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The Future of Direct Potable Reuse in California: Overcoming Public Acceptance Barriers

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Acronyms

afy	acre-feet per year
BOD	biological oxygen demand
Cal/EPA	California Environmental Protection Agency
CDPH	California Department of Public Health
CECs	constituents of emerging concern
CRMWD	Colorado River Municipal Water District
DPR	direct potable reuse
GWRS	Groundwater Replenishment System
IPR	indirect potable reuse
MCL	maximum contaminant level
MGD	million gallons per day
MOA	memorandum of agreement
NPDES	National Pollutant Discharge Elimination System
OCWD	Orange County Water District
OCSD	Orange County Sanitation District
PUB	Public Utilities Board
PWS	Public Water System
RWQCB	Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
SWTR	Surface Water Treatment Rule
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency
UV	ultraviolet
WHO	World Health Organization

Abstract

Due to the water shortages, population growth, and competing demands for water in California, the possibility of incorporating direct potable reuse technology in the state's water supply portfolio is being considered by various water resource providers. This paper focuses on public acceptance challenges that may be encountered. By evaluating best practices employed by six different potable water reuse case studies, recommendations for future direct potable reuse projects are developed. It is recommended that future project proponents plan early and conduct public opinion surveys regarding this type of technology, develop and implement public outreach and education plans that include best practices defined in the case study analysis, and develop outreach and education materials that meet the interests of various audiences. Specific practices that should be considered include: educating the public about where existing supply sources come from when describing the need for DPR technology, garnering support from health professionals and local politicians, targeting outreach efforts to groups of people that may be wary of this type of technology, and offering public tours of advanced water purification facilities.

Executive Summary

Introduction and Background

To address water scarcity concerns, communities throughout the world, including the U.S., are beginning to consider potable water reuse technologies as a feasible and sustainable water supply alternative. Potable water reuse involves advanced treatment of wastewater which typically involves microfiltration, reverse osmosis, and ultraviolet processes such that the water quality meets or exceeds state and federal drinking water standards. In general, there are two types of potable water reuse technologies: indirect potable reuse (IPR) and direct potable reuse (DPR). The main difference between the two is that IPR involves placement of advanced treated water in either a groundwater aquifer or surface reservoir (environmental buffer) which serves as a point for blending with traditional water supply sources, whereas DPR does not include an environmental buffer.

While both IPR and DPR technologies benefit local water supplies, DPR technology is considered more cost-effective and more flexible as no environmental buffer is needed. Research has found that directing advanced treated wastewater into a groundwater aquifer or surface reservoir may not actually improve water quality and can expose purified water to potential environmental contaminants (Leverenz et al., 2011). Because DPR technology does not require pumping of product water from a groundwater aquifer or reservoir, this type of technology may be less energy intensive and more cost-effective than IPR.

Despite the benefits of DPR technology, there are three primary concerns that will need to be addressed by DPR project proponents: (1) regulatory considerations, (2) public health concerns, and (3) public acceptance barriers. With respect to regulatory considerations, no regulations have been developed for DPR yet but approvals will be required from the State Water Resources Control Board (SWRCB) and the applicable Regional Water Quality Control Board (RWQCB). Primary public health concerns that will need to be addressed include constituents of concern and constituents of emerging concerns, both of which will need to be minimized to extremely low levels. As DPR technology lacks an environmental buffer, this type of technology will also need to ensure that multiple treatment barriers are in place to address reduction of constituents of concern. Of the three principal concerns, gaining public acceptance is the biggest barrier to DPR project implementation. Without public support, oftentimes projects such as these can fail early in the planning process and therefore plays an important role in DPR project planning.

Research Objective

As public acceptance is a big barrier to DPR project implementation, this research paper focuses on determining the key best practices that should be used for addressing public acceptance barriers by reviewing and assessing potable water reuse case studies. These best practices may facilitate future implementation of DPR projects in California.

Case Study Analysis

Since there are very few DPR projects currently in operation, this paper evaluates both DPR and IPR projects in attempt to better understand how these projects overcame public acceptance challenges. The following case studies were evaluated:

1. Windhoek, Namibia (DPR project)
2. NEWater projects in Singapore (IPR project)
3. South Queensland, Australia (IPR project)
4. Orange County Water District's (OCWD's) Groundwater Replenishment System (IPR project)
5. Colorado River Municipal Water District's (CRMWD's) Big Springs Raw Water Production Facility (DPR project)
6. City of San Diego's San Vicente Reservoir Augmentation Project (IPR project from 1999 and pilot project)

To assess how well each case study overcame public acceptance challenges, each was evaluated against the below-listed best practices. These best practices were developed based on literature review, reports prepared by non-profit water and recycled water organizations, and other publicly available information. Specific best practices include:

1. Clearly define the region's water supply problems.
2. Rename the product water using terminologies related to water quality improvement.
3. Break the connection between the water source and its quality by clearly describing the high quality of the water the treatment processes used to treat recycled water.

4. Clarify that treated water is constantly monitored to ensure high water quality of product water.
5. Develop a public outreach plan that includes stakeholder meetings, public tours, and opportunities for youth.
6. Reach out to groups that may be wary of the project and its technology and gain support from prominent leaders in the community
7. Use consistent terminology that is clear and understandable to the general layperson.
8. Develop a website devoted to the DPR project and take advantage of social media.

Results

Of the six case studies, both the South Queensland and the City of San Diego's 1999 San Vicente Reservoir Augmentation Projects failed. Neither project implemented many of the above-listed best practices. The Southeast Queensland project was planned during a time of drought and seemed to lack sufficient time to plan the project. The San Diego project did not clearly define the project and did not sufficiently notify city council members.

The remaining four case studies were successfully implemented but some projects did a better a job at implementing best practices than others. For example, neither the Namibia DPR project nor the Big Springs DPR project seemed to sufficiently implement best practices #s 3, 4, 5, 6, and 7. The NEWater projects and the OCWD project implemented all eight best practices and seem to have accomplished higher levels of public acceptance than the other case studies.

Recommendations and Conclusions

Given that gaining public acceptance for future DPR projects in California will likely be more challenging than IPR projects, it is recommended that water agencies consider implementing all eight best practices. However, if time and resources are limited, based on the number of best practices that were met or somewhat met by the four successful case studies, it is recommended that the following be prioritized: #s 1, 3, 4, 5, and 6. If time and resources are available, the remaining three practices (#s 2, 7, and 8) should also be implemented. Development of a project website and use of social media, along with practices #s 2 and 7 go hand in hand as a website would provide an opportunity for entities to develop a clear and consistent message about the project.

Based on discussions with staff involved in the OCWD and Big Springs projects, other general recommendations that should be considered by water resource agencies include: conducting public opinion surveys, start the planning process early, and develop and implement a public outreach and education plan that includes recommended best practices. Examples of public outreach and education materials that should be developed include: a fact sheet, information card, frequently asked questions (FAQs), table top displays for community events, and a media kit. Several of these materials can be made easily available on a project website. Additional best practices that should be considered by future project proponents include clearly describing where the applicable region's water supply problems come from and garnering support from health professionals.

In conclusion, it is likely that DPR will someday be part of California's water supply portfolio; therefore, water resource agencies should begin thinking through upcoming challenges. Public acceptance is the biggest hurdle to overcome for DPR projects. As this type of technology has not been implemented in California yet, it is expected that members of the public will generally be more apprehensive about DPR in comparison to IPR. With strategic planning and incorporation of the recommended best practices, hopefully greater public acceptance and a smoother planning process can be achieved by future DPR projects.

1. Introduction

1.1 Water Scarcity and Advancement in Technology

As many Californians and other communities in the southwest are aware, we are in a water crisis and nearing a point at which traditional groundwater and surface water resources may not be sustainable in the long-term unless alternative water supply solutions are explored. With population growth, climate change, increased urbanization, regional droughts, and competing demands for water among various users, pressures on fresh surface water and groundwater resources are ever increasing. Water scarcity is a serious concern in the U.S. and in the last five years, nearly every region in the country has experienced water shortages (USEPA, 2014). In California, the current drought highlights the fact that freshwater is a finite resource, existing water supplies must conserved more efficiently, and alternative water supply solutions should be explored.

To address water scarcity concerns, several municipalities in Texas, California, and other places in the U.S. have acknowledged the need to increase water conservation efforts and develop long-term water supply options that embrace increased water reuse. While increased conservation efforts are certainly important, such efforts can only reduce the demand-supply gap to a limited degree. Thus, many municipalities are investigating other ways to expand their water supply portfolios.

Over the last 50 years, water recycling technologies such as advanced treatment of wastewater (potable water reuse) have advanced and is considered a potentially viable solution to these water supply challenges. This technology is sophisticated enough to achieve water quality that meets drinking water standards and has also been proven to be both more energy efficient and cost-effective than other alternative water supply options like desalination (Poussade et al., 2011).

1.2 Wastewater Reuse: Alternative Solution for Addressing Water Scarcity

Potable water reuse technologies, such as indirect potable reuse (IPR) and direct potable reuse (DPR), may be feasible and sustainable water supply options in arid and/or densely populated regions because they are not rainfall dependent and are capable of achieving high quality recycled water that is compliant with state and federal drinking water standards (Rodriguez et al., 2009). Although wastewater is highly contaminated and if improperly treated can pose a significant risk to public health (Cook et al., 1999), both technologies have advanced over the years and thus far no major public health problems have been encountered by existing potable water reuse projects. To date, several IPR projects have been successfully implemented throughout the world in countries including Singapore and Australia, and throughout the U.S., in Texas and southern California. Currently, the only operating DPR projects are in Windhoek, Namibia and in the Cities of Big Springs and Wichita Falls, Texas (Lawler, 2014).

Of the two potable water reuse technologies, DPR is thought to provide several benefits over IPR technology. This type of technology involves treating wastewater to potable water standards and routing it to the raw water supply system without use of an environmental buffer (Gale, n.d), while IPR requires an environmental buffer (e.g., a reservoir or groundwater aquifer). DPR is also thought to be more energy efficient than IPR as the cost associated with pumping water from an environmental buffer is avoided.

1.2.1 Barriers to DPR Implementation

Regardless of the benefits offered by DPR, U.S. communities have been slow at implementing this alternative water supply technology for the primary reasons: concern for human health risks, lack of supportive state or federal regulations, and public acceptance and perception issues.

Of these barriers, one of the biggest challenges to DPR projects are expanding the perceived role of water reuse and gaining acceptance from the public. In a way, water resource agencies need to market or sell the idea that water reuse is not just a method for conserving and treating water but it is a method of recovering important resources like water and energy (McClelland et al., 2012). While people generally favor water reuse for non-potable uses like irrigation and industrial purposes, as the probability of human contact increases, the public’s support for potable water reuse generally declines. The negative branding of these projects as “toilet to tap” has further created community anxiety and strong public and political opposition, which can prevent DPR projects from moving forward (Gunderson, 2011).

Although regulatory concerns and public health risks are unique to the public acceptance challenges, all three are inextricably linked. Perhaps once the public understands that regulations are in place to ensure human health risks are low, public acceptance will increase. Vice versa, as public perceptions and acceptance of DPR technology increase, regulatory agencies may be pressed to pass regulations for this alternative water supply technology.

1.3 Research Objectives

This paper summarizes the key concerns related to DPR use and further explores public acceptance challenges through review and assessment of potable water reuse case studies. Based on review of these case studies, best practices and recommendations related to public acceptance are developed. These best practices may facilitate future implementation of DPR technology in California.

1.4 Organization of this Research Paper

This paper is organized in the following manner. Chapter 2 explains recycled water and the differences between IPR and DPR technologies. This chapter will also describe in more detail the primary benefits of DPR. Chapter 3 summarizes the history of water recycling in California, the need for expanding water reuse and the potential applications of DPR in California. Chapter 4 describes the key challenges to DPR in the following categories: regulatory considerations, human health risks, and public acceptance. Chapter 5 establishes best practices for evaluating potable water reuse case studies, and includes a description and brief assessment of six case studies. Chapter 6 summarizes the results of the case study analysis, and discusses the key challenges and methods used for overcoming some of these public acceptance barriers. Chapter 6 also includes conclusions and lessons learned from the case studies. Chapter 7 provides recommendations for the future development of DPR projects in California.

2. Overview of Water Reuse, IPR, and DPR

2.1 Definitions

This section provides a brief history and overview of water reuse and includes definitions of IPR and DPR as they are used throughout this document.

2.1.1 History of Water Reuse and Definitions

In the mid-19th century, wastewater collection systems were used to divert household waste away from residences to nearby waterways. Over time and as illnesses spread, people began to understand the relationship between the pathogens in the water to such illnesses. In 1913, engineers developed solutions such as chlorine disinfection and activated sludge processes to treat wastewater. In the early 1930s, reclaimed water was used to irrigate Golden Gate Park in San Francisco and by the 1960s, reclaimed water was largely used for landscape irrigation purposes. It was not until then that planned urban water reuse systems were developed to address the rapid urbanization throughout California, Colorado, and Florida (Levine et al., 2007).

