Advanced Water Purification Facility Study Report

Executive Summary

The City of San Diego (City) has limited local water sources and relies on importing approximately 85 percent of its water supply. In the past, importing water from the Colorado River and Northern California has been a reliable option, but environmental stresses, court-ordered pumping restrictions in Northern California, and a historic dry period and drought on the Colorado River have reduced the amount of water that can be delivered to San Diego. These circumstances and the possibility of further limitations have intensified the need for new sources of water that are under local control.

As part of the City's effort to provide a local and sustainable water supply, the Water Purification Demonstration Project (Demonstration Project) evaluated the feasibility of indirect potable reuse through reservoir augmentation (IPR/RA) to provide safe and reliable water for San Diego. The Demonstration Project results will help the City to determine if IPR/RA is a feasible option for San Diego, and if the City should move forward with implementation.

One component of the multi-faceted Demonstration Project was the Advanced Water Purification (AWP) Facility Study. The AWP Facility Study included two primary elements: (1) the design, installation, operation, and testing of a one million gallon per day (mgd) Demonstration Facility located at the North City Water Reclamation Plant (North City) and (2) a conceptual design and cost estimate for a potential Full-Scale Facility (18-mgd capacity and 15-mgd annual average purified water production).

The following summarize the key findings of the AWP Facility Study, which are further discussed in this report:

- Over 9,000 water quality tests were performed throughout the testing period that demonstrated that the water purification process can reliably produce purified water that consistently meets all drinking water quality standards and anticipated reuse regulations.
- Beyond the 231 monitored constituents related to existing or anticipated regulations, 127 additional unregulated constituents were monitored (111 when accounting for duplication with regulated constituents), including unregulated constituents identified for monitoring by the U.S. Environmental Protection Agency (EPA) and other constituents and constituents of emerging concern (CECs) identified in the Testing and Monitoring Plan. Of the 111 additional constituents sampled, only six were found to be quantifiably detected in the purified water at any time.
- Sixteen constituents were monitored as potential performance indicators and removals generally exceeded 95 percent by reverse osmosis, and in some cases greater than 99.9 percent, indicating the integrity and performance reliability of the RO process. The advanced oxidation process was shown to further remove or destroy these constituents to below quantifiable levels.
- Water quality goals included nutrients, which are specific to Reservoir Augmentation. The Demonstration Facility produced water that was below the established water quality goals for nutrient removal. This information was used for the Demonstration Project to make conclusions about maintaining reservoir water quality.

- Energy consumption was monitored at the Demonstration Plant. Power costs make up a substantial portion of the operation and maintenance cost (O&M) costs (33 percent). Testing showed that utilizing a two-stage RO configuration equipped with energy recovery devices can reduce the energy consumption by up to 16 percent compared to operating full-scale facilities that use a three-stage configuration without energy recovery.
- The estimated capital cost for an 18-mgd Full-Scale Facility (excluding the purified water pump station and pipeline) is $144,700,000. The estimated annual O&M cost is $8,145,000.
- Almost 3,000 visitors toured the Demonstration Facility during the 13.5 month start up and testing period, supporting the City's goal to educate the public about the Demonstration Project.

ES.1 AWP Facility Study Background

The primary purpose of the City's Demonstration Facility is to demonstrate the feasibility of water purification technologies to produce purified water that can be sent to the San Vicente Reservoir, a raw water reservoir, to blend with existing water supplies. Prior to distribution to City water customers, water from the reservoir is treated at a drinking water treatment plant. To achieve this primary purpose, the following objectives were defined for the Demonstration Facility and the AWP Facility Study:

- Demonstrate the feasibility of an AWP Facility to reliably produce purified water that is consistently in compliance with all drinking water quality standards.
- Implement a monitoring plan for CECs that is tailored to the wastewater received at North City.
- Demonstrate integrity monitoring techniques and performance reliability measures for the treatment equipment.
- Generate data to be able to make conclusions on maintaining reservoir water quality.
- Assess energy consumption and develop energy conservation opportunities.
- Develop recommendations for design and operation of a Full-Scale Facility that assures only safe purified water leaves the plant.
- Develop a cost estimate for a Full-Scale Facility.
- Educate the public about the Demonstration Project through community outreach, informational materials, and AWP Facility tours.

Figure ES-1 represents the IPR/RA concept for the City's potential full-scale project and a schematic of the demonstration-scale project. The figure shows that wastewater, generated at our homes and businesses, is currently treated at North City to recycled water quality standards. The City uses the recycled water for traditional recycled water uses that include irrigation and industrial use. For the Demonstration Project, a portion of this recycled water is directed to the Demonstration Facility where it is treated by membrane filtration, reverse osmosis, and advanced oxidation. Since this is a demonstration project, the purified water is sent to the recycled water system. If the project is approved for full-scale, the purified water would be conveyed to the San Vicente Reservoir, as represented by the dashed arrow. After detention time in the reservoir, the water would be treated at one of the City's drinking water treatment plants before being introduced into the drinking water distribution system to be used in our homes and businesses.

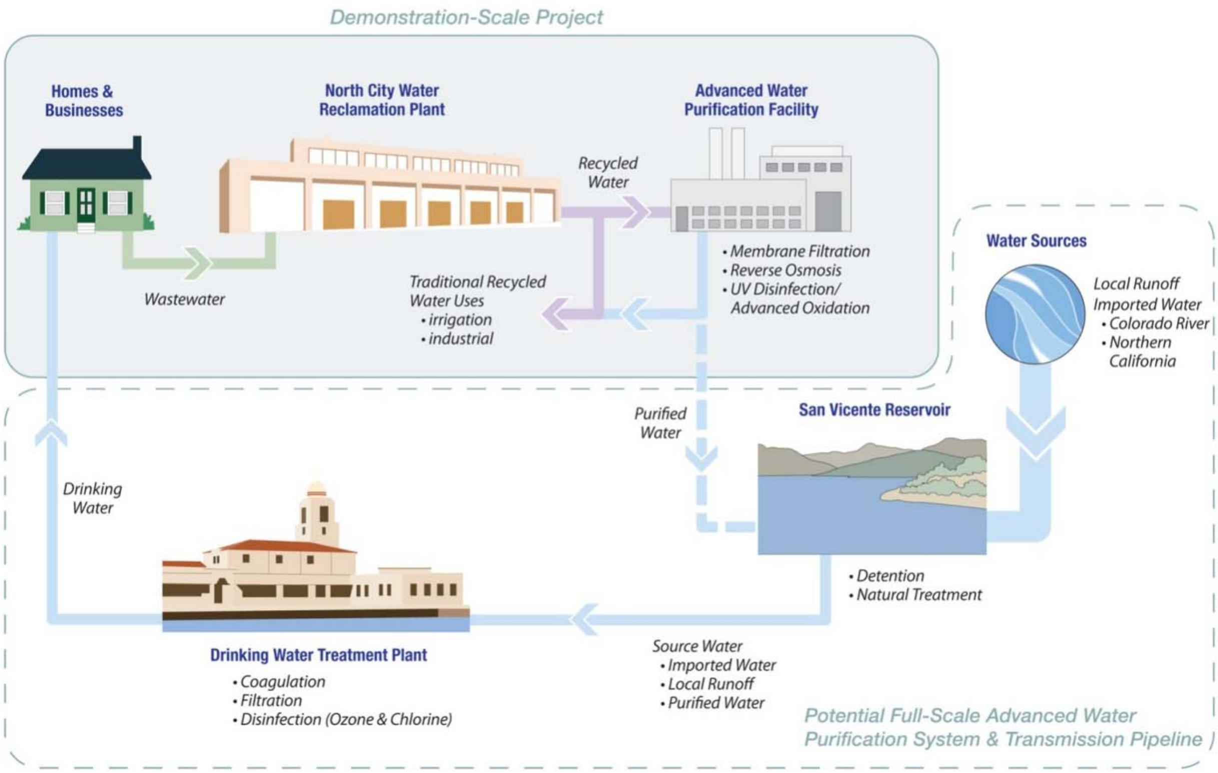

Figure ES-1
Demonstration-Scale and
Potential Full-Scale IPR/RA Projects Schematic

This AWP Facility Study Report summarizes the results and conclusions from the Demonstration Facility, and includes a conceptual design and cost estimate for a Full-Scale Facility. The overall Demonstration Project is summarized in the Demonstration Project Report. Additional discussion on the background of the overall Demonstration Project and the AWP Facility Study is presented in Section 1.

