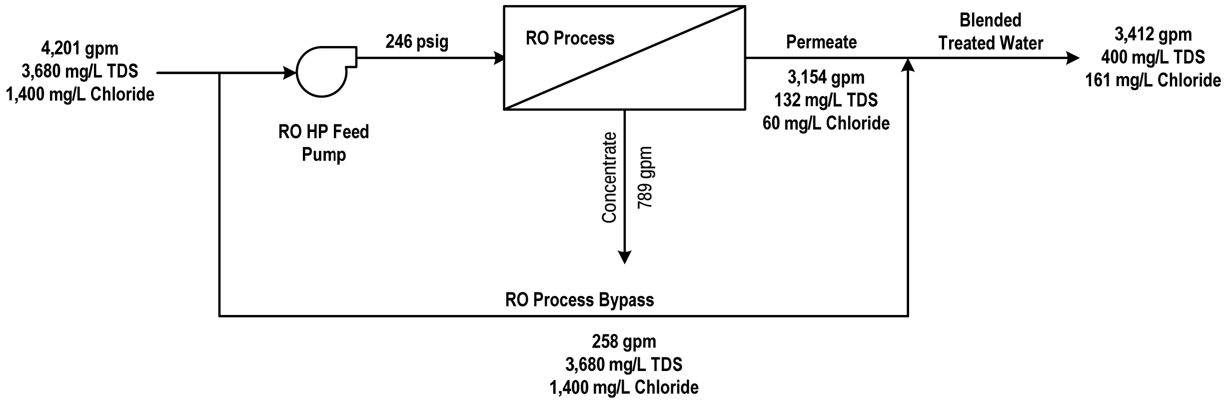


**Figure 2-3**
Goldsworthy Desalter Process Flow Diagram with 1,400 mg/L Chloride Feed Concentration
(5 Year Membrane Age, 5 mgd Blended Treated Water)



## 2.2.2 Chloride Concentration Operating Cost Impact Analysis

### 2.2.2.1 Assumptions

The following assumptions were made in to evaluate the impact of the increase in the groundwater chloride concentration on the Goldsworthy Desalter operating costs:

1. 95 percent on-line operating factor for the Desalter RO process that yields 8,322 hours of operation per year, or 346 days of operation per year.
2. The expanded Desalter will have a 5 mgd blended product water production capacity and will operate at that capacity for 346 days per year to produce about 5,320 acre-feet per year of potable water.
3. The energy requirement of the constant speed well pump is assumed to be the same regardless of the pumped groundwater chloride concentration. No allowance for a change in required energy has been

included in the analysis. The operational costs consist only of those costs that will change substantially with a change in the pumped groundwater chloride concentration. These include the RO process feed pump energy and chemical use.

4. A weighted annual average unit power cost of $0.08/kWh. The Desalter energy billings are based upon the Southern California Edison's (SCE's) Pumping and Agricultural Real-Time Pricing (PA-RTP) rate schedule. The SCE rate varies seasonally and with time of day, and provides energy users the benefit of being able to shift or reduce energy usage to times when temperatures (and electricity prices) are lower. The SCE power billings for 2011 for the Goldsworthy Desalter were analyzed to calculate the weighted annual unit power cost. The SCE PA-RTP rate fact sheet is included in **Appendix A.**
5. TDS increases associated with increasing the chloride concentration were calculated by increasing the sodium, potassium, calcium, magnesium, manganese, chloride and sulfate (only) at the same ratio as the chloride concentration increase. Base case is the existing groundwater Desalter feed water produced by Madrona Well No. 2.
6. Data from various wells in the vicinity of the Goldsworthy Desalter were analyzed for manganese. A linear fit of chloride concentration versus manganese concentrations was created with manganese concentrations increasing with chloride concentrations. Based upon that fit, manganese concentrations corresponding to their associated chloride concentrations were used to estimate the quantity of sequestering agent required.
7. Regarding RO permeate TDS and feed pressures, RO projections were run with CSM software using the RO-8040 BE membrane which is the membrane model currently installed in the Desalter RO process. An average membrane life for permeate water quality projections of 5 years (10 year total membrane life) was used for the RO process performance projections. Projected permeate TDS and chloride concentrations were doubled as a factor of safety.
8. Costs associated with continuous chemical dosing are based upon the following information supplied by the Desalter operating staff (John Aguiar correspondence of March 29, 2012). **Table 2-1** lists the chemical consumption rates and the chemical purchase costs. The treatment chemical costs are based upon the average Desalter flows over the last year, which are:
   - RO Feed Flow Rate = 1,400 gpm
   - RO Permeate Production Rate = 1,120 gpm
   - Bypass Flow Rate = 200 gpm

**Table 2-1**
Continuous Chemical Usage Rates and Costs

| Chemical | Current Use (Gallons Per Day) | Cost/Gallon ($) |
|---|---|---|
| Ammonia | 7 | $4.00 |
| Threshold Inhibitor | 10 | $14.00 |
| Sodium Hypochlorite | 70 | $0.75 |
| Sulfuric Acid | 52 | $1.50 |
| Sodium Hydroxide | 32 | $0.90 |
| Ortho P (Sequestering) | 17 | $7.75 |

9. Regarding RO Cleaning:
    a. Cleaning frequency is based upon the square of the RO permeate flow differences. Membrane cleaning was assumed to be based upon membrane fouling, with scaling under control via the scale inhibitor (threshold inhibitor).
    b. The current regimen for RO Clean-in-Place (CIP) is to use King Lee 1000 and King Lee 2000 every CIP. Every third CIP, King Lee 3000 is used. 1 pound of each of these chemicals is diluted in 10 gallons of CIP solution and we assumed that the 3000 was used in addition to the 1000 and 2000 every 3rd CIP. The Desalter operating staff provided the CIP chemical costs listed in **Table 2-2**.

**Table 2-2**
RO Process CIP Cleaning Chemical Costs

| Chemical | Cost/lb |
|---|---|
| King Lee 1000 | \$3.90 |
| King Lee 2000 | \$4.19 |
| King Lee 3000 | \$5.56 |

### 2.2.2.2 Flow and Energy Analysis

For each analyzed feed chloride concentration, a feed water TDS was calculated with ions in the same ratio as those in the existing Madrona Well No. 2 groundwater being pumped to the Goldsworthy Desalter. CSM's CSMPRO software program was used to analyze the estimated average required RO feed pressure and permeate quality. The projected permeate quality was doubled as a factor of safety for the analysis. A mass balance was then developed for each chloride concentration to determine the allowable RO treatment process bypass flow to attain a target TDS of 400 mg/L in the blended product water. This resulted in a more precise estimate of the required RO permeate flow, so another RO projection was run to attain a more accurate feed pressure. RO feed pressure requirements are presented with and without the addition of an interstage turbocharger energy recovery device.

With this information, the RO feed pump energy was calculated as follows, using the existing chloride concentration of 660 mg/L as an example (see Figure 2-2 above):

$$\frac{\$}{year} = (4{,}097 - 670)gpm * 179\ psi * \ 0.000434 * \frac{1}{0.85} * \frac{1}{0.95} * \frac{\$0.08}{kwh} * \ 24\frac{hrs}{day} * 346.75\frac{days}{yr} = \$\ 219{,}500$$

**Table 2-3** summarizes the results of the energy and flow analysis, and presents the estimated annual energy costs for the Desalter RO process without and with an interstage turbocharger.

### 2.2.2.3 Continuously Dosed Chemicals

Antiscalant (threshold inhibitor or TI) and sulfuric acid ($H_2SO_4$) pre-treatment chemicals are dosed into the RO feed water upstream of the cartridge filters and high-pressure feed pumps. The Ortho P sequestering agent is dosed in the RO process bypass water. In addition, three other chemicals, including aqua ammonia (AA), sodium hypochlorite (NaOCl) and sodium hydroxide (NaOH), are dosed into the blended product water before it is pumped into the City of Torrance water distribution system. Sodium hypochlorite and aqua ammonia are dosed into the blended product water to achieve chloramination disinfection. The sodium hydroxide is dosed into the blended product water upstream of the disinfection chemicals to increase the pH of the water to mitigate corrosion in the water distribution system pipelines. The flow rates for the RO process and the RO bypass will vary with the pumped groundwater chloride concentration, but in all cases the final blended flow will be the same. Thus the post treatment chemical costs are not dependent upon the feed groundwater chloride concentration and will remain the same for all of the chloride concentrations analyzed.

**Table 2-3**
Energy Use, Flows and Costs as a Function of RO Feed Chloride Concentration

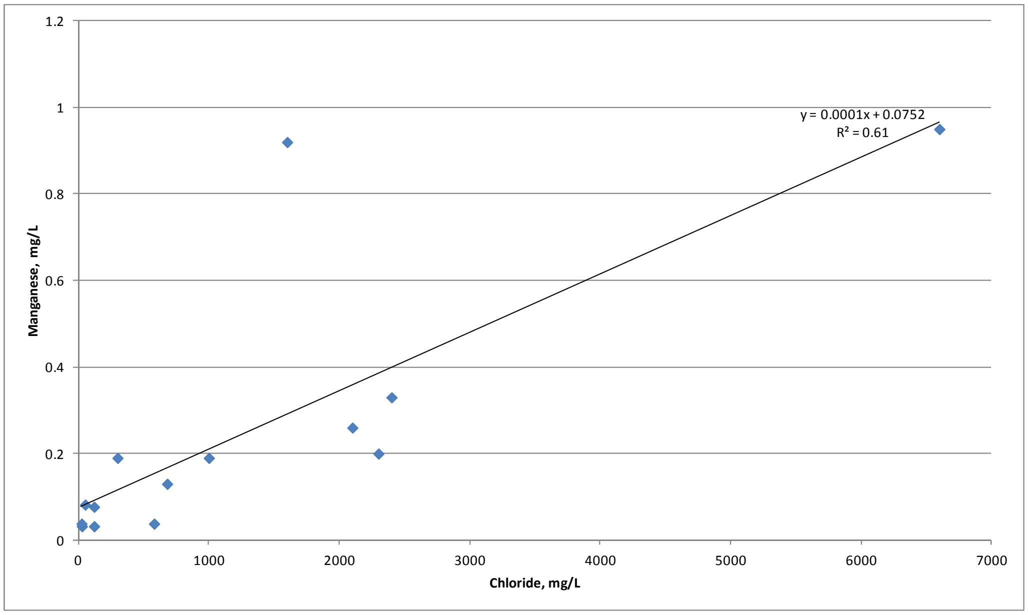
| Feed Water Chloride ( mg/L) | Feed Water TDS ( mg/L) | Projected Permeate TDS ( mg/L) | Blend Flow (gpm) | RO Feed Flow (gpm) | RO Feed Pressure w/o turbo (psi) | RO Feed Pressure w/ turbo (psi) | Yearly Energy Cost w/o Turbocharger | Yearly Energy Cost w/ Turbocharger |
|---|---|---|---|---|---|---|---|---|
| 660 | 1,774 | 64 | 670 | 3,428 | 179 | 161 | $219,500 | $197,400 |
| 1,400 | 3,680 | 132 | 528 | 3,943 | 246 | 217 | $347,000 | $306,100 |
| 1,800 | 4,149 | 156 | 208 | 4,005 | 266 | 232 | $381,200 | $332,500 |
| 2,400 | 5,817 | 218 | 111 | 4,126 | 315 | 265 | $465,100 | $391,300 |

A sample calculation for the TI chemical cost follows, and is based on the existing groundwater chloride concentration of 660 mg/L as an example (see figure 2-2 above). All chemical costs with the exception of the sequestering agent were assumed to vary only by flow rate as follows:

$$TI\,\frac{\$}{yr} = \frac{10\ gpd}{1{,}400\ gpm} * 3{,}428\ gpm * 346.75\,\frac{days}{yr} * \frac{\$14}{gallon} = \$118{,}800$$

Because the sequestering agent chemical costs can be substantial, data from various wells in the vicinity of the Goldsworthy Desalter were analyzed for manganese concentrations. A curve fit of chloride concentration versus manganese concentration was created with manganese concentrations increasing with chloride concentrations as shown in **Figure 2-4**.

**Figure 2-4**
Manganese vs. Chloride Levels in Wells in the Vicinity of the Goldsworthy Desalter



Manganese concentrations corresponding to their associated chloride levels were then used to estimate the quantity of sequestering agent required. The following calculation example is for the feed chloride level of 1,400 mg/L:

Manganese Concentration (mg/L) = 0.0001* Chloride (mg/L) + 0.0752 = 0.22 mg/L

$$Ortho\ P\frac{\$}{yr} = \frac{17\ gpd}{200\ gpm} * 258gpm * \frac{0.22\ ppm}{0.14\ ppm} * \ 365\frac{days}{yr} * \frac{\$7.75}{gallon} = \$94{,}500$$

**Table 2-4** summarizes the estimated annual chemical for the different feed water chloride concentrations analyzed. The chemical costs presented in the table are based on continuous chemical dosing while the RO process is in operation.

**Table 2-4**
Treatment Chemical Costs as a Function of Feed Chloride Concentration

| Feed Water Quality and RO Flow Rates | | | | | Estimated Treatment Chemical Costs | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Feed Water Chloride (mg/L)** | **Feed Water TDS (mg/L)** | **Blend Flow (gpm)** | **RO Feed Flow (gpm)** | **Ro Permeate Flow (gpm)** | **TI Cost ($/yr)** | **Sulfuric Acid Cost ($/yr)** | **Ortho P Cost ($/yr)** | **Aqua Ammonia Cost ( $/yr)** | **Sodium Hypochlorite Cost ( $/yr)** | **Sodium Hydroxide Cost ($/yr)** | **Total Chemical Cost ($/yr)** |
| 660 | 1,774 | 670 | 3,428 | 2,742 | $118,100 | $66,200 | $153,100 | $25,500 | $47,800 | $26,200 | $437,600 |
| 1,400 | 3,680 | 258 | 3,943 | 3,154 | $136,700 | $76,200 | $ 89,800 | $25,500 | $47,800 | $26,200 | $402,200 |
| 1,800 | 4,149 | 208 | 4,005 | 3,204 | $138,900 | $77,400 | $85,900 | $25,500 | $47,800 | $26,200 | $401,600 |
| 2,400 | 5,817 | 111 | 4,126 | 3,300 | $143,100 | $79,800 | $56,600 | $25,500 | $47,800 | $26,200 | $378,900 |

The annual total chemical costs for the analyzed chloride concentrations are presented in **Table 2-5**. The chemical costs presented in the table are based on the Desalter producing 5,320 acre-feet per year (producing 5 mgd of blended treated water for 346.75 days per year). The chemical cost decreases with increase in the chloride concentration because the manganese in the groundwater also increases, which reduces the amount of water that can be bypassed around the RO process and the sequestering agent chemical usage and costs.

**Table 2-5**
Annual and Incremental Chemical Costs ($/AF)

| Feed Water Chloride Concentration (mg/L) | Annual Chemical Cost ($/AF) | Incremental Chemical Cost ($/AF) |
|---|---|---|
| 660 | $82.26 | --- |
| 1,400 | $75.60 | -$6.66 |
| 1,800 | $75.49 | -$6.77 |
| 2,400 | $71.22 | -$11.04 |

#### 2.2.2.4 RO Clean In Place (CIP) Chemicals

Based upon the RO data collected, the Goldsworthy Desalter RO process has been cleaned about 2 to 3 times between mid 2010 and mid 2011. It was therefore assumed that at the maximum permeate flow of 3,300 gpm for the 2,400 mg/L chloride concentration condition (4,126 gpm * 80% recovery = 3,300 gpm) the RO process will require four CIPs per year.

The CIP frequency is calculated as a square of the RO flow differences. The following example using the existing chloride level of 660 mg/L demonstrates the calculation for the King Lee 1000 CIP chemical cost per year:

$$Estimated\ \#\ CIP\ per\ year = (\tfrac{2{,}742}{3{,}300})\text{^2 * 4 CIP/yr = 2.8 CIP/yr}$$

$$\frac{\$}{yr} King\ Lee\ 1000 = 2.8\frac{CIP}{yr} * 4{,}000\frac{gal}{CIP} * \frac{1\ lbs}{10\ gal} *\ 2\% * \frac{1}{1.1\ spgr} * \frac{\$3.90}{lb} = \$3{,}970$$

**Table 2-6** summarizes the RO process CIP chemical costs for the different chloride concentrations being analyzed.

**Table 2-6**
RO Process CIP Chemical Costs as a Function of Feed Water Chloride Concentration

| Feed Water Cl- (mg/L) | Feed Water TDS (mg/L) | Estimated No. CIP Per Year | Annual CIP Chemical Cost ($/Yr) |
|---|---|---|---|
| 660 | 1,774 | 2.8 | 10,500 |
| 1,400 | 3,680 | 3.7 | 13,200 |
| 1,800 | 4,149 | 3.8 | 13,580 |
| 2,400 | 5,817 | 4.0 | 14,300 |

#### 2.2.2.5 Analysis Summary

**Table 2-7** summarizes the RO process feed pump energy and chemical costs for the baseline chloride concentration (660 mg/L), and the other chloride concentrations being analyzed. Note that:

1. The addition of an interstage turbocharger on the RO trains will reduce these costs by $23,000 to $78,000 per year
2. The cost per pound of salt removed per year is reduced dramatically as the feed TDS increases.

**Table 2-8** presents the estimated annual RO pump energy plus chemical costs on a $/AF basis, based on an annual blended product water volume of 5,320 acre-feet (AF)/year. The total annual power and chemical costs range from about $125/AF for the current Goldsworthy Desalter feed water chloride concentration of 660 mg/L to about $161/AF for a feed water chloride concentration of 2,400 mg/L, without the installation of interstage turbochargers. The maximum incremental cost is about $36/AF between the baseline chloride concentration and the maximum chloride concentration analyzed. Installing the interstage turbochargers on the RO trains reduces the annual cost from about 3 percent at the current chloride concentration to about 9 percent for the maximum chloride concentration of 2,400 mg/L. The cost savings are predominantly the energy cost savings from the interstage turbochargers, with additional cost savings being realized by the reduction in sequestering agent use corresponding to the bypass flow rate decrease as the chloride concentration increases. The maximum incremental cost with the interstage turbochargers installed in the RO process is about $26/AF, which is less than the corresponding incremental cost without the interstage turbocharger

**Table 2-7**
Operating Costs as a Function of Feed Chloride Concentration

| Feed Water Chloride Concentration (mg/L) | Feed Water TDS (mg/L) | Annual RO Pump Energy Plus Chemicals ($/Year) | | Yearly RO Pump Energy Plus Chemicals $/lb salt removed | |
|---|---|---|---|---|---|
| | | w/o turbo | w/turbo | w/o turbo | w/turbo |
| 660 | 1,774 | $667,600 | $645,600 | $0.028 | $0.027 |
| 1,400 | 3,680 | $762,400 | $721,500 | $0.015 | $0.014 |
| 1,800 | 4,149 | $796,400 | $747,600 | $0.013 | $0.013 |
| 2,400 | 5,817 | $858,200 | $784,400 | $0.010 | $0.009 |

**Table 2-8**
Annual RO Pump Plus RO Process Chemical Costs ($/AF)

| Feed Water Chloride Concentration (mg/L) | Annual RO Pump Energy Plus Chemicals Cost ($/AF) | | | |
|---|---|---|---|---|
| | Total Cost w/o Turbo | Incremental Cost w/o Turbo | Total Cost w/ Turbo | Incremental Cost w/ Turbo |
| 660 | $125.49 | $0 | $121.35 | $0 |
| 1,400 | $143.31 | $17.82 | $135.62 | $14.27 |
| 1,800 | $149.70 | $24.21 | $140.53 | $19.18 |
| 2,400 | $161.32 | $35.82 | $147.44 | $26.09 |

**Figure 2-5** and **Figure 2-6** show the breakdown of the Desalter operating costs without an interstage turbocharger and with an interstage turbocharger, respectively.

The Ortho P sequestering agent is the most expensive chemical in use at the Goldsworthy Desalter and its cost decreases with increasing chloride and feed TDS levels and the corresponding decrease in bypass flow. However, the savings in Ortho P costs at the higher chloride levels is overwhelmed by the increase in cost of other chemicals and in RO feed pumping energy. WRD needs to weigh the additional costs in treating higher chloride/TDS water against the need to treat higher chloride water to ensure that the feed chloride to the Desalter remains above 1,000 mg/L so that WRD can maintain the groundwater pumping exemption.

Based on the foregoing analysis, it is recommended that:

1. If WRD wants to qualify for the groundwater pumping exemption, target a groundwater chloride feed concentration to the RO process of 1,400 mg/L. Based on Table 2-7 above, this recommendation will incur a minimal O&M cost increase and allow for variability in the well chloride concentration before the minimum pumping exemption chloride concentration of 1,000 mg/L is reached.
2. Maintain the current Madrona Well No. 2 groundwater chloride concentration of about 660 mg/L if WRD is not considering the groundwater pumping exemption to further minimize the Desalter operating costs. If WRD wants to qualify for the groundwater pumping exemption, and considering the uncertainty of the success of rehabilitating Madrona Well No. 2, then the drilling of two new

Even though the “Do Nothing/No Project” alternative is not considered a viable alternative, it will be carried forward and will serve as the baseline condition against which the other study alternatives will be evaluated from a benefit/cost perspective.

## 4.1.3 Existing Goldsworthy Desalter Expansion

### 4.1.3.1 Desalter Facilities

This alternative will expand the existing Goldsworthy Desalter from its present combined product water capacity of 2.5 mgd to an ultimate capacity of 5 mgd. The original Desalter construction included the treatment system facilities to accommodate the Desalter expansion; thus the expansion of the Desalter will require only the installation of the following equipment:

1. One stainless steel cartridge filter, including connecting piping and valving and filter elements.
2. One high-pressure RO feed pump for RO Train No. 2 (1,970 gpm @ 275 psi delivery pressure), including Variable Frequency Drive.
3. RO Train No. 2 system consisting of RO train frame, membrane pressure vessels, membranes and inter-connecting piping and valving.
4. Installation of interstage Turbochargers in RO Train No. 2 and retrofit interstage Turbocharger to existing RO Train No. 1.
5. RO system field instrumentation for RO Train No. 2, including new second stage flow meter and transmitter, and retrofit of second stage flow meter and transmitter into existing RO Train No. 1.
6. One treated water distribution pump (1,750 gpm @ 234 feet of TDH), including Variable Frequency Drive and piping and valving to connect the new pump into the existing piping system.
7. Sequestering agent chemical storage and feed system for the RO process bypass flows.
8. Electrical panels and controls.
9. Expansion of the existing Supervisory Control and Data Acquisition (SCADA) system to incorporate the new desalination system facilities.

In addition to the above-listed Desalter facility improvements, this alternative will also require the following improvements to address the observed operating deficiencies with the existing Desalter facilities:

1. Replacement of the Threshold Inhibitor (TI) flow meter and indicator/transmitter.
2. Replacement of chemical storage tank isolation valves.
3. Replacement of the chemical piping and secondary containment piping, including the installation of additional supports.
4. Replacement of chemical pump control panels.
5. Replacement of the chemical pump pulsation dampeners and pressure switches.
6. Replacement of chemical pumps and motors.
7. Installation of sump level switch and alarm.
8. Apply coating to chemical metering pump concrete pedestals.
9. Apply coating to TI area concrete flooring.
10. Installation of chemical area cantilevered canopy.
11. Installation of diaphragm valves on sodium hypochlorite storage tank.
12. Replacement of RO system Victaulic couplings.
13. Control system analysis and upgrades.

#### 4.1.3.2 Groundwater Production Wells and Options

Because WRD has not been successful with two previous well rehabilitation efforts it is uncertain that the rehabilitation procedure recommended for the existing Madrona Well No. 2 will successfully restore the well's groundwater production capacity to its original production capacity. It is also considered unlikely that the well will be able to maintain that greater production capacity over the life of the project (30 years). Therefore, it was assumed that this alternative would require the drilling of two new groundwater wells. The following groundwater well sites were identified as possible locations for this alternative:

1. Delthorne Park (2)
2. Panasonic Building eastern parking area (4)
3. Torrance Police Department parking area (7)
4. Torrance Civic Center Swimming Pool green-space (9)
5. Business complex parking area on southwest corner of Madrona Avenue and Torrance Boulevard (10)

The business complex parking area site on the southwest corner of Madrona Avenue and Torrance Boulevard (10) is across the intersection from the Torrance Civic Center Swimming Pool green space site (9). Accordingly, those two well sites are considered the same, and the former well site (10) should be considered if the latter well site (9) is found not to be available. For the purpose of this feasibility study, those two well sites will be represented by the Torrance Civic Center Swimming Pool green space site (9).

A total of five groundwater well combination options were developed for the evaluation of this alternative. The well options are as follows:

**Option 1**: One new well at the Delthorne Park site (2) and a second new well located at the Torrance Civic Center Swimming Pool green space site (9). **Figure 4-2** shows this groundwater production well option.

**Option 2**: One new well at the Delthorne Park site (2) and a second new well at the Torrance Police Department parking area (7). **Figure 4-3** shows this groundwater production well option.

**Option 3**: One new well at the Torrance Civic Center Swimming Pool green space site (9) and a second new well at the Torrance Police Department parking area (7). **Figure 4-4** shows this groundwater production well option.

**Option 4**: One new well at the Delthorne Park site (2) and a second new well at the Panasonic Building eastern parking area (4). **Figure 4-5** shows this groundwater production well option.

**Option 5**: One new well at the Torrance Police Department parking area (7) and a second new well at the Panasonic Building eastern parking area (4). **Figure 4-6** shows this groundwater production well option.

New pipelines will be required to convey the pumped groundwater from the respective well site locations to the existing Goldsworthy Desalter site. The pumped groundwater conveyance pipeline routes are shown in the figures. The well pump equipment, wellhead facilities and pumped groundwater conveyance pipeline facilities are described in greater detail in Section 5 of this report, with the described facilities serving as the basis for estimation of construction cost for the various alternatives.

#### 4.1.3.3 Alternative Feasibility

As previously stated, the Goldsworthy Desalter was originally designed and constructed to accommodate expansion from a combined treated water capacity of 2.5 mgd to 5 mgd at minimal cost and that two new groundwater production wells will be required for this alternative in case the recommended rehabilitation of the existing Madrona No. 2 Well is unsuccessful. Each of the five options listed above were identified as potential backup options in case the preferred well siting option(s) were to become unavailable for any reason. Based on the foregoing, the alternative to expand the existing Goldsworthy Desalter is considered a viable alternative for further consideration.

