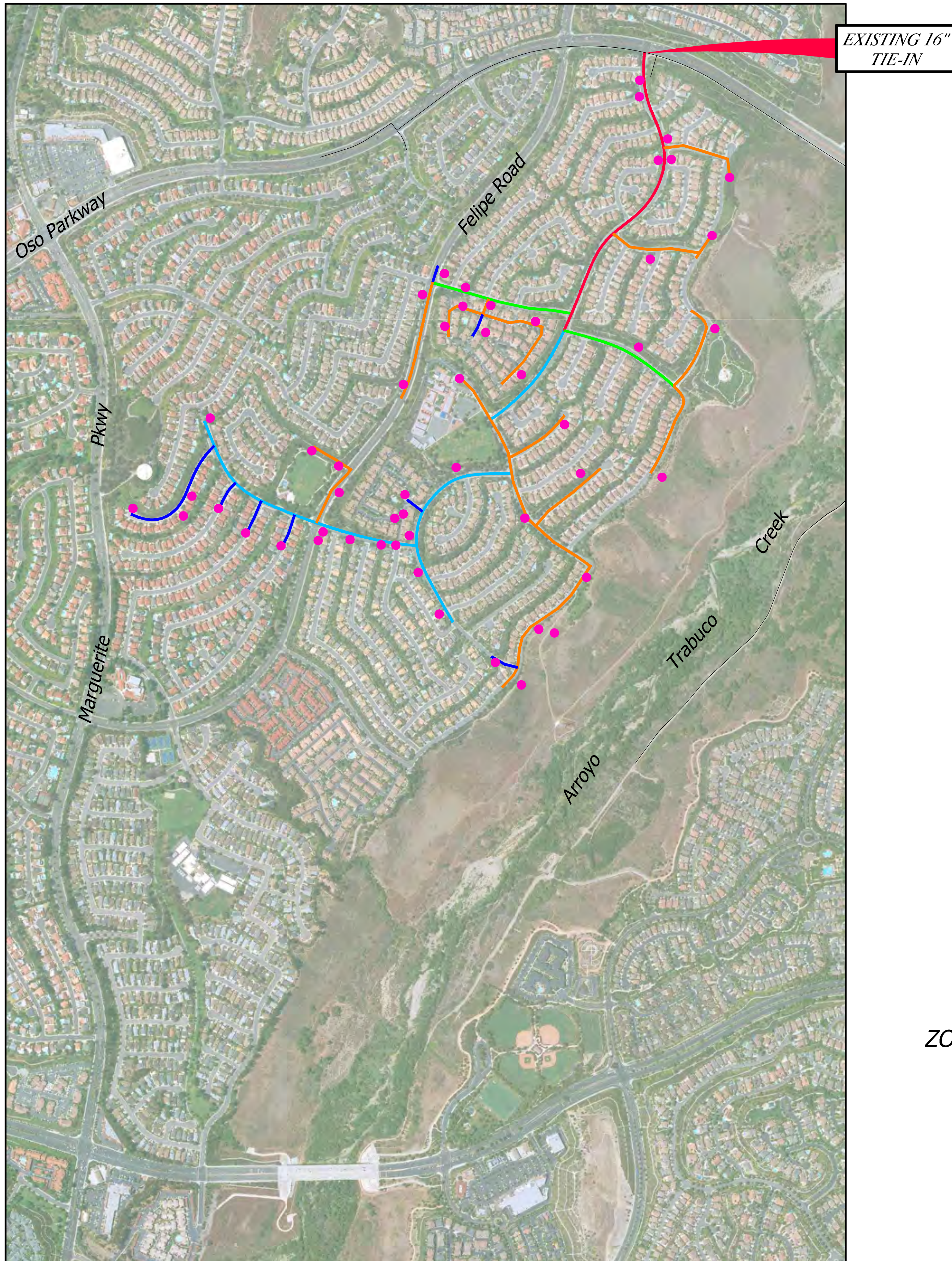
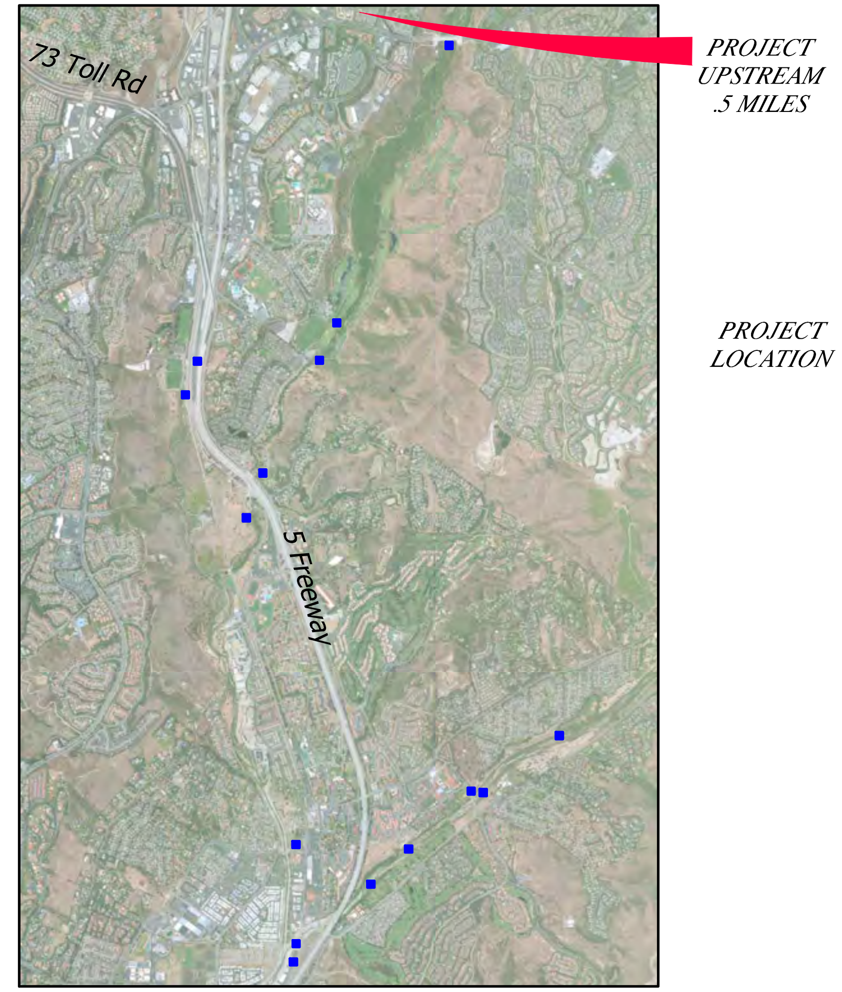
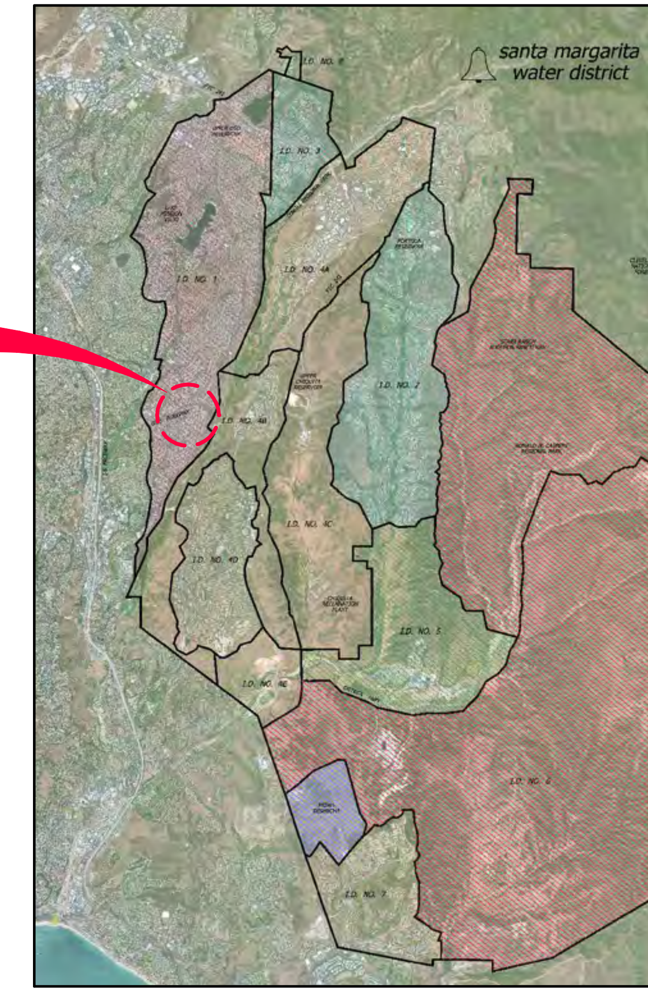




EXISTING DOWNSTREAM SURFACE WATER MONITORING LOCATIONS

NOT TO SCALE



SMWD Service Area Boundary

NOT TO SCALE

ZONE C IMPROVEMENTS

- 2" PIPE
- 4" PIPE
- 6" PIPE
- 8" PIPE
- 12" PIPE
- USER LOCATION

NOTES:

1. NO GROUNDWATER OR SURFACE WATER WILL BE AFFECTED BY THIS PROJECT.
2. NO DAC'S EXIST WITHIN THE PROJECT SERVICE AREA.
3. PROJECT HAS NO DIRECT EFFECT ON WATER RESOURCES AND NO PROPOSED NEW MONITORING LOCATIONS.

SCALE: NONE

SOUTH ORANGE COUNTY WMA IRWM DROUGHT GRANT APPLICATION	CALIFIA RECYCLED WATER PROJECT MAP	Santa Margarita Water District	JUNE 2014 Figure No. 1

P:\PROJECTS\SMWD MISC TASKS\CALIFIA CONVERSION\Project Location June 17.dwg, File date: 6/17/2014 12:16 PM, Print date: 6/17/2014 2:28 PM, by: Rivas, Alex

LOCATION OF NEW WATER PIPELINES

Legend

- Existing Recycled Water Lines
- Proposed Recycled Water Lines (6,400 ft)
- M Approx. Location of Existing Potable Irrigation Meters
- Existing Water Quality Monitoring Locations

N

0 250 500 1,000 Feet

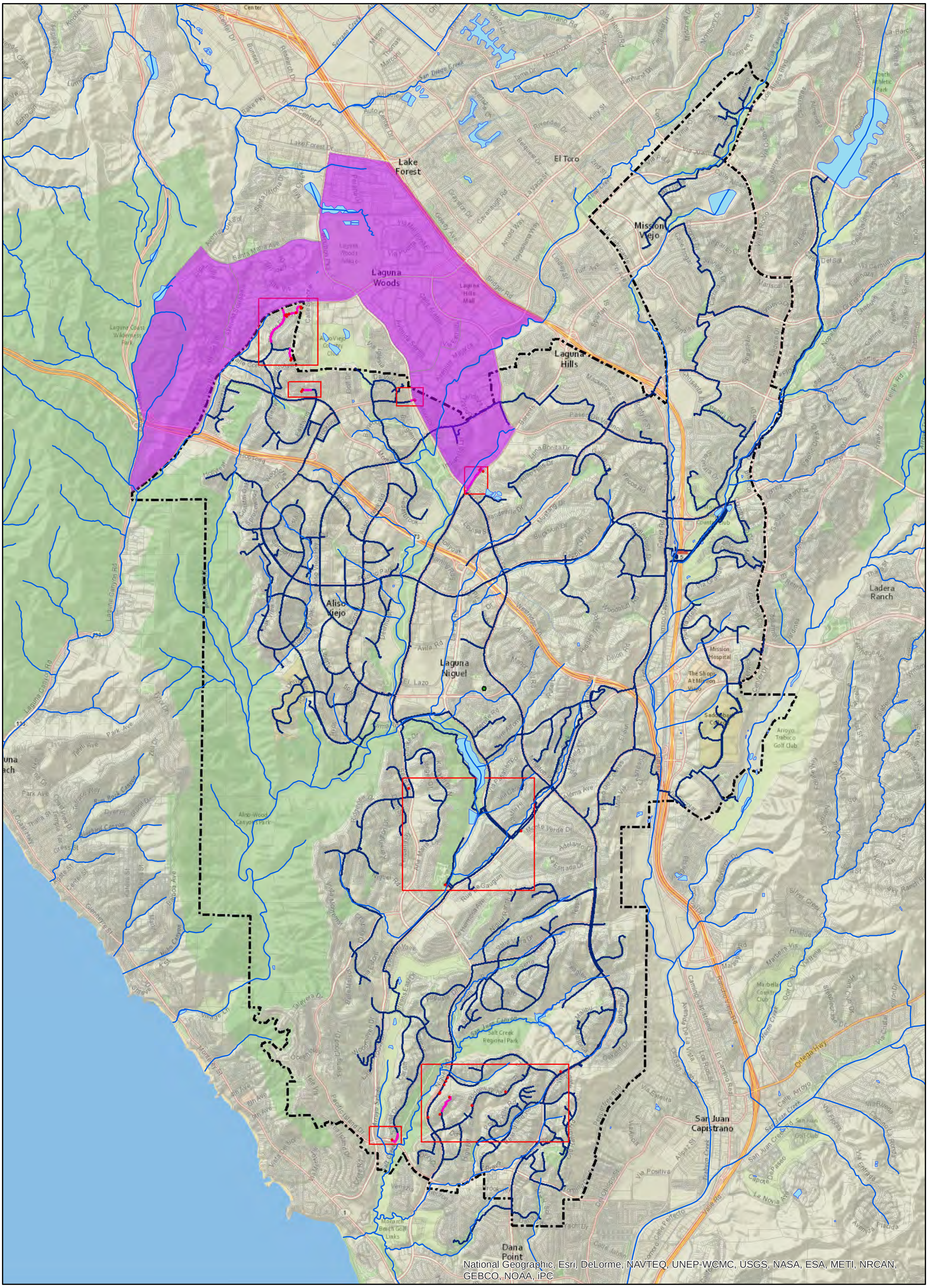
SOUTH COAST WATER DISTRICT

RECYCLED WATER SYSTEM EXTENSION PROJECT

Project will have no direct effect on water resources and no new monitoring locations are proposed.

Figure No. 2

7/21/14



Proposed RW Meters

Proposed Recycled Mains

Existing Recycled Mains

NHD Hydrology

NHD Waterbodies

Project Areas

District Boundary

Parcels

DAC Tracts

Project has no direct effect on water resources and no proposed new monitoring locations.

N

0 0.5 1 2 Miles

Scale =1:52,765

Moulton Niguel Water
Leading the Way in Service

MNWD Recycled Water System Extension Project
Figure No. 3

South Orange County Integrated Regional Watershed Management Program

Figure 4: SOCWMA Regional Map and Project Locations

0 1 2 4 Miles

Legend

Site Specific Grant Projects

SOCWMA

Watersheds

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.

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West Basin
Municipal Water District

West Basin Municipal Water District

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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
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

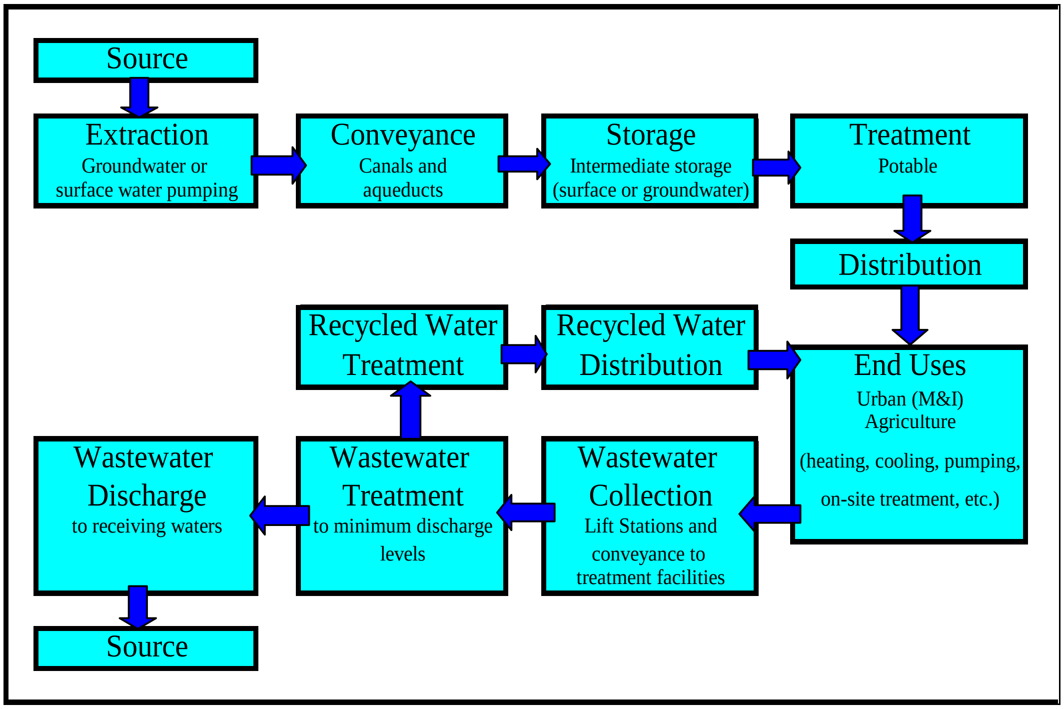
Individual water users use energy to further treat water supplies (e.g. softeners, filters, etc.), circulate and pressurize water supplies (e.g. building circulation pumps), and heat and cool water for various purposes.

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.

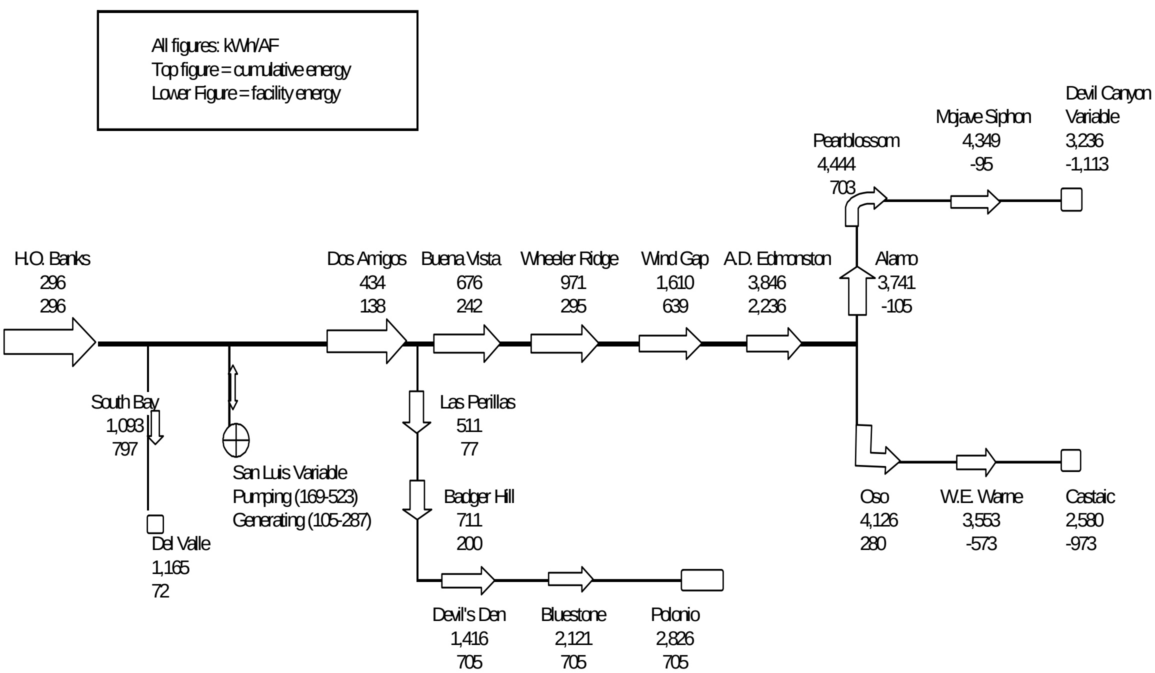
Energy requirements would be considerably higher if the SWP was delivering full contract volumes of water. The project delivered an average of approximately 2.0 mafy, or half its contracted volumes, throughout the 1980s and 1990s.[21] Since 2000 the volumes of imported water have generally increased.

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.)

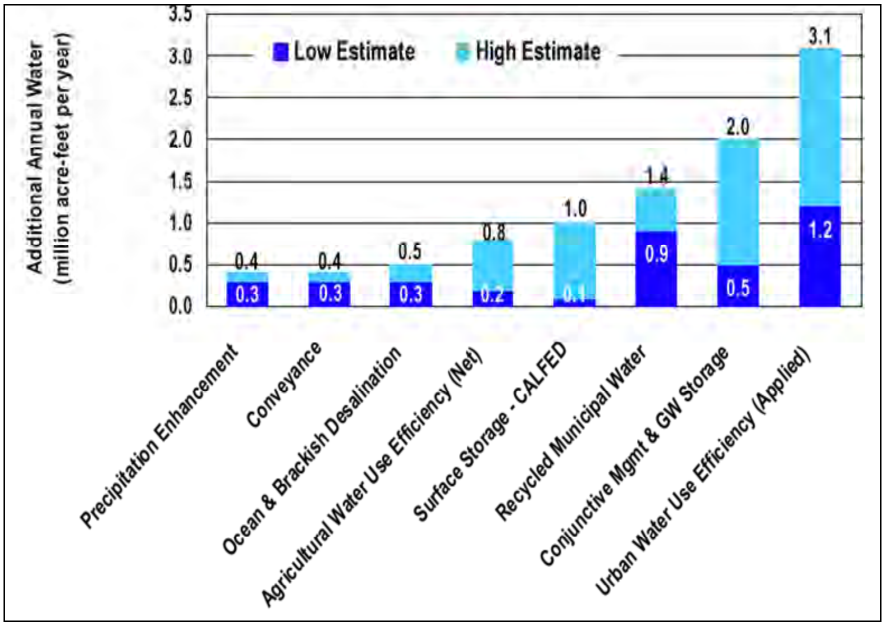
The legislation set forth the range of local supply options to be considered:

> 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

[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

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

National Water Research Institute

AN NWRI WHITE PAPER

Direct Potable Reuse: Benefits for Public Water Supplies, Agriculture, the Environment, and Energy Conservation

Prepared by:

EDWARD SCHROEDER, GEORGE TCHOBANOGLOUS, HAROLD L. LEVERENZ, AND TAKASHI ASANO

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NWRI White Paper

Direct Potable Reuse:
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About NWRI

A 501c3 nonprofit organization, the National Water Research Institute (NWRI) was founded in 1991 by a group of California water agencies in partnership with the Joan Irvine Smith and Athalie R. Clarke Foundation to promote the protection, maintenance, and restoration of water supplies and to protect public health and improve the environment. NWRI's member agencies include Inland Empire Utilities Agency, Irvine Ranch Water District, Los Angeles Department of Water and Power, Orange County Sanitation District, Orange County Water District, and West Basin Municipal Water District.

