Sherwood Design Engineers
One Union Street, 2nd floor
San Francisco, CA 94111
t [415] 677-7300
f [415] 677-7301
info@sherwoodengineers.com

Water Management Challenges in the Loreto Region

Baja California Sur, Mexico

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1 Executive Summary

The Loreto region in Baja California Sur, Mexico is experiencing rapid growth in the tourism and land development sectors. In light of this trend, planners are anticipating a parallel growth in demand for potable water supply, which is already stressed in Loreto's arid climate. According to the *Alternatives Future Study for Greater Loreto (Steinitz, 2005)*, the potential for water demand to exceed the existing water resources in the region is probable without intervention. In response, decision-makers are considering desalination technology as an option to supplement existing potable water provisions. This paper investigates next steps for effectively managing Loreto's water resources as well as the best practices of desalination technology in providing additional potable water sources within the context of the Loreto Urban Development Plan.

The response to these challenges should include a combined effort including water conservation, efficiency upgrades to existing infrastructure, augmentation of existing resources, and an investigation of the feasibility of desalination facilities. Prior to pursuing desalination, it is essential to investigate the potential for better use and management of existing water resources. This includes evaluating the potential for water conservation measures and quantifying the increased water benefit realized from their implementation. The assessment of existing infrastructure should occur in conjunction with conservation measures.

The process of desalinating seawater into potable water is not a new technology. A wide range of methods exist for accessing saline water, removing salts, and disposing of desalination waste, each process having impacts to the environment. Current methods used to intake water and to dispose of waste brine can be intrusive to marine environments. Today, the preferred technology to desalinate brackish and seawater is reverse osmosis (RO). Reverse osmosis technology persists as a feasible desalination solution typically due to lower energy and land use requirements.

The products of desalination processes are a high-quality potable water resource and an extremely saline, brine waste effluent. Many challenges are posed when integrating a desalination plant with existing potable water infrastructure, but more difficult, is the sustainable disposal of the highly saline waste stream. To date, saline effluents are discharged back into large bodies of water, usually into the ocean. Disposal of desalination effluent in this manner poses a significant environmental threat with regards to the unique marine life and habitat of the Loreto region.

This document lays out a set of desalination best practices that should be incorporated in the design and siting of a desalination facility. There are no collective best practices for desalination in any environment; rather best practices are site specific to each location's natural and development constraints. The best practices for desalination technology should be based on site conditions, the quality of water needed, the availability of engineering and construction resources, and the potential impacts to existing water resources such as aquifers. At best practices should include methods for intake of brackish groundwater, alternative methods for pretreatment, specific desalinating processes, and brine disposal.

The Loreto region has specific constraints associated with siting a desalination facility. These include the presence of the Loreto Bay National Marine Park and the location of existing water supplies. Additionally, the existing infrastructure and rapid growth of the region accelerate the potential development of individual desalination facilities. The community's application of best practices and their understanding of how desalination will shape the future of the region will be pivotal in determining Loreto's future.

2 Introduction

The Loreto region is an ecologically unique and historic region situated in a coastal setting on the east coast of Baja California Sur, Mexico (Figure 1). Loreto is in a phase of development that is extending the use of its natural resources, particularly potable water. Often development can be inhibited by the lack of electricity, potable water, and adequate waste disposal facilities. As the use of alternative resources is investigated, it is important to understand the social, economic, and environmental implications of accelerating the pace of development beyond existing natural resource levels.

The Loreto region has specific constraints associated with siting a desalination facility. These include the presence of a marine park and the location of existing water supplies. Additionally, the existing infrastructure and rapid growth of the region accelerate the desire of some residents to develop private desalination facilities. The application of best practices and understanding of the implications of how desalination will shape the future of the region will be a pivotal component to approaching a well-integrated and productive solution.

Upon its establishment in 1973 by the Mexican federal government, FONATUR (Fondo Nacional de Fomento Al Turismo, or the National Trust Fund for Tourism Development) identified five destinations in Mexico with the highest future tourism potential: Cancun, Los Cabos, Ixtapa-Zihuatanejo, Huatulco and Loreto. Loreto is the only one of these areas that has not been developed into a prime tourist destination, mainly owing to its poor quality beaches and historic lack of private investment. As a result, the success of the Loreto market will depend more on the preferences of homeowners looking for short-term luxury stays in ownership properties than on tourists seeking specific resort features. Such ownership markets have the potential to develop their public infrastructure in a more comprehensive and community-based manner than markets built up as traditional tourism destinations. FONATUR currently owns nearly 30 square kilometers of land in the Loreto area that is intended for development, mainly in Nópolo and the Puerto Escondido-Ligui region (Steinitz et al. 2005).

In 2005, the "Alternative Futures Study for Greater Loreto", led by Carl Steinitz of Harvard University's Graduate School of Design examined possible population growth scenarios in response to a FONATUR-proposed urban development plan. The study examines the effects of economic performance, demographic changes, private and public investments and public policy on conservation and urban development in the Loreto region in Baja California Sur, Mexico. Projections made in the study consider the next two decades in an effort to assess how such changes will inevitably impact the region's natural landscape, as well as its social, economic and aesthetic features. The study presents various *alternative futures* for the Loreto region through the use of computer based, digital models that evaluated the regional appeal for the major land use types of the area through 2025 (see www.futurosalternativosloreto.org for the full report).

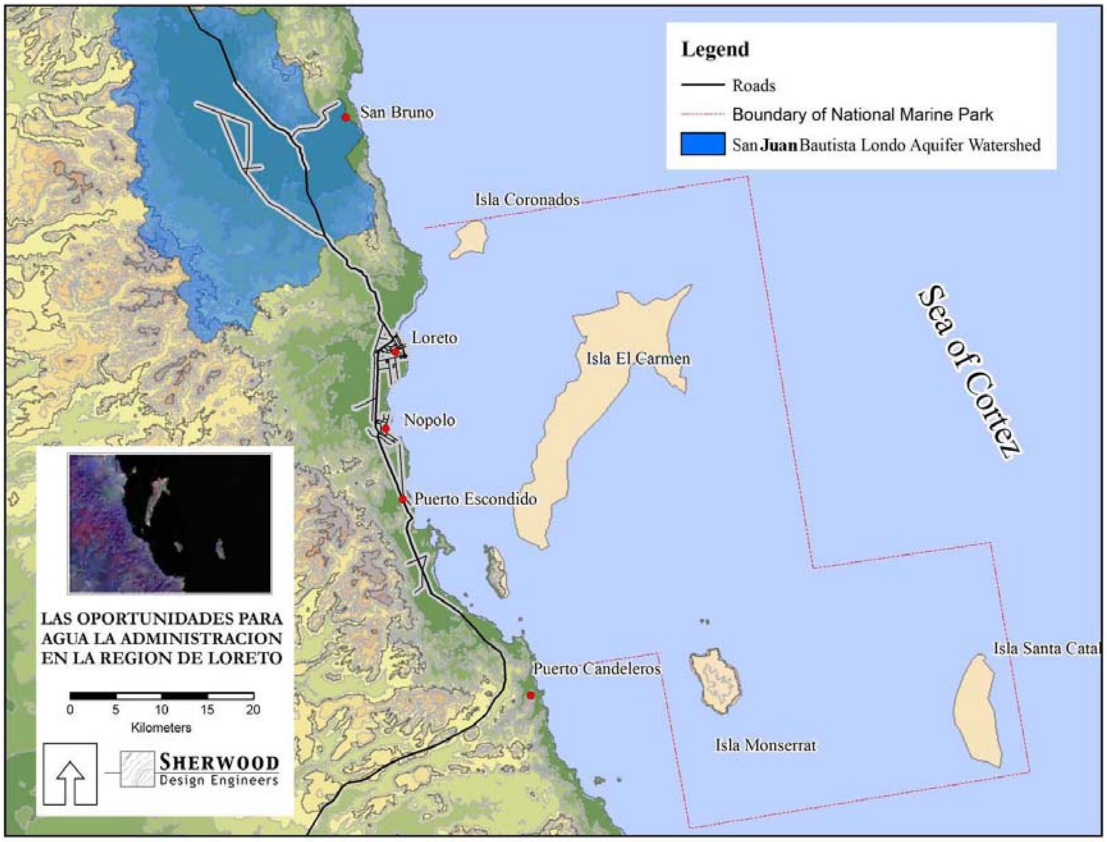

Figure 1: Regional Map of Loreto and Surrounding Towns

These digital models prepared for the *Alternative Futures Study* were also used to predict the economic, ecological, hydrologic and visual impacts associated with each alternative across a range of policy options. The options covered five build-out population scenarios: 30,000, 60,000 and 90,000, each with a population to rooms ratio of 15:1; 120,000, with a population to rooms ratio of 10:1; and 240,000, with a population to rooms ratios of 20:1 (Steinitz et al. 2005).

- *Sin Planeacion* presumes that all land in the Loreto region is available for development. Nevertheless, those areas with especially steep slopes or frequent flooding are not included in order to account for probable behavioral choices of landowners and developers.

