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OCEAN DESALINATION IN SOUTHERN CALIFORNIA

An Evaluation of Environmental, Economic and Energy Impacts of the Carlsbad Desalination Plant

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Executive Summary

Due to its arid, Mediterranean climate, lack of rainfall and scarce supplies of local water, Southern California relies on the northern half of the state and the Colorado River to satisfy most of its water needs. As demand rises due to population growth and economic expansion, Southern California's reliance on imported water from the Colorado River and the Sacramento-San Joaquin Bay-Delta is beginning to show signs of uncertainty from drought, reallocation of water for the endangered Delta Smelt and other Colorado River Basin states a declining snow pack that has left reservoirs at their lowest levels in ten years.

In an effort to increase the reliability and decrease the scarcity of future water supply, many water agencies are considering ocean desalination as a response strategy. Once an expensive alternative, recent advances in technology, coupled with increases in the cost of imported water, have made ocean desalination more economically viable.

While ocean desalination offers a drought proof and reliable supplement to existing water supplies, its unique environmental impacts, energy requirements and social costs are cause for concern. As stated in the Governor's Desalination Task Force Recommendations Summary, these factors, along with the process and permitting of ocean desalination in California, need to be clear to public, state and local government and policy makers alike. (CA Water Plan 2005) Therefore, this document has been developed to educate the public about the process, costs, benefits and environmental

impacts of ocean desalination. It may also serve as a template for regional water planners that wish to compare ocean desalination with other water management strategies.
This interdisciplinary report in part, summarizes current literature and offers assessment tools to clarify complicated points. It is divided into three sections—the first will discuss the current status and future threats to water supply in Southern California, with an introduction to alternative management strategies (water conservation, water recycling and ocean desalination). The second part evaluates the impacts of Carlsbad Desalination Plant (CDP) on coastal marine ecosystems and compares its energy intensities with alternative water supplies in San Diego County. Finally, an economic evaluation examines the social cost of water of desalinated water compared with the social costs of different water projects in San Diego.

Preliminary research focused on the following proposed ocean desalination facilities in Southern California as points of comparison and to outline the regional variability in plant scale and design-- Carlsbad Desalination Plant (City of Carlsbad), Camp Pendleton (San Diego Water Authority), Dana Point (Municipal Water District of