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CONTENTS

TABLES

ACRONYMS

DPR	Direct potable reuse
H_2O_2	Hydrogen peroxide
IPR	Indirect potable reuse
MWD	Metropolitan Water District of Southern California
TDS	Total dissolved solids

ABBREVIATIONS FOR UNITS OF MEASURE

ac	Acre; 43,560 ft^2 [$(5,280\ ft/mi)^2 \times (640\ ac/mi^2)$]
ac-ft	Acre-foot
ft	Foot
gal/capita•d	Gallons per capita per day
gal/lb	Gallons per pound
GWh/yr	Gigawatt hour per year
ha	Hectare; ten thousand square meters (100 m × 100 m)
hm^3	Cubic hectometer; million cubic meters (100 m × 100 m × 100 m)
hm^3/d	Cubic hectometer per day; million cubic meters per day
hm^3/yr	Cubic hectometer per year; million cubic meters per year
kg	Kilogram
km	Kilometer
kWh	Kilowatt
kWh/ac-ft	Kilowatt hour per acre-foot
kWh/m^3	Kilowatt hour per cubic meter
kWh/Mgal	Kilowatt hour per million gallons
L/capita•d	Liter per capita per day
m	Meter
Mac-ft	Million acre-feet
Mac-ft/yr	Million acre-feet per year
mg/L	Milligram per liter
Mgal/d	Million gallons per day
Mgal/yr	Million gallons per year
mi	Mile
Mlb	Million pounds
m^3	Cubic meter
m^3/kg	Cubic meter per kilogram
tonne	Metric tonne (1,000 kg)
TWh/yr	Terawatt-hour per year
µm	Micrometer

1. INTRODUCTION

Direct potable reuse (DPR), in which purified municipal wastewater is introduced into a water treatment plant intake or directly into the water distribution system, is becoming an increasingly attractive alternative to developing new water sources (Tchobanoglous et al., 2011). The rationale for DPR is based on the technical ability to reliably produce purified water that meets all drinking water standards and the need to secure dependable water supplies in areas that have, or are expected to have, limited and/or highly variable sources. To meet the purification level required, wastewater treated by conventional means undergoes additional treatment steps to remove residual suspended and dissolved matter, including trace organics. Questions of public acceptance are answered, in part, by the successful incorporation of DPR in the small resort town of Cloudcroft, New Mexico; by the Colorado River Water District serving a population of 250,000 in Big Spring, Stanton, Midland, and Odessa, Texas; and by the results of a recent public acceptance survey (Macpherson and Snyder, in press).

The focus of this white paper is on the role that DPR will have in the management of water resources in the future. For example, in many parts of the world, DPR will be the most economical and reliable method of meeting future water supply needs. The topics considered in this white paper include:

- An examination of beneficial impacts of DPR.
- A case study to demonstrate the relationship between DPR and urban water supplies, agriculture, the environment, and energy conservation, based on Southern California and the California State Water Project.
- The next steps that should be taken by water agencies to prepare for DPR in the future.

2. BENEFITS OF DIRECT POTABLE REUSE

Direct potable reuse can be implemented to provide a new and stable source of water supply for cities. However, the potential benefits accrued for agriculture, environmental preservation and enhancement, and energy conservation through the application of DPR may be more important.

2.1 Benefits for Public Water Supplies

Alternative solutions to meet urban water supply requirements include the development of inter-basin water transfer systems, desalinization of brackish water and seawater, and DPR. With inter-basin transfer, the availability of water for food production is limited, source area ecosystems are often destroyed, and transmission systems are subject to damage from earthquakes, floods, and other natural and human-made disasters. With desalination, energy requirements are comparatively large and brine disposal is a serious environmental issue. By comparison, DPR will have relatively modest energy requirements and provide a stable local source of water that is less subject to natural disasters. Because the water requirements of cities are greater than wastewater discharges, DPR will not be a stand-alone water supply. However, in many cases, sustainable local sources combined with DPR will be adequate. The application of DPR to create decentralized water resource management systems will allow the use of less pumping and energy consumption – factors that will mitigate increased treatment costs.

As urban areas grow, pressure on local water supplies, particularly groundwater, will increase. At present, groundwater aquifers used by over half of the world population are being over-drafted (Brown, 2011). The attractiveness of DPR will increase as the world's population becomes increasingly urbanized and concentrated near coastlines where local water supplies are limited and brine disposal is possible (Creel, 2003).

2.2 Benefits for Agriculture

Water exported for urban use decreases its availability for food production. The present world population of 7 billion is expected to reach 9.5 billion by 2050 (U.S. Census Bureau, 2011). A pattern of increased incorporation of animal and dairy products into the diet as people become more affluent and the need to protect aquatic ecosystems provide additional demands on the available water in source regions. The impact of diet on water use is demonstrated by the following statistics (Pimentel and Pimentel, 2003):

- Beef requires 12,000 gallons per pound (gal/lb) [100 cubic meters per kilogram (m^3/kg)] of water.
- Soybeans require 240 gal/lb (2.0 m^3/kg) of water.
- Wheat requires 110 gal/lb (0.90 m^3/kg) of water.

Municipal wastewater generation in the United States averages approximately 75 gallons per capita per day (gal/capita•d) [280 liters per capita per day (L/capita•d)] and is relatively constant throughout the year. Where collection systems are in poor condition, the wastewater generation rate may be considerably higher or lower due to infiltration/inflow or exfiltration, respectively. Thus, the potential municipal water supply offset by DPR for a community of 1-million people will be approximately 75 million gallons per day (Mgal/d) [0.28 million cubic meters per day (hm^3/d)] or 27,400 million gallons per year (Mgal/yr) [104 million cubic meters per year (hm^3/yr)]. Assuming adequate storage is available and evaporation losses are minimal, the water saved in the source region through the application of DPR by a population of 1-million people could result in the annual production of 2.3 million pounds (Mlb) (1,050 tonne) of beef, 114 Mlb (51,800 tonne) of soybeans, or 253 Mlb (115,000 tonne) of wheat. Given losses at various points in the system, the actual available water would most likely be about 50 percent of the potential value, but resulting agricultural production would still be impressive.

2.3 Benefits for the Environment

The elimination or minimization of water importation to cities through inter-basin transfers will reduce environmental impacts resulting from the construction of reservoirs and canals. A classic example of an environmental impact resulting from inter-basin transfers is the purchase of land and water rights in the Owens Valley, which is east of the Sierra Nevada, by the City of Los Angeles in the early twentieth century (Los Angeles Department of Water and Power, 2004). The City constructed reservoirs and the 233 mile (mi) [375 kilometer (km)] Los Angeles Aqueduct that stripped the valley of water for farming and cut off water to Owens Lake. Agriculture in the Owens Valley was decimated. Owens Lake dried up and became a major source of airborne particulate matter. In fact, dust emission from the dry lakebed is the nation's largest source of particles less than 10 micrometer (μm) in size and accounts for approximately 6 percent of all dust generation in the United States (Gill and Cahill, 1992; U.S. Environmental Protection Agency, 2004). Extension of the aqueduct into the Mono Lake watershed in 1941 resulted in the loss of 31 percent of the lake volume over the following 40 years. Suits by local governments and environmental groups have resulted in decreases in water imports by the City, a significant rise in the water level of Mono Lake, and a plan to manage dust emissions from Owens Lake.

2.4 Reduced Energy for Pumping Water

Inter-basin transfers of water often require large expenditures of energy to pump water over the mountain ranges separating and defining the basins. As a gravity flow system, the Los Angeles Aqueduct is somewhat of an exception to the general rule. However, the much larger Colorado River Aqueduct constructed in the 1930s by the Metropolitan Water District of Southern California (MWD) is an example of the amount of energy often required to import water to urban regions (Wilkinson, 2007). To bring 1.2 million acre-feet per year (Mac-ft/yr) (1,500 hm^3/yr) of water from the Colorado River to Southern California requires lifting water 1,616 feet (ft) [493 meters (m)] and a net power input of 2,400 gigawatt hours per year (GWh/yr) [2,000 kilowatt hours per acre-feet (kWh/ac-ft), 1.6 kilowatt hours per cubic meter (kWh/m^3)], not including the energy and materials required to construct and maintain the 242 mi (387 km) aqueduct consisting of 63 mi (101 km) of canals, 92 mi (147 km) of tunnels, and 84 mi (134 km) of pipes and siphons (Wilkinson, 2007).

3. SOUTHERN CALIFORNIA – AN EXAMPLE

Using a portion of the treated wastewater now being discharged to the Pacific Ocean through the application of DPR could stabilize the water supplies for both Southern California and San Joaquin Valley agriculture, significantly decrease the energy required for transporting water, protect and enhance the ecosystems of the Sacramento-San Joaquin Delta, and decrease the pollution of near shore waters and beaches in Southern California.

3.1 Current Southern California Water Supply

Four counties in Southern California (Los Angeles, Orange, Riverside, and San Diego) import the major portion of their water from Northern California through the State Water Project, the Colorado River, and the Owens Valley. With the exception of the portion from the Owens Valley, water importation is managed by MWD. Estimated average daily use in the four counties is 3,110 Mgal/d (3.48 Mac-ft/yr; 4,290 hm^3/yr), as shown in Table 1. The California State Water Project has a projected supply of over 4.0 Mac-ft/yr (4,900 hm^3/yr). A maximum allotment of 2.56 Mac-ft/yr (3,160 hm^3/yr) is contracted to Southern California water agencies, of which 2.01 Mac-ft/yr (2,480 hm^3/yr) is allotted to MWD. Water districts in the San Joaquin Valley have a maximum allotment of 1.20 Mac-ft/yr (1,480 hm^3/yr), with 83 percent allotted to the Kern County Water Agency. Nearly all of the water allotted to districts in the San Joaquin Valley is used for agriculture.

Table 1: Estimated Freshwater Use by Public Systems in Four Southern California Counties in 2005[a]

Item	Los Angeles	Orange	San Diego	Riverside
Population (1,000s)	9,935	2,988	2,933	1,946
Water Use by County (Mgal/d[b])				
Groundwater	331	49	75	86
Surface Water[c]	1,529	335	356	349
Total	1,860	384	431	435

[a] Adapted from U.S. Geological Survey (2005).
[b] 264 Mgal/d = 1 hm^3/d.
[c] Nearly all imported through inter-basin transfers.

"Maximum" is a key word in describing the distribution of State Project water. Since 2000, the allocations have averaged 69 percent of the maximum value, with average values for MWD and the San Joaquin Valley water districts being 1.35 and 0.83 Mac-ft/yr (1,670 and 1,020 hm^3/yr), respectively, as reported in Table 2. Southern California has responded to water supply limitations through water use restrictions, increased emphasis on conservation, and new water recycling projects emphasizing groundwater recharge. Water limitations to the San Joaquin

Valley water districts have been responded to, in part, by improved irrigation management and planting crops that have low water requirements, but the principal response is to reduce cultivated land.

Table 2: State Water Project Allocations to MWD and San Joaquin Valley Water Districts[a]

Year	Total All Contractors (Mac-ft/yr[b])	Percent of Capacity	MWD (Mac-ft/yr[b])	San Joaquin Valley (Mac-ft/yr[b])
Maximum	4.13	100	2.01	1.20
2011	3.34	80	1.53	0.91
2010	1.88	50	0.96	0.57
2009	1.67	40	0.76	0.47
2008	2.46	35	0.67	0.41
2007	2.47	60	1.21	0.72
2006	4.13	100	1.91	1.17
2005	3.71	90	1.72	1.05
2004	2.68	65	1.31	0.77
2003	3.71	90	1.81	1.08
2002	2.89	70	1.41	0.84
2001	1.61	39	0.78	0.47
2000	3.41	83	1.51	1.10
Average	2.93	69	1.35	0.83

[a] Adapted from California Department of Water Resources (2011).
[b] 1 Mac-ft/yr = 1,233 hm^3/yr.

The predicted impacts of climate change on water supplies in California include an overall decrease in annual precipitation, greater year-to-year variability, larger storms, and longer droughts. Thus, the variation in future allocations from the State Water Project is likely to become greater than those experienced since 2000.

3.2 Value of Agriculture in the San Joaquin Valley

The San Joaquin Valley of California is the most productive agricultural region in the world, but depends almost completely on irrigation because of limited annual precipitation extending from May through October. The value of agriculture in the valley will increase as global population increases and crops suitable for energy production are grown. The principal crops include a wide range of vegetables, grapes, melons, nuts, and stone fruits, many of which are grown almost exclusively in the valley, as shown in Table 3. Although a small portion of the total U.S. cotton crop, 90 percent of the nation's long fiber Pima cotton is grown in the valley (Starrs and Goin, 2010). Similarly, hay production is a small portion of the national crop, but is used locally for the large dairy herds in the valley that make California the leading producer of milk and cheese in the U.S. Although not usually recognized as a wine producing region, approximately 380,000 acres (ac) (150,000 hectares [ha]) of the State's 535,000 ac (217,000 ha) of wine grapes are grown in the Central Valley.

Table 3: Data for Selected California Crops Produced Principally in the Central Valley in 2008[a]

Crop	Percentage of U.S. Commercial Crop	Area Planted (ac[b])	Dollar Value	Approximate Annual Water Requirement (ft[b])
Almonds	99	680,000	2,400,000,000	4.3
Walnuts	99	218,000	750,000,000	3.3
Pistachios	96	150,000	600,000,000	3.5
Peaches	70	55,000	498,000,000	3.5
Nectarines	98	31,000	284,000,000	2.8
Pears	29	14,000	106,000,000	2.8
Apricots	95	24,100	35,000000	2.9
Plums	99	102,000	218,000,000	2.9
Oranges	30	184,000	1,100,000,000	3.9
Mandarins[c]	37	16,000	77,152,000	3.9
Grapes	91	590,000[d]	4,000,000,000	3.0
Cantaloupe	55	46,000	150,000,000	2.5
Tomatoes-processing[e]	95	276,000	812,000,000	2.1
Hay	6	570,000	1,400,000,000	4.0
Cotton	8	268,000	326,000,000	2.4

[a]Adapted from Starrs and Goin (2010).
[b] 2.47 ac = 1 ha; 3.28 ft = 1 m.
[c]California Fruit and Nut Review (2008).
[d]Central Valley only.
[e]California Processing Tomato Report (2008).

3.3 Potential for DPR in Southern California

Treated wastewater in the four Southern California counties is recycled for urban applications, used to recharge groundwater, or discharged to the Pacific Ocean. The greatest fraction of municipal wastewater is conveyed to treatment plants near the coast and discharged into the

Pacific Ocean through long ocean outfalls. Ocean discharge, comprising the most available source water for DPR, averages 1,259 Mgal/d [1.410 Mac-ft/yr (1,739 hm^3/yr)], as reported in Table 4. Purified water used for groundwater recharge is primarily from the upper reaches of the drainage basins and must be treated at least to the tertiary level. A significant portion of the wastewater is not used for recharge because of high salt concentrations.

Table 4: Quantities of Municipal Wastewater Discharged to the Pacific Ocean and Recycled in Southern California[a]

	Quantity (Mgal/d[b])	
Drainage Basin	**Ocean**	**Recycled**
Los Angeles	696	206
Santa Ana	246	44
San Diego	317	37
Total	1,259	287

[a] Adapted from Heal The Ocean (2010).
[b] 264 Mgal/d = 1 hm^3/d.

A model for potable reuse has been provided by the Orange County Water District, which operates a 70 Mgal/d (0.26 hm^3/d) advanced treatment facility purifying wastewater to drinking water standards and beyond (Orange County Water District, 2011). About half of the water is used for indirect potable reuse (IPR) through surface infiltration to the aquifer with an approximate residence time of 6 months, and the other half is used for injection wells to prevent seawater intrusion into coastal aquifers. It should be noted that the quality of purified water is reduced when it is blended into groundwater aquifers due to the presence of groundwater constituents.

Water Quantity: Treating a significant fraction of the wastewater now being discharged to the ocean to drinking water standards and introducing DPR will stabilize the water supply in Southern California. For example, using one-half the volume now discharged to the ocean [0.70 Mac-ft/yr (860 hm^3/yr)], would make up the difference between the average water allotment since the year 2000 and maximum State Water Project. Further, in the event that the delivery of State Water Project water to Southern California was interrupted due to an unforeseen event, such as a natural or human-made disaster, a substantial local water supply would still be available.

Water Quality: Improvement in Southern California water quality is an added benefit of DPR. State Project and Colorado River water have total dissolved solids (TDS) concentrations of approximately 300 and 650 milligrams per liter (mg/L), respectively, and contain trace organic compounds from agricultural runoff and upstream cities, most notably Las Vegas, Sacramento, and Stockton (Metropolitan Water District of Southern California, 2010, 2011a). Water leaving the DPR treatment facilities will have a TDS concentration of about 50 mg/L after mineral addition to provide chemical stabilization.

Cost of DPR: The Orange County Water District obtains treated wastewater from the Orange County Sanitation District (Orange County Water District, 2011). The treatment steps include microfiltration, reverse osmosis, and advanced oxidation with ultraviolet light and hydrogen peroxide (H_2O_2), and combined chlorine disinfection. The total capital and operating costs of treatment for the 2009-2010 fiscal year was $747/acre-foot (ac-ft) [$0.61/cubic meter (m^3)]. For comparison, MWD sells treated potable water for $742/ac-ft ($0.60/m^3) and untreated water for $527/ac-ft ($0.43/m^3), with increases to 794 and $560/ac-ft (0.64 and $0.45/$m^3$), respectively, starting in January 1, 2012 (Metropolitan Water District of Southern California, 2011b).

The Value of Water: In addition to the above considerations, the value of the purified water relative to other water sources must also be considered in assessing the potential of DPR. Such an assessment is of importance in light of recent court decisions regarding the allocation of water from Northern California and from the Colorado River to Southern California. Based on an analysis by the California Department of Water Resources, the cost of developing additional water supply in Southern California ranges from about 1,000 to $10,000/ac-ft (0.81 to $8.10/$m^3$) for alternatives such as desalination, water storage, and water conservation; municipal water reuse projects were identified as the least-cost, highest-gain option for long-term water supply reliability (Legislative Analyst's Office, 2008). A marginal cost analysis would be needed to assess the potential value of DPR as a water source.

3.4 Stabilization of the San Joaquin Valley Water Districts' Supply

The production of 0.70 Mac-ft/yr (860 hm^3/yr) of potable water through DPR in Southern California would make the same volume available to San Joaquin Valley water districts on a reliable basis. In low precipitation years, such as 2008, when allotments were 35 percent of the maximum, the districts could receive close to a full allotment [0.40 + 0.70 Mac-ft (490 + 860 hm^3)]. In years with more precipitation, the excess water could be used for other purposes, such as increasing farmed acreage, enhancement of the Sacramento-San Joaquin Delta, increasing storage volume, or groundwater recharge in the Central Valley. Water made available in the San Joaquin Valley through DPR in Southern California does not need to be treated before use in irrigation.

The decision of how the water made available would be allocated will be difficult because of the number of stakeholders involved. Farmers, environmentalists, and water districts in the San Francisco Bay area and originating areas north of Sacramento, as well as Southern California water districts, will become involved.

3.5 Environmental Enhancement

Instituting DPR in Southern California could greatly decrease environmental stress on the Sacramento-San Joaquin Delta. The State Water Project was highly controversial because of the environmental impacts foreseen and because water originating north of Sacramento was being transferred to the San Joaquin Valley and, more significantly, to Southern California. The initial phase of the California State Water Project, comprising 34 reservoirs and dams and 700 mi (1,120 km) of canals and pipelines, was completed in 1973. Since 1973, some additional phases have been completed, such as the 100 mi (160 km) coastal branch conveying water to San Luis

Obispo and Santa Barbara Counties. However, what remains unresolved is how best to convey water through or around the Sacramento-San Joaquin Delta.

The protection of endangered species, notably Delta smelt and winter-run salmon, and preventing salinity intrusion that impacts both the Delta ecosystems and water quality of communities in the East Bay and of water entering the California Aqueduct at the south end of the Delta, have resulted in a political stalemate for nearly 40 years. Numerous studies have been conducted and solutions proposed that address the environmental issues of the Delta. Each proposed solution has been attacked by one or more of the stakeholders – Delta environmental groups, Delta and East Bay water districts, MWD, and the San Joaquin Valley water districts receiving State Project water. A reliable source of 0.70 Mac-ft/yr (860 hm^3/yr) produced by application of DPR (which is 17 percent of the maximum annual yield of the State Water Project) could address most of the concerns, if political agreement can be reached.

3.6 Energy Conservation

At present, 19 percent of the electric power consumption in California is used to transport water (California Energy Commission, 2005). Consumption for urban water use, including wastewater treatment, is approximately 3,800 kilowatt hours per million gallons (kWh/Mgal) [1,200 kWh/ac-ft (1.0 kWh/m^3)], excluding conveyance. Importing water to Southern California requires an additional 8,750 kWh/Mgal [2,850 kWh/ac-ft (2.31 kWh/m^3)], as reported in Table 5.

Table 5: Electric Power Consumption in Typical Urban Water Systems[a]

Use	Power Consumption (kWh/Mgal[b])	
	Northern California	Southern California
Supply and Conveyance	150	8,900
Treatment	100	100
Distribution	1,200	1,200
Wastewater Treatment	2,500	2,500
Total	3,950	12,700

[a] Adapted from California Energy Commission (2005).
[b] 3785 kWh/Mgal = 1 kWh/m^3.

The energy required for the production of purified water will vary from 3,800 to 5,700 kWh/Mgal [1,200 to 1,900 kWh/ac-ft (1.0 to 1.5 kWh/m^3)] beyond secondary treatment, depending on the wastewater total dissolved solids (i.e., about 500 to 1,000 mg/L). For comparison, desalination of seawater requires 13,000 to 15,000 kWh/Mgal [4,200 to 4,900 kWh/ac-ft (3.4 to 4.0 kWh/m^3)]. The potential net energy savings in Southern California of developing 0.70 Mac-ft/yr (860 hm^3/yr) of purified water by DPR can be computed as the energy savings for supply/conveyance [estimated to be 8,750 kWh/Mgal (2.31 kWh/m^3)] reduced by the energy input required for the purification process [estimated to range from 3,800 to 5,700 kWh/Mgal (1.0 to 1.5 kWh/m^3)]. Thus, the estimated net energy savings ranges from 3,000 to 5,000 kWh/Mgal (0.8 to 1.3 kWh/m^3), or 0.7 to 1 terawatt-hours per year (TWh/yr). At $0.075/kWh, the savings would be 50 to $87 million per year.

4. IMPLICATIONS OF FINDINGS AND NEXT STEPS

DPR is a technically feasible method of stabilizing water supplies for municipalities and agriculture; preventing, minimizing, or correcting environmental damage resulting from inter-basin water transfers; and conserving energy. However, the application of DPR on a large scale, such as in Southern California, will raise significant political issues related to the ownership of water that will need to be resolved.

Given appropriate terminology and context, there is strong support for DPR based on the findings from a recently completed study of public attitudes (Macpherson and Synder, in press). Based on this finding, it is clear that the water and wastewater industry should undertake an initiative to develop a planning process to examine the potential of DPR and impediments to its implementation.

One of the major steps that should be taken by the water and wastewater industry is to develop closer ties with respect to the management of available water resources. As water distribution system modifications and replacements are planned and implemented, attention should be focused on appropriate locations within an existing system where engineered storage buffers or water purification plants can be located (e.g., near existing water treatment plants or other suitable locations within the service area). Studies should be undertaken to assess what blending ratios would be acceptable with the existing water supply to protect public health, maintain water quality, and control corrosion.

For example, conventional wastewater treatment systems will need to be designed or modified to optimize overall performance and enhance the reliability of the DPR water purification system. Measures that can be undertaken to enhance the reliability of a DPR system include: enhanced (targeted) source control programs, enhanced physical screening, upstream flow equalization, elimination of untreated return flows, modifying the mode of operation of biological treatment processes, improved performance monitoring systems, and the use of pilot test facilities for the ongoing evaluation of new technologies and process modifications (Tchobanoglous et al., 2011).