In 1968, the first DPR project was constructed and operating in Windhoek, Namibia. Around that same time in the U.S., the Clean Water Act was passed in 1972, which established pollution control programs that set wastewater standards for the industry and also helped fund construction of new wastewater treatment plants (USEPA, 2014a). Passage of this act and its subsequent amendments led to substantial water quality improvements of surface water and construction of centralized wastewater treatment plants that you see today in the U.S. Treated wastewater is typically discharged into adjacent water bodies such as rivers or the ocean. In some places like the Mississippi River, where wastewater gets discharged to rivers and downstream users rely on river water for drinking purposes, those downstream users are actually recycling wastewater. This method of recycling is referred to as unplanned IPR. This concept is important to bear in mind when comparing unplanned IPR to the concept of planned potable water reuse.

This paper addresses two types of planned potable water reuse technologies (IPR and DPR) but before delving into those topics, it is important to understand the standard wastewater treatment process. Table 1 summarizes the general wastewater treatment scheme, which generally includes three levels of treatment: primary, secondary, and tertiary level treatment. Not all wastewater treatment plants have the capability of treating water to a tertiary level but for potable water reuse systems, wastewater must undergo tertiary treatment prior to advanced treatment.

Table 1. Wastewater Treatment Processes

Process	Description
Primary Treatment	Typically the first phase of wastewater treatment, this phase includes removal of solid objects and gross, suspending solids from incoming sewage. Screens, settling tanks, and/or skimming devices are used. Biological oxygen demand (BOD) is reduced 20-30% and total suspended solids is reduced by 50-60%.
Secondary Treatment	Includes removal of biodegradable organic substances and suspended solids, with or without nutrient removal. Microbes consume organic matter, which convert it to carbon dioxide, water, and energy. Suspended solids are then removed through use of settling tanks.
Tertiary Treatment	Although not all wastewater treatment plants include tertiary treatment, this level of treatment commonly uses filtration to extract microscopic particles from wastewater. Tertiary treatment can remove up to more than 99% of the contaminants in wastewater.
Disinfection	This is the last step in the tertiary treatment process. Sodium hypochlorite or chlorine is added to the treated wastewater to destroy disease-causing organisms. UV light is an alternative method of disinfection.
Advanced treatment	Removal of residual trace constituents following treatment by micro- and ultrafiltration, with or without demineralization, as required for specific water reuse applications.

Sources: Vetiver.org; WorldBank, 2014; City of San Diego, 2014; Tchobanoglous et al., 2011.

Table 2 summarizes terms frequently used throughout this paper. To distinguish the difference between applications of wastewater reuse, it is first important to understand that potable water is not required for all uses. For instance, non-potable water can be used for landscaping and irrigation. Application of non-potable reclaimed water or recycled water must be delivered via a different distribution system referred as "purple pipes." In California, the term "recycled water" is commonly used and the term "water reuse" is more widely used across other regions. California Water Code define recycled water as water that "as a result of treatment of waste, is suitable for a direct beneficial use or controlled use that would not otherwise occur." For the purpose of this paper, both terms are used interchangeably and are defined as treated wastewater for beneficial uses like landscaping, agricultural irrigation, vehicle washing, industrial cooling, and wetlands and wildlife habitat.

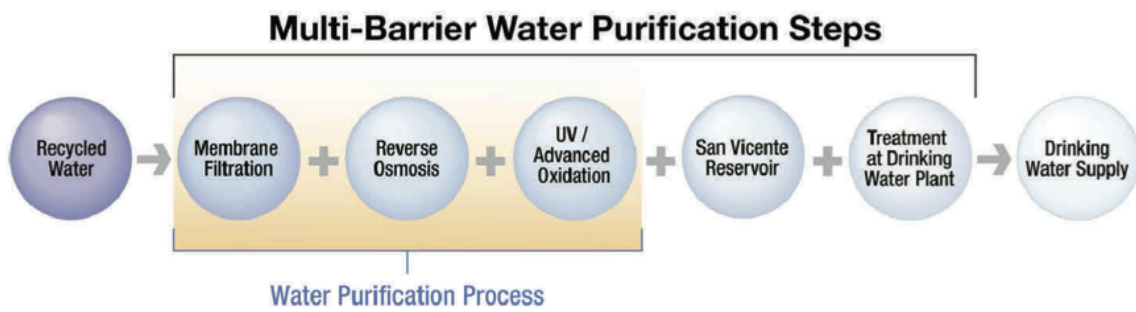
Table 2. Terminology Used Throughout Paper

Term	Definition
Effluent	"Cleaned" wastewater that is released from a treatment plant (typically gets directed to surface water body).
Environmental buffer	A natural water body such as a lake, river, or reservoir that serves as a physical separation between purified water, a water recycling facility, and a typical water treatment plant. An aquifer acts as the environmental buffer for groundwater replenishment projects.
Direct potable reuse (DPR)	Introducing advanced treated recycled water directly into a potable drinking water system either downstream or upstream of a water treatment plant. Other DPR schemes are described in Section 2.1.3, below.
Indirect potable reuse (IPR)	Supplementing a drinking water source with purified recycled water followed by an environmental buffer and treatment at a normal water treatment plant.
Retention time	In IPR systems, retention time is the interval between completion of the water purification phase and redirecting that water to the distribution system. Retention time allows any remaining impurities to be broken down by physical processes (UV light) or biological processes.
Reclaimed Water	The product of wastewater treated to a tertiary level.

Sources: Crook, 2010, and City of San Diego, 2014.

2.1.2 Indirect Potable Reuse (IPR)

In IPR, wastewater treated to a tertiary level undergoes further treatment at an advanced treatment facility and then gets discharged to either a groundwater aquifer/well or surface water reservoir for a certain amount of time. This water is subsequently treated at a normal water treatment plant and directed to the water supply system. Under both scenarios, the aquifer and reservoir serve as an environmental buffer, which is thought to improve the quality of the added wastewater. An IPR scheme for San Diego's Water Purification Project is presented in Figure 1 below.



Source: City of San Diego, 2014.

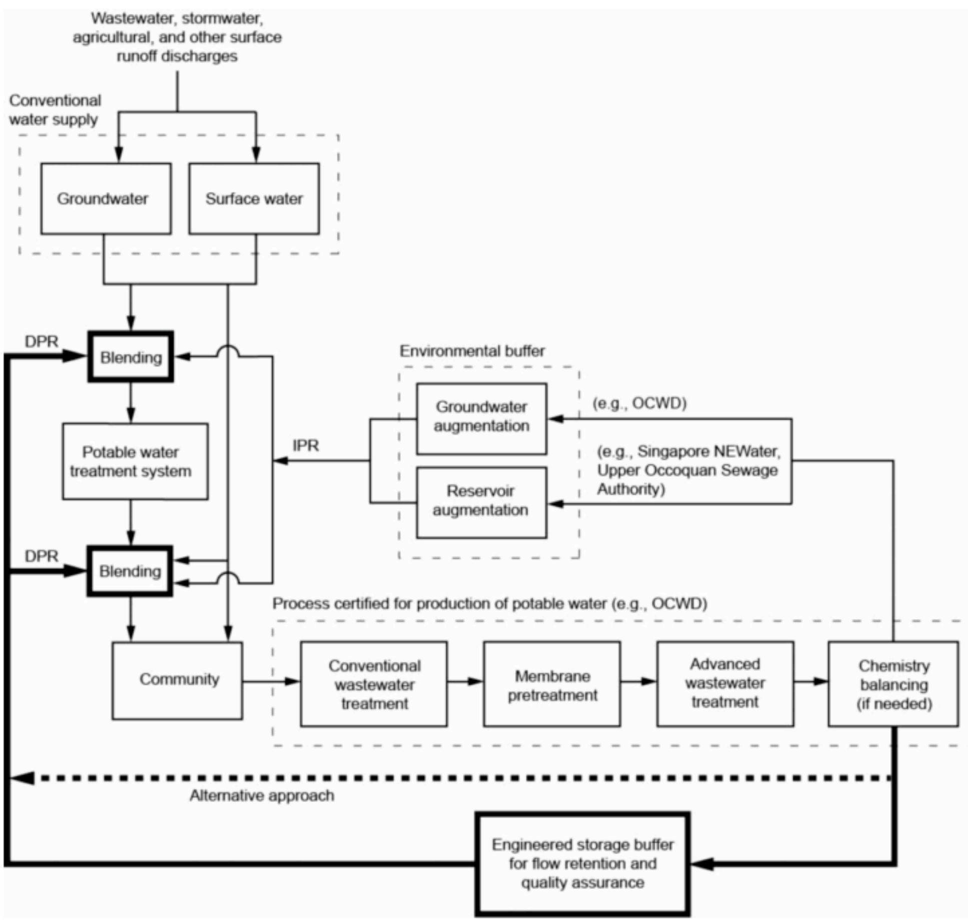
Figure 1. IPR Water Purification Scheme for City of San Diego's Water Purification Project

At the time IPR technology was first introduced, the quality of water was not as high as it is today and placement of treated wastewater in an environmental buffer was thought to improve the water quality. Additionally, the buffer and retention time served as mechanisms that minimized the "yuck factor" associated with the water source and thereby was viewed more favorably by the public as it provided time to fix any issues detected in the water (Leverenz et al. 2011).

In California, the California Department of Public Health (CDPH) adopted regulations in June 2014 for groundwater recharge of recycled water but has not yet adopted regulations for surface water augmentation of recycled water. According to the State's Water Code Section 13562, regulations for surface water augmentation of recycled water are anticipated to be approved by the end of December 2016.

2.1.3 Direct Potable Reuse (DPR)

Although there seem to be multiple definitions of DPR, in this report, DPR is simply defined as purified recycled water that is directed into a potable water distribution system but can be altered such that the treated wastewater is blended with traditional groundwater and surface water supplies. Unlike IPR, DPR does not involve use of an environmental buffer. Rather, two main DPR scenarios may be considered (see Figure 2). Under one scenario, advanced treated wastewater is placed in an engineered storage buffer and can either be mixed with the main water supply source prior to water treatment or be mixed with already treated drinking water. Under the second scenario, purified water is blended with either of the two previously mentioned water sources (without an engineered storage buffer) (Leverenz et al., 2011). The flow diagram in Figure 2 also compares the IPR treatment process.



Source: Leverenz et al., 2011.

Figure 2. Alternative DPR Flow Diagram

2.2 Benefits of DPR

With recent advancements in DPR technologies, DPR is becoming a more appealing alternative to developing new water supply infrastructure in areas where dependable water supplies are diminishing. The following section describes the various benefits of DPR. In many cases both IPR and DPR offer the same benefits but in other cases, DPR has benefits over IPR technologies.

2.2.1 DPR vs. IPR

Many water treatment experts argue that because DPR technologies have proven to consistently generate purified water that is compliant with all drinking water standards, there is no need for an environmental buffer. An environmental buffer was believed to provide a level of advanced treatment in earlier IPR projects when the quality of product water was not as high as it is today. The buffer serves as a loss of identity and an extra level of safety. The retention time of the water stored in an environmental buffer was thought to help correct any issues in the event that any water impurities were found. Since the early 1960s, when IPR was first applied in Los Angeles County, DPR technologies have advanced such that the need for an environmental buffer is eliminated. In fact, when water undergoes advanced treatment, directing this water into a groundwater aquifer or surface reservoir may not actually improve water quality and can actually result in exposure of high quality water to potential environmental contaminants (Leverenz et al. 2011). Nonetheless, given that there are no regulations governing DPR, regulatory agencies still must be convinced that DPR is in fact a safe and reliable water supply option.

2.2.2 Benefits to Public Water Supply

As previously described, both DPR and IPR are thought to help supplement water supply systems in arid regions of the U.S. As urban areas continue to grow and the demand for agricultural resources remains, demands for local and regional water supplies (particularly groundwater) will continue to increase. In California, groundwater makes up 30 to 46% of the State’s general water supply (DWR, 2014) and provides much more during drought years. With this year’s drought, it is expected that California farmers and cities will have pumped over 20 million acre-feet from aquifers. Overdraft of the state’s groundwater basins and land subsidence are serious problems throughout California’s Central Valley and in some coastal and southern California areas.

DPR and IPR are thought to ease pressure on groundwater supplies, especially during times of drought. Since water demands of cities are greater than its wastewater discharge volumes, DPR and IPR sources would not serve as the only water supply sources. In most cases for DPR projects, local sources would be combined with DPR water prior to distributing to a city's water supply system.

2.2.3 Benefits to Agriculture

Application of DPR or IPR for urban uses is expected to benefit water demands for food production. California's current population is 38.3 million (U.S. Census, 2014). By 2049, its population will surpass 50 million, and by 2060 it will reach approximately 52.7 million (California Department of Finance, 2013). As our state population increases, so too will our demand for food crops, animal, and dairy products, resources that rely on substantial amounts of water. Beef, for example, requires 12,000 gallons of water per pound and soybeans require 240 gallons of water per pound (Schroeder et al., 2012; Pimentel and Pimentel, 2003). If urban communities incorporate DPR or IPR to their water supply system, local water resources that would have otherwise supported urban uses could be allocated for agricultural uses.