ES.2 Demonstration Facility Description and Observations

This section includes a description of the Demonstration Facility and an overview of the observations made during operations. This information is presented in more detail in Section 2.

ES.2.1 Demonstration Facility Description

The one-mgd Demonstration Facility is located at and treats recycled water produced by North City (tertiary effluent prior to chlorination) using the following water purification processes:

- Membrane filtration: parallel microfiltration (MF) and ultrafiltration (UF) systems
- Reverse osmosis (RO) system with two parallel trains to test two different configurations: two-stage (Train A) and three-stage (Train B)

- Ultraviolet (UV) light disinfection and advanced oxidation system

As shown in Figure ES-1, during the demonstration phase the purified water is returned to the North City recycled water system and is used for irrigation and industrial purposes. Figure ES-2 presents a flow diagram of the Demonstration Facility processes.

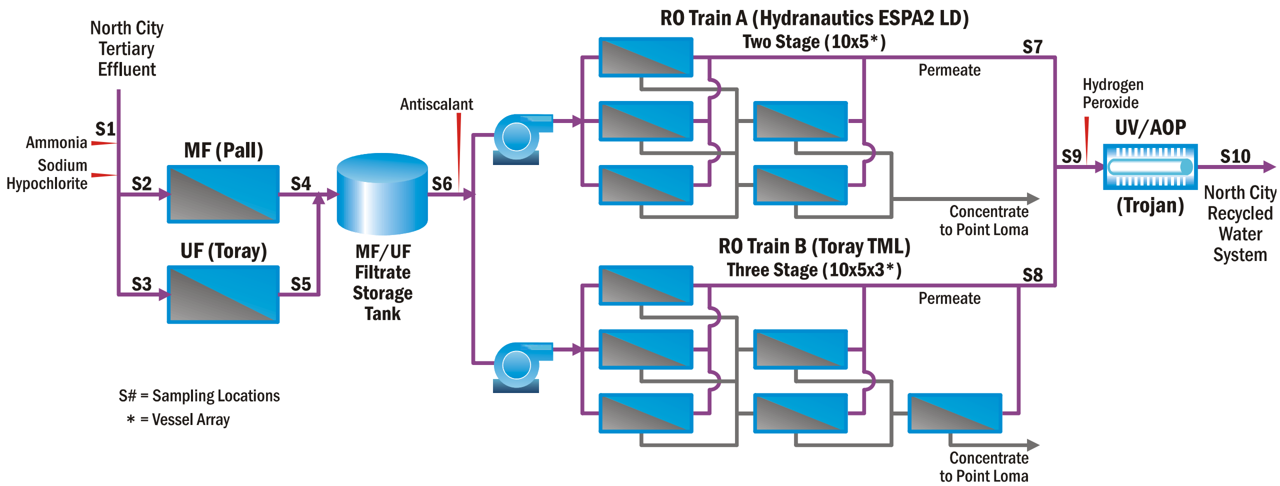

Figure ES-2
Demonstration Facility Processes

The Demonstration Facility was designed, installed, operated, and tested between 2010 and 2012, which is shown graphically in Figure ES-3. The facility start-up period was 1.5 months (mid-June 2011 through the end of July 2011) with full operational testing continuing for one year (August 2011 through July 2012). The results and conclusions from this 13.5-month period are the focus of this report. The Demonstration Facility is continuing to operate after the testing period for tours.

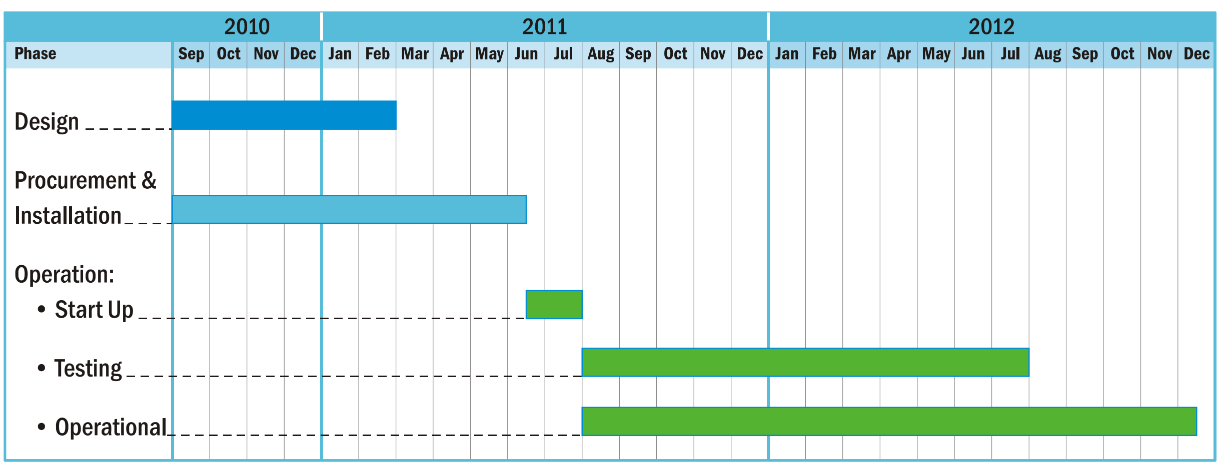

Figure ES-3
Demonstration Facility Schedule

During the testing period of the Demonstration Facility, the purified water and the integrity of the water purification processes were tested to determine the effectiveness of the processes in removing contaminants. Operational data were gathered and analyzed to refine O&M cost estimates for a Full-Scale Facility.

ES.2.2 Demonstration Facility Public Outreach and Tours

One of the objectives of the Demonstration Facility was to support public education and outreach activities to acquaint San Diego residents and stakeholders with the concepts and processes related to IPR/RA. The Demonstration Facility was designed and constructed to facilitate public tours as part of the City's ongoing Education and Outreach program.

The Demonstration Facility tours fulfilled four critical purposes:

- Introduce and graphically illustrate the water purification processes and technologies.
- Show how North City, the potential Full-Scale Facility, the approximately 23-mile pipeline, the San Vicente Reservoir, and the City's drinking water treatment plants work together to provide multiple barriers of protection.
- Communicate information about expert oversight and continuous monitoring of treatment processes to enhance public trust in the reliability of these facilities to provide a safe and clean supply of water.
- Place the water purification process in a water cycle context to reframe mental models about how water is continuously used and reused.

The Demonstration Project Public Education and Outreach program is summarized in the Demonstration Project Report.

ES.2.3 Summary of Operations

The Final Testing and Monitoring Plan (CDM Smith/MWH, 2011) established the testing program and water quality goals for the Demonstration Facility. The Testing and Monitoring Plan was reviewed and commented on by the Demonstration Project's Independent Advisory Panel (IAP), the California Department of Public Health (CDPH), and the San Diego Regional Water Quality Control Board (Regional Board). As a result of the comments received, the Testing and Monitoring Plan was expanded to include sampling for additional water quality parameters and increased frequency and number of samples for constituents that were identified in the draft plan. These comments and a description of how the comments were addressed are included as an appendix to the Testing and Monitoring Plan (the Testing and Monitoring Plan is included as Appendix A to this report). The first quarter testing and monitoring results were presented to the IAP in December 2011. As a result of the comments received, the third and fourth quarter sampling was focused on improving the correlation of indicator compounds for performance and integrity monitoring.