5. SUMMARY

As a result of worldwide population growth, urbanization, and climate change, public water supplies are becoming stressed and tapping new water supplies for metropolitan areas is becoming more difficult, if not impossible. In the future, it is anticipated that DPR will become an imperative (Leverenz et al., 2011). When compared with other options, water reuse is the most cost-effective approach to long-term water supply sustainability. The case study of Southern California illustrates the potential impact of DPR: stabilization of water supplies for a large urban population and a major agricultural region and energy savings ranging from 0.7 to 1 TWh/yr, roughly a savings of $50 to $87 million per year. Thus, the steps that will be necessary to make DPR a reality and the elements of an implementation plan should be identified. Starting the planning process now will allow for early identification of the changes required to both the water and wastewater infrastructure to accommodate DPR. These findings are applicable not only in California, but also worldwide.

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6. Recycled Water

6.1. Agency Coordination

There are a number of water agencies in south Orange County that provide potable water service as well as wastewater collection and treatment. These agencies depend on imported water supplies for the majority of their potable water supplies due to misfortune of geography in that very little groundwater supplies are available. These agencies have been in the forefront of recycled water development to diversify water supplies. Over the years most agencies have given up individual wastewater treatment facilities and joined SOCWA.

Table 6-1: Participating Agencies

Participating Agencies	Participated
Water Agencies	MWDOC
Wastewater Agencies	SOCWA, MNWD

6.2. Wastewater Description and Disposal

MNWD collects wastewater via a network of gravity lines, lift stations, and force mains throughout the service area. Wastewater is primarily residential in nature. There is very little contribution from commercial and industrial activities as MNWD is primarily residential. Wastewater collected by MNWD is sent to the South Orange County Wastewater Authority (SOCWA) plants for treatment and disposal. SOCWA is a Joint Powers Authority (JPA) that collects, treats, and disposes of wastewater and sludge in south Orange County. MNWD is a member agency of SOCWA. Other SOCWA member agencies include City of Laguna Beach, Trabuco Canyon Water District, Emerald Bay Services District, South Coast Water District, Irvine Ranch Water District, the City of San Clemente, City of San Juan Capistrano and Santa Margarita Water District. Costs for the operation and maintenance of treatment facilities are proportioned to each member agency primarily based on volume deliveries and/or capacity ownership of the plants. The current total average daily flow tributary to the SOCWA J.B.Latham Treatment Plant is 8.5 million gallons per day (MGD). The plant has a design capacity of 13 MGD. The SOCWA Joint Regional Treatment Plant has a capacity of 12 MGD and is currently processing slightly over 10 MGD. Plant 3A has a secondary treatment capacity of 8 MGD and is currently processing 4 MGD. MNWD owns 22.7 MGD of secondary treatment capacity in the SOCWA treatment plants.

The SOCWA plants use a conventional activated sludge process that treats wastewater to secondary treatment standards. The SOCWA plant effluent is disposed by means of ocean outfalls that discharge off the coasts of Dana Point and Laguna Beach.

Table 6-2 summarizes the past, current, and projected wastewater volumes collected and treated, and the quantity of wastewater treated to recycled water standards for treatment plants within SOCWA's service area. Table 6-3 summarizes the disposal method, and treatment level of discharge volumes.

Table 6-2: Wastewater Collection and Treatment (AFY)

Type of Wastewater	Fiscal Year Ending						
	2005	2010	2015	2020	2025	2030	2035-opt
Wastewater Collected & Treated in Service Area	29,223	28,149	30,460	31,536	32,249	32,249	32,249
Volume that Meets Recycled Water Standards	8,678	8,887	9,598	15,540	17,021	17,021	17,021

Table 6-3: Disposal of Wastewater (Non-Recycled) (AFY)

Method of Disposal	Treatment Level	Fiscal Year Ending					
		2010	2015	2020	2025	2030	2035-opt
Ocean Outfall	Secondary	19,262	20,862	15,996	15,228	15,228	15,228

6.3. Current Recycled Water Uses

In 1984, the MNWD constructed a 0.6 MGD Advanced Wastewater Treatment Plant (AWT) at the AWMA plant in Laguna Niguel, currently known as SOCWA Joint Regional Wastewater Treatment Plant (JRTP). This tertiary treatment facility produced water for irrigating the El Niguel Country Club in Laguna Niguel and produced approximately 350 acre-feet of water per year for the Country Club.

In 1989, the AWT facility was expanded from 0.6 to 2.4 MGD of tertiary treatment capacity. MNWD now services the El Niguel Country Club, Crown Valley Community Park, Laguna Niguel Regional Park, and several greenbelt areas within the City of Laguna Niguel.

In 1996, MNWD constructed a second AWT at the JRTP with a capacity of 9 MGD along with an underground reclaimed water storage tank.

In 1991, MNWD constructed a 2.4 MGD AWT facility at Plant 3A to provide recycled water for irrigation use. MNWD has expanded its reclaimed water supply capacity to provide maximum-month demands for its reclaimed water distribution system. This system serves two separate hydrologic areas: Laguna HA 1.1 (including the Laguna Niguel, Aliso Viejo, and Dana Point hydrologic sub-areas), and Mission Viejo HA 1.2. The system serves reclaimed water from three water reclamation treatment plants: (1) MNWD Plant 3A AWT, (2) SOCWA JRTP AWT, and (3) South Coast Water District Water Recycling Plant (WRP), which is interconnected to the MNWD distribution system. MNWD currently has 15.2 MGD of tertiary treatment capacity in compliance with Title 22 Recycled Water requirements. MNWD also has 1,000 AF of seasonal storage for its recycled water distribution system.

MNWD has 2.4 MGD capacity in Plant 3A; 11.4 MGD capacity in the SOCWA Joint Regional Treatment Plant; and 1.4 MGD of capacity in the SOCWA Coastal Treatment Plant.

Table 6-4 below illustrates the current uses for recycled water in MNWD. The usage is limited to landscape irrigation with a tertiary treatment level.

Table 6-4: Current Recycled Water Uses (AFY)

User Type	Treatment Level	Fiscal Year Ending
		2010
Agriculture		
Landscape	Tertiary	7,779
Wildlife Habitat		
Wetlands		
Industrial		
Groundwater Recharge		
Total		**7,779**

6.4. Potential Recycled Water Uses

MNWD's demands for recycled water continue to increase as new services are continually being connected to the recycled water system. Recycled water represents approximately 21% of MNWD's supply. With the planned expansion of MNWD's recycled water distribution system, recycled water will increase to about 23% of the supply by 2035.

Tables 6-5 and 6-6 present projected recycled water use within MNWD's service area through 2035. Recycled water use will increase to approximately 23% through the 25-year period, with landscape irrigation as its sole use.

Table 6-5: Projected Future Use of Recycled Water in Service Area (AFY)

User Type	Fiscal Year Ending					
	2010	2015	2020	2025	2030	2035-opt
Projected Use of Recycled Water	7,779	8,500	8,700	8,900	9,000	9,100

Table 6-6: Projected Recycled Water Uses (AFY)

User Type	Treatment Level	Fiscal Year Ending				
		2015	2020	2025	2030	2035-opt
Agriculture						
Landscape	Tertiary	8,500	8,700	8,900	9,000	9,100
Wildlife Habitat						
Wetlands						
Industrial						
Groundwater Recharge						
Total		**8,500**	**8,700**	**8,900**	**9,000**	**9,100**

Table 6-7 compares the recycled water use projections from MNWD's 2005 UWMP with MNWD's actual 2010 recycled water use.

Table 6-7: Recycled Water Uses – 2005 Projections compared with 2010 Actual (AFY)

User Type	2005 Projection for 2010	2010 Actual Use
Agriculture		
Landscape	9,800	7,779
Wildlife Habitat		
Wetlands		
Industrial		
Groundwater Recharge		
Total	**9,800**	**7,779**

6.4.1. Direct Non-Potable Reuse

MNWD currently uses water from their recycled water system for direct non-potable reuse such as landscape irrigation.

6.4.2. Indirect Potable Reuse

MNWD does not have the potential for indirect potable reuse within its service area.

6.5. Optimization Plan

In Orange County, the majority of recycled water is used for irrigating golf courses, parks, schools, business and communal landscaping. However, future recycled water use can increase by requiring dual piping in new developments, retrofitting existing landscaped areas and constructing recycled water pumping stations and transmission mains to reach areas far from the treatment plants. Gains in implementing some of these projects have been made throughout the county; however, the additional costs, large energy requirements, and facilities make such projects very expensive to pursue.

To optimize the use of recycled water, cost/benefit analyses must be conducted for each potential project. Once again, this brings about the discussion on technical and economic feasibility of a recycled water project requiring a relative comparison to alternative water supply options.

MNWD will conduct future cost/benefit analyses for recycled water projects, and seek creative solutions and a balance to recycled water use, in coordination with MWDOC, Metropolitan and other cooperative agencies. These include solutions for funding, regulatory requirements, institutional arrangements and public acceptance.

ratio) of 8.18 for the overall mix of water efficiency programs. A B/C ratio of greater than one indicates the conservation activity would make the utility and its ratepayers better off. This represents a net present value of approximately $180 million over the lifetime of the proposed conservation activities.

Table 4-2
Benefit and Costs of Proposed WUE Plan Activities

Activity Name	Class	Unit Cost ($/AF)	Unit Benefit ($/AF)	B/C Ratio
Residential Surveys, MF (A3)	Multi Family	$ 3,016	$ 1,810	0.60
Residential Surveys, SF (A3)	Single Family	$ 975	$ 1,651	1.69
Customer Request High Water Use MF (A2)	Multi Family	$ 3,016	$ 1,841	0.61
Customer Request High Water Use SF (A2)	Single Family	$ 975	$ 1,678	1.72
Residential HE Toilets	Single Family	$ 51	$ 2,439	48.14
Residential HE Washer	Single Family	$ 318	$ 2,151	6.76
Residential Leak Detection and Repair MF (O2)	Multi Family	$ 1,502	$ 1,794	1.19
Residential Leak Detection and Repair SF (O2)	Single Family	$ 487	$ 1,646	3.38
Efficient Irrigation Nozzles, Small SF/Comm	Single Family	$ -	$ 1,557	-
Commercial Efficient Irrigation Nozzles	Irrigation	$ -	$ 1,765	-
Residential Irrigation Controller, SF	Single Family	$ 201	$ 1,773	8.83
Residential Turf Replacement and Synthetic	Single Family	$ 55	$ 1,782	32.39
Commercial Turf Replacement and Synthetic	Irrigation	$ 71	$ 1,789	25.29
Large Land. Irrigation Controller	Irrigation	$ -	$ 1,731	-
Water Smart Landscape Water Budgets	Irrigation	$ -	$ 1,442	-
Gobernadora - Landscape Potable to Recycled Conversions	Irrigation	$ 678	$ 3,198	4.72
Possible Conversion Projects	Irrigation	$ 32	$ 3,741	115.98
SMWD Shovel Ready - CALIFIA	Irrigation	$ 268	$ 3,311	12.36
SMWD Shovel Ready - COTO DE CAZA	Irrigation	$ 224	$ 3,651	16.26
SMWD Shovel Ready - CASTA DEL SOL EXPANSION	Irrigation	$ 202	$ 3,311	16.39
SMWD Shovel Ready - TRES VISTA	Irrigation	$ 101	$ 3,311	32.78
SMWD Shovel Ready - QUAIL RUN	Irrigation	$ 7	$ 3,154	468.30
SMWD Shovel Ready - CANADA VISTA PARK	Irrigation	$ 431	$ 3,651	8.47
SMWD Shovel Ready - LAKE MISSION VIEJO FILL PROJ	Lakefill, Construc	$ 539	$ 3,651	6.78
TOTAL		**$ 376**	**$ 3,079**	**8.18**

In order to achieve the potential results indicated in this plan, an increase in SMWD's budgeted expenditures for Water Use Efficiency will be necessary. There is a rigorous economic justification that compares the WUE programmatic expenditures against the direct economic cost savings (the avoided costs of water delivery mentioned above). Thus, the B/C ratio for SMWD is positive using these conservative assumptions. Moving forward, the landscape market requires more complex products and services and therefore water savings in this sector costs more.

WATEREUSE ASSOCIATION

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Seawater Desalination Power Consumption

White Paper

November 2011

The WateReuse Desalination Committee's White Papers are living documents. The intent of the Committee is to enhance the content of the papers periodically as new and pertinent information on the topics becomes available. Members of the desalination stakeholder community are encouraged to submit their constructive comments to white-papers@watereuse.org and share their experience and/or case studies for consideration for inclusion in the next issuance of the white papers.

WATEREUSE ASSOCIATION
DESALINATION COMMITTEE

Seawater Desalination Power Consumption

White Paper

I Introduction

Virtually everything we do affects our ability to harness and expend energy. One simple, small-scale example is the energy expended by our bodies to fight the effect of gravity as salts and impurities are removed from our body. On a much larger scale, energy is necessary to meet the needs of society, which include obtaining, transporting, treating, and distributing potable water.

Access to clean, safe, and reliable sources of drinking water is a basic goal in today's world. As society has developed, so has our ability to transport water over great distances to meet that fundamental objective, as well as the ability to measure the quality of water to ensure that it is safe to drink. To a large extent, the advent of analytical techniques to measure contaminants, viruses, and pathogens in water paved the way for the US Environmental Protection Agency (US EPA) in the early 1970's to develop rules and regulations requiring drinking water to be treated, or "manufactured", to meet standards for the benefit and protection of public health. Rules and regulations have evolved since the 1970's, commensurate with our understanding of contaminants and ability to measure them. This "evolution" of standards led the US EPA to identify membrane filtration – including reverse osmosis desalination – as one treatment technology for drinking water supplies to meet increasingly difficult water quality challenges.

Today, virtually every drinking water supply is treated in some form or fashion, driven by a number of factors primarily associated with the discovery of new contaminants: advanced testing methods; public perception; verifiable health risks; and development of improved/new water quality standards. The extent of water treatment – and the energy and power needed to meet those requirements – can vary considerably, as expected, because of the accessibility and initial quality of a raw water supply.

Seawater desalination, like any other water treatment technology or separation processes, requires the use of energy to produce water. As a drinking water treatment technology, however, seawater desalination requires more energy than most other water treatment methods. Often, however, the power consumption associated with seawater desalination is exaggerated or inaccurately represented, particularly when compared to other treatment technologies or alternatives assuring safe, reliable public water supply.

This paper reviews and outlines the power requirements associated with seawater desalination, measures used to compare and offset seawater desalination power consumption to other water supply alternatives, and the opportunities for future reduced energy demand.

II Treated Water Power Consumption

A. Water Project – Energy Requirements

Every drinking water supply requires energy, and there are four principal areas consuming energy. These are:[1]

1. Source water extraction and delivery to the treatment plant (could be imported or nearby);
2. The treatment/purification process;
3. Distribution of drinking water; and
4. Residuals management, treatment, and discharge

Power costs associated with heating and cooling buildings and work spaces (HVAC), parking lot lighting, or other miscellaneous items are generally very small (compared to the total energy cost) and quite similar for comparable drinking water facilities of a similar size.

The hydraulics associated with transporting water requires pumps of varying capacity and pressure amongst each of the four power-consuming areas previously described. For illustrative purposes, individual factors that influence these areas are contained in Figure 1. Note that the actual percentage of energy contribution to the total can vary and is discussed later on in this document.

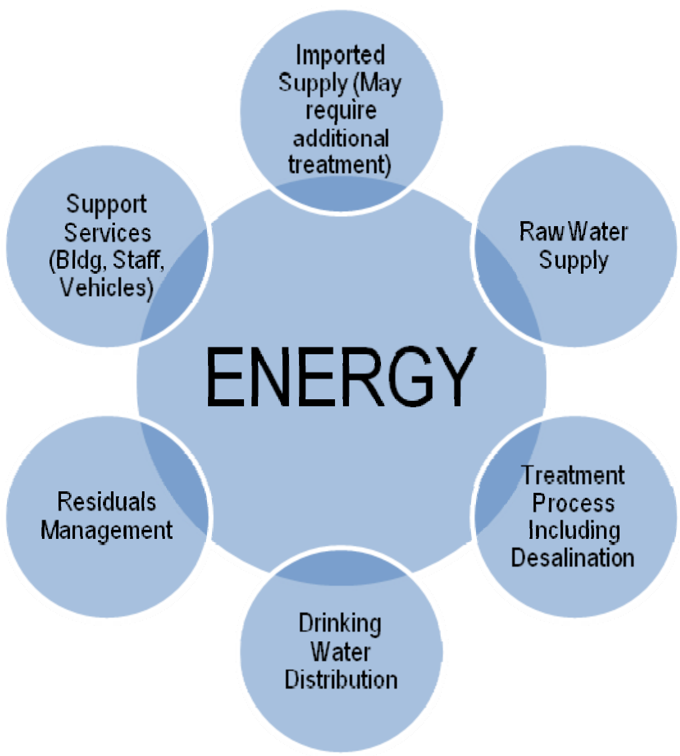


Figure 1
Areas Contributing to Energy Consumption for Water Projects[2]

1 Analysis of the Energy Intensity of Water Supplies for the West Basin Municipal Water District.
2 Graphic: Dietrich Consulting Group, LLC.

Generally, the power costs associated with elevation changes, piping distance, and pressure requirements can be easily estimated (area numbers 1, 3, and 4). Understanding the energy associated with the treatment/purification such as the seawater desalination process – area number 2 identified above – is fundamental and the primary topic of this paper.

B. Desalination Energy - Osmotic Driver

Within the "fenceline" of a seawater desalination plant, feed water salinity has the most significant impact on power consumption. Why? Compared to brackish water or other alternative surface water supplies, seawater contains a greater quantity of dissolved salts. The desalination process must overcome osmotic pressure to reverse the flow, forcing water from the "salty" feed side of a membrane to flow to the "purified" water (also known as permeate, or product water) side of the membrane (Figure 2); hence, "reverse osmosis desalination."

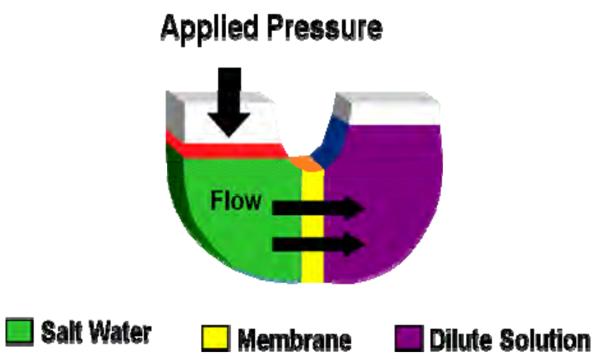


Figure 2
Producing Drinking Water by Applying Pressure[3]

A fresh, non-seawater surface water supply may not require desalination treatment if the salinity is already within secondary US EPA water quality guidelines. However, in an increasing number of utilities, brackish water desalination is utilized for targeted reduction of undesirable parameters (and in some cases, even removal of TDS to for existing distribution system compatibility). Fresh surface water – just like seawater – is associated with containing viruses and pathogens. Therefore, microfiltration (MF) or ultrafiltration (UF) are membrane-based alternatives to conventional granular media or other similar treatment processes to meet US EPA drinking water quality standards if desalination is not needed. Because of this, MF and UF are frequently utilized as low-pressure membrane pretreatment alternatives for removal of non-ionic species such as suspended matter or viruses and pathogens.

Table 1 (below) contains the range of typical pressures associated with feed water salinity. As such, it is clear to see that as feed water salinity increases, so does the requirement for an increase in membrane feed pressure (and associated energy) until the practical limitation of 1200 psi (82.7 bar) for drinking water

3 Southeast Desalting Association (SEDA): www.southeastdesalting.com.

production is reached; at which point the actual feed water recovery is typically decreased to stay within design pressure limitations.

Table 1
Source Water Quality and Pressure Requirements[4]

Source	Associated Salinity, (mg/L)	Typical Pressure Range, psi (bar)
Surface (Fresh) Water (MF/UF)	<500	15 – 30 (1 – 2)
Brackish Water (RO)	500 – 3500	50 – 150 (3.4 – 10.3)
Brackish to Saline (RO / SWRO)	3500 – 18,000	150 – 650 (10.3 – 44.8)
Seawater, typical range[5] • USA • Middle East	18,000 – 36,000 18,000 – 45,000+	650 – 1200 (44.8 – 82.7)

The viscosity of water changes with temperature. A change of one degree Centigrade in the temperature of the feed water results in a 3% rate of change (increase/decrease) in membrane throughput[6]. Throughput, or flux, describes the hydraulic capacity of water produced by the desalination membrane. Therefore, to achieve an equivalent production value or throughput, more pressure is applied (in varying increments), additional reverse osmosis capacity is brought on line, or production decreases. The relative influence that feed water temperature has on required seawater reverse osmosis (SWRO) pressures, at a fixed average seawater salinity of 34,000 mg/L (34 parts per thousand, ppt) and a SWRO recovery of 50%, is illustrated in Figure 3.

4 Dietrich Consulting Group, LLC.
5 Ranges can vary widely and are site specific. For illustrative purposes only.
6 This is corrected from another published document “An Investigation of the Marginal Cost of Seawater Desalination in California”; Fryer, James; March 18, 2010, R4RD.

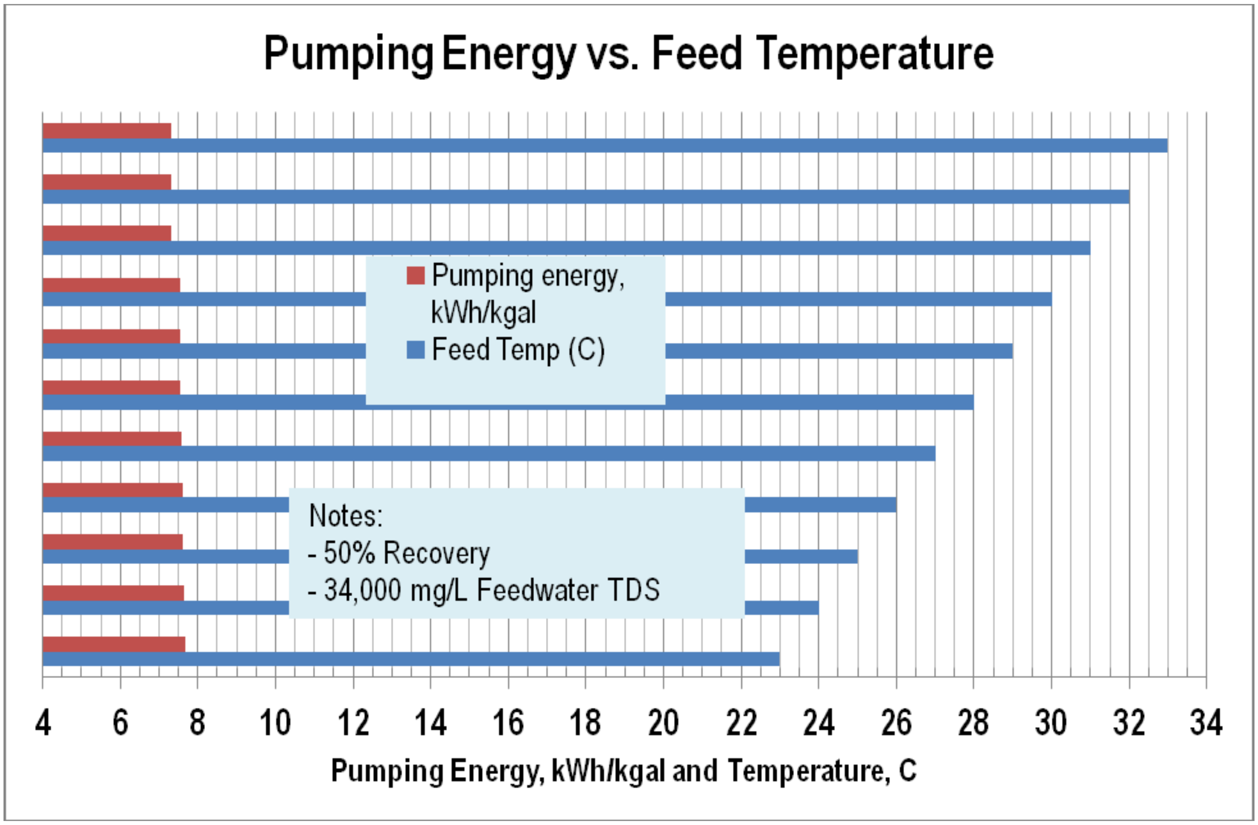


Figure 3[7]
Effect of Feed Water Temperature on Pumping Energy

The example in Figure 3 is for seawater with a salinity of 34,000 mg/L. Because salinity is variable around the coastal United States (and around the rest of the world), the required driving pressure and associated energy needed to produce the same throughput (flux) for different salinities will vary accordingly. A general "rule of thumb" is that the net driving pressure needed to produce an equivalent amount of permeate will increase (or decrease) by about 11 psi (0.76 bar) for each 1000 mg/L (1 ppt) incremental change in feed water salinity. Figure 4 illustrates how salinity varies around the coastal United States.