- *Plan Propuesto*, proposed by FONATUR, Mexico's tourism development agency, envisions an increase in Loreto's full-time population from approximately 15,000 to 240,000[1] and an introduction of 12,000 tourist-geared rooms (hotel, time shares and condominiums) by the year 2025 (Steinitz et al. 2005).

- *Loreto 2025* is the name of a local organization, consisting of civic and business groups, that developed an alternative to FONATUR'S Plan Propuesto. The Loreto 2025 plan, however,

[1] Using the SEMARNAT official standards of 20:1 ratio of residents: hotel rooms yields a population of 240,000 residents for 12,000 hotel rooms. The published FONATUR plan used a ratio of 9.7:1 (or 116,400 residents for 12,000 hotel beds.

seeks to restrict population growth in Loreto to 60,000 and restricts most of the future growth to the northern areas immediately surrounding Loreto (Steinitz et al. 2005).

- *Proactivo Moderado* focuses on the protection of important "public goods", such as those considered hydrological, ecological, visual, recreational and economic assets. Areas that are considered ecologically or visually valuable, in addition to areas that are subject to hurricane flooding, arroyos (which flood frequently), areas with valuable biodiversity, steep slopes and high-quality view corridors, are protected in this policy option.

- *Proactivo Muy Regulado* establishes the same guidelines as those used in *Proactivo Moderado*, though its policies on visual protection are much more stringent; as a result, there are further restrictions placed on land development in the region.

The study concludes, "any future development must find an alternative water source for that development and the associated growth in supporting population" (Steinitz et al. 2005). The premise of this report is that this "alternative water source" can best be acquired in the short term through resource protection and enhancement possibly coupled with the development of an entirely new source, desalination. The basis for protection and enhancement, which primarily consists of conservation, infrastructure upgrades and expansion of existing supplies, will first be examined, but the focus will be on evaluating the current state of desalination technology and identifying the environmental risks and technical constraints associated with its implementation.

3 Background of the Loreto Region

3.1 General

The first Spanish town established on the Baja California Peninsula, Loreto was once the capital of Las Californias (Baja California, which originally included all of the Mexican peninsula, and Alta California, which was composed of the current American states of California, Nevada, Utah, Arizona and Wyoming) from 1697 to 1777 and presently serves as one of the five municipalities of the state of Baja California Sur. Approximately 16,000 people comprise the population of the region, of which the majority live in the town of Loreto.

3.2 Loreto Bay National Marine Park

The Loreto region also includes a dedicated marine protected area. The Loreto Bay National Marine Park, depicted in Figure 1, encompasses an area of nearly 2,065 square kilometers, which encompass most of the ocean included in the study area used in the *Alternative Futures Study* (Steinitz et al. 2005). Originally established by a Presidential Decree, the Loreto Bay National Marine Park was approved by the Mexican Federal Congress on July 19, 1996 and was designated as a UNESCO World Heritage Site by the United Nations on July 14, 2005. The ecological significance of the 510,253-acre Loreto Bay National Marine Park Bay is derived from its location in the Sea of Cortez, which is home to 35% of the world's marine mammal species, 60% of all cetacean species on Earth, species of(which include whales, dolphins porpoises) and nearly 800 fish species of fish (The Nature Conservancy, 2006).

Biodiversity in the Park is high with over 1,000 species of plants and animals that represent 33% of the species present in the Sea of Cortez. Of those, 139 are classified as endangered, threatened, rare, or under special protection, and are therefore protected by law (Lopez et al. 2006). In addition to the biodiversity and wildlife value of the region, fishing for sustenance and for sport is widely popular, and contributes to the culture and the economy that sustain the existing population of Loreto.

4 Existing and Predicted Population Growth and Water Demand

4.1 Current Potable Water Resources and Use in Loreto

SAPAL (Sistema de Agua Potable y Alcantarillado de Leon, or the Leon Water and Sewer System) operates the existing municipal water system that provides service to seven communities in the Loreto Region under the authority of Comisión Nacional del Agua (C.N.A). The primary water source for the town of Loreto and a portion of the water resource for the community of Nópolo is the San Juan Bautista Londo Aquifer depicted in Figure 1. The aquifer is located approximately 30 kilometers to the northwest of Loreto, and it is serviced by four wells operated by FONATUR that extract groundwater and distribute it throughout these two communities. Nópolo's water supply is augmented by 2 deep wells that operate in an area known as the "Twins". Water supply wells previously operated in the Loreto groundwater basin, but were determined to be unusable approximately 20 years ago because of contamination. For this reason, there is currently no municipal use of groundwater from the Loreto aquifer (Quintero 2006).

SAPAL estimates that the existing distribution system wastes between 30% and 40% of its water through normal usage due to leaks and inefficient infrastructure. Per capita, Loretanos use approximately 513 liters/day, compared with the standard water use in Baja California Sur of 300 liters/day. Therefore the 16,000 Loreto region residents consume an amount equivalent to that typically consumed by over 27,000 people, or 8,200 m^3/day. The aquifer also serves agricultural uses to the north of Loreto in the San Juan Londo Basin, although there are no available estimates of the volume of this use (Quintero 2006).

4.2 Predicted Water Use in Loreto

Without significant advocacy efforts, it is not anticipated that water use patterns will change as Loreto grows, so Loretanos' consumption of water is not expected to significantly decrease. Unless mitigation measures are applied to encourage conservation and upgrade existing infrastructure, it is expected water use rates per capita will remain near where they are today. Table 1 below shows the projected water use in the Loreto Region as determined by the Alternative Futures Study.

Population in 2025	Sin Planeacion (m^3/day)	Plan Propuesto (m^3/day)	Loreto 2025 (m^3/day)	Proactivo (m^3/day)[1]
30,000	**18,000**	**15,000**	**15,000**	**15,000**
60,000	**32,400**	**27,000**	**27,000**	**27,000**
90,000	**42,750**	**36,000**	**36,000**	**36,000**
120,000	**49,800**	**42,000**	**42,000**	**42,000**
240,000	**84,000**	**72,000**	**72,000**	**72,000**

Table 1: Predicted Water Use in Loreto (Steinitz et al 2005, Quintero 2006)

1. The estimated water demands for the Proactivo Moderado and Proactivo Muy Regulado growth scenarios are combined in Table 1 since their water use and population are the same.

4.3 Challenges of Future Water Supply

Loreto's existing water supply would not support the per capita demands associated with the population predictions described in the *Alternative Futures Study*. A hydrogeologic study prepared by the University of Arizona in support of the *Alternative Futures Study* predicted that under existing recharge conditions; the San Juan Londo Aquifer system would experience seawater intrusion under all of the growth scenarios proposed for Loreto. Some of this intrusion is expected to occur within the next three years under the *Sin Planeacion* growth scenario *(Maddock 2005)*. An additional study released by Sociedad Hístoria Natural de Niparajá also predicted that demands on the aquifer would exceed its sustainable yield in the future, although not because of seawater intrusion. Sociedad Hístoria Natural de Niparajá concluded the major risk in the aquifer is contamination by thermal waters, containing boron and sulfate among other contaminants. This contamination is expected to occur even if there is no additional development within the Loreto Region and groundwater extraction continues at current rates. (Cassassuce 2006).

These recent studies of the San Juan Londo aquifer system, coupled with the projected water demands presented in Table 1, make it clear the Loreto region will face significant water supply challenges in the future. The existing population is currently using approximately 8,200 m^3/day and is expected to use anywhere from twice to ten times that amount within 20 years according to the population predictions in the *Alternative Futures Study*. The cited groundwater analyses both found deficiencies in the existing sustainable yield of the aquifer system, and both predict overdraft conditions if current growth rates and water use continue. As growth continues in Loreto, the existing water supply will simply not meet the demand.

5 Opportunities for Water Management in Loreto

As mentioned in the Introduction, local decision-makers have four opportunities to improve existing water supply conditions, as well and prevent future shortages in Loreto. They are water conservation, improvements to infrastructure, expansion of existing freshwater resources, and development of new water sources. Although the specific water savings that can be achieved through implementation of the first three measures cannot be quantified without additional study, all have well-documented track records as effective, cost efficient ways to stretch existing supplies. As a result, their potential should be thoroughly evaluated before resources are committed to developing more costly and potentially more environmentally damaging alternative water sources.

The preparation of a regional water management plan is the first step in determining the applicability of conservation, infrastructure improvement and supply expansion measures to Loreto's particular water supply and delivery conditions. Water management plans begin by quantifying existing water demands and existing sources of supply, and then establish service goals and make projections for anticipated future loads on the regional water system. These documents are often completed in conjunction with a planning effort or the development of an Urban Development Plan and can be extremely useful in determining if water supplies match plans for population growth[2].

5.1 Improving Water Conservation

In a region where water resources are stretched by the increase in development, the most practical method is to adjust current water use patterns to maximize the existing water supply. Water conservation measures represent the first best practice related to adapting an existing water supply to a growing population. However, actual water savings must first be quantified relative to the implementation of specific conservation measures. Comparing the volume of water savings associated with each measure to the cost of implementation will determine whether the measure is both feasible and cost effective. In addition, this comparison will illustrate the degree to which it can help forestall the development of additional water resources needed to support future growth.