Full-time operation of the Demonstration Facility began on June 16, 2011. The operation and testing results were presented in quarterly reports over the operating period as summarized in Table ES-1. The data collected in previous quarters were included in subsequent reports (e.g., Quarterly Testing Report No. 3 includes data from Quarter 1 [Q1] through Quarter 3 [Q3]) and Quarterly Testing Report No. 4 and this report include all of the operations and testing results gathered over the one year operational testing period.

Table ES-1 Demonstration Facility Testing Periods

Testing Period	Testing Quarter	Operating Period		Report Date
		Test Period Start	Test Period End	
Testing Period 1	Quarter 1 (Q1)	6/16/2011	10/31/2011	December 2011
Testing Period 2	Quarter 2 (Q2)	11/1/2011	2/10/2012	March 2012
Testing Period 3	Quarter 3 (Q3)	2/11/2012	5/14/2012	June 2012
Testing Period 4	Quarter 4 (Q4)	5/15/2012	7/31/2012	September 2012

The following subsections summarize the operations of the membrane filtration, reverse osmosis, and UV disinfection and advanced oxidation systems.

ES.2.3.1 Membrane Filtration

The membrane filtration equipment used at the Demonstration Facility included two parallel 0.63-mgd systems, each treating half the facility flow. One system was a Pall MF system utilizing membranes with a nominal pore size of 0.1 micron, while the second system was an engineered UF system utilizing Toray membranes with a nominal pore size ten times smaller at 0.01 micron. Although both systems were expected to be efficient in removal of suspended solids, bacteria, and protozoa as the first step in the multi-barrier process, previous testing of UF membranes suggested that the smaller pore size might provide better treatment, but with potentially higher energy requirements (Reardon et al, 2006). Therefore, side-by-side testing was performed to determine the feasibility of using either MF or UF for the Full-Scale Facility.

Based on the similarities in operational performance and water quality performance, both MF and UF are suitable systems for membrane filtration in a Full-Scale Facility. For the Full-Scale Facility, pilot testing of the specific MF and UF systems being considered should be conducted to confirm recommended operating conditions and to allow the City to select the membrane filtration system on a lifecycle basis.

The results of the testing showed the following:

- **Recovery:** The MF system operated at a recovery of 93 percent, and the UF system operated at 95 percent recovery.
- **Chemical Cleaning:** Two chemical cleanings were conducted on both the MF and UF systems during Testing Periods 1 through 3, and one was conducted on the UF system during Testing Period 4. These cleanings were effective at restoring the performance to the level observed when the membranes were new.
- **Energy Use:** The side-by-side testing showed that the smaller pore size on the UF membrane did not result in higher pressure/energy requirements. The MF and UF system pressures and resulting energy consumption were essentially equal.
- **Water Quality:** Water quality monitoring of the MF and UF systems showed that both consistently produced water with similar concentrations for key water quality parameters including turbidity, total organic carbon (TOC), and UV 254 absorbance (UV254). Pathogen testing indicted that both MF and UF removed protozoa and bacteria to undetectable

concentrations. The MF was shown to remove more than 99 percent of the measured virus. The UF provided even greater virus removal, which was attributed to its smaller pore size.

ES.2.3.2 Reverse Osmosis

Two reverse osmosis configurations were tested for energy consumption and fouling characteristics: Train A, a two-stage configuration; and Train B, a three-stage configuration. Each RO train was equipped with an energy recovery device designed to transfer energy from the concentrate to the feed of the last stage, reducing the total energy required to treat the water and improving the flow balance between the stages. The different configurations were tested to compare hydraulic conditions and potential operating advantages of one configuration over the other. The two-stage configuration was anticipated to use less energy than the three-stage configuration; however, the three-stage configuration is more commonly used at other AWP facilities.

Two types of membranes were also tested to determine if one had higher removal of targeted constituents compared with the other (focusing primarily on expected differences in total nitrogen rejection).

The results of the testing showed:

- **Recovery:** For the first 8.5 months, both Trains A and B were operated at 80 percent recovery. For the last 3.5 months, both Trains A and B were operated at 85 percent recovery. Testing showed that both the two-stage and three-stage configurations can reliably operate at 85 percent recovery, although the rate of fouling in the final stage was higher for the three-stage configuration than the two-stage configuration.

- **Chemical Cleanings:** Per manufacturers' recommendations, two chemical cleanings were performed for Trains A and B.

- **Energy Use:** The power monitors on the RO system Train A (two-stage) and Train B (three-stage) showed that the three-stage configuration required on average 8 percent more energy than the two-stage configuration. An interstage boost from the energy recovery device resulted in an additional 8 percent energy reduction for Train A and 5 percent for Train B.

- **Water Quality:** The two types of membranes consistently produced water with nearly identical water quality characteristics. Nitrate rejection had been expected to be higher for the Train B membranes than the Train A, however, actual rejection was better than expected for Train A, and lower than expected in Train B, resulting in identical total nitrogen concentrations from both trains.

ES.2.3.3 Ultraviolet Disinfection and Advanced Oxidation

During the testing period, the UV disinfection and advanced oxidation system, which includes ultraviolet light and hydrogen peroxide, was operated to achieve a target 1.2-log (94 percent) removal of N-Nitrosodimethylamine (NDMA) and 0.5-log (68 percent) removal of 1,4-dioxane based on the 2008 CDPH Groundwater Replenishment Reuse Draft Regulations. While the NDMA removal requirement was removed in the most current draft regulations released in November 2011, the permit for the Full-Scale Facility will include NDMA permit limits based on the California Toxics Rule (CTR). Throughout the testing period, the UV disinfection and advanced oxidation process achieved the target NDMA and 1,4-dioxane removal defined in the 2008 and 2011 CDPH Groundwater Replenishment Reuse Draft Regulations.

The average electrical energy per order (EEO) value predicted for NDMA was 0.26 kWh/1000 gallons/log removal; however, when directly measured during the testing period, the EEO was better than projected ranging from 0.18 to 0.21 kWh/1000 gallons/log removal. This EEO is similar to the tested EEO of 0.19 to 0.23 kWh/1000 gallons/log removal for the UV disinfection and advanced oxidation system at the West Basin Municipal Water District's Edward C. Little Water Recycling Facility, a full-scale AWP Facility. The EEO observed for 1, 4-dioxane destruction ranged from 0.5 to 0.7 kWh/1,000 gallons/log removal with a peroxide dose of 2.5 mg/L. This EEO is similar to the EEO of 0.5 kWh/1,000 gallons/log removal reported by the Orange County Water District after initial testing at their Groundwater Replenishment System.

ES.2.4 Water Quality and Regulatory Relevance

This section discusses the water quality monitoring objectives and goals for the Demonstration Project, the regulatory relevance of the water quality monitoring results for regulated constituents, a summary of the water quality monitoring results for other non-regulated constituents, and results of the integrity and reliability monitoring conducted at the Demonstration Facility.

ES.2.4.1 Water Quality Monitoring Objectives and Goals

Water quality tests were performed before and after each water purification process (membrane filtration, RO, and advanced oxidation) and imported aqueduct water. Over 9,000 tests were performed to measure 342 constituents. These constituents included all 231 regulated constituents and 111 unregulated constituents, which are considered to be of potential concern for indirect potable reuse facilities.

The Testing and Monitoring Plan also identified 21 key water quality parameters to serve as a primary focus of the water quality testing, with project specific goals established for each parameter. These key constituents were identified because they can be challenging to remove by the treatment processes employed or because they are widely used parameters to measure performance of water treatment processes. Additionally, nutrients are a specific concern when introducing purified water to the San Vicente Reservoir, and five specific nutrient goals were identified as part of the key water quality parameters. A comparison of these key water quality results and the Demonstration Facility goals is presented in Table ES-2. The table shows that the average concentrations of all constituents measured in the purified water are below the established Demonstration Facility goals.