CH2MHILL®

# POTABLE WATER
# PURCHASED PRODUCED

| MWD Purchases | | | MWD Purchases | | | MWD Purchases | | |
|---|---|---|---|---|---|---|---|---|
| 2014 | Acre Feet | \ccumulativ | 2013 | Acre Feet | \ccumulativ | 2012 | Acre Feet | \ccumulativ |
| January | 1,443.60 | 1,443.60 | January | 1,119.40 | 1,119.40 | January | 1,163.90 | 1,163.90 |
| February | 1,020.70 | 2,464.30 | February | 1,056.80 | 2,176.20 | February | 1,032.40 | 2,196.30 |
| March | 1,270.80 | 3,735.10 | March | 1,282.20 | 3,458.40 | March | 1,237.30 | 3,433.60 |
| April | 1,341.60 | 5,076.70 | April | 1,285.90 | 4,744.30 | April | 1,131.90 | 4,565.50 |
| May | 1,622.50 | 6,699.20 | May | 1,469.70 | 6,214.00 | May | 1,390.20 | 5,955.70 |
| June | 0.00 | 6,699.20 | June | 1,552.90 | 7,766.90 | June | 1,462.40 | 7,418.10 |
| July | | | July | 1,739.30 | 9,506.20 | July | 1,599.60 | 9,017.70 |
| August | | | August | 1,631.50 | 11,137.70 | August | 1,657.90 | 10,675.60 |
| September | | | September | 1,509.10 | 12,646.80 | September | 1,753.60 | 12,429.20 |
| October | | | October | 1,400.30 | 14,047.10 | October | 1,638.20 | 14,067.40 |
| November | | | November | 1,261.00 | 15,308.10 | November | 1,374.60 | 15,442.00 |
| December | | | December | 1,393.10 | 16,701.20 | December | 1,064.40 | 16,506.40 |
| Total Purch | 6,699.20 | | Total Purch | 16,701.20 | 80.9 | Total Purch | 16,506.40 | |

| WRD Desalter Purchases | | | WRD Desalter Purchases | | | WRD Desalter Purchases | | |
|---|---|---|---|---|---|---|---|---|
| 2014 | Acre Feet | \ccumulativ | 2013 | Acre Feet | \ccumulativ | 2012 | Acre Feet | \ccumulativ |
| January | 20.14 | 20.14 | January | 172.23 | 172.23 | January | 166.17 | 166.17 |
| February | 142.06 | 162.20 | February | 160.67 | 332.90 | February | 118.15 | 284.32 |
| March | 141.65 | 303.85 | March | 150.15 | 483.05 | March | 160.75 | 445.07 |
| April | 68.55 | 372.40 | April | 139.52 | 622.57 | April | 174.27 | 619.34 |
| May | 0.00 | 372.40 | May | 171.84 | 794.41 | May | 173.75 | 793.09 |
| June | | 372.40 | June | 126.42 | 920.83 | June | 164.77 | 957.86 |
| July | | | July | 0.00 | 920.83 | July | 158.77 | 1,116.63 |
| August | | | August | 120.24 | 1,041.07 | August | 160.12 | 1,276.75 |
| September | | | September | 169.67 | 1,210.74 | September | 0.00 | 1,276.75 |
| October | | | October | 169.76 | 1,380.50 | October | 0.00 | 1,276.75 |
| November | | | November | 147.39 | 1,527.89 | November | 0.00 | 1,276.75 |
| December | | | December | 39.42 | 1,567.31 | December | 149.93 | 1,426.68 |
| Total Purch | 372.40 | | Total Purch | 1,567.31 | 7.6% | Total Purch | 1,426.68 | |

| Well #9 Production | | | Well #9 Production | | | Well #9 Production | | |
|---|---|---|---|---|---|---|---|---|
| 2014 | Acre Feet | \ccumulativ | 2013 | Acre Feet | \ccumulativ | 2012 | Acre Feet | \ccumulativ |
| January | 234.79 | 234.79 | January | 165.32 | 165.32 | January | 212.90 | 212.90 |
| February | 199.90 | 434.69 | February | 150.64 | 315.96 | February | 203.16 | 416.06 |
| March | 109.03 | 543.72 | March | 171.28 | 487.24 | March | 214.38 | 630.44 |
| April | 200.17 | 743.89 | April | 227.27 | 714.51 | April | 196.76 | 827.20 |
| May | | 743.89 | May | 231.36 | 945.87 | May | 201.09 | 1,028.29 |
| June | | 743.89 | June | 198.80 | 1,144.67 | June | 197.04 | 1,225.33 |
| July | | | July | 240.97 | 1,385.64 | July | 188.98 | 1,414.31 |
| August | | | August | 231.99 | 1,617.63 | August | 204.47 | 1,618.78 |
| September | | | September | 187.11 | 1,804.74 | September | 198.66 | 1,817.44 |
| October | | | October | 215.89 | 2,020.63 | October | 160.82 | 1,978.26 |
| November | | | November | 231.40 | 2,020.63 | November | 160.58 | 2,138.84 |
| December | | | December | 105.47 | 2,020.63 | December | 115.93 | 2,254.77 |
| | 743.89 | | | 2,357.50 | 11.4 | | 2,254.77 | |

| Well #7 Production | | | Well #7 Production | | | Well #7 Production | | |
|---|---|---|---|---|---|---|---|---|
| 2014 | Acre Feet | \ccumulativ | 2013 | Acre Feet | \ccumulativ | 2012 | Acre Feet | \ccumulativ |
| January | 0.00 | 0.00 | January | 0.00 | 0.00 | January | 0.00 | 0.00 |
| February | 0.00 | 0.00 | February | 0.00 | 0.00 | February | 0.00 | 0.00 |
| March | 0.00 | 0.00 | March | 0.00 | 0.00 | March | 0.00 | 0.00 |
| April | 0.00 | 0.00 | April | 0.00 | 0.00 | April | 0.00 | 0.00 |
| May | 0.00 | 0.00 | May | 0.00 | 0.00 | May | 0.00 | 0.00 |
| June | 0.00 | 0.00 | June | 0.00 | 0.00 | June | 0.00 | 0.00 |
| July | | | July | 0.00 | | July | 0.00 | |
| August | | | August | | | August | 0.00 | |
| September | | | September | | | September | 0.00 | |
| October | | | October | | | October | 0.00 | |
| November | | | November | | | November | 0.00 | |
| December | | | December | | | December | 0.00 | |
| | 0.00 | | | 0.00 | | | 0.00 | |
| Total Produ | 7,815.49 | | Total Produ | 20,626.01 | | Total Produ | 20,187.85 | |

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MWD WRD Well 6
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# POTABLE WATER
# PURCHASED PRODUCED

| MWD Purchases | | | MWD Purchases | | | MWD Purchases | | |
|---|---|---|---|---|---|---|---|---|
| 2012 | Acre Feet | ccumulativ | 2011 | Acre Feet | ccumulativ | 2010 | Acre Feet | ccumulativ |
| January | 1,163.90 | 1,163.90 | January | 1,250.10 | 1,250.10 | January | 1,047.20 | 1,047.20 |
| February | 1,032.40 | 2,196.30 | February | 1,128.10 | 2,378.20 | February | 748.60 | 1,795.80 |
| March | 1,237.30 | 3,433.60 | March | 1,022.60 | 3,400.80 | March | 1,125.30 | 2,921.10 |
| April | 1,131.90 | 4,565.50 | April | 1,410.60 | 4,811.40 | April | 1,311.40 | 4,232.50 |
| May | 1,390.20 | 5,955.70 | May | 1,697.30 | 6,508.70 | May | 1,550.80 | 5,783.30 |
| June | 1,462.40 | 7,418.10 | June | 1,598.30 | 8,107.00 | June | 1,493.70 | 7,277.00 |
| July | 1,599.60 | 9,017.70 | July | 1,697.80 | 9,804.80 | July | 1,603.80 | 8,880.80 |
| August | 1,657.90 | 10,675.60 | August | 1,655.00 | 11,459.80 | August | 1,684.10 | 10,564.90 |
| September | 1,753.60 | 12,429.20 | September | 1,537.70 | 12,997.50 | September | 1,859.90 | 12,424.80 |
| October | 1,638.20 | 14,067.40 | October | 1,470.00 | 14,467.50 | October | 1,520.80 | 13,945.60 |
| November | 1,374.60 | 15,442.00 | November | 1,115.10 | 15,582.60 | November | 1,388.20 | 15,333.80 |
| December | 1,064.40 | 16,506.40 | December | 1,192.80 | 16,775.40 | December | 1,222.70 | 16,556.50 |
| Total Purch | 16,506.40 | | Total Purch | 16,775.40 | | Total Purch | 16,556.50 | |

| WRD Desalter Purchases | | | WRD Desalter Purchases | | | WRD Desalter Purchases | | |
|---|---|---|---|---|---|---|---|---|
| 2012 | Acre Feet | ccumulativ | 2011 | Acre Feet | ccumulativ | 2010 | Acre Feet | ccumulativ |
| January | 166.17 | 166.17 | January | 167.11 | 167.11 | January | 63.73 | 63.73 |
| February | 118.15 | 284.32 | February | 134.84 | 301.95 | February | 172.41 | 236.14 |
| March | 160.75 | 445.07 | March | 175.23 | 477.18 | March | 101.38 | 337.52 |
| April | 174.27 | 619.34 | April | 0.00 | 477.18 | April | 0.00 | 337.52 |
| May | 173.75 | 793.09 | May | 0.00 | 477.18 | May | 33.27 | 370.79 |
| June | 164.77 | 957.86 | June | 107.85 | 585.03 | June | 179.58 | 550.37 |
| July | 158.77 | 1,116.63 | July | 185.49 | 770.52 | July | 191.43 | 741.80 |
| August | 160.12 | 1,276.75 | August | 155.46 | 925.98 | August | 132.91 | 874.71 |
| September | 0.00 | 1,276.75 | September | 103.44 | 1,029.42 | September | 0.00 | 874.71 |
| October | 0.00 | 1,276.75 | October | 97.54 | 1,126.96 | October | 0.00 | 874.71 |
| November | 0.00 | 1,276.75 | November | 171.47 | 1,298.43 | November | 147.69 | 1,022.40 |
| December | 0.00 | 1,276.75 | December | 165.95 | 1,464.38 | December | 203.59 | 1,225.99 |
| Total Purch | 1,276.75 | | Total Purch | 1,464.38 | | Total Purch | 1,225.99 | |

| Well #9 Production | | | Well #6 Production | | | Well #6 Production | | |
|---|---|---|---|---|---|---|---|---|
| 2012 | Acre Feet | ccumulativ | 2011 | Acre Feet | ccumulativ | 2010 | Acre Feet | ccumulativ |
| January | 212.90 | 212.90 | January | 0.00 | 0.00 | January | 84.69 | 84.69 |
| February | 203.16 | 416.06 | February | 0.00 | 0.00 | February | 83.45 | 168.14 |
| March | 214.38 | 630.44 | March | 161.87 | 161.87 | March | 91.29 | 259.43 |
| April | 196.76 | 827.20 | April | 171.53 | 333.40 | April | 86.15 | 345.58 |
| May | 201.09 | 1,028.29 | May | 155.38 | 488.78 | May | 83.47 | 429.05 |
| June | 197.04 | 1,225.33 | June | 198.53 | 687.31 | June | 80.51 | 509.56 |
| July | 188.98 | 1,414.31 | July | 208.96 | 896.27 | July | 78.36 | 587.92 |
| August | 204.47 | 1,618.78 | August | 221.61 | 1,117.88 | August | 85.20 | 673.12 |
| September | 198.66 | 1,817.44 | September | 215.42 | 1,333.30 | September | 27.09 | 700.21 |
| October | 160.82 | 1,978.26 | October | 218.61 | 1,551.91 | October | 71.52 | 771.73 |
| November | 160.58 | 2,138.84 | November | 211.61 | 1,763.52 | November | 81.86 | 853.59 |
| December | 0.00 | 2,138.84 | December | 218.60 | 1,982.12 | December | 0.52 | 854.11 |
| | 2,138.84 | | | 1,982.12 | | | 854.11 | |

| Well #7 Production | | | Well #7 Production | | | Well #7 Production | | |
|---|---|---|---|---|---|---|---|---|
| 2012 | Acre Feet | ccumulativ | 2011 | Acre Feet | ccumulativ | 2010 | Acre Feet | ccumulativ |
| January | 0.00 | 0.00 | January | 0.00 | 0.00 | January | 0.00 | 0.00 |
| February | 0.00 | 0.00 | February | 0.00 | 0.00 | February | 0.00 | 0.00 |
| March | 0.00 | 0.00 | March | 0.00 | 0.00 | March | 0.00 | 0.00 |
| April | 0.00 | 0.00 | April | 0.00 | 0.00 | April | 0.00 | 0.00 |
| May | 0.00 | 0.00 | May | 0.00 | 0.00 | May | 0.00 | 0.00 |
| June | 0.00 | 0.00 | June | 0.00 | 0.00 | June | 0.00 | 0.00 |
| July | 0.00 | | July | 0.00 | 0.00 | July | 0.00 | 0.00 |
| August | 0.00 | | August | 0.00 | 0.00 | August | 0.00 | 0.00 |
| September | 0.00 | | September | 0.00 | 0.00 | September | 0.00 | 0.00 |
| October | 0.00 | | October | 0.00 | 0.00 | October | 0.00 | 0.00 |
| November | 0.00 | | November | 0.00 | 0.00 | November | 0.00 | 0.00 |
| December | 0.00 | | December | 0.00 | 0.00 | December | 0.00 | 0.00 |
| | 0.00 | | | 0.00 | | | 0.00 | |
| Total Produ | 19,921.99 | | Total Produ | 20,221.90 | | Total Produ | 18,636.60 | |

P:\EXCEL\Water Cost Analysis 1995 to Current
MWD WRD Well 6
Calendar Years
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1/16/2013
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| | | |
|---|---|---|
| **Torrance, City of** | Project: Torrance WRD | Work Order: 14D0401 |
| 3031 Torrance Blvd. | Sub Project: Monthly Monitoring: Madrona Well 2 | Received: 04/02/14 15:45 |
| Torrance CA, 90503 | Project Manager: Fred Molina | Reported: 04/15/14 |

**Madrona Well 2** **14D0401-01 (Water)** **Sample Date:** 04/02/14 9:15 **Sampler:** Fred Molina

| Analyte | Method | Result | Units | Rep. Limit | MCL | Prepared | Analyzed | Batch | Qualifier |
|---|---|---|---|---|---|---|---|---|---|
| **General Chemical Analyses** | | | | | | | | | |
| **Chloride (Cl)** | EPA 300.0 | **790** | mg/L | 5.0 | 500 | 04/14/14 | 04/15/14 | 1416057 | |
| **pH (Lab)** | SM 4500HB | **7.6** | pH Units | | | 04/03/14 | 04/03/14 | 1414343 | |
| **Sulfate (SO4)** | EPA 300.0 | **320** | mg/L | 0.50 | 500 | 04/04/14 | 04/05/14 | 1414389 | |
| **Total Filterable Residue/TDS** | SM 2540C | **2000** | mg/L | 5.0 | 1000 | 04/09/14 | 04/09/14 | 1415054 | |
| **Metals** | | | | | | | | | |
| **Manganese (Mn)** | EPA 200.7 | **140** | ug/L | 20 | 50 | 04/07/14 | 04/07/14 | 1415034 | |

pH (Lab) was analyzed ASAP but received and analyzed past the 15 minute hold time.

ND Analyte NOT DETECTED at or above the reporting limit

**Robin Glenney**

**Project Manager**

# Clinical Laboratory of San Bernardino, Inc.

## EDT Transfer Confirmation 1

Work Order: 14D0401

Report Date: 04/15/2014

Analyzing Lab: Clinical Laboratory of San Bernardino, Inc. ELAP 1088

TORRANCE-CITY, WATER DEPT. User ID: 4TH System: 1910213

MADRONA WELL 2 Station No.: 1910213-009 Sampled: 140402 09:15

| | | | | |
|---|---|---|---|---|
| PH (LABORATORY) | Result: 7.6 | Units: UNITS | Entry No.: 00403 | Analyzed: 140403 |
| CHLORIDE | Result: 790 | Units: MG/L | Entry No.: 00940 | Analyzed: 140415 |
| SULFATE | Result: 320 | Units: MG/L | Entry No.: 00945 | Analyzed: 140405 |
| MANGANESE | Result: 140 | Units: UG/L | Entry No.: 01055 | Analyzed: 140407 |
| TOTAL DISSOLVED SOLIDS | Result: 2000 | Units: MG/L | Entry No.: 70300 | Analyzed: 140409 |

Printed: 04/15/2014 01:51:38 PM Results of 14D0401 FINAL WRITEON 1910213-009

**Clinical Laboratory of San Bernardino, Inc.** P **Chain of Custody**

14D0401

| | | | |
|---|---|---|---|
| **Client** | City of Torrance | **System Number** | |
| **Address** | 20500 Madrona Avenue<br>Torrance, CA 90503 | 1910213 | |
| **Contact** | *Fred Molina* | **Email Address:** | Fmolina@TorranceCA.Gov |
| **Phone #** | (310) 781-6961 | **Fax #:** | (310) 618-6256 |
| **Project** | *WRD* | **Reporting Requests:** | |
| **Sub Project** | Monthly Monitoring: Madrona Well 2 | ( ) State EDT<br>( ) Test Share<br>( ) CC's To:____ | |
| **Sampled by** | Molina | (☒) RUSH REQUEST 5 days *upon laboratory approval | |

| Date | Time | Sample Identification | Matrix | Type | Preservatives | Bottle Number | Total Chlorine | Temp C | Sulfate | Chloride | TDS | Manganese | pH | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4/2 | 9:15a | Madrona Well 2 | DW | 1 | 7 | 1 | | | X | X | X | X | X | | | 1910213-009 |

*Matrix:* DW-Drinking Water, WW-Waste Water, SW-Storm Water, GW- Ground Water *Type* 1-Routine, 2-Repeat, 3-Replacement, 4-Special *Preservative* (1) Na2S2O3 (2) HCl (3) HNO3 (4) NH4Cl (5) H2SO4 (6) Na2SO3 (7) Cold (8) Other:____

| Relinquished By (Sign) | Print Name / Company | Date / Time | Received By (Sign) | Print Name / Company |
|---|---|---|---|---|
| | Torrance | 4-2-14 1:15 | | CLSB |
| | CLSB | " 3:45 | | |

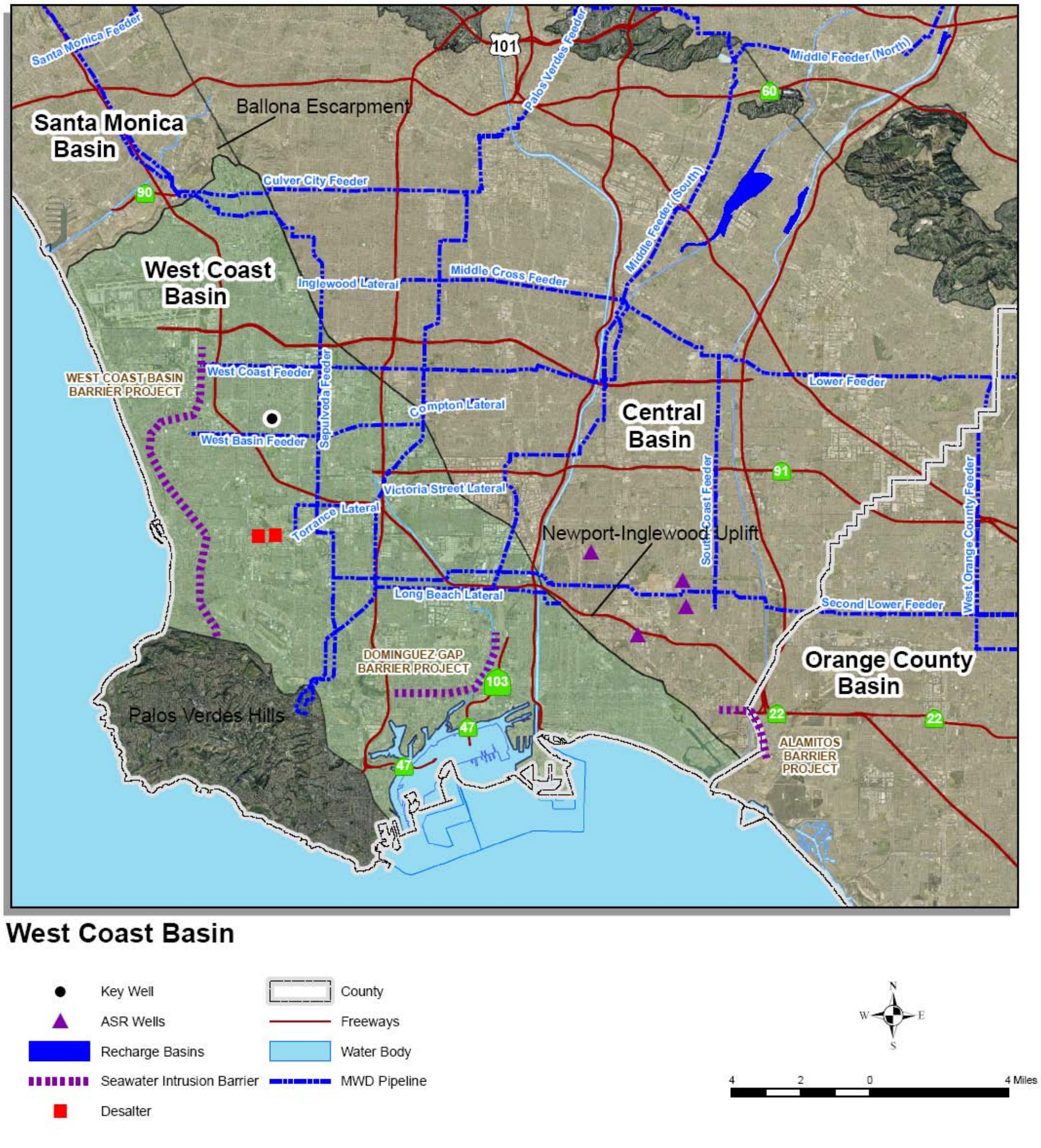
*Samples received:* (✓) *On ice* ( ) *Intact* ( ) *Custody seals Temp* 9 ( ) F (✓) C

*ELAP # 1088*

*Page*

The West Coast Basin lies along the coast in western Los Angeles County. It overlies the service areas of Metropolitan member agencies: West Basin Municipal Water District (WBMWD), City of Los Angeles, City of Torrance, and the City of Long Beach. The cities of El Segundo, Manhattan Beach, Hermosa Beach, Redondo Beach, Torrance, Inglewood, Hawthorne, Gardena, Lomita, Carson and Long Beach overlie the basin. A map of the West Coast Basin is provided in **Figure 4-1**.

**Figure 4-1**
**Map of the West Coast Basin**



## BASIN CHARACTERIZATION

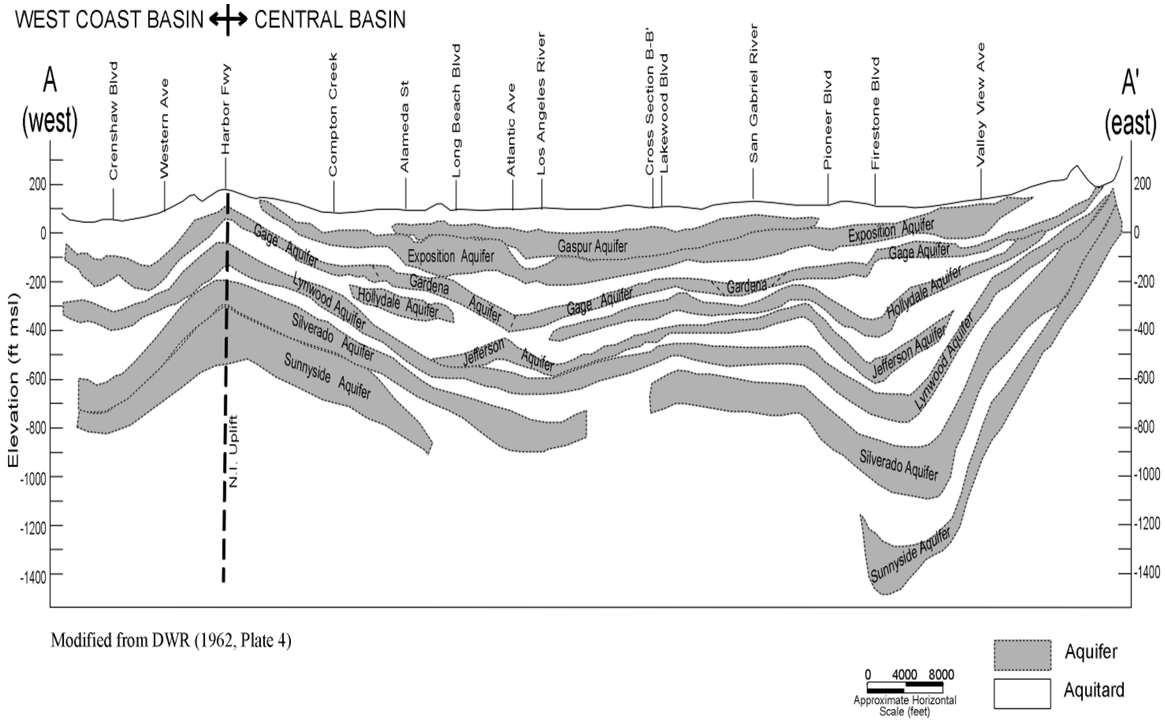
The following section provides a physical description of the West Coast Basin, including its geographic location and hydrogeologic character.

### Basin Producing Zones and Storage Capacity

The West Coast Basin is bounded on the south and west by the Pacific Ocean, on the north by the Ballona Escarpment, on the east by the Newport-Inglewood Uplift, and on the south by the Palos Verdes Hills (DWR, 2005). Hydrogeologic parameters for the West Coast Basin are summarized in **Table 4-1**.

Groundwater in the West Coast Basin is generally confined. The Silverado aquifer underlying most of West Coast Basin is the most productive aquifer in the basin. It ranges from 100 to 500 feet thick and yields 80 to 90 percent of the groundwater extracted annually (DWR, 2004). This aquifer generally correlates with the Main aquifer of Orange County. A generalized cross section is shown in **Figure 4-2**. Minor yield also comes from the Gage, or "200-foot sand", aquifer, the Lynwood, or "400-foot gravel", aquifer and the Sunnyside, or Lower San Pedro aquifer.

**Figure 4-2**
**Generalized Hydrogeologic Cross Section of West Coast Basin and Central Basin**



Source: WRD, 2004

### Table 4-1
### Summary of Hydrogeologic Parameters of West Coast Basin

| Parameter | Description |
|---|---|
| **Structure** | |
| Aquifer(s) | Pressure area (confined)<br>• Alluvium (Gaspur and Semi-perched aquifers)<br>• Lakewood Formation (Gardena and Gage “200-foot sand” aquifers)<br>• San Pedro Formation (Lynwood “400-foot gravel”, Silverado, and Sunnyside aquifers) |
| Depth of groundwater basin | ~800 to 2,000 feet |
| Thickness of water-bearing units | Alluvium (up to 180 feet)<br>Lakewood Formation (up to 320 feet)<br>San Pedro Formation (up to 1,050 feet) |
| **Yield and storage** | |
| Natural safe yield | 26,300 AFY (WRD, 2006e) |
| Adjudicated Rights | 64,468.25 AFY |
| Total Storage | 6.5 million AF |
| Unused Storage Space | 1.1 million AF |
| Portion of Unused Storage Space Available for Storage | 120,000 AF |

Source: WRD, 2006c and 2006e and DWR, 2004.

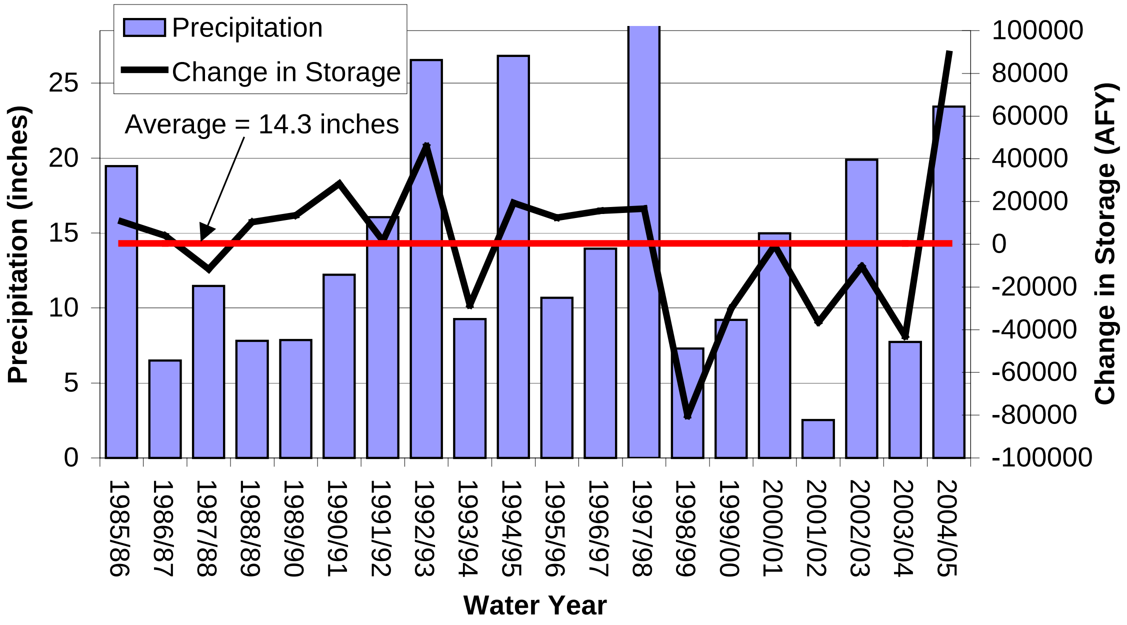
Total storage in the West Coast Basin is estimated to be approximately 6.5 million AF. Unused storage space is estimated to be approximately 1.1 million AF. Of the unused storage space, the amount available for groundwater storage is approximately 120,000 AF assuming that up to 75 feet below the ground surface is actually available (WRD, 2006e).

**Safe Yield/Long-Term Balance of Recharge and Discharge**

**Figure 4-3** shows the historical precipitation as it relates to the change in storage calculated by WRD (2006c). These data show that the average precipitation in the West Coast Basin is approximately 14.3 inches per year. In general, storage in the West Coast Basin increases during wet years and decreases during dry years. The average change in storage in the combined Central and West Coast Basins since 1985 was approximately 1,300 AFY, suggesting that the basins are nearly balanced.

The primary source of natural recharge to the West Coast Basin is subsurface inflow from the Central Basin and surface inflow into the uppermost aquifers from rainfall. This natural safe yield, which represents the yield as a result of native waters alone, of the West Coast Basins has been estimated by WRD to be approximately 26,300 AFY (WRD, 2006e), of which approximately 7,100 AFY is from seawater intrusion (WRD, 2006e). The managed safe yield of West Coast Basin is equal to the 64,468.25 AFY (the adjudicated production limit discussed below), which is substantially higher than the natural safe yield. This higher yield is possible because of artificial recharge maintained by the Water Replenishment District of Southern California (WRD).

**Figure 4-3**
**Historical Precipitation and Change in Storage for West Coast Basin**



## GROUNDWATER MANAGEMENT

The following section describes how the West Coast Basin is currently managed.

### Basin Governance

The West Coast Basin is adjudicated. The West Coast Basin adjudication (Judgment) was finalized in 1961 and capped annual production at 64,468 AFY. The Judgment allows annual carryover of unpumped adjudicated right not to exceed 20 percent and also allows up to 20 percent excess production to be made up by under-production the following year. The Judgment also allows up to 10,000 AF of emergency overpumping under specified conditions. The California Department of Water Resources (DWR) serves as Watermaster. The Water Replenishment District of Southern California (WRD), established in 1959, has the statutory authority to replenish the groundwater basin and address water quality issues. The

Los Angeles County Department of Public Works (LACDPW) owns and operates the West Coast Barrier Project and the Dominguez Gap Barrier Project. WRD procures imported and recycled water to be recharged by LACDPW at these facilities.

**Table 4-2** provides a list of the management agencies in the West Coast Basin.

Each year WRD makes a determination of the amount of supplemental recharge that is needed based on an estimation of the ensuing year's groundwater production and an estimation of the annual change in storage based on groundwater levels collected throughout the basin.

The WRD adopted Interim Rules for Conjunctive Use Storage and In-Lieu Exchange and Recovery in the Central and West Coast Basins in May 2005. The rules govern storage in the basins outside and above the adjudicated water rights that would utilize up to 450,000 AF (120,000 AF in West Coast Basin and 330,000 AF in Central Basin) of unused space in the two basins. As of June 2006, the interim rules were the subject of on-going controversy among some groundwater producers in the basins and WRD.

**Table 4-2**
**Summary of Management Agencies in the West Coast Basin**

| Agency | Role |
|---|---|
| California Department of Water Resources | Court appointed Watermaster to administer the Judgment |
| Water Replenishment District of Southern California | Replenish groundwater, address water quality, administer storage in Central and West Coast Basins |
| Los Angeles County Department of Public Works | Operation of West Coast Barrier Project and Dominguez Gap Barrier Project facilities |
| California Regional Water Quality Control Board – Los Angeles Region (Regional Board) | Issuance of permit for injection of recycled water in seawater intrusion barriers |

**Note**: WRD's authority to administer storage is the subject of disagreement among basin parties.

Available storage capacity addressed by WRD Interim Rules is 450,000 acre-feet (a portion of this is in Central Basin). This estimated capacity is based upon modeling and takes into account water level requirements but not soil or water quality issues that could reduce the available storage capacity.

## Interactions with Adjoining Basins

The Newport Inglewood Uplift is a major structural feature that acts as a partial barrier to groundwater flow between the Central and West Coast Basins. Discontinuities associated with Charnock and Overland faults in West Coast Basin also appear to affect groundwater flow

(USGS, 2003). Approximately 7,100 AFY is estimated to enter the West Coast Basin from the ocean (WRD, 2006e;USGS, 2003). Most of this occurs on the seaward side of the barriers or in areas where production does not occur.