According to the National Oceanic and Atmospheric Administration (NOAA), the 3-Zone Average Annual Salinity Digital Geography in Figure 4 was developed using geographic information system (GIS) technology, and are the average annual salinities found in certain estuaries along the coastal United States. The mapped areas include the entire Atlantic, Gulf of Mexico, and Pacific coasts of the United States.

7 Source: Dietrich Consulting Group, LLC.

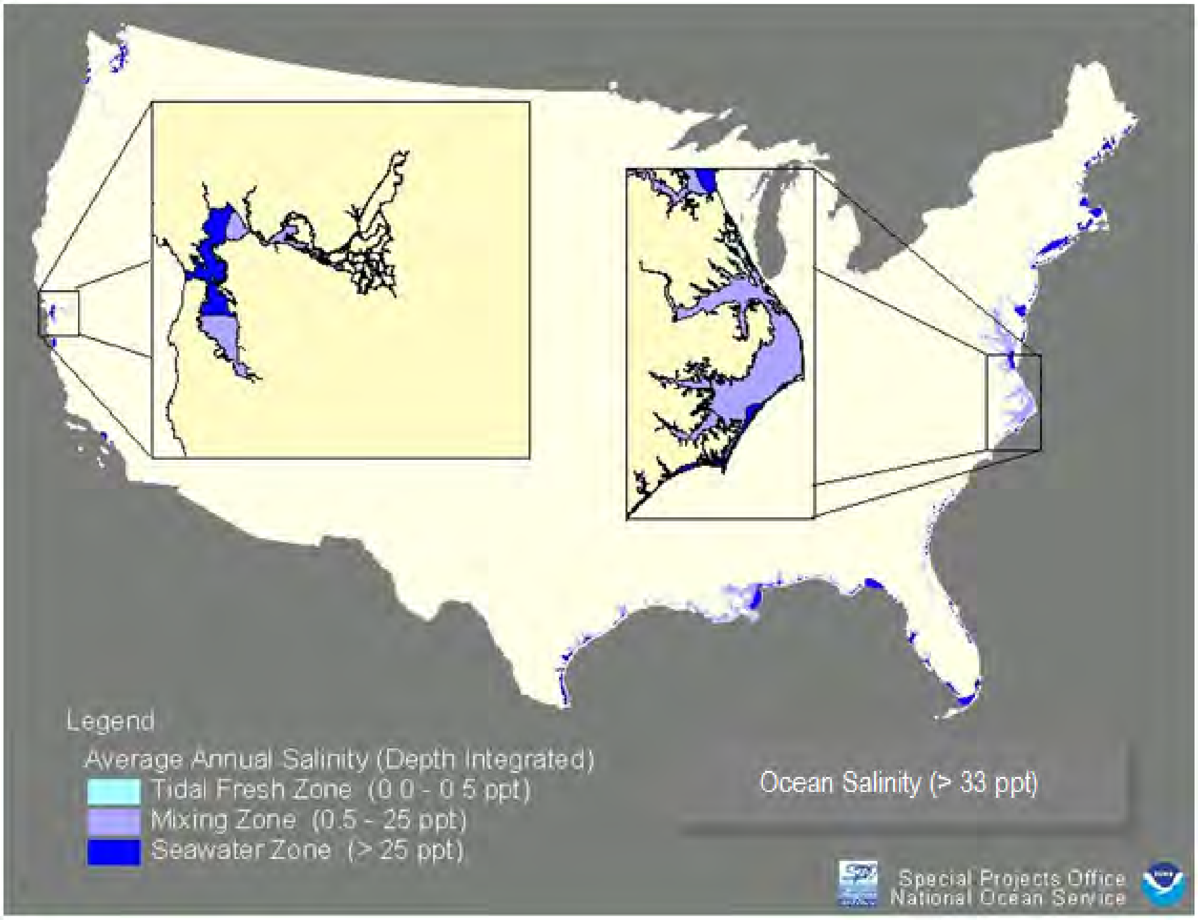


Figure 4
United States Coastal Salinity Zones[8]

III Power-Contributing Components of the Desalination Process

Figure 1 contains the individual areas of a water supply project that contribute to the total energy. The impact, range, and percentage each of these areas are further illustrated by breaking out each area individually for discussion purposes.

Because the seawater desalination treatment process is typically associated with being the most energy-intensive, it is a convenient starting point. The remaining areas identified in Figure 1 are discussed below. It is important to note that the power consumption costs utilized throughout this document are relative to each treatment process. The sum of the components with respect to the quantity of water produced is also called specific power[9]. This paper discusses each of the individual components of the water treatment process which add up to the total.

8 NOAA's Coastal Geospatial Data Project; http://coastalgeospatial.noaa.gov.
9 33,000 mg/L feed water salinity; 25 deg. C; 9 GFD flux.

The seawater desalination treatment process includes:

- Pretreatment, or pre-filtration;
- SWRO (membrane) desalination; and
- Post-treatment of permeate

Pretreatment

Reverse osmosis membranes are subject to fouling or plugging on the membrane surface. This can decrease the permeate production capacity of the membrane or require an increase in operating pressure (and subsequent energy) to overcome the fouling effect. As a result, virtually every membrane desalination facility in the world (including SWRO) requires properly pretreated seawater. The pretreatment equipment used in SWRO facilities is similar to what you would find at any other drinking water treatment facility elsewhere and incorporates, individually or in combination: flocculation / sedimentation to remove suspended material; dissolved air flotation (DAF) to remove potential algal biomass or potential hydrocarbons; granular media filtration (GMF); and/or low-pressure UF or MF to remove suspended particulate matter. The pretreatment energy requirements are comparable to any other surface water treatment plant, and range from 0.9 to 1.5 KWh/kgal (293 – 489 kWh/AF). When compared to the energy costs associated with the rest of a typical SWRO facility, pretreatment accounts for 8 to 12% of the total.

SWRO Process

Seawater RO membrane energy consumption is related to site-specific salinity and temperature (as previously discussed) and other design-specific characteristics such as hydraulic loading rates (flux) and the percentage of feed water recovered. The primary power-consuming devices are the pumps required to achieve the feed pressure needed to facilitate the reverse osmosis process. The range of pressures listed in Table 2 is typical for the United States. Elsewhere in the world – for example, in the Middle East, where salinity can be significantly higher – the net energy required (including recovered energy) will increase 15 to 20% above those values contained in Table 2. For lower salinity applications, there is an associated decrease in power demand. Coastal embayment areas under the influence of river or other surface water runoff will require, at a minimum, 15 to 20% less power.

Any processes or practice that can reduce power consumption will, by definition, decrease the costs associated with operating a SWRO plant (or any plant, for that matter). For this reason – and because of the potential to recover the power necessary for the reverse osmosis process – energy recovery systems are almost always a part of the mechanical equipment incorporated into the desalination process. The principle behind an energy recovery device is to use the energy of the concentrate, which is about 1 to 2% less than the feed pressure energy, and transfer this energy back into the system to cause a net decrease in overall power consumption.

Energy recovery devices offer significantly improved efficiencies compared to equipment utilized decades ago. Energy recovery devices can operate at an efficiency of 85 to 95% and hydraulically recapture a portion of the power consumed by the high-pressure SWRO pump.

Engineers, designers, and operators also pay serious consideration to power savings with adjustable frequency drives (AFD). For example, a coastal upper bay experiencing a relatively wide salinity range of 20,000 mg/L to 32,000 mg/L (such as in Tampa Bay, FL), must meet a SWRO feed water pressure differential of up to 400 psig (27.6 bar) to desalinate the seawater. An AFD allows for operation of a pump on a practically "infinite" number of speed curves depending on the required operating conditions, in lieu of "burning off" excess pressure (and power cost) that may not be necessary during certain times when salinity is lower, and yet still allow production of the required volume of water. Ultimately, the choice of energy recovery devices and/or AFDs is site specific and depends on the configuration of the membrane system, pressure requirements, and budget.

The Affordable Desalination Collaboration (ADC) Project

The ADC is a non-profit organization comprised of government and state agencies such as the California Department of Water Resources, California Energy Commission, City of Santa Cruz/Soquel Creek Water District, Metropolitan Water District of Southern California, Marin Municipal Water District, Municipal Water District of Orange County, Naval Facilities Engineering Service Center, San Diego County Water Authority, Sandia National Laboratories, and the West Basin Municipal Water District. The organization's members also include leading equipment manufacturers and consulting engineering firms with seawater desalination experience. Work accomplished by the ADC towards assisting water industry professionals in understanding the energy associated with desalination, as well as the costs associated with desalination processes, is significant. The ADC established the lowest energy use and costs that were obtained by applying modern desalination technology and equipment. The ADC has since achieved its goals including demonstrating very low energy consumption for the desalination process, and discontinued testing in 2010.

In 2008, after two years of extensive testing of various membrane manufacturers' products using "off the shelf" modern technology, including the aforementioned adjustable frequency drives, the ADC concluded that the range of energy requirements for the SWRO process (including energy recovery) is 6.8 – 8.2 kWh/kgal (2216 kWh/AF – 2672 kWh/AF) depending upon the type of manufacturers' membranes tested during the study[10]. Figure 4 shows how the power costs varied with membrane type and feed water recovery (%). In the figure, "Total Treatment Energy" is calculated in the upper curves and includes power estimates for the rest of the plant treatment equipment and components.

When compared to the total energy costs associated with a modern SWRO facility, the SWRO component (not including feed conveyance or finished water distribution) ranges from 65 to 85% of the total energy cost. Accordingly, within the fence line of the desalination facility, the SWRO process itself consumes the greatest percentage of total power.

10 MacHarg, J., Seacord, T., Sessions, B., "ADC Baseline Tests Reveal Trends in Membrane Performance", *Desalination and Water Reuse*, Vol 18/2, 2008.

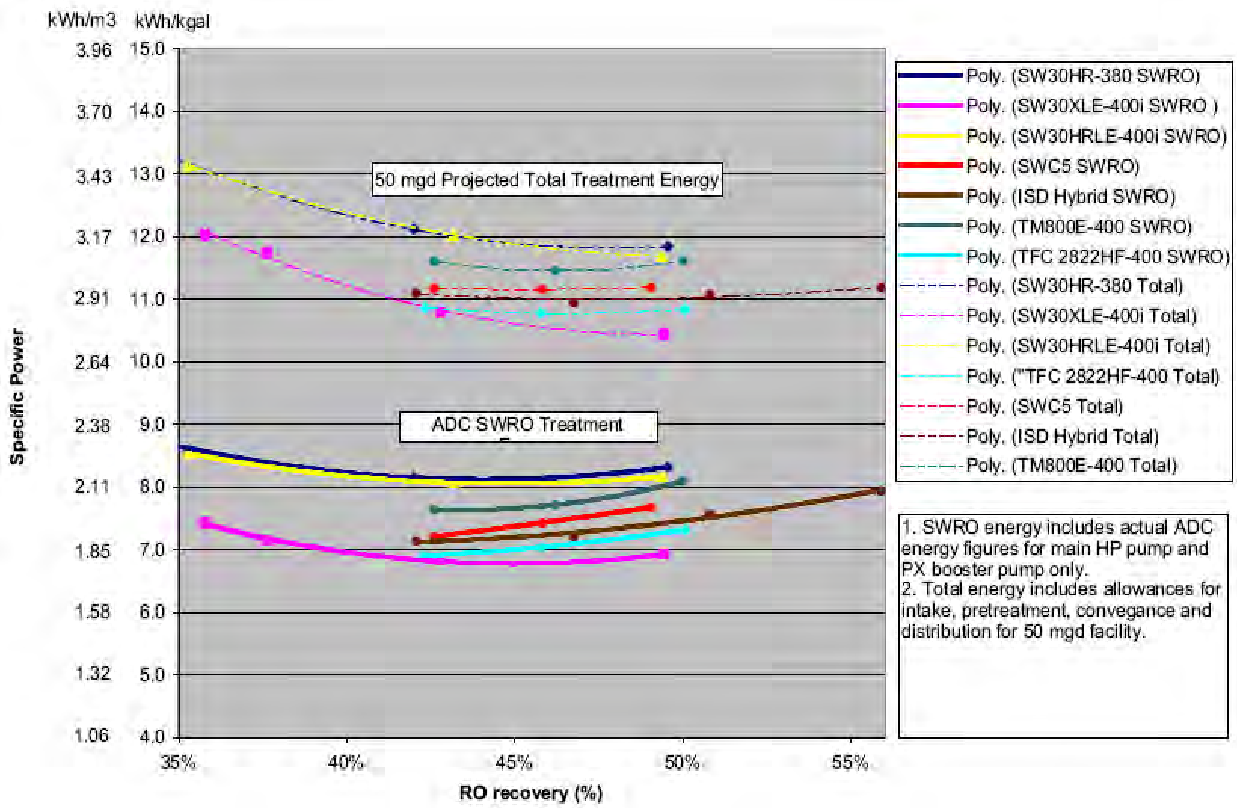


Figure 4
SWRO+Energy Recovery – Energy Consumption vs. Recovery at 9 GFD[11]

Post Treatment Conditioning

The next treatment step in a SWRO facility is post-treatment conditioning of the permeate. Permeate produced by the desalination process requires the addition of conditioning chemicals for buffering and stabilization prior to entering a drinking water distribution system. Buffering and stabilization requires very little energy; most of the power is associated with pumping SWRO permeate high enough (e.g., 30 feet (10m)) to trickle-down through limestone (calcite) reactors for buffering or the minute energy associated with a lime slaking system. These energy expenditures are less than 2% of the total power requirement for a typical seawater desalination facility.

Additional methods of drinking water post treatment, and the energy associated with such treatment, are common among virtually all other treatment processes in the US. These include (but are not limited to) disinfection with chlorine and/or chloramination, fluoridation, addition of corrosion inhibitors, and blending.

IV Remaining Areas Contributing to Energy Consumption for Water Projects

Any water supply project also considers how the available supply (to be treated or otherwise consumed) is transported and pumped through pipelines to the treatment site, and, after treatment, how the potable water

11 Ibid; MacHarg, J.

will be pumped and conveyed through pipelines to the public. As one can imagine, the energy costs associated with these two components can range in significance, depending upon how far the facility is from the source and distribution area.

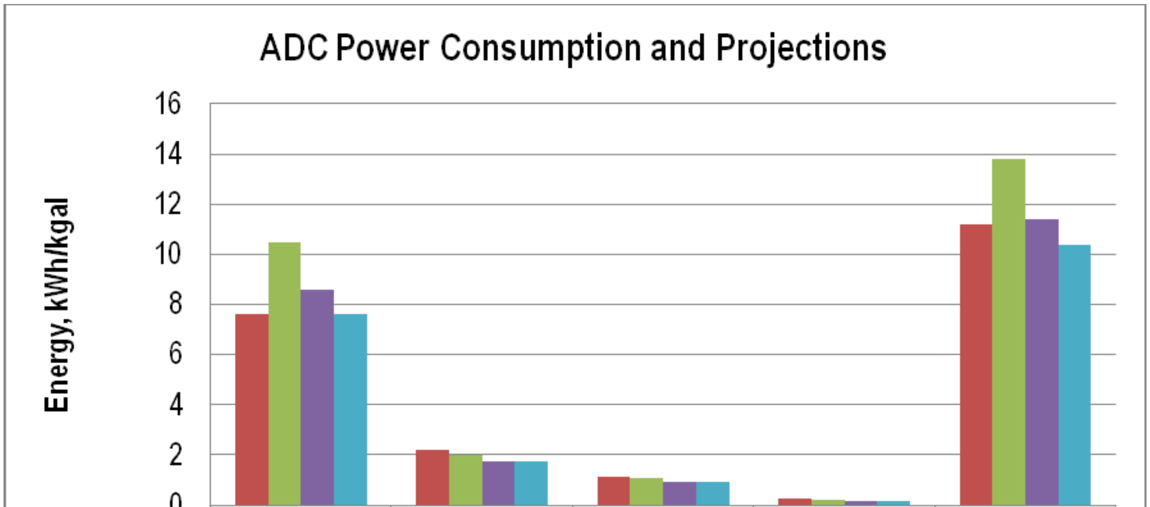
Energy Associated with Supply

This area might be one of the most understated or overlooked components of water projects. Perhaps this is because in coastal areas where a seawater desalination facility is located next to the ocean, the power cost to pump seawater to the facility are usually associated with overcoming a short distance and relatively short elevation to reach the treatment facility. Close proximity to the ocean makes economic sense, if at all feasible. However, when evaluating the total energy equation, such as comparing one water supply versus another, the power costs for supplying inland conventional water supplies to coastal areas can be greater than a coastal desal facility.

For example, the bulk of Southern California drinking water comes from the Colorado River via massive aqueduct and conveyance systems. This involves pumping (and re-pumping) raw water through a wide variety of elevations (hillsides and mountains) to ultimately reach the Southern California consumer. The energy costs associated with supplying this water is a major element of the typical southern Californian's consumption of energy – about 14% to 19% of the total residential energy demand (which includes air conditioning)[12].

For a conventional intake system where the supply source is nearby the SWRO facility, power consumption will range from 15% to 20% of the total power consumed by the water treatment process. Figure 5, developed by the ADC, shows a comparison of energy requirements for the different treatment components of a SWRO facility producing 0.3, 10, and 50 million gallons per day. An additional benefit of the ADC chart is the effect economies of scale have on power cost.

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



	SWRO Process	Intake	Prefiltration	Permeate Treatment	Total Treatment
ADC MAP	7.6	2.19	1.15	0.25	11.2
0.3 MGD	10.5	2.01	1.06	0.23	13.8
10 MGD	8.6	1.74	0.91	0.17	11.4
50 MGD	7.6	1.72	0.9	0.16	10.4

Figure 5
ADC – Energy Consumption and Projections[13]

Energy Associated with Distribution

Just as the feed water source to a water treatment facility has an energy impact, so too does the energy associated with pumping drinking water from the treatment facility to the consumer. Local terrain, elevation, subsurface impediments (geologic or man-made), required delivery pressure, and accessibility all factor in into the power cost.

For example, the West Basin Municipal Water District (WBMWD), located near Los Angeles in Southern California, evaluated a scenario incorporating both the imported water and distribution energy cost. Figure 6 displays a comparison of the costs. As the figure demonstrates, power consumption associated with seawater desalination (including the feed water conveyance and distribution) are competitive with other current, alternative sources of supply.

13 "Affordable Desalination Profiles State of the Art SWRO", www.affordabledesal.com , March 27, 2008. Test conditions: (excluding ADC Record): 885 psi feed pressure, 9.0 gfd, 48% recovery, 156 mg/L permeate TDS, 0.8 mg/l Boron, feed TDS 31,742 mg/L, 60˚F.

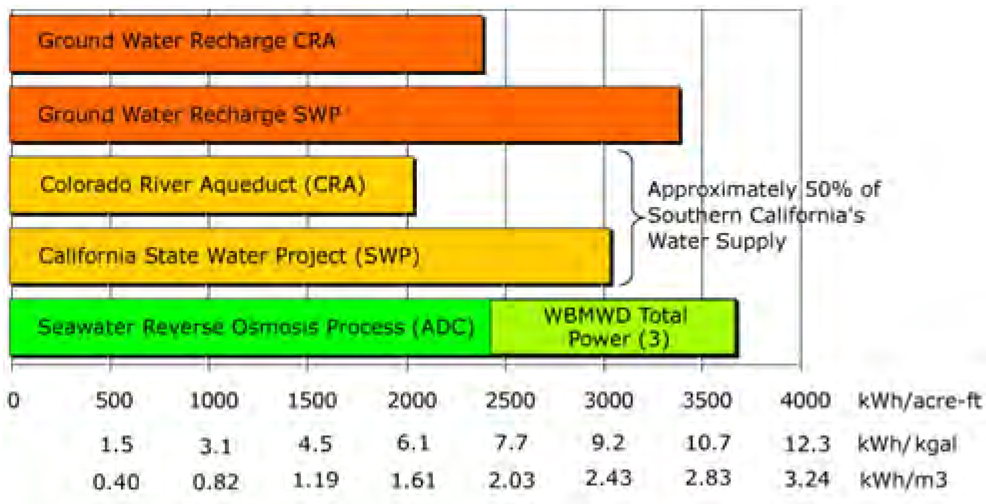


Figure 6
Water Supply Energy Consumption Comparison at West Basin[14]

Residuals Management and Support Services

This energy component of a seawater desalination facility includes the remaining items that support the proper function and operation of the plant excluding the treatment process itself. For example, similar to a commercial park or residential household, typical support services would include building lighting and air conditioning. Because pretreatment requires occasional backwash and cleaning, and RO membranes also require periodic cleaning, energy associated with pumps, heaters, blowers, and chemical feeders are accounted for. Figure 7 shows a typical breakdown of ancillary support power associated with a typical desalination facility.

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

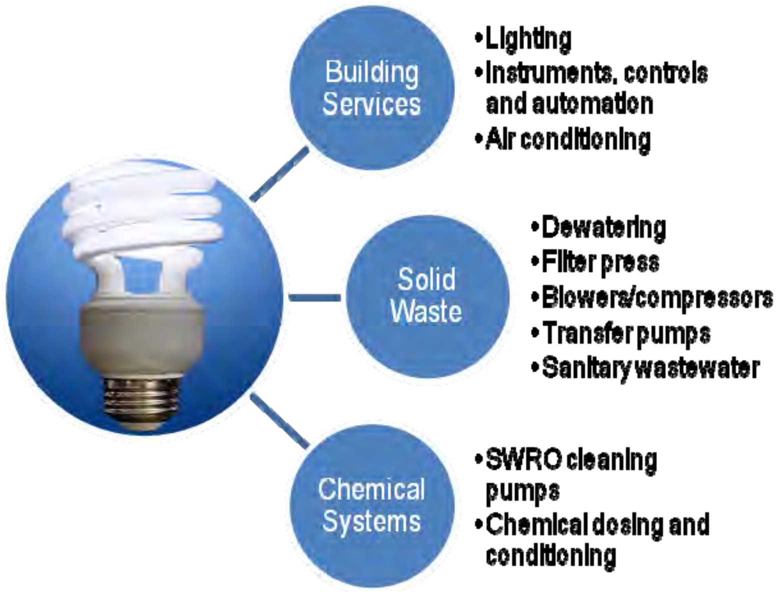


Figure 7[15]
Ancillary (Facility) Components of SWRO Energy

These components, when added together and compared to the rest of the facility, account for between 10 and 15% of the total power consumption. Many of the services attributed to power consumption are similar to any other conventional drinking water facility, with the exception of the membrane cleaning system(s). Note that the actual value can vary among differing facilities based on the specific needs of the plant and personnel.