Table ES-2 Comparison of Key Water Quality Results and Demonstration Goals

Constituent		Units	Laboratory Reporting Level	Purified Water			Water Quality Goal[b]
				Number of Samples	Average Concentration[a]	Maximum Concentration	
Removal Challenge	Bromoform	µg/L	0.5	9	ND	ND	0.5
	Methylene Chloride	µg/L	0.50	9	ND	0.59	4.7
	Trihalomethanes, Total	µg/L	2.0	9	ND	ND	80
	Bromodichloromethane	µg/L	0.5	9	ND	0.7	0.56
	Dibromochloromethane	µg/L	0.5	9	ND	ND	0.5
	Haloacetic Acids (HAA5)	µg/L	1	9	ND	ND	60
	N-Nitrosodiethylamine (NDEA)	ng/L	2	12	ND	4.9	10
	N-Nitrosodimethylamine (NDMA)	ng/L	2	12	ND	5.5	2
	1,4-Dioxane	µg/L	0.5	16	ND	ND	1
	1,2-Dichloroethane	µg/L	0.5	16	ND	ND	0.5
	Boron	mg/L	0.01	28	0.23	0.29	1.0
Common Parameters	Total Organic Carbon[d]	mg/L	0.3	97	ND	ND	0.5
	Total Dissolved Solids	mg/L	10	29	14	19	300
	Chloride	mg/L	0.5	29	3.1	4.3	50
	Sulfate	mg/L	0.5	28	ND	1.1	65
	Turbidity	NTU	-	298	0.05	0.10	0.2
Nutrients	Nitrate as N	mg/L	0.11	74	0.65	1.2	1
	Nitrite as N	mg/L	0.09	71	ND	0.1	1
	Ammonia as N (unionized)	mg/L	varies[c]	71	<0.007[c]	0.027[c]	0.025
	Phosphorus, Total	mg/L	0.01	66	0.02	0.42	0.10
	Nitrogen, Total	mg/L	0.1	74	0.8	1.3	1

Notes:

a. Average concentration calculation assumes non-quantifiable results are half of the laboratory reporting level and non-detectable results are half of the method detection limit.

b. See Testing and Monitoring Plan, Table 5-2 (Appendix A).

c. Unionized values of ammonia were estimated based on EPA's *Aqueous Ammonia Equilibrium – Tabulation of Percent Un-ionized Ammonia (EPA-600/3-79-091)* using average values of temperature and pH measured on-site.

d. Laboratory results showed a single positive result of 1.4 mg/L on January 12, 2012. However, online monitoring for that same day recorded that the TOC was <0.1 mg/L. See Section 2.5.1 for more information on the online monitoring of TOC.

Acronyms:

ND – Not detectable or not quantifiable, shown for all values below laboratory reporting level
mg/L – milligrams per liter, equivalent to parts per million (ppm)
µg/L – micrograms per liter, equivalent to parts per billion (ppb)
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)
NTU – Nephelometric Turbidity Units

ES.2.4.2 Water Quality Monitoring Results – Regulated Constituents

A full-scale IPR/RA project will be subject to requirements put forth by CDPH and the Regional Board. At this time, definitive requirements have not been established. However, results from the water quality monitoring show that the Demonstration Facility produced purified water that reliably met drinking water quality standards. The water also met all water quality requirements of the 2008 and 2011 CDPH Groundwater Replenishment Reuse Draft Regulations.

Water quality monitoring results relative to the current regulations and guidelines are summarized in Table ES-3:

- **Federal and State Drinking Water Maximum Contaminant Levels (MCLs)**
  - **Primary MCLs:** Results from the water quality monitoring show that the purified water consistently meets all primary MCLs established at both the federal and state levels. The federal drinking water MCLs are established by the U.S. Environmental Protection Agency (EPA) and the state MCLs are established by CDPH.
  - **Secondary MCLs:** The purified water met all numerical secondary drinking water MCLs, which are established for non-health based concerns.
  - **Microbial:** Microbial tests were all non-detect in the purified water.
- **CDPH Notification Levels:** During the testing period, the 30 constituents for which CDPH has established Notification Levels were monitored quarterly. Results from the monitoring show that the purified water was consistently below all the Notification Levels established by CDPH. These are advisory levels that require actions on the part of a water agency should concentrations in drinking water exceed the Notification Levels.
- **Groundwater Replenishment Reuse Draft Regulations:** The most recent Groundwater Replenishment Reuse Draft Regulations were issued in November 2011 as part of an informal stakeholder process prior to CDPH initiating a formal rulemaking process to adopt the regulations. Additionally, CDPH is currently developing draft regulations for the use of recycled water for surface water augmentation that have not been released for public review. For the time being, a reasonable assumption is that the CDPH water quality and treatment conditions for a groundwater recharge project that uses 100 percent purified water for groundwater recharge can be used as possible CDPH requirements for this project. Purified water from the Demonstration Facility met all of the water quality requirements in these draft regulations.
- **Regional Board Requirements for the Reservoir:** The San Diego Regional Board's Water Quality Control Plan (Basin Plan) has been established to preserve and enhance water quality and protect the beneficial uses of all regional water bodies. All of the requirements of the Basin Plan have not been defined for the Full-Scale Facility; however, it is expected that the Full-Scale Facility must comply with the Basin Plan numeric and narrative water quality objectives and the CTR criteria for Priority Pollutants. CTR is a federal regulation established to protect both aquatic life and human health by limiting surface water discharges based on 105 priority toxic pollutants. During the testing period, general parameters of the Basin Plan numeric objectives were sampled on a weekly, bi-weekly or monthly basis and Priority Pollutant testing was conducted quarterly. Results from the monitoring show that the purified water produced at the Demonstration Facility consistently met the Basin Plan objectives for those parameters that

have been defined. In addition, requirements have not yet been defined for the CTR, due to uncertainty regarding the applicability of mixing zones. The City will assess the water quality results of the Demonstration Facility and the final permit limits based on the remaining Basin Plan objectives and CTR criteria when they are established.

Table ES-3 Water Quality Monitoring Results of Regulated Constituents

Regulating Authority	Regulation and Guideline Group	Number of Constituents / Parameters	Total Number of Tests[1]	Purified Water Results
Federal and State MCLs	Primary Drinking Water MCL [2]	90	1,781	√ Meets all
	Secondary Drinking Water MCL [3]	18	1,290	√ Meets all
	Microbial [4]	4	1,547	√ Non-Detect
CDPH	CDPH Notification Level [5]	30	716	√ Below all
	CDPH Groundwater Replenishment [6]	142	2,244	√ Meets all
Regional Board	Regional Board Requirements for the Reservoir [7]	143	4,404	√ Meets all
	Total Number of Constituents / Parameters[8]	231[8]	7,523[8]	-----------------

Notes:

[1] The total number of tests represents the approximate number of tests conducted at all sample locations shown in Figure ES-2 and the Imported Raw Aqueduct Water.

[2] Maximum Contaminant Levels and Regulatory Dates for Drinking Water U.S. EPA VS. California November 2008.

[3] California Code of Regulation: Title 22, Division 4, Environmental Health Chapter 15. Domestic Water Quality and Monitoring Regulations Article 16. Secondary Water Standards. Purified water met all Federal and State Secondary MCLs with the exception of pH and corrosivity. The potential Full-Scale Facility would include post treatment to meet these requirements.

[4] EPA Total Coliform Rule (published 29 June 1989/effective 31 December 1990). Samples from the Demonstration Facility were analyzed for the following microbial contaminants: Total coliform, Fecal Coliform, and Viruses (Somatic and Male Specific Bacteriophage).

[5] Drinking Water Notification Levels and Response Levels: An Overview. CDPH Drinking Water Program Last Update: December 14, 2010.

[6] 2011 CDPH Groundwater Replenishment Reuse Draft Regulations. Purified water meets all numerical water quality requirements for indirect potable reuse via groundwater replenishment.

[7] EPA Numeric Criteria for Priority Pollutants Toxic Pollutants for the State of California Rule. Regional Board San Diego Basin Plan Numeric objectives; note, some objectives have not been defined.