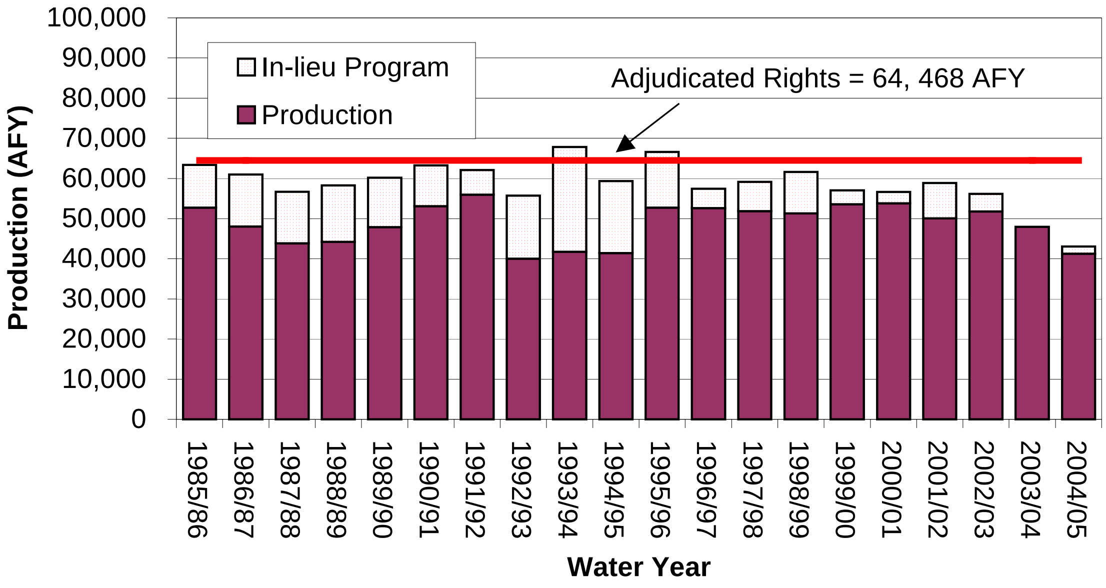
## WATER SUPPLY FACILITIES AND OPERATIONS

The following provides a summary of the facilities within the West Coast Basin. Key storage and extraction facilities include 111 production wells and associated facilities, 247 injection wells associated with the Dominguez Gap and West Coast Basin Barrier Projects, 514 monitoring wells and two desalters (DWR, 2005).

### Municipal Production Wells

There are currently 111 municipal production wells in the West Coast Basin, 63 active wells and 48 inactive wells (DWR, 2005). There are also 761 other wells in the basin that include groundwater monitoring wells or seawater intrusion barrier wells. These data are provided in **Table 4-3**. Historical production from all sources between water years 1985/86 and 2004/05 is shown in **Figure 4-4**. An average of approximately 48,797 AFY was produced from the West Coast Basin between water years 1985/86 and 2004/05. This average is nearly 16,000 AFY less than the allowable extractions under the Judgment.

**Figure 4-4**
**Historical Groundwater Production in the West Coast Basin**



West Coast Basin producers participate in an in-lieu groundwater replenishment programs whereby they receive imported water from Metropolitan in lieu of pumping groundwater.

Between water years 1985/86 and 2004/05, about 9,800 AFY was stored in-lieu. These and other storage programs are discussed in more detail below.

**Table 4-3**
**Summary of Production Wells in the West Coast Basin**

| Category | Number of Wells | Estimated Production Capacity (AFY) | Average Production 1985-2004 (AFY) | Well Operation Cost ($/AF) |
|---|---|---|---|---|
| Municipal | 111 | Data not available | 48,797 | $65 Pumping Cost |
| Active | 63 | | | |
| Inactive | 48 | | | |
| Other | 761 | | | |
| **Total** | **872** | | | |

Source: WRD, 2006d and DWR, 2005

### Other Production

Production data provided above includes water that is desalted by the Goldsworthy and Brewer desalters. These facilities are discussed in more detail below.

### ASR Wells

There are no ASR wells in the West Coast Basin.

### Spreading Basin

There are no spreading basins in the West Coast Basin.

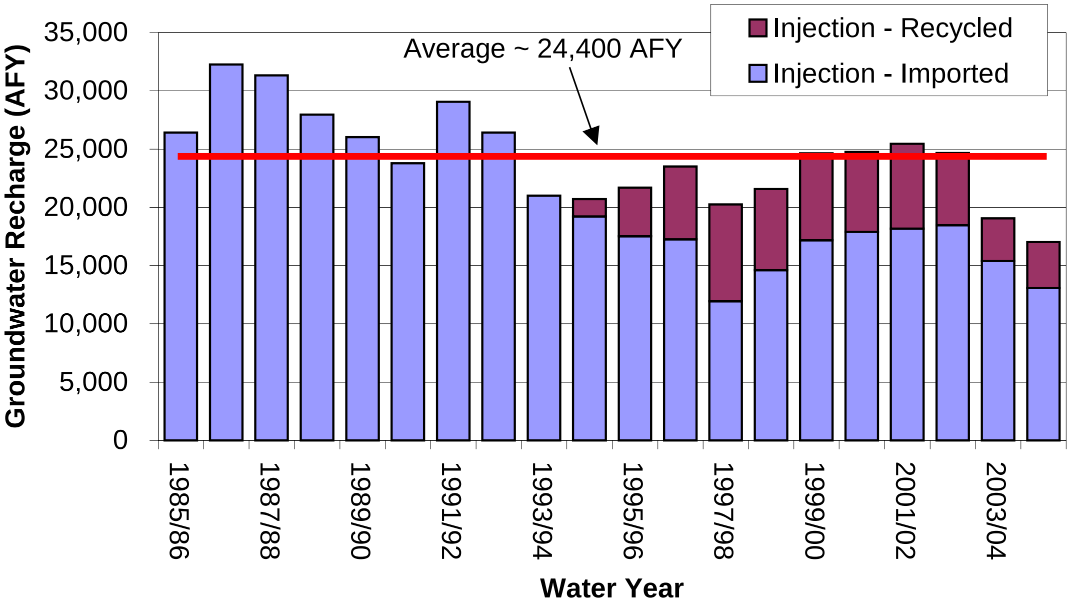
### Seawater Intrusion Barriers

There are two seawater intrusion barriers in the West Coast Basin: the West Coast Basin Barrier Project and the Dominguez Gap Barrier Project. Amounts of water injected are summarized in **Figure 4-5**. An average of about 24,400 AFY was injected into these barriers between water years 1985/86 and 2004/05.

The West Coast Basin Barrier Project, which began operation in 1953, is a line of 153 injection wells that parallels the coastline from Los Angeles International Airport to the Palos Verdes Hills. It is owned and operated by the Los Angeles County Department of Public Works. Since 1995, the West Coast Basin Barrier Project has injected an approximate 35 percent blend of imported water from Metropolitan and tertiary (including reverse osmosis) treated wastewater from the Hyperion Plant. It injects water into the "200-foot sand", Silverado and Lower San Pedro aquifers to impede seawater intrusion (LACDPW, 2006).

The Dominguez Gap Barrier Project began operation in 1971. The barrier currently comprises a line of 41 injection wells and 107 observation wells along the Dominguez Channel to the 110 Freeway in the City of Carson (LACDPW, 2006). Imported water from Metropolitan is currently injected into the "200-foot sand," "400-foot gravel" and Silverado aquifers in this area. WRD, LACDPW, and LADWP initiated delivery of recycled water to this barrier in 2006.

**Figure 4-5**
**Historical Groundwater Recharge in the West Coast Basin**



## Desalters

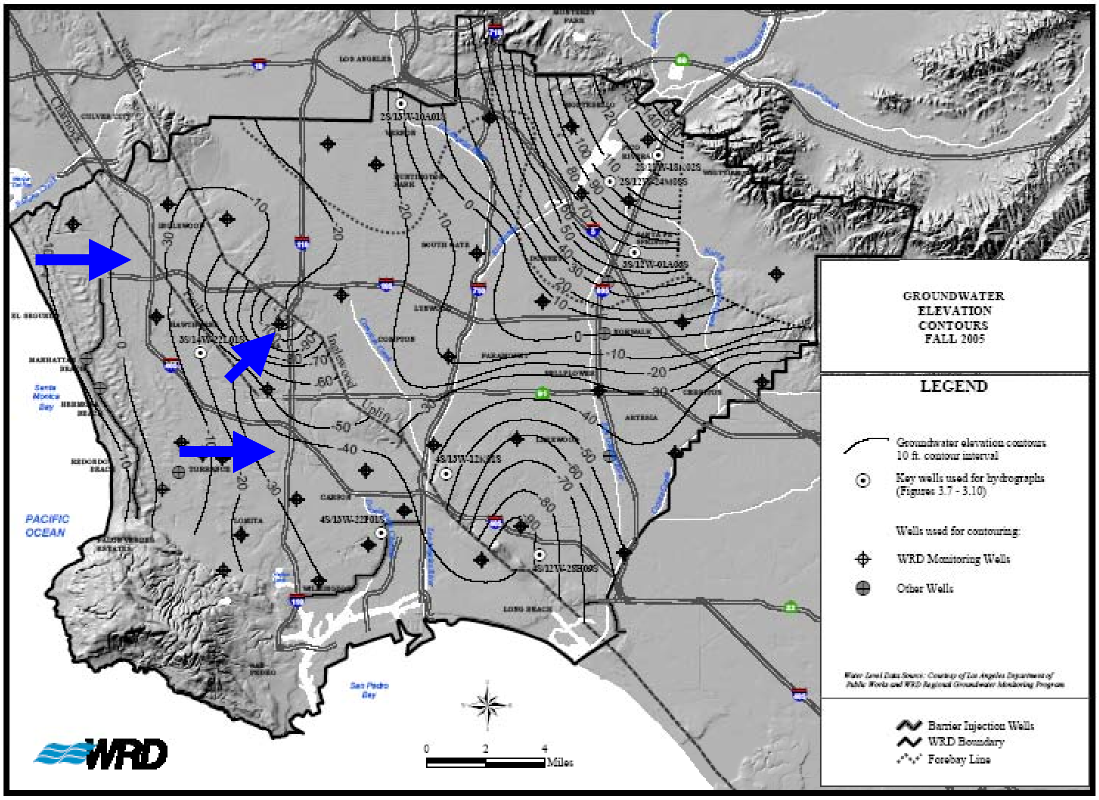
Two desalter projects used to treat brackish groundwater trapped within the Silverado aquifer on the landward side of the West Coast Basin Barrier Project are operating within the City of Torrance: Brewer Desalter and the Goldsworthy Desalter. An average of about 2,500 AFY was treated by the two desalters as of 2004/05. The Brewer Desalter was constructed by WBMWD in 1993 and is now operated by California Water Service Company. The capacity of the Brewer Desalter is 1.5 MGD. The Brewer Desalter was offline during 2004 and 2005 during the construction of a new desalter well.

WRD constructed and has operated the Goldsworthy Desalter since 2001. An average of approximately 1,900 AFY was treated between 2001 and the end of water year 2004/05.

## GROUNDWATER LEVELS

As shown in **Figure 4-6** groundwater levels in fall 2005 range from about 10 feet above MSL in the northern part of the basin to more than 110 feet below MSL inland near the community of Gardena. Groundwater levels throughout most of the West Coast Basin are below sea level and generally flow from the west-northwest to the east-southeast.  In the key well shown in **Figure 4-7**, water levels increased about 10 feet between water years 1985/86 and 2004/05, which is consistent with the water balance discussed above.

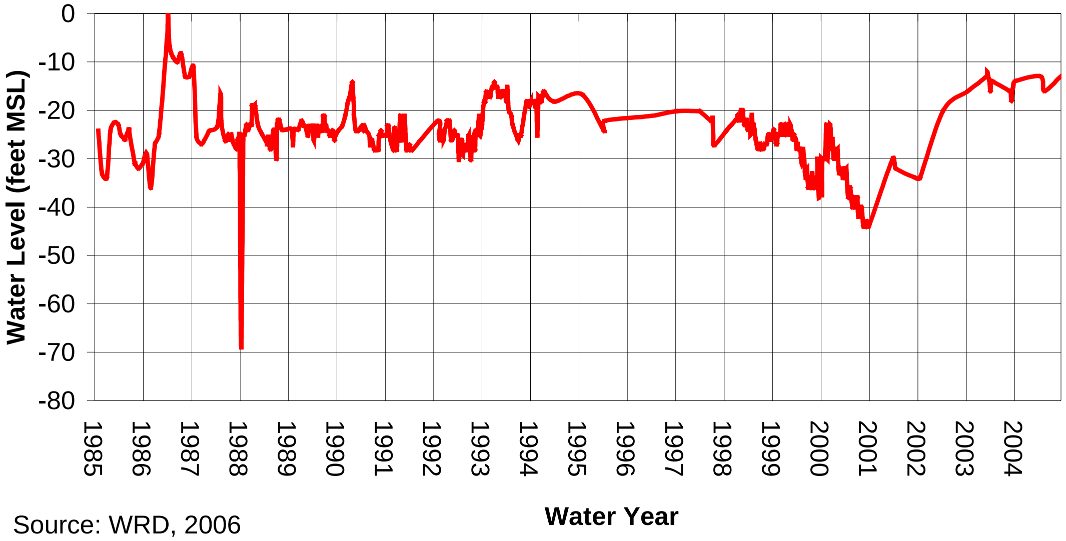
**Figure 4-6**
**Groundwater Contour Map in the West Coast Basin – Fall 2005**



## GROUNDWATER QUALITY

In general, groundwater in the main producing aquifers of the basins is of good quality with average total dissolved solids (TDS) concentrations around 500 mg/L.  Localized areas of marginal to poor water quality exist, primarily on the basin margins and in the shallower and deeper aquifers impacted by seawater intrusion.  The following section provides a brief description of the groundwater quality issues in the West Coast Basin.

**Figure 4-7**
**Historical Water Levels in West Coast Basin**



Source: WRD, 2006

## Groundwater Quality Monitoring

In 1995, WRD and the U.S. Geological Survey (USGS) began a cooperative study to improve the understanding of the geohydrology and geochemistry of Central and West Coast Basins. Out of this effort, came WRD's geographic information system (GIS) and the Regional Groundwater Monitoring Program. Twenty-one depth-specific, nested monitoring wells located throughout the basin allow water quality and groundwater levels to be evaluated on an aquifer-specific basis. Regional Groundwater Monitoring Reports are published by WRD for each water year. Constituents monitored include: TDS, iron, manganese, nitrate, TCE, PCE, arsenic, chromium including hexavalent chromium, MTBE, and perchlorate.

## Groundwater Contaminants

Constituents of concern TDS, TCE, PCE, perchlorate, nitrate, iron, manganese and chloride are summarized in **Table 4-4**. Most production wells have TDS concentrations less than 750 mg/L with a range of 150 to 13,600 mg/L in the monitoring wells measured by WRD. Higher TDS concentrations found in production wells in Torrance/Hawthorne area and in monitoring wells within the brackish plume.

Organic constituents of concern (TCE, PCE, or perchlorate) were not detected in concentrations above applicable MCLs in the West Coast Basin. Neither TCE nor PCE were detected in any production well in the West Coast Basin. TCE was detected in three monitoring wells and PCE was detected in one monitoring well.

Nitrate (as nitrogen) concentrations range from non-detect to 12 mg/L in the monitoring wells in the West Coast Basin. Higher concentrations tend to be limited to the uppermost zones and are likely due to localized infiltration and leaching. Production wells have nitrate concentrations less than 3 mg/L.

**Table 4-4**
**Summary of Constituents of Concern in the West Coast Basin**

| Constituent | Units | Range | Description |
|---|---|---|---|
| **TDS**<br>Secondary MCL = 500 | mg/L | 150 to 13,600<br>Average: 500 | Most production wells have TDS less than 750 mg/L. Higher TDS concentrations found in production wells in Torrance/Hawthorne area and in monitoring wells within saline plume. |
| **VOCs**<br>**(TCE and PCE)**<br>Primary MCL for TCE = 5<br>Primary MCL for PCE = 5 | µg/L | ND to 18 for TCE<br>ND to 0.8 for PCE | TCE nor PCE not detected in production wells. TCE detected in three monitoring wells. PCE detected in one monitoring well. |
| **Perchlorate**<br>Notification level = 6 | µg/L | Data not available | Detected in three monitoring wells below action level in shallow zones |
| **Nitrate (as N)**<br>Primary MCL = 10 | mg/L | ND to 12 mg/L | Higher concentrations tend to be limited to the uppermost zones and are likely due to localized infiltration and leaching. Production wells have concentrations less than three mg/L. |
| **Iron and manganese**<br>Secondary MCL for iron =0.3<br>Secondary MCL for Mn = 0.05 | mg/L | ND to 1.2 for iron and manganese | Nearly 1/3 of all production wells in northwestern portion of West Coast Basin exceed secondary MCL for iron. 17 of 30 production wells tested had concentrations above secondary MCL for manganese |
| **Chloride**<br>Secondary MCL = 500 | mg/L | 5.8 to 6,180 mg/L | Chloride concentrations exceed chloride MCL in five of 15 nested monitoring wells due to seawater intrusion. One production well had concentrations above MCL. |

Source: WRD, 2006b

Iron and manganese were detected in concentrations above the secondary MCL for these constituents in both monitoring wells and production wells in the basin. Nearly one-third of all production wells in northwestern portion of West Coast Basin have concentrations that exceed secondary MCL for iron. Seventeen of 30 production wells tested had concentrations above secondary MCL for manganese.

As discussed above, seawater has invaded the Silverado Aquifer along the coastal stretch of the West Coast Basin and chloride concentrations range from 1,000 to 6,000mg/l. (DWR, 2005). Chloride concentrations exceed the chloride MCL in five of 15 nested monitoring wells due to seawater intrusion. One production well had chloride concentrations above MCL.

### Blending Needs

Data related to blending needs and practices are not available for the West Coast Basin.

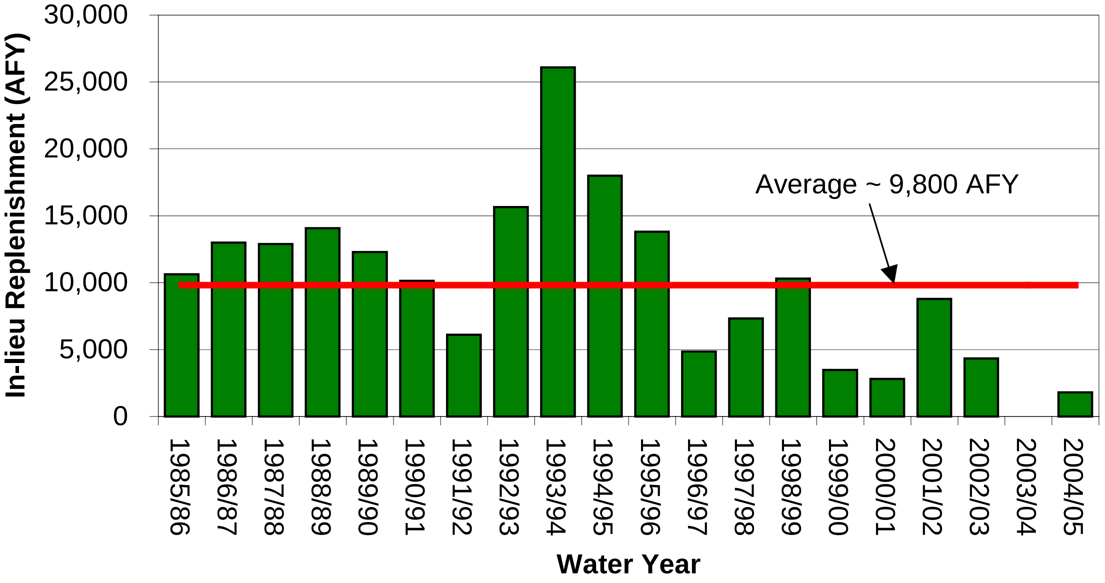
### Groundwater Treatment

As discussed above, about 2,500 AFY has been treated by the Brewer and Goldsworthy desalters since 2000. In addition, oil recovery and cleanup programs operated by the oil refineries in the West Coast Basin have treated an average of about 900 AFY since 2000. About 7 percent of the total water produced in 2004/05 in the West Coast Basin was treated. Costs for treatment are not available at this time.

## EXISTING GROUNDWATER STORAGE PROGRAMS

WRD operates an in-lieu replenishment program. An average of about 9,800 AFY of in-lieu storage has been generated in the West Coast Basin through this program since 1985. These data are summarized in **Figure 4-8**. No other formal groundwater storage programs are operational in the West Coast Basin.

**Figure 4-8**
**Historical In-lieu Storage for West Coast Basin**



## BASIN MANAGEMENT CONSIDERATIONS

Management considerations in the West Coast Basin include:

- Extraction is limited by the Judgment to 64,468 AFY.
- The Regional Board regulates injection of recycled water and limits the amount of recycled water that can be injected.
- Brackish water inland of the West Coast Basin Barrier may limit the ability to store and extract water in some parts of the basin. The Brewer and Goldsworthy Desalters have increased the ability to use this part of the basin.
- Because most of the West Coast Basin is confined, there are no identified locations for spreading.
- Disagreements related to the Interim Rules for Conjunctive Use Storage and In-Lieu Exchange and Recovery in the Central and West Coast Basins may limit the ability to store water in the West Coast Basin. At this time, the approval of storage projects is administered by WRD using the framework defined in the Interim Rules for Conjunctive Use Storage and In-Lieu Exchange and Recovery in the Central and West Coast Basins.

**References:**

California Department of Water Resources (DWR), 1961. Bulletin 104 Planned Utilization of the Ground Water Basins of Coastal Plain of Los Angeles County. Appendix A, Ground Water Geology.

California Department of Water Resources (DWR), 2004. California's Groundwater Bulletin 118 – Los Angeles County Coastal Plain West Coast Basin. Updated 2/27/04. Website: http://www.dpla2.water.ca.gov/publications/groundwater/bulletin118/basins/pdfs_desc/4-11.03.pdf Accessed 6/12/07.

California Department of Water Resources (DWR), 2005. Watermaster Service in the West Coast Basin, Los Angeles County, July 1, 2004 – June 30, 2005. September 2005.

Los Angles County Department of Public Works, 2006. Website: http://ladpw.org/wrd/Barriers/Facility.cfm. Accessed September 18, 2006.

United States Geological Survey (USGS), 2003. Water Resources Investigations Report 03-4065. Geohydrology, Geochemistry, and Ground-Water Simulation – Optimization of the Central and West Coast Basins, Los Angeles County, California.

Water Replenishment District of Southern California (WRD),2004. Technical Bulletin – An Introduction to the Central and West Coast Groundwater Basins.

Water Replenishment District of Southern California (WRD), 2006a. Website: http://www.wrd.org/articles/Century%20of%20Groundwater.htm Accessed August 24, 2006.

Water Replenishment District of Southern California (WRD), 2006b. Regional Groundwater Monitoring Report – Water Year 2004-2005, Central and West Coast Basins Los Angeles County, California, March 2006.

Water Replenishment District of Southern California (WRD), 2006c. Engineering Survey and Report, Updated June 21, 2006.

Water Replenishment District of Southern California (WRD), 2006d. Groundwater Study Questionnaire.

Water Replenishment District of Southern California (WRD), 2006e. Personal communication with Ted Johnson, September 21, 2006.

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# NEWS RELEASE

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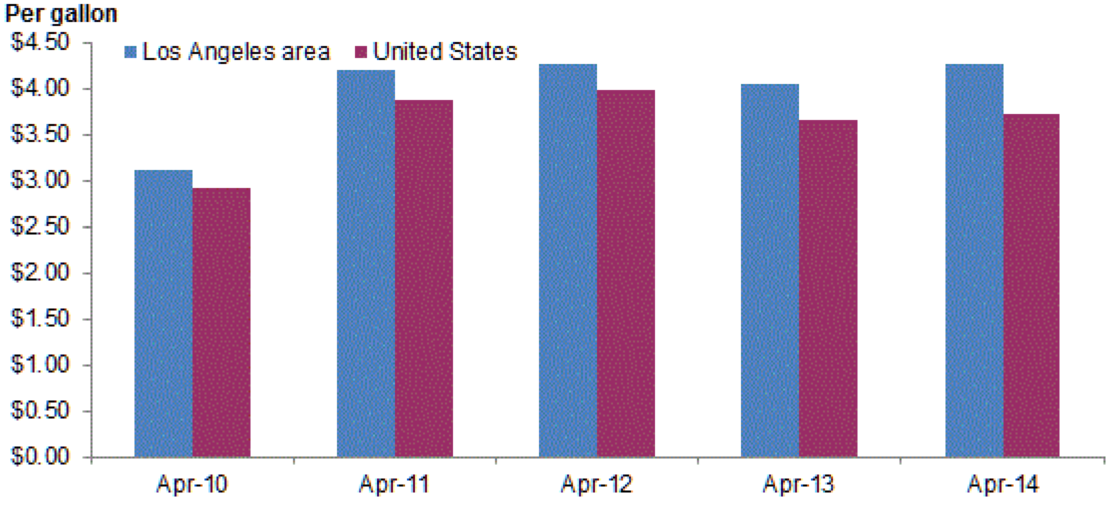
## AVERAGE ENERGY PRICES, LOS ANGELES-RIVERSIDE-ORANGE COUNTY
## APRIL 2014

Gasoline prices averaged $4.263 a gallon in the Los Angeles-Riverside-Orange County area in April 2014, the U.S. Bureau of Labor Statistics reported today. Regional Commissioner Richard J. Holden noted that area gasoline prices were down 22.0 cents compared to last April when they averaged $4.043 per gallon. Los Angeles area households paid an average of 17.8 cents per kilowatt hour (kWh) of electricity in April 2014, down from 21.6 cents per kWh in April 2013. The average cost of utility (piped) gas at $1.211 per therm in April was more than the 1.077 cents per therm spent last year. (Data in this release are not seasonally adjusted; accordingly, over-the-year-analysis is used throughout.)

At $4.263 a gallon, Los Angeles area consumers paid 14.7 percent more than the $3.717 national average in April 2014. A year earlier, consumers in the Los Angeles area paid 10.9 percent more than the national average for a gallon of gasoline. The local price of a gallon of gasoline has exceeded the national average by at least 6 percent in the month of April in each of the past five years.
(See chart 1.)

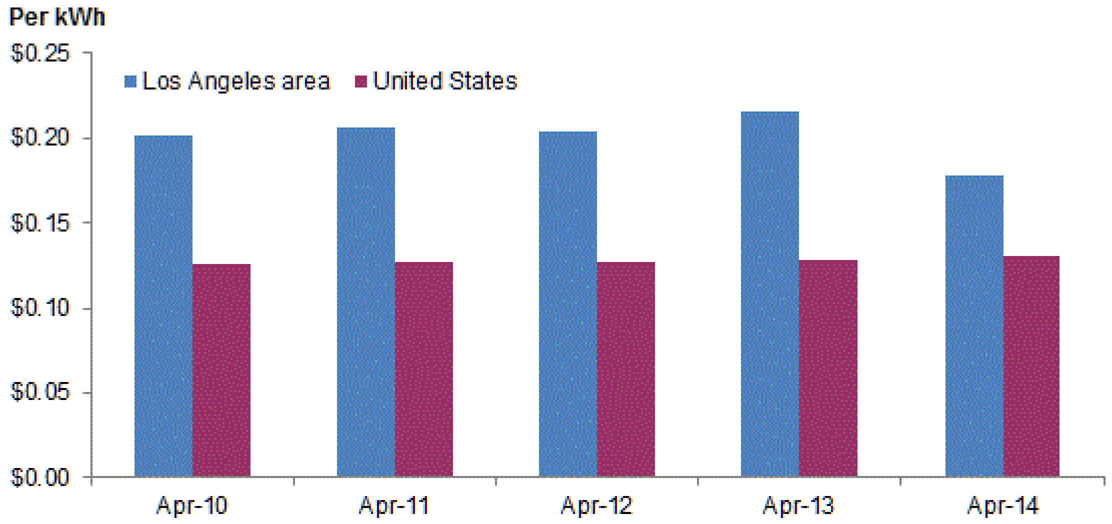
**Chart 1. Average prices for gasoline, Los Angeles-Riverside-Orange County and the United States, 2010-2014 (as of April)**



SOURCE: U.S. Bureau of Labor Statistics.

The 17.8 cents per kWh Los Angeles households paid for electricity in April 2014 was 35.9 percent more than the nationwide average of 13.1 cents per kWh. Last April, electricity costs were 68.8 percent higher in Los Angeles compared to the nation. In the past five years, prices paid by Los Angeles area consumers for electricity exceeded the U.S. average by 35.9 percent or more in the month of April. (See chart 2.)

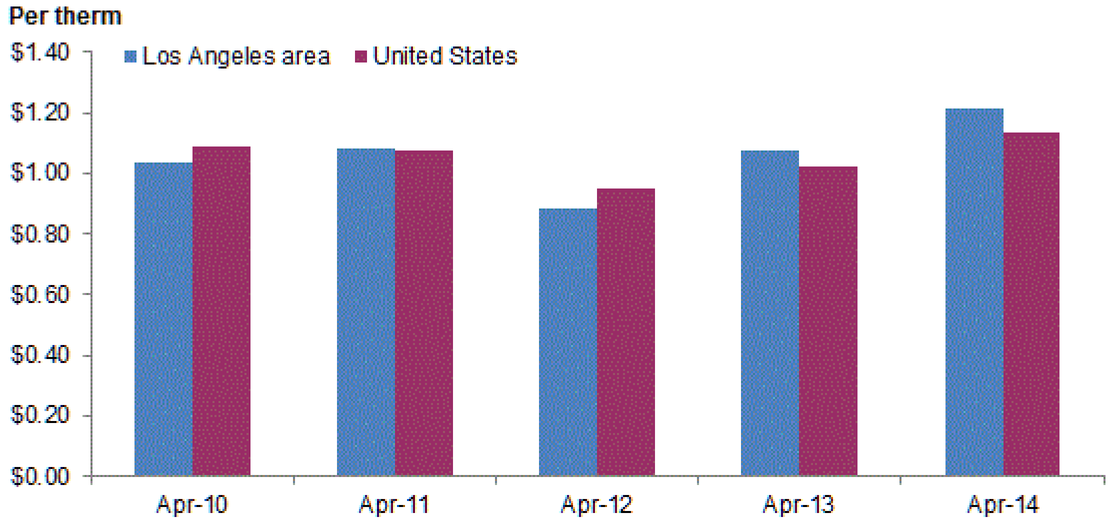
**Chart 2. Average prices for electrictity, Los Angeles-Riverside-Orange County and the United States, 2010-2014 (as of April)**



SOURCE: U.S. Bureau of Labor Statistics.

Prices paid by Los Angeles area consumers for utility (piped) gas, commonly referred to as natural gas, were $1.211 per therm, or 6.5 percent more compared to the national average in April 2014 ($1.137 per therm). A year earlier, area consumers paid 5.6 percent more per therm for natural gas compared to the nation. In the Los Angeles area over the past five years, the per therm cost for natural gas in April has varied between 7.2 percent below and 6.5 percent above the U.S. average.
(See chart 3.)