2.2.4 Benefits to Environment

Similarly, application of potable water reuse technology in urban areas could help reduce environmental impacts in several ways. For instance, use of IPR or DPR would reduce surface water diversions, allowing more water for downstream users and subsequently improved downstream water quality. Application of potable water reuse would also improve downstream water quality, as the volume of wastewater effluent flowing to receiving water bodies would be reduced. Collectively, reduced water diversions and a reduction in discharges of wastewater effluent would improve downstream water quality, and ultimately benefit aquatic plants and animals that also rely on surface water supplies (Anderson, 2003). Both technologies would also eliminate or reduce water importation to urban areas through inter-basin transfers and construction of other water storage and supply infrastructure, which often result in a multitude of environmental effects on biological resources (Schroeder et al., 2012).

2.2.5 Energy and Cost-effectiveness of DPR

Both DPR and IPR are thought to be more cost-effective than other water distribution methods that entail pumping water across long distances. Incorporation of potable water reuse in communities such as southern California could result in substantial energy savings associated with the pumping of water from northern California to southern California. According to one study that compared energy usage amongst four different water supply sources (including DPR), the energy required to provide 1 acre-foot of water to Orange County would be: approximately 3,700 kilowatt-hours (kWh) through ocean desalination, 3,500 kWh via the State Water Project, and 2,500 kWh via the Colorado River. This same study found that application of DPR in Orange County would require between 800 and 1,500 kWh, which in comparison to the three other sources, represents a substantial reduction in the amount of energy used due to the unnecessary need for pumping of water (Tchobanoglous et al., 2011).

DPR is also thought to be less energy intensive and more cost-effective than IPR technologies. DPR avoids the pumping costs associated with pumping product water blended with groundwater supplies, which is required for an IPR scheme. For DPR projects, the product water can be blended with raw water supplies (or not) and then directed to a water treatment plant or immediately to the drinking water distribution system. Furthermore, DPR systems prove more flexibility than IPR systems as they do not require an underground or surface environmental buffer.

3. Opportunities for DPR in California

3.1 Water Reuse in California

Water reuse in California is not a new concept and, along with conservation and efficiency efforts, is considered an essential drought-proof element of the state’s water supply (Gleick et al., 2003). In the late 1800s, wastewater was for crop irrigation. Golden Gate Park in San Francisco was once watered with untreated wastewater until odor complaints put an end to this use (Sangree, 2014). In the 1960s, water agencies such as Orange County Water District used highly treated municipal wastewater to augment groundwater basins near the coast to prevent seawater intrusion. Over the years, use of recycled water in California has expanded. One survey conducted in the late 1970s indicated that California was using approximately 175,000 acre-feet per year (afy) of reclaimed water for agriculture. In 2009, Californians used approximately 669,000 acre-feet (Sangree, 2014).

3.2 Need for Expanding Water Reuse in California

Given the current drought and the many challenges in the Bay-Delta ecosystem, more and more Californians recognize the need to expand water reuse. In 2009, this need was reflected through the State Water Resources Control Board's (SWRCB's) adoption of an aggressive Recycled Water Policy. The Recycled Water Policy aims to increase recycled water usage above 2002 levels by 1 million afy by 2020 and by 2 million afy by 2030. The policy also includes the goal to substitute recycled water for potable water to the extent possible by 2030 (SWRCB, 2009). While this policy does not specifically address DPR, it includes permitting requirements that are meant to fast-track implementation of most water recycling projects in California. Former Governor Schwarzenegger instructed state agencies including the SWRCB, CDPH, and others, to draft a plan that reduces per capita urban water use by 20% in urban areas by the year 2020. In addition to expanding water conservation, this plan also calls for expanding use of recycled water as a way to reduce use of drinking water supplies (DWR et al., 2010). Consistent with this policy, and as part of the state's drought relief measures, the state set aside $200 million in grants to help initiate recycled water programs and reduced interest rates on $800 million more in loans (Sangree, 2014).

3.3 Potential Future of DPR in California

As discussed in Section 2.2, because of the benefits related to DPR, some communities in California are looking to DPR as a potential solution to addressing water supply needs. In response to the increased interest in DPR, in 2010, the Governor signed into law Senate Bill 918. Not only does this bill mandate that CDPH adopt water recycling criteria for IPR for groundwater recharge by 2013, it also requires them to research the feasibility of drafting regulatory criteria for DPR by December 2016 (Tchobanoglous et al., 2011).

Two communities in southern California have either implemented or are planning to implement IPR projects and DPR may also soon be part of California's water supply. For example, the City of San Diego recently completed a pilot project, which confirmed that San Diego can use advanced wastewater treatment technology to provide a local and safe drinking water supply for San Diego. As a result, the City of San Diego is now launching a 20-year program that involves construction of a fully operational advanced water purification facility to eventually produce 83 million gallons per day (MGD) by 2035 (City of San Diego, 2014). This program may include both IPR and DPR practices.

In the San Francisco Bay Area, the City of San Jose and the Santa Clara Valley Water District recently constructed a new 8 MGD advanced water purification facility that takes treated wastewater and purifies it using three processes (microfiltration, reverse osmosis and ultraviolet [UV] light). This water is subsequently blended with recycled water produced at the nearby wastewater facility, enabling enhancement of water quality and expansion of water recycling in the South Bay. Eventually, the facility may be used to produce water that can be used for other purposes such as drinking water but no decision to do so would be made until an extensive public engagement process has been completed (SCVWD, 2014).

As summarized above, IPR is already being used in southern California and eventually DPR technologies will likely have a role in the state's water supply. Before such technologies can be incorporated, several concerns and issues related to DPR need to be addressed.

4. Primary Concerns Related to DPR in California

4.1 Public Health Concerns and Technical Challenges Associated with DPR

One of the main barriers to DPR relates to the public health concerns associated with this practice. While there is limited experience with DPR (there are only three DPR projects in the world), in the last 30 years, epidemiological, animal testing, and toxicological health effects studies have been performed on the product water treated at IPR facilities and at DPR pilot facilities to evaluate the health effects of potable water reuse (Rodriguez et al., 2009). Thus far, none of the analyses have shown that water produced at these facilities would present any more health risks than those from normal drinking water supplies. However, the data from such epidemiological and toxicological health effects studies are still considered sparse due to the limited nature of the methods used for the analyses, which preclude extrapolation of these results to potable water reuse projects (Crook, 2010). The principal public health concerns and technical challenges associated with DPR are broken down into three categories: constituents of concern, compensation for the lack of an environmental buffer, and the potential need for multiple barriers to ensure adequate health protection.

4.1.2 Constituents of Concern

Constituents of concern for DPR include chemicals and microbial pathogens that may cause health hazards. Chemical contaminants include pharmaceutically active compounds, ingredients in personal care products, heavy metals, and endocrine disrupting compounds. Microbial pathogens consist of viruses, bacteria, and parasites. Because municipal wastewater contains a host of chemical contaminants and microbial pathogens, DPR projects would need to demonstrate that these constituents of concern could be minimized to incredibly low levels. In addition, while water quality scientists and engineers state that best available technology for advanced wastewater treatment may consistently reduce constituents of concern, monitoring will be necessary to assure that the product water is reliably "safe" for consumption.

Constituents of emerging concern (CECs) are increasingly becoming a concern in drinking water systems including DPR water. CECs are contaminants that have been recently found and are unregulated, which means that they are not subject to monitoring, removal methods, and concentration standards. Examples of CECs include personal care products, pharmaceuticals, disinfection byproducts, and other organic chemicals (ACWA, 2014). CECs are present in wastewater at high concentrations and are also found in natural water sources. Due to the limited scientific knowledge about CECs and their effects on humans, there is currently a lack of regulations for CECs, which poses a challenge for both wastewater treatment and potable water reuse. The SWRCB's Recycled Water Policy (described in Section 3.2) addresses this issue by stating that regulations for recycled water shall be based on the best available peer-reviewed science and that the SWRCB shall pull together a "blue-ribbon" advisory panel to direct future regulatory actions regarding CECs (SWRCB, 2009). Addressing CECs in both the wastewater treatment and potable water reuse industries will continue to be an issue for regulators. As more information is known about CECs, regulations may not adequately address this problem.

4.1.3 Compensation for Loss of an Environmental Buffer and Consideration of Multiple Barriers

Although water reuse treatment processes have successfully shown that concentrations of constituents of concern can be reduced to suitable levels, the removal of unknown constituents is still somewhat unknown. Given that regulatory agencies recently accepted the idea of an environmental buffer for IPR projects as a method that provides additional improvements to the quality of recycled water and provides time for remedial action, DPR proponents will likely need to develop a method for compensating for the loss of an environmental buffer.

To satisfy potential concerns of SWRCB, even more robust multiple treatment barriers will likely be necessary. Multiple barriers are thought to prevent chemical constituents and microbial pathogens from passing through to the water supply system and are already required in the design and operation of IPR projects by SWRCB (e.g., the environmental buffer). Examples of multiple barriers include: source control programs that preclude constituents of concern from entering wastewater collection systems, monitoring of constituents at several points of treatment, a mixture of treatment processes in which each process addresses reduction of a particular constituent, and design and operational measures that detect any abnormalities and allows for corrective action (Crook, 2010).

4.2 Regulatory Framework

Thus far, there are no regulations for DPR in California and the method has not been accepted by regulatory agencies due to a shortage of information related to public health protection. Since the 1960s when DPR was first considered, treatment technology and monitoring methodologies have advanced and may soon be a suitable supply option. Two primary regulatory agencies that would be involved in the DPR approval process include the SWRCB and the applicable Regional Water Quality Control Board (RWQCB). The below sub-sections summarize existing regulations and agencies that would be involved in the DPR project approval process in California.

4.2.1 Clean Water Act vs. Safe Drinking Water Act

This section provides an overview of the federal Clean Water Act and Safe Drinking Water Act, both regulations that govern the quality of water. While neither regulation directly applies to potable water reuse, both require consideration. The 1972 Clean Water Act regulates releases of pollutants into surface waters or what is referred as the waters of the U.S. Under the Clean Water Act, the U.S. Environmental Protection Agency (USEPA) has developed wastewater and water quality standards for all impurities in surface waters (USEPA, 2014a). To control the quality of effluent discharged from wastewater treatment plants, USEPA requires that all plant operators have a National Pollutant Discharge Elimination System (NPDES) permit. In California, the applicable RWQCB issues this permit.

The 1974 Safe Drinking Water Act is the U.S.' primary federal regulation pertaining to the quality of drinking water. Last amended in 1996, this act has numerous requirements to protect drinking water and its sources including reservoirs, lakes, rivers, and groundwater wells. Under this act, the USEPA has also developed federal standards for drinking water to protect against both man-made and natural contaminants that may be present in drinking water. Man-made contaminants encompass a multitude of impurities, including: animal wastes, chemicals disposed of improperly, pesticides, human waste, and waste installed deep belowground. The USEPA works with state governments to ensure that drinking water standards are met (USEPA, 2014b).

4.2.2 Regulatory Authority of SWRCB and RWQCBs

In California, the main regulatory agencies involved in water reuse are the SWRCB and the nine RWQCBs. Prior to July 2014, the CDPH served as another primary agency that was responsible for enforcing drinking water regulations but, as described in more detail below, the CDPH's drinking water programs was transferred to the SWRCB.

State Water Resources Control Board

The SWRCB is accountable for establishing statewide policy and coordinating with the state's nine RWQCBs. Of the SWRCB's six divisions, three divisions may be involved with development of DPR regulations: the Division of Water Quality, Division of Water Rights, and the Division of Drinking Water.

The Division of Water Quality is responsible for providing a statewide stance on a variety of water quality and regulatory issues, including the State's Porter-Cologne Water Quality Control Act programs. This comprehensive program pertains to surface waters, groundwater, and both point and non-point sources of pollution. Through the Porter-Cologne Act, the nine RWQCBs were established to oversee water quality at a local and regional level. The Division of Water Quality coordinates with the RWQCBs to ensure protection of water quality at the local level.

The SWRCB's Division of Water Rights manages water rights for California. Throughout the planning process of potable water reuse projects, water rights issues will need to be addressed since these projects would result in a reduction or possibly elimination of existing wastewater discharges to water courses (Crook, 201). The Division of Water Rights would also be involved in instances where wastewater treatment plants direct effluent to a river and downstream users rely on surface water from that river. Since operation of DPR projects would reduce flows to those downstream users, the Division of Water Rights may need to be involved to determine DPR projects' effects on downstream water rights.

As previously mentioned, the CDPH's Drinking Water Program was recently transferred to the SWRCB's Division of Drinking Water in July 2014. The primary goal for this transfer was to better align the state's water quality programs in a more organized manner and, in doing so, consolidates water quality regulations related to the hydrologic cycle along with water quality protection for drinking water, irrigation, and other beneficial uses. Other benefits of the transfer include: establishment of one primary agency responsible for financing water quality and supply infrastructure projects, and promotion of a more comprehensive method of addressing drinking water, wastewater, water recycling, storm water and desalination (Health and Human Services Agency and CalEPA, 2014).

The Drinking Water Program is responsible for regulating the federal and state Safe Drinking Water Acts. Primary responsibilities of this program include: issuance of permits for drinking water systems, inspections of water systems, monitor drinking water quality, and establish and enforce drinking water standards and requirements. This division issues Public Water System (PWS) permits to each water provider serving a certain number of connections as defined in California's Health and Safety Code. The permit addresses each water source used by the system and, with respect to potable water reuse, would require that the use of recycled water for drinking purposes be stated in the PWS permit. Specific drinking water regulations or policies that require consideration for DPR projects are summarized in Table 3.