V Rolled-Up Power Costs for Seawater Desalination Facilities

Although the basic application of membrane technology is the same among seawater desalination plants, published reports on the total (rolled-up) power consumption of SWRO facilities vary significantly. This is because SWRO projects are specifically designed for the locale, accounting for energy costs associated with changes in feed water salinity and temperature, changes in elevation, the local cost of power and fuel, degree of pretreatment, distance to feed water supply source, and the distribution point. The pie chart in Figure 8 contains a range of costs for the various components of a SWRO facility, based on actual costs at operational SWRO facilities. The energy "slice" is 28% to 50%, which can approach (or exceed) the capital recovery. A range is provided because the specific technical components factoring into the range will vary by project, and the capital recovery cost is driven by many factors such as interest, bond cost, payment time frame, and other financing schemes.

15 Dietrich Consulting Group, LLC.

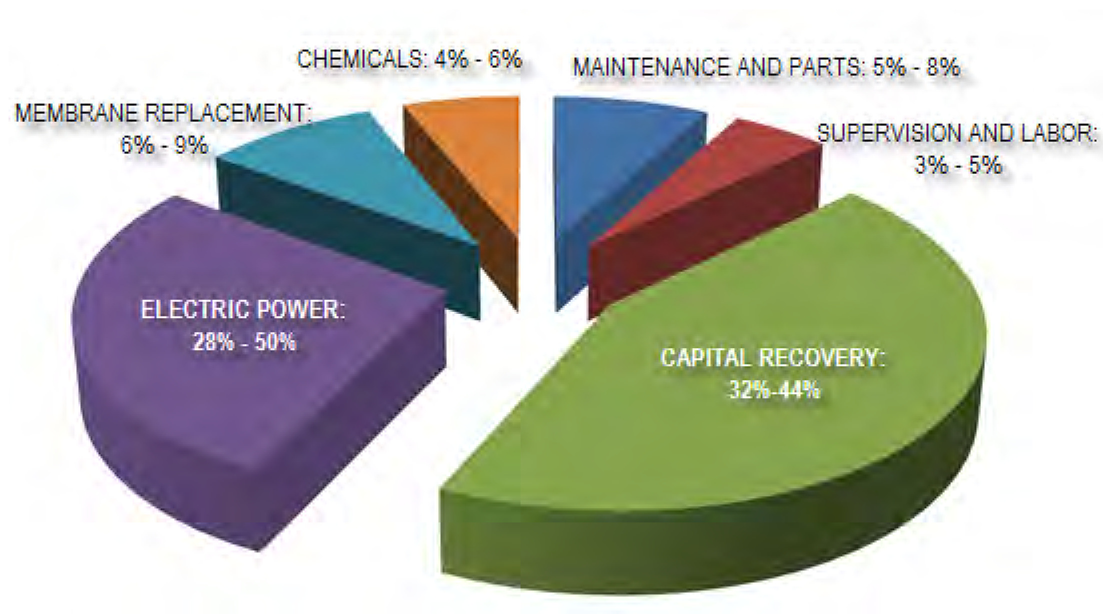


Figure 8
Typical Range of SWRO Facility Cost Components as a Percentage of Total[16]

VI Power Cost Comparison with Other Water Supply Alternatives

Seawater desalination is but one consideration in the portfolio of water supply alternatives that a utility may have to choose from. Fresh groundwater supply may be plentiful in certain areas of Florida, but its availability is becoming very limited in coastal and inland areas. An example of this occurred in the Tampa Bay region in the late 1990's, where permitted groundwater withdrawals had to be reduced from 192 mgd to 90 mgd to reduce environmental impacts related to the withdrawals. After decades of repetitive drought cycles, the drought-proof alternative chosen by the local master utility (Tampa Bay Water) was the seawater desalination plant.

For comparison purposes, the energy use of various water supply alternatives is contained in Table 2. For example, a SWRO plant along the Gulf of Mexico consumes the same amount of power as California imported water, even before the California water is treated. This is but one simple, illustrative example of the energy competiveness of SWRO desalination, although it must be considered in the right context. That said, SWRO along the Pacific coast is competitive, although accurate energy consumption can only be compared once specifics of the site are defined.

16 Graphic provided by Dietrich Consulting Group, LLC.

Table 2
Energy Use of Various Water Supply Alternatives
(1 kWh/kgal = 325.8 kWh/AF)

Supply Alternative[17]	Power Consumption, Range	
	kWh/kgal	kWh/AF
State Water Project (California)		
Raw water delivery to treatment points	9.0 – 10.6	2930 – 3450
Conventional treatment	0.8 – 1.5	260 – 490
State Water Project (California) – Total	9.8 – 12.1	3190 – 3940
Imported Colorado River (California)		
Raw water delivery to treatment points	6.0 – 8.0	1950 – 2600
Conventional treatment	0.8 – 1.5	260 – 490
Imported Colorado River (California) – Total	6.8 – 9.5	2210 – 3090
Reclaimed water for Indirect Potable Reuse		
Wastewater treatment	2.0 – 4.0	650 – 1300
Tertiary treatment for Indirect Potable Reuse	5.0 – 7.5	1630 – 2440
Reclaimed water for indirect potable reuse – Total	7.0 – 11.5	2280 – 3740
Brackish Water Desalination	3.0 – 5.0	980 – 1630
Desalination of Pacific Ocean Water	10.0 – 14.0	3260 – 4560
Desalination of Gulf of Mexico Water	9.1 – 13.2	2970 – 4300

VII Challenges and Perceptions: Is the Relative Power Consumption REALLY Excessive?

No, the relative power consumption is not excessive. Documented yearly gains in SWRO efficiency certainly help. In fact, the total power cost to produce desalinated seawater for a family of four[18] is equivalent to the power consumption of about one household refrigerator. Considering carbon footprint issues, the impact of seawater desalination is comparatively modest; for example, the average person, through the natural process of breathing, produces approximately 2.3 pounds (1 kg) of carbon dioxide per day[19]. Similarly, the amount of carbon dioxide generated from 3-4 minutes of moderate exercise (e.g., taking the stairs instead of the elevator) is equivalent to the CO2 emissions from a SWRO facility producing one gallon of water for an individual to drink throughout the day[20].

Additionally, the energy requirements of conventional water treatment processes are increasing. The reason is that for most surface water sources, the typical treatment process is chemical addition, coagulation and settling, followed by filtration and disinfection. In the case of groundwater (well) systems,

17 http://www.affordabledesal.com/home/news/WConPurJan07.pdf
18 Family of four consuming 400 gpd at 0.0144 kWh/gal with a total annual energy use for water production = 2,102 kW/yr; versus a 16 cu ft. refrigerator with consumption of 725 (http://www.energysavers.gov/your_home/appliances/index.cfm/mytopic=10040) x a conservative 33% operating time = 2,117 kW/yr.
19 United States Environmental Protection Agency. Considered part of the "Natural emissions"cycle and does not count towards greenhouse gas generation.
20 Calculation based on 600 lbs. CO2 generated per MWh, which is a recognized, conservative equivalent value representative of a power provider in Southern California; 50 MGD SWRO facility; 35 MWh power required for SWRO facility; 120 gpd consumed per 3.2-person household; and respiration rate doubled during exercise time.

the treatment may consist of only disinfection with chlorine. Wells that are under the influence of surface water must meet surface water treatment criterion. All methods of treatment must comply with certain treatment techniques, water quality goals, and contaminant removal criterion. As a result, future implementation of new drinking water regulations will increase the use of higher energy consuming processes, such as ozone and membrane filtration.[21]

In 2002, the California Legislature approved Assembly Bill 2717 (Hertzberg, Chapter 957), which asked the Department of Water Resources (DWR) to convene the California Water Desalination Task Force to look into potential opportunities and impediments for using seawater and brackish water desalination, and to examine what role, if any, the State should play in furthering the use of desalination technology[22]. A primary finding of the Task Force is that economically and environmentally acceptable seawater desalination should be considered as part of a balanced water portfolio to help meet California's existing and future water supply and environmental needs. One significant energy-related conclusion of the Report is that the energy generation capacity of the State would not be a constraint to implementation of currently proposed desalination projects. In fact, applying 2002 SWRO membrane technology, over half a dozen proposed SWRO facilities (totaling more than 350 mgd[23]) would add about 0.4% to the State's peak power load. Since the time of that Report, and considering current SWRO membrane technology advances and increases in energy recovery device efficiencies, the addition would be reduced to 0.35% or less.

SWRO energy consumption can be relatively high compared to many other water treatment methods. However, when considering the total water/energy equation, including intake source, location, distance, and quality, the power numbers can become quite competitive and perhaps even attractive. The added benefit of utilizing a state-of-the-art water treatment method, producing the highest quality drinking water available, certainly helps. In addition, other (alternative) water supplies 1) may be declining; 2) are becoming more impaired and require more treatment; and 3) regulations are becoming more stringent which, in turn, is requiring more treatment of unimpaired surface waters.

As the amount of necessary energy decreases with increased membrane efficiencies and new products, the power requirements of SWRO will continue to approach the energy cost of existing sources of conventional supply, in particular the existing sources requiring further treatment to meet drinking water standards and regulations.

21 Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities,* Electric Power Research Institute Report CR-106941.
22 California Desalination Task Force: "Water Desalination: Findings and Recommendations," October, 2003.
23 http://www.water.ca.gov/desalination/pud_pdf/Desal_Handbook.pdf

Chapter 6
Recycled Water Master Plan

As discussed in Chapter 3, the State of California is in a water crisis. Uncertainties that affect California's water resources, which in turn impact supplies to Southern California, have received widespread media coverage and public attention in recent months. The 2007 federal court ruling setting operational limits on Delta pumping for a portion of the year to protect endangered Delta species is expected to reduce supplies to Metropolitan and other SWP Contractors.

The District's existing recycled water system provides the District with a supplemental, non-interruptible supply of irrigation water. This section describes and evaluates the District's existing recycled water system and investigates the possibility of expanding recycled water use within the District's service area. Since increasing the recycled water system utilization would reduce dependence on imported water, the District's Board of Directors has expressed an active interest in expanding the system.

6.1 Recycled Water System Description

The District began distributing recycled water in 1984. The District's recycled water facilities consist of pump stations, reservoirs, and a distribution system serving multiple irrigation sites throughout the Laguna Beach and Dana Point communities. The District is also contracted to supply up to 1.44 MGD to MNWD from the Joint Reservoir. However, MNWD only takes flow from the District in an emergency or during routine maintenance periods. The system is supplied by the SOCWA Coastal Treatment Plant and Advanced Water Treatment (AWT) facility. These facilities are described below.

6.1.1 Existing Recycled Water Facilities

SOCWA is the general permit holder for water reclamation activities in most of southern Orange County. Waste Discharge Permit Order 97-52, issued through the San Diego Regional Water Quality Control Board, governs the quality of recycled water produced at the AWT facility. The permit regulates the water quality specifications for constituents like TDS, coliform, turbidity and iron. The District and the County Health Department conduct annual inspections of all users to ensure that all regulations are strictly followed.

The AWT facility receives influent from the adjacent SOCWA Coastal Treatment Plant, located just outside of the District's northeast boundary in Unincorporated County land (Aliso and Wood Canyons Wilderness Park) and is designed to produce 2.61 MGD of recycled water. With additional treatment, filtration, and disinfection, the secondary effluent from the Coastal Treatment Plant is converted to recycled water that meets California's health criteria for landscape irrigation use. Recycled water is used to irrigate parks, golf courses, sports fields and greenbelts and helps free drinking water for human consumption.

The District's recycled water system consists of 15 miles of pipeline, three pump stations and three storage tanks that can hold 4.7 million gallons (MG). The District delivers approximately

960 AFY of recycled water to 98 accounts (33 customers; 171 meters) in Laguna Beach and Dana Point, including MNWD, which annually uses about 15 percent of the average supply.

A map of the District's existing recycled water system is shown in Figure 6-1. The distribution system begins at the AWT facility to the north and a 12 inch pipeline runs south along Pacific Coast Highway to Stonehill Drive. The existing recycled water system currently has a hydraulic bottleneck along Pacific Coast Highway, where the recycled water pipeline decreases in size from a 12 inch pipeline to a 10 inch pipeline, and then increases back to a 12 inch pipeline at 10th Street. Pump stations and reservoirs are used to convey the recycled water from the lower pressure zone along the coast to the higher pressure zone inland, as illustrated in Figure 6-2.

PS #1 is located at the AWT facility adjacent to a 2 MG forebay reservoir (Reservoir #1) and has two 800 gallon per minute (gpm) centrifugal pumps to serve the Low Zone. PS #2, located along Aliso Way, is a booster station equipped with two 1,600 gpm centrifugal pumps. PS #2 has a manual bypass that is opened when the pump station is not in operation. The pumps run during the off-peak period to help fill Reservoir #2 (HWL = 290 feet). The Low Zone begins at the AWT facility and services the majority of the District via a 10 inch transmission line along coast Highway.

PS #3 serves the High Zone and has two 1,450 gpm centrifugal pumps to serve Dana Point and Niguel Shores. The pump station is manually operated through SCADA, based on the water level of Reservoir #3.

Reservoir #1, located at the AWT facility, serves as a forebay reservoir for the Low Zone with a water level of approximately 138 feet. The total storage capacity in this zone is 2.0 MG. Reservoir #2 is located at PS #3 and serves the Low Zone with a hydraulic grade of approximately 290 feet. The total storage capacity is 1.7 MG. The District also has a 1.1 MG share of the joint 3.3 MG reservoir with MNWD that is located along Golden Lantern Drive. The reservoir has an HWL of 590 feet and is served by PS #3 to serve the High Zone.

Table 6-1 summarizes the existing pump station data and Table 6-2 summarizes the existing reservoir data.

Water Quality

The District is committed to providing safe and reliable recycled water to its customers. Recycled water receives extensive treatment and testing based on stringent State and Federal regulations. Recycled water standards can very depending on the application, but for most applications in California recycled water is treated to Title 22 Standards. Title 22 standards allow human full body contact with recycled water but not potable consumption without further treatment. In the District, recycled water is currently used for non-potable irrigation uses only.

Total Dissolved Solids (TDS) is commonly used as a water quality parameter for recycled water. The District's recycled water TDS has ranged from 872 mg/L to 1,356 mg/L from 2001 to 2007, based on water quality data received from SOCWA. The 2006 average TDS was 1,055 mg/L. As a comparison, southern California water customers received potable water with TDS ranging from 500 to 600 mg/L and recycled water ranging from 900 to 1,100 mg/L. Water exceeding a 1,000 mg/L TDS threshold is considered only marginally suitable for many irrigation applications, particularly where there are soils with a high clay content.

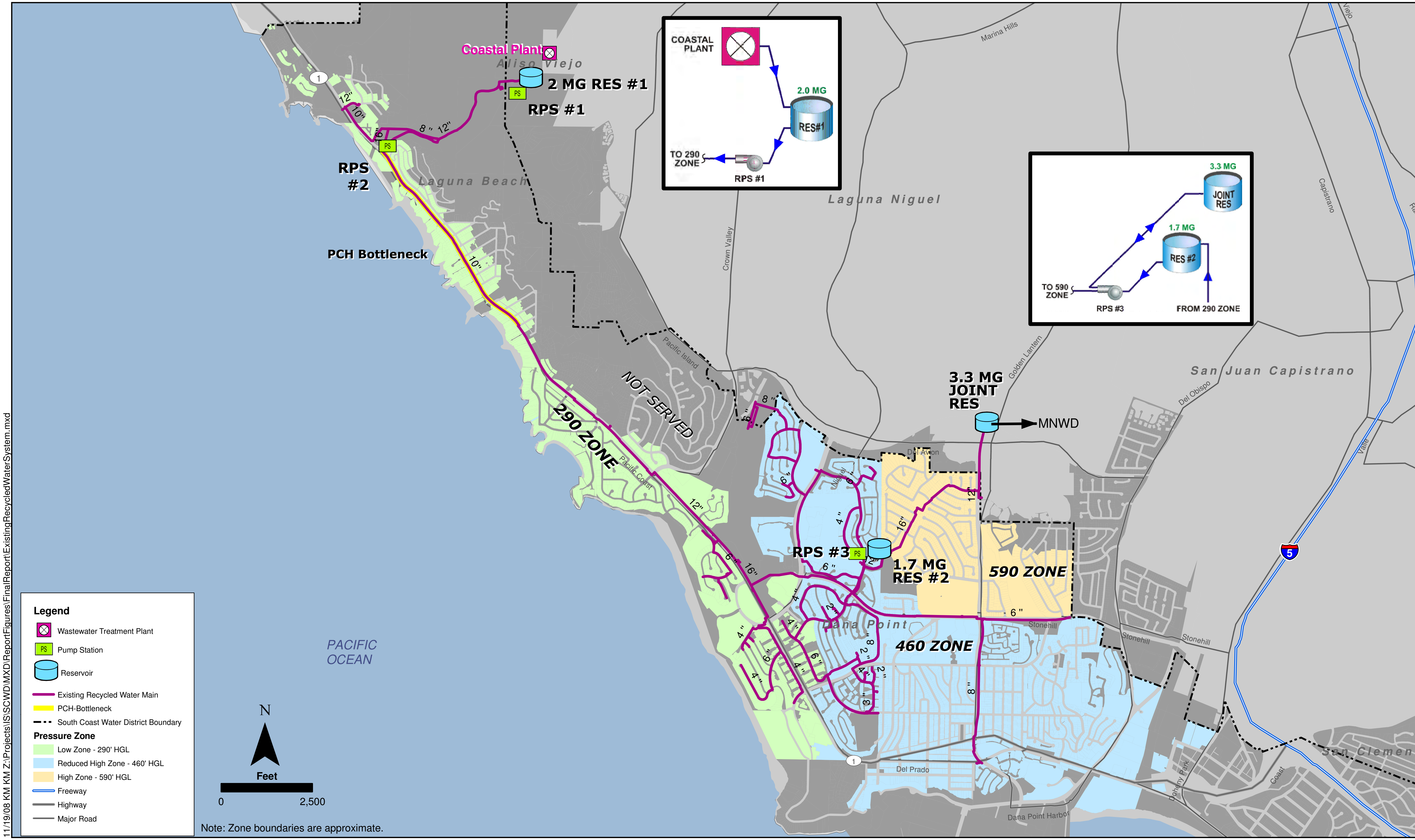


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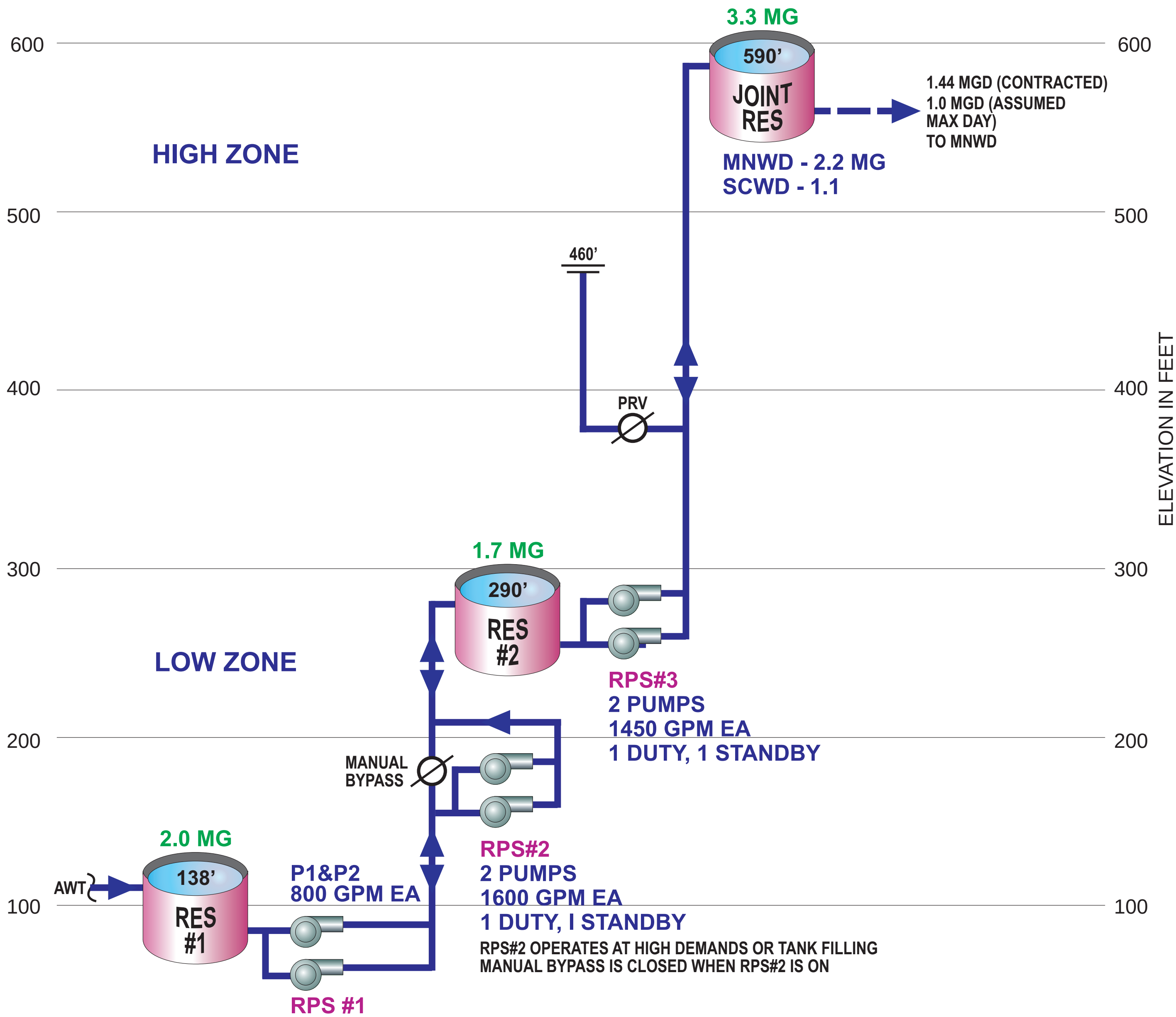
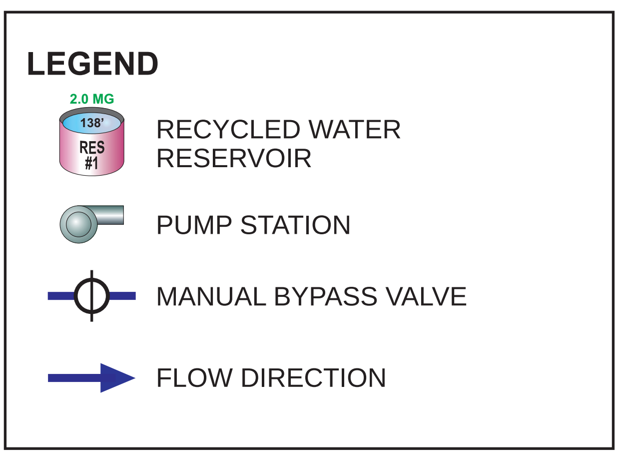
Figure 6-1
South Coast Water District
EXISTING RECYCLED WATER SYSTEM





EXISTING RECYCLED WATER SYSTEM SCHEMATIC

FIGURE 6-2

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FinalFigs\620889syst-Exist-RW.cdr November 18, 2008

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South Coast Water District Master Plan
November 2008

Table 6-1. Existing Recycled Water Pump Station Summary

Pump Station No.	Date Re-Constructed[1]	Number of Pumps	Rated Discharge (gpm)	Total Capacity (gpm)	Discharge Pressure Zone	Back-up Power
1	1991	2	800	1,600	290	None
2	1991	2	1,600	3,200	290	None
3	1992	2	1,450	2,900	580	None

(1) Original construction in the 1980s.