Monitoring how Loretanos are using water in their residences and businesses should be the first step in developing a conservation strategy. The most effective way to do this is by installing meters (which can also provide a means of controlling water use, as described below) for all industrial, commercial and residential end users of water. Currently only 37% of end users of the water distribution system have meters installed (Quintero 2006). Increasing the number of meters will improve the overall understanding of the water system and how the actual water demand is distributed. While the metering program gets underway, preliminary information can be obtained through the use of consumer surveys. Such surveys can often reveal users' underlying water use preferences and potentially wasteful habits, providing early insight into the types of community-wide behavior modification that may be needed to achieve real conservation savings.

[2] The California Department of Water Resources provides a guidebook for water purveyors to develop Urban Water Management plans on their website (http://www.owue.water.ca.gov/urbanplan/docs/GuidebookUrban.pdf). This guidebook outlines conservation measures and forces the users to apply realistic use number to anticipated populations.

Aside from these efforts to quantify and understand existing water use, water purveyors (primarily SAPAL in the Loreto Region) and local governments can also join together to limit future water use through a combination of public education, institutional modifications and financial incentives. Examples of such programs that have worked for other communities include:

- Educate directly in public schools, on the value of water conservation. As the population grows the next generation becomes decision-makers, thus automatically altering water policy in the future.
- Educate the general public using public service announcements and advertising throughout the region.
- Offer financial incentives for the public when they are responsible for identifying and repairing private leaks.
- Apply limits and fees for wasteful activities such as washing driveways and sidewalks instead of sweeping, watering lawns during the day, etc.
- Institute financial incentive programs for commercial, industrial, and institutional accounts to participate in and promote conservation in everyday practices.
- Require water purveyors to dedicate a member of their staff as a water conservation coordinator to centralize conservation efforts, making the program more efficient and easier for the public to access.
- Institute financial incentives that use a tiered billing system; customers using less water are rewarded with lower prices.
- Require water purveyors to audit residential customers and make them aware of both their water usage and their potential to receive incentives or reduced water costs.
- Require that public and large-scale private landscaping consist of drought-resistant plants native to the region so that supplemental irrigation is not necessary.
- Offer incentives for retrofits of household appliances with reduced water demands, such as high efficiency washing machines, low flow shower heads, or ultra-low flow toilets.

5.2 Investing in Existing Infrastructure

Based on the existing conditions of the potable water infrastructure in the Loreto region, there is an opportunity to capture water lost to leaks and inefficiencies throughout the system. Repair of infrastructure may allow the existing water resources to accommodate a larger percentage of the increasing water demand. The estimated volume of water lost in the system must be quantified (it is currently estimated between 30 and 40% by SAPAL) and the capital investment associated with the repair of the system calculated. Methods to identify leaks and estimate the volume lost and repair costs include: installing and periodically calibrating customer meters, pressure tests, and computer modeling of the distribution system.

It is necessary for an infrastructure assessment to be performed on the 40 year-old water system in Loreto and to determine the specific needs for new construction, repair and reconstruction in order to offset the need to develop additional water resources. This effort should occur regardless of the development of additional water resources in Loreto because, once, additional supplies are made available, a significant portion of those supplies will still be lost with the infrastructure as it stands today. The relatively small capital investment associated with assessing the cost of repair to existing infrastructure and the augmentation of existing water supplies should provide reasonable and necessary options before developing an additional water resource, such as desalination.

5.3 Expansion of Existing Resources

Aside from reducing water use through conservation and limiting water losses through infrastructure repair, it may be possible to expand Loreto's existing water supply by:

- Identifying enhanced recharge options and locations to augment the existing wells in the San Juan Londo Aquifer system;
- Investigating the potential to replace some existing water used for landscape and golf course irrigation, as well as for other non-potable uses, with reclaimed water.
- And, determining whether existing groundwater contamination around the old wells in the Loreto groundwater basin can be effectively remediated.

Enhanced recharge would involve an expansion of the studies performed on the San Juan Londo Aquifer system. The development of a recycled water resource would require an investment in the existing wastewater treatment plants in the region. The improvements needed to raise treatment to levels suitable for recycling and to install the associated treated effluent distribution system can be very costly, but they could potentially provide an additional benefit by reducing wastewater discharges to the Marine Reserve. The potential for remediation of existing wells in Loreto would require testing of the wells in conjunction with an evaluation of why the wells were decommissioned approximately 20 years ago.

5.4 Alternative Water Resources: Desalination

The construction and operation of a desalination plant requires feasibility studies and decisions regarding system components. The following sections provide basic information about existing desalination technologies, describe the infrastructure and support facilities required to operate a desalination plant, and identify the most financially and environmentally responsible options for implementation of a desalination program.

5.4.1 Historical and Current Application

Desalination is the process of removing dissolved solids or salts from water in either a brackish water or seawater environment. Desalination has been historically used to produce water to accommodate the need for ultra-pure process water for industrial purposes. Power plants and manufacturing processes that require steam use desalination technology to address concerns of scaling, corrosion, and steam efficiency. Desalination of seawater along the shoreline has the benefit of an unlimited supply of water and an accessible source for cooling.

In the past, desalination for industrial purposes tended to utilize thermal processes, which have historically been inefficient and energy intensive. With the development and refinement of more recent desalination technologies, such as Reverse Osmosis (RO), it has become more feasible to produce a potable, municipal water supply through desalination. The basic technical concepts surrounding desalination processes are presented below.

5.4.2 Intake Facilities

Source water for desalination can be acquired in multiple ways. Source water is generally comprised of either seawater or brackish groundwater. Current methods of obtaining delivering source water are described below.

General Issues: Siting, Cost and Environmental Concerns

Seawater desalination facilities require an intake system capable of providing an accessible, reliable quantity of clean seawater with minimum ecological impact. To meet these objectives, it is essential that a comprehensive evaluation of site conditions be performed. Physical characteristics, oceanographic conditions, marine biology, and the potential effects of fouling, pollution, and navigation must be evaluated. Intake designs are highly site specific, potentially more than any other characteristic of the desalination facility, and can represent as much as 20% of the capital cost of the entire facility (Pankratz 2004).

It is important to consider marine life impingement and entrainment associated with intake designs, including hard-to-quantify constraints that may represent the most significant direct adverse environmental impact of seawater desalination. Technologies for seawater intake facilities range from large surface water intakes along the shore, to offshore intake structures, to screened wells onshore. Each technology poses different challenges in the forms of design, power consumption, and environmental considerations. However the most significant environmental concern when designing open seawater intake facilities is the impingement and entrainment of marine life.
Impingement, which occurs when larger marine life is trapped in or against the screens, is relatively easy to mitigate using available technologies. However entrainment is much more difficult to control, since it involves very small and microscopic organisms (such as phytoplankton, zooplankton, eggs and larvae) that are pulled through the screen and into the intake. This can lead to a decrease in recruitment to the local habitat, as well as a decrease in the overall productivity of the ecosystem, adversely affecting the commercial and recreation fishing opportunities in the region (Lopez 2006).

Open Water Intakes

Open water intakes extract water from the ocean or sea and can be sized to have unlimited capacities. The main concern when designing an intake is to prevent marine life and other debris from entering the desalination system, not only because of the impact on marine life, but also because, as described in a subsequent section, it can foul the desalination membranes. The three main technologies currently used to address these concerns associated with direct sweater extraction are listed below.

- *Traveling Water Screens* consist of large wire mesh panels used to prevent the intake of debris or marine organisms. Panels revolve for cleaning and can be located directly onshore or at the end of a long channel, intake pipe, or forebay that extends beyond the surf zone.
- *Velocity Caps* consist of an offshore intake in a T-shape that converts vertical flow to horizontal flow to reduce fish impingement and entrainment.
- *Passive Screens* utilize slotted screens aligned on a horizontal axis with the ultimate intake extracting water on a vertical axis as shown in (Figure 2). Often the passive screens are constructed of significantly larger pipe than the ultimate intake pipes, to reduce flow velocities.

Figure 2: Passive Screen Intake (Photo: Courtesy of Euroslot Industry)

Subsurface Intakes

Subsurface intakes employ the concepts of groundwater extraction within a coastal environment. Because they draw in water through saturated sand beds or other pervious, underground strata, they generally have little or no impact on local marine life, and can provide a prefiltered water source for the desalination process. For this reason, particularly within sensitive marine environments like Loreto's, subsurface wells are utilized where permitted by cost considerations and geologic conditions. And because these wells rely on the permeability and the stability of subsurface materials, as well as on the reliability of the subject groundwater source, all require detailed geotechnical evaluation prior to construction. The three major types of subsurface intakes are detailed below.

- Seawater Beach Wells – A typical beach well consists of a perforated intake pipe that extends offshore beneath the ocean floor, as depicted in Figure 3. These systems can usually supply desalination plants with a capacity of approximately 19,000 m^3/day or smaller (Pankratz 2004). Currently Loreto uses approximately 8,327 m^3/day. Therefore without implementation of the previously described conservation and infrastructure upgrade measures, 19,000 m^3/day would serve approximately 36,000 Loretanos.