Regional Water Quality Control Boards

The nine RWQCBs were created based on major watersheds in California, each serving as the principal agency responsible for ensuring protection of water quality at the local level. Through the Porter-Cologne Act, the RWQCBs regulate discharges by issuing waste discharge requirements and NPDES requirements, which limit the pollutants in discharges. RWQCBs also adopt water quality control plans (Basin Plans), which are approved by the SWRCB. Basin Plans identify beneficial uses and assign water quality objectives (criteria) for surface water and groundwater to protect those uses, and also establish implementation programs. Coordination with the applicable RWQCB would be necessary for future DPR projects as they are responsible for issuing NPDES permits for wastewater treatment facilities.

Table 3. Drinking Water Regulations and Policies Relevant to Potable Water Reuse Projects

Policy or Regulation	Description
California Drinking Water Regulations	▪ Division of Drinking Water adopted maximum contaminant levels (MCLs) for chemicals found in drinking water that must be met by public water systems. ▪ Each PWS must prepare a Consumer Confidence Report on an annual basis to let the public know where their water comes from and any water quality issues. If DPR is approved, this report will likely need to identify the sources of DPR. ▪ Surface Water Treatment Rule includes regulations that are meant to prevent waterborne diseases caused by viruses. This requires that the water source be approved. Wastewater and recycled water purified for drinking purposes are considered as surface water sources and must meet all surface water treatment requirements.
Drinking Water Source Assessment and Protection (DWSAP) Program	Includes two main components: a drinking water source assessment and source protection. The assessment shall review all potential contaminant that could affect the drinking water supply. The source water protection program should include measures/practices that prevent contamination of groundwater and surface water (sources of supply). Before a PWS permit can be issued, the assessment must be completed and submitted to SWRCB's Division of Drinking Water (previously CDPH).
Water Recycling Criteria	▪ Division of Drinking Water is required to develop and adopt water recycling criteria under Title 22 of the CA Water Code of Regulations. ▪ Water recycling criteria includes a variety of requirements for non-potable recycled water applications and requirements for groundwater recharge of drinking water supply aquifers. ▪ Water recycling criteria are enforced by the RWQCBs through their permitting process.
California Groundwater Recharge Regulations	Prior to operation of a groundwater recharge replenishment project, the project sponsor must obtain approval of a plan describing measures that the project sponsor will implement to provide the alternative drinking water supply to users drinking water well or a SWRCB-approved treatment mechanism that the project sponsor will provide. The project sponsor shall ensure that recycled municipal wastewater is derived from a wastewater management agency that has a source control program. Recycled municipal water used for recharge must achieve specified reduction levels for enteric viruses, Giardia cysts, and Cryptosporidium oocysts. The overall treatment process must consist of at least three separate treatment processes. Recycled municipal wastewater must meet the definitions of filtered wastewater and disinfected tertiary recycled water. Other requirements include: compliance with drinking water MCLs; a 6-month retention time underground; monitoring of recycled water and monitoring wells for major hazardous pollutants, chemicals, and unregulated constituents; and an operations plan and contingency plan.
Proposed framework for Regulating IPR via Surface Water Augmentation	Although water recycling criteria for IPR via surface water augmentation are being developed, the California Potable Reuse Committee found that this method of IPR could be acceptable if the following criteria were met: ▪ Best available technology is applied ▪ Appropriate retention times are determined pursuant to reservoir dynamics ▪ Maintain operational reliability of advanced wastewater treatment plant to comply with main chemical, microbiological, and standard drinking water standards. ▪ Meet applicable State criteria for groundwater recharge ▪ Reservoir water quality is maintained ▪ A successful source control program is in place

4.2.3 Applicability of Regulations to Future DPR Projects

As presented in the table above, there are several regulations and policies that need to be considered for IPR projects as well as future DPR projects. With the recent consolidation of the

SWRCB and CDPH's Drinking Water Program, the SWRCB will serve as the primary agency that would be involved in the permitting and approval process. Consolidation of the two agencies will actually benefit future planning of DPR projects as project sponsors will now only need to consult with two agencies (RWQCB and SWRCB) as opposed to three. Applicable RWQCBs would need to be consulted as they have authority of prescribing water reclamation requirements and administer permits for proposed water recycling projects.

4.3 Public Acceptance Challenges

While many communities have embraced water reuse for non-potable uses like irrigation for golf courses and parks, they are reluctant to accept the idea of using of purified recycled water for potable uses. Lack of trust in public wastewater agencies and emotions such as the "yuck factor" play an important role in the general public's lack of acceptance. Without gaining the public's acceptance of this type of technology, potable water reuse projects often times cannot go forward. Since water supply providers are required to tell their customers where their water comes from, educating the public about this water supply source is key to obtaining public acceptance. Much research has been conducted on this topic and is considered a large hindrance to implementation of DPR projects.

Since the 1970s, surveys of public attitudes toward water reuse have been conducted. Recent studies consistently find that public acceptability declines as level of contact with treated recycled water increases (Hartley, 2006). For example, a recent study in Arizona found that over half of the respondents accept the use of recycled water for household cleaning, washing clothes, and bathing but less than half of the respondents supported use of recycled water for uses like cooking or drinking (Rock et al., 2012). Respondents asked how they felt about the use of recycled water for landscaping and irrigation was generally considered highly acceptable. In general, this effect is observed globally from the U.S., to Australia, and Israel. Similar sentiments were also observed across age groups, both women and men, and all age groups and income levels (Bell and Aitken, 2008). Based on a review of surveys and case study research conducted between the 1970s and 2000, Hartley (2006) concluded that the following factors seem to increase levels of public acceptance of water recycling:

- Extent of human contact is minimal
- Water reuse project proponents clearly communicate that public health is protected
- Environmental protection is described as a benefit of water reuse

- Support for water conservation is described as a benefit of water reuse
- Cost of potable water reuse systems and technologies are reasonable
- General understanding of existing water supply issues in the community is high
- Clear understanding of how reclaimed water fits in the water cycle is established
- Impression of the quality of recycled water is high
- Trust in local government and public utilities and treatment technologies is high

Municipalities that are considering implementation of DPR projects should also consider national and regional trends. While general trust in pubic officials and agencies is on the decline, so is trust in wastewater utility districts (Hartley, 2006). A 2008 study conducted in Arizona found that 79% if its respondents expressed lack of confidence in their local government's ability to address the region's water supply and infrastructure challenges (Browning-Aiken et al., 2011). Similarly, based on pubic surveys conducted, while people generally trust university-level scientists and medical experts, most people tend to believe their own notions of water quality (based on appearance like turbidity) over what the experts say.

Consistent with the lack of trust in public utilities and wastewater experts, the belief that the most advanced wastewater treatment technologies can effectively remove contaminants in wastewater is declining (Hartley, 2006). Public concerns are not only associated with the lack of understanding of potable water reuse technology but also relate to legitimate concerns regarding health risks of CECs (e.g., drugs and hormones). As regulators and water quality experts are still learning more about CECs, proponents of potable water reuse need to also develop a consistent manner in communicating risks associated with potable water reuse technologies.

In addition, negative publicity has a substantial impact on public acceptance for potable water reuse projects. For example, during the 1990s, when numerous IPR projects were being proposed in the U.S., newspapers were using terms like "Toilet to Tap" and "Sewage Beverage." Use of these terms in the public discourse led to firm opposition from the public and prevented these IPR projects from being implemented. In order to help gain public acceptance, municipalities, wastewater and water agencies that are planning potable water reuse projects need to improve their public relations.

The terminology that wastewater agencies use also influences public perception of potable water reuse. A statewide survey conducted in Arizona found that respondents responded positively to terms such as ‘water reuse’ (64%), ‘recycled water’ (62%), ‘repurified water’ (62%); the most negative response was for the term ‘reclaimed water’ at 20%. Interestingly, respondents had the least negative response to the term ‘repurified water’ (Rock et al., 2012).

One study conducted in California found that while public education and outreach generally increased support, these activities also intensified stances on potable water reuse. For instance, even after participating in public education workshops, opponents of water reuse became even more opposed; those that were in support of water reuse became even more supportive (Hartley, 2006). This just goes to show how the “yuck factor” can stick with some people. Even after being more educated of potable water reuse, some people will still simply reject the technology due to an irrational emotional response.

Many advocates for potable water reuse assume that public rejection of IPR and DPR technology is largely due to lack of understanding of the treatment technologies and health risks (Bell and Aitken, 2008). Water and wastewater professionals agree that public outreach and public participation in potable water reuse projects are necessary to overcoming barriers to public acceptance. From the perspective of the wastewater engineers and scientists, if only the public could understand what they already know, public acceptance can be achieved. Some supporters of potable water reuse believe that a shift is needed in the way that water professionals educate and communicate with public about this type of technology and refer to IPR and DPR as a ‘socio-technology’ (Bell and Aitken, 2008). At a broader level, according to Bell and Aitken (2008), potable water reuse technologies should be reconsidered as this type of technology cannot exist unless it is embedded in societal, institutional, infrastructural and environmental networks.

The key question of how to effectively gain public support for DPR projects is further addressed throughout this paper.

5. Case Study Analysis

5.1 Purpose of Case Study Review

This section looks at case studies of IPR and DPR projects in attempt to better understand how these projects overcame public acceptance barriers addressed in Section 4. Because there are only three DPR projects in operation at this time, this case study analysis evaluates both DPR and IPR projects. While each case study is unique, future DPR projects will face many of the same public acceptance challenges encountered by these implemented potable reuse projects. The intention of this review is to identify best practices that may be useful in gaining public acceptance for DPR projects and learn from past potable water reuse projects. These practices and lessons learned may be useful to communities looking to implement DPR projects in the future.

5.2 Best Practices used to Compare Case Studies

The case studies selected for this analysis include IPR and DPR projects that have been implemented or are in the pilot study phase. In order to compare what worked and did not work for these projects, a list of best practices was developed for evaluating the potable water reuse project's success in overcoming public acceptance barriers. These practices were developed based on review of literature on the topic, reports prepared by non-profit organizations supporting research of water and wastewater technologies, and review of publicly available information on the Internet. When it comes to gaining public acceptance, project proponents should consider what public benefits are gained by a DPR or IPR project. A project's level of success regarding public acceptance was determined based on whether the project implemented the following best practices.

1. Clearly define the region's water supply problems.
2. Rename the product water using terminologies related to water quality improvement.
3. Break the connection between the water source and its quality by clearly describing the high quality of the water the treatment processes used to treat recycled water.
4. Clarify that treated water is constantly monitored to ensure high water quality of product water.
5. Develop a public outreach plan that includes stakeholder meetings, public tours, and opportunities for youth.
6. Reach out to groups that may be wary of the project and its technology and gain support from prominent leaders in the community
7. Use consistent terminology that is clear and understandable to the general layperson.
8. Develop a website devoted to the DPR project and take advantage of social media.

Each case study is evaluated against these best practices and to determine how well each project implemented these, are generally given the following ratings: implemented, somewhat implemented, or did not implement the practice. In some instances it was unknown whether a best practice was implemented due to the circumstances of the project or due to the lack of publicly available information. The following sections describe each case study and then assess how well each project implemented the above-listed practices.

5.3 Case Study #1 – Namibia DPR Project

5.3.1 Description

Namibia is one of the driest countries in the world as it is flanked by the Namib desert to the west and the Kalahari desert to the east. The city of Windhoek (shown in Figure 3), Namibia's capital, receives approximately 370 millimeters of rain per year yet the evaporation rate is much higher, between 3,200 and 3,400 millimeters per acre (Lahnsteiner and Lempert, 2007). The City of Windhoek has a population of 250,000 people. The city relies on surface and groundwater but nearly all of its potable resources within 500 kilometers of the city have been fully exploited. Three dams provide water to Windoek: the Von Bach Dam, Swakoppoort Dam and Omatako Lake. Currently, groundwater is extracted from 50 municipal production boreholes, providing approximately 8 million cubic meters of water per year (Boucher et al., 2011). Rainfall is uncertain and the region is accustomed long periods of drought. Given these conditions, Windhoek was in dire need of an alternative water supply source. Thus, in 1994, Windhoek approved an integrated water demand management program encompassing direct potable reuse, education, policy issues, and technical and financial measures.

Figure 3. Windhoek, Namibia Map

To address the serious water supply constraints, in 1968, the City of Windhoek's Water and Waste Management Department, reconfigured the Goreangab water treatment plant to treat both secondary sewage effluent and water from Nambia's dams (du Pisani and Menge, 2013).

The treated water was then combined and introduced to Windhoek's drinking water system, representing the first direct potable reuse project in the world. Over the years, the Goreangab plant has been improved to its capacity of 2 MGD and embraces the multiple barrier concept previously described in Section 4.1.3, above. In 2001, a new Goreangab Plant was also constructed, at which point the first Goreangab Plant was referred to as the Old Goreangab Reclamation Plant. The New Goreangab Plant has the capacity to treat 5.5 MGD of water (Boucher et al., 2011).