Table 6-2. Existing Recycled Water Reservoir Summary

Reservoir ID	Zone	Capacity (MG)	Year Installed	Ground Elev. (ft)	Diameter (ft)	Material
1	Low	2.0	1990	106.5	104	Welded Steel
2	Low	1.7	1986	267.0	134	Welded Steel
Joint[1]	High	3.3	1991	556.8	158	Buried PCC

(1) SCWD has 1.1 MG capacity of the 3.3 MG shared Joint Reservoir with MNWD

6.1.2 Proposed Recycled Water Supply Projects

The AWT facility is operating close to its maximum capacity at peak periods and assuming contracted flows delivered to MNWD, as discussed further in Section 6.3.3. Therefore, the District is considering participation in regional projects described herein. Between 8.5 and 30 MGD potential regional recycled water supply for future use has been identified in proposed new projects and facility expansions. Regional recycled water supply projects are described below.

San Clemente and San Juan Capistrano Recycled Water Project Grants
H.R. 1140 was introduced to the House of Representatives on February 16, 2007 by Rep. Ken Calvert (R-CA-44). H.R. 1140 would amend the Reclamation Wastewater and Groundwater Study and Facilities Act (P.L. 102-575, title XVI; 43 U.S.C. 390h et seq.) and authorizes funding for two separate water recycling projects in the vicinity of the District.

The San Juan Capistrano project would treat secondary effluent from the Latham Treatment Plant in Dana Point. The current total average daily flow tributary to the Latham Treatment Plant is 8.5 MGD. The plant has a design capacity of 13 MGD. Effluent is currently treated to secondary levels and conveyed directly to the San Juan Creek Outfall. The new facility is a regional project which would consist of a new AWT and an extensive recycled water system that could serve not only the City of San Juan Capistrano but also portions of MNWD and SCWD. The District has agreed to participate with the City of San Juan Capistrano and MNWD in a 0.5 MGD pilot program through 2010.

The San Clemente project would double the capacity of the city's water recycling plant, extend pumping and recycled water transmission infrastructure, and build a reservoir to hold recycled water for peak usage. It is estimated that an extension of transmission infrastructure would allow the City to replace 3,340 AFY of potable irrigation water with recycled water—reducing the city's total use of imported potable water by more than 25 percent.

The legislation specifies that the Federal government is responsible for 25 percent of the total cost of each project, but is not responsible for the operation and maintenance of either facility. This bill authorizes the appropriation of $18,500,000 for the San Juan Capistrano project and $5,000,000 for the San Clemente project.

On May 2, 2007, the Natural Resources Committee met to consider the bill. It was favorably reported to the House of Representatives by unanimous consent. H.R. 1140 has been sent to the Senate for consideration and is under review by the Committee on Energy and Natural Resources.

Salt Creek Reclamation Project and Sea Terrace Park Reservoir
A potential recycled water project that has been discussed at the District staff level is a new recycled water reservoir at the proposed Sea Terrace Park and the use of the effluent from the Salt Creek Ozone Treatment Plant. The Plant would have to be modified to include RO treatment to reduce salinity. As previously described, the existing recycled water system currently has a bottleneck along Pacific Coast Highway (PCH), where the recycled water pipeline decreases in size from a 12 inch pipeline to a 10 inch pipeline, and then increases back to a 12 inch pipeline at Crown Valley Parkway. The new reservoir and potential supplemental recycled water from the Salt Creek Ozone Treatment Plant could possibly alleviate this bottleneck and the added supply could lower the overall TDS concentration in the recycled water system. Section 6.5 includes the hydraulic analysis of the bottleneck section. Brine discharge from ozone treatment plants is a critical issue and the cost of RO treatment and brine disposal must be considered when evaluating the viability of this project. The Salt Creek Ozone Treatment Plant currently discharges into Sewer Lift Station #6.

Aliso Creek Water Harvesting Project
The District has conducted a preliminary investigation of a project to intercept and treat a portion of the urban runoff in lower Aliso Creek for subsequent use in the recycled water system (see Chapter 3). Treatment would consist of filtration and reverse osmosis facilities near the Coastal Plant. The plant would produce up to 0.5 MGD of low TDS water which, when blended into the District's recycled water system, would result in reduced salinity to make the recycled water more attractive for irrigation users.

Upgrade of AWT Facility to Increase Capacity
An option which should be considered if additional recycled water is needed to meet the peak demands of an expanded recycled water system is an upgrade to the AWT facility. The existing tertiary system consists of chemical coagulation and filtration to meet Title 22 requirements. Since the AWT facility was designed and constructed in the mid-1980s, a cost effective upgrade using more current technology might be identified to increase the capacity.

The projects described above are possible options to increase recycled water supply; however, the magnitude of future recycled water demands in the District is limited by the potential for new customers to be added within a reasonable cost. However, with the current limited available water supply, proposed new developments may seek to fund recycled water expansion projects to offset there estimated potable use. The need for additional future supply is discussed further in Section 6.3.3.

6.2 Recycled Water System Design Criteria

Presented in Table 6-3 are the recycled water system criteria for the District. The criteria were developed based on the following:

- Meetings and discussion with the District's engineering and operations staff
- Review of historical demands and SCADA data
- Comparison to other recycled water purveyor criteria

The recycled water criteria are similar in many respects to the potable water criteria, which are discussed in detail in Section 4.2 of this report. One major difference is reservoir storage. Reservoir storage in recycled water systems has a larger operational component due to the limited nighttime irrigation window, but fire flow and emergency supply criteria are typically not applied to recycled water reservoirs.

Table 6-3. Recycled Water Infrastructure Criteria

Item	Criteria
Peaking Factors	
Max Day/Avg Day Ratio	1.8
Max Month/Avg Month Ratio	1.6
Peak Hour/Avg Day Ratio	5.4
Pressure Criteria	
Maximum Desirable	120 psi
Minimum Static	70 psi
Minimum Pressure (Peak Hour)	50 psi
Velocity Criteria	
Maximum Velocity (Peak Hour)	5 to 7 fps
Storage	
Operating Storage	2/3 MDD (8 hour irrigation period)

6.3 Recycled Water Demand Forecast

Recycled water usage in the District has increased slowly, but continued demand growth is constrained by the limited recycled water infrastructure available to serve customers and potential high costs for users to retrofit their systems. Demands will continue to increase only as the District continues to invest in recycled water infrastructure. Recycled water demands can be classified into three categories:

- **Existing customers**: Customers currently using recycled water.
- **Conversion customers**: Customers that are currently using potable water via dedicated irrigation meters; demands that could be met by recycled water if it were available. Conversion customers are typically assessed by whether they are located within an economically feasible distance to the recycled water facilities.

- **New customers**: Because the District is primarily built out, few new customers are anticipated. Significant redevelopment projects may be considered new projects if substantial renovations, including new landscape and irrigation systems, are part of the project.

6.3.1 Demand Criteria

Similar to potable water, unit demands were used to estimate future recycled water usage. An average unit demand of 2,200 gallons per day per irrigated acre (gpd/ac) was applied. This equates to an irrigation application rate of 2.5 feet of water per acre per year. Irrigation application rates typically range from 2 to 4 feet per year per acre depending on the local climate and soils. The unit demand is consistent with previous District planning efforts. However, when planning for expanded or conversion to recycled water use at existing customer sites, historic billing data is the best guide for estimating future recycled water demands.

Figure 6-3 displays monthly recycled water demands from 2005 to 2007 based on records from the SCWD Monthly Recycled Water Monitoring Reports. As expected, the predominantly landscape-based demands vary seasonally with higher demands in the dry summer months and lower demands in the wet winter months. The annual average day demand (AAD) in 2006 was 0.81 MGD, including MNWD. Contractually, MNWD could increase its demand in the summer months at a peak day potentially minimizing the available supply for the District.

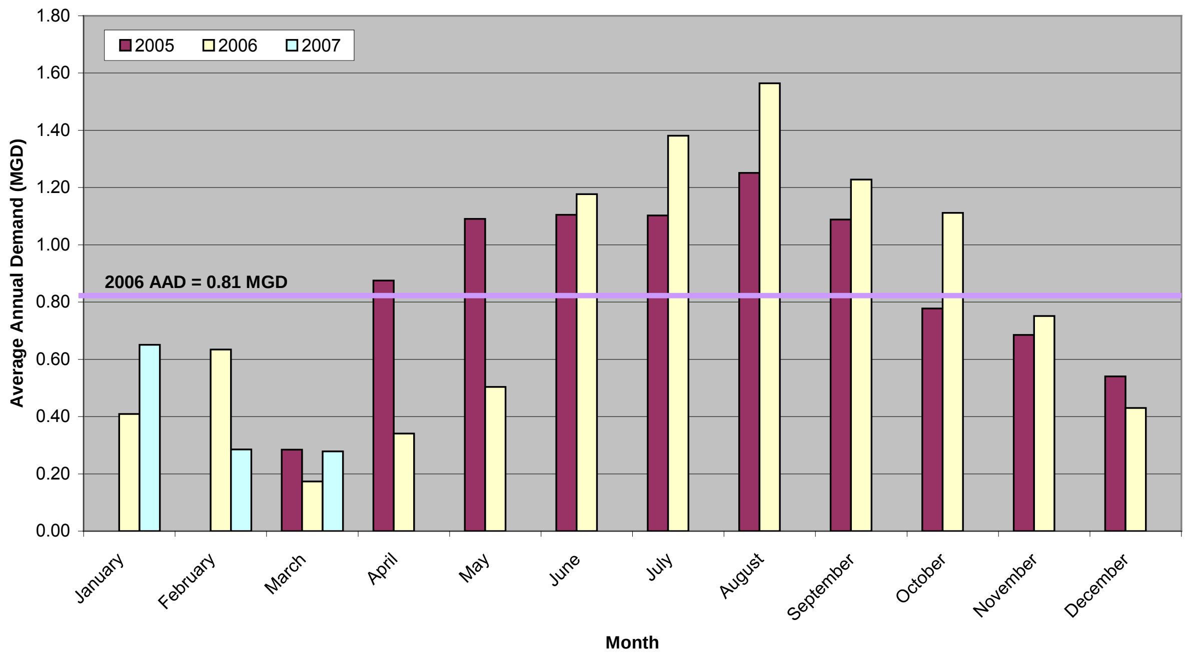


Figure 6-3. Monthly Recycled Water Demand 2005-2007

6.3.2 Distribution System Peaking Factors

Peaking criteria is extremely important in recycled water system sizing. An unrealistically high peaking factor can lead to an oversized system and water quality issues. A low peaking factor can result in insufficient capacity. Future changes in management approaches could assist in increases to system capacity without additional infrastructure. These changes could include adding onsite storage ponds at golf courses, longer irrigation windows, or proactive management by the District to coordinate water operation of major users and reduce peaks on the system.

Distribution system assessment typically uses maximum day and peak hour scenarios to evaluate system performance. Peaking factors are used to convert average annual water usage to these specific conditions. In general, the larger the service area, the smaller the variation in peak demands to average demands. The master plan demand scenarios include the entire District. Therefore, the peaking factors used in the overall master plan hydraulic model could be considered lower than what would be appropriate for a smaller area study, a development plan, or an individual pressure zone analysis.

The following summarizes the master plan peaking factors utilized in the recycled water distribution system analysis. These factors were developed based on historical supply records and operational data. Recycled water peaking factors for smaller areas should be discussed with District staff.

- Maximum Day - Representative of the highest use day during the peak month in each year and is typically used to assess distribution system operation. For recycled water irrigation systems, the maximum month demand is considered to be essentially equal to the maximum day demand. Figure 6-4 shows the monthly peaking factors based on 2 year averaged flow data, including MNWD supplies. A value of 1.8 was used in the hydraulic analysis to determine available capacity in the existing system and assess overall operations.
- Peak Hour – Representative of the highest rate of water use during the maximum day. In recycled water systems, this can be approximately calculated by dividing the maximum day factor by the irrigation application period (in hours) and multiplying by 24 hours. A peaking factor value of 5.4 was used for the master plan hydraulic analysis, assuming an 8 hour irrigation period. The District requires that recycled water irrigation occur between 10:00 p.m. and 6:00 a.m.

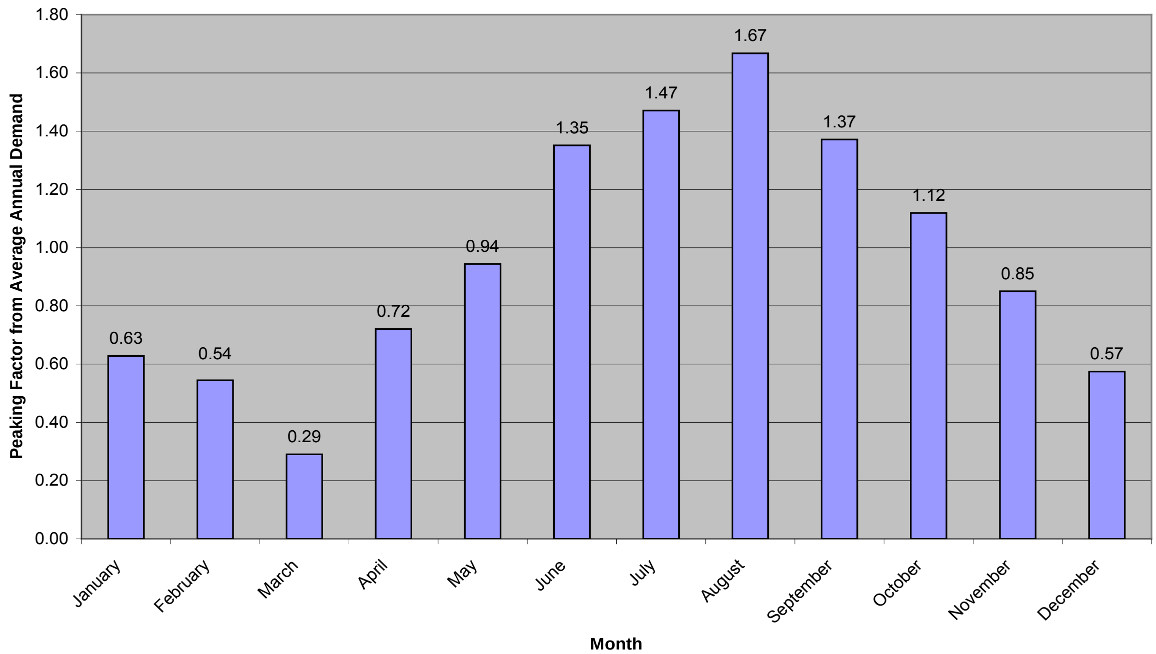


Figure 6-4. Recycled Water Monthly Peaking Factors 2005-2007

6.3.3 Historic and Existing Demands

Recycled water deliveries to District customers began in 1984. The demands have steadily increased since the system's inception — reaching approximately 940 AFY of demand and 171 meters served in 2006. Recycled water now accounts for approximately 11 percent of the total water used in the District. The recycled water usage is primarily for landscape irrigation such as golf courses, parks, and landscaped medians. A list of the existing recycled water users (2006 billing data) is provided in Table 6-4.

Monarch Beach Golf Links is the District's largest recycled water customer using approximately 282 AF in 2006. The second largest customer is Niguel Shores HOA (50 irrigation meters in total) using approximately 130 AF. The third largest customer is MNWD which has an agreement with SCWD to receive a contracted amount not to exceed 1.44 MGD. Historically, MNWD has not taken more than approximately 1.0 MGD out of the Joint Reservoir during the summer months. In 2006 the total average annual use for MNWD was 128 AFY or 0.11 MGD. In order to minimize MNWD's annual demand, SCWD will allow MNWD to "exchange" excess supply from the Joint Reservoir to offset the MNWD demand.

Excluding MNWD, the District uses 0.72 MGD of recycled water from the AWT facility on an average day and approximately 1.3 MGD on a maximum day. Contractually, MNWD can take the remaining supply during the summer months. The AWT facility has a capacity of 2.61 MGD, so recycled water available to serve new markets on a max day could be limited to approximately 0.3 MGD (330 AFY), depending on the quantity supplied to MNWD. The District could also feasibly provide new markets with recycled water by utilizing potable makeup water during the summer months. The total quantities required from the potable system would be very small; sufficient only to supplement the small deficit during short term peaks in demand. Moreover, it is recommended that SCWD modify its agreement with MNWD to limit their usage rate of recycled water during the summer months.

Table 6-4. Existing Recycled Water Customers

Customer	City	2006 Demand (AFY)
Monarch Beach Golf Links	Dana Point	282.14
Niguel Shores HOA	Dana Point	130.36
Moulton Niguel Water District	Dana Point	127.83[(1)]
City of Dana Point	Dana Point	66.93
Ritz Cove HOA	Dana Point	32.45
Emerald Ridge	Dana Point	31.46
County of Orange	Dana Point	25.06
Capo Unified School District	Dana Point	23.17
Monarch Beach Master Association	Dana Point	22.52
Laguna Beach Resorts	Laguna Beach	21.87
Corniche Sur Mer HOA	Dana Point	21.01
Monarch Hills Condo Association	Dana Point	20.64
Regatta Homeowners Association	Dana Point	17.24
Tennis Villas	Dana Point	13.94
Pointe Monarch	Dana Point	13.68
City of Laguna Beach	Laguna Beach	10.53
SOCWA	Laguna Niguel	10.29
Estates at Monarch Beach	Dana Point	7.74
Monarch Bay Association	Dana Point	6.81
Antigua HOA	Dana Point	6.80
Ritz Pointe at Monarch Beach	Dana Point	6.62
Montego at Monarch Beach Association	Dana Point	5.92
Corniche Master Association	Dana Point	5.31
St Regis	Dana Point	5.27
Cape Cove HOA	Dana Point	5.09
Marquesa/Monarch Beach	Dana Point	2.84
Villas at Monarch Beach	Dana Point	2.01
Monarch Cove Community Association	Dana Point	1.92
Niguel Shores Prof. Building	Dana Point	1.71
ARR Properties	Dana Point	1.54
Tennis Club at Monarch Beach	Dana Point	0.95
Monarch Bay Chevron	Dana Point	0.58
South Coast Water District	Dana Point	0.26
Total		932.49

(1) MNWD average annual use. Actual seasonal use varies depending on MNWD system needs.

6.3.4 Buildout/Ultimate Demands

Ultimate recycled water customers include existing recycled customers, conversion customers and new customers. Potential recycled water customers were subjected to a preliminary screening to evaluate whether it would be feasible to connect by examining their proximity to existing and potential infrastructure. The Capistrano Beach area was excluded from this analysis due to its proximity to existing infrastructure; however, Caltrans could potentially be a large customer and if the Latham Plant moves forward with an AWT, the District should consider its capacity rights at Latham and the potential to service the Capistrano Beach area.

Overall, an upper limit of an additional 480 AFY of demand has been targeted, as described in the following sections. Ultimately, recycled water demands could continue to increase beyond that limit in small increments if other existing potable water users are converted. However, the potential numbers and quantities are relatively small. Single-family residential irrigation customers were excluded from ultimate conversion demands, as it is difficult to permit and control recycled water use for single-family residential irrigation.

Conversion Customers

In the District's service area, approximately 13 percent of the potable water supply is used for landscape irrigation. Conversion customers represent a significant potential market for expanding recycled water usage. Conversion customers currently use potable water for uses that could be served by recycled water, such as irrigating medians, homeowner's association landscaping, school playgrounds, and golf courses. These customers also typically have dedicated irrigation meters to serve their irrigation system. Conversion customers require retrofitting, which can be costly, both in expenses and District staff coordination time. Retrofitting is the conversion of existing potable water uses to recycled water use. Retrofitting of the customer's onsite piping system must be designed, achieve regulatory approval, and be constructed. A market assessment is critical to assess retrofit customers. The preliminary assessment performed as part of this master plan was primarily based on these main questions:

- Could the customer's existing water use be met with recycled water?
- How much water could they use?
- What is the proximity to existing and planned infrastructure?

Billing information was used to map existing landscape irrigation customers throughout the District. Usage was summarized based on potable water irrigation meter records from 2006.

The targeted customers typically use over 1 AFY and are located near existing infrastructure. When systems are retrofitted, an overall reduction in water use is typical. The reduction can be caused by a number of factors including replacement of leaking or less efficient irrigation systems, better water management, or cost/practicality constraints limiting the conversion to only certain portions of the existing potable system. To be conservative in evaluating the recycled water system limitations, conversion demands will be assumed at 80 percent of 2006 potable water irrigation demands.

Potable irrigation customers along the existing recycled water infrastructure corridors were primary targets for conversion to recycled water. Actual on-site retrofit costs were not considered when creating this approach but may limit the number of potential customers considered. Potential conversion customers were grouped into the following tiers and are shown on Figure 6-5. A description of the proposed tiers is provided as follows:

- **Tier I** – potable irrigation customers within 500 feet of the existing recycled water system
- **Tier II** – potable irrigation customers with large demands requiring an extension of the existing recycled water pipeline. Smaller demand customers that can be served along the pipeline extension were also included in this Tier.
- **Tier III** – potable irrigation customers with smaller demands that can be served off additional pipeline extensions and future/redevelopment projects.

Tier I. Table 6-5 lists the Tier I users. Existing potable water landscape irrigation users within 500 feet of the existing recycled water distribution system represent approximately 239AFY of potential demand that could be converted to the recycled water system.

The largest Tier I conversion customer is Aliso Creek Inn and Golf Course which used 65.81 AF of potable water for irrigation in 2006. The Aliso Creek Inn and Golf Course is planning to undergo redevelopment which may increase its potential recycled water demand. The Ritz Carlton is the second largest Tier I conversion customer and is located off Pacific Coast Highway. In 2006, the site used 35 AF of potable water for irrigation.