[8] Because some constituents and parameters are in multiple regulations / guidelines the total of unique parameters is less than the sum.

ES.2.4.3 Water Quality Monitoring Results – Non-regulated Constituents

Additional non-regulated constituents were monitored at various locations in the purification process and the imported raw aqueduct water. These constituents are grouped into two main categories: those included in the 2012 EPA Unregulated Contaminant Monitoring Rule (UCMR3) and other CECs, such as pharmaceutical compounds and personal care products. In addition, lithium was monitored in the purified water, based on the recommendation of the Demonstration Project Independent Advisory

Panel, and six nitrosamine compounds were monitored beyond the two nitrosamine compounds (NDMA and N-Nitrosodiethylamine [NDEA]) already being tested for in the routine water sampling. All together, 127 non-regulated constituents were evaluated, 111 when accounting for duplication with regulated constituents.

Of the 111 additional non-regulated constituents sampled for at the Demonstration Facility, only six were found to be quantifiably detected in the purified water at any time, including three constituents from the UCMR3 list and three CECs. These six constituents are discussed further in Section 2 of this report. Table ES-4 provides a summary of the six constituents, including average and maximum values measured in both the purified water and imported raw aqueduct water. The following sections present the results for these compounds grouped as UCMR3 constituents and CECs.

Summary of UCMR3 Sampling Results

Results from the testing period show that 27 of the 30 compounds included in the UCMR3 were consistently below quantifiably detectable levels in the purified water. Three constituents, bromochloromethane, hexavalent chromium, and strontium, were quantifiably detected in the purified water. The first two of these constituents can be considered disinfection byproducts and may have been formed at low levels within the treatment processes. The third constituent is a naturally occurring metal used as a dietary supplement and in manufacturing. Additional information on these three constituents is presented in Section 2.4.4.

Summary of CEC Sampling Results

The CEC results in Table ES-4 (the last three constituents shown in the table) are presented in the units of nanogram per liter (ng/L). Analogies commonly used to describe the quantity represented by a concentration of one ng/L are 1 penny in 10 billion dollars or one drop in 20 Olympic-size swimming pools. When assessing low level CEC results such as these it is important to keep in mind that analytical variability and influence of false positive/negative results becomes a more significant issue at such minute levels. Technologies were not available to measure compounds at these low concentrations a decade ago, and there is still considerable debate about the significance of such low measured concentrations.

Results showed the RO and advanced oxidation process are effective at removing the majority of the CECs present in the North City tertiary effluent, and advanced oxidation further reduced the remaining constituents. For constituents found in significant concentrations in the tertiary effluent, the purification process achieved greater than 98 percent removal. Only three CECs were detected at quantifiable concentrations in the purified water. These compounds were iohexal, acesulfame-k, and triclosan. Additional information on these three constituents is discussed in Section 2.4.4.

Drinking Water Equivalent Levels

Since these UCMR3 and CEC constituents do not have regulatory limits, it can be difficult to interpret these water quality results. One method to interpret the results is to compare concentrations to the constituent's Drinking Water Equivalent Level (DWEL) or to an EPA identified Health Reference Level, when such information is available. DWELs and Health Reference Levels both represent an acceptable concentration in drinking water, assuming an average person consumes two liters of water (about 8.5 cups) per day over 70 years. DWELs are developed from tolerable daily intakes (TDIs) or acceptable daily intakes (ADIs), or EPA identified References Doses (RfDs), which all describe a daily dose below which risks to public health are judged to be minimal, assuming repeated daily exposure over a lifetime through consumption of drinking water. DWELs or Health Reference Levels were available for all of the six constituents quantifiably detected in the purified water, with detected values between 18 times and 10 million times lower thant the associated DWEL or Health Reference Level.

Additional information on these six constituents and the potential significance of the measured concentrations are discussed Section 2.4.4.

Table ES-4 Summary of Other Non-regulated Constituents in Purified Water and Imported Raw Aqueduct Water (Detected Constituents of 111 Monitored)

Constituent	Classification/ Common Use	Units	Laboratory Reporting Level	Purified Water			Imported Raw Aqueduct Water		
				Number of Samples	Average Concentration[a]	Maximum Concentration	Number of Samples	Average Concentration[a]	Maximum Concentration
Bromochloromethane	UCMR3 Disinfection byproduct	µg/L	0.06	4	0.23	0.25	4	ND	0.08
Chromium (VI)[b]	UCMR3 Disinfection byproduct, industrial byproduct	µg/L	0.02	4	0.09	0.16	4	0.05	0.05
Strontium	UCMR3 Naturally occurring metal, Dietary Supplement	µg/L	0.3	4	ND	0.37	4	405	610
Acesulfame-K	CEC Sugar Substitute	ng/L	20	9	ND	50	4	343	370
Iohexal	CEC X-ray contrast agent	ng/L	10	9	ND	19	4	43	55
Triclosan	CEC Antibacterial	ng/L	10	9	ND	19	5	ND	ND

Notes:

a. Average concentration calculation assumes non-quantifiable results are half of the laboratory reporting level and non-detectable results are half of the method detection limit.
b. Three Chromium (VI) samples were sent to another lab and all results were below the detection limit of 0.0059 µg/L. The CDPH Detection Limit for purposes of Reporting (DLR) is 1 µg/L.

Acronyms:

ND – Not detectable or not quantifiable, shown for all values below laboratory reporting level
µg/L – micrograms per liter, equivalent to parts per billion (ppb)
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)

ES.2.5 Integrity and Reliability Monitoring

Verifying the integrity and reliability of the water purification processes is critical to assure that only safe water leaves a Full-Scale Facility. To develop recommendations for monitoring at the Full-Scale Facility, the Demonstration Facility processes were evaluated closely. Integrity monitoring was conducted using a mix of direct and indirect methods during operations. In addition, a critical control-point monitoring plan was implemented to identify any changes in performance of the treatment processes that could adversely impact final water quality. Integrity monitoring and critical control point monitoring showed that the equipment remained intact, met the intended treatment performance on a continuous basis, and was reliable throughout the operational period. This evaluation process also made it possible to identify useful procedures for the Full-Scale Facility, as outlined in Section 4.3.

The critical control point monitoring implemented for the Demonstration Facility is summarized in Table ES-5. During the design phase for the Full-Scale Facility, the City would develop a similar on-line monitoring and response plan that provides sufficient features and assurances that any foreseeable malfunction could be promptly identified and appropriate responses applied.

Table ES-5 Summary of Demonstration Facility Critical Control Point Monitoring

Critical Control Point	Critical Limit Parameter	Monitoring Frequency	Alert Limit	Critical Limit	Example Corrective Actions
MF/UF	Pressure Decay	1 per day	Value above baseline that approaches critical limit.	0.4 psi / 5 min based on the maximum decay predicted to achieve 4-log removal Cryptosporidium	Confirm Results. Assess fiber breakage. Isolate/ repair/replace damaged membrane.
RO	TOC, Conductivity	Continuous	Percent change of measured concentration in combined RO permeate	Online permeate conductivity = 150 µS/cm. Online permeate TOC = 100 ppb or greater for five consecutive measurements.	Automatic shutdown (conductivity). Monitor individual RO trains. Verify analyzer accuracy. Conduct vessel probing.
UV	Reactor Power Level	Continuous	System ramps up 100% if 2 to 7 lamps fail or 1 to 3 ballasts fail	0% (8 or more lamp failures or 4 ballast failures)	System alarm. Automatic increase of reactor power to 100% or system shutdown. Check/ replace lamps and/or ballasts.
UV	Hydrogen peroxide dose rate/Continuous Flow Confirmation	1 per day by draw down Continuous flow confirmation	Minimum dose (~22 mL/min.) to provide 3 mg/L peroxide	0 mL/min indicating pump failure or loss of flow confirmation	Check dosing system. Recalibrate pump. Auto switch to standby pump.