Since 1968, four of its treatment processes have been upgraded and the latest occurred in 2002 (Crook, 2010). Treatment processes include: activated sludge with secondary treatment and nutrient removal, application of powdered activated carbon and acids when necessary, filtration, ozonation, chlorination, and stablization with sodium hydroxide (Crook, 2010). Before introducing the water to Windhoek's water supply system, the water is blended with water treated at the city's normal water treatment plant. The actual proportion of recycled water in Windhoek's water supply is relatively low: on average, recycled water represented 4% from 1968 to 1991. After the more recent upgrades, the plant provides 35% of the drinking water supply but is permitted to provide 50% of Windhoek's water supply portfolio (Lahnsteiner and Lempert, 2007).

Although the Old Goreangab Water Reclamation Plant has been up and running for over 40 years, obtaining and retaining public acceptance did not come easily at first. In contrast to IPR projects, treated wastewater is blended with normal water from the City of Windhoek's water treatment plant and is subsequently directed to its water distribution system. That very notion made the public reluctant to use this water initially (du Pisani, 2004). When the New Goreangab Water Reclamation Plant was constructed, public education campaigns, advertising campaigns (including full television and media coverage), and public education for younger children were implemented to promote awareness (Boucher et al., 2011). However, the city continued few educational campaigns after the plant's grand opening. The plant is open to the public, and is available for school visits and visiting members of the scientific community (Boucher et al., 2011). The City of Windhoek also invested in new laboratory facilities and analytical equipment to ensure continual monitoring of water treated at the Goreangab Treatment Plant. If any water quality issues are encountered, the water gets recycled again and is not delivered. Parameters that are measured include pathogens like viruses, *Giardia* and *Cryptosporidium* (du Pisani, 2004).

More recently, students from Worcester Polytechnic Institute, Massachusetts conducted an in-depth evaluation of public perception issues of water recycling in Windhoek for the city. Surveys were disseminated to Windhoek residents to better understand public knowledge of Windhoek's reclamation system and their perception on water quality. The study found that most respondents found the water to be of fair or good quality and that it was safe for drinking purposes (Boucher et al., 2011). Although respondents claimed to know how Windhoek receives its water, a large proportion of the respondents were not aware of the New Goreangab Water Reclamation Plant. Residents that have been living in Windhoek for over 11 years seemed to be more aware of the city's water resources, whereas citizens who have lived in the city less than 10 years knew the least about its supply sources (37%). This study also found that Namibians with a higher level of education were less trusting of the city's reclamation process in comparison to less educated people. This study suggests that Windhoek's residents are perhaps not well informed about the treatment technologies.

5.3.2 Case Study Assessment

Based on the survey conducted by Boucher et al. (2011), it appears that public outreach efforts could still be improved upon in Windhoek. This case study is unique in comparison to the other case studies because DPR has been an ongoing practice in Namibia for a long time; thus current residents are mostly familiar and comfortable with the water supply technology. Best practices that appear to have been implemented include:

- ***#1** (clarify water supply problems).* Granted that DPR practices have been employed in Windhoek for over 30 years now, its residents are generally aware of the source of their drinking water. Because DPR has been an ongoing practice in Namibia and because water supply challenges are fairly well understood, best practice #1 has been met.

Best practices that appear to be somewhat implemented include the following:

- ***#3** (break the connection between the water source and water quality).* Similar to best practice #1, people in Windhoek seem accustomed to their water supply. However, the recent survey conducted by Boucher et al. (2011) found that Namibians with a higher level of education tend to have less trust in the City's reclamation process, which indicates that the "yuck factor" has not been completely broken.

- ***#4*** *(ensure monitoring of product water).* While the City of Windhoek continually monitors its water throughout the treatment process, it does not appear that this information is well publicized to Windhoek residents.
- ***#5*** *(public outreach plan that includes stakeholder meetings, tours and educational opportunities)* and ***#6*** *(target public outreach to groups wary in community and prominent leaders)*: Based on the study conducted by Boucher et al. (2011), educational and outreach efforts could be expanded upon since the majority of survey respondents were not even aware of the New Goreangab Water Reclamation Plant. Lastly, upon review of the City of Goreangab's Department of Water and Technical Services website, the Department has indicated that community education is a focus area of theirs but could not find additional information about the plant, treatment process or who to contact about educational opportunities.

The following practice was not met by the project:

- ***#8*** *(project website and public media tools).* Based on Internet research, it does not appear that a dedicated website has been developed for the New Goreangab Water Reclamation Plant nor have public media tools been developed to disseminate information about the project.

Based on publicly available information, it is unknown whether the City of Windhoek used terminologies to imply water quality improvement or whether these terms were described clearly to the public (best practices #s 2 and 7).

5.4 Case Study #2 – NEWater Facility in Singapore

5.4.1 Description

Singapore is an island nation. It typically receives a substantial amount of rainfall but, due to its small area (approximately 680 square kilometers), the country is only able to store 50% of their water supply in reservoirs (Funamizu et al., 2009). In the past, the remaining half of its water supply came from a river in Malaysia. Since the early 1960s, Singapore and Malaysia have been abiding by two major water agreements that allow Singapore to transfer water from the state of Johor via three large pipelines. As the water agreement expires in 2061, the two countries are in the process of negotiating a possible extension of this agreement (Tortajada, 2006). The

Singaporean government expected water prices to increase but was largely concerned about how the price modifications would be decided. Given the space constraint, increased demand for water associated with population growth and economic development, and the uncertainty of future supplies from Malaysia, Singapore's future water security was at risk.

In effort to reduce reliance on Malaysian water, Singapore's Public Utilities Board (PUB) funded a new water management plan to ensure water security and self-reliance for the post 2011-period. The plan included entirely new water policies focused on water efficiency, and included big-picture ideas for development and investment in desalination and water reuse systems. Consistent with the water management plan, the country has been focused on developing desalination plants and water reuse facilities. In 2005, the first seawater desalination plant (the Tuas Desalination Plant) was launched. The facility cost $200 million to construct and has capacity of 30 MGD.

On the water reuse front, Singapore has been considering expansion of wastewater reuse since the 1970s. The first pilot recycling plant was shut down in 1975 because it was considered costly and unreliable. Since then, PUB furthered reclamation studies and successfully developed another pilot plant in 2000 at a location just downstream of the Bedok wastewater treatment plant. This plant utilizes double membrane technology to generate water suitable for IPR and was proven suitable for industrial uses (Rodriguez et al., 2009). Since then, three full-scale water reclamation plants have been constructed and are marketed as "NEWater." Using advanced membrane technology and UV disinfection, the quality of water produced at NEWater plants meets the World Health Organization (WHO) Drinking Water Guidelines and the USEPA Drinking Water Standards (Tortajada, 2006). This water is primarily used for industrial uses and commercial centers but is also used to supplement Singapore's drinking water supply. When used for potable uses, the NEWater is directed to a reservoir before undergoing subsequent water purification processes (Funamizu et al., 2009). Currently, NEWater comprises 30% of the country's overall water needs and by 2060, Singapore aims to triple its NEWater capacity, enabling them to provide approximately 55% of the country's future demand (PUB, 2014).

Public acceptance of the NEWater technology has been considered high and is largely attributable to the PUB's extensive marketing campaigns and education programs. The government strategically engaged the public through various public education programs, which is evident through its development of the NEWater Visitor Center in 2003 (Funamizu et al., 2009). Tours of the visitor center are conducted daily and, throughout these tours people are educated about the water purification process. Each visitor is also given a complimentary bottle of NEWater to sample. In addition, the facility has a "NEWater Scientist Program" catered for elementary-level students; this is an interactive program that allows students to dress up as scientists and embark on a mission to complete water quests through the NEWater Visitor Center (N. Jamallodin, personal communication, October 16, 2014).

5.4.2 Case Study Assessment

This case study is considered successful in several ways. Not only was the government supportive of expanding water reuse and has consistently proven that water quality produced at NEWater facilities meets or exceeds the drinking standards of both the USEPA and WHO, but Singapore was successful in getting the public on-board with this technology. As summarized below, all of the best practices were implemented by this case study.

- ***#1** (clarify region's water supply problems)*. Water supply problems have been a challenge for Singapore for a while now so the problem statement has seems clearly defined for the public and is apparent on the NEWater website.
- ***#2** (rename product water)* and ***#7** (use consistent terminology)*. The PUB used effective marketing campaigns by branding their product water as "NEWater," which de-emphasizes the notion of wastewater reuse. Analysts believe that the prefix "re" may be understood as an idea that it is water already used.
- ***#3** (break the 'yuck factor' perception)*, ***#5** (develop and implement an extensive public outreach plan),* and ***#6** (gain support from prominent leaders in the community)*. Due to large support from the Singaporean government and PUB's emphasis on the high quality of the water generated at the NEWater facilities, the project successfully gained support from the broader public.
- ***#4** (clarify the multi-barrier approach and water quality monitoring process).*
- ***#8** (develop a website and effectively used public media to enhance public involvement)*. The PUB's website contains a wealth of information about the water purification process and Singapore's history and need for potable water reuse options. The website also includes links to Facebook and Twitter, which enables people to 'follow' the project.

5.5 Case Study #3 – South Queensland, Australia

5.5.1 Description

South East Queensland, Australia experienced one of its most severe droughts between 2000 and 2012 and is currently under drought conditions again. Located in eastern Australia, the region relies primarily on the Wivenhoe, Somerset, and North Pine dams for surface water supply and were last full in the summer of 2000 to 2001 (Department of Natural Resources and Water, 2007). In 2007, inflows from the Wivenhoe-Somerset Dam system were 20% lower than the worst year recorded and water levels in the dams were below 40%. These dire conditions, coupled with the fact that water supply projections had indicated shortfalls in the next ten years and beyond, heightened the need for increased water recycling (WaterReuse, 2014).

In response to this critical water supply situation, Queensland Water Commission created a demand management program including water use limits and efficiency measures. From 2005 to 2007, residential demand decreased by 180 L/person/day. The Queensland Government also initiated large-scale recycled water projects to address water supply needs including the Tugun Desalination Plant on the Gold Coast and the Western Corridor Recycled Water Pipeline Project. The desalination plant has capacity of 125 megalitres/day (27.5 MGD) and the Western Corridor Project can provide up to 232 megalitres/day (62 MGD). At the time, other major capital improvement projects such as construction of the new Traveston and Wyaralong Dams were proposed to provide 250 megalitres/day for the region. Because construction of these projects were thought to take too long and the immediate demand for water, the Queensland government expedited construction of the Western Corridor Project (Traves et al., 2008).

Construction of the Western Corridor Project ($2 billion project) began in 2006 and was completed in 2009. This project entailed construction of three advanced water treatment plants and an extensive 200-mile-long recycled water pipeline system (see Figure 4). The three advanced water purification plants receive water from nearby existing wastewater treatment plants; each purifies the water using microfiltration, advanced oxidation, reverse osmosis and residual disinfection treatment technologies. At the beginning of project operations, recycled water was used at the Tarong and Swanbank power stations to offset demand of surface water supplies from nearby dams.

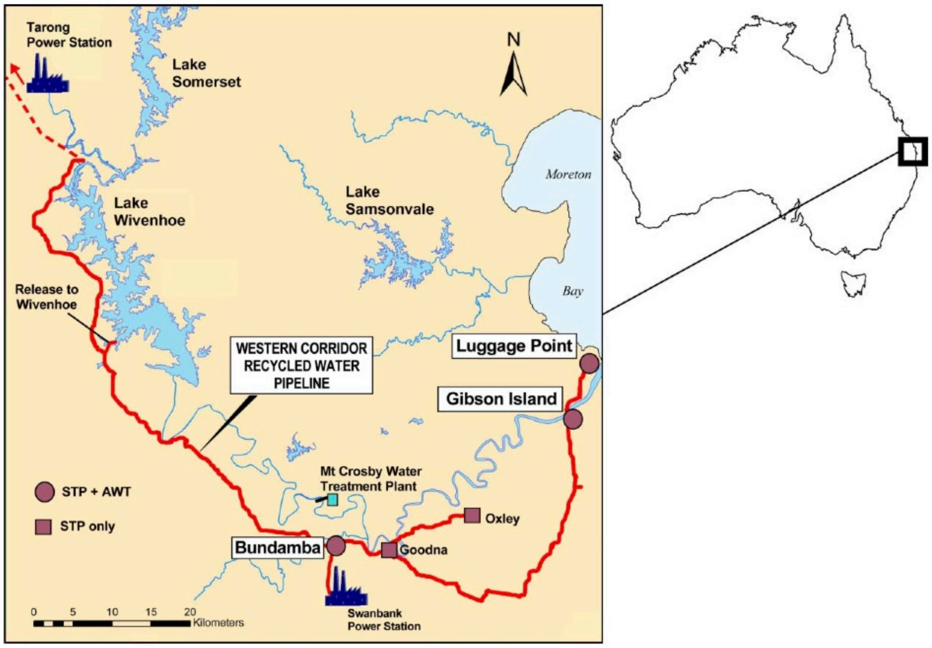


Figure 4. Location of Western Corridor Recycled Water Pipeline Project (Traves et al., 2008)

The public participation process was particularly challenging in Queensland. At the time the project was being constructed, the government had envisioned augmenting reservoir levels in Wivenhoe Dam with advanced treated recycled water from the Western Corridor project. In 2006, the City of Toowoomba held a public voting process on the proposed IPR scheme but consistent with public opinion surveys, only 38% of its voters were in favor of this practice (Bell and Aitken, 2008). The voting process was structured such that residents could only choose between 'yes' and 'no' for the proposal and did not provide an opportunity for residents to consider the pros, cons, risks, or alternatives. Regardless of the voting results, the drought continued to worsen and a promised referendum for the southeast region of Queensland was cancelled (Bell and Aitken, 2008). In early 2007, because of the critical need for water, the Queensland Government decided to use product water from the Western Corridor Water Supply Project for IPR uses by end of 2008. Because of South Queensland's dire water supply situation, the community became more open to the concept of IPR between but interestingly, shortly thereafter, rainfall increased in the region such that the dam capacity increased above 45%. As a result of the increased rainfall, support for IPR scheme declined again and, in 2008, the Queensland Government revised its recycled water policy from constant use of IPR to urgent use only reservoir levels are under 40% (Rodriguez et al., 2009). Most of the public concerns regarding IPR use of recycled water pertained to health risks from reuse of wastewater, risk of breakdown, and issues of fairness (Nancarrow et al., 2007).