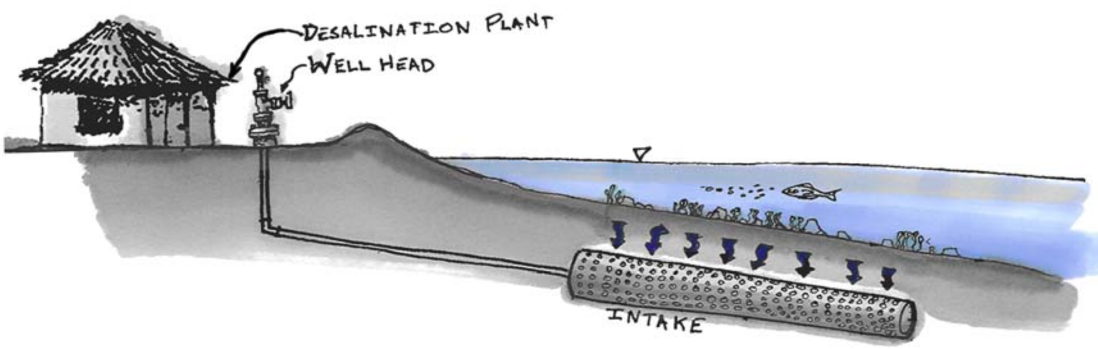

Figure 3: Schematic of Seawater Beach Wells

- Radial Subsurface Wells – This particular design includes a large capacity sump or well caisson that is connected to a series of horizontal wells that run along the seafloor, depicted in Figure 4. Capacities for this subsurface intake are generally high. A single caisson could likely serve the existing population of Loreto. Actual production rates are dependent on the number of intakes and the underlying geologic conditions. These wells also benefit from the natural filtration of material on the seafloor. If installing horizontal wells is not cost effective or if the seabed material is not conducive to this application, infiltration galleries can be constructed instead. Infiltration galleries share the same concept of radial subsurface wells, but the horizontal wells are replaced by excavated trenches that are backfilled with gravel or other filter material. The effects of constructing infiltration galleries can be disruptive to marine systems and may significantly affect the marine environment in sensitive areas such as productive reefs.

- Brackish Beach Wells –This technology is similar to that employed in seawater beach well extraction. The primary difference is that the intake facility is typically placed farther inland than the seawater beach well shown in Figure 3. These wells capture brackish water with a significantly reduced salt content, typically less than 5,500 parts per million, in comparison to seawater, typically 45,000 parts per million. Because brackish water is essentially "cleaner," it is easier and far less costly to remove the salts, making it a preferred source when readily available.

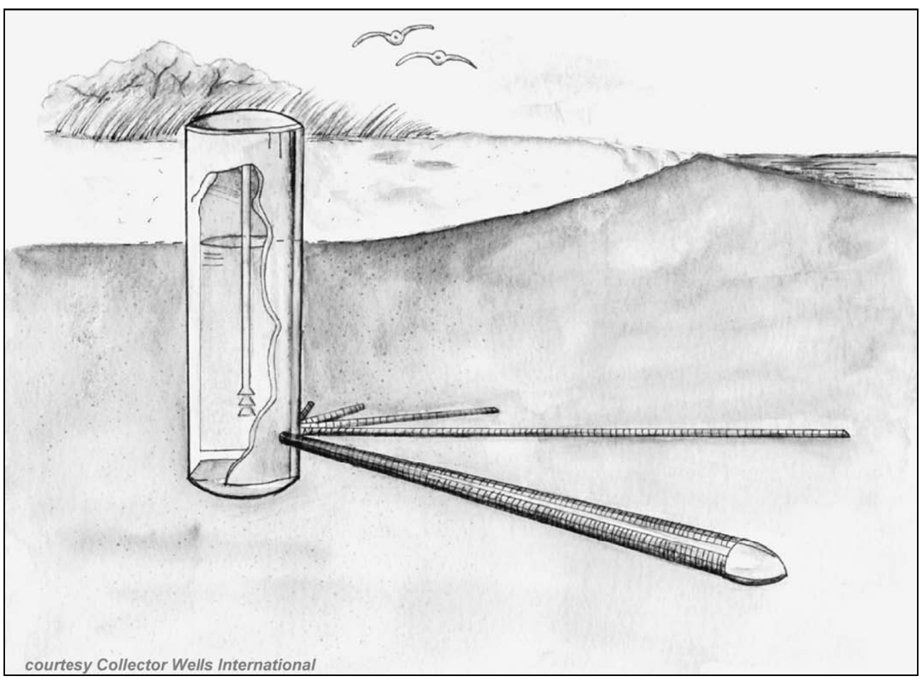

Figure 4: Radial Horizontal Well Illustration

5.4.3 Process Technologies

No single desalination technology is considered a panacea for producing potable water. Most technologies use either thermal or membrane processes, however other technologies exist and many more are under development. Desalination technologies need to be chosen based on site specific conditions including salt content, accessibility to engineering and construction services, and the quality of water needed by the end user. Often, maintenance requirements for a given technology will determine the type of system chosen for desalination plants.

Technology Trends

The current trends in desalination applications are dependent on source water specifics, power availability, the date when the desalination facility was installed, and the ultimate use of product water. Prior to the development of membrane processes, desalination was accomplished primarily through variations of thermal distillation technologies (which include multiple stage flash evaporation and multiple effect distillation). However, by the year 2000, membrane processes represented 79% of the 13,600 desalination plants operating worldwide (Glueckstern 2004). The preference for membrane systems, specifically RO, over other techniques is due in part to the development in recent decades of membranes with higher recovery rates and lower pressure needs, making them more efficient to operate. The application of different desalination technologies worldwide with respect to volume of product water produced is presented below in Figure 6.

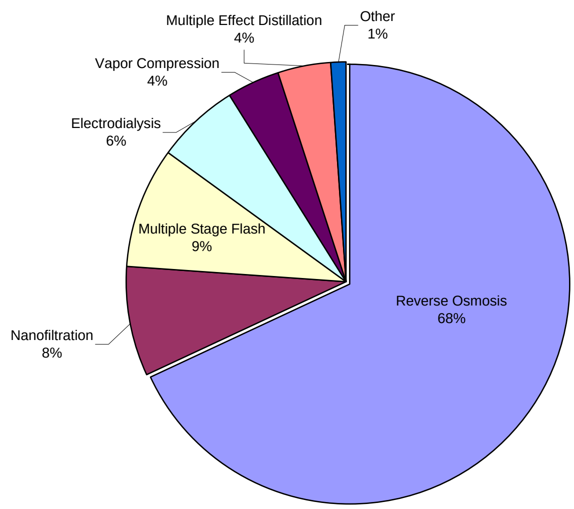

Figure 5: Desalination Technologies Capacity Worldwide (Glueckstern 2004)

The source water for desalination differs from region to region based on access to the ocean, supply of brackish groundwater, the water supplier's ability to produce (and public acceptance of using) recycled wastewater, and the technology available at the specific location chosen. For example, source water for desalination processes worldwide is 56% seawater, whereas in California seawater only represents 17% of source water for desalination, mainly because large amounts of brackish water are readily available (Cooley 2006). It is noted that the use of treated wastewater as a source for desalination has not been considered in this study, since it is not yet generally accepted by the public as a potable water supply.

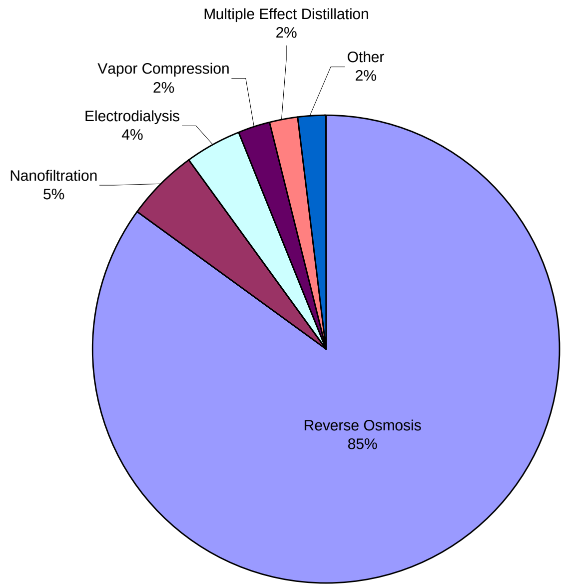

Figure 6: Desalination Technologies Capacity in California (Cooley 2006)

The domination of RO in California is even more significant, as illustrated by Figure 7. Most desalination in California occurs in the southern portion of the state, which has climatic and water use patterns similar to Loreto's. Similarly, in Cabo San Lucas roughly a dozen desalination plants are now in operation, all using RO technology. As a result, it is expected RO will be the most appropriate technology for desalination facilities developed in the Loreto region. Brief descriptions of currently available alternative technologies, as well as technologies still under development, are presented below, but energy demands, technical requirements, and/or uncertainties associated with unproven performance records will likely make them unsuitable for application in the Loreto region.