Acronyms:

TOC – total organic carbon
mL/min – milliliters per minute
mg/L – milligrams per liter
psi – pounds per square inch
min – minute
µS/cm – microsiemens/centimeter
ppb – parts per billion, equivalent to micrograms per liter (µg/L)

The Demonstration Facility testing also included performance indicator monitoring to determine if any constituents could be used to indicate the treatment efficiency of the RO and advanced oxidation processes. Many of the constituents monitored at the Demonstration Facility were removed by the RO to levels at or below quantifiable limits, demonstrating strong performance of the RO process. Therefore, identifying usable performance indicators to accurately measure advanced oxidation removal was a challenge.

Sixteen constituents were monitored as performance indicators and removal generally exceeded 95 percent within the RO when sufficient quantities were present in the membrane filtration filtrate to calculate such removals. In some cases, greater than 99.9 percent removal was observed.

Surrogate compounds, such as TOC, conductivity, ammonia, monochloramines, and UV 254, may prove to be more reliable as CEC removal performance indicators due to their ease of measurement and their reliable presence in the water downstream of both the RO and advanced oxidation. For the RO process, the average removal results were: TOC = 99.6 percent, conductivity = 99.0 percent, and UV254 = 88.8 percent. For the advanced oxidation process, the average removal results were: UV254 = 68.7 percent and monochloramines = 72.8 percent.

The results of the performance indicator monitoring are summarized in Table ES-6.

Table ES-6 Performance Indicator Monitoring Results

Category	Compound	Units	Average RO Feed	Average RO Perm.	Average UV/AOP	RO Removal	UV/AOP Removal
CEC Potential Indicators	Acesulfame-K	ng/L	33,000	<27	<22	>99.9%	>16.5%
	Amoxicillin	ng/L	220	<6.4	<6.4	>97%	-
	Carbamazepine	ng/L	190	<5	<1.2	>99%	-
	Dilantin	ng/L	120	<13	<13	>88.8%	-
	Diuron	ng/L	77	<1.8	<5	>97.7%	-
	Fluoxetine	ng/L	84	<10	<10	>88%	-
	Lidocaine	ng/L	170	<1.1	<1.1	>99.3%	-
	Lopressor	ng/L	340	<20	<5.1	>97.6%	-
	NDMA	ng/L	3	<2	<0.96	>65.5%	-
	Primidone	ng/L	100	<4.8	<4.8	>95.4%	-
	Sucralose	ng/L	55,000	<100	<42	>99.9%	-
	Sulfamethoxazole	ng/L	950	<2.8	<2.8	>99.7%	-
	TCEP	ng/L	300	<10	<10	>98.3%	-
	TCPP	ng/L	2,000	<100	<100	>97.6%	-
	Triclosan	ng/L	48	<10	<10	>84.1%	-
	Trimethoprim	ng/L	330	<5	<5	>99.1%	-
Online Monitoring Surrogates	Conductivity	µS/cm	1,348	14	--	99.0%	--
	Monochloramine	mg/L	--	3.14	0.85	--	72.8%
	TOC	mg/L	7.2	0.031	--	99.6%	--
	UV254	cm^{-1}	0.158	0.018	0.006	88.8%	68.7%

Notes:

a. For calculating average concentrations, results reported below the laboratory reporting level were considered the value of the laboratory reporting level and for values reported below the method detection limit, the value of the method detection limit was used.

b. Dashes are shown for values that were not measured or could not be calculated.

Acronyms:

mg/L – milligrams per liter, equivalent to parts per million (ppm)
µS/cm – microSiemens per centimeter
cm^{-1} – centimeters to the negative first power
ng/L – nanograms per liter, equivalent to parts per trillion (ppt)

ES.3 Full-Scale Facility Considerations

This section describes design considerations for the Full-Scale Facility that were developed based on the Demonstration Facility operations. Since energy conservation will be a major focus of the Full-Scale Facility, design considerations related to energy conservation are summarized in Section ES.3.1. Other design considerations are summarized in Section ES.3.2. See Section 3 for more information.

ES.3.1 Energy Conservation

Water purification processes are energy intensive and power costs are a substantial part (33 percent) of the annual operations cost for an AWP facility. Therefore, one of the objectives of Demonstration Facility was to understand the power requirements of a Full-Scale Facility and identify potential energy conservation opportunities. These energy conservation opportunities are summarized below.

Membrane Filtration

- **AWP Facility Influent Pumps:** The pumps should be equipped with variable frequency drives making it possible to efficiently ramp up and ramp down pump speed.

- **Membrane Filtration Overall Power Requirements:** The membrane filtration system for the Full-Scale Facility should be selected based on a lifecycle cost evaluation that takes power usage into account. Candidate membrane filtration systems should be pilot tested to gather actual operational data to be used for the lifecycle bid evaluation.

Reverse Osmosis

- **Two-stage RO System:** The power monitors on the RO system Train A (two-stage) and Train B (three-stage) showed that the two-stage configuration required on average 8 percent less energy than the three-stage configuration. A two-stage RO system should be considered to reduce the overall Full-Scale Facility power usage.

- **Energy Recovery Devices:** Energy recovery devices used at the Demonstration Facility were shown to reduce the energy use by 8 percent. Manufacturer's projections were used to estimate the efficiency of the energy recovery devices for the Full-Scale Facility. Based on these projections, energy recovery devices are estimated to reduce energy use by 4 percent to 7 percent over the life of the membranes, which equates to a payback period of less than six years for the future Full-Scale Facility.

UV Disinfection and Advanced Oxidation

- **Electrical Energy per Order**: Multiple UV vessels in series should be considered to improve reactor hydraulics to further reduce the energy requirements. Candidate UV system suppliers should be pilot tested to gather actual operational data from alternative UV systems to be used for the lifecycle bid evaluation.

- **UV Reactor Controls:** The design for the Full-Scale Facility should optimize the UV system to provide effective treatment allowing power to increase only to the extent needed to respond to lamp and/or ballast failure.

ES.3.2 Other Full-Scale Facility Considerations

In addition to energy, additional design considerations for the Full-Scale Facility are summarized in Table ES-7.

Table ES-7 Other Full-Scale Facility Considerations

Design Consideration	Effect
Membrane Filtration System	
Evaluate multiple manufacturers	• Promote competitive bidding • Determine best available equipment
Increase flux rate	• Smaller facility footprint • Reduce capital cost • Increase fouling, operational pressure, and O&M costs
Use of chemically enhanced backwashes	• Decreased clean in place frequency • Increase chemical usage
Reverse Osmosis	
Evaluate multiple manufacturers	• Promote competitive bidding
85 percent recovery	• Maximize water production
Increase flux rate	• Smaller facility footprint • Reduce capital cost • May improve hydraulics and reduce fouling/scaling potential
Add pH suppression capability	• Reduce potential fouling if water quality changes
UV Disinfection and Advanced Oxidation	
Evaluate multiple manufacturers	• Promote competitive bidding • Determine best available equipment
Reduce hydrogen peroxide dose	• Reduce chemical usage

ES.4 Full-Scale Facility Conceptual Design

A conceptual design for the Full-Scale Facility was developed consistent with the water purification processes that were operated at the Demonstration Facility. The Full-Scale Facility conceptual design is described in detail in Section 4. The design consists of the following components:

- AWP Facility influent pump station.
- Membrane filtration (MF or UF) system, which includes pretreatment chemical addition (chloramination for biofouling control) and break tank.
- RO system, which includes RO transfer pumps, cartridge filters, RO feed pumps, RO pre-treatment chemical addition (antiscalant and sulfuric acid for scale control).
- UV disinfection and advanced oxidation using ultraviolet light with hydrogen peroxide.
- Post treatment/stabilization chemical addition (pH and LSI adjustment for corrosion control).
- Purified water pump station and approximately 23-mile pipeline to San Vicente Reservoir (see the Purified Water Conveyance System Final Conceptual Design Report for more information).