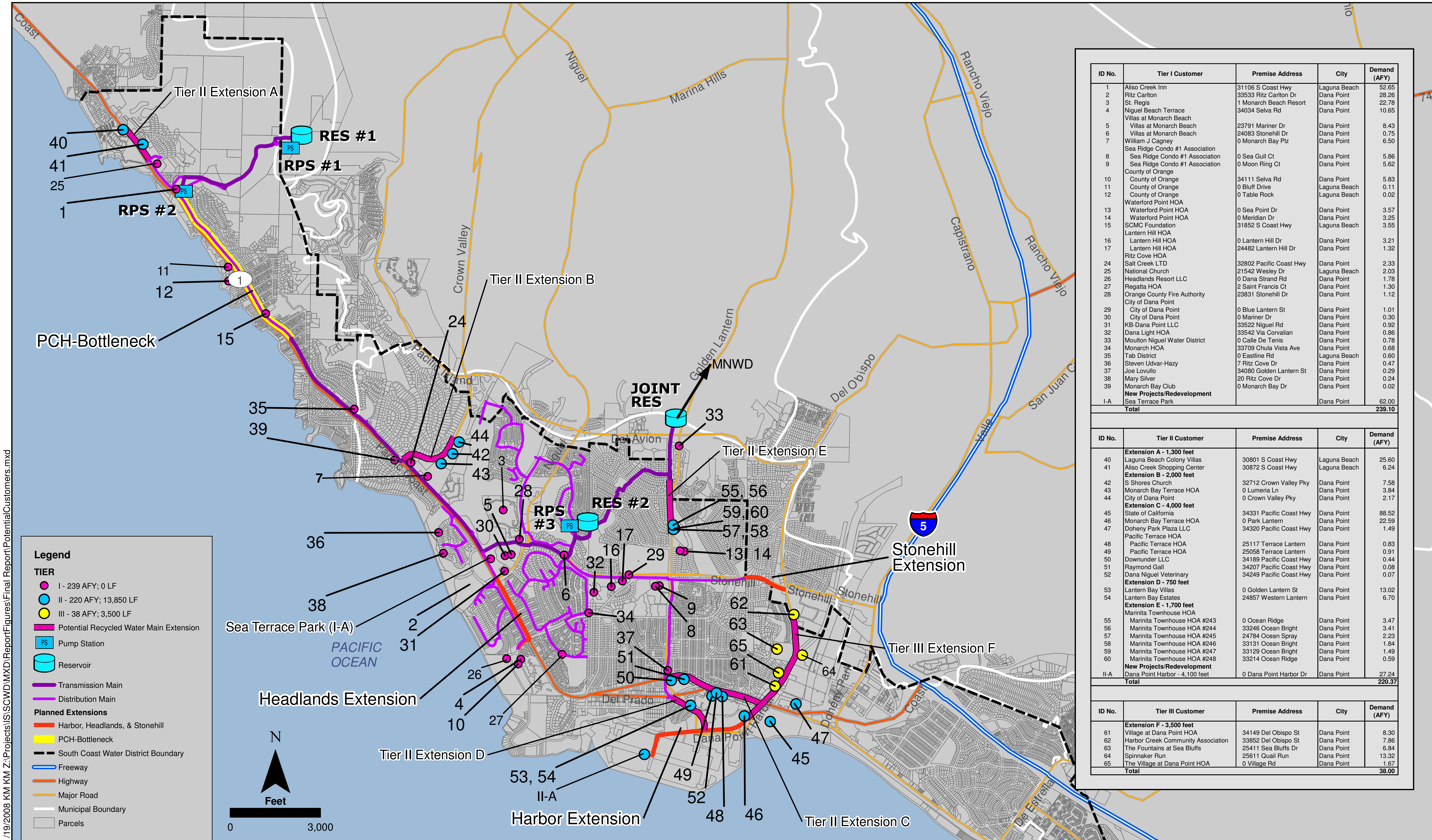
The City of Dana Point is currently planning to use recycled water for the proposed Sea Terrace Park. The park is estimated to be 21.6 acres and would use approximately 62 AFY of water for irrigation, per proposed plans. The park would be an ideal candidate for recycled water, as it is located near the existing recycled water system.

Tier II. Table 6-6 lists the Tier II users, which are characterized as large potable water users not located along the existing recycled water system. Tier II conversion customers are grouped by the proposed five pipeline extensions, labeled A to E on Figure 6-5. Together, these potable water landscape users represent 220 AFY of potential irrigation demand that could be converted to the recycled water system.

The largest Tier II customer is the State of California Park, located south of Dana Point Harbor. In 2006, the park used 110 AF of potable water for irrigation. The second largest Tier II customer is Laguna Beach Colony Villas which used 32 AF potable water for irrigation in 2006.

The District is considering a 4,100-foot recycled water pipeline extension to serve the Dana Point Harbor. The Dana Point Harbor had a potable irrigation demand of 34 AF in 2006 that could be converted to recycled water irrigation. The Dana Point Harbor Extension is shown on Figure 6-5.

Tier III. In addition to the demands served by Tier II pipeline extensions, an additional 38 AFY of recycled water irrigation could be served with additional pipeline extensions. Approximately 48 AFY of potable water irrigation can be converted to recycled water by constructing 3,500 feet of pipe (Extension F) north of the end of Tier II's Extension C. Tier III extensions are labeled on Figure 6-5. Potential Tier III customers are listed in Table 6-7.



ID No.	Tier I Customer	Premise Address	City	Demand (AFY)
1	Aliso Creek Inn	31106 S Coast Hwy	Laguna Beach	52.65
2	Ritz Carlton	33533 Ritz Carlton Dr	Dana Point	28.26
3	St. Regis	1 Monarch Beach Resort	Dana Point	22.78
4	Niguel Beach Terrace	34034 Selva Rd	Dana Point	10.65
	Villas at Monarch Beach			
5	Villas at Monarch Beach	23791 Mariner Dr	Dana Point	8.43
6	Villas at Monarch Beach	24083 Stonehill Dr	Dana Point	0.75
7	William J Cagney	0 Monarch Bay Plz	Dana Point	6.50
	Sea Ridge Condo #1 Association			
8	Sea Ridge Condo #1 Association	0 Sea Gull Ct	Dana Point	5.86
9	Sea Ridge Condo #1 Association	0 Moon Ring Ct	Dana Point	5.62
	County of Orange			
10	County of Orange	34111 Selva Rd	Dana Point	5.83
11	County of Orange	0 Bluff Drive	Laguna Beach	0.11
12	County of Orange	0 Table Rock	Laguna Beach	0.02
	Waterford Point HOA			
13	Waterford Point HOA	0 Sea Point Dr	Dana Point	3.57
14	Waterford Point HOA	0 Meridian Dr	Dana Point	3.25
15	SCMC Foundation	31852 S Coast Hwy	Laguna Beach	3.55
	Lantern Hill HOA			
16	Lantern Hill HOA	0 Lantern Hill Dr	Dana Point	3.21
17	Lantern Hill HOA	24482 Lantern Hill Dr	Dana Point	1.32
	Ritz Cove HOA			
24	Salt Creek LTD	32802 Pacific Coast Hwy	Dana Point	2.33
25	National Church	21542 Wesley Dr	Laguna Beach	2.03
26	Headlands Resort LLC	0 Dana Strand Rd	Dana Point	1.78
27	Regatta HOA	2 Saint Francis Ct	Dana Point	1.30
28	Orange County Fire Authority	23831 Stonehill Dr	Dana Point	1.12
	City of Dana Point			
29	City of Dana Point	0 Blue Lantern St	Dana Point	1.01
30	City of Dana Point	0 Mariner Dr	Dana Point	0.30
31	KB-Dana Point LLC	33522 Niguel Rd	Dana Point	0.92
32	Dana Light HOA	33542 Via Corvalian	Dana Point	0.86
33	Moulton Niguel Water District	0 Calle De Tenis	Dana Point	0.78
34	Monarch HOA	33709 Chula Vista Ave	Dana Point	0.68
35	Tab District	0 Eastline Rd	Laguna Beach	0.60
36	Steven Udvar-Hazy	7 Ritz Cove Dr	Dana Point	0.47
37	Joe Lovullo	34080 Golden Lantern St	Dana Point	0.29
38	Mary Silver	20 Ritz Cove Dr	Dana Point	0.24
39	Monarch Bay Club	0 Monarch Bay Dr	Dana Point	0.02
	New Projects/Redevelopment			
I-A	Sea Terrace Park		Dana Point	62.00
	Total			**239.10**

ID No.	Tier II Customer	Premise Address	City	Demand (AFY)
	Extension A - 1,300 feet			
40	Laguna Beach Colony Villas	30801 S Coast Hwy	Laguna Beach	25.60
41	Aliso Creek Shopping Center	30872 S Coast Hwy	Laguna Beach	6.24
	Extension B - 2,000 feet			
42	S Shores Church	32712 Crown Valley Pky	Dana Point	7.58
43	Monarch Bay Terrace HOA	0 Lumeria Ln	Dana Point	3.84
44	City of Dana Point	0 Crown Valley Pky	Dana Point	2.17
	Extension C - 4,000 feet			
45	State of California	34331 Pacific Coast Hwy	Dana Point	88.52
46	Monarch Bay Terrace HOA	0 Park Lantern	Dana Point	22.59
47	Doheny Park Plaza LLC	34320 Pacific Coast Hwy	Dana Point	1.49
	Pacific Terrace HOA			
48	Pacific Terrace HOA	25117 Terrace Lantern	Dana Point	0.83
49	Pacific Terrace HOA	25058 Terrace Lantern	Dana Point	0.91
50	Downunder LLC	34189 Pacific Coast Hwy	Dana Point	0.44
51	Raymond Gall	34207 Pacific Coast Hwy	Dana Point	0.08
52	Dana Niguel Veterinary	34249 Pacific Coast Hwy	Dana Point	0.07
	Extension D - 750 feet			
53	Lantern Bay Villas	0 Golden Lantern St	Dana Point	13.02
54	Lantern Bay Estates	24857 Western Lantern	Dana Point	6.70
	Extension E - 1,700 feet			
	Marinita Townhouse HOA			
55	Marinita Townhouse HOA #243	0 Ocean Ridge	Dana Point	3.47
56	Marinita Townhouse HOA #244	33246 Ocean Bright	Dana Point	3.41
57	Marinita Townhouse HOA #245	24784 Ocean Spray	Dana Point	2.23
58	Marinita Townhouse HOA #246	33131 Ocean Bright	Dana Point	1.84
59	Marinita Townhouse HOA #247	33129 Ocean Bright	Dana Point	1.49
60	Marinita Townhouse HOA #248	33214 Ocean Ridge	Dana Point	0.59
	New Projects/Redevelopment			
II-A	Dana Point Harbor - 4,100 feet	0 Dana Point Harbor Dr	Dana Point	27.24
	Total			**220.37**

ID No.	Tier III Customer	Premise Address	City	Demand (AFY)
	Extension F - 3,500 feet			
61	Village at Dana Point HOA	34149 Del Obispo St	Dana Point	8.30
62	Harbor Creek Community Association	33852 Del Obispo St	Dana Point	7.86
63	The Fountains at Sea Bluffs	25411 Sea Bluffs Dr	Dana Point	6.84
64	Spinnaker Run	25611 Quail Run	Dana Point	13.32
65	The Village at Dana Point HOA	0 Village Rd	Dana Point	1.67
	Total			**38.00**

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Figure 6-5
South Coast Water District
POTENTIAL RECYCLED WATER CUSTOMERS

Table 6-5. Tier I Potential Conversion Customers

ID No.	Customer	Premise Address	City	2006 Demand (AFY)	Conversion Reduction Factor	Retrofit Demand (AFY)
1	Aliso Creek Inn	31106 S Coast Hwy	Laguna Beach	65.81	80%	52.65
2	Ritz Carlton	33533 Ritz Carlton Dr	Dana Point	35.33	80%	28.26
3	St. Regis	1 Monarch Beach Resort	Dana Point	28.48	80%	22.78
4	Niguel Beach Terrace	34034 Selva Rd	Dana Point	13.32	80%	10.65
	Villas at Monarch Beach					
5	Villas at Monarch Beach	23791 Mariner Dr	Dana Point	10.54	80%	8.43
6	Villas at Monarch Beach	24083 Stonehill Dr	Dana Point	0.93	80%	0.75
7	William J Cagney	0 Monarch Bay Plz	Dana Point	8.13	80%	6.50
	Sea Ridge Condo #1 Association					
8	Sea Ridge Condo #1 Assoc	0 Sea Gull Ct	Dana Point	7.32	80%	5.86
9	Sea Ridge Condo #1 Assoc	0 Moon Ring Ct	Dana Point	7.02	80%	5.62
	County of Orange					
10	County of Orange	34111 Selva Rd	Dana Point	7.28	80%	5.83
11	County of Orange	0 Bluff Drive	Laguna Beach	0.13	80%	0.11
12	County of Orange	0 Table Rock	Laguna Beach	0.03	80%	0.02
	Waterford Point HOA					
13	Waterford Point HOA	0 Sea Point Dr	Dana Point	4.46	80%	3.57
14	Waterford Point HOA	0 Meridian Dr	Dana Point	4.07	80%	3.25
15	SCMC Foundation	31852 S Coast Hwy	Laguna Beach	4.44	80%	3.55
	Lantern Hill HOA					
16	Lantern Hill HOA	0 Lantern Hill Dr	Dana Point	4.02	80%	3.21
17	Lantern Hill HOA	24482 Lantern Hill Dr	Dana Point	1.65	80%	1.32
24	Salt Creek LTD	32802 Pacific Coast Hwy	Dana Point	2.91	80%	2.33
25	National Church	21542 Wesley Dr	Laguna Beach	2.54	80%	2.03
26	Headlands Resort LLC[(1)]	0 Dana Strand Rd	Dana Point	2.23	80%	1.78
27	Regatta HOA	2 Saint Francis Ct	Dana Point	1.62	80%	1.30
28	Orange County Fire Authority	23831 Stonehill Dr	Dana Point	1.40	80%	1.12
	City of Dana Point					
29	City of Dana Point	0 Blue Lantern St	Dana Point	1.26	80%	1.01
30	City of Dana Point	0 Mariner Dr	Dana Point	0.38	80%	0.30
31	KB-Dana Point LLC	33522 Niguel Rd	Dana Point	1.15	80%	0.92
32	Dana Light HOA	33542 Via Corvalian	Dana Point	1.07	80%	0.86
33	Moulton Niguel Water District	0 Calle De Tenis	Dana Point	0.97	80%	0.78
34	Monarch HOA	33709 Chula Vista Ave	Dana Point	0.85	80%	0.68
35	Tab District	0 Eastline Rd	Laguna Beach	0.75	80%	0.60
36	Steven Udvar-Hazy	7 Ritz Cove Dr	Dana Point	0.58	80%	0.47
37	Joe Lovullo	34080 Golden Lantern St	Dana Point	0.36	80%	0.29
38	Mary Silver	20 Ritz Cove Dr	Dana Point	0.30	80%	0.24
39	Monarch Bay Club	0 Monarch Bay Dr	Dana Point	0.03	80%	0.02
	New Project/Redevelopment					
I-A	Sea Terrace Park		Dana Point	-	-	62.00
	Total			**166.63**		**239.10**

Notes: Demands have been adjusted to account for retrofit induced conversions and system limitations on retrofit conversions. Future efforts should validate the ability to connect users and the minimum threshold demand by confirming costs to benefits.
(1) The demands for Headlands Resort LLC (#26) are the projected usage for 2009.

Table 6-6. Tier II Potential Conversion Customers

ID No.	Customer	Premise Address	City	2006 Demand (AFY)	Conversion Reduction Factor	Retrofit Demand (AFY)
	Extension A - 1,300 feet					
40	Laguna Beach Colony Villas	30801 S Coast Hwy	Laguna Beach	32.01	80%	25.60
41	Aliso Creek Shopping Center	30872 S Coast Hwy	Laguna Beach	7.81	80%	6.24
	Extension B - 2,000 feet					
42	S Shores Church	32712 Crown Valley Pky	Dana Point	9.47	80%	7.58
43	Monarch Bay Terrace HOA	0 Lumeria Ln	Dana Point	4.79	80%	3.84
44	City of Dana Point	0 Crown Valley Pky	Dana Point	2.72	80%	2.17
	Extension C - 4,000 feet					
45	State of California	34331 Pacific Coast Hwy	Dana Point	110.65	80%	88.52
46	Monarch Bay Terrace HOA	0 Park Lantern	Dana Point	28.24	80%	22.59
47	Doheny Park Plaza LLC	34320 Pacific Coast Hwy	Dana Point	1.86	80%	1.49
48	Pacific Terrace HOA	25117 Terrace Lantern	Dana Point	1.04	80%	0.83
49	Pacific Terrace HOA	25058 Terrace Lantern	Dana Point	1.14	80%	0.91
50	Downunder LLC	34189 Pacific Coast Hwy	Dana Point	0.55	80%	0.44
51	Raymond Gall	34207 Pacific Coast Hwy	Dana Point	0.11	80%	0.08
52	Dana Niguel Veterinary	34249 Pacific Coast Hwy	Dana Point	0.09	80%	0.07
	Extension D - 750 feet					
53	Lantern Bay Villas	0 Golden Lantern St	Dana Point	16.28	80%	13.02
54	Lantern Bay Estates	24857 Western Lantern	Dana Point	8.38	80%	6.70
	Extension E - 1,700 feet					
55	Marinita Townhouse HOA #243	0 Ocean Ridge	Dana Point	4.33	80%	3.47
56	Marinita Townhouse HOA #244	33246 Ocean Bright	Dana Point	4.27	80%	3.41
57	Marinita Townhouse HOA #245	24784 Ocean Spray	Dana Point	2.79	80%	2.23
58	Marinita Townhouse HOA #246	33131 Ocean Bright	Dana Point	2.30	80%	1.84
59	Marinita Townhouse HOA #247	33129 Ocean Bright	Dana Point	1.86	80%	1.49
60	Marinita Townhouse HOA #248	33214 Ocean Ridge	Dana Point	0.74	80%	0.59
	New Projects/Redevelopment					
II-A	Dana Point Harbor - 4,100 feet	0 Dana Point Harbor Dr	Dana Point	34.06	80%	27.24
	Total			**275.46**		**220.37**

Notes: Demands have been adjusted to account for retrofit induced conversions and system limitations on retrofit conversions. Future efforts should validate the ability to connect users and the minimum threshold demand by confirming costs to benefits.

Table 6-7. Tier III Potential Conversion Customers

ID No.	Customer	Premise Address	City	2006 Demand (AFY)	Conversion Reduction Factor	Retrofit Demand (AFY)
	Extension F - 3,500 feet					
61	Village at Dana Point HOA	34149 Del Obispo St	Dana Point	10.37	80%	8.30
62	Harbor Creek Community Assoc	33852 Del Obispo St	Dana Point	9.83	80%	7.86
63	The Fountains at Sea Bluffs	25411 Sea Bluffs Dr	Dana Point	8.56	80%	6.84
64	Spinnaker Run	25611 Quail Run	Dana Point	16.65	80%	13.32
65	The Village at Dana Point HOA	0 Village Rd	Dana Point	2.09	80%	1.67
	Total			**47.50**		**38.00**

Notes: Demands have been adjusted to account for retrofit induced conversions and system limitations on retrofit conversions. Future efforts should validate the ability to connect users and the minimum threshold demand by confirming costs to benefits.

Potential New Customers
The District is in the process of implementing several recycled water expansion projects as noted below and shown on Figure 6-5.

Headlands Development. The Headlands Development is a 35-acre site located in Dana Point and is planned to include residential units, restaurant, and commercial space. The District is currently evaluating a 2,800 foot recycled water extension in Pacific Coast Highway to serve the Headlands irrigation needs in the future. This would be considered a Tier II candidate.

Stonehill Drive Expansion. A 1,500 foot recycled pipeline is being planned to extend the end of the recycled water pipeline in Stonehill Drive. This extension will allow the District to serve customers farther east and possibly provide the option of pipeline looping if future recycled water extensions are constructed.

Fuel Modification Zones. There are a number of development areas within the District that interface with wildland and canyon areas. There are new requirements for landscaping along urban interface areas to better protect structures from wildfires. In the future, the District may have opportunities to use recycled water for irrigation of these fuel modification zones. Demands are currently not identified for this use and have not been included in Tier I, II, or III totals.

Future Retrofit/Conversion Considerations
Evaluation criteria should be developed to provide guidance on future retrofit decisions. The criteria goal would provide a qualitative and quantitative means to determine whether the District should invest in recycled water retrofits or distribution pipeline extensions. In deciding which existing potable customers are suitable candidates for conversion to recycled water, the following considerations should be made:

Quantitative Considerations

- Surplus recycled water must be available to meet peak demands.
- Operational costs may increase with demand due to additional pump operation.
- Infrastructure costs (pipeline, reservoirs, pumps)
- Retrofit costs per site compared to potential recycled water revenue
- Revenue generated by recycled water sales (current rate = $892/AF) and savings associated with purchasing and delivering less potable water (current rate = $1,116/AF)

Qualitative Considerations

- Increased recycled water use is consistent with District goals.
- Recycled water is a local, reliable water resource.
- Recycled water is considered uninterruptible, providing an economic benefit during droughts.
- Potable water cost inflation is projected to outpace recycled water supply costs and could offset the need to improve or expand the potable water system.
- Converting customers to recycled water reduces the overall potable water demand.

- Converting potable to recycled water use will not normally capture 100 percent of existing usage for.
- Retrofits can be difficult in design, costly and require significant staff time to coordinate.
- Recycled water quality may impact landscaping as compared to potable water.

Retrofit cost data was evaluated from various sources, including recent recycled water studies in nearby areas. Retrofit conversion costs include on-site engineering design and planning, meters and backflow preventers, piping and isolation valves, construction inspection and testing, and District review. Costs are estimated to range from $20,000 to $50,000 per site, depending on total irrigation acreage and potential recycled water demand.

6.4 Recycled Water System Hydraulic Model

A detailed hydraulic computer model was developed to analyze the District's recycled water system. The steps of model formulation included obtaining the system's physical data (the facilities such as pipelines, and reservoirs), translating the physical data into a network of nodes (demand locations) and links (pipelines), determining pressure zone boundaries, importing demands, and verifying that the network matches existing data.

Existing System Computer Model

The District's existing recycled water system model was developed using GIS and digitizing methodology. The computer model includes all the major transmission and distribution mains, 4 inch diameter and larger. The model includes annotation of pipeline size and material, and isolation/control valve sizes and type of valve. Node elevations were obtained via the same process discussed in Chapter 4. Reservoirs were annotated with capacity, HWL, diameter, and height. Pump stations were added with their corresponding pump curves. The manual bypass valve at PS #2 was also added with controls to open only when the pump station was not in operation. The District may want to consider converting the bypass valve to an automatic motor-operated valve for ease in operation.

Ultimate System Computer Model

The ultimate water system was also assessed using the hydraulic computer model. Proposed transmission mains, reservoirs, pump stations, and potential improvements were added to the existing system hydraulic model based on proposed conversion customers. Ultimate facilities were identified and discussed at meetings with District staff.

Model Calibration

Recycled water SCADA data and existing billing records were the primary tools to validate the hydraulic model. A steady state recycled water model calibration was performed utilizing District pump station SCADA data to confirm that the observed flow was simulated through the system. SCADA data for tank levels was also reviewed to determine appropriate level settings. However, tank levels fluctuation is not observed in a steady state model.

6.5 Existing Recycled Water System Analysis

As previously discussed, the District experiences operational issues through a hydraulic bottleneck in Pacific Coast Highway. The first step in the recycled water analysis was to evaluate existing storage and pump capacity thresholds for the existing recycled water system. Following this analysis, an evaluation of the impact of the bottleneck was completed to determine if pipe replacement or other mitigating measures were necessary to serve existing and ultimate customers.

6.5.1 Existing Storage and Pumping Analysis

The recycled water system reservoir storage was assessed to determine if storage criteria was met under existing demands. Recycled water storage criterion was evaluated at two-thirds of a MDD. The resulting storage assessment is included in Table 6-8.

Table 6-8. Existing Recycled Water Reservoir Analysis

	Existing Average Annual Demand (District Only)		Max Day Demand (AAD x 1.8)	Required Operational Storage per Design Criteria	Existing Storage		
Pressure Zone	**gpm**	**MGD**	**MGD**	**(0.67 x MDD)**	**Storage Facility**	**Capacity**	**Surplus/ (Deficit)**
Low	316	0.45	0.82	0.55 MG	Res #1	2.0 MG[(1)]	1.15 MG
					Res #2	1.7 MG	
High	186	0.27	0.48	0.32 MG	Joint Res[(2)]	1.1 MG	0.78 MG
Totals	**502**	**0.72**	**1.30**	**0.87 MG**		**2.8 MG**	**1.93 MG**

(1) Res #1 is not included in Operational storage as it serves as a forebay reservoir for PS #1.
(2) SCWD has 1.1 MG capacity of the 3.3 MG shared Joint Reservoir with MNWD

The current reservoirs have sufficient capacity for the existing system demands. An additional requirement is that this operational storage can be fully used and replaced on maximum day demand. Under steady-state simulations, the model confirmed that adequate trial replenishment occurs at Reservoir #2 and the Joint Reservoir.