5.5.2 Case Study Assessment

Based on review of the Western Corridor Water Supply Project, it is evident that the South Queensland government was unsuccessful in gaining public support for the IPR scheme associated with this large-scale recycled water project. While the water is being used for industrial and irrigation purposes, the intent to use the highly purified water for surface water augmentation was rejected. The government did not appear to sufficiently educate its community about this technology. The very fact that the government first allowed public involvement through a voting process but then retracting the public's vote shows that much more needs to be done to gain public acceptance of this issue.

Many of the best practices listed above in Section 5.2 were not met. This is partially because the Western Corridor Water Supply Project was built in a time of drought and perhaps not enough time was allocated to planning the public outreach strategy. The project only implemented best practice #1 as the public was certainly aware of region's drought conditions throughout the early 2000s but perhaps did not understand why use of an IPR scheme in combination with the Western Corridor Water Supply Project was the preferred alternative when compared to other water supply options. This case study is also interesting because the drought was so bad that the government disregarded results of the referendum and planned on implementing the IPR project anyway. Clearly, much more outreach should have been conducted prior to the 2006 referendum.

5.6 Case Study #4 – OCWD Groundwater Replenishment Project

5.6.1 Description

The Orange County Water District (OCWD) is tasked with managing the Orange County groundwater basin, which provides approximately 70% of the county's water supply for over 2.4 million people. Figure 5 includes a map of OCWD's service area. While this groundwater basin is vast, sources of recharge including flows from the Santa Ana River, direct percolation from rainfall, and imported water supplies have dwindled (GWRS, 2014). Imported water sources for southern California include water from Lake Oroville, which is transported from the northern part of the state via the State Water Project (SWP). Orange County also relies on Colorado River water, which is also relied upon by six other states, Mexico and Native American Indian tribes. In 2003, southern California's share in Colorado River water was cut by 50%. In addition to these water supply challenges, as the basin is situated along the coast of southern California, overexploitation of the groundwater basin has lead to seawater intrusion.

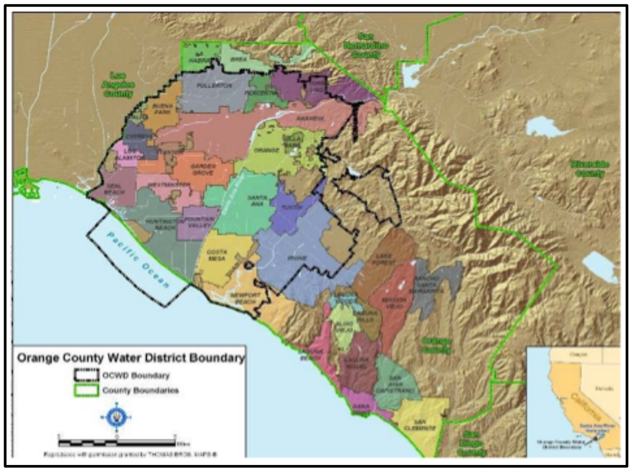


Figure 5. OCWD Service Area (OCWD, 2014)

In the mid-1970s, to address the region's seawater intrusion and water supply in issues, OCWD began operating Water Factory 21, a project that provided purified drinking water for a series of injection wells that served as a seawater intrusion barrier. This project had production capacity of 19 megalitres per day. Since then, as the population in Orange County continues to increase, extraction from the County's groundwater basin has continued and expansion of the seawater barrier became necessary. All of this led to the eventual closure of the Water Factory 21 project in 2004 and planning of the OCWD's Groundwater Replenishment (GWRS) Project.

In 2008, the OCWD and Orange County Sanitation District (OCSD) began operating a 70 MGD advanced treatment facility to purify wastewater to USEPA's drinking water standards. This $481 million facility uses secondary effluent from the OCSD and is used to replenish the region's groundwater basin (Tchobanoglous et al., 2011). This facility employs reverse osmosis, microfiltration, and advanced oxidation technologies, and provides approximately 15% of OCWD's water supply. Approximately 50% of the purified water (35 MGD) is used for IPR in which the water is infiltrated to an aquifer and is held for 6 months (residence time). The other portion of purified water is directed to injection wells to protect coastal aquifers from seawater intrusion (Schroeder et al., 2012).

Prior to construction of the GWRS project, the OCWD and OCSD had to obtain permits from CDPH and the RWQCB. Both agencies require that recycled water remain underground for at least 6 months before being used for drinking water purposes. A tracer must be added to track travel time in aquifers, and limits the overall amount of recycled water that is useable for recharge (amount varies by project) (Johnson, 2009). One of the permit requirements includes establishment of an Independent Advisory Panel comprised of experts in chemistry, toxicology, hydrogeology, microbiology, public health, water treatment technology, and environmental engineering. The panel is required to convene at least once per year during the GWRS' first five years of operation, and subsequently every two years after that.

Although it took some time, OCWD and OCSD worked collaboratively to build the public's trust of the GWRS Project. In 2000, consumer surveys conducted throughout Orange County indicated that members of the public were concerned that the reclaimed water was originally wastewater (Hartley, 2006). To overcome the "yuck factor," the project proponents made sure that key politicians (at both the state and local level) were onboard with the project from the beginning and reached out to various communities that the district knew would be apprehensive of the project including Latino and Vietnamese communities, and mothers' groups (Miller, 2012). Letters of commitment were requested and received by California Assemblymen, Senator Feinstein, and local politicians (M. Patel, personal communication, November 17, 2014). Although public acceptance information about the project was difficult to find, the OCWD is devoted to outreach and education of the GRWS project. OCWD continues to free public tours of its facilities, has a website devoted to educating the public about the project and its benefits. The project also has Facebook and Twitter accounts and a YouTube channel, which allow members of the public to follow project updates.

OCWD and OCSD secured $92 million in grants to help finance the project. The project also receives a $7.5 million annual subsidy from the Metropolitan Water District. Currently, OCWD is expanding the GWRS to create an additional 30 MGD; the expansion is expected to be complete by 2015.

5.6.2 Case Study Assessment

This project is deemed successful in several ways. Proponents of the project reached out to the appropriate audiences including local politicians and groups that were originally apprehensive of the IPR technology. OCWD and OCSD also strategically developed a website and brand name associated with the GWRS project. The logo of a three blue water drops infers that the treated water is drinkable and pure; each droplet represents the different purification phases. The GWRS website also includes a wealth of information that is organized in a clear manner. For example, the website includes links to the "Project Need" and "Project Benefits," which makes it easier for the public to understand the region's water supply needs and the direct benefits offered by the project. This project implemented all eight best practices, as discussed below:

- ***#1** (clear definition of water supply problem).* As shown on the GWRS project website, project proponents have framed the project need.
- ***#2** (rename the product water and use terms related to improvement of water quality)*. The GWRS project website uses the term 'purification' to describe the process in which the wastewater from OCSD is treated further using reverse osmosis, microfiltration, and UV light. The project has even adopted a logo consisting of three water droplets in different shades of blue to symbolize these processes.
- ***#3** (break the 'yuck factor'), **#5** (public outreach plan)* and ***#6** (outreach to apprehensive groups of people and prominent community leaders)*. OCWD continues to educate the community about the GRWS project through tours that are conducted on a regular basis and even has an active speakers bureau program in which OCWD representatives respond to requests by speaking to organizations, schools and conferences about the GRWS project.
- ***#4*** (*ensure public understands water quality monitoring process throughout treatment process).* As part of OCWD's education program about the advanced water treatment process, the multi-barrier method and water quality monitoring system is described (M. Patel, personal communication, November 17, 2014).
- ***#7** (use consistent terminology that is clear)*. To avoid any confusion about the project, OCWD and OCSD staff use consistent terms and messaging when discussing the GWRS with members of the public (OCWD, 2013 and M. Patel, personal communication, November 17, 2014).
- ***#8** (develop project website and effectively use of public media)*. As mentioned above, a GWRS project website was developed and provides key information about the water purification processes, including video clips of these processes. The website also includes white papers that address the GWRS and water reuse, press coverage, bio-sketches of the project's Independent Advisory Panel, general information about the water cycle, and public tour information. The OCWD and OCSD have taken advantage of social media by

creating pages/accounts on Facebook, Twitter, and YouTube so that members of the public can stay informed about the project.

5.7 Case Study #5 – Big Springs, Texas Project

5.7.1 Description

The Colorado River Municipal Water District (CRMWD) is responsible for supplying water to five cities in West Texas including Big Spring, Odessa, and Snyder in West Texas. Since the 1950s, CRMWD has built new reservoirs to store water from the Colorado River and expanded groundwater supplies in Ward County to provide water supplies to western Texas, a very arid region. Due to the high costs of pumping and transmitting groundwater to CRMWD's service area, CRMWD realized that future demands could not be met unless additional supplies were sought. Between the late 1980s and early 1990s, the district began considering alternative water supply options and after experiencing a drought that lasted more than a decade, the district more seriously considered DPR as a potentially viable water supply solution.

In 2002, CRMWD began the planning process of the CRMWD Big Springs Raw Water Production Facility in Big Springs and by the spring of 2013 facility construction was completed (J. Womack, personal communication, November 18, 2014). This 2.5 MGD plant accepts treated wastewater from the nearby Big Spring Water Reclamation Facility and purifies it using reverse osmosis, microfiltration, and advanced oxidation technology including UV light. Approximately 5 to 20% of the water is blended with surface water from one of CRMWD's reservoirs. The water is subsequently delivered to Big Spring's conventional water treatment plant and is then distributed to the Midland-Odessa area. This is the first DPR project in the U.S. and received final regulatory approvals in April 2013 (Wythe, 2013).

In general, residents in the Big Springs, Odessa, and Snyder communities have been relatively receptive to this water treatment technology but a fair number are still opposed to the project. Interestingly, based on communication with CRMWD's systems operations manager, the public was generally responsive to the project during the initial planning phase but once project construction was completed, more public opposition was encountered (J. Womack, personal communication, November 19, 2014). According to John Grant, general manager of CRMWD, there are always a few people that refuse to drink the water but most people in their service area have a greater appreciation for water than you might see in an area where supply is not an issue

(Bute, 2013). CRMWD has found that once people have gone through a tour of the facility and better understand the treatment process, they are able to get over the "yuck factor" (J. Womack, personal communication, November 19, 2014). To appease the public, water officials in Big Springs have clarified that water quality is monitored throughout each phase of treatment: from microfiltration, reverse osmosis, and UV disinfection. The water quality is tested even before it reaches the raw water production facility. If the water does not meet the district's parameters at any step of the treatment process, the water is redirected to the beginning of the process (Bute, 2013).

Similar to CRMWD, other communities like Wichita Falls have implemented DPR projects within the last year. The Texas Water Development Board, which has the responsibility of planning Texas' water and wastewater services, has retained consultants to prepare a resource document describing the future of direct potable reuse projects in Texas. The goal of this document is to help the public overcome public acceptance barriers and will be available to the Texas community. This document will address contaminants of concern, describe treatment technologies, and describe pilot projects (Texas Water Development Board, 2014).

5.7.2 Case Study Assessment

The Big Springs Raw Water Production Facility project seems to be relatively successful in West Texas. The West Texas region is unique in that it has undergone serious water supply challenges that the public has been aware of for a long time. CRMWD explored all kinds of surface water storage and groundwater supply projects before looking to DPR as an alternative water supply source. Thus, best practice #1 (clear definition of project need) was clearly met.

For such a big project as this, I had difficulty finding publicly available information about this project on the CRMWD and City of Big Springs' websites. Media mentions of this project were generally positive; however, some newspaper articles that included interviews with local Texans focused on the lack of acceptance that seems to persist. For this reason, best practices that appear to be somewhat met include:

- ***#3** (break the connection between the water source and its quality).* As mentioned above, the majority of CRMWD's constituents have accepted the DPR scheme but many still have not gotten over the 'yuck factor.'
- ***#4** (clarify that water is constantly monitored to ensure that high water quality is maintained).* While the CRMWD general manager confirmed that monitoring of the

water at every step of the water purification process is key to detecting any water impurities, no public educational materials related to the project were found online. Therefore, it is uncertain whether this information is well understood by the communities that receive water from CRMWD.