The City's Full-Scale Reservoir Augmentation Capacity Analysis Technical Memorandum (RMC, 2011) has defined a capacity for the Full-Scale Facility of 18 mgd, which considers the capacity of North City and the need to continue supplying recycled water to existing and planned customers. Design criteria and preliminary equipment layouts are presented for the 18-mgd capacity Full-Scale Facility in Section 4. The capital cost estimates presented in Section 5 are based on a capacity of 18 mgd, while the O&M cost estimates are based on an annual average production of 15 mgd.

The proposed project site will be located on the property immediately north of North City. Process areas not enclosed in a building will be installed under canopies. A pipe gallery/access tunnel will be provided under Eastgate Mall Road, connecting North City just west of the guard shack to the Full-Scale Facility.

North City treats wastewater flows that would otherwise be treated at the Point Loma Wastewater Treatment Plant (Point Loma). North City can divert flow to Point Loma and go offline any time either by ceasing diversion from the sewer or diverting off-specification water back to the sewer for treatment at Point Loma. The Full-Scale Facility will also have the capability to go offline by ceasing to receive recycled water from North City. Because the Full-Scale Facility has the ability to shut-down at any time, the conceptual facility design includes limited redundancy. The redundancy provided will allow the Full-Scale Facility to continue to operate at capacity when a single unit is offline for maintenance or cleaning.

Instrumentation and automation will be provided to continuously verify conditions are maintained for sustainable operation and effective treatment. The controls system is provided with this electronic monitoring so that if a problem is detected in the system, then the system will automatically shut itself down to prevent water that does not meet the water quality requirements from being introduced into the reservoir. Manual checks will also be made of water produced by individual units within each system to identify operational trends and detect anomalies that require attention. These electronic systems controls and manual procedures, in concert with the critical control point monitoring described in Section ES.2.5, will assure that only safe water leaves the Full-Scale Facility.

ES.5 Estimated Costs

This section summarizes the estimated capital and O&M costs for the Full-Scale Facility, as well as for the Full-Scale Project.

ES.5.1 Estimated Costs for the Full-Scale Facility

The estimated capital costs was prepared based on the conceptual design for an 18-mgd Full-Scale Facility and O&M cost estimates were based on an annual average production of 15 mgd. For the construction cost, Appendix D includes a breakdown of each of the process areas and buildings. The construction cost includes the contractor direct costs plus construction allowances, permits and sales tax.

The O&M cost estimate is based on the preliminary design criteria developed for the Full-Scale Facility (see Section 4) and considers power costs, chemical costs, equipment replacement costs, maintenance costs, and labor costs. The average power demand for the Full-Scale Facility (annual average purified water production of 15 mgd) is approximately 2.1 to 3.1 megawatts, and the estimated total annual power consumption is 18,200,000 to 27,400,000 kilowatt-hours per year (kWh/yr).

The estimated capital and O&M costs for the Full-Scale Facility are presented in Table ES-8 and Table ES-9, respectively. Additional detail is provided in Section 5.

The estimated O&M cost for the Full-Scale Facility was compared to the O&M cost of the Demonstration Facility. The estimated O&M costs for the Full-Scale Facility for most of the unit processes are within 5 to 30 percent of the O&M costs for the Demonstration Facility. The differences are within an appropriate level of contingency, since the Demonstration Facility was operated within the first year of the equipment and membrane life, and many variables are anticipated to change over the course of the facility operation as the membrane filtration and RO membranes age. Additional discussion of the differences between the assumptions for the Full-Scale Facility and the operations data collected at the Demonstration Facility are included in Section 5.

Table ES-8 Estimated Construction Cost for the Full-Scale Facility

Parameter	Capital Cost[2,3]
Construction Costs[4]	
AWP Facility Influent Pump Station	$2,800,000
Site Civil/Yard Piping[5,6]	$5,800,000
Operations, Maintenance, and Administration Building	$1,600,000
Membrane Filtration Break Tank and Pump Station	$4,000,000
Chemical Storage Area #1 (Pre-Treatment Chemical Facility)[7]	$2,400,000
Membrane Filtration Facility[8]	$25,300,000
Reverse Osmosis Facility[9]	$21,300,000
UV Disinfection and Advanced Oxidation System[10]	$9,900,000
Chemical Storage Area #2 (Post-Treatment Chemical Facility)[11]	$2,100,000
Construction Subtotal	**$75,200,000**
Contingency (30% of Construction Total)	$22,600,000
Overhead & Profit	$9,800,000
Insurance & Bond	$2,900,000
Construction Total	***$110,500,000***
Implementation Costs	
Engineering & Pre-Construction (20% of Total Construction Cost)	$22,100,000
Environmental Documentation	$1,000,000
Construction Management (10% of Total Construction Cost)	$11,100,000
Implementation Total	***$34,200,000***
Total Capital Cost (Construction Total + Implementation Total)[12]	**$144,700,000**

Notes:

1) This table presents costs for the Full-Scale AWP Facility only. For costs related to the Purified Water Pump Station and Purified Water Pipeline, refer to Table ES-10 and the Demonstration Project Report.
2) Includes installation costs and indirect costs (project management, field management and support, training, quality assurance and control, project safety, construction allowances, permits, and sales tax).
3) All costs are in February 2012 dollars. The Engineering News Record (ENR) Construction Cost Index is 9267.57 and the ENR Building Cost Index is 5144.49 for February 2012.
4) Construction duration is assumed to be 30 months. Based on a 40 hour work week with no overtime.
5) No rock excavation is assumed to be required. Only nominal dewatering is assumed to be needed. No consideration for contaminated soils or hazardous materials (e.g. asbestos, lead) is included. Site grading, drainage and containment are included with assumptions made based on the aerial photograph.
6) Includes pressure membrane filtration feed pipeline, gravity membrane filtration backwash, pressure RO concentrate pipelines, and chemical feed pipelines.
7) Includes sodium hypochlorite, ammonium hydroxide, sulfuric acid, and antiscalant.
8) Includes citric acid and sodium hydroxide system for membrane filtration chemical cleaning systems.
9) Includes cartridge filters and RO feed pumps.
10) Hydrogen peroxide system is included with the UV disinfection and advanced oxidation system.
11) Includes calcium chloride and sodium hydroxide.

Table ES-9 Estimated Annual O&M Costs for the Full-Scale Facility

Parameter	Annual O&M Cost[1]
Power Costs[2]	
AWP Facility Influent Pump Station	$306,000
Membrane Filtration System	$43,000
Reverse Osmosis System	$1,614,000
UV Disinfection and Advanced Oxidation System	$185,000
Miscellaneous Equipment	$7,000
Buildings	$481,000
Power Costs – Subtotal	***$2,636,000***
Chemical Costs	
Membrane Filtration Pretreatment	$223,000
Reverse Osmosis Pretreatment	$431,000
Hydrogen Peroxide for Advanced Oxidation	$216,000
Post Treatment	$358,000
Membrane Cleaning	$103,000
Chemical Costs – Subtotal	***$1,331,000***
Replacement of Consumables (Equipment Replacement)	
Membrane Filtration Membranes	$441,000
Reverse Osmosis Cartridge Filters and Reverse Osmosis Membranes	$319,000
UV Lamps and Ballasts	$281,000
Replacement of Consumables – Subtotal	***$1,041,000***
Maintenance Costs[3]	***$1,409,000***
Other Costs (Compliance Testing and Security)[4]	***$310,000***
Labor Costs[5]	***$1,418,000***
Total Annual O&M Cost	**$8,145,000**

Notes:

1) All costs are in February 2012 dollars.
2) Power cost is assumed to be $0.12 per kilowatt-hours (kWh).
3) Assumed to be 1.7% of the equipment construction cost based on a review of actual maintenance costs for the Orange County Water District's Groundwater Replenishment System.
4) The annual compliance testing cost is assumed to be $150,000/year. This is based on half of the Demonstration Facility compliance testing cost of $300,000/year.
5) Estimated staffing = 12 personnel plus outside lab allowance, based on information provided by the City. The estimated staffing of 12 personnel was based on assessment of the department wide resources and additional needs to support and integrate this new facility as part of the City's existing treatment facilities. However, it is anticipated that this labor estimate will be updated in the future when the full-scale facility is constructed and the evaluation of new treatment technology provided at that time.
6) This table presents costs for the Full-Scale Facility only. For costs related to the Purified Water Pump Station and Purified Water Pipeline, refer to Table ES-11 and the Demonstration Project Report.