Thermal

Prior to the development of RO and Nanofiltration (NF) technologies, the majority of desalination efforts were thermal based. The fundamental principle of thermal processes consists of heating water beyond or near its boiling point, collecting the steam, and cooling it to produce a clean water source. Thermal technologies tend to be more energy intensive and less efficient than other processes, but are suitable for applications that typically do not include municipal water supply. The two major types of thermal technology are Multiple Stage Flash (MSF) Evaporation and Multiple Effect Distillation (MED). The MSF Evaporator produces distilled water from feedwater by heating it until it is ready to vaporize. The vapor is drawn to a location where it is condensed and collected as fresh water. MED is an older technology that uses a series of chambers exchanging heat through vapor condensation to distill water. Because they consume a large amount of energy per liter of product water, these technologies are rarely used to produce a municipal drinking water supply. However, thermal processes are still used by industries that require a very pure water supply, since they can produce water with much lower salt content than membrane systems, typically averaging less than 25 parts per million (ppm) (U.S. Bureau of Reclamation 2003). Total dissolved solids concentrations of around 500 ppm are typically acceptable for drinking water, so the additional removal efficiencies provided by thermal processes would not be worth the additional operating costs for expansion of Loreto's potable water supply.

Mechanical

In addition to thermal processes, mechanical processes have been used to desalinate seawater. The most common process is vapor compression (VC). VC is a process where mechanical energy is used to compress the vapor, which increases its temperature and ultimately distills water. Often VC technology is combined with thermal technology to increase efficiencies in the thermal process. Mechanical VC is often used in remote areas for small applications such as resorts or small industrial processes. It is unlikely that VC technology would be an appropriate choice for desalination facilities in the Loreto region, since operating costs are generally higher than RO and Loreto is not considered a remote location.

Electro-Dialysis Desalination (ED)

In Electro-Dialysis desalination (ED), a direct electrical current is run through brackish water to separate dissolved salts and minerals into positive and negative ions. These are then strained through one of two semi-permeable membranes that allow only the positive or negative ions to pass through, leaving desalted water behind. While ED is effective on brackish water; this technology is still under development for use in seawater desalination. Generally, ED is not cost-effective at removing salt concentrations above 4,000 mg/l (Pacific Ocean seawater averages approximately 35,000 mg/l), so, unless suitable low salinity brackish sources can be found, it is unlikely that ED would be a suitable choice for a Loreto desalination facility.

Potential Technologies

A number of other technologies are in the development stages for both seawater and brackish water desalination in an effort to reduce energy costs and minimize brine disposal problems. Notable technologies that are suitable for desalinating seawater, yet are not completely developed for large scale use are listed below:

- Freeze Separation – source water is frozen to separate ice crystals from salt crystals;
- Ion Exchange – source water is passed through columns of resins that remove undesirable ions based on the specific resin's preference for certain ions;
- Membrane Distillation – combines the concepts of thermal and membrane processes to remove salts;
- Rapid Spray Evaporation – source water is sprayed at high velocity through vaporizing nozzles to separate salts from water; and
- Freezing With Hydrates – a saltwater vapor/gas mixture is cooled, and the hydrates formed are then separated from brine.

Membrane Processes - Reverse Osmosis/Nanofiltration

Reverse Osmosis and Nanofiltration (RO/NF) are similar pressure driven, membrane processes used in the desalination of water. The NF membranes generally operate at lower pressure than RO and are typically used for brackish water applications. RO membranes are typically used in desalination of seawater because of these membranes' higher salt rejection capacity than NF membranes. The fundamental principles of both technologies consist of the separation of salt from water when the feedwater is applied to a membrane at high pressure. Fundamentally, the process of osmosis is reverse as water passes through a semi-permeable membrane and the salts remain on the feedwater side (Figure 5). The water that passes through the membrane is ultra-pure while the remaining water increases in salt concentration. The high-saline water becomes the waste stream or "brine" and is then discharged while the product water is collected for use.

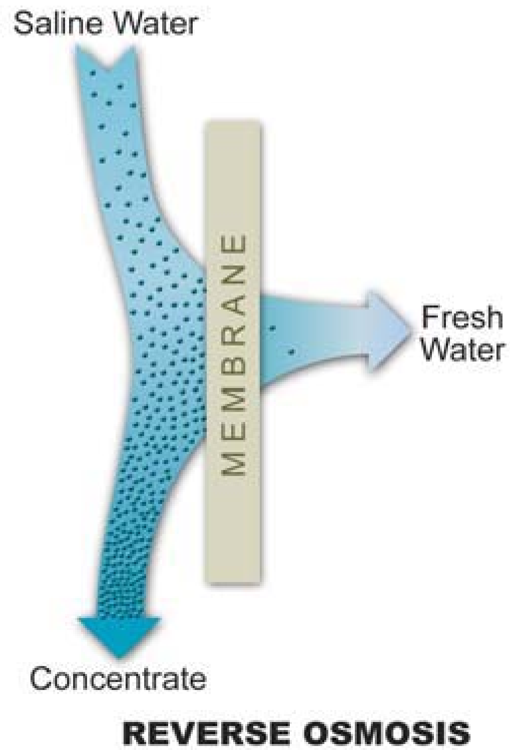

Figure 7: Reverse Osmosis Process (Courtesy of RBF Consulting)

Reverse Osmosis technology is experiencing rapid growth due to extensive research and development in recent years. The intense competition between a number of membrane manufacturers has provoked much of this research. Operating experience with reverse osmosis technology has improved over the past 15 years; fewer plants have had long-term operational problems. Assuming that a properly designed and constructed unit is installed, the major operational elements associated with the use of RO technology will be the day-to-day monitoring of the system and a systematic program of preventive maintenance. Operation, maintenance, and monitoring of RO plants require trained engineering staff. Staffing levels are approximately one person for a 200 m^3/day plant, increasing to three persons for a 4,000 m^3/day plant.

The amount of desalinated water that can be recovered from saline water ranges between 30%-85% of the volume of the input water, depending on the initial water quality, the quality of the product needed, and the technology and membranes involved (Cooley 2006). Currently, desalination facilities are typically defined as small if production is less than 3,700 m^3/day;

medium-sized if production is between 3,700 and 37,000 m^3/ day; and large if production is over 37,000 m^3/ day. However, the physical size of a large reverse osmosis desalination facility is small relative to any thermal technology plant, which usually requires a boiler, power generation facilities, and significant land area for the facility. The land areas required for multiple types of desalination facilities is presented below in Table 2.

Source Water/Technology	Plant Volume Produced	Population Served	Footprint
Seawater/RO	1,100m^3/ day[1]	2,000	0.02 Hectare
Seawater/Thermal	17,000 m^3/day[2]	33,000	3.03 Hectare
Seawater/RO	272,500 m^3/day[3]	530,000	7.432 Hectare
Brackish Water/RO	7,570 m^3/day[4]	15,000	0.068 Hectare

Table 2: Surface Area Requirements for Desalination Facilities
1. Durban, James 2006 2. Water Desalination International 1998 3. SPG Media 2006 4. SPG Media (2006)

As described above, nanofiltration (NF) membranes are generally not suitable for seawater desalination, but can function as a cost effective alternative to RO if brackish water conditions exist. The fundamental principles of NF are the same as RO; however NF membranes have less salt rejection capacity than RO membranes. Operating costs are less lower primarily because NF membranes require lower operating pressures. Therefore if ideal source water conditions exist, NF is generally preferable to RO.

Although significant advancements in technology have extended membrane life while lowering energy requirements, overall energy consumption remains extremely high due to the very high-pressure requirements of reverse osmosis membranes. Among the more significant recent technology advancements, the Long Beach, California Water Department has developed a two-stage Nanofiltration Process, or Long Beach Method, as it has become known. It has been demonstrated to be 20 to 30 percent more energy efficient than RO, which is the current state-of-the-art technology (Long Beach Water Department 2006). The Long Beach Method technology is not yet being applied to a municipal water scale at this time, however it demonstrates the promise of advancements in desalination technology in the future.

5.4.4 Pre-Treatment and General Maintenance

Pretreatment is an important component of desalination systems, especially in the application of membrane processes. Pretreatment is the process of preparing source water for the desalination process. Thermal desalination processes require filtration and occasionally chemical treatments but do not require the level of pre-treatment that RO membranes do. Incorporating subsurface intakes and providing the most suitable technology to address water quality conditions in the source water prior to desalination can drastically reduce these costs. All desalination plants require preventive maintenance including: instrument calibration, pump adjustment, chemical feed inspection and adjustment, leak detection and repair, and structural repair of the system on a planned schedule.

Depending on the chemical composition of the feedwater and the method of intake to the desalination plant, pre-treatment for RO plants can account for up to 50% of the total cost of the facility's operation (Pankratz 2004). RO membranes can become fouled easily by particulate matter, scaling, and biological growth. Scaling is the deposition of minerals, caused by partially insoluble salts in the source water, on piping materials and membranes, which can reduce process efficiency and foul membranes. These salts precipitate out of solution and accumulate on the membranes causing the membranes to degrade, often past repair. To reduce these effects, membrane based desalination plants use large particulate filtration augmented by the addition of anti-scaling chemicals and/or more refined filter technology, such as microfiltration or ultrafiltration.