A recycled water pump station capacity analysis was performed and is summarized in Table 6-9. As previously noted, the District is contracted with MNWD to deliver up to 1.44 MGD of recycled water. Currently, under normal operating conditions, MNWD “exchanges” recycled water on a monthly basis out of the Joint Reservoir to minimize the monthly charge for water it takes from SCWD. Typically, MNWD will only take recycled water from SCWD, without exchange, if they have one of their treatment plants down for maintenance. For the purposes of this study and capacity analysis it is assumed that 1 MGD of recycled water is delivered to MNWD under maximum day demand conditions.

PS #1 must have capacity to serve the Low and High Zone demands plus the MNWD demand out of the Joint Reservoir. PS #1 is near capacity to meet the maximum day demands of the existing system, assuming 1.0 MGD supply to MNWD.

Table 6-9. Existing Recycled Water Pump Station Analysis

Pressure Zone	Pump Station No.	No. of Pumps	Rated Discharge	Total Capacity	Zone Average Annual Demand	Max Day Demand (AAD x 1.8)	Available PS Capacity[(1)]	AAD Surplus/ (Deficit)	MDD Surplus/ (Deficit)
			gpm	gpm	gpm	gpm	gpm	gpm	gpm
Low	1	2	800	1,600	578[(3)]	1,598[(5)]	1,600	1,022	2
	2[(2)]	2	1,600						
High	3	2	1,450	2,900	263[(4)]	1,030[(5)]	1,450	1,187	420

(1) Available PS Capacity includes duty pumps; stand-by or emergency pumps are not included.
(2) PS #2 works in series with PS #1 during peak demands.
(3) Low and High Zone demand + MNWD average demand of 0.11 MGD
(4) High Zone demand + MNWD average demand of 0.11 MGD
(5) Max Day Demand includes MNWD Max Day demand of 1.0 MGD

6.5.2 Hydraulic Bottleneck Analysis

The existing recycled water system has a 6,100-foot hydraulic bottleneck in PCH, just downstream of PS #2, where the pipe diameter reduces from 12 inch to 10 inch for approximately 3,100 feet and then returns to a 12 inch pipeline. The 10 inch pipe is encased within a 16 inch pipe with redwood spacers. The headloss across the bottleneck is approximately 110 feet. Figure 6-6 shows the hydraulic grade line from Reservoir #1 to Reservoir #2.

An analysis was performed on the existing recycled water system to evaluate replacing the bottleneck with a 16 inch pipeline. The headloss across this stretch of pipe was reduced and total flow capacity through the Low Zone increased. The improved hydraulic grade line is shown in Figure 6-7.

6.5.3 Existing Operational Analysis

The recycled water pipeline network is relatively simple and includes both transmission and distribution facilities. The hydraulic computer model was utilized to assess the existing system operation. Appendix D includes the steady-state simulation results from the computer model.

System pressures ranged from 24 to 96 psi at all nodes. Every node that had a demand had predicted pressures within 44 psi and 96 psi. The City of Dana Point Golden Lantern Street connection had a maximum pressure of 180 psi (Node AIM-RWSV-111). The hydraulic model predicted system pipeline velocities below 7 feet per second.

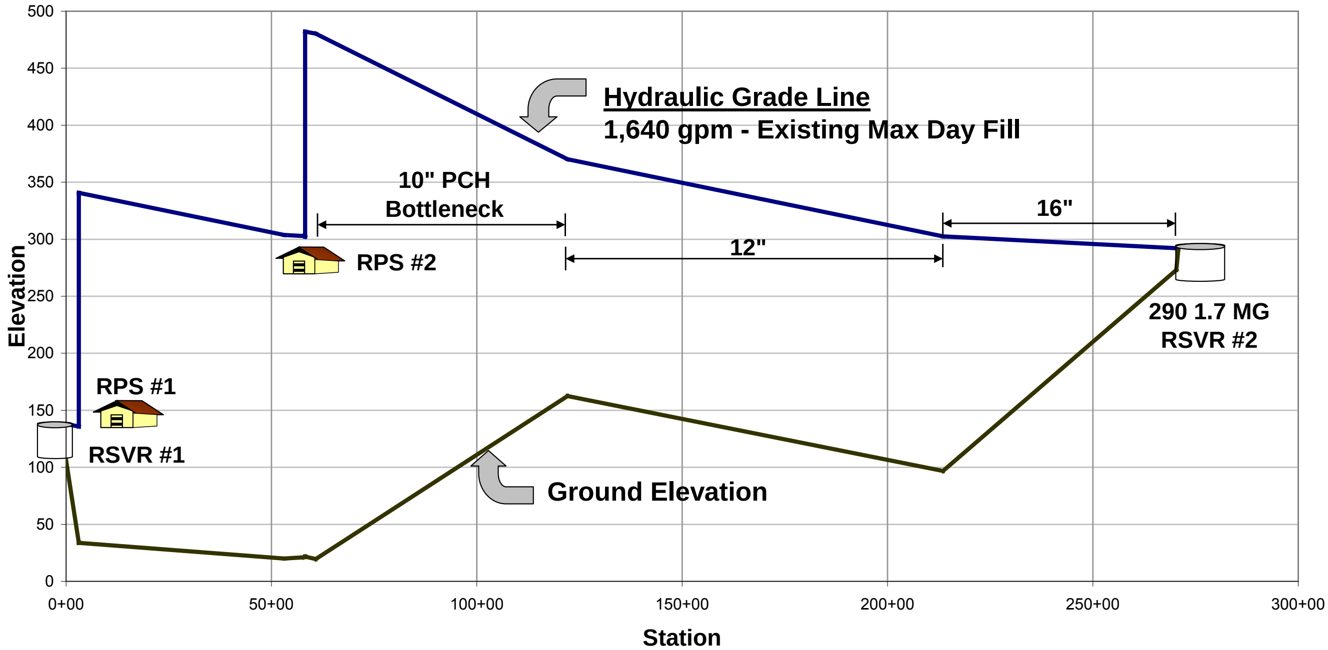

Figure 6-6. Existing Hydraulic Grade Line

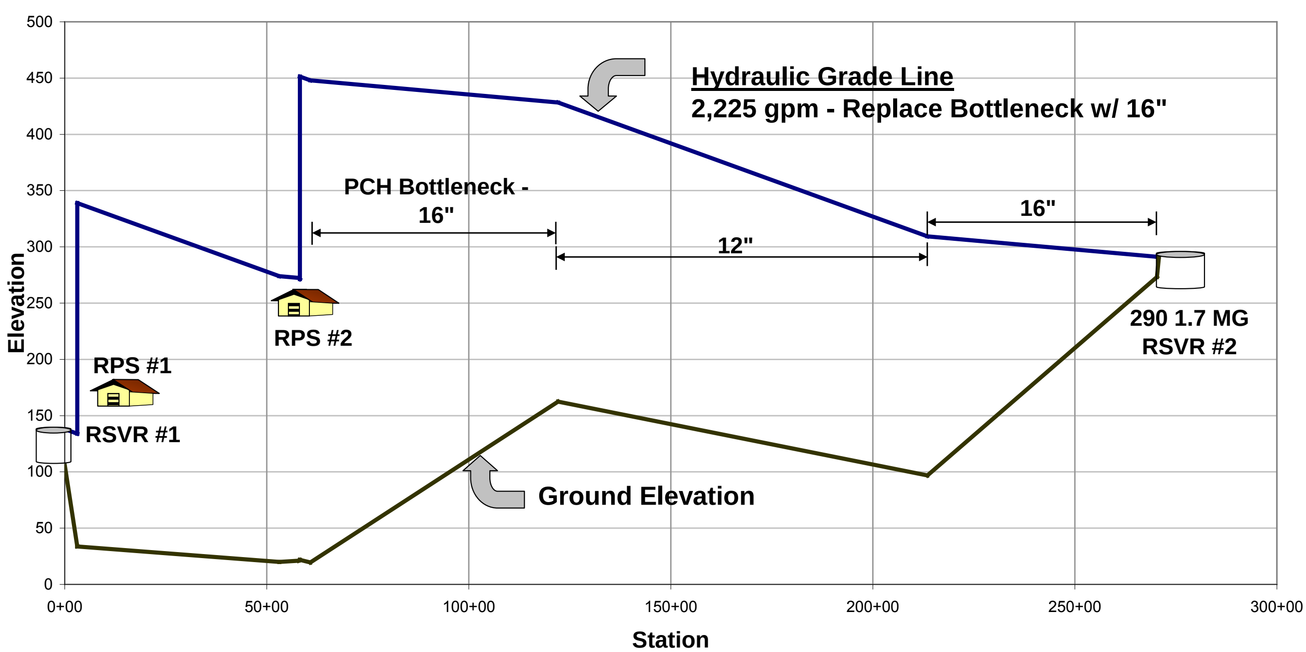

Figure 6-7. Proposed Hydraulic Grade Line

6.6 Ultimate Recycled Water System Analysis

The future recycled water system was evaluated to include Tier I, II, and III demands.

6.6.1 AWT Facility Capacity Analysis

The production capacity of the AWT facility should be considered when evaluating the recycled water system and potential expansion. The AWT facility has a design capacity of 2.61 MGD, which was compared to future recycled water demands at each Tier addition. The AWT facility capacity analysis is summarized in Table 6-10.

Table 6-10. AWT Production Capacity Analysis

	Average Demand		Max Day Demand (1.8 x AAD)	
	MGD	gpm	MGD	gpm
AWT			2.61	1,813
Existing [1]	0.72	497	1.29	895
MNWD	0.11	78	1.00 [2]	694
Tier I	0.21	146	0.38	267
Tier II	0.20	137	0.35	246
Tier III	0.03	24	0.06	42
Unidentified Future Use	0.10	68	0.18	122
Total	**1.36**	**949**	**3.26**	**2,266**
Surplus/(Deficit)				
Existing + MNWD			**0.32**	
w/Tier I			**(0.005)**	
w/Tier II			**(0.41)**	
Ultimate			**(0.65)**	

Note: Unidentified future use assumes 20% of Tier I-III totals.
[1] Existing SCWD demand less 128 AFY for MNWD
[2] Assumed contracted capacity of 1.0 MGD during maximum day demand

The AWT facility is near capacity to serve existing demands. By utilizing existing reservoir surplus storage, Tier I demands could be served without additional recycled water supply. However, the addition of Tier II demands would result in a 0.4 MGD deficit in recycled water supply under maximum day conditions. Ultimate future demands assuming all three tiers were implemented would require 0.65 MGD above the AWT facility's capacity.

The District is currently participating in regional studies of projects which could provide additional recycled water supply to the system, as discussed earlier in Section 6.1.2. In addition to the Latham Plant, Salt Creek, and Aliso Creek project evaluations underway, it is recommended that the District initiate a study of the feasibility of upgrading the Coastal Plant AWT to increase its rated capacity. Furthermore, the District should review its current contract agreement with MNWD to determine the required supply during maximum day and revisit opportunities to reduce this commitment, in order to free-up supply for the District's future customers. Continued involvement in these studies and assessments will help ensure that the District will have the available capacity to serve future recycled water markets.

The ultimate recycled water demand beyond the AWT facility capacity is relatively small compared to the total recycled water demands. The District could potentially serve future users by supplementing their recycled water supply with potable make-up water. The recycled water Reservoir #2 is located adjacent to potable water Reservoir #5-A. Reservoir #5-A has a 2.0 MG capacity and has historically had water quality issues due to reduced use. The potable water Reservoir could be retrofitted for use as a recycled water Reservoir to store water that would serve the future demands in the recycled water system.

6.6.2 Ultimate Storage and Pumping Analysis

The recycled water system reservoir storage was assessed to determine if storage criteria was met under ultimate demands. Recycled water storage criterion was evaluated at two-thirds of a MDD. The resulting storage assessment is included in Table 6-11.

Table 6-11. Ultimate Recycled Water Reservoir Analysis

Demand	Average Annual Demand (District Only) gpm	Average Annual Demand (District Only) MGD	Max Day Demand (AAD x 1.8) MGD	Required Operational Storage per Design Criteria (0.67 x MDD)	Storage Facility	Capacity	Cumulative Ultimate Surplus/(Deficit)
Low	466	0.67	1.21	0.81 MG	Res #1	2.0 MG[1]	0.89 MG
					Res #2	1.7 MG	
High	341	0.49	0.89	0.59 MG	Joint Res[2]	1.1 MG	1.71 MG
Totals	**805**	**1.16**	**2.10**	**1.39 MG**		**4.0 MG**	**2.61 MG**

(1) Res #1 is not included in Operational storage as it serves as a fore-bay reservoir for PS #1.
(2) SCWD has 1.1 MG capacity of the 3.3 MG shared Joint Reservoir with MNWD

The current reservoirs have sufficient capacity for the ultimate system demands. An additional requirement is that this operational storage can be fully used and replaced on maximum day demand. Hydraulic factors, such as pump capacity, the PCH bottleneck, requested flows from MNWD, and utilization of storage operation, can limit the ability for the District to replace maximum day demands. By replacing the bottleneck and upgrading PS #1, the District should ultimately fully use its operational storage.

A recycled water pump station analysis was performed for ultimate demands and summarized in Table 6-12.

PS #1 must have capacity to serve the Low and High Zone demands plus the MNWD demand out of the Joint Reservoir. The pump station has deficient capacity to meet the maximum day demands of the ultimate system. An additional 800-gpm pump at PS #1 would increase the system capacity to serve future demands.

Table 6-12. Ultimate Recycled Water Pump Station Analysis

Pressure Zone	Pump Station No.	Number of Pumps	Rated Discharge gpm	Total Capacity gpm	Zone Average Annual Demand gpm	Max Day Demand (AADx1.8) gpm	Available PS Capacity(1) gpm	AAD Surplus/ (Deficit) gpm	MDD Surplus/ (Deficit) gpm
Low	1	2	800	1,600	881 (3)	2,143 (5)	1,600	719	(543)
	2(2)	2	1,600						
New Pump	***1***	***1***	***800***	***2,400***			***2,400***	***1,519***	***257***
High(4)	3	2	1,450	2,900	418 (4)	1,309 (5)	1,450	1,032	141

(1) Available PS Capacity includes duty pumps; stand-by or emergency pumps are not included.
(2) PS #2 works in series with PS #1 during peak demands.
(3) Low and High Zone demand + MNWD average demand of 0.11 MGD
(4) High Zone demand + MNWD average demand of 0.11 MGD
(5) Max Day Demand includes MNWD Max Day demand of 1.0 MGD

6.6.3 Ultimate Operational Analysis

The future recycled water system is limited by the total capacity of the AWT facility, transmission system, and pump station capacities. In order for the District to serve new or conversion recycled water customers, system improvements should be completed to provide more capacity within the recycled water system.

Replacing the 10 inch bottleneck in PCH with a 16 inch pipeline provides approximately 550 gpm more maximum day supply to serve existing and future recycled water demands. In order to accommodate this higher flow, an additional 800-gpm pump is required at PS #1. This additional capacity would serve Tier I and II customers under maximum day conditions.

Tier I customers can be served with minimal or relatively minor off-site pipeline improvements. However, it is recommended that a site-specific customer market assessment be conducted to evaluate the feasibility of converting all Tier I customers to recycled water. On-site retrofits would be required for each conversion site.

Tier II customers require off-site pipeline extensions to connect to the existing recycled water system. As shown in Tables 6-6 and 6-7, pipeline extensions range from 750 to 4,000 feet in length.

An evaluation of the AWT facility technology upgrade was discussed in Section 6.1.2. If the AWT facility is upgraded to expand its total capacity, the District should consider upgrading the 9,100 feet of 12 inch pipeline in PCH between the bottleneck and existing 16 inch pipeline to a 16 inch diameter pipeline. This pipeline improvement would provide up to 2,900 gpm of maximum day supply through the Low Zone.

The District is currently participating in discussions involving regional projects and new recycled water sources. These projects were not evaluated as part of this Master Plan but should be considered during the initial design process of any existing recycled water facility improvements.

6.7 Summary of Recommended Improvements

In order for the District to continue to provide existing customers and expand the reliable service of the recycled water system, the following recommended improvements are proposed. As part of any facility design, the District should review and validate the assumptions of this plan to confirm final facility sizes.

Phase I – 5-Year Recycled Water Capacity CIP (2009-2013)

RW-1 – PCH Bottleneck Replacement. Replace approximately 3,100 feet of the existing 10 inch diameter pipeline in the bottleneck in PCH with 16 inch diameter pipeline. Upgrading the bottleneck will decrease headloss within the pipe and provide more capacity within the system.

RW-2 – New 800-gpm pump at PS #1. Upgrade PS #1 with an additional 800-gpm pump to increase capacity to Reservoir #2.

RW-3 – Bypass Valve at PS #2. Install new motor-operated valve at Control (Bypass) Valve to facilitate operation of PS #2.

RW-4 – Customer Market Assessment Study - Tier I Customers. Perform customer market assessment and cost analysis study for all Tier I potential recycled water customers, including site visits.

RW-5 – Participation in Regional Studies. Continue participation in studies and pilot testing of possible AWT at Latham Treatment Plant. Conduct Feasibility Study of upgrade to Coastal Treatment Plant AWT to increase rated capacity.

RW-18 – Recycled Water Retrofit Conversion Design and Construction Tier I. Prepare preliminary design of onsite facilities needed to connect Tier I Potential Recycled Water Customers, including retrofit conversion. Implement Tier I retrofit conversions.

RW-21 – TDS Reduction at AWT. Conduct alternatives study of possible measures to reduce TDS of Coastal Treatment Plant AWT effluent to make it more attractive for irrigation customers.

Phase II – 5-Year Recycled Water Capacity CIP (2014-2018)

RW-6 – Customer Market Assessment Study - Tier II Customers. Perform customer market assessment and cost analysis study for all Tier II potential recycled water customers, including site visits.

RW-7 to RW-14 – Recycled Water Pipeline Extensions. Tier II Pipeline Extensions A through E, Dana Point Harbor, Headlands, and Stonehill.

RW-17 – Prepare conceptual study for Potable Reservoir R-5A conversion to a Recycled Water Reservoir. Prepare Conceptual Feasibility Study for Potable Reservoir 5-A (2.0 MG) conversion to a Recycled Water Reservoir to identify opportunities and constraints. Identify piping requirements and new potable makeup water connection and review benefits of integration into existing recycled system.

RW-19 – Recycled Water Retrofit Conversion Design and Construction Tier II. Prepare preliminary design of onsite facilities needed to connect Tier II Potential Recycled Water Customers, including retrofit conversion. Implement Tier I retrofit conversions.

RW-22 – Replace 12" PCH pipeline with 16" diameter pipeline – Replace 12" pipeline from bottleneck to existing 16" pipe in PCH. Contingent on AWT facility expansion

RW-23 – Stand-by Pump Upgrades at PS #1 and #2. Upgrade recycled Pump Stations #1 and #2 with backup pumps for improved reliability. This project may be necessary should the recycled water system be used for fire protection.

Phase III – 5-Year Recycled Water Capacity CIP (2019-Beyond)

RW-15 – Customer Market Assessment Study - Tier III Customers. Perform customer market assessment and cost analysis study for all Tier III potential recycled water customers, including site visits.

RW-16 – Recycled Water Pipeline Extensions. Tier III Pipeline Extension F, if retrofit conversions are considered to be a viable project, construct pipeline extensions and retrofit conversions.

RW-20 – Recycled Water Retrofit Conversion Design and Construction Tier III. Prepare preliminary design of onsite facilities needed to connect Tier I Potential Recycled Water Customers, including retrofit conversion. Implement Tier I retrofit conversions.

RW-24 – Rebuild PS #1. Rebuild PS #1 to match capabilities of PS #2 to balance and optimize system hydraulics. Matching pump station capabilities also improves efficiency and simplifies operations.

eGRID 9th edition Version 1.0 Year 2010 GHG Annual Output Emission Rates

Annual total output emission rates for greenhouse gases (GHGs) can be used as default factors for estimating GHG emissions from electricity use when developing a carbon footprint or emission inventory. Annual non-baseload output emission rates should not be used for those purposes, but can be used to estimate GHG emissions reductions from reductions in electricity use.

		Annual total output emission rates			Annual non-baseload output emission rates		
eGRID subregion acronym	eGRID subregion name	Carbon dioxide (CO_2) (lb/MWh)	Methane (CH_4) (lb/GWh)	Nitrous oxide (N_2O) (lb/GWh)	Carbon dioxide (CO_2) (lb/MWh)	Methane (CH_4) (lb/GWh)	Nitrous oxide (N_2O) (lb/GWh)
AKGD	ASCC Alaska Grid	1,256.87	26.08	7.18	1,387.37	34.05	6.93
AKMS	ASCC Miscellaneous	448.57	18.74	3.68	1,427.76	59.97	11.80
AZNM	WECC Southwest	1,177.61	19.21	15.72	1,210.44	21.88	9.86
CAMX	WECC California	610.82	28.49	6.03	932.82	35.91	4.55
ERCT	ERCOT All	1,218.17	16.85	14.07	1,181.70	20.12	7.63
FRCC	FRCC All	1,196.71	38.91	13.75	1,277.42	38.73	10.83
HIMS	HICC Miscellaneous	1,330.16	73.98	13.88	1,690.72	104.05	19.12
HIOA	HICC Oahu	1,621.86	99.30	22.41	1,588.23	119.48	20.10
MROE	MRO East	1,610.80	24.29	27.52	1,755.66	31.53	27.99
MROW	MRO West	1,536.36	28.53	26.29	2,054.55	59.86	35.53
NEWE	NPCC New England	722.07	71.76	12.98	1,106.82	61.55	12.07
NWPP	WECC Northwest	842.58	16.05	13.07	1,340.34	41.38	17.84
NYCW	NPCC NYC/Westchester	622.42	23.81	2.80	1,131.63	23.58	2.44
NYLI	NPCC Long Island	1,336.11	81.49	10.28	1,445.94	34.03	3.91
NYUP	NPCC Upstate NY	545.79	16.30	7.24	1,253.77	36.83	13.67
RFCE	RFC East	1,001.72	27.07	15.33	1,562.72	35.93	20.02
RFCM	RFC Michigan	1,629.38	30.46	26.84	1,744.52	32.31	26.00
RFCW	RFC West	1,503.47	18.20	24.75	1,982.87	24.50	31.07
RMPA	WECC Rockies	1,896.74	22.66	29.21	1,808.03	24.56	22.89
SPNO	SPP North	1,799.45	20.81	28.62	1,951.83	25.15	26.90
SPSO	SPP South	1,580.60	23.20	20.85	1,436.29	27.94	12.10
SRMV	SERC Mississippi Valley	1,029.82	20.66	10.76	1,222.40	27.71	6.63
SRMW	SERC Midwest	1,810.83	20.48	29.57	1,964.98	23.93	29.65
SRSO	SERC South	1,354.09	22.82	20.89	1,574.37	26.52	21.49
SRTV	SERC Tennessee Valley	1,389.20	17.70	22.41	1,873.83	24.99	28.88
SRVC	SERC Virginia/Carolina	1,073.65	21.69	17.64	1,624.71	36.42	23.06
U.S.		**1,232.35**	**24.14**	**18.26**	**1,520.20**	**31.27**	**18.34**