**Chart 3. Average prices for utility (piped) gas, Los Angeles-Riverside-Orange County and the United States, 2010-2014 (as of April)**



SOURCE: U.S. Bureau of Labor Statistics.

The Los Angeles-Riverside-Orange County, Calif. metropolitan area consists of Los Angeles, Orange, Riverside, San Bernardino and Ventura Counties in California.

## Technical Note

Average prices are estimated from Consumer Price Index (CPI) data for selected commodity series to support the research and analytic needs of CPI data users. Average prices for electricity, utility (piped) gas, and gasoline are published monthly for the U.S. city average, the 4 regions, the 3 population size classes, 10 region/size-class cross-classifications, and the 14 largest local index areas. For electricity, average prices per kilowatt-hour (kWh) and per 500 kWh are published. For utility (piped) gas, average prices per therm, per 40 therms, and per 100 therms are published. For gasoline, the average price per gallon is published. Average prices for commonly available grades of gasoline are published as well as the average price across all grades.

Price quotes for 40 therms and 100 therms of utility (piped) gas and for 500 kWh of electricity are collected in sample outlets for use in the average price programs only. Since they are for specified consumption amounts, they are not used in the CPI. All other price quotes used for average price estimation are regular CPI data.

With the exception of the 40 therms, 100 therms, and 500 kWh price quotes, all eligible prices are converted to a price per normalized quantity. These prices are then used to estimate a price for a defined fixed quantity.

The average price per kilowatt-hour represents the total bill divided by the kilowatt-hour usage. The total bill is the sum of all items applicable to all consumers appearing on an electricity bill including, but not limited to, variable rates per kWh, fixed costs, taxes, surcharges, and credits.  This calculation also applies to the average price per therm for utility (piped) gas.

Information from this release will be made available to sensory impaired individuals upon request. Voice phone: 202-691-5200, Federal Relay Service: 800-877-8339.

**Table 1. Average prices for gasoline, electricty, and utility (piped) gas, Los Angeles-Riverside-Orange County and the United States, April 2013-April 2014, not seasonally adjusted**

| | Gasoline per gallon | | Electricity per kWh | | Utillity (piped) gas per therm | |
|---|---|---|---|---|---|---|
| | Los Angeles area | United States | Los Angeles area | United States | Los Angeles area | United States |
| 2013 | | | | | | |
| April | $4.043 | $3.647 | $0.216 | $0.128 | $1.077 | $1.020 |
| May | 4.060 | 3.682 | 0.216 | 0.131 | 1.200 | 1.036 |
| June | 4.073 | 3.693 | 0.203 | 0.137 | 1.275 | 1.038 |
| July | 4.115 | 3.687 | 0.203 | 0.137 | 1.239 | 1.025 |
| August | 3.955 | 3.658 | 0.203 | 0.137 | 1.230 | 1.003 |
| September | 4.008 | 3.616 | 0.203 | 0.137 | 1.183 | 1.000 |
| October | 3.767 | 3.434 | 0.215 | 0.132 | 1.175 | 0.999 |
| November | 3.651 | 3.310 | 0.215 | 0.130 | 1.113 | 0.999 |
| December | 3.661 | 3.333 | 0.220 | 0.131 | 1.109 | 0.998 |
| 2014 | | | | | | |
| January | 3.665 | 3.378 | 0.215 | 0.134 | 1.195 | 1.040 |
| February | 3.812 | 3.422 | 0.215 | 0.134 | 1.236 | 1.078 |
| March | 4.046 | 3.590 | 0.215 | 0.135 | 1.321 | 1.154 |
| April | 4.263 | 3.717 | 0.178 | 0.131 | 1.211 | 1.137 |

# Analysis of the Energy Intensity of Water Supplies for West Basin Municipal Water District

March, 2007

Robert C. Wilkinson, Ph.D.

## Note to Readers

This report for West Basin Municipal Water District is an update and revision of an analysis and report by Robert Wilkinson, Fawzi Karajeh, and Julie Mottin (Hannah) conducted in April 2005. The earlier report, *Water Sources "Powering" Southern California: Imported Water, Recycled Water, Ground Water, and Desalinated Water*, was undertaken with support from the California Department of Water Resources, and it examined the energy intensity of water supply sources for both West Basin and Central Basin Municipal Water Districts. This analysis focuses exclusively on West Basin, and it includes new data for ocean desalination based on new engineering developments that have occurred over the past year and a half.

## Principal Investigator: Robert C. Wilkinson, Ph.D.

Dr. Wilkinson is Director of the Water Policy Program at the Donald Bren School of Environmental Science and Management, and Lecturer in the Environmental Studies Program, at the University of California, Santa Barbara. His teaching, research, and consulting focuses on water policy, climate change, and environmental policy issues. Dr. Wilkinson advises private sector entities and government agencies in the U.S. and internationally. He currently served on the public advisory committee for California's 2005 State Water Plan, and he represented the University of California on the Governor's Task Force on Desalination.
Contact: wilkinson@es.ucsb.edu

**West Basin Municipal Water District**

**Contact:** Richard Nagel, General Manager
West Basin Municipal Water District
17140 South Avalon Boulevard, Suite 210
Carson, CA 90746
(310) 217 2411 phone, (310) 217-2414 fax
richn@westbasin.org

West Basin Municipal Water District www.westbasin.org

# Overview

Southern California relies on imported and local water supplies for both potable and non-potable uses. Imported water travels great distances and over significant elevation gains through both the California State Water Project (SWP) and Colorado River Aqueduct (CRA) before arriving in Southern California, consuming a large amount of energy in the process. Local sources of water often require less energy to provide a sustainable supply of water. Three water source alternatives which are found or produced locally and could reduce the amount of imported water are desalinated ocean water, groundwater, and recycled water. Groundwater and recycled water are significantly less energy intensive than imports, while ocean desalination is getting close to the energy intensity of imports.

Energy requirements vary considerably between these four water sources. All water sources require pumping, treatment, and distribution. Differences in energy requirements arise from the varying processes needed to produce water to meet appropriate standards. This study examines the energy needed to complete each process for the waters supplied by West Basin Municipal Water District (West Basin).

Specific elements of energy inputs examined in this study for each water source are as follows:

- Energy required to **import water** includes three processes: pumping California SWP and CRA supplies to water providers; treating water to applicable standards; and distributing it to customers.
- **Desalination of ocean water** includes three basic processes: 1) pumping water from the ocean or intermediate source (e.g. a powerplant) to the desalination plant; 2) pre-treating and then desalting water including discharge of concentrate; and 3) distributing water from the desalination plant to customers.
- **Groundwater** usage requires energy for three processes: pumping groundwater from local aquifers to treatment facilities; treating water to applicable standards; and distributing water from the treatment plant to customers. Additional injection energy is sometimes needed for groundwater replenishment.
- Energy required to **recycle water** includes three processes: pumping water from secondary treatment plants to tertiary treatment plants; tertiary treatment of the water, and distributing water from the treatment plant to customers.

The energy intensity results of this study are summarized in the table on the following page. They indicate that recycled water is among the least energy-intensive supply options available, followed by groundwater that is naturally recharged and recharged with recycled water. Imported water and ocean desalination are the most energy intensive water supply options in California. East Branch State Water Project water is close in energy intensity to desalination figures based on current technology, and at some points along the system, SWP supplies exceed estimated ocean desalination energy intensity. The following table identifies energy inputs to each of the water supplies including estimated energy requirements for desalination. Details describing the West Basin system operations are included in the water source sections. Note that the Title 22 recycled water energy figure reflects only the *marginal* energy required to treat secondary effluent wastewater which has been processed to meet legal discharge requirements, along with the energy to convey it to user

## Energy Intensity of Water Supplies for West Basin Municipal Water District

| | af/yr | Percentage of Total Source Type | kWh/af Conveyance Pumping | kWh/af MWD Treatment | kWh/af Recycled Treatment | kWh/af Groundwater Pumping | kWh/af Groundwater Treatment | kWh/af Desalination | kWh/af WBMWD Distribution | Total kWh/af | Total kWh/year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Imported Deliveries** | | | | | | | | | | | |
| State Water Project (SWP) [1] | 57,559 | 43% | 3,000 | 44 | NA | NA | NA | NA | 0 | 3,044 | 175,209,596 |
| Colorado River Aqueduct (CRA) [1]<br>(other that replenishment water) | 76,300 | 57% | 2,000 | 44 | NA | NA | NA | NA | 0 | 2,044 | 155,957,200 |
| **Groundwater**[2] | | | | | | | | | | | |
| natural recharge | 19,720 | 40% | NA | NA | NA | 350 | 0 | NA | 0 | 350 | 6,902,030 |
| replenished with (injected) SWP water [1] | 9,367 | 19% | 3,000 | 44 | NA | 350 | 0 | NA | 0 | 3,394 | 31,791,598 |
| replenished with (injected) CRA water [1] | 11,831 | 24% | 2,000 | 44 | NA | 350 | 0 | NA | 0 | 2,394 | 28,323,432 |
| replenished with (injected) recycled water | 8,381 | 17% | 205 | 0 | 790 | 350 | 0 | NA | 220 | 1,565 | 13,116,278 |
| **Recycled Water** | | | | | | | | | | | |
| West Basin Treatment, Title 22 | 21,506 | 60% | 205 | NA | 0 | NA | NA | NA | 285 | 490 | 10,537,940 |
| West Basin Treatment, RO | 14,337<br>35,843 | 40% | 205 | NA | 790 | NA | NA | NA | 285 | 1,280 | 18,351,360 |
| **Ocean Desalination** | 20,000 | 100% | 200 | NA | NA | NA | NA | 3,027 | 460 | 3,687 | 82,588,800 |

Notes:

NA Not applicable

[1] Imported water based on percentage of CRA and SWP water MWD received, averaged over an 11-year period. Note that the figures for imports do not include an accounting for system losses due to evaporation and other factors. These losses clearly exist, and an estimate of 5% or more may be reasonable. The figures for imports above should therefore be understood to be conservative (that is, the actual energy intensity is in fact higher for imported supplies than indicated by the figures).

[2] Groundwater values include entire basin, West Basin service area covers approximately 86% of the basin. Groundwater values are specific to aquifer characteristics, including depth, within the basin.

# Energy Intensity of Water

Water treatment and delivery systems in California, including extraction of "raw water" supplies from natural sources, conveyance, treatment and distribution, end-use, and wastewater collection and treatment, account for one of the largest energy uses in the state.[1] The California Energy Commission estimated in its 2005 Integrated Energy Policy Report that approximately 19% of California's electricity is used for water related purposes including delivery, end-uses, and wastewater treatment.[2] The total energy embodied in a unit of water (that is, the amount of energy required to transport, treat, and process a given amount of water) varies with location, source, and use within the state. In many areas, the energy intensity may increase in the future due to limits on water resource extraction, and regulatory requirements for water quality, and other factors.[3] Technology improvements may offset this trend to some extent.

> ***Energy intensity*** is the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location.

## The Water-Energy Nexus

Water and energy systems are interconnected in several important ways in California. Water systems both provide energy – through hydropower – and consume large amounts of energy, mainly through pumping. Critical elements of California's water infrastructure are highly energy-intensive. Moving large quantities of water long distances and over significant elevation gains, treating and distributing it within the state's communities and rural areas, using it for various purposes, and treating the resulting wastewater, accounts for one of the largest uses of electrical energy in the state.[4]

Improving the efficiency with which water is used provides an important opportunity to increase related energy efficiency. (*"Efficiency"* as used here describes the useful work or service provided by a given amount of water.) Significant potential economic as well as environmental benefits can be cost-effectively achieved in the energy sector through efficiency improvements in the state's water systems and through shifting to less energy intensive local sources. The California Public Utilities Commission is currently planning to include water efficiency improvements as a means of achieving energy efficiency benefits for the state.[5]

## Overview of Energy Inputs to Water Systems

There are four principle energy elements in water systems:

1. primary water extraction and supply delivery (imported and local)
2. treatment and distribution within service areas
3. on-site water pumping, treatment, and thermal inputs (heating and cooling)

4. wastewater collection, treatment, and discharge

Pumping water in each of these four stages is energy-intensive. Other important components of embedded energy in water include groundwater pumping, treatment and pressurization of water supply systems, treatment and thermal energy (heating and cooling) applications at the point of end-use, and wastewater pumping and treatment.[6]

***1. Primary water extraction and supply delivery***
Moving water from near sea-level in the Sacramento-San Joaquin Delta to the San Joaquin-Tulare Lake Basin, the Central Coast, and Southern California, and from the Colorado River to metropolitan Southern California, is highly energy intensive. Approximately 3,236 kWh is required to pump one acre-foot of SWP water to the end of the East Branch in Southern California, and 2,580 kWh for the West Branch. About 2,000 kWh is required to pump one acre foot of water through the CRA to southern California.[7] Groundwater pumping also requires significant amounts of energy depending on the depth of the source. (Data on groundwater is incomplete and difficult to obtain because California does not systematically manage groundwater resources.)

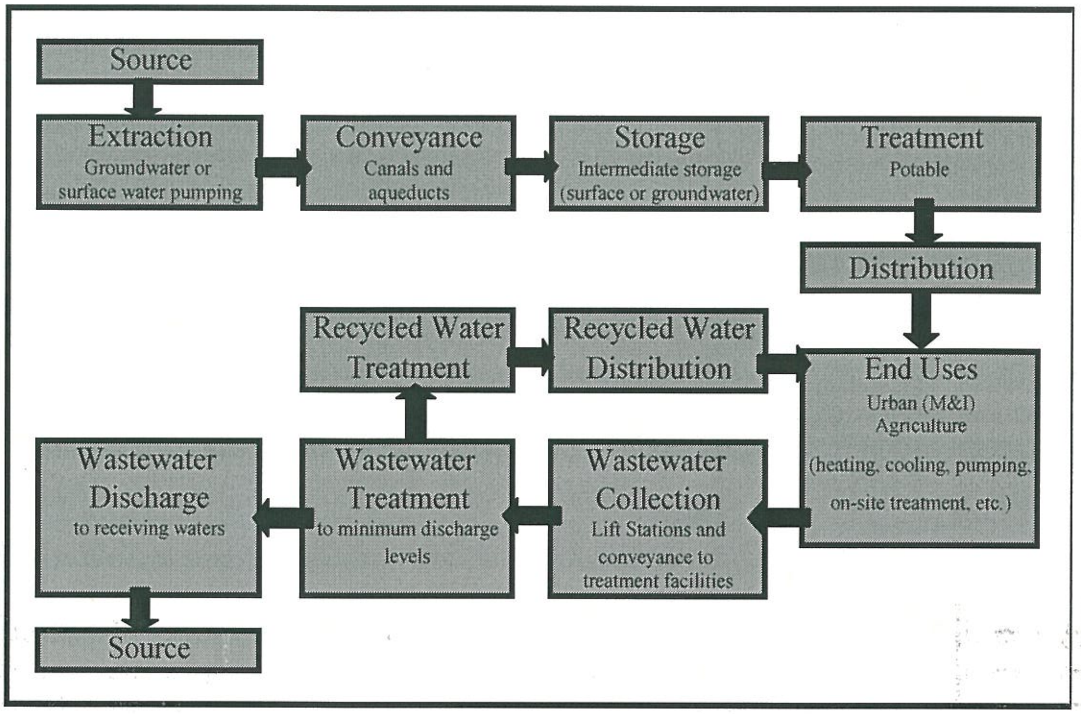
***2. Treatment and distribution within service areas***
Within local service areas, water is treated, pumped, and pressurized for distribution. Local conditions and sources determine both the treatment requirements and the energy required for pumping and pressurization.

***3. On-site water pumping, treatment, and thermal inputs***
Individual water users use energy to further treat water supplies (e.g. softeners, filters, etc.), circulate and pressurize water supplies (e.g. building circulation pumps), and heat and cool water for various purposes.

***4. Wastewater collection, treatment, and discharge***
Finally, wastewater is collected and treated by a wastewater authority (unless a septic system or other alternative is being used). Wastewater is often pumped to treatment facilities where gravity flow is not possible, and standard treatment processes require energy for pumping, aeration, and other processes. (In cases where water is reclaimed and re-used, the calculation of total energy intensity is adjusted to account for wastewater as a *source* of water supply. The energy intensity generally includes the additional energy for treatment processes beyond the level required for wastewater discharge, plus distribution.)

The simplified flow chart below illustrates the steps in the water system process. A spreadsheet computer model is available to allow cumulative calculations of the energy inputs embedded at each stage of the process. This methodology is consistent with that applied by the California Energy Commission in its analysis of the energy intensity of water.

## Simplified Flow Diagram of Energy Inputs to Water Systems



Source: Robert Wilkinson, UCSB[8]

## Calculating Energy Intensity

Total energy intensity, or the amount of energy required to facilitate the use of a given amount of water in a specific location, may be calculated by accounting for the summing the energy requirements for the following factors:

- imported supplies
- local supplies
- regional distribution
- treatment
- local distribution
- on-site thermal (heating or cooling)
- on-site pumping
- wastewater collection
- wastewater treatment

Water pumping, and specifically the long-distance transport of water in conveyance systems, is a major element of California's total demand for electricity as noted above. Water use (based on embedded energy) is the next largest consumer of electricity in a typical Southern California home after refrigerators and air conditioners. Electricity required to support water service in the typical home in Southern California is estimated at between 14% to 19% of total residential energy demand.[9] If air conditioning is not a factor the figure is even higher. Nearly three quarters of this energy demand is for pumping imported water.

### Interbasin Transfers

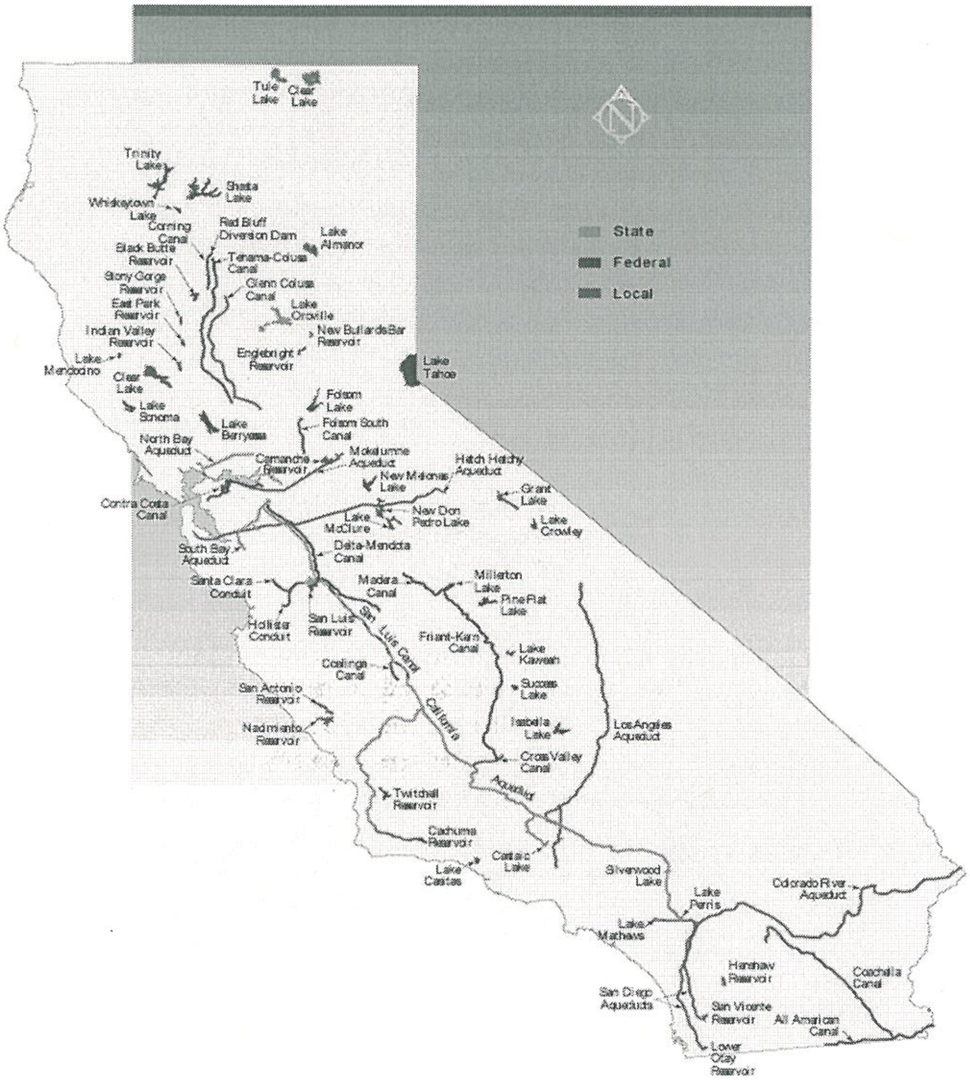
Some of California's water systems are uniquely energy-intensive, relative to national averages, due to the pumping requirements of major conveyance systems which move large volumes of water long distances and over thousands of feet in elevation lift. Some of the interbasin transfer systems (systems that move water from one watershed to another) are net energy producers, such as the San Francisco and Los Angeles aqueducts. Others, such as the SWP and the CRA require large amounts of electrical energy to convey water. On *average*, approximately 3,000 kWh is necessary to pump one AF of SWP water to southern California,[10] and 2,000 kWh is required to pump one AF of water through the CRA to southern California.[11]

Total energy savings for reducing the full embedded energy of *marginal* (e.g. imported) supplies of water used indoors in Southern California is estimated at about 3,500 kWh/af.[12] Conveyance over long distances and over mountain ranges accounts for this high marginal energy intensity. In addition to avoiding the energy and other costs of pumping additional water supplies, there are environmental benefits through reduced extractions from stressed ecosystems such as the delta.

## Imported Water: The State Water Project and the Colorado River Aqueduct

Water diversion, conveyance, and storage systems developed in California in the 20th century are remarkable engineering accomplishments. These water works move millions of AF of water around the state annually. The state's 1,200-plus reservoirs have a total storage capacity of more than 42.7 million acre feet (maf).[13] West Basin receives imported water from Northern California through the State Water Project and Colorado River water via the Colorado River Aqueduct. The Metropolitan Water District of Southern California delivers both of these imported water supplies to the West Basin.

**California's Major Interbasin Water Projects**



## The State Water Project

The State Water Project (SWP) is a state-owned system. It was built and is managed by the California Department of Water Resources (DWR). The SWP provides supplemental water for agricultural and urban uses.[14] SWP facilities include 28 dams and reservoirs, 22 pumping and generating plants, and nearly 660 miles of aqueducts.[15] Lake Oroville on the Feather River, the project's largest storage facility, has a total capacity of about 3.5 maf.[16] Oroville Dam is the tallest and one of the largest earth-fill dams in the United States.[17]

Water is pumped out of the delta for the SWP at two locations. In the northern Delta, Barker Slough Pumping Plant diverts water for delivery to Napa and Solano counties through the North Bay

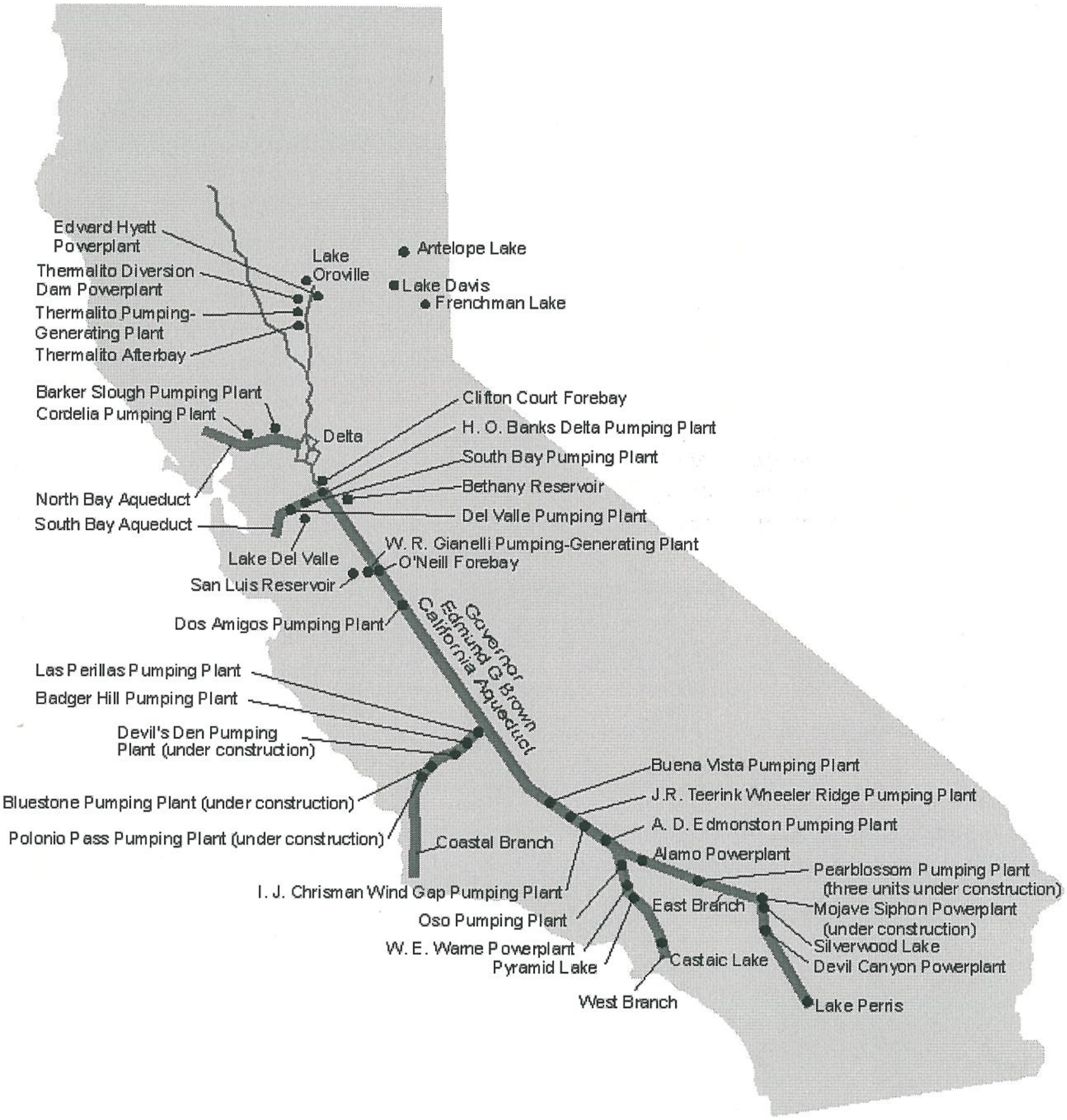
Aqueduct.[18] Further south at the Clifton Court Forebay, water is pumped into Bethany Reservoir by the Banks Pumping Plant. From Bethany Reservoir, the majority of the water is conveyed south in the 444-mile-long Governor Edmund G. Brown California Aqueduct to agricultural users in the San Joaquin Valley and to urban users in Southern California. The South Bay Pumping Plant also lifts water from the Bethany Reservoir into the South Bay Aqueduct. [19]

The State Water Project is the largest consumer of electrical energy in the state, requiring an average of 5,000 GWh per year.[20] The energy required to operate the SWP is provided by a combination of DWR's own hydroelectric and other generation plants and power purchased from other utilities. The project's eight hydroelectric power plants, including three pumping-generating plants, and a coal-fired plant produce enough electricity in a normal year to supply about two-thirds of the project's necessary power.

Energy requirements would be considerably higher if the SWP was delivering full contract volumes of water. The project delivered an average of approximately 2.0 mafy, or half its contracted volumes, throughout the 1980s and 1990s.[21] Since 2000 the volumes of imported water have generally increased.

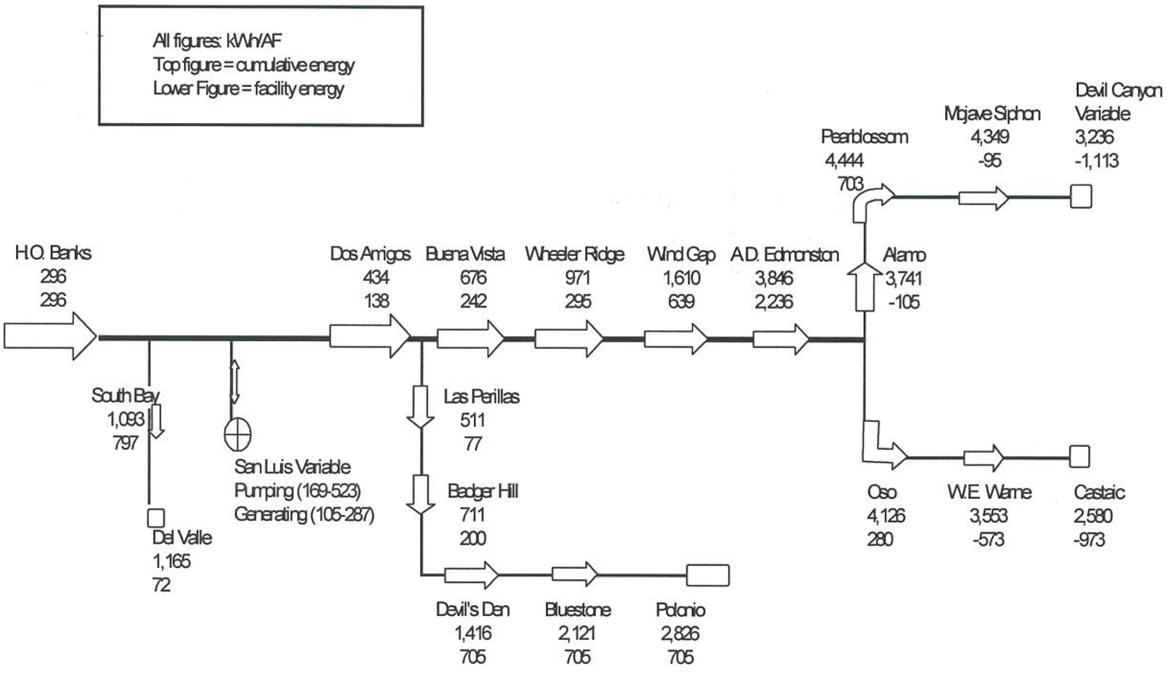
The following map indicates the location of the pumping and power generation facilities on the SWP.

## Names and Locations of Primary State Water Delivery Facilities



The following schematic shows each individual pumping unit on the State Water Project, along with data for both the individual and cumulative energy required to deliver an AF of water to that point in the system. Note that the figures include energy recovery in the system, but they do not account for losses due to evaporation and other factors. These losses may be in the range of 5% or more. While more study of this issue is in order, it is important to observe that the energy intensity numbers are conservative (e.g. low) in that they assume that all of the water originally pumped from the delta reaches the ends of the system without loss.