ES.5.2 Estimated Costs for the Full-Scale Project

The estimated costs for the Full-Scale Project incorporate the Full-Scale Facility, Purified Water Pump Station, and the Purified Water Pipeline. Table ES-10 presents the estimated construction costs for the Full-Scale Project, Table ES-11 presents the estimated O&M costs for the Full-Scale Project, and Table ES-12 presents the estimated additional auxiliary program costs to support the Full-Scale Project. The Full-Scale Project and the associated costs are discussed in more detail in the Demonstration Project Report

Table ES-10 Estimated Construction Costs for the Full-Scale Project

Parameter	Capital Cost
Total Full-Scale Facility Capital Cost (Construction Total + Implementation Total)[1]	**$144,700,000**
Purified Water Pipeline System Construction Costs[2]	
Purified Water Pump Station	$8,000,000
Purified Water Pipeline	$114,200,000
Pipeline System Construction Total	***$122,200,000***
Pipeline System Implementation Costs	
Contingency (30% of Construction Total)	$36,700,000
Engineering & Construction Management (30% of Construction Total)[3]	$36,700,000
Environmental Documentation and Mitigation	$24,400,000
Land Acquisition	$4,500,000
Pipeline System Implementation Total	***$102,300,000***
Total Pipeline System Capital Cost (Construction & Implementation)[2]	**$224,500,000**
Total Capital Cost (Full-Scale Facility and Pipeline System)	**$369,200,000**

Notes:

1) Refer to Table ES-8 for a breakdown of the Full-Scale Facility construction costs.
2) From the Demonstration Project Report.
3) Includes costs associated with regulatory compliance and permitting.

Table ES-11 Estimated Annual O&M Costs for the Full-Scale Project

Parameter	Annual O&M Cost[1]
Full-Scale Facility[1]	$8,145,000
Treatment at North City to Support Full-Scale Facility[2]	$3,965,000
Purified Water Pump Station[2,3]	$1,885,000
Purified Water Pipeline[2,4]	$1,500,000
Total Annual O&M Cost	**$15,495,000**

Notes:

1) Refer to Table ES-9 for a breakdown of the Full-Scale Facility O&M costs.
2) From the Demonstration Project Report.
3) Includes power and maintenance.
4) Includes maintenance.

Table ES-12 Estimated Auxiliary Program Costs for the Full-Scale Project[1]

Parameter	Auxiliary Cost
Auxiliary Upfront Cost	
Source Control Program Upfront Cost[2]	$500,000
Auxiliary Annual Cost	
Source Control Program Annual Costs[3]	$50,000
Public Outreach Annual Program Costs[4]	$700,000

Notes:

1) From the Demonstration Project Report.
2) Source control upfront costs include a chemical inventory program and GIS tracking database (approximately $50,000), a pollutant prioritization program to be completed by existing City staff (approximately $50,000 for initial set-up work), and a local limits evaluation for North City (approximately $400,000). For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
3) Source control annual costs include $25,000/yr for annual updates to the chemical inventory program and GIS tracking database, an average of $10,000/yr for periodic updates to the pollutant prioritization program, and $15,000/yr, on average, for updates to the local limits analysis. For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
4) Public outreach annual costs include initial start-up of outreach efforts. Annual public outreach costs will be scaled back following full-scale reservoir augmentation project operations.

ES.6 Conclusions

The primary purpose of the City's Demonstration Facility was to demonstrate the feasibility of water purification technologies to produce purified water for the City to determine the feasibility of a full-scale IPR/RA project. A full-scale project would assist with the City's effort to provide a local and sustainable water supply. To achieve this primary purpose, the following objectives were defined for the Demonstration Facility and the AWP Facility Study:

- Demonstrate the feasibility of an AWP Facility to reliably produce purified water that is consistently in compliance with all drinking water quality standards.
- Implement a monitoring plan for constituents of emerging concern (CECs) that is tailored to the wastewater received at North City.
- Demonstrate integrity monitoring techniques and performance reliability measures for the treatment equipment.
- Generate data to be able to make conclusions on maintaining reservoir water quality.
- Assess energy consumption and develop energy conservation opportunities.
- Develop recommendations for design and operation of a Full-Scale Facility that assures only safe purified water leaves the plant.
- Develop a cost estimate for a Full-Scale Facility.
- Educate the public about the Demonstration Project through community outreach, informational materials, and AWP Facility tours.

The Demonstration Facility and AWP Facility Study met all of these established objectives and the results of this project are supporting the City's pursuit of a full-scale IPR/RA project. Table ES-13 summarizes how the each objective was met.

Table ES-13 Demonstration Facility and AWP Facility Study Objectives and Key Findings

Objectives	Key Findings
Demonstrate the feasibility of an AWP Facility to reliably produce purified water that is consistently in compliance with all drinking water quality standards.	Water quality monitoring throughout the testing period demonstrated that membrane filtration, followed by RO, and UV disinfection and advanced oxidation can reliably produce water that meets or exceeds all of the drinking water requirements and also provides multiple barriers for regulated and unregulated chemical and microbial constituents.
Implement a monitoring plan for constituents of emerging concern (CECs) that is tailored to the wastewater received at North City.	Key constituents and water quality goals for each were identified in the Testing and Monitoring Plan. The average concentration of each constituent measured in the purified water is below the established Demonstration Facility goals.
Demonstrate integrity monitoring techniques and performance reliability measures for the treatment equipment.	Sixteen constituents were monitored as performance indicators, and removal generally exceeded 95 percent in the RO. In some cases, greater than 99.9 percent removal was observed, demonstrating strong performance of the RO process. Five surrogate compounds were also identified. The RO process averaged 99 percent or greater removal for TOC and conductivity and 88.8 percent for UV254. The advanced oxidation process further removed UV254 by 68.7 percent and monochloramines by 72.8 percent.
Generate data to be able to make conclusions on maintaining reservoir water quality.	143 constituents/parameters were monitored based on anticipated Regional Board requirements for the San Vicente Reservoir. The results were used to conclude that the addition of purified water would not impair existing conditions of the San Vicente Reservoir, and could improve nutrient-related water quality issues as further discussed in the Demonstration Project Report.
Assess energy consumption and develop energy conservation opportunities.	Energy consumption was monitored at the Demonstration Plant and, combined with experience from other Full-Scale Plants, energy conservation opportunities for the Full-Scale Facility were recommended. Energy recovery devices tested at the Demonstration Facility were successful in reducing energy consumption and are estimated to reduce energy use at a Full-Scale Facility by 4 to 7 percent over the life of the membranes. Use of a two-stage RO configuration at the Full-Scale Facility instead of a three stage RO configuration will reduce energy consumption by approximately 8 percent, while producing the same quality and quantity of RO permeate.
Develop recommendations for design and operation of a Full-Scale Facility that assures only safe purified water leaves the plant.	Design criteria, purification process layouts, system controls, and monitoring for a Full-Scale Facility were developed to assure that only water that meets all drinking water standards leaves the plant.
Develop a cost estimate for a Full-Scale Facility.	Operational data and observations collected from the Demonstration Facility testing period were used to estimate construction costs and annual operation and maintenance costs for a Full-Scale Facility. For a Full-Scale Facility with 18-mgd capacity with an annual average production of 15 mgd, the estimated capital cost is $144,700,000, and the estimated annual O&M cost is $8,145,000.
Educate the public about the Demonstration Project through community outreach, informational materials, and AWP Facility tours.	Almost 3,000 visitors toured the Demonstration Facility during the 13.5-month start up and testing period.