- ***#5*** *(public outreach plan)* and ***#6*** *(outreach to apprehensive groups of people and prominent community leaders)***.** While the district developed a formal public outreach plan, conducted public meetings, offered public tours of its facilities to media members, and offered some tours for schools, it is unclear whether these efforts were enough.
- *#7 (use clear and understandable terminology).* The public was receptive to the project once the process was explained in simple terms. It is unclear whether some residents are wary of this technology due to a lack of understanding of the terminologies used to describe the treatment process.

Since it is apparent that many members of the public are still wary of the project, it is unknown whether CRMWD used terminology related to water quality improvement (best practice #2). Lastly, it is apparent that CRMWD has not implemented best practice #8 since no project website or social media accounts have been established for the project.

5.8 Case Study #6 – City of San Diego, CA

5.8.1 Description

Similar to Orange County, San Diego County also heavily relies on imported water from northern California via the SWP, Owens Valley, and the Colorado River. Today, these sources make up 85% of its supply. As a result of a legal agreement in 1994, the city was mandated to construct a 45 MGD water recycling system to meet established water recycling goals. Due to the limited demand for reclaimed water generated at this facility and in effort to increase local water supplies, the city and the San Diego Water Authority worked together to develop an IPR project in San Diego. The city's wastewater department mostly spearheaded this project. At the time, the City of San Diego had envisioned taking treated water, purifying it further at an advanced water treatment facility, and then using that water for augmenting San Vicente Reservoir. Project planning continued for several years and even gained support from the CDPH and water experts. Throughout the planning process, Project staff conducted public surveys, focus groups, and held stakeholder interviews to better understand public concerns (Hartley, 2006).

Despite all of this, in 1999, the project faced opposition from the public. Although project staff thought that San Diego's city council was kept abreast about the project's status, one city councilman claimed disagreed. The city's water department also attended all the meetings but their input on the project was not found in the public record (Resource Trends, 2004). The proposed IPR project in San Diego gained even more negative attention when a local newspaper released an animation of a dog drinking water from a toilet and a man standing beside the dog says, "Move over…"

In addition, environmental justice issues were raised over the potential application of IPR water being used to augment San Vicente Reservoir. Although IPR water directed to the reservoir would have served people of all economic statuses throughout San Diego, the community adjacent to the reservoir believed that the reservoir would just serve the southern part of the city, which was mostly comprised of low-income African American residents. As a result of these concerns, the project quickly came to halt (Hartley, 2006).

Since then, the City has continued to pursue IPR uses of reclaimed water by conducting additional feasibility studies. In 2004, the City Council approved an analysis to evaluate the increased use of recycled water generated at the City's two reclamation plants. This particular study evaluated different options and identified augmentation of the City's San Vicente Reservoir as the preferred approach. A few years later, in 2007, the San Diego City Council approved proceeding with the demonstration project to verify the feasibility of using purified recycled water that is delivered to a reservoir and later distributed as part of San Diego's distribution system. The demonstration-scale Advanced Water Purification Facility has been operating since June 2011 and is currently open for public tours (City of San Diego, 2014).

The public outreach and involvement of the project's second go-around has greatly improved since the IPR project was first conceived in the late 1990s. The City of San Diego has developed a website devoted to the project and is referred as "Pure Water San Diego Program." The website contains links to the feasibility study, general information, news articles about the project, tours of the demonstration facility, community events and presentations sponsored by the City's Public Utilities Department. The website also includes testimonials from prominent leaders and members of the San Diego community (City of San Diego, 2014).

5.8.2 Case Study Assessment

The city's first attempt at implementing this project was deemed unsuccessful and did not get approved mainly because it lacked acceptance from the general public including one city councilmember. This project seemed to have an extensive public outreach program in place (best practice #5) but did not implement the following practices:

- ***#1** (clear definition of the water supply issue and project's need).* While a substantial amount of outreach was conducted for this project, project proponents did not seem to clearly describe how the project would improve water quality or the basic components of the project. It seemed as though the public perceived the project as the least costly alternative for the city to dispose of wastewater (Resource Trends, 2004).
- ***#6** (extend public outreach to groups that may be wary of the project and prominent leaders in the community).* Due to lack of clear communication about the project, the project encountered environmental justice issues as the low-income community located near San Vicente Reservoir had the inaccurate perception that the project would only be serving that community. The project also clearly did not gain acceptance from the one city councilmember that claimed he/she was only notified about the project at the last minute. The City's wastewater department also did not seem to adequately keep the water department engaged throughout the decision-making process.
- Based on the above, this project did not implement best practice ***#3** (break the "yuck factor).*

It's unclear whether the project implemented best practices ***#4*** (*assure public about constant water quality monitoring*) or ***#2*** (*rename product water using terminologies implying improvement*). Best practice #8 does not apply to the project's first go-around.

The city's second attempt to this project appears to be successful thus far. The city seems to be following the best practices implemented by the GWRS project by developing a website devoted to the City of San Diego's Water Purification Demonstration Project and offering free tours of the facility. The project also seems to have won support and praise from leaders in the community, which is demonstrated on the project's website.

6. Results

This section reviews, compares, and contrasts the results of the case study analysis. This section also describes which best practices seemed critical in ensuring implementation of past potable water reuse projects, and what practices should not be followed when planning future DPR projects. Table 4**,** below, summarizes: each study; the public acceptance challenges encountered by each project; and best practices that were implemented, somewhat implemented, and not implemented by each project. Table 5 summarizes best practices that were implemented by the case studies. In Table 5, a check mark indicates that the practice was implemented and a blank cell indicates that the practice was not implemented. In instances where the best practice was somewhat implemented or where it is unknown whether the project implemented the practice, this is noted in Table 5. The following subsections describe characteristics of both the unsuccessful IPR projects and the successful IPR and DPR projects that ultimately got implemented.

6.1 Unsuccessful IPR Projects

Of the six case studies, the IPR scheme proposed as part of Southeast Queensland government's Western Corridor Project and the City of San Diego's 1999 San Vicente Reservoir Augmentation Project failed. Neither project implemented many of the best practices established in Section 5.1. The outcomes of these two case studies provide several lessons learned that could benefit future DPR projects.

While the drought situation was well understood by Southeast Queensland residents, it is apparent that the government lacked sufficient time to reach out to the community about the project. This project was interesting because the Southeast Queensland government put the project up for a referendum, indicating that the government had good intentions of engaging the public in the project. However, the government did not seem to fully think through their approach in conveying the project to the public and after the public voted against the IPR scheme, the drought worsened. The situation was so bad that the government disregarded the results of the referendum and planned on implementing the IPR project anyway. Then, as soon as the drought ended, the government changed the project such that advanced treated wastewater would only be used when water levels in the system's reservoir were below 40%. Had the government conducted public outreach education efforts earlier in the planning process, consistent with best practices #s 5 and 6, it is quite possible that the IPR scheme would have received higher acceptance the first time it went to the public's vote.

Unlike the Southeast Queensland Project, the San Diego IPR project in 1999 conducted extensive public outreach efforts (consistent with best practice #5) but largely failed because the city's wastewater department did not clearly define the project need (best practice #1) and did not sufficiently engage with key City council members (best practice #6). Environmental justice issues also arose because the community near San Vicente Reservoir (proposed for augmentation with treated wastewater) misunderstood the project. Had the city more clearly defined the project and its need, such environmental justice issues could have been avoided. Similarly, had the project proponents made a concerted effort to gain support from all its city council members, the project's outcome may have been different.

Table 4. Summary of Case Studies, Challenges, and Best Practices Implemented

#	Case Study Name	Project Summary	Public Acceptance Challenges	Best Practices Implemented	Best Practices Somewhat Implemented	Best Practices Not Implemented
1	Namibia DPR Project	▪ Reconfiguration of the Goreangab water treatment plant; facility has been in operation since 1968 and provides 2 MGD of water that is blended with surface water. ▪ New Goreangab Water Reclamation Plant (5.5 MGD) was constructed in 2001.	▪ Public outreach efforts could improve. While most Namibians are aware of water source, residents of less than 10 years were unaware of the New Water Reclamation Plant.	1. Water supply problems clarified.	3. Connection between the water source and its water quality. 4. Dissemination of water quality monitoring could be improved. 5. Public outreach and education efforts could go farther. 6. Although most Namibians are satisfied with the drinking water source, outreach to wary groups could improve.	2 and 7. Unknown whether terminologies used imply water quality improvement or were clearly defined. 8. No project website or social media tools used.
2	NEWater Projects in Singapore	▪ NEWater plants began operating in Kranji and Bedok in 2003. ▪ Most recent plant has 50 MGD capacity and was opened in May 2010 in Changi.	▪ Public acceptance was and currently is high.	1.Water supply problems clarified. 2.Product water renamed. 3. "Yuck factor" broken. 4. Public educated about multi-barrier approach and water quality monitoring throughout treatment process. 5. Extensive public outreach plan. 6. Support from prominent government leaders. 7. Terminology used was clear. 8. Effectively uses project website and social media to educate public about project.	None	None
3	Western Corridor Recycled Water Project	▪ South Queensland government expedited construction of this project between 2006 and 2009 due to region's severe drought conditions. ▪ Construction of three 200-mile-long recycled water pipelines and three advanced water treatment plants	▪ Despite a referendum held in 2006 in which majority of citizens voted against project, government implemented project anyway due to drought conditions. ▪ Once drought ended, IPR scheme was demoted to only go into effect when dam levels below 40%.	1. Public fully understood critical water supply challenges.	None	2 through 8. Insufficient time to complete public education and outreach efforts. Unique case study since project was proposed during a severe drought.
4	OCWD Groundwater Replenishment	▪ 70 MGD advanced water treatment facility built in 2008 to purify wastewater.	▪ "Yuck factor" was a big concern based on consumer surveys	1. Clear definition of water supply challenges. 2. Renamed product water/used	None	None

#	Case Study Name	Project Summary	Public Acceptance Challenges	Best Practices Implemented	Best Practices Somewhat Implemented	Best Practices Not Implemented
	System	▪ Purified water then used to replenish Orange County groundwater basin.	conducted in 2000.	terms related to water quality improvement. 3. Break the water source and quality issue. 4. OCWD educates the public about water quality monitoring throughout advanced treatment process. 5. Extensive public outreach 6. Outreach to wary groups of people and community leaders. 7. Terminology was clear. 8. Project website and effective use of social media.		
5	CRMWD Big Springs Raw Water Production Facility	▪ 2.5 MGD raw water production facility was constructed in Big Springs, Texas in spring of 2013. ▪ 5-20% of the advanced treated water is mixed with surface water and then delivered to the nearby water treatment plant.	▪ Yuck factor was an issue continues to be a concern. However, due to the region's severe water shortages, the public has been generally accepting.	1. Clear definition of water supply challenges.	3. Broke the water source and quality issue. 4. Clarified that water is constantly monitored throughout advanced treatment phase. 5-7. Public outreach and education efforts could be improved.	2. Unknown whether terminologies related to water quality improvement was used. 8. No dedicated project website.
6	City of San Diego's San Vicente Reservoir Augmentation Project	▪ In 1999, the City of San Diego tried to implement an IPR project that entailed directing advanced treated wastewater in San Vicente Reservoir. Project failed due to stiff public opposition. ▪ Since then, the City has conducted additional studies and in 2007 proceeded with pilot project.	▪ Lacked support from one city councilmember that claimed he/she was not fully engaged throughout the process. ▪ Environmental justice issues. Due to lack of clear project definition, community near San Vicente Reservoir misunderstood the project and thought that the IPR water would be delivered to the neighborhood (although it was planned to be supplied to the entire city).	<u>1999 Project:</u> 5. Conducted numerous stakeholder meetings and public outreach. <u>Demonstration Project</u>: Appears to have implemented all eight best practices thus far.	None	<u>1999 Project</u>: 1. Lacked clear definition of project need. 3. Did not completely break the "yuck factor". 6. More outreach needed in the community near San Vicente Reservoir and city council members. 2, 4, and 7. Unknown whether practices were implemented.

Table 5. Best Practices Implemented by Case Studies

Best Practices	Case Study						
	Namibia DPR Project	NEWater IPR Projects - Singapore	Western Corridor Recycled Water – SE Queensland, Australia	GWRS – Orange County, CA	Big Springs Reclamation Facility – Big Springs, TX	San Vicente Reservoir Augmentation Project - San Diego, CA	
						1999 project	Demonstration Project
1. Water Supply Problems Clarified	✔	✔	✔	✔	✔		✔
2. Renamed the product water using terminologies related to improvement in water quality	Unknown	✔		✔	Unknown	Unknown	✔
3. Break the connection between water source and its quality ("yuck factor").	Somewhat implemented	✔		✔	Somewhat implemented		Somewhat implemented
4.Clarify the water quality monitoring process to ensure high water quality.	Somewhat implemented	✔		✔	✔	Unknown	✔
5. Extensive public outreach plan that includes stakeholder meetings, tours, community events, education.	Somewhat implemented	✔		✔	Somewhat implemented	✔	✔
6. Conduct outreach to targeted groups (e.g., community leaders, wary individuals).	Somewhat implemented	✔		✔	Somewhat implemented		✔
7. Use consistent terminology that is clear and understandable for general layperson	Unknown	✔		✔	Somewhat implemented	Unknown	✔
8. Develop project website and use social media to enhance public involvement.		✔		✔			✔

6.2 Successful Case Studies

For the purposes of this analysis, the Namibia, NEWater, GWRS and Big Springs potable water reuse projects are considered successful because all four ultimately got implemented. However, some of these projects did a better than others at implementing best practices. For instance, Namibia's DPR project fully implemented best practice #1 and somewhat implemented four practices (#s 3 through 6). The Big Springs project fully implemented best practice #1 and somewhat implemented best practices #s 3 and 5-7. Conversely, the NEWater and GWRS projects implemented all of the best practices listed in Section 5.1. Note that although the San Diego advanced water purification project is not complete as it is in the pilot project phase, Tables 4 and 5 show how well this pilot project implemented these practices as well.