**State Water Project**
**Kilowatt-Hours per Acre Foot Pumped**
(Includes Transmission Losses)



Source: Wilkinson, based on data from: California Department of Water Resources, State Water Project Analysis Office, Division of Operations and Maintenance, *Bulletin 132-97*, 4/25/97.

## The Colorado River Aqueduct

Significant volumes of water are imported to the Los Angeles Basin and San Diego in Southern California from the Colorado River via the Colorado River Aqueduct (CRA). The aqueduct was built by the Metropolitan Water District of Southern California (MWD). Though MWD's allotment of the Colorado River water is 550,000 afy, it has historically extracted as much as 1.3 mafy through a combination of waste reduction arrangements with Imperial Irrigation District (IID) (adding about 106,000 afy) and by using "surplus" water.[22] The Colorado River water supplies require about 2,000 kWh/af for conveyance to the Los Angeles basin.

The Colorado River Aqueduct extends 242 miles from Lake Havasu on the Colorado River to its terminal reservoir, Lake Mathews, near Riverside. The CRA was completed in 1941 and expanded in 1961 to a capacity of more than 1 MAF per year. Five pumping plants lift the water 1,616 feet, over several mountain ranges, to southern California. To pump an average of 1.2 maf of water per year into the Los Angeles basin requires approximately 2,400 GWh of energy for the CRA's five pumping plants.[23] On average, the energy required to import Colorado River water is about 2,000 kWh/AF. The aqueduct was designed to carry a flow of 1,605 cfs (with the capacity for an additional 15%).

The sequence for CRA pumping is as follows: The Whitsett Pumping Plant elevates water from Lake Havasu 291 feet out of the Colorado River basin. At "mile 2," Gene pumping plant elevates water 303 feet to Iron Mountain pumping plant at mile 69, which then boosts the water another 144 feet. The last two pumping plants provide the highest lifts - Eagle Mountain, at mile 110, lifts the water 438 feet, and Hinds Pumping Plant, located at mile 126, lifts the water 441 feet.[24]

MWD has recently improved the system's energy efficiency. The average energy requirement for the CRA was reduced from approximately 2,100 kWh /af to about 2,000 kWh /af "through the increase in unit efficiencies provided through an energy efficiency program." The energy required to pump each acre foot of water through the CRA is essentially constant, regardless of the total annual volume of water pumped. This is due to the 8-pump design at each pumping plant. The average pumping energy efficiency does not vary with the number of pumps operated, and MWD states that the same 2,000 kWh/af estimate is appropriate for both the "Maximum Delivery Case" and the "Minimum Delivery Case."[25]

It appears that there are limited opportunities to shift pumping off of peak times on the CRA. Due to the relatively steep grade of the CRA, limited active water storage, and transit times between plants, the system does not generally lend itself to shifting pumping loads from on-peak to off-peak. Under the Minimum Delivery Case, the reduced annual water deliveries would not necessarily bring a reduction in annual peak load, since an 8-pump flow may still need to be maintained in certain months.

Electricity to run the CRA pumps is provided by power from hydroelectric projects on the Colorado River as well as off-peak power purchased from a number of utilities. The Metropolitan Water District has contractual hydroelectric rights on the Colorado River to "more than 20 percent of the firm energy and contingent capacity of the Hoover power plant and 50 percent of the energy and capacity of the Parker power plant."[26] Energy purchased from utilities makes up approximately 25 percent of the remaining energy needed to power the Colorado River Aqueduct.[27]

## Minimizing the Need for Inter-Basin Transfers

For over 100 years, California has sought to transfer water from one watershed for use in another. The practice has caused a number of problems. As of 2001, California law requires that the state examine ways to "*minimize the need to import water from other hydrologic regions*" and report on these approaches in the official State Water Plan.[28] A new focus and priority has been placed on developing *local* water supply sources, including efficiency, reuse, recharge, and desalination. The law directs the Department of Water Resources as follows:[29]

> The department, as a part of the preparation of the department's Bulletin 160-03, shall include in the California Water Plan a report on the development of regional and local water projects within each hydrologic region of the state, as described in the department's Bulletin 160-98, to improve water supplies to meet municipal, agricultural, and environmental water needs and *minimize the need to import water from other hydrologic regions.*

(Note that Bulletin 160-03 became Bulletin 160-05 due to a slip in the completion schedule.)

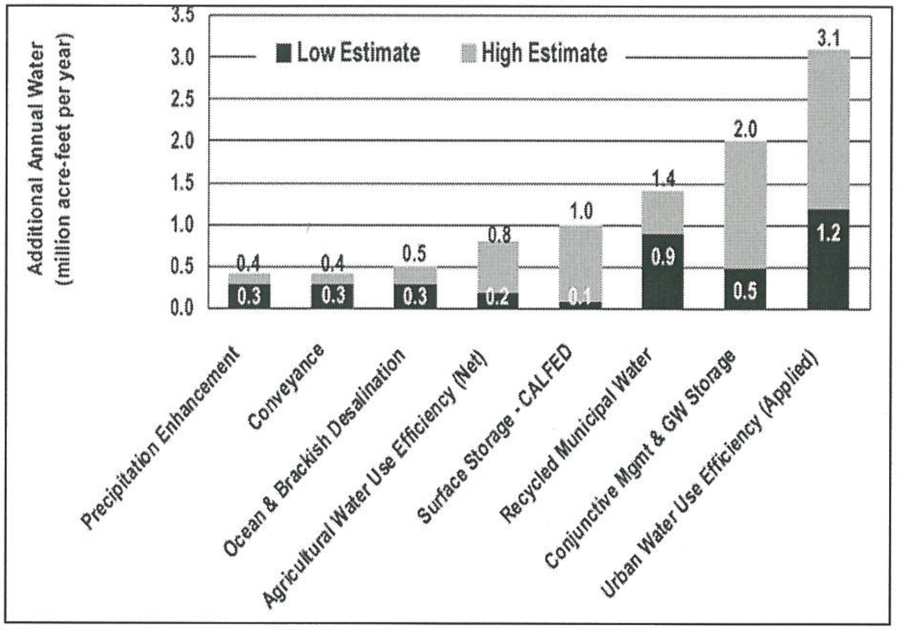
The legislation set forth the range of local supply options to be considered:

> The report shall include, but is not limited to, regional and local water projects that use technologies for desalting brackish groundwater and ocean water, reclaiming water for use within the community generating the water to be reclaimed, the construction of improved potable water treatment facilities so that water from sources determined to be unsuitable can be used, and the construction of dual water systems and brine lines, particularly in connection with new developments and when replacing water piping in developed or redeveloped areas.

This law calls for a thorough consideration in the state's official water planning process of work that is already going on in various areas of the state. The significance of the legislation is that for the first time, local supply development is designated as a priority in order to minimize inter-basin transfers.

The Department of Water Resources State Water Plan (Bulletin 160-05) reflects this new direction for the state in its projection of water supply options for the next quarter century. The following graph clearly indicates the importance of local water supplies from various sources in the future.

**California State Water Plan 2005**
**Water Management and Supply Options for the Next 25 Years**



Source: *California Water Plan Update 2005.*[30]

## Energy Requirements for Treatment of State Water Project and the Colorado River Aqueduct Supplies

Imported SWP and CRA supplies require an estimated 44 kWh/af for treatment before it enters the local distribution systems. Water pressure from MWD's system is sufficient to move supplies through the West Basin distribution system without requiring additional pressure.

# Groundwater and Recycled Water at West Basin MWD

Nearly half of the water used in the service area of the Metropolitan Water District of Southern California (from Ventura to Mexico) is secured from *local* sources, and the percentage of total supplies provided by local sources is growing steadily.[31] This figure is up from approximately one-third of the supply provided by local resources in the mid-1990s.[32] MWD has encouraged local supply development through support for recycling, groundwater recovery, conservation, groundwater storage, and most recently, ocean desalination.

Groundwater and recycled water are important and growing supply sources for West Basin. Water flows through natural hydrologic cycles continuously. The water we use today has made the journey many times. In water recycling programs, water is treated and re-used for various purposes including recharging groundwater aquifers. The treatment processes essentially short-circuit the longer-term process of natural evaporation and precipitation. In cities around the world water is used and then returned to natural water systems where it flows along to more users down stream. It is often used again and again before it flows to the ocean or to a terminal salt sink.

## Groundwater at West Basin MWD

Groundwater reservoirs in West Basin are replenished with four water sources; natural recharge, SWP supplies, CRA supplies, and recycled water supplies. The largest portion (approximately 40%) of groundwater supplies is derived from natural recharge. The energy associated with recovering this naturally recharged supply is estimated at 350 kWh/af for groundwater pumping.

Imported water, from both the SWP and CRA, is injected into the groundwater supply in West Basin. The imported water remains at sufficient pressure for injection, so no additional energy is required. The energy requirements for importing water are significant, however, primarily due to the energy associated with importing the water from northern California and the Colorado River. The imported water also passes through MWD's treatment plant, incurring additional energy requirements. The total energy intensity for West Basin's imported water used for recharge of groundwater storage from the SWP is 3,394 kWh/af and from the CRA is 2,394 kWh/af.

Recycled water is also used to recharge groundwater in the basin. West Basin replenishes groundwater by injecting RO treated recycled water from the West Basin Water Recycling Facility (WBWRF). The total energy use is 1,565 kWh/af. Details for the recycled water energy are described in the next section.

## Recycled Water at West Basin MWD

Many cities in California are using advanced processes and filtering technology to treat wastewater so it can be re-used for irrigation, industry, and other purposes. In response to increasing demands for water, limitations on imported water supplies, and the threat of drought, West Basin has developed state-of-the-art regional water recycling programs. Water is increasingly being used more than once within systems at both the end-use level and at the municipal level. This is because scarce water resources (and wastewater discharges) are increasing in cost and because cost-effective technologies and techniques for re-using water have been developed that meet health and safety requirements. At the end-use, water is recycled within processes such as cooling towers and industrial processes prior to entering the wastewater system. Once-through systems are increasingly being replaced by re-use technologies. At the municipal level, water re-use has become a significant source of supplies for both landscape irrigation and for commercial and industrial processes. MWD of Southern California is supporting 33 recycling programs in which treated wastewater is used for non-potable purposes.[33]

West Basin provides customers with recycled water used for municipal, commercial and industrial applications. Approximately 27,000 AF of recycled water is annually distributed to more than 210 sites in the South Bay. These sites use recycled water for a wide range of non-potable applications. Based in El Segundo, California, the WBWRF is among the largest projects of its kind in the nation, producing five qualities of recycled water with the capacity at full build-out to recycle 100,000 AF per year of wastewater from the Los Angeles Hyperion Treatment Plant.

In 1998, West Basin began to construct the nation's only regional high-purity water treatment facility, the Carson Regional Water Recycling Facility (CRWRF). A pipeline stretching through five South Bay communities connects the CRWRP to West Basin's El Segundo facility. At the CRWRF, West Basin ultra-purifies the recycled water it gets from the El Segundo facility. From the CRWRF, West Basin uses service lines to transport two types of purified water to the BP Refinery in Carson. The West Basin expansion also includes a new disposal pipeline to carry brine reject water from the CRWRF to a Los Angeles County Sanitation District's outfall.

In order to provide perspective on the energy requirements for the WBWRF, two water qualities and associated energy intensity are presented. "Title 22" water, produced by a gravity filter treatment system, requires conveyance pumping energy from Hyperion to WBWRF at 205 kWh/af. The water flows through the filters via gravity, thus no additional energy is required for treatment. The final energy requirement is 285 kWh/af for distribution with a total energy requirement of 490 kWh/af. This is the lowest grade of recycled water that WBWRF produces. Contrasting the Title 22 water, WBWRF produces RO water with a total energy requirement of 1,280 kWh/af. This includes 205 kWh/af for conveyance from Hyperion, 790 kWh/af for treatment with RO, and 285 kWh/af for distribution.

More than 210 South Bay sites use 9 billion gallons of West Basin's recycled water for applications including irrigation, industrial processes, indirect potable uses, and seawater barrier injection. West Basin has been successful in changing the perception of recycled water from merely a conservation tool with minimal applications to a cost-effective business tool that can reduce costs and improve reliability.

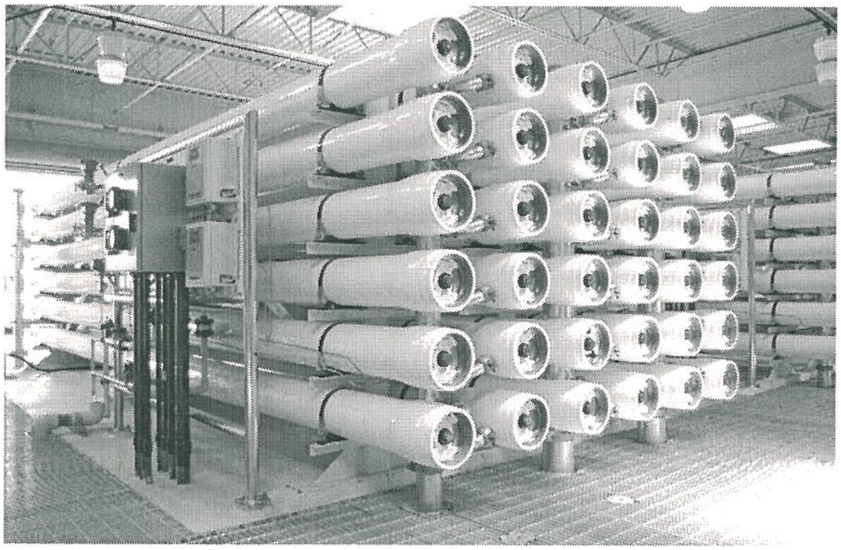
Local oil refineries are major customers for West Basin's recycled water. The Chevron Refinery in El Segundo, the Exxon-Mobile refinery in Torrance, and the BP refinery in Carson use recycled water for cooling towers and in the boiler feed systems.

## Ocean Water Desalination Development

Desalination technologies are in use around the world. A number of approaches work well and produce high quality water. Many workable and proven technology options are available to remove salt from water. During World War Two, desalination technology was developed as a water source for military operations.[34] Grand plans for nuclear-driven desalination systems in California were drawn up after the war, but they were never implemented due to cost and feasibility problems.

Desalination techniques range from distillation to "reverse osmosis" (RO) technologies. Current applications around the world are dominated by the "multistage flash distillation" process (at about 44% of the world's applications), and RO, (at about 42%).[35] Other desalting technologies include electrodialysis (6%), vapor compression (4%), multi-effect distillation (4%), and membrane softening (2%) to remove salts.[36] All of the ocean desalination projects currently in place or proposed for municipal water supply in California employ RO technology.

**Reverse Osmosis Membranes**



A recent inventory of desalination facilities world-wide indicated that as of the beginning of 1998, a total of 12,451 desalting units with a total capacity of 6.72 afy[37] had been installed or contracted worldwide.[38] (Note that *capacity* does not indicate actual operation.) Non-seawater desalination plants have a capacity 7,620 af/d[39], whereas the seawater desalination plant capacity reached 10,781af/d.[40]

Desalination systems are being used in over 100 countries, but 10 countries are responsible for 75 percent of the capacity.[41] Almost half of the desalting capacity is used to desalt seawater in the Middle East and North Africa. Saudi Arabia ranks first in total capacity (about 24 percent of the world's capacity) followed by the United Arab Emirates and Kuwait, with most of the capacity being made up of seawater desalting units that use the distillation process.[42]

The salinity of ocean water varies, with the average generally exceeding 30 grams per liter (g/l).[43] The Pacific Ocean is 34-38 g/l, the Atlantic Ocean averages about 35 g/l, and the Persian Gulf is 45 g/l. Brackish water drops to 0.5 to 3.0 g/l.[44] Potable water salt levels should be below 0.5 g/l.

Reducing salt levels from over 30 g/l to 0.5 g/l and lower (drinking water standards) using existing technologies requires considerable amounts of energy, either for thermal processes or for the pressure to drive water through extremely fine filters such as RO, or for some combination of thermal and pressure processes. Recent improvements in energy efficiency have reduced the amount of thermal and pumping energy required for the various processes, but high energy intensity is still an issue. The energy required is in part a function of the degree of salinity and the temperature of the water.

West Basin is in the process of developing plans to construct an ocean desalinating plant. Estimated energy requirements have been calculated by Gerry Filteau of Separation Processes, Inc for each step in the process.[45] The values presented for desalination are based on his work. Since the proposed plant will tap the source water at the power plant, there is no ocean intake pumping required. The source water is estimated to require 200 kWh/af this energy will bring ocean water from the power plant to the desalination system, approximately one quarter of a mile in distance. Pre-treatment of the source water is estimated at 341 kWh/af. This figure includes microfiltration and transfer to the RO units via a 5-10 micron cartridge filter. The RO process requires 2,686 kWh/af if operated at the most energy-efficient level. A slightly less efficient but more cost-effective level of operation would require 2,900 kWh/af, or 214 kWh/af additional energy input according to Filteau. Finally, an estimated 460 kWh/af is required to deliver the product water to the distribution system, including elevation gain, conveyance over distance, and pressurization to 90 psi. No additional energy is required to discharge the brine, as it flows back to the ocean outfall line by gravity.

The energy intensity figures presented here for desalination are lower than previous estimates. This is mainly due to improved membrane technologies, efficiency improvements for high pressure pumps, and pressure recovery systems. It should be noted that the figures provided here are based on engineering estimates, not on actual plant operations.

The total energy required to desalinate the ocean water, including each of the steps above, is estimated to be 3,687 kWh/af. If the energy intensity is increased slightly to improve cost-effectiveness, the total figure increases to 3,901 kWh/af.

# Summary

This study examined the energy intensity of imported and local water supplies (ocean water, groundwater, and recycled water) for both potable and non-potable uses for West Basin. All water sources require pumping, treatment, and distribution. Differences in energy requirements arise from varying pumping, treatment, and distribution processes needed to produce water to meet appropriate standards for different uses.

The key findings of this study are: 1) the marginal energy required to treat and deliver recycled water is among the *least* energy intensive supply options available, 2) naturally recharged groundwater is low in energy intensity, though replenishment with imported water is not, and 3) current ocean desalination technology is getting close to the level of energy intensity of imported supplies.

Further refinement of the data in this study, such as applying an agency's own energy values, may provide a more accurate basis for decision-making tailored to a unique water system. The information presented, however, provides a reasonable basis for water managers to explore energy (and cost) benefits of increased use of local water sources, and it indicates that desalination of ocean water is getting close to the energy intensity of existing supplies.

# Sources

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[1] Water systems account for roughly 7% of California's electricity use: See Wilkinson, Robert C., 2000. Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency.

[2] California Energy Commission, 2005. *Integrated Energy Policy Report*, November 2005, CEC-100-2005-007-CMF.

[3] Franklin Burton, in a recent study for the Electric Power Research Institute (EPRI), includes the following elements in water systems: "Water systems involve the transportation of water from its source(s) of treatment plants, storage facilities, and the customer. Currently, most of the electricity used is for pumping; comparatively little is used in treatment. For most surface sources, treatment is required consisting usually of chemical addition, coagulation and settling, followed by filtration and disinfection. In the case of groundwater (well) systems, the treatment may consist only of disinfection with chlorine. In the future, however, implementation of new drinking water regulations will increase the use of higher energy consuming processes, such as ozone and membrane filtration." Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities.* (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.3-1.

[4] Wilkinson, Robert C., 2000. *Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency.

[5] California Public Utilities Commission, Order Instituting Rulemaking Regarding to Examine the Commission's post-2005 Energy Efficiency Policies, Programs, Evaluation, Measurement and Verification, and Related Issues, Rulemaking 06-04-010 (Filed April 13, 2006)

[6] An AF of water is the volume of water that would cover one acre to a depth of one foot. An AF equals 325,851 gallons, or 43,560 cubic feet, or 1233.65 cubic meters.

[7] Metropolitan Water District of Southern California, *Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations*, 1996, p.5.

[8] This schematic, based on the original analysis by Wilkinson (2000) has been refined and improved with input from Gary Wolff, Gary Klein, William Kost, and others. It is the basic approach reflected in the CEC IEPR and other analyses.

[9] QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency*, Report for the Southern California Edison Company, p. 24.

[10] Figures cited are *net* energy requirements (gross energy for pumping minus energy recovered through generation).

[11] Metropolitan Water District of Southern California, *Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations*, 1996, p.5.

[12] Wilkinson, Robert C., 2000. *Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency.

[13] California Department of Finance. California Statistical Abstract. Tables G-2, "Gross Capacities of Reservoirs by Hydrographic Region," and G-3 "Major Dams and Reservoirs of California." January 2001. (http://www.dof.ca.gov/html/fs_data/stat-abs/toc.htm)

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[14] "The SWP, managed by the Department of Water Resources, is the largest state-built, multi-purpose water project in the country. Approximately 19 million of California's 32 million residents receive at least part of their water from the SWP. SWP water irrigates approximately 600,000 acres of farmland. The SWP was designed and built to deliver water, control floods, generate power, provide recreational opportunities, and enhance habitats for fish and wildlife." California Department of Water Resources, *Management of the California State Water Project.* Bulletin 132-96. p.xix.

[15] California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.p.xix.

[16] Three small reservoirs upstream of Lake Oroville — Lake Davis, Frenchman Lake, and Antelope Lake — are also SWP facilities. California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.

[17] California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96. Power is generated at the Oroville Dam as water is released down the Feather River, which flows into the Sacramento River, through the Sacramento-San Joaquin Delta, and to the ocean through the San Francisco Bay.

[18] The North Bay Aqueduct was completed in 1988. (California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.)

[19] The South Bay Aqueduct provided initial deliveries for Alameda and Santa Clara counties in 1962 and has been fully operational since 1965. (California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.)

[20] Carrie Anderson, 1999, "Energy Use in the Supply, Use and Disposal of Water in California", Process Energy Group, Energy Efficiency Division, California Energy Commission, p.1.

[21] Average deliveries for 1980-89 were just under 2.0 mafy, deliveries for 1990-99 were just over 2.0 mafy. There is disagreement regarding the ability of the SWP to deliver the roughly 4.2 mafy that has been contracted for.

[22] According to MWD, "Metropolitan's annual dependable supply from the Colorado River is approximately 656,000 AF -- about 550,000 AF of entitlement and at least 106,000 AF obtained through a conservation program Metropolitan funds in the Imperial Irrigation District in the southeast corner of the state. However, Metropolitan has been allowed to take up to 1.3 maf of river water a year by diverting either surplus water or the unused portions of other agencies' apportionments." Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[23] Metropolitan Water District of Southern California, 1999, http://www.mwd.dst.ca.us/pr/powres/summ.htm.

[24] The five pumping plants each have nine pumps. The plants are designed for a maximum flow of 225 cubic feet per second (cfs). The CRA is designed to operate at full capacity with eight pumps in operation at each plant (1800 cfs). The ninth pump operates as a spare to facilitating maintenance, emergency operations, and repairs. Metropolitan Water District of Southern California, 1999, Colorado River Aqueduct: http://aqueduct.mwd.dst.ca.us/areas/desert.htm, 08/01/99.

[25] Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, p.5.

[26] Metropolitan Water District of Southern California, 1999, "Summary of Metropolitan's Power Operation". February, 1999, p.1, http://aqueduct.mwd.dst.ca.us/areas/desert.htm.

[27] Metropolitan Water District of Southern California, 1999, http://www.mwd.dst.ca.us/pr/powres/summ.htm. MWD provides further important system information as follows: Metropolitan owns and operates 305 miles of 230 kV transmission lines from the Mead Substation in southern Nevada. The transmission system is used to deliver power from Hoover and Parker to the CRA pumps. Additionally, Mead is the primary interconnection point for Metropolitan's economy energy purchases. Metropolitan's transmission system is interconnected with several utilities at multiple

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interconnection points. Metropolitan's CRA lies within Edison's control area. Resources for the load are contractually integrated with Edison's system pursuant to a Service and Interchange Agreement (Agreement), which terminates in 2017. Hoover and Parker resources provide spinning reserves and ramping capability, as well as peaking capacity and energy to Edison, thereby displacing higher cost alternative resources. Edison, in turn, provides Metropolitan with exchange energy, replacement capacity, supplemental power, dynamic control and use of Edison's transmission system.

[28] SB 672, Machado, 2001. California Water Plan: Urban Water Management Plans. (The law amended Section 10620 of, and adds Section 10013 to, the Water Code) September 2001.

[29] SEC. 2. Section 10013 to the Water Code, 10013. (a) SB 672, Machado. California Water Plan: Urban Water Management Plans. September 2001, (Emphasis added.)

[30] California Department of Water Resources, 2005. California Water Plan Update 2005. Bulletin 160-05, California Department of Water Resources, Sacramento, CA.

[31] Metropolitan Water District of Southern California, 2000. *The Regional Urban Water Management Plan for the Metropolitan Water District of Southern California*, p.A.2-3.

[32] "About 1.36 maf per year (34 percent) of the region's average supply is developed locally using groundwater basins and surface reservoirs and diversions to capture natural runoff." Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, Vol.1, p.1-2.

[33] MWD estimates that reclaimed water will ultimately produce 190,000 AF of water annually. Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[34] Buros notes that "American government, through creation and funding of the Office of Saline Water (OSW) in the early 1960s and its successor organizations like the Office of Water Research and echnology (OWRT), made one of the most concentrated efforts to develop the desalting industry. The American government actively funded research and development for over 30 years, spending about $300 million in the process. This money helped to provide much of the basic investigation of the different technologies for desalting sea and brackish waters." Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts, p.5. This very useful summary is available at http://www.ida.bm/PDFS/Publications/ABCs.pdf

[35] Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts, p.5. This very useful summary is available at http://www.ida.bm/PDFS/Publications/ABCs.pdf See also; Buros et al.1980. *The USAID Desalination Manual.* Produced by CH2M HILL International for the U.S. Agency for International Development.

[36] Wangnick,Klaus.1998 *IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association; and Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts, p.5.

[37] Desalination systems with a unit size of 100 m3/d or more. Figures in original cited as 6,000 mgd.

[38] Wangnick Consulting GMBH (http://www.wangnick.com) maintains a permanent desalting plants inventory and publishes the results biennially in co-operation with the International Desalination Association, as the IDA Worldwide Desalting Plants Inventory Report. Thus far, fifteen reports have been published, with the latest report having data through the end of 1997; and see Wangnick,Klaus.*1998 IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association. The data cited are as of December 31, 1997.

[39] Cited in original as 9,400,000 m3/d.

[40] Wangnick,Klaus.*1998 IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association. (Cited in original in m3d (13,300,000 m3/d).

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[41] Wangnick,Klaus.1998 *IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association; and Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts. The United States ranks second in over-all capacity (16 %) with most of the capacity in the RO process used to treat brackish water. The largest plant, at Yuma, Arizona, is not in use.

[42] Wangnick,Klaus.1998. *IDA Worldwide Desalting Plants Inventory Report No.15.* Produced by Wangnick Consulting for International Desalination Association; and Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts.

[43] Salinity levels referenced in metric units.

[44] OTV. 1999. "Desalinating seawater." Memotechnique, Planete Technical Section, No. 31 (February), p.1; and Gleick, Peter H. 2000. *The World's Water: 2000-2001*, Island Press, Covelo, p.94.

[45] Gerry Filteau, Separation Processes, Inc., 2386 Faraday Ave., Suite 100, Calsbad, CA 92008, www.spi-engineering.com

# California Climate Action Registry
# General Reporting Protocol

## Reporting Entity-Wide Greenhouse Gas Emissions

Version 3.1 | January 2009

Thus, regional/power pool emission factors for electricity consumption can be used to determine emissions based on electricity consumed. If you can obtain verified emission factors specific to the supplier of your electricity, you are encouraged to use those factors in calculating your indirect emissions from electricity generation. If your electricity provider reports an electricity delivery metric under the California Registry's Power/Utility Protocol, you may use this factor to determine your emissions, as it is more accurate than the default regional factor. Utility-specific emission factors are available in the Members-Only section of the California Registry website and through your utility's Power/Utility Protocol report in CARROT.

This Protocol provides power pool-based carbon dioxide, methane, and nitrous oxide emission factors from the U.S. EPA's eGRID database (see Figure III.6.1), which are provided in Appendix C, Table C.2. These are updated in the Protocol and the California Registry's reporting tool, CARROT, as often as they are updated by eGRID.

To look up your eGRID subregion using your zip code, please visit U.S. EPA's "Power Profiler" tool at www.epa.gov/cleanenergy/energy-and-you/how-clean.html.

Fuel used to generate electricity varies from year to year, so emission factors also fluctuate. When possible, you should use emission factors that correspond to the calendar year of data you are reporting. $CO_2$, $CH_4$, and $N_2O$ emission factors for historical years are available in Appendix E. If emission factors are not available for the year you are reporting, use the most recently published figures.

## U.S. EPA Emissions and Generation Resource Integrated Database (eGRID)

The Emissions & Generation Resource Integrated Database (eGRID) provides information on the air quality attributes of almost all the electric power generated in the United States. eGRID provides search options, including information for individual power plants, generating companies, states, and regions of the power grid. eGRID integrates 24 different federal data sources on power plants and power companies, from three different federal agencies: EPA, the Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). Emissions data from EPA are combined with generation data from EIA to produce values like pounds per megawatt-hour (lbs/MWh) of emissions, which allows direct comparison of the environmental attributes of electricity generation. eGRID also provides aggregated data to facilitate comparison by company, state or power grid region. eGRID's data encompasses more than 4,700 power plants and nearly 2,000 generating companies. eGRID also documents power flows and industry structural changes. www.epa.gov/cleanenergy/egrid/index.htm.

**Figure III.6.1 eGRID Subregions**

Source: eGRID2007 Version 1.1, December 2008 (Year 2005 data).

# Project 7

# Be a Water Saver Conservation Program Project

# Supporting Documents

Sylvir Consulting, Inc.

# TECHNICAL MEMORANDUM

| | |
|---|---|
| DATE: | July 15, 2014 |
| TO: | Jeanette Meyer, Marketing Manager |
| FROM: | Sheri Lasick, Sylvir Consulting, Inc. |
| Reviewed by: | Kapil Kulkarni, Marketing Associate |
| SUBJECT: | City of Burbank Water and Power Water Conservation Programs |

## SUMMARY

On January 17, 2014, Governor Edmund G. Brown, Jr. issued a drought emergency proclamation following three dry or critically dry years in California. The National Drought Mitigation Center research now shows that nearly 80 percent of California is in an “extreme drought” and 100 percent of the State is experiencing drought conditions of varying degrees, and the County of Los Angeles is located in an area of the State that is experiencing “exceptional drought” conditions.[1]

There are many ways to boost local water supplies such as recycling treated wastewater and reusing some household or industrial water onsite. However, conservation is the easiest, most efficient and most cost effective way to quickly reduce water demand and extend supplies into the next year, providing flexibility for all California communities.