Microfiltration will remove particles generally greater than 10 microns (µm or one millionth of a meter) and ultrafiltration will remove particles greater than 0.1 µm, both filtration processes are pressure driven. Ultrafiltration can be used instead of adding chemicals to prevent biological growth and scaling. If ultrafiltration is not used, chemicals, such as acids are added to reduce the effects of scaling. Unfortunately, the addition of anti-scalent chemicals can cause an increase in biological growth on membranes which results in plugging, reduced efficiency, increased operating costs, and potentially, actual destruction of the membrane itself. The extent of biofouling is dependent on multiple factors, such as the amount of sunlight, the type and amount of anti-scalents used, the pH of the feed water, and the amount of algae present in the source water. Additional pre-treatment is required to reduce biofouling; however membranes cannot be disinfected with chlorine.

Pre-treatment chemicals are often disposed of and discharged in the waste stream with brine. In the Loreto region this may be problematic due to the presence of the Loreto Bay National Marine Park. Extra mitigation efforts or advanced pretreatment technologies, such as ultrafiltration, may be required in order to prevent the pollution of the Loreto Bay National Marine Park or other fragile ecosystems in the region.

5.4.5 Power Consumption

The majority of large-scale water treatment systems require power for their operations. Desalination processes, as opposed to other methods of water treatment, have significantly higher power requirements. The development of Reverse Osmosis (RO) technology has made desalination viable as a municipal water supply largely because of the increased efficiency this technology offers over other systems. Thermal technologies are energy-intensive and even MSF, the most efficient of thermal technologies, uses significantly more energy than RO to desalinate typical seawater (Wangnick 2004). Table 3 presents a range of published energy consumption values associated with RO systems. The associated costs of powering RO desalination plants can be determined by applying these values to the existing and anticipated market rate of power.

Table 3: Reverse Osmosis Electrical Consumption

RO System	Energy Consumed
Theoretical minimum[1]	0.8 kWhr/ m^3
Typical Pacific seawater[2]	3.9 kWhr/ m^3
With energy recovery[3]	1.6 kWhr/ m^3

1. Cooley 2006. 2. Marin Municipal Water District 2006. 3. Energy Recovery Inc. 2006.

Electrical energy use can represent up to 44% of the cost of water derived from an RO system, so any gained efficiency in energy used can reduce the cost to the end user (Cooley 2006). Energy recovery systems can increase the efficiency of an RO plant by up to 57%. Existing energy recovery technologies include turbines and wastewater pressure exchangers. Both systems work by recapturing a portion of the energy used in the RO process by harnessing the pressure of the wastewater (brine) and transferring it to the energy input requirements of the production stream. Figure 8 below depicts the general process of a pressure exchanging system.

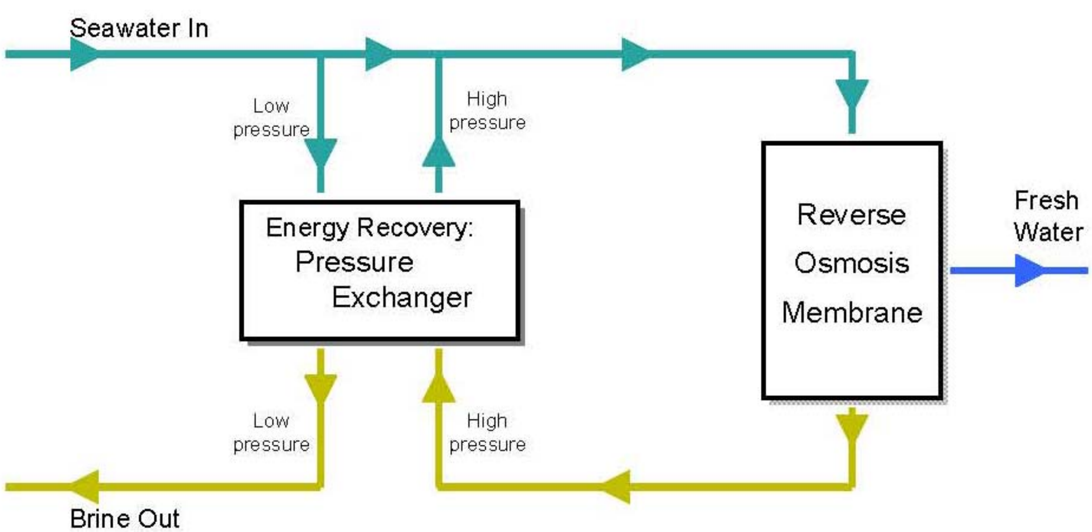

Figure 8: Pressure Exchanger Schematic

Pressure exchangers have been used with success in the reverse osmosis process to reduce energy demands. The development of this technology is ongoing with many manufacturers advertising high levels of recovery. With energy recovery systems, manufacturers have been able to operate RO systems consuming 1.6 kWhr/ m^3 (ERI 2006). This is less than half the energy consumption required to typically desalinate Pacific Ocean Water and approaching the theoretical energy value of 0.8 kWhr/ m^3.

5.4.6 Product Water and Waste Water

The desalination process produces a product stream and a waste stream. The product stream in a municipal application is generally potable water and the waste stream is referred to as brine or concentrated salt water. Often considered when evaluating the desalination processes is the percentage of recovery or the amount of potable water produced relative to the amount of brine produced, typically between 40-60% ratio of product water to brine.

5.4.7 Product Water

The quality of desalinated water is generally high, depending on the feed water and technology used. However, membrane technologies significantly alter the pH of product water, so additional treatment is warranted before distribution. Primarily this is done to prevent corrosion of distribution infrastructure, but also to ensure the aesthetic quality of the water. Product water is then routed to a holding tank where it is polished or treated with chlorine prior to final distribution. If the product water is treated adequately to prevent corrosion, the additional required treatment outlined above is the same as that used by the water purveyor to polish or treat water from other production sources such as well water.

5.4.8 Brine

Disposing of brine can take multiple forms, however the most common is disposal to the ocean or surface water streams. This method is a form of dilution based on the volume of discharge relative to the receiving water body. Surface water disposal can be accomplished by directly dumping brine into a water body, installing engineering controls such as outfall diffusion devices, or mixing brine with other less saline waste streams before ultimate discharge. At present, 48% of all desalination facilities in the United States dispose of their brine to surface water, while 40% dispose of their water to sewers to be mixed and treated with wastewater (U.S. Bureau of Reclamation 2003). This disposal method is currently the easiest to design and least expensive options available for desalination facilities. Unfortunately it exacts heavy costs on the environment. Other methods of brine disposal include the use of evaporation ponds, injection into confined aquifers via wells, discharge to saline streams flowing into estuaries, discharge to local wastewater facilities via sanitary sewers, or injection into saline aquifers via seawater wells.

One of the most significant problems with desalination is finding environmentally sensitive options for disposal of brine. It can be suggested that the next evolutionary step in the development of desalination technologies will be to either reduce the amount of brine or find a beneficial use for it. Listed below are brief descriptions of the currently available methods for disposing of brine:

- Evaporative Ponds – Brine is spread in shallow ponds, where it gradually evaporates. The residual solids left behind are then disposed of in a landfill or collected for re-use.
- Deep Well Injection – Brine is injected, via wells, into confined, non-potable aquifer systems or into brackish aquifers occurring along the coast.
- Discharge to Sewer System - Brine is conveyed directly to existing wastewater treatment facilities.
- Ocean Outfall – Brine is discharged directly to the ocean, where it is diluted by the surrounding seawater. This dilution can be enhanced through the use of diffusers that spread the discharge over a wider area, thereby lowering the concentration at any one location.
- Surface Water Discharge – Discharge is to a stream, river, and/or lake, using the same dilution concepts as ocean outfall. Surface waters are usually used when the fresh water

body is in close proximity to an estuary; however this practice is not necessarily a good practice.

In Loreto, the existence of the marine park, in addition to the potential environmental impacts to rare and endangered species and habitats along the coastline, makes brine disposal to the ocean an unattractive choice. Mexico's National Protected Area Service (CONANP) has not issued criteria or standards for intake or discharge in a marine protected area; therefore, it would be unwise to pursue open water brine discharge as a first option within the boundaries of the Marine Park.

6 Benefits and Risks of Desalination

6.1 Benefits

Coastal populations often consider desalination as the ideal solution to provide an unlimited supply of freshwater. Desalination technology has the ability to produce a high quality product using minimal additional conventional drinking water treatment. In addition, desalination offers the potential of enhanced groundwater recharge and ecosystem restoration by relieving demand on groundwater and surface water sources, such as aquifers, rivers and streams. A benefit that particularly appeals to water purveyors is desalination's resistance to drought conditions. A year round, reliable supply of high quality water is a simple justification for communities to consider desalination as a water resource.