All four successful projects and San Diego's demonstration project fully implemented best practice #1 (water supply problems clarified). These projects either fully met or somewhat implemented the following best practices. Discussion regarding each project's ability to implement these measures follows.

- ***#3*** (break the connection between the water source and its quality – "yuck factor")
- ***#4*** (ensure that public understands that water quality is constantly monitored throughout advanced treatment process)
- ***#5*** (public outreach meetings, tours, and events)
- ***#6*** (extend outreach to wary members and prominent leaders)

<u>Best Practice #1</u>

With respect to best practice #1, the water supply problems were well understood by the communities in Namibia and Big Springs for a longer period of time as both regions have faced severe droughts over the past century. Implementing this particular best practice for the NEWater and GWRS projects was possibly more crucial as the general public perhaps was not as well informed about water supply challenges in Orange County and Singapore, respectively.

<u>Best Practices #s 3 and 4</u>

Ensuring that the public got over the "yuck factor" through education (best practice #3) was crucial for all four projects. In a way, the City of San Diego is currently trying to achieve best practice #3 by implementing the pilot project as the sole purpose of the facility is to demonstrate that IPR technology is a safe and reliable drinking water technology. Regarding best practice #4, all four of these projects have conveyed to the public that the product water is constantly monitored throughout the advanced treatment process to ensure it meets drinking water standards.

Best Practices #s 5, and 6

Regarding best practices #s 5 and 6, NEWater, GWRS, and San Diego's water purification demonstration project fully implemented these practices as each project proponent carefully developed a public outreach plan that included various stakeholder meetings, free informational tours of the facilities, community events, and youth education programs. The Namibia project partially implemented these practices because the Namibian government did conduct public education and advertising campaigns at the beginning of the New Goreangab Water Treatment Plant project but in comparison to the other IPR projects, such efforts were short-lived. Based on the public survey conducted by Boucher et al. (2011), a large proportion of Windhoek's citizens were unaware of the New Goreangab Water Treatment Plant, indicating that public outreach and education efforts about this facility should continue to be implemented. As for the Big Springs project, CRMWD also conducted several public meetings but due to the level of opposition after facility construction was completed, it seems like the project would have benefited from additional outreach and education efforts.

Best Practices #s 2, 7, and 8

In addition to conducting extensive public outreach campaigns, the NEWater, GWRS and San Diego's water purification project developed websites and social media devoted to the IPR projects (best practice #8), used terms that reflected water quality improvement (best practice #2), and used terminology that was clear and understandable (best practice #7). In a way, implementing all three best practices seem to go hand in hand as development of a project website provides an opportunity for entities to develop a clear project message. These avenues of outreach and education also offer an opportunity to ensure that the message is consistent across all forms of social media. These three projects seemed to carefully develop a strategic marketing campaign that used terms implying water quality improvement such as "PureWaterSD" and "NEWater", and the GWRS logo consisting of water droplets symbolizes renewal. The websites of all three projects contain multiple links so that members of the public can easily find information about the IPR project, the project's background and need, educational materials, and contact information.

Conversely, no project websites were developed for the Namibia or Big Springs DPR projects and it is unknown whether these projects used terminology implying water quality improvement.

6.3 Other Considerations

As summarized above, the case studies that implemented most of the best practices are considered more successful in terms of gaining public acceptance than those that implemented fewer best practices. The success of the Namibia, NEWater, GWRS, and Big Springs projects is not, however, entirely due to the public outreach and education efforts conducted by the project proponents. This section describes other factors that may have contributed to the success of these four projects.

Although the Namibia and Big Springs DPR projects implemented fewer of the best practices but were successfully implemented, other factors such as water supply needs and cultural differences require consideration. Both Windhoek and west Texas are regions that have experienced severe droughts for over the last 50 years and have exploited most of their water supply sources. Although San Diego and Orange County are located in arid regions as well, the need for alternative water supplies was not as dire as for Windhoek and the Big Springs area in Texas. Additionally, it is unclear how Namibians and Texans' perceptions of DPR compare to Californians. Bearing these factors in mind is important when comparing the outcome of these two DPR projects to the other IPR projects and the future of DPR technology in California.

Secondly, while the NEWater project implemented the same best practices as the GWRS project, it is unclear whether all of the approaches are transferrable to future DPR projects in California. The highest level of government promoted IPR technology in Singapore; whereas in California, a project such as this would be promoted from local agencies. Cultural practices and social norms are also very different from California and the U.S. Therefore, it is unclear how Singaporeans' cultural differences influence public perceptions of IPR technology when comparing those perceptions to Californians.

7. Recommendations and Conclusions

This section includes recommended best practices for agencies interested in implementing future DPR projects in California. These recommendations are based on findings of the case study analysis, lessons learned, and review of project materials generated by the more successful case studies, as well as the technical and regulatory concerns addressed in Section 4.

7.1 Recommended Best Practices

Based on the case study analysis, it is apparent that both the GWRS and NEWater projects implemented all eight best practices and were the most successful in terms of gaining public acceptance. Given that gaining public acceptance for future DPR projects in California will likely be more challenging than IPR projects, it is recommended that water resource agencies consider implementing all of the best practices identified in Section 5. However, in reviewing which practices were met and somewhat met by the four successful case studies, it is recommended that project proponents prioritize best practices as follows:

- #1. Water supply problems in the project region should be clearly defined so that the public understands why the DPR project is needed.
- #3. Emphasize the high quality of the product water while de-emphasizing the source of the water.
- #4. Clearly describe the DPR treatment process, emphasizing the multiple treatment barriers and the monitoring process to ensure high quality water is created prior to distributing the product water to customers.
- #5. Develop a formal public outreach and education plan that includes stakeholder meetings, public tours, community events, and youth education programs.
- #6. Extend outreach efforts to prominent community leaders (e.g., city council, mayor) and groups that are apprehensive about the DPR project.

The above-listed practices are considered higher priority than the others. However, if resources are available, implementation of the three remaining best practices is also recommended:

- #2. Rename the produce water using terms related to water quality improvement. Avoid terms like "treated wastewater," "reclaimed water," and "reuse".
- #7. Use consistent terminology so that it is clear and understandable to the general layperson.
- #8. Develop a project website and use social media so that the public can easily find information about the DPR project.

The last two best practices can be easily be incorporated with the other above-mentioned practices.

7.2 DPR Project Planning Recommendations

Before even implementing the above-described best practices, several other big-picture steps should occur in the DPR project-planning phase. The following sub-section describes additional key practices that agencies should consider when planning a DPR project in California. This information was developed based on communication with staff involved in the GWRS and Big Springs projects, and publicly available information about San Diego's water purification demonstration project's public outreach and education process.

7.2.1 Research

Agencies that are interested in pursuing DPR projects should start the planning process early and conduct public surveys to understand the community's perception of DPR technology. Based on the multiple case study evaluation, several of the potable water reuse projects required at least ten years of planning or more before project construction was completed. For example, the Big Springs DPR project began planning in 2002 and was implemented in 2013. As seen in the San Diego case study, it has taken one project failure and over 10 years for the city to gain a relatively high level of acceptance for IPR technology. Substantial time will also be needed to engage with regulatory agencies like the SWRCB and applicable RWQCB, develop engineered project designs, and conduct the environmental review process.

Public opinion surveys can be conducted various ways. One way to obtain feedback from communities easily is to enclose questionnaires with water utility bills that get sent to residents. Surveys can also be conducted via phone, one-on-one, or by interviewing focus groups. Ideally, an independent party should conduct these surveys to ensure that responses are unbiased. Water agencies can even partner with local universities to gain assistance with these surveys. For example, a research methods class at San Diego State University helped conduct in-depth interviews with local residents for the City of San Diego. Students at Worcester Polytechnic Institute also helped the City of Windhoek by conducting a public perception analysis of water reuse for drinking purposes.

7.2.2 Develop and Implement a Public Outreach and Education Plan

Once water resource agencies have a baseline understanding of the community's stance on DPR technology, they should then develop a strategic public outreach and education plan to address the community's concerns. At this point in the planning phase, resource agencies should consider which best practices (identified in Section 7.1) should be implemented. Survey results will inform which strategies and practices should be focused on in more detail. Examples of public outreach and education materials that should be addressed in the plan are described in more detail below.

Public Outreach and Education Materials

Informational materials developed to explain information about a DPR project and the science behind the purification process should be tailored to the interests of various audiences and should be available in both hard copy and electronic versions. Similarly, all outreach and education materials should be translated into other languages such as Spanish and possibly Chinese and Vietnamese (depends on the demographics). Based on review of the materials developed for the GWRS (OCWD, 2013) and San Diego's Water Purification Demonstration Project (City of San Diego, 2008), example materials that should be developed include:

- **Fact Sheet.** A simple one-page fact sheet that provides a brief summary of the DPR project highlighting the need for the project, and schematic of the advanced purification process. This sheet can be distributed at public meetings, community events, at public tours, or can be left at City Council offices.
- **Information Card.** Similar to a fact sheet, an informational card that is business card-sized should be developed. This card should have a few information points or project messages that can be distributed at meetings and events. It should also contain links to project websites and contact information.
- **FAQs.** Frequently asked questions (FAQs) provides water agencies the opportunity to further explain any misconceptions about the project or technology. FAQs can be posted on a project website or formatted on a handout.
- **Table Top Displays.** When conducting outreach at community events, water agencies should plan to have a poster board and other handouts that are ready for table-top display.
- **Media Kit**. Similar to was done for the San Diego project, water agencies should develop a media kit so that staff are prepared to distribute project information to local and national media representatives in a consistent manner. The media kit should consist of the FAQs, project fact sheet, any white papers developed about the project, brochures, and other relevant materials.

- **Website.** While addressed as best practice #8, having a website should serve as a hub for publicizing almost all public education and outreach materials including a fact sheet, information card, project background, facility tour registration, FAQs, contact information, links to social media pages, any PowerPoint presentations, white papers, and testimonials from community leaders.

Additional Best Practices

In addition to the best practices identified in Section 5, based on conversations with staff at CRMWD and OCWD, a few other recommendations arose that should be considered by future DPR projects. Both entities found that people in general do not know much about their water supply. Therefore, when addressing the need for a DPR project (best practice #1), water agencies should clearly describe where the community's water supplies come from. Not only would people better understand the source of their drinking water, but also realize that most water we drink is recycled to some degree.

The GWRS program manager emphasized that in addition to gaining support from both local community leaders and state officials, garnering support from health professionals in the form of testimonials was important for the GWRS project's success (M. Patel, personal communication, November 17, 2014). In line best practice #6, Mr. Patel also stressed that educating key groups like women, mothers, minorities and the elderly was also important. Lastly, the CRMWD water systems operation manager further confirmed that offering public tours and water tastings were crucial in changing public perceptions of DPR technology (J. Womack, personal communication, November 18, 2014).

7.3 Summary and Conclusions

Going forward, it is foreseeable that DPR will someday be part of California's water supply portfolio; thus water resource agencies interested in this alternative technology should start thinking through upcoming challenges. Some of the primary concerns related to DPR pertain to CECs present in the water, compensation for loss of an environmental buffer, and the need for multiple barriers to ensure that the water meets USEPA drinking water standards. As CECs continue to be a concern for all water resources, DPR technology will also need to continue evolve. Furthermore, as regulations for DPR are already underway, it will be interesting to see what the SWRCB and RWQCBs require of water resource agencies and it is expected that the regulations for CECs will only become more stringent.

Gaining public acceptance is the biggest challenge to overcome for DPR projects and many factors require careful consideration. As addressed in the case study analysis, some potable water reuse projects like the Southeast Queensland project and the City of San Diego's IPR project in the mid-1990s practically failed because specific practices were not implemented. Because no DPR project has been implemented in California yet and knowing that members of the public will generally be more apprehensive about this type of technology in comparison to IPR, it is possible that future DPR projects may need to go farther than IPR projects in order to gain public acceptance. For this reason, it is recommended that all eight best practices (evaluated in the case study analysis) as well as the additional best practices identified in Section 7.2 be implemented. Education should emphasize the multiple treatment barriers used to compensate for the lack of an environmental buffer and emphasize the health and safety of this treatment technology. These tools and practices will hopefully ensure greater public acceptance over time and an overall smoother planning process for future DPR projects.

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