Due to the fact that the City has no rights to water and must purchase all of the water necessary, water conservation and the distribution of recycled water are both critical to managing water resources and costs to the utility and customers. Any water conserved or recycled results in an equal, one-to-one decrease in treated imported water.

The intent of this Technical Memorandum is to provide technical justification for increasing water conservation efforts through the offering of customer incentives.

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[1] U.S. Drought Monitor-California, accessed 7/10/14. http://droughtmonitor.unl.edu/Home/StateDroughtMonitor.aspx?CA

## INTRODUCTION

Water use in the City of Burbank is for urban purposes, encompassing residential, industrial, commercial and governmental uses; there are no agricultural water services, although some services are used exclusively for landscape irrigation. The customer classes are Residential, Commercial, Industrial, City, Fire Protection, Reclaimed—Commercial, and Reclaimed---City.

Potable water is served to a population of approximately105,000 city residents.

Water Use in Burbank is distributed as follows:

| | |
|---|---|
| Residential uses | 71.2% |
| Commercial uses | 20.6% |
| Industrial uses | 3.9% |
| City Departments | 4.3% |
| Fire Protection | 0.1% |

The City of Burbank Water and Power (BWP), Water Division, provides potable water, fire protection water, and recycled water for the City of Burbank. Burbank’s total annual water supply 5-year average is 21,131 acre feet, including recycled water which accounts for approximately 2,100 AF. Burbank's potable water is supplied by a combination of Metropolitan Water District of Southern California (MWD) imported water from the State Water Project (SWP) and the Colorado River, and groundwater from local wells. The groundwater is treated at two treatment plants for removal of volatile organic chemicals. Recycled water comes from the Burbank Water Reclamation Plant. It is estimated that over 10,000 AF of recycled water per year is available for reuse; however, currently 2,100-2300 AF is distributed for landscape irrigation, commercial irrigation, golf courses, and industrial reuse at the BWP power plant with the rest discharged to the Los Angeles River via the Burbank Channel.

The groundwater levels of the San Fernando Basin can partially support the communities served within the adjudicated levels in the 1979 Judgment. However, the groundwater was declared a Superfund site by the US EPA in 1986. 1980 tests revealed that this groundwater basin, which was providing water to more than 800,000 people, had concentrations of volatile organic compounds (VOCs) including trichloroethylene (TCE) and perchloroethylene (PCE) were found to be above the Federal maximum contaminant levels (MCL). Groundwater monitoring wells from 1981-1987 revealed over 50 percent of the water supply wells in the eastern portion of the San Fernando Valley Groundwater Basin were contaminated, and more than 60 public drinking water supply wells---11 of which are the City of Burbank’s wells. This required the shutdown of many of these wells and forced the City to seek more expensive sources of water (i.e. imported SWP and Colorado River water). Therefore, limited water is extracted from this groundwater basin and that which is extracted must undergo significant treatment and blending with non-contaminated water prior to distribution. Despite efforts to maintain a safe yield operation for the basin, the water level of this groundwater basin is noted by the Metropolitan Water District of

Southern California to be in a "long-term decline"[2]. A source water assessment was completed in December 2002 for both the groundwater and the surface water supplies. The groundwater source is considered most vulnerable to the known contaminant plume that resulted in the construction of the Burbank Operable Unit Plant in 1989, which is a component of the superfund site remedy. Possible contaminating activities include automobile repair shops, petroleum pipeline, National Pollutant Discharge Elimination System (NPDS) permitted discharges, metal plating, underground storage tanks, plastics producer, airport, military installations, and automobile gas stations.

Burbank's system has been designed to recognize the inherent variability of water demands. Large storage reservoirs are included in the system, and these reservoirs provide for hourly flow/demand variations throughout the distribution system. The storage capacity is also large enough to allow for short interruptions, one to three days, in the water supply.

The City of Burbank does not have ownership rights to naturally occurring water underneath the City within the San Fernando Valley Basin. The San Fernando Valley Groundwater Basin is an adjudicated basin, with water rights retained by the City of Los Angeles, which is also the court-appointed Watermaster for this water source. Burbank's drinking water comes from two different sources: local groundwater from the San Fernando Basin and water purchased from the Metropolitan Water District of Southern California. However, Burbank receives a right to pump groundwater (groundwater credits) equivalent to 20% of the total water it delivers. These "Import Return Credits" represents the portion of the imported water that is applied to landscape irrigation and percolates down into the aquifer, thereby resulting in the estimated 20% credit. To augment the groundwater supply, BWP is able to purchase lower-cost untreated water that is imported to the local area and directly placed into the ground at the Pacoima Spreading Grounds; BWP receives water credits from this water at a 1:1 ratio, which comprises 33% of Burbank's water supply. These credits allow BWP to pump from its groundwater wells. The groundwater is treated to remove VOCs such as TCE and PCE before it enters the distribution system. Burbank has two treatment facilities, the Lake Street Plant and the Burbank Operable Unit (BOU) Plant. For the year 2013, 53% of the City's water supply came from the groundwater that was treated solely at the BOU.

The Colorado River Aqueduct and the State Water Project comprise the imported water supplies before delivering them to Burbank. For the year 2013, 71% of the City's drinking water came from MWD treated and untreated. Both BOU and MWD treated sources meet all Federal and State drinking water standards.

Over the past ten years, the cost of treated water purchased from MWD has nearly doubled from $549/acre-foot to $1,032/per acre-foot in 2014[3] creating an even greater need to evaluate water conservation as a long term solution to reducing reliance upon imported water to lessen the costs to rate payers.

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[2] MWD of Southern California Groundwater Assessment Study, Plate ES-4, September 2007. http://www.mwdh2o.com/mwdh2o/pages/yourwater/supply/groundwater/PDFs/ES-4.pdf

[3] MWD Adopted Water Rates and Charges.
http://www.mwdh2o.com/mwdh2o/pages/finance/finance_03.html

## BWP WATER CONSERVATION PROGRAM BACKGROUND

The City of Burbank's dependence upon imported water resources led to an early commitment to conserving water. The following timeline represents a summary of the City's past conservation actions:

- BWP began offering cash rebates to Burbank Residents and businesses in 1991 to replace high water using toilets with Ultra-Low Flow Toilets (ULFTs). Approximately 18,000 toilets were replaced under this very successful program, saving an estimated 700 acre-feet of water annually.

- July 21, 1992 - The City of Burbank becomes one of the early adopters of the California Urban Water Conservation Council Best Management Practices and a signatory member to the MOU. Burbank offers several residential and business water and energy savings programs.

- In December 2008, the City Council adopted a recycled Water Use Policy that requires the use of Recycled water for all approved uses where it is available and practical for use. This is a condition for potable water service on the same premises.

- In 2009, the state of California enacted Senate Bill (SB) 7x7, mandating urban water agencies to reduce water usage by 20 percent by the end of 2020. Additional requirements included an interim reduction goal of 10 percent by the end of 2014, and the establishment of baselines and targets. In response to restricted MWD supply options caused by drought conditions and other state regulations in 2008, BWP began an ambitious water conservation effort, committing two percent of water sales annually to fund water conservation in the City of Burbank and set a goal to offset the City's total water use by at least one percent each year through conservation measures.

- In July 2009, a Sustainable Water Use Practices Ordinance was approved by the Burbank City Council, and a Stage II, "3 day per week" watering restriction became effective. Water conservation incentives in the form of free, low-flow showerheads and aerators were offered, as well as rebates for the installation of high efficiency toilets (maximum of 1.28 gallons per flush), high efficiency washers, and a comprehensive energy and water indoor/outdoor audit program called, "Green Home House Call" were initiated. Through these efforts, BWP reduced its water use from 184 gpcd in 2006 to 153 gpcd in 2011. There was an increase to 161 in 2013, after the "3 days a week" watering ordinance was relaxed.

- 2009 – Conservation Rate Structure. A tiered water rate, adopted for single-family residential water users, increases the cost of potable water as usage increases. The tiered rate for single-family residential customers sends a price signal that discretionary water use is more costly.

  Seasonal water rates were also adopted for multi-family residential, commercial and industrial services to encourage conservation during the warmer months of the year.

- In 2009, BWP implemented the Water Fixture Upgrade program. This program required the 6,200 business and multi-family owners in Burbank to certify that their plumbing fixtures met specific deficiency levels. Failure to certify would lead to a monthly 25% surcharge on their water bill. In nine months, 90% of customers responded. The Certifications listed the number of plumbing fixtures upgraded to meet Burbank's requirements, allowing for estimated water savings. Requirement notifications were sent via direct mail, online and print advertising, with Burbank committing staff to personally contact over 4,300 customers. Additionally, to help mitigate the financial impact of replacing plumbing fixtures, Burbank provided, at no cost to users, nearly 22,000 low-flow showerheads, over 41, 000 low-flow faucet aerators, and funded over $300,000 in high efficiency toilet rebates.[4]

  The Burbank Water Fixture Upgrade program provided over 227 million gallons of water savings.

- Summer 2010 – The City's recycled water distribution system water master plan implementation began with the upgrade of the pump station at the water reclamation plant, followed by the construction of multiple distribution pipelines through 2013.

- August 2010 - Ordinance 3786, a Retrofit Upon Resale Program for Water Efficiency in Residential and Commercial Buildings, was approved and implemented.

- July 22, 2014 – Anticipated City Council action to implement a Stage 2 water restriction limiting outdoor watering to no more than three (3) days per week and limiting the duration to no more than 15 minutes per station.

The City of Burbank's water conservation policies, ordinances, and incentives were developed based on state regulations and as an essential aspect of the City's water demand management. The conservation policies, along with other actions (ground water recharge, recycled water distribution, and storage) have allowed the City to avoid increasing the amount of imported water needed even as the City's population has grown. In fact, the City has been able to reduce its volume of MWD imported water from 13,503.30 acre feet in 2000, to 8,325.10 acre feet in 2012.[5]

Since beginning its water conservation measures, the City has met all of the retail agency AB1420 Best Management Practice requirements.

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[4] 2010 Urban Water Management Plan, Burbank Water and Power, June 2011. Pages 7-2, 7-3

[5] Burbank Water and Power 2012 Annual Report to the California Urban Water Conservation Council.

The City has offered residents and businesses a variety of incentives including:

- ✓ Ultra Low Flow Toilets
- ✓ High Efficiency Toilets
- ✓ High Efficiency Washers
- ✓ Direct install of: Low Flow aerators, faucets, and showerheads, Toilet flappers and dams
- ✓ Drip Irrigation Kits
- ✓ High Efficiency Urinals
- ✓ Smart ET Controllers
- ✓ Go Native! Turf Removal
- ✓ Rain Barrel Rebates
- ✓ Zero Water Urinals
- ✓ Synthetic Turf
- ✓ Landscape Audits
- ✓ Rotating Sprinkler nozzles
- ✓ Retrofit Upon Resale
- ✓ Water Leak Detection
- ✓ Educational Outreach

As a result of the City’s water conservation efforts, it is estimated that an average of 464 acre-feet has been saved annually, or 3,708 acre-feet in total since 2005 through customer incentives. Recycled water distributions are now up to more than 2,100 acre feet per year for sales July 1, 2013 through May 31, 2014, and that amount is projected to exceed 2,300 acre feet for distributions through June 30, 2014.[6]

## WATER CONSERVATION MEASURES BENEFITS

Upon review of the performance for the various water conservation measures offered by the City, the following measures were identified as the best performing and/or having the greatest potential for long-term, sustainable savings.

### 1) HE TOILETS, 1.28 GALLONS

Each year, BWP and MWD jointly provide a total of approximately 200 rebates for HE toilets to single-family residents living in the City of Burbank. This program has been very successful, with a total distribution of 7,535 to date, for an annual savings of 52.68 acre feet, and a lifetime savings of 1,053.60 assuming a 20 year life expectancy.

Due to the ease of replacement, the simplicity of this water conservation measure for the customer to achieve the saving, the immediacy of the savings, and the sustainability of the water savings, greater investment in funding this water conservation measure should be provided until such time as customer interest wanes and/or saturation has been met.

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[6] Personal Communication with Burbank Water and Power Principal Engineer, Matthew Elsner, July 9, 2014.

Replacement should also not be restricted to only non-conserving toilet, as the replacement of 1.6 gallon ultra-low flush toilets (ULFTs) with the HE toilets will still yield a water savings of 20 percent. Furthermore, some ULFT models are not as effective at flushing waste as expected, and would require additional flushes resulting in no savings over non-conserving models.

Market research suggests that the average cost to purchase and install a HE toilet is $195. If the City were to offer a greater rebate amount, it is likely that the City would see an increase in the number of participants and with a 20 year life expectancy, this conservation measure represents a long-term, sustainable water savings supporting drought preparedness.

When estimating savings, the City assumes a conservative savings of 2,270 gallons per toilet. This is estimate is based on the assumptions:

- ✓ 5.1 flushes per person[7]
- ✓ Burbank average household population of 2.4 people[8]
- ✓ Assume that 90% of the toilets being replaced are ULFTs (1.6 gallons) and 10% of the toilets use a 3.5 or higher gallons per flush rate (gpf) for an average of 1.79 gpf for pre-installation use rates
- ✓ Life expectancy = 20 years[9]

Calculated savings: 1.79 – 1.28=.51 gpf saved x 2.4 people = 1.22 gpf
1.22 gpf x 5.1 uses= 6.22 gpd
6.22 gpd x 365 = 2270.30 gallons per toilet/year

By increasing the City's annual available rebates from 200 to 650, the City would be able to increase new potable water savings to 1,475,695 gallons per year, or 4.53 acre feet.

## 2) GREEN HOME HOUSE CALL PROGRAM (GHHC).

This award-winning program has been very successful and BWP receives many positive comments and much gratitude from customers participating in the program. This program is often the first contact with homeowners who know nothing about the other conservation programs and have a lot of questions about water conservation. GHHC provides a one-on-one opportunity to alert homeowners that they could upgrade their toilet, get a rain barrel, and Go Native! with turf replacement and is an opportunity to education residents about the benefits of these actions. This program exceeds the typical basic home survey and handout of aerators and faucets and tips on conservation that the homeowner can do. It is a very comprehensive and customized conservation effort that begins with an indoor and outdoor audit and concludes with the direct

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[7] 5.1 flushes per person per day, AWWA Research Foundation, 1999, Residential End Uses of Water, page 169, http://www.waterrf.org/PublicReportLibrary/RFR90781_1999_241A.pdf

[8] http://quickfacts.census.gov/qfd/states/06/0608954.html; 105,000 residents divided by 43,000 households equals 2.4 persons per household

[9] EPA Water Sense, http://www.epa.gov/WaterSense/products/toilets.html , calculation based on annual and lifetime savings = 20 years

installation of aerators and faucets, adjustments to sprinklers and irrigation controllers, and more; all provided as a cost free benefit to residents requesting this service.

### TABLE 1: GREEN HOME HOUSE CALL PROGRAM SAVINGS

| GHHC Program Element | Annual Quantity | Annual Savings (AF) | Lifetime Savings (AF) |
|---|---|---|---|
| Landscape Water Audit | 500 | 51.95 | 259.77 |
| Kitchen Faucet Aerators | 465 | 12.66 | 63.29 |
| Bathroom Faucet Aerators | 830 | 30.12 | 150.61 |
| Low-Flow Showerheads | 586 | 4.43 | 22.16 |

This program is highly variable, as it is dependent upon the needs of the individual residences and the customers' interest; however, based on historical data, continued customer interest, and the performance of the water savings for this program support investing in this program. While increasing participation rates in this program would increase benefits, participation seems to have stabilized. If the City were to begin offering the direct installation of HE toilets to complement the HE toilet rebate program, participation may increase for both conservation programs.

### TABLE 2: GREEN HOME HOUSE CALL AGGREGATE SAVINGS

| GHHC Annual Savings (AF) | GHHC Lifetime Savings (AF) |
|---|---|
| 99-100 | 496 |

The water savings estimates are based on the following assumptions:

- i. Landscape Audit
    - a. Average annual single family household water usage in Burbank : 169,280 gallons
    - b. Apply 20% savings rate, based on range of estimates[10], [11]
        - i. Estimate of up to **30% reduction** in usage for a single family home after successful audit.[12] ,[13]
        - ii. Irrigation water audits typically reduce water use by **25 to 40 percent**."[14]
- ii. Bathroom Faucet Aerators
    - a. Water use of 8.1 minutes per person per day[15]

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[10] Prepared by A & N Technical Services, Inc on behalf of California Urban Water Conservation Council, page 2-247, http://www.doe2.com/download/Water-Energy/CUWCC_BMPCostsSavingsStudy.pdf

[11] Lake Oswego, OR. Public Works Dept. http://www.ci.oswego.or.us/publicworks/about-us

[12] *City of Waukesha, WI* http://www.ci.waukesha.wi.us/web/guest/wateraudit

[13] *Maryland Department of the Environment* http://www.mde.state.md.us/assets/document/resaudit.pdf

[14] Texas A&M http://texaswater.tamu.edu/conservation/home-water-audits

    b. 8.1 minutes per day *365 days per year * 2 person = 5913 minutes per year
    c. Replace 3.0 gpm with 1.0 gpm bath aerator = 2.0 gpm saved
    d. 11,826 gallons per bath aerator

iii. Kitchen Aerators
    a. Water use of 8.1 minutes per person per day[16]
    b. 8.1 minutes per day *365 days per year * 2 person = 5913 minutes per year
    c. Replace 3.0 gpm with 1.5 gpm kitchen aerator = 1.5 gpm saved
    d. 8,870 gallons per kitchen aerator

iv. Low Flow Showerheads
    a. Low flow showerhead water use of 8.8 gallons per person per day[17]
    b. Non-low flow showerhead water use of 13.3 gallons per person per day[18]
    c. 2 persons per showerhead * 0.75 showers per person per day
    d. 4.5 gallons saved * 1.5 showers per day * 365 days per year
    e. 2,464 gallons per low flow showerhead
v. Life Expectancy – 5 years (conservatively), likely closer to 10 years

## 3) OUTDOOR WATER EFFICIENCY REBATES AND DEVICES

### a. Go Native! Turf Removal

The City has only been offering a turf removal program for about 18 months. During this time, the turf removal incentive was offered only to residential customers and participants were able to obtain $2/sqft for turf removed (MWD and BWP each contributed $1/sqft). Within this first year, 32 projects were completed and 27,000 square feet of turf were removed. MWD calculates the replacement of turf with native plants and acceptable ground cover materials at 43.8 gallons per square foot converted, resulting in an annual savings of 3.63 AF with a conservative life span of 10 years. [19]

MWD has recently increased its contribution to $2/sf for a total of $3/sf when BWP's funding is included. With this increase in funding from MWD, customer interest has increased more than 200%. The City should invest sufficient funds to support the increased interest in this

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[15] AWWA Research Foundation, 1999, Residential End Uses of Water, page 96, http://www.waterrf.org/PublicReportLibrary/RFR90781_1999_241A.pdf

[16] AWWA Research Foundation, 1999, Residential End Uses of Water, page 96, http://www.waterrf.org/PublicReportLibrary/RFR90781_1999_241A.pdf

[17] AWWA Research Foundation, 1999, Residential End Uses of Water, page 134, http://www.waterrf.org/PublicReportLibrary/RFR90781_1999_241A.pdf

[18] AWWA Research Foundation, 1999, Residential End Uses of Water, page 134, http://www.waterrf.org/PublicReportLibrary/RFR90781_1999_241A.pdf

[19] Lifetime – 10 years, based on Southern Nevada Water Authority, page 26, http://www.westernresourceadvocates.org/media/pdf/Smart%20Savings%20Water%20Conservation.pdf

long-term, sustainable conservation measure. This conservation measure represents a significant financial commitment for the customer as well, as the total cost to remove and replace turf ranges from $5/sf to $20/sf depending on the landscape design and plant selections.[20] A suggested goal is to convert 300,000 sf of turf to native landscapes within the next two years, whether it be it residential or commercial. If successful, this will result in an **estimated annual savings of 40 AF, and lifetime savings of 403 AF.**

### b. Rain Barrels

According to the California Urban Water Conservation Council website www.h2ouse.org , it is possible to capture an astonishing 934 gallons of water from the rooftop of an average sized home of 1,500SF, which results in the potential savings of 15,215 gal/year, per residential property; assuming an average annual rainfall of 16.29[21] inches. While this savings is directly associated with one's ability to capture the rainwater and reuse it, it is quite plausible that a homeowner could capture nearly all, if not all, of the rain from their roof tops with two 60-gallon rain barrels during an average Burbank storm (the average amount of rainfall during a single storm event ranges between 0.10 to 0.25 inches) and use this water for such non-potable uses as irrigation, car washing, washing exterior windows, etc.

In the event that the rain harvested exceeds the capacity of the rain barrel, rain barrels are able to be designed and installed to divert water to landscaped areas (i.e. rain garden) upon reaching capacity, thereby still allowing the customer to capture the water and use it on site, limiting and potentially eliminating storm runoff and maximizing stormwater capture.

Burbank has funded this program minimally in the past; however, given the potential water savings, the low cost to the city and the customers, and the potential for sustainable savings, this program should be promoted and encouraged for both residential and commercial properties.

If Burbank were to distribute 400 rain barrels to residential and commercial customers, the City would have the potential to save an estimated 10 AFY annually, and 200 AF over a lifetime of 20 years.

The savings are based on the following assumptions:

i. Calculation of Savings:

  a. 934 gal x 16.29 inches=15,215 x .55 efficiency =8,368.25 gallons per rain barrel per year x 400 rain barrels
    - Annual rainfall of 16.29 inches for the City of Burbank
    - 934 gal of water from the rooftop of an average sized home of 1,500 sqft for every one inch of rainfall[22]
    - 8368.25 gallons per rain barrel

ii. Lifetime – Estimate of 20 years[23]

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[20] http://turfreplacement.watersmartsd.org/budgeting_success

[21] Burbank, California Average Rainfall. Western Regional Climate Center. Accessed 3/5/2014. http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ca1194

[22] http://www.h2ouse.org/tour/rain-harvesting.cfm

## 4) EDUCATION

### a. Home Water Reports And Customer Web Portal

A web-based software application to track, compare and provide bi-monthly residential water use and efficiency measure reports will show customers how much water they used compared to similar homes in their neighborhood and a sustainable home of similar size. Additionally, the proposed program will include a web-based portal customers can log on to and view real time data usage rates on an incremental basis (i.e. hourly, daily).

This represents a new conservation program the City could pilot targeting those residential customers with Tier 2 consumption rates in this program to maximize water savings and to compare water savings to a control group not receiving this service.

Based on literature from Water Smart, a vendor providing a home water reports and customer web portal service, and a pilot study conducted by East Bay Municipal Utility District and the California Water Foundation, it is estimated that participants in this program will save 5%[24]. Assuming up to 50% of the City's residential customers were to participate in this program, this program has the potential to save **341 AF of water annually.**

Due to the fact that this service has not been available for more than a couple of years, the sustainable savings (life expectancy) is unknown. The life expectancy used for the purposes of this document is ten years; however with continued availability of usage data and educational tips, continued savings would likely extend beyond ten years. This assumption is based on the sustainability of water conservation programs since the 1970s that led to behavioral changes that people incorporated into their day to day lives that persist today and are exercised by their children as well. This is the ultimate goal, educate end users to reduce their demands for water and develop a new normal through education.

Estimated water savings is based on the following assumptions:

1) Applied to average annual potable water sales = 19,208 AF
2) 71% residential customers, of which 50% are single family
3) Average savings among 10,000 participating households is 11,110 gallons per household, per year
4) Life expectancy: 10 years

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[23] https://www.portlandoregon.gov/bes/article/127467 and http://www.ct.gov/deep/lib/deep/water/watershed_management/wm_plans/lid/what_is_a_rain_barrel.pdf

[24] Savings – 5% based on EBMUD, http://californiawaterfoundation.org/uploads/1389391749-Watersmart_evaluation_report_FINAL_12-12-13(00238356).pdf

b. **WaterWise Gardening Website**
The WaterWise Gardening Website provides a wealth of information regarding native plants and creating native landscapes. This website supports the City's Go Native! turf removal program and is also an excellent resource for all customers interested in learning about native and invasive plants.

c. **Landscape Classes**
The landscaping classes support the Go Native! Program, but participants are not required to take the classes. These classes will be provided to residents and businesses and will teach customers about native plants, planting techniques, turf removal, etc.

## SUMMARY AND RECOMMENDATIONS

The City of Burbank Water and Power (BWP) in partnership with Metropolitan Water District of southern California (MWD) should expand existing water conservation efforts over the next two years to quickly address drought preparedness and reduce impacts on the State's finite water supply. The proposed two-year program includes the following water conservation elements:

**Table 3 – BWP Program Savings**

| Item | Current Annual Participation Rates | Current Annual Savings (AF) | Potential Annual Participation Rates | Potential Annual Savings after 1st year (AF) | Potential Annual Savings after 2nd year (AF) |
|---|---|---|---|---|---|
| HE Toilet Rebates | 200 | 1.39 | 650 | 4.53 | 9 |
| Green Home House Call Residential | 500 | 100 | 500 | 100 | 200* |
| Go Native! Turf Replacement | 50,000 SF | 6.7 | 150,000 SF | 20 | 40 |
| Rain Water Harvesting Rain Barrel | 24 | 0.62 | 200 | 5 | 10 |
| Home Water Reports and Customer Web | 0 | 0 | 10,000 | 341 | 341 |
| **Total Potential Water Savings** | | | | **470.53** | **600** |

*Includes continued water savings of 100 AF from those customers who participated in the first year.

These programs were selected based on customer interest, immediate savings, and potential for sustainable, long-term water savings.

Through expanding and increasing participation rates in a comprehensive water conservation program, BWP will improve and provide immediate regional and local drought preparedness benefits, increase local water supply reliability, and reduce water conflicts by saving approximately 500 AF of water annually and 600AF over the two-year term. Additionally, the capture of stormwater runoff through rain barrels and native landscapes will reduce non-point source pollutants and improve watershed management. Ecosystems and fisheries will also benefit by reducing the amount of water diverted from the Bay-Delta, and water quality benefits will result from less water diversions and less pollutants entering the Los Angeles River from urban runoff.

Drought conditions are increasing public interest in water conservation in Burbank and more funds are needed to meet the increasing demands. The City should continue to partner with MWD to share the financial costs of providing these water conservation measures and should also seek grant funding to maximize participation rates and water savings in order to meet increasing demand. Investing in these conservation programs will allow the City to provide an immediate reduction to water demand through engaging the public in water conservation without delays typical of capital infrastructure projects and without ongoing operations and maintenance costs to the City.

BWP staff will continually monitor customer participation in each of the conservation measures, and may make funding adjustments between programs to maximize savings by matching the interests of the customers. At the close of the recommended two-year period, the City should evaluate the benefits and participation rates and determine if the City's water conservation goals have been achieved and determine what funding levels will be appropriate going forward.

- **ALTERNATIVE OPTIONS**

Burbank Water and Power has a Recycled Water Master Plan that includes capital projects and is updated as capital projects are completed. Through this effort, BWP has effectively constructed miles of pipelines to distribute recycled water for non-potable uses (e.g. parks, golf courses, cemeteries, landscape areas, power plant, and more) resulting in an estimated annual distribution of more than 2,300 acre feet of water for the current 2013/14 fiscal year. This alternative water source represents an effective, sustainable alternative to potable water and specifically, imported water. However, the capital costs are significantly greater than that for the conservation programs and the benefit is not immediately realized, as there is a delay during which time the customers must complete their connections to receive the recycled water. For the purposes of implementing immediate water saving benefits that have a long-term sustainability benefit to support drought preparedness and mitigation, water conservation measures such as those recommended provide the least cost alternative.

## NEXT STEPS

### *Sustainable Water Master Plan*

Burbank Water and Power has partnered with the University of California, Santa Barbara Bren School of Environmental Science and Management to create a *Sustainable Water Master Plan*. The objective of this plan is to identify and evaluate a variety of supply-side projects, including stormwater capture, recycled water, and gray water reuse, and demand-side water conservation programs that BWP can implement at city-owned and customer-owned properties. The most feasible options will be used to develop a Plan that BWP can implement to help reduce reliance on MWD imported water and purchasing costs, reduce/stabilize water rates and increase customer satisfaction.

The Plan will include information on additional conservation measures and actions the City can implement and employ to further efforts to conserve water and reduce reliance upon imported water.

The research to develop this plan will also likely be useful for other water agencies interested in developing similar options or for comparative data on water supply and demand savings and costs.

Completion of this Plan is expected in spring of 2015.

### *Energy Savings*

The City currently uses a general formula for determining energy savings associated with water saved through its various conservation programs. It may be more beneficial to the City to develop a formula based specifically on the City's costs to treat and deliver potable water, as well as wastewater treatment.

# Analysis of the Energy Intensity of Water Supplies for West Basin Municipal Water District

March, 2007

Robert C. Wilkinson, Ph.D.

## Note to Readers

This report for West Basin Municipal Water District is an update and revision of an analysis and report by Robert Wilkinson, Fawzi Karajeh, and Julie Mottin (Hannah) conducted in April 2005. The earlier report, *Water Sources "Powering" Southern California: Imported Water, Recycled Water, Ground Water, and Desalinated Water*, was undertaken with support from the California Department of Water Resources, and it examined the energy intensity of water supply sources for both West Basin and Central Basin Municipal Water Districts. This analysis focuses exclusively on West Basin, and it includes new data for ocean desalination based on new engineering developments that have occurred over the past year and a half.

## Principal Investigator: Robert C. Wilkinson, Ph.D.

Dr. Wilkinson is Director of the Water Policy Program at the Donald Bren School of Environmental Science and Management, and Lecturer in the Environmental Studies Program, at the University of California, Santa Barbara. His teaching, research, and consulting focuses on water policy, climate change, and environmental policy issues. Dr. Wilkinson advises private sector entities and government agencies in the U.S. and internationally. He currently served on the public advisory committee for California's 2005 State Water Plan, and he represented the University of California on the Governor's Task Force on Desalination.
Contact: wilkinson@es.ucsb.edu

## West Basin Municipal Water District

**Contact:** Richard Nagel, General Manager
West Basin Municipal Water District
17140 South Avalon Boulevard, Suite 210
Carson, CA 90746
(310) 217 2411 phone, (310) 217-2414 fax
richn@westbasin.org

West Basin Municipal Water District www.westbasin.org

# Overview

Southern California relies on imported and local water supplies for both potable and non-potable uses. Imported water travels great distances and over significant elevation gains through both the California State Water Project (SWP) and Colorado River Aqueduct (CRA) before arriving in Southern California, consuming a large amount of energy in the process. Local sources of water often require less energy to provide a sustainable supply of water. Three water source alternatives which are found or produced locally and could reduce the amount of imported water are desalinated ocean water, groundwater, and recycled water. Groundwater and recycled water are significantly less energy intensive than imports, while ocean desalination is getting close to the energy intensity of imports.