Desalination is also an easy option to consider for coastal communities not currently plumbed into the existing municipal infrastructure. One compelling benefit to these communities is that small package treatment plants are easily available for purchase from multiple manufacturers. Desalination can offer an isolated community more autonomy and flexibility for growth when other water resources are not available. Desalination can be used to provide potable water for communities in Loreto that may be far from existing water infrastructure and wish to develop independently of SAPAL.

6.2 Risks

6.2.1 Environmental Impacts

There are multiple ways in which a desalination facility can negatively impact the surrounding environment; therefore, particular attention should be paid to each potential site prior to construction in order to minimize these risks. One of the most significant impacts of seawater desalination activities can be on the marine habitat adjacent to the desalination plant. Brine discharge released as effluent in the waste from the facility can potentially harm marine organisms by raising the salinity to unhealthy or even fatal levels. In addition to brine discharge, intake facilities, the disposal of pre-treatment chemicals and the production of energy through the use of fossil fuels are also potential threats to the environment. The environmental risks of desalination are presented below in the sequential order of the treatment process.

Intake Facilities

Seawater intakes often receive scrutiny during siting, primarily because the impact these facilities have on marine life. Marine organisms can be harmed through the intake and during the desalination process. Large marine organisms, such as fish, birds, invertebrates and mammals, can be killed on a desalination plant's intake screen (impingement). These organisms, which are small enough to pass through the intake screen, are destroyed during the desalination process (entrainment) reducing the available food supply for larger organisms and disturbing the overall ecological balance of the marine environment. Additionally impacts occur during the construction of each type of seawater intake. Usually these impacts are temporary if construction is completed responsibly; however long-term impacts to be avoided are the destruction of reefs or rocky habitat areas as well as permanent structures that will affect wildlife.

Pre-Treatment

Chemicals used in pre-treatment and for membrane cleaning and storage are potentially harmful to the environment and are usually discharged with the brine in the waste stream. Pre-treatment chemicals such as acids (anti-scalents) or biocides released to the marine environment can kill fish and degrade marine habitats in proximity to the discharge location. The discharge of these chemicals to wastewater treatment facilities can also be problematic. To minimize this risk ultrafiltration can be used to pre-treat source water. Post-treatment is often necessary prior to disposal, however this can be difficult to accomplish because of the increased density and salinity of the waste stream.

Brine

The waste from the desalination process or brine disposal can provide a significant challenge when siting and designing a desalination facility. The high salinity of brine can have serious negative effects on marine resources surrounding the discharge structure. While some marine life can adapt to the increase in salinity, there are some species, such as sea urchins that are extremely sensitive to salinity changes (RBF Consulting 2004). Any shift or negative impact to specific species in any marine environment is detrimental to the ecosystem. This is particularly true in the Loreto region with the presence of a National Marine Park.

Brine discharge to existing sewer facilities is usually not a viable option unless the sewer system has the capacity to handle the large volume of additional loading. In addition, large amounts of brine discharged to the sewer system can change the treatment scheme of a plant and require the plant to undergo retrofit or operational changes. Based on an assessment performed by SAPAL, the existing sewer system in Loreto is already strained and would not be able to handle the large volumes of brine expected from a desalination facility (Quintero 2006). Additionally, the conventional wastewater treatment system that exists in Loreto has limited ability to reduce the dissolved solid content of water; therefore the only benefit would be dilution. Ultimately, a significant retrofit effort would be likely to accommodate brine waste in the existing sewer system.

Product Water

The product water produced from desalination is often corrosive because reverse osmosis and distillation alter the chemical composition of the product water, increasing the pH. Post-treatment of the product water is often required to avoid corrosion to the distribution system or the leaching of toxic metals from the distribution systems piping. Product water can be further treated to increase the pH or diluted with an existing potable water resource to reduce this effect.

6.2.2 Non-Integrated Solutions and Unplanned Applications

The advantages associated when integrating desalination projects with existing power and potable water infrastructures are often realized on a regional scale. The integration of these plants into existing systems allows a community to expand its water resource portfolio and share the energy demands of providing an additional water resource. If desalination facilities are not integrated into existing water infrastructure, water shortages, drought conditions, or contamination of water resources affect the portions of the community that are reliant solely on those resources. Alternatively, if energy prices increase significantly, the portions of the community that depend on desalination as a sole resource can be susceptible to much higher prices for the same water if energy prices increase. Ultimately, non-integrated or poorly planned desalination facilities can separate portions of the community from water resources as the result of energy price or water shortages. By blending all of these resources into one system, the community is not dependent on one specific resource providing additional protection against changing climate and economic conditions.

6.2.3 Loss of Conservation Measures

With the introduction of a desalination facility to a community, the public may perceive that an unlimited supply of water exists. Water conservation measures should be implemented and fully ingrained within a community's culture prior to a shift towards an "inexhaustible" resource such as desalination. For the Loreto region, conservation measures should be implemented immediately. These measures should be as comprehensive as possible and have a strong focus on consumer education. Not only will these changes help Loretanos avoid the adverse economic impacts of water shortages, it will also curb the rate of environmental degradation associated with desalination.

6.2.4 Potential of Fluctuating and Prohibitive Costs to Users

As desalination is an energy-intensive process, a community that depends on the distribution of desalinated water exposes itself to energy price variability and, subsequently, increases in energy prices over time. The cost of desalinated water is directly tied to energy costs. The economic viability of seawater desalination is understandably dependent on the availability of low-cost power; which at the present makes desalination feasible in Baja California Sur. Capital investment in renewable energy technologies and energy recovery systems within a desalination facility can offset power costs. The use of renewable energy sources to avoid price fluctuations of fossil fuel generated electricity is an essential component of long-term water management planning.

7 Desalination Technology Best Practices

There are no universal best practices for desalination. Best practices are determined by site-specific conditions. Every proposed desalination facility should be evaluated to understand the existing constraints sensitive environmental resources that may be affected. The practices listed below reflect currently available and developed technologies:

Centralized/Integrated Facilities - The siting of a desalination facility should recognize the limits of the existing infrastructure and provide for compatibility and connectivity to that infrastructure. To avoid the problems associated with multiple private desalination facilities, communities need to collaborate on a centralized facility. Incentives and regulations need to be provided to encourage private developers to cooperate and commit to a regional water resource solution. This prevents the risks associated with the unplanned applications as described above and also allows for a single point of regulation of desalination activities.

Intake – All efforts must be made to avoid direct extraction from surface water. Therefore the preferred method of capturing saline water in a coastal environment should consist of subsurface intakes or beach wells. Beach wells generally have lower capacities and require subsurface investigations such as pumping tests and test wells. If the required capacity cannot be reached using beach wells, radial horizontal subsurface wells should be considered. These wells are generally more expensive to construct, however, similar to the beach wells, radial horizontal wells have minimal long-term impact on marine life. If no subsurface options are available and an open water intake is required, the least intrusive method of salt water recovery is passive screen intakes. It must be noted that all of the above methods will have some degree of environmental impact. Thee options have been presented with a bias toward those systems that minimize both the construction related and operating impacts. All intakes siting should be accompanied by the appropriate level of environmental review.

Pre-Treatment – The most effective method of pre-treatment for desalination source water is the use of sub-surface wells as filtration intakes to the system. The filtration of particles and organisms through in-situ soils (typically sands) serves an added benefit to the system operation. Membrane technologies such as reverse osmosis often require additional pre-treatment to minimize fouling of the membranes. Chemicals are often used to adjust pH, act as a biocide, or to remove partially soluble elements. The residue of these treatments ends up in the waste stream and can be problematic when disposing of brine. The presence of pretreatment chemicals that are disposed of in conjunction with the brine can change the classification of the waste stream to a pollutant (versus highly concentrated seawater) and the resultant environmental impacts should be evaluated prior to permitting. Physical separation techniques, such as ultrafiltration, should be used to avoid the use of additional chemicals to counteract the chemical mixture added in pre-treatment. An effective method of physical separation is ultrafiltration which provides the removal of most organisms and particulate matter.

Process Technology – Membrane technology is currently the most widespread desalination technology worldwide. Therefore the amount of research and development that is input into refining reverse osmosis technology will make it the most efficient and most likely technology to be introduced for desalinating seawater in the Loreto region. The benefits of using reverse osmosis are reduced energy costs relative to thermal technologies, ongoing research and development pushing higher efficiencies, and commercially available energy recovery systems. The use of reverse osmosis technology should incorporate low pressure membranes and energy recovery systems. The initial capital investment associated with both of these energy saving measures will reduce energy consumption and assist in mitigating fluctuating energy costs associated with producing a potable water supply.

Brine Disposal – There is no single best practice for brine disposal. A site-specific approach is required when determining the appropriate method of brine disposal and often one single method of disposal is not adequate. A conjunctive disposal method should always be considered in the initial site investigation. This effort will reduce the specific impact of disposal on one sector of the environment and allow flexibility throughout operation of the plant. Critical components in reducing the effects of brine disposal are reduction of the volume of brine that must be discharged and minimization of the adverse chemicals found in the brine.

A conjunctive approach that has the least impact on marine life would be injection of the brine into a confined aquifer system combined with the use of evaporative ponds. Evaporative ponds are an ideal method of disposal but can be cost prohibitive because of the large amount of land needed and the undesirable aesthetic component of the ponds. However, evaporative ponds allow minimize impacts to marine environments and allow for the remaining solids to be reused or disposed of appropriately in a landfill.

Deep well injection disposes of brine underground to be diluted within an existing aquifer system. Deep well injection requires a comprehensive hydrogoelogic investigation to ensure that existing or adjacent groundwater resources will not be contaminated and that the aquifer system has the capacity to sustain injection indefinitely.

Open water disposal should only be considered as a last option. If open water disposal is selected, outfalls utilizing diffusers represent the best available solution. Outfalls need to be sited with an understanding of currents, the relative densities of the brine and seawater (brine generally has a higher density than seawater) and the properties of any additional diluents, such as wastewater. The effects of open water outfalls should be conceptually and numerically modeled prior to outfall siting.

Siting a Desalination Facility in the Loreto Region

The majority of the potential coastal development in the Loreto Region is within the boundaries of the National Marine Park. If desalination facilities are to be planned and sited within the National Marine Park, baseline studies of the surrounding marine and estuarine environments should to be performed to assess the ecological significance of the site and the potential impacts of the facility to those systems.

Subsequent to the collection of baseline data, hydrogeologic investigations should be required to determine the feasibility of subsurface intakes and deep-well injection of brine. Surface intakes and ocean outfalls should only be considered as a last resort and only be implemented after hydrodynamic modeling of the intake structures and dispersion modeling of the outfall structures are complete. The results from these studies need to indicate that impact to seawater quality and marine life is nominal. Given these constraints, the construction of desalination facilities within the boundaries of the Loreto Bay National Marine Park must be very carefully evaluated.

Waste brine disposal from any site, whether in or out of the Marine Park, would likely require some level of mitigation. If an ocean outfall is considered for applications outside of the Marine Park, the same level of due diligence would be required as if the facility were located in the National Marine Park. This is primarily to account for the affect of currents transporting brine or disrupting migratory pathways of marine species in an out of the Park. Appropriate measures should be taken to offset the negative environmental impacts of desalination regardless of the plant's location.

8 Conclusion – Best Practices for Water Management in Loreto

Development in the Loreto Region has been rapidly accelerating and warrants increased planning and coordination between government agencies, local municipalities, investors, and residents. As with any growth, a major concern is providing the adequate resources to sustain the population and protect public health. As the community looks to desalination to address the increased water demand and parallel failing of the San Juan Bautista Londo Aquifer, caution is required to ensure that supplemental water resources are developed in a sustainable and conscientious manner.

The practices presented below outline the prioritization of best practices for ensuring an adequate water supply for Loreto as it grows. Desalination is listed as the last resort relative to other actions. This is because the benefits of addressing other system inefficiencies will have lasting benefits and limited negative impacts relative to desalination. By applying priority methods to serve the growing population's needs, desalination can be delayed to ensure that it is applied correctly and to allow for desalination technologies to improve prior to introduction to the region.

1) Water Conservation
    a. Creation and implementation of a water management plan
    b. Education
    c. Financial incentives
    d. Local enforcement
2) Distribution System Repair and Maintenance
    a. Existing infrastructure assessment
    b. Potential replacement or repair of existing system
    c. Increased maintenance
3) Existing Resource Augmentation
    a. Enhanced groundwater recharge
    b. Water recycling
    c. Remediation of contaminated wells
4) Desalination[3] –
    a. Centralized - integrated desalination facilities
    b. Compilation - baseline ecological data
    c. Intake - subsurface providing brackish water
    d. Pre-treatment – combination of subsurface intake and ultrafiltration
    e. Reverse osmosis - using low pressure membrane and energy recovery systems
    f. Brine disposal – reduction and conjunctive disposal using deep injection wells and land disposal
    g. Siting for Loreto – Detailed environmental impact assessment, hydrogeologic investigations, hydrodynamic modeling of adjacent marine environment.

[3] Technologies presented in this list are condensed and represent best commercially available technologies under ideal conditions. For example, subsurface disposal may not be an option if hydrogoelogic conditions are not suitable or the presence of a functioning fresh water aquifer nearby can be fouled. More in depth descriptions of technology options are presented in Chapter 7.

The practices presented in this document provide methods and steps necessary to maximize existing water resources in conjunction with evaluating methods for implementing desalination. This does not infer the removal of environmental, economic, and social risks of augmenting Loreto's existing water supply by developing a desalination facility or other means of production. More accurately, it provides alternatives prior to establishing the absolute need for desalination. It offers guidance at the time desalination is deemed appropriate to properly site and integrate desalination facilities, and ultimately reduce the negative effects that the desalination technologies may bring. By maximizing existing resources, desalination may be avoided in the near-term, and when finally necessary, its implementation can occur responsibly.

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Appendix

A. Author Biographies

Bry Sarté, Principal Engineer

Bry Sarté is founder of the San Francisco and New York City based civil and environmental engineering firm Sherwood Design Engineers. As Principal of the San Francisco office, Mr. Sarté leads development of the firm's international, national and local project work. He has years of international engineering experience ranging from environmental master planning and sustainable infrastructure design in urban, mixed-use and resort developments to site planning for individual buildings and single sites. Mr. Sarté has provided engineering direction to masterplan and improvements projects throughout North America and in world-class destinations in the Caribbean, the South Pacific, Africa and Europe. During development of an ecologically-oriented masterplan at Butterfly Bay in Northern New Zealand, Mr. Sarté facilitated communication between local agencies and parties representing community and indigenous interests that informed the project. Mr. Sarté also led civil design for the incorporation of water conservation into existing infrastructure along Italy's historic coastline of Costa Smeralda. Mr. Sarté is currently managing Sherwood's development of low-impact infrastructure design on the secluded islands of Seychelles Archipelago in the Indian Ocean. In addition he manages similar project work in Catalina Island off the coast of Southern California, Draper Lake in Florida, Tagahazout in Northern Morocco, Loreto Bay in Mexico and St. Kitts Island in the Caribbean.

Mr. Sarté has been published internationally and has made significant contributions to contemporary research involving global environmental issues affecting architecture, material science and energy use. He has appeared as a guest lecturer at the University of California Berkeley and Stanford University, presenting materials on environmentally sensitive infrastructure design and construction. Mr. Sarté has presented on similar topics at San Francisco Planning and Urban Research, and both the American Society of Landscape Architecture's national and statewide conferences.

Andrew J. Leahy, Senior Engineer

Andy Leahy has over twenty-five years experience as an engineer and planner in the design and analysis of civil engineering infrastructure and environmental restoration. Mr. Leahy serves as Senior Design Engineer on many of Sherwood Design Engineers' most extensive infrastructure masterplan projects. He has worked both as an independent consultant and with firms such as Greiner Engineering, Inc. a civil engineering and land planning firm that provides engineering and architectural design services on projects throughout the United States and in the Asia/Pacific region. Mr. Leahy's experience spans all aspects of the land development and civil improvement process from local government, to private construction contracting, to engineering and city planning consulting. His broad background provides a solid foundation for the identification of efficient, cost effective and ecologically sound engineering solutions for infrastructure development, resource allocation and project management.

Mr. Leahy has prepared engineering designs and performed environmental analyses for a wide range of projects throughout North America and extensively in California. As an engineer with a master's degree in city planning, Mr. Leahy is able to successfully bridge the gap that so often separates planning goals from construction implementation. The scope of his experience includes circulation layout design, roadway and earthwork design, assessment district formation, stormwater management, water supply and distribution, wastewater treatment and disposal, hydrology and water quality assessments, soils and geology, wetlands mitigation and stream restoration along with all facets of civil engineering design and plan preparation.

Eric Zickler, Senior Designer

Eric Zickler has over 6 years of experience as an engineer in the design and analysis of water treatment systems. Mr. Zickler holds a B.S., Civil Engineering, Colorado State University and a M.S., Civil and Environmental Engineering from California Polytechnic State University, San Luis Obispo. Mr Zickler's focus and specialty has been in alternative water resource engineering and advanced water treatment systems. Mr. Zickler has authored Urban Water Management Plans, Managed Groundwater Basins, and assisted in developing Recycled Water Programs throughout California. Mr. Zickler has also managed and participated in multiple surface and groundwater modeling studies to evaluate sustainable yield values in aquifers and investigate the potential for conjunctive water uses.

Manon Terrell, Student Researcher

Manon Terrell, LEED AP, is a student at Stanford University in the Department of Civil and Environmental Engineering. Her research interests include sustainable building materials and environmentally-sensitive design and construction techniques, particularly for lower-income and/or developing communities within the United States and abroad. She also has a growing interest in sustainable infrastructure best practices in urban contexts.

Julia Campbell, Student Researcher

Julia Campbell is currently a student in the Civil and Environmental Engineering at the University of California, Berkeley. Her studies focus on engineered systems and she has a strong interest in weaving sustainable features, such as green buildings, low-impact transportation systems, and high-efficiency municipal systems, into the designed landscape.