Energy requirements vary considerably between these four water sources. All water sources require pumping, treatment, and distribution. Differences in energy requirements arise from the varying processes needed to produce water to meet appropriate standards. This study examines the energy needed to complete each process for the waters supplied by West Basin Municipal Water District (West Basin).

Specific elements of energy inputs examined in this study for each water source are as follows:

- Energy required to **import water** includes three processes: pumping California SWP and CRA supplies to water providers; treating water to applicable standards; and distributing it to customers.
- **Desalination of ocean water** includes three basic processes: 1) pumping water from the ocean or intermediate source (e.g. a powerplant) to the desalination plant; 2) pre-treating and then desalting water including discharge of concentrate; and 3) distributing water from the desalination plant to customers.
- **Groundwater** usage requires energy for three processes: pumping groundwater from local aquifers to treatment facilities; treating water to applicable standards; and distributing water from the treatment plant to customers. Additional injection energy is sometimes needed for groundwater replenishment.
- Energy required to **recycle water** includes three processes: pumping water from secondary treatment plants to tertiary treatment plants; tertiary treatment of the water, and distributing water from the treatment plant to customers.

The energy intensity results of this study are summarized in the table on the following page. They indicate that recycled water is among the least energy-intensive supply options available, followed by groundwater that is naturally recharged and recharged with recycled water. Imported water and ocean desalination are the most energy intensive water supply options in California. East Branch State Water Project water is close in energy intensity to desalination figures based on current technology, and at some points along the system, SWP supplies exceed estimated ocean desalination energy intensity. The following table identifies energy inputs to each of the water supplies including estimated energy requirements for desalination. Details describing the West Basin system operations are included in the water source sections. Note that the Title 22 recycled water energy figure reflects only the *marginal* energy required to treat secondary effluent wastewater which has been processed to meet legal discharge requirements, along with the energy to convey it to user

## Energy Intensity of Water Supplies for West Basin Municipal Water District

| | af/yr | Percentage of Total Source Type | kWh/af Conveyance Pumping | kWh/af MWD Treatment | kWh/af Recycled Treatment | kWh/af Groundwater Pumping | kWh/af Groundwater Treatment | kWh/af Desalination | kWh/af WBMWD Distribution | Total kWh/af | Total kWh/year |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Imported Deliveries** | | | | | | | | | | | |
| State Water Project (SWP) [1] | 57,559 | 43% | 3,000 | 44 | NA | NA | NA | NA | 0 | 3,044 | 175,209,596 |
| Colorado River Aqueduct (CRA) [1] (other that replenishment water) | 76,300 | 57% | 2,000 | 44 | NA | NA | NA | NA | 0 | 2,044 | 155,957,200 |
| **Groundwater[2]** | | | | | | | | | | | |
| natural recharge | 19,720 | 40% | NA | NA | NA | 350 | 0 | NA | 0 | 350 | 6,902,030 |
| replenished with (injected) SWP water [1] | 9,367 | 19% | 3,000 | 44 | NA | 350 | 0 | NA | 0 | 3,394 | 31,791,598 |
| replenished with (injected) CRA water [1] | 11,831 | 24% | 2,000 | 44 | NA | 350 | 0 | NA | 0 | 2,394 | 28,323,432 |
| replenished with (injected) recycled water | 8,381 | 17% | 205 | 0 | 790 | 350 | 0 | NA | 220 | 1,565 | 13,116,278 |
| **Recycled Water** | | | | | | | | | | | |
| West Basin Treatment, Title 22 | 21,506 | 60% | 205 | NA | 0 | NA | NA | NA | 285 | 490 | 10,537,940 |
| West Basin Treatment, RO | 14,337 | 40% | 205 | NA | 790 | NA | NA | NA | 285 | 1,280 | 18,351,360 |
| | 35,843 | | | | | | | | | | |
| **Ocean Desalination** | 20,000 | 100% | 200 | NA | NA | NA | NA | 3,027 | 460 | 3,687 | 82,588,800 |

Notes:

NA Not applicable

[1] Imported water based on percentage of CRA and SWP water MWD received, averaged over an 11-year period. Note that the figures for imports do not include an accounting for system losses due to evaporation and other factors. These losses clearly exist, and an estimate of 5% or more may be reasonable. The figures for imports above should therefore be understood to be conservative (that is, the actual energy intensity is in fact higher for imported supplies than indicated by the figures).

[2] Groundwater values include entire basin, West Basin service area covers approximately 86% of the basin. Groundwater values are specific to aquifer characteristics, including depth, within the basin.

# Energy Intensity of Water

Water treatment and delivery systems in California, including extraction of "raw water" supplies from natural sources, conveyance, treatment and distribution, end-use, and wastewater collection and treatment, account for one of the largest energy uses in the state.[1] The California Energy Commission estimated in its 2005 Integrated Energy Policy Report that approximately 19% of California's electricity is used for water related purposes including delivery, end-uses, and wastewater treatment.[2] The total energy embodied in a unit of water (that is, the amount of energy required to transport, treat, and process a given amount of water) varies with location, source, and use within the state. In many areas, the energy intensity may increase in the future due to limits on water resource extraction, and regulatory requirements for water quality, and other factors.[3] Technology improvements may offset this trend to some extent.

> ***Energy intensity*** is the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location.

## The Water-Energy Nexus

Water and energy systems are interconnected in several important ways in California. Water systems both provide energy – through hydropower – and consume large amounts of energy, mainly through pumping. Critical elements of California's water infrastructure are highly energy-intensive. Moving large quantities of water long distances and over significant elevation gains, treating and distributing it within the state's communities and rural areas, using it for various purposes, and treating the resulting wastewater, accounts for one of the largest uses of electrical energy in the state.[4]

Improving the efficiency with which water is used provides an important opportunity to increase related energy efficiency. (*"Efficiency"* as used here describes the useful work or service provided by a given amount of water.) Significant potential economic as well as environmental benefits can be cost-effectively achieved in the energy sector through efficiency improvements in the state's water systems and through shifting to less energy intensive local sources. The California Public Utilities Commission is currently planning to include water efficiency improvements as a means of achieving energy efficiency benefits for the state.[5]

## Overview of Energy Inputs to Water Systems

There are four principle energy elements in water systems:

1. primary water extraction and supply delivery (imported and local)
2. treatment and distribution within service areas
3. on-site water pumping, treatment, and thermal inputs (heating and cooling)

4. wastewater collection, treatment, and discharge

Pumping water in each of these four stages is energy-intensive. Other important components of embedded energy in water include groundwater pumping, treatment and pressurization of water supply systems, treatment and thermal energy (heating and cooling) applications at the point of end-use, and wastewater pumping and treatment.[6]

***1. Primary water extraction and supply delivery***

Moving water from near sea-level in the Sacramento-San Joaquin Delta to the San Joaquin-Tulare Lake Basin, the Central Coast, and Southern California, and from the Colorado River to metropolitan Southern California, is highly energy intensive. Approximately 3,236 kWh is required to pump one acre-foot of SWP water to the end of the East Branch in Southern California, and 2,580 kWh for the West Branch. About 2,000 kWh is required to pump one acre foot of water through the CRA to southern California.[7] Groundwater pumping also requires significant amounts of energy depending on the depth of the source. (Data on groundwater is incomplete and difficult to obtain because California does not systematically manage groundwater resources.)

***2. Treatment and distribution within service areas***

Within local service areas, water is treated, pumped, and pressurized for distribution. Local conditions and sources determine both the treatment requirements and the energy required for pumping and pressurization.

***3. On-site water pumping, treatment, and thermal inputs***

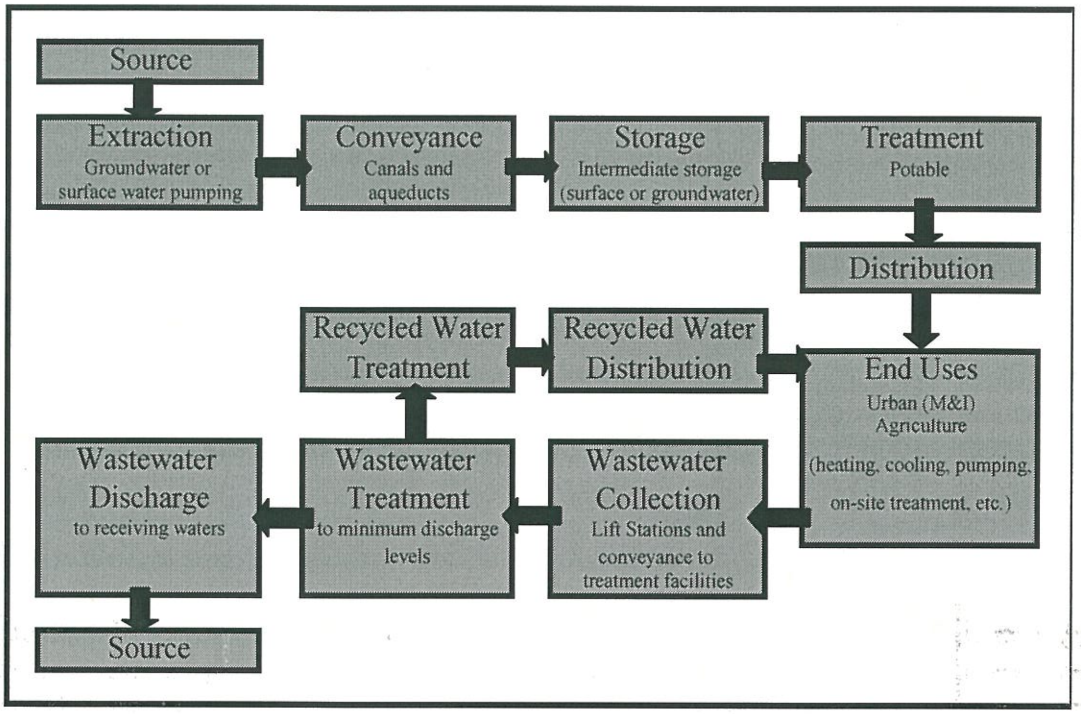
Individual water users use energy to further treat water supplies (e.g. softeners, filters, etc.), circulate and pressurize water supplies (e.g. building circulation pumps), and heat and cool water for various purposes.

***4. Wastewater collection, treatment, and discharge***

Finally, wastewater is collected and treated by a wastewater authority (unless a septic system or other alternative is being used). Wastewater is often pumped to treatment facilities where gravity flow is not possible, and standard treatment processes require energy for pumping, aeration, and other processes. (In cases where water is reclaimed and re-used, the calculation of total energy intensity is adjusted to account for wastewater as a *source* of water supply. The energy intensity generally includes the additional energy for treatment processes beyond the level required for wastewater discharge, plus distribution.)

The simplified flow chart below illustrates the steps in the water system process. A spreadsheet computer model is available to allow cumulative calculations of the energy inputs embedded at each stage of the process. This methodology is consistent with that applied by the California Energy Commission in its analysis of the energy intensity of water.

## Simplified Flow Diagram of Energy Inputs to Water Systems



Source: Robert Wilkinson, UCSB[8]

## Calculating Energy Intensity

Total energy intensity, or the amount of energy required to facilitate the use of a given amount of water in a specific location, may be calculated by accounting for the summing the energy requirements for the following factors:

- imported supplies
- local supplies
- regional distribution
- treatment
- local distribution
- on-site thermal (heating or cooling)
- on-site pumping
- wastewater collection
- wastewater treatment

Water pumping, and specifically the long-distance transport of water in conveyance systems, is a major element of California's total demand for electricity as noted above. Water use (based on embedded energy) is the next largest consumer of electricity in a typical Southern California home after refrigerators and air conditioners. Electricity required to support water service in the typical home in Southern California is estimated at between 14% to 19% of total residential energy demand.[9] If air conditioning is not a factor the figure is even higher. Nearly three quarters of this energy demand is for pumping imported water.

### Interbasin Transfers

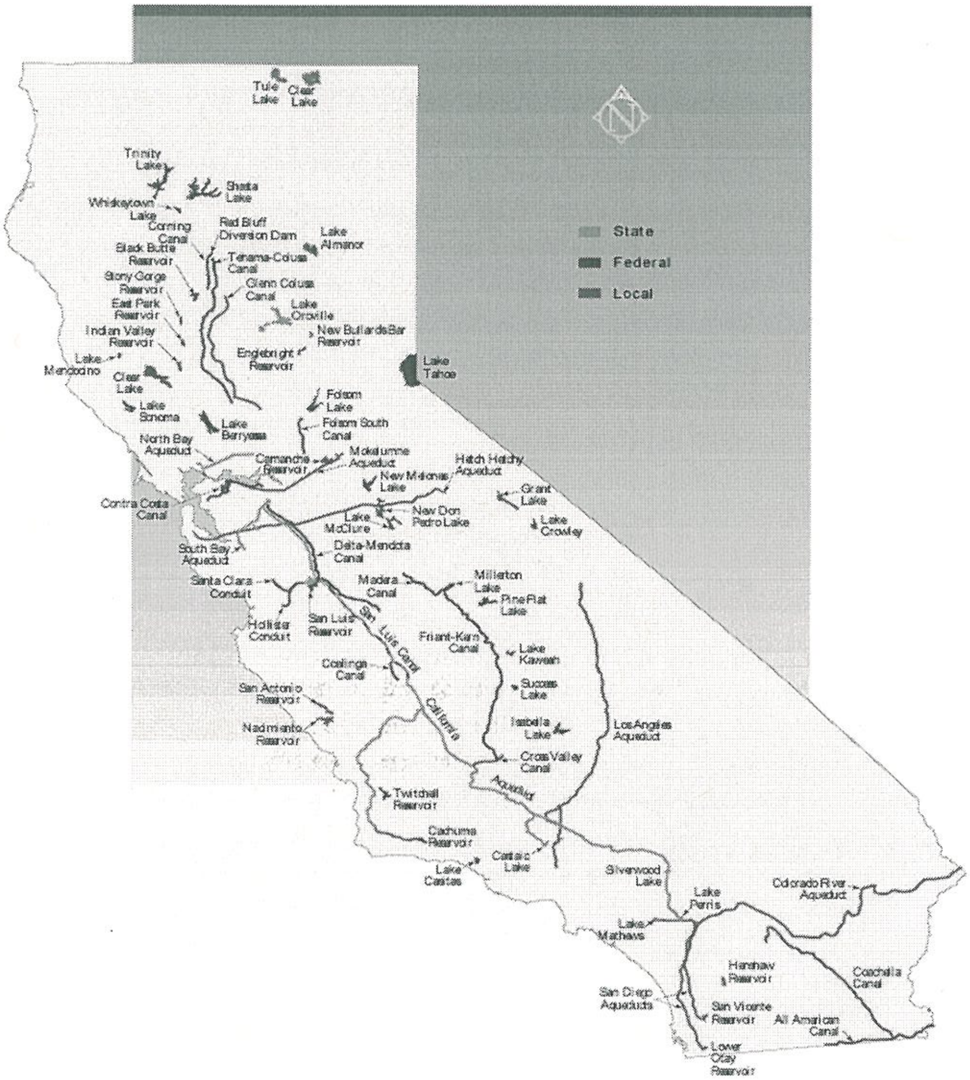
Some of California's water systems are uniquely energy-intensive, relative to national averages, due to the pumping requirements of major conveyance systems which move large volumes of water long distances and over thousands of feet in elevation lift. Some of the interbasin transfer systems (systems that move water from one watershed to another) are net energy producers, such as the San Francisco and Los Angeles aqueducts. Others, such as the SWP and the CRA require large amounts of electrical energy to convey water. On *average*, approximately 3,000 kWh is necessary to pump one AF of SWP water to southern California,[10] and 2,000 kWh is required to pump one AF of water through the CRA to southern California.[11]

Total energy savings for reducing the full embedded energy of *marginal* (e.g. imported) supplies of water used indoors in Southern California is estimated at about 3,500 kWh/af.[12] Conveyance over long distances and over mountain ranges accounts for this high marginal energy intensity. In addition to avoiding the energy and other costs of pumping additional water supplies, there are environmental benefits through reduced extractions from stressed ecosystems such as the delta.

## Imported Water:
## The State Water Project and the Colorado River Aqueduct

Water diversion, conveyance, and storage systems developed in California in the 20th century are remarkable engineering accomplishments. These water works move millions of AF of water around the state annually. The state's 1,200-plus reservoirs have a total storage capacity of more than 42.7 million acre feet (maf).[13] West Basin receives imported water from Northern California through the State Water Project and Colorado River water via the Colorado River Aqueduct. The Metropolitan Water District of Southern California delivers both of these imported water supplies to the West Basin.

**California's Major Interbasin Water Projects**



## The State Water Project

The State Water Project (SWP) is a state-owned system. It was built and is managed by the California Department of Water Resources (DWR). The SWP provides supplemental water for agricultural and urban uses.[14] SWP facilities include 28 dams and reservoirs, 22 pumping and generating plants, and nearly 660 miles of aqueducts.[15] Lake Oroville on the Feather River, the project's largest storage facility, has a total capacity of about 3.5 maf.[16] Oroville Dam is the tallest and one of the largest earth-fill dams in the United States.[17]

Water is pumped out of the delta for the SWP at two locations. In the northern Delta, Barker Slough Pumping Plant diverts water for delivery to Napa and Solano counties through the North Bay

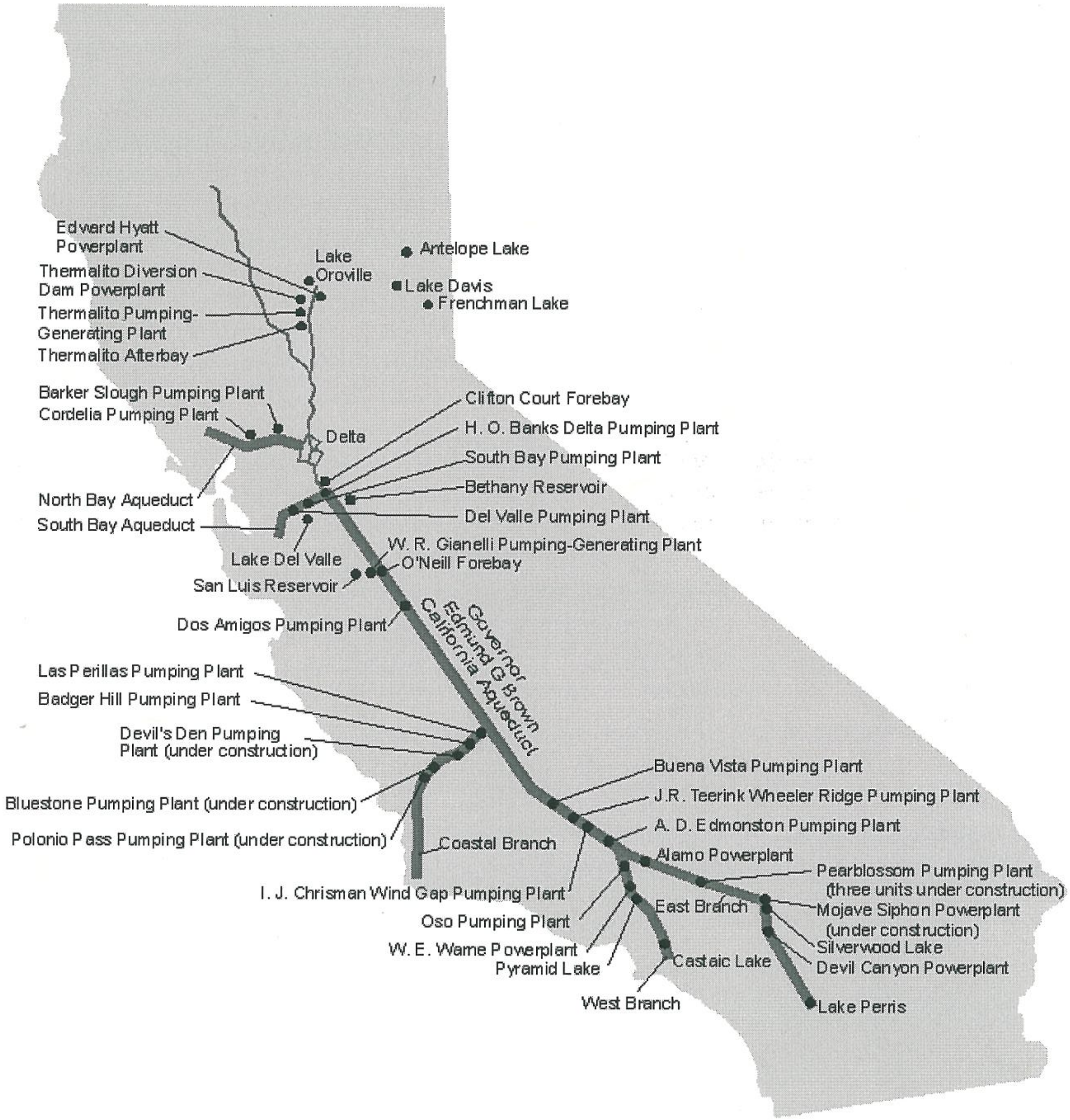
Aqueduct.[18] Further south at the Clifton Court Forebay, water is pumped into Bethany Reservoir by the Banks Pumping Plant. From Bethany Reservoir, the majority of the water is conveyed south in the 444-mile-long Governor Edmund G. Brown California Aqueduct to agricultural users in the San Joaquin Valley and to urban users in Southern California. The South Bay Pumping Plant also lifts water from the Bethany Reservoir into the South Bay Aqueduct.[19]

The State Water Project is the largest consumer of electrical energy in the state, requiring an average of 5,000 GWh per year.[20] The energy required to operate the SWP is provided by a combination of DWR's own hydroelectric and other generation plants and power purchased from other utilities. The project's eight hydroelectric power plants, including three pumping-generating plants, and a coal-fired plant produce enough electricity in a normal year to supply about two-thirds of the project's necessary power.

Energy requirements would be considerably higher if the SWP was delivering full contract volumes of water. The project delivered an average of approximately 2.0 mafy, or half its contracted volumes, throughout the 1980s and 1990s.[21] Since 2000 the volumes of imported water have generally increased.

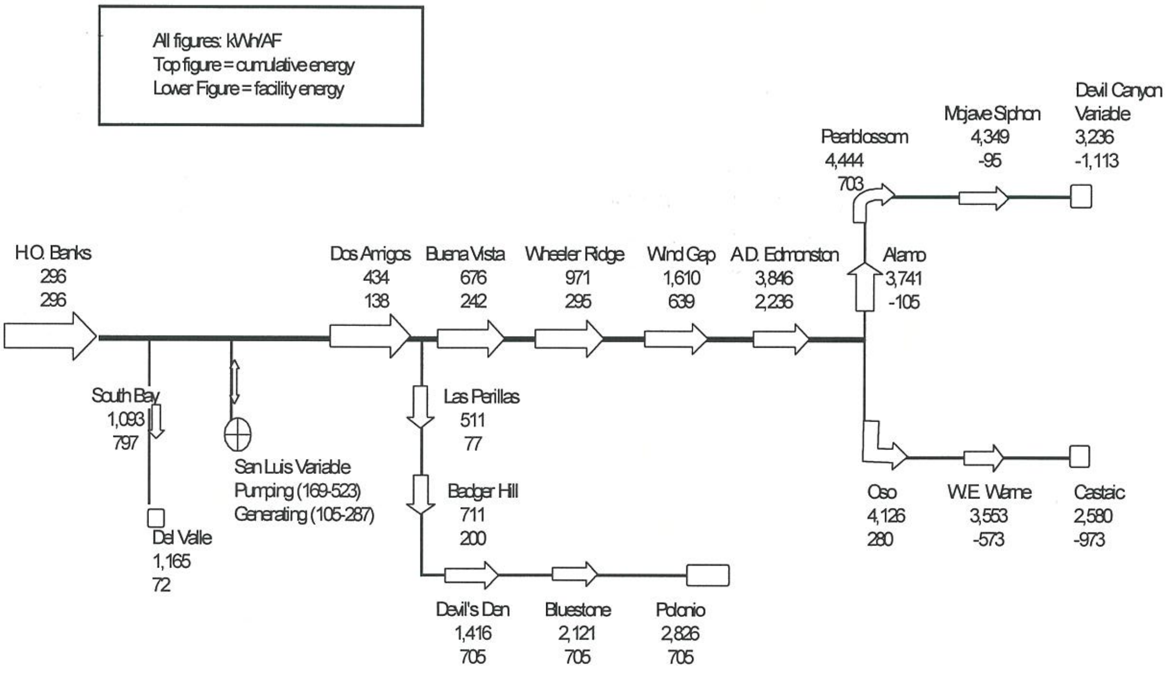
The following map indicates the location of the pumping and power generation facilities on the SWP.

## Names and Locations of Primary State Water Delivery Facilities



The following schematic shows each individual pumping unit on the State Water Project, along with data for both the individual and cumulative energy required to deliver an AF of water to that point in the system. Note that the figures include energy recovery in the system, but they do not account for losses due to evaporation and other factors. These losses may be in the range of 5% or more. While more study of this issue is in order, it is important to observe that the energy intensity numbers are conservative (e.g. low) in that they assume that all of the water originally pumped from the delta reaches the ends of the system without loss.

**State Water Project**
**Kilowatt-Hours per Acre Foot Pumped**
(Includes Transmission Losses)



Source: Wilkinson, based on data from: California Department of Water Resources, State Water Project Analysis Office, Division of Operations and Maintenance, *Bulletin 132-97*, 4/25/97.

## The Colorado River Aqueduct

Significant volumes of water are imported to the Los Angeles Basin and San Diego in Southern California from the Colorado River via the Colorado River Aqueduct (CRA). The aqueduct was built by the Metropolitan Water District of Southern California (MWD). Though MWD's allotment of the Colorado River water is 550,000 afy, it has historically extracted as much as 1.3 mafy through a combination of waste reduction arrangements with Imperial Irrigation District (IID) (adding about 106,000 afy) and by using "surplus" water.[22] The Colorado River water supplies require about 2,000 kWh/af for conveyance to the Los Angeles basin.

The Colorado River Aqueduct extends 242 miles from Lake Havasu on the Colorado River to its terminal reservoir, Lake Mathews, near Riverside. The CRA was completed in 1941 and expanded in 1961 to a capacity of more than 1 MAF per year. Five pumping plants lift the water 1,616 feet, over several mountain ranges, to southern California. To pump an average of 1.2 maf of water per year into the Los Angeles basin requires approximately 2,400 GWh of energy for the CRA's five pumping plants.[23] On average, the energy required to import Colorado River water is about 2,000 kWh/AF. The aqueduct was designed to carry a flow of 1,605 cfs (with the capacity for an additional 15%).

The sequence for CRA pumping is as follows: The Whitsett Pumping Plant elevates water from Lake Havasu 291 feet out of the Colorado River basin. At "mile 2," Gene pumping plant elevates water 303 feet to Iron Mountain pumping plant at mile 69, which then boosts the water another 144 feet. The last two pumping plants provide the highest lifts - Eagle Mountain, at mile 110, lifts the water 438 feet, and Hinds Pumping Plant, located at mile 126, lifts the water 441 feet.[24]

MWD has recently improved the system's energy efficiency. The average energy requirement for the CRA was reduced from approximately 2,100 kWh /af to about 2,000 kWh /af "through the increase in unit efficiencies provided through an energy efficiency program." The energy required to pump each acre foot of water through the CRA is essentially constant, regardless of the total annual volume of water pumped. This is due to the 8-pump design at each pumping plant. The average pumping energy efficiency does not vary with the number of pumps operated, and MWD states that the same 2,000 kWh/af estimate is appropriate for both the "Maximum Delivery Case" and the "Minimum Delivery Case."[25]

It appears that there are limited opportunities to shift pumping off of peak times on the CRA. Due to the relatively steep grade of the CRA, limited active water storage, and transit times between plants, the system does not generally lend itself to shifting pumping loads from on-peak to off-peak. Under the Minimum Delivery Case, the reduced annual water deliveries would not necessarily bring a reduction in annual peak load, since an 8-pump flow may still need to be maintained in certain months.

Electricity to run the CRA pumps is provided by power from hydroelectric projects on the Colorado River as well as off-peak power purchased from a number of utilities. The Metropolitan Water District has contractual hydroelectric rights on the Colorado River to "more than 20 percent of the firm energy and contingent capacity of the Hoover power plant and 50 percent of the energy and capacity of the Parker power plant."[26] Energy purchased from utilities makes up approximately 25 percent of the remaining energy needed to power the Colorado River Aqueduct.[27]

## Minimizing the Need for Inter-Basin Transfers

For over 100 years, California has sought to transfer water from one watershed for use in another. The practice has caused a number of problems. As of 2001, California law requires that the state examine ways to "*minimize the need to import water from other hydrologic regions*" and report on these approaches in the official State Water Plan.[28] A new focus and priority has been placed on developing *local* water supply sources, including efficiency, reuse, recharge, and desalination. The law directs the Department of Water Resources as follows:[29]

> The department, as a part of the preparation of the department's Bulletin 160-03, shall include in the California Water Plan a report on the development of regional and local water projects within each hydrologic region of the state, as described in the department's Bulletin 160-98, to improve water supplies to meet municipal, agricultural, and environmental water needs and *minimize the need to import water from other hydrologic regions.*

(Note that Bulletin 160-03 became Bulletin 160-05 due to a slip in the completion schedule.)

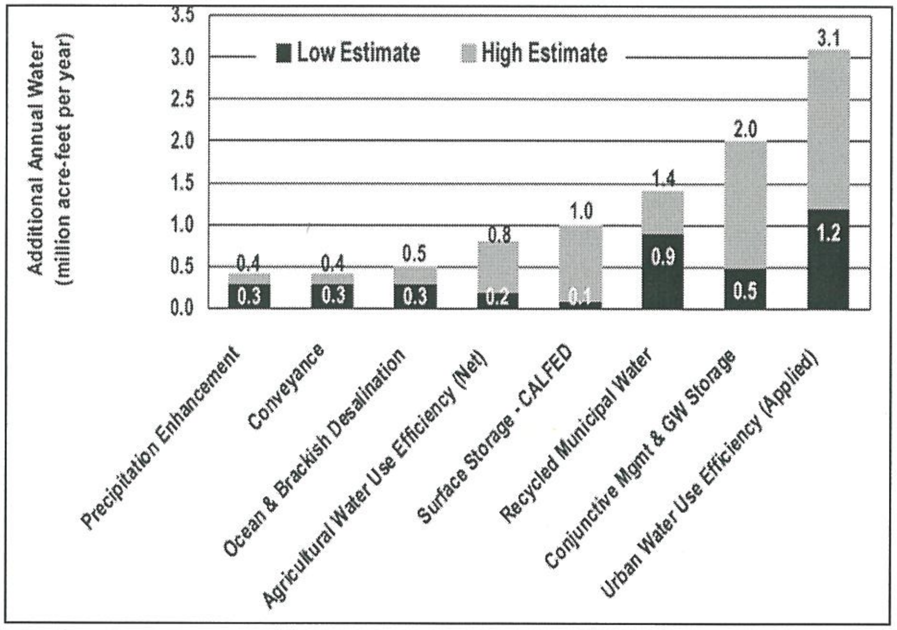
The legislation set forth the range of local supply options to be considered:

> The report shall include, but is not limited to, regional and local water projects that use technologies for desalting brackish groundwater and ocean water, reclaiming water for use within the community generating the water to be reclaimed, the construction of improved potable water treatment facilities so that water from sources determined to be unsuitable can be used, and the construction of dual water systems and brine lines, particularly in connection with new developments and when replacing water piping in developed or redeveloped areas.

This law calls for a thorough consideration in the state's official water planning process of work that is already going on in various areas of the state. The significance of the legislation is that for the first time, local supply development is designated as a priority in order to minimize inter-basin transfers.

The Department of Water Resources State Water Plan (Bulletin 160-05) reflects this new direction for the state in its projection of water supply options for the next quarter century. The following graph clearly indicates the importance of local water supplies from various sources in the future.

**California State Water Plan 2005**
**Water Management and Supply Options for the Next 25 Years**



Source: *California Water Plan Update 2005.*[30]

## Energy Requirements for Treatment of State Water Project and the Colorado River Aqueduct Supplies

Imported SWP and CRA supplies require an estimated 44 kWh/af for treatment before it enters the local distribution systems. Water pressure from MWD's system is sufficient to move supplies through the West Basin distribution system without requiring additional pressure.

# Groundwater and Recycled Water at West Basin MWD

Nearly half of the water used in the service area of the Metropolitan Water District of Southern California (from Ventura to Mexico) is secured from *local* sources, and the percentage of total supplies provided by local sources is growing steadily.[31] This figure is up from approximately one-third of the supply provided by local resources in the mid-1990s.[32] MWD has encouraged local supply development through support for recycling, groundwater recovery, conservation, groundwater storage, and most recently, ocean desalination.

Groundwater and recycled water are important and growing supply sources for West Basin. Water flows through natural hydrologic cycles continuously. The water we use today has made the journey many times. In water recycling programs, water is treated and re-used for various purposes including recharging groundwater aquifers. The treatment processes essentially short-circuit the longer-term process of natural evaporation and precipitation. In cities around the world water is used and then returned to natural water systems where it flows along to more users down stream. It is often used again and again before it flows to the ocean or to a terminal salt sink.

## Groundwater at West Basin MWD

Groundwater reservoirs in West Basin are replenished with four water sources; natural recharge, SWP supplies, CRA supplies, and recycled water supplies. The largest portion (approximately 40%) of groundwater supplies is derived from natural recharge. The energy associated with recovering this naturally recharged supply is estimated at 350 kWh/af for groundwater pumping.

Imported water, from both the SWP and CRA, is injected into the groundwater supply in West Basin. The imported water remains at sufficient pressure for injection, so no additional energy is required. The energy requirements for importing water are significant, however, primarily due to the energy associated with importing the water from northern California and the Colorado River. The imported water also passes through MWD's treatment plant, incurring additional energy requirements. The total energy intensity for West Basin's imported water used for recharge of groundwater storage from the SWP is 3,394 kWh/af and from the CRA is 2,394 kWh/af.

Recycled water is also used to recharge groundwater in the basin. West Basin replenishes groundwater by injecting RO treated recycled water from the West Basin Water Recycling Facility (WBWRF). The total energy use is 1,565 kWh/af. Details for the recycled water energy are described in the next section.

## Recycled Water at West Basin MWD

Many cities in California are using advanced processes and filtering technology to treat wastewater so it can be re-used for irrigation, industry, and other purposes. In response to increasing demands for water, limitations on imported water supplies, and the threat of drought, West Basin has developed state-of-the-art regional water recycling programs. Water is increasingly being used more than once within systems at both the end-use level and at the municipal level. This is because scarce water resources (and wastewater discharges) are increasing in cost and because cost-effective technologies and techniques for re-using water have been developed that meet health and safety requirements. At the end-use, water is recycled within processes such as cooling towers and industrial processes prior to entering the wastewater system. Once-through systems are increasingly being replaced by re-use technologies. At the municipal level, water re-use has become a significant source of supplies for both landscape irrigation and for commercial and industrial processes. MWD of Southern California is supporting 33 recycling programs in which treated wastewater is used for non-potable purposes. [33]

West Basin provides customers with recycled water used for municipal, commercial and industrial applications. Approximately 27,000 AF of recycled water is annually distributed to more than 210 sites in the South Bay. These sites use recycled water for a wide range of non-potable applications. Based in El Segundo, California, the WBWRF is among the largest projects of its kind in the nation, producing five qualities of recycled water with the capacity at full build-out to recycle 100,000 AF per year of wastewater from the Los Angeles Hyperion Treatment Plant.

In 1998, West Basin began to construct the nation's only regional high-purity water treatment facility, the Carson Regional Water Recycling Facility (CRWRF). A pipeline stretching through five South Bay communities connects the CRWRP to West Basin's El Segundo facility. At the CRWRF, West Basin ultra-purifies the recycled water it gets from the El Segundo facility. From the CRWRF, West Basin uses service lines to transport two types of purified water to the BP Refinery in Carson. The West Basin expansion also includes a new disposal pipeline to carry brine reject water from the CRWRF to a Los Angeles County Sanitation District's outfall.

In order to provide perspective on the energy requirements for the WBWRF, two water qualities and associated energy intensity are presented. "Title 22" water, produced by a gravity filter treatment system, requires conveyance pumping energy from Hyperion to WBWRF at 205 kWh/af. The water flows through the filters via gravity, thus no additional energy is required for treatment. The final energy requirement is 285 kWh/af for distribution with a total energy requirement of 490 kWh/af. This is the lowest grade of recycled water that WBWRF produces. Contrasting the Title 22 water, WBWRF produces RO water with a total energy requirement of 1,280 kWh/af. This includes 205 kWh/af for conveyance from Hyperion, 790 kWh/af for treatment with RO, and 285 kWh/af for distribution.

More than 210 South Bay sites use 9 billion gallons of West Basin's recycled water for applications including irrigation, industrial processes, indirect potable uses, and seawater barrier injection. West Basin has been successful in changing the perception of recycled water from merely a conservation tool with minimal applications to a cost-effective business tool that can reduce costs and improve reliability.

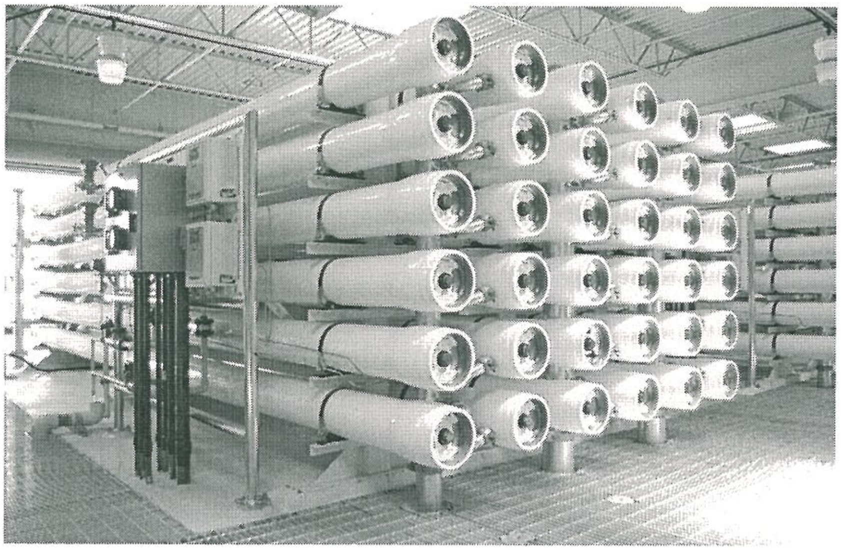
Local oil refineries are major customers for West Basin's recycled water. The Chevron Refinery in El Segundo, the Exxon-Mobile refinery in Torrance, and the BP refinery in Carson use recycled water for cooling towers and in the boiler feed systems.

## Ocean Water Desalination Development

Desalination technologies are in use around the world. A number of approaches work well and produce high quality water. Many workable and proven technology options are available to remove salt from water. During World War Two, desalination technology was developed as a water source for military operations.[34] Grand plans for nuclear-driven desalination systems in California were drawn up after the war, but they were never implemented due to cost and feasibility problems.

Desalination techniques range from distillation to "reverse osmosis" (RO) technologies. Current applications around the world are dominated by the "multistage flash distillation" process (at about 44% of the world's applications), and RO, (at about 42%).[35] Other desalting technologies include electrodialysis (6%), vapor compression (4%), multi-effect distillation (4%), and membrane softening (2%) to remove salts.[36] All of the ocean desalination projects currently in place or proposed for municipal water supply in California employ RO technology.

**Reverse Osmosis Membranes**



A recent inventory of desalination facilities world-wide indicated that as of the beginning of 1998, a total of 12,451 desalting units with a total capacity of 6.72 afy[37] had been installed or contracted worldwide.[38] (Note that *capacity* does not indicate actual operation.) Non-seawater desalination plants have a capacity 7,620 af/d[39], whereas the seawater desalination plant capacity reached 10,781af/d.[40]

Desalination systems are being used in over 100 countries, but 10 countries are responsible for 75 percent of the capacity.[41] Almost half of the desalting capacity is used to desalt seawater in the Middle East and North Africa. Saudi Arabia ranks first in total capacity (about 24 percent of the world's capacity) followed by the United Arab Emirates and Kuwait, with most of the capacity being made up of seawater desalting units that use the distillation process.[42]

The salinity of ocean water varies, with the average generally exceeding 30 grams per liter (g/l).[43] The Pacific Ocean is 34-38 g/l, the Atlantic Ocean averages about 35 g/l, and the Persian Gulf is 45 g/l. Brackish water drops to 0.5 to 3.0 g/l.[44] Potable water salt levels should be below 0.5 g/l.

Reducing salt levels from over 30 g/l to 0.5 g/l and lower (drinking water standards) using existing technologies requires considerable amounts of energy, either for thermal processes or for the pressure to drive water through extremely fine filters such as RO, or for some combination of thermal and pressure processes. Recent improvements in energy efficiency have reduced the amount of thermal and pumping energy required for the various processes, but high energy intensity is still an issue. The energy required is in part a function of the degree of salinity and the temperature of the water.

West Basin is in the process of developing plans to construct an ocean desalinating plant. Estimated energy requirements have been calculated by Gerry Filteau of Separation Processes, Inc for each step in the process.[45] The values presented for desalination are based on his work. Since the proposed plant will tap the source water at the power plant, there is no ocean intake pumping required. The source water is estimated to require 200 kWh/af this energy will bring ocean water from the power plant to the desalination system, approximately one quarter of a mile in distance. Pre-treatment of the source water is estimated at 341 kWh/af. This figure includes microfiltration and transfer to the RO units via a 5-10 micron cartridge filter. The RO process requires 2,686 kWh/af if operated at the most energy-efficient level. A slightly less efficient but more cost-effective level of operation would require 2,900 kWh/af, or 214 kWh/af additional energy input according to Filteau. Finally, an estimated 460 kWh/af is required to deliver the product water to the distribution system, including elevation gain, conveyance over distance, and pressurization to 90 psi. No additional energy is required to discharge the brine, as it flows back to the ocean outfall line by gravity.

The energy intensity figures presented here for desalination are lower than previous estimates. This is mainly due to improved membrane technologies, efficiency improvements for high pressure pumps, and pressure recovery systems. It should be noted that the figures provided here are based on engineering estimates, not on actual plant operations.

The total energy required to desalinate the ocean water, including each of the steps above, is estimated to be 3,687 kWh/af. If the energy intensity is increased slightly to improve cost-effectiveness, the total figure increases to 3,901 kWh/af.

# Summary

This study examined the energy intensity of imported and local water supplies (ocean water, groundwater, and recycled water) for both potable and non-potable uses for West Basin. All water sources require pumping, treatment, and distribution. Differences in energy requirements arise from varying pumping, treatment, and distribution processes needed to produce water to meet appropriate standards for different uses.

The key findings of this study are: 1) the marginal energy required to treat and deliver recycled water is among the *least* energy intensive supply options available, 2) naturally recharged groundwater is low in energy intensity, though replenishment with imported water is not, and 3) current ocean desalination technology is getting close to the level of energy intensity of imported supplies.

Further refinement of the data in this study, such as applying an agency's own energy values, may provide a more accurate basis for decision-making tailored to a unique water system. The information presented, however, provides a reasonable basis for water managers to explore energy (and cost) benefits of increased use of local water sources, and it indicates that desalination of ocean water is getting close to the energy intensity of existing supplies.

# Sources

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[1] Water systems account for roughly 7% of California's electricity use: See Wilkinson, Robert C., 2000. Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency.

[2] California Energy Commission, 2005. *Integrated Energy Policy Report*, November 2005, CEC-100-2005-007-CMF.

[3] Franklin Burton, in a recent study for the Electric Power Research Institute (EPRI), includes the following elements in water systems: "Water systems involve the transportation of water from its source(s) of treatment plants, storage facilities, and the customer. Currently, most of the electricity used is for pumping; comparatively little is used in treatment. For most surface sources, treatment is required consisting usually of chemical addition, coagulation and settling, followed by filtration and disinfection. In the case of groundwater (well) systems, the treatment may consist only of disinfection with chlorine. In the future, however, implementation of new drinking water regulations will increase the use of higher energy consuming processes, such as ozone and membrane filtration." Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities.* (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.3-1.

[4] Wilkinson, Robert C., 2000. *Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency.

[5] California Public Utilities Commission, Order Instituting Rulemaking Regarding to Examine the Commission's post-2005 Energy Efficiency Policies, Programs, Evaluation, Measurement and Verification, and Related Issues, Rulemaking 06-04-010 (Filed April 13, 2006)

[6] An AF of water is the volume of water that would cover one acre to a depth of one foot. An AF equals 325,851 gallons, or 43,560 cubic feet, or 1233.65 cubic meters.

[7] Metropolitan Water District of Southern California, *Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations*, 1996, p.5.

[8] This schematic, based on the original analysis by Wilkinson (2000) has been refined and improved with input from Gary Wolff, Gary Klein, William Kost, and others. It is the basic approach reflected in the CEC IEPR and other analyses.

[9] QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency*, Report for the Southern California Edison Company, p. 24.

[10] Figures cited are *net* energy requirements (gross energy for pumping minus energy recovered through generation).

[11] Metropolitan Water District of Southern California, *Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations*, 1996, p.5.

[12] Wilkinson, Robert C., 2000. *Methodology For Analysis of The Energy Intensity of California's Water Systems, and an Assessment of Multiple Potential Benefits Through Integrated Water-Energy Efficiency Measures*, Exploratory Research Project, Ernest Orlando Lawrence Berkeley Laboratory, California Institute for Energy Efficiency.

[13] California Department of Finance. California Statistical Abstract. Tables G-2, "Gross Capacities of Reservoirs by Hydrographic Region," and G-3 "Major Dams and Reservoirs of California." January 2001. (http://www.dof.ca.gov/html/fs_data/stat-abs/toc.htm)

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[14] "The SWP, managed by the Department of Water Resources, is the largest state-built, multi-purpose water project in the country. Approximately 19 million of California's 32 million residents receive at least part of their water from the SWP. SWP water irrigates approximately 600,000 acres of farmland. The SWP was designed and built to deliver water, control floods, generate power, provide recreational opportunities, and enhance habitats for fish and wildlife." California Department of Water Resources, *Management of the California State Water Project.* Bulletin 132-96. p.xix.

[15] California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.p.xix.

[16] Three small reservoirs upstream of Lake Oroville — Lake Davis, Frenchman Lake, and Antelope Lake — are also SWP facilities. California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.

[17] California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96. Power is generated at the Oroville Dam as water is released down the Feather River, which flows into the Sacramento River, through the Sacramento-San Joaquin Delta, and to the ocean through the San Francisco Bay.

[18] The North Bay Aqueduct was completed in 1988. (California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.)

[19] The South Bay Aqueduct provided initial deliveries for Alameda and Santa Clara counties in 1962 and has been fully operational since 1965. (California Department of Water Resources, 1996, *Management of the California State Water Project.* Bulletin 132-96.)

[20] Carrie Anderson, 1999, "Energy Use in the Supply, Use and Disposal of Water in California", Process Energy Group, Energy Efficiency Division, California Energy Commission, p.1.

[21] Average deliveries for 1980-89 were just under 2.0 mafy, deliveries for 1990-99 were just over 2.0 mafy. There is disagreement regarding the ability of the SWP to deliver the roughly 4.2 mafy that has been contracted for.

[22] According to MWD, "Metropolitan's annual dependable supply from the Colorado River is approximately 656,000 AF -- about 550,000 AF of entitlement and at least 106,000 AF obtained through a conservation program Metropolitan funds in the Imperial Irrigation District in the southeast corner of the state. However, Metropolitan has been allowed to take up to 1.3 maf of river water a year by diverting either surplus water or the unused portions of other agencies' apportionments." Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[23] Metropolitan Water District of Southern California, 1999, http://www.mwd.dst.ca.us/pr/powres/summ.htm.

[24] The five pumping plants each have nine pumps. The plants are designed for a maximum flow of 225 cubic feet per second (cfs). The CRA is designed to operate at full capacity with eight pumps in operation at each plant (1800 cfs). The ninth pump operates as a spare to facilitating maintenance, emergency operations, and repairs. Metropolitan Water District of Southern California, 1999, Colorado River Aqueduct: http://aqueduct.mwd.dst.ca.us/areas/desert.htm, 08/01/99.

[25] Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, p.5.

[26] Metropolitan Water District of Southern California, 1999, "Summary of Metropolitan's Power Operation". February, 1999, p.1, http://aqueduct.mwd.dst.ca.us/areas/desert.htm.

[27] Metropolitan Water District of Southern California, 1999, http://www.mwd.dst.ca.us/pr/powres/summ.htm. MWD provides further important system information as follows: Metropolitan owns and operates 305 miles of 230 kV transmission lines from the Mead Substation in southern Nevada. The transmission system is used to deliver power from Hoover and Parker to the CRA pumps. Additionally, Mead is the primary interconnection point for Metropolitan's economy energy purchases. Metropolitan's transmission system is interconnected with several utilities at multiple

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interconnection points. Metropolitan's CRA lies within Edison's control area. Resources for the load are contractually integrated with Edison's system pursuant to a Service and Interchange Agreement (Agreement), which terminates in 2017. Hoover and Parker resources provide spinning reserves and ramping capability, as well as peaking capacity and energy to Edison, thereby displacing higher cost alternative resources. Edison, in turn, provides Metropolitan with exchange energy, replacement capacity, supplemental power, dynamic control and use of Edison's transmission system.

[28] SB 672, Machado, 2001. California Water Plan: Urban Water Management Plans. (The law amended Section 10620 of, and adds Section 10013 to, the Water Code) September 2001.

[29] SEC. 2. Section 10013 to the Water Code, 10013. (a) SB 672, Machado. California Water Plan: Urban Water Management Plans. September 2001, (Emphasis added.)

[30] California Department of Water Resources, 2005. California Water Plan Update 2005. Bulletin 160-05, California Department of Water Resources, Sacramento, CA.

[31] Metropolitan Water District of Southern California, 2000. *The Regional Urban Water Management Plan for the Metropolitan Water District of Southern California*, p.A.2-3.

[32] "About 1.36 maf per year (34 percent) of the region's average supply is developed locally using groundwater basins and surface reservoirs and diversions to capture natural runoff." Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, Vol.1, p.1-2.

[33] MWD estimates that reclaimed water will ultimately produce 190,000 AF of water annually. Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[34] Buros notes that "American government, through creation and funding of the Office of Saline Water (OSW) in the early 1960s and its successor organizations like the Office of Water Research and echnology (OWRT), made one of the most concentrated efforts to develop the desalting industry. The American government actively funded research and development for over 30 years, spending about $300 million in the process. This money helped to provide much of the basic investigation of the different technologies for desalting sea and brackish waters." Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts, p.5. This very useful summary is available at http://www.ida.bm/PDFS/Publications/ABCs.pdf

[35] Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts, p.5. This very useful summary is available at http://www.ida.bm/PDFS/Publications/ABCs.pdf See also; Buros et al.1980. *The USAID Desalination Manual.* Produced by CH2M HILL International for the U.S. Agency for International Development.

[36] Wangnick,Klaus.1998 *IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association; and Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts, p.5.

[37] Desalination systems with a unit size of 100 m3/d or more. Figures in original cited as 6,000 mgd.

[38] Wangnick Consulting GMBH (http://www.wangnick.com) maintains a permanent desalting plants inventory and publishes the results biennially in co-operation with the International Desalination Association, as the IDA Worldwide Desalting Plants Inventory Report. Thus far, fifteen reports have been published, with the latest report having data through the end of 1997; and see Wangnick,Klaus.*1998 IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association. The data cited are as of December 31, 1997.

[39] Cited in original as 9,400,000 m3/d.

[40] Wangnick,Klaus.*1998 IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association. (Cited in original in m3d (13,300,000 m3/d).

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[41] Wangnick,Klaus.1998 *IDA Worldwide Desalting Plants Inventory Report No.15.*Produced by Wangnick Consulting for International Desalination Association; and Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts. The United States ranks second in over-all capacity (16 %) with most of the capacity in the RO process used to treat brackish water. The largest plant, at Yuma, Arizona, is not in use.

[42] Wangnick,Klaus.1998. *IDA Worldwide Desalting Plants Inventory Report No.15.* Produced by Wangnick Consulting for International Desalination Association; and Buros, O.K., 2000. *The ABCs of Desalting, International Desalination Association*, Topfield, Massachusetts.

[43] Salinity levels referenced in metric units.

[44] OTV. 1999. "Desalinating seawater." Memotechnique, Planete Technical Section, No. 31 (February), p.1; and Gleick, Peter H. 2000. *The World's Water: 2000-2001*, Island Press, Covelo, p.94.

[45] Gerry Filteau, Separation Processes, Inc., 2386 Faraday Ave., Suite 100, Calsbad, CA 92008, www.spi-engineering.com

## Table 1 (364 AFY)

| | | |
|---|---|---|
| Average Annual Imported Water Offset | 364 | AFY |
| SWP Conveyance and Pumping | 3,000 | kWh/AF |
| Proportion from SWP | 2,850 | 95% |
| CRA Conveyance and Pumping | 2,000 | kWh/AF |
| Proportion from CRA | 100 | 5% |
| Total Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Average Cost of Electricity (2014): | $0.178 | per kWh |
| Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Energy Used to Import Water (AFY*kWh/AF) | 1,073,800 | kWh/year |

## Table 2 (393 AFY)

| | | |
|---|---|---|
| Average Annual Imported Water Offset | 393 | AFY |
| SWP Conveyance and Pumping | 3,000 | kWh/AF |
| Proportion from SWP | 2,850 | 95% |
| CRA Conveyance and Pumping | 2,000 | kWh/AF |
| Proportion from CRA | 100 | 5% |
| Total Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Average Cost of Electricity (2014): | $0.178 | per kWh |
| Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Energy Used to Import Water (AFY*kWh/AF) | 1,159,350 | kWh/year |

## Table 3 (38 AFY)

| | | |
|---|---|---|
| Average Annual Imported Water Offset | 38 | AFY |
| SWP Conveyance and Pumping | 3,000 | kWh/AF |
| Proportion from SWP | 2,850 | 95% |
| CRA Conveyance and Pumping | 2,000 | kWh/AF |
| Proportion from CRA | 100 | 5% |
| Total Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Average Cost of Electricity (2014): | $0.178 | per kWh |
| Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Energy Used to Import Water (AFY*kWh/AF) | 112,100 | kWh/year |

## Table 4 (18 AFY)

| | | |
|---|---|---|
| Average Annual Imported Water Offset | 18 | AFY |
| SWP Conveyance and Pumping | 3,000 | kWh/AF |
| Proportion from SWP | 2,850 | 95% |
| CRA Conveyance and Pumping | 2,000 | kWh/AF |
| Proportion from CRA | 100 | 5% |
| Total Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Average Cost of Electricity (2014): | $0.178 | per kWh |
| Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Energy Used to Import Water (AFY*kWh/AF) | 53,100 | kWh/year |

## Table 3 (9.5 AFY)

| | | |
|---|---|---|
| Average Annual Imported Water Offset | 9.5 | AFY |
| SWP Conveyance and Pumping | 3,000 | kWh/AF |
| Proportion from SWP | 2,850 | 95% |
| CRA Conveyance and Pumping | 2,000 | kWh/AF |
| Proportion from CRA | 100 | 5% |
| Total Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Average Cost of Electricity (2014): | $0.178 | per kWh |
| Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| Energy Used to Import Water (AFY*kWh/AF) | 28,025 | kWh/year |

| **Table 1 (364 AFY)** | | | |
|---|---|---|---|
| | Average Cost of Electricity (2014): | $0.178 | per kWh |
| | Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| | Average Annual Imported Water Offset | 364 | AFY |
| | Conversion Factor | 0.724 | lbs of $CO_2$/kWh |
| **GHG Emissions to Import Water** | Energy Required for Importing x Conv. Factor | 2,136 | lbs $CO_2$/AF |
| | Energy Required for Importing Conv. To Met Tons | 0.969 | metric tons/AF |
| | GHG Emissions to Import Water Annually (Without Project) | 353 | metric tons |

| **Table 2 (393 AFY)** | | | |
|---|---|---|---|
| | Average Cost of Electricity (2014): | $0.178 | per kWh |
| | Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| | Average Annual Imported Water Offset | 393 | AFY |
| | Conversion Factor | 0.724 | lbs of $CO_2$/kWh |
| **GHG Emissions to Import Water** | Energy Required for Importing x Conv. Factor | 2,136 | lbs $CO_2$/AF |
| | Energy Required for Importing Conv. To Met Tons | 0.969 | metric tons/AF |
| | GHG Emissions to Import Water Annually (Without Project) | 381 | metric tons |

| **Table 2 (38 AFY)** | | | |
|---|---|---|---|
| | Average Cost of Electricity (2014): | $0.178 | per kWh |
| | Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| | Average Annual Imported Water Offset | 38 | AFY |
| | Conversion Factor | 0.724 | lbs of $CO_2$/kWh |
| **GHG Emissions to Import Water** | Energy Required for Importing x Conv. Factor | 2,136 | lbs $CO_2$/AF |
| | Energy Required for Importing Conv. To Met Tons | 0.969 | metric tons/AF |
| | GHG Emissions to Import Water Annually (Without Project) | 37 | metric tons |

| **Table 2 (18 AFY)** | | | |
|---|---|---|---|
| | Average Cost of Electricity (2014): | $0.178 | per kWh |
| | Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| | Average Annual Imported Water Offset | 18 | AFY |
| | Conversion Factor | 0.724 | lbs of $CO_2$/kWh |
| **GHG Emissions to Import Water** | Energy Required for Importing x Conv. Factor | 2,136 | lbs $CO_2$/AF |
| | Energy Required for Importing Conv. To Met Tons | 0.969 | metric tons/AF |
| | GHG Emissions to Import Water Annually (Without Project) | 17 | metric tons |

| **Table 2 (9.5 AFY)** | | | |
|---|---|---|---|
| | Average Cost of Electricity (2014): | $0.178 | per kWh |
| | Energy Required for Conveyance and Pumping | 2,950 | kWh/AF |
| | Average Annual Imported Water Offset | 10 | AFY |
| | Conversion Factor | 0.724 | lbs of $CO_2$/kWh |
| **GHG Emissions to Import Water** | Energy Required for Importing x Conv. Factor | 2,136 | lbs $CO_2$/AF |
| | Energy Required for Importing Conv. To Met Tons | 0.969 | metric tons/AF |
| | GHG Emissions to Import Water Annually (Without Project) | 9 | metric tons |

# California Climate Action Registry
# General Reporting Protocol

## Reporting Entity-Wide Greenhouse Gas Emissions

Version 3.1 | January 2009

Thus, regional/power pool emission factors for electricity consumption can be used to determine emissions based on electricity consumed. If you can obtain verified emission factors specific to the supplier of your electricity, you are encouraged to use those factors in calculating your indirect emissions from electricity generation. If your electricity provider reports an electricity delivery metric under the California Registry's Power/Utility Protocol, you may use this factor to determine your emissions, as it is more accurate than the default regional factor. Utility-specific emission factors are available in the Members-Only section of the California Registry website and through your utility's Power/Utility Protocol report in CARROT.

This Protocol provides power pool-based carbon dioxide, methane, and nitrous oxide emission factors from the U.S. EPA's eGRID database (see Figure III.6.1), which are provided in Appendix C, Table C.2. These are updated in the Protocol and the California Registry's reporting tool, CARROT, as often as they are updated by eGRID.

To look up your eGRID subregion using your zip code, please visit U.S. EPA's "Power Profiler" tool at www.epa.gov/cleanenergy/energy-and-you/how-clean.html.

Fuel used to generate electricity varies from year to year, so emission factors also fluctuate. When possible, you should use emission factors that correspond to the calendar year of data you are reporting. $CO_2$, $CH_4$, and $N_2O$ emission factors for historical years are available in Appendix E. If emission factors are not available for the year you are reporting, use the most recently published figures.

## U.S. EPA Emissions and Generation Resource Integrated Database (eGRID)

The Emissions & Generation Resource Integrated Database (eGRID) provides information on the air quality attributes of almost all the electric power generated in the United States. eGRID provides search options, including information for individual power plants, generating companies, states, and regions of the power grid. eGRID integrates 24 different federal data sources on power plants and power companies, from three different federal agencies: EPA, the Energy Information Administration (EIA), and the Federal Energy Regulatory Commission (FERC). Emissions data from EPA are combined with generation data from EIA to produce values like pounds per megawatt-hour (lbs/MWh) of emissions, which allows direct comparison of the environmental attributes of electricity generation. eGRID also provides aggregated data to facilitate comparison by company, state or power grid region. eGRID's data encompasses more than 4,700 power plants and nearly 2,000 generating companies. eGRID also documents power flows and industry structural changes. www.epa.gov/cleanenergy/egrid/index.htm.

**Figure III.6.1 eGRID Subregions**

Source: eGRID2007 Version 1.1, December 2008 (Year 2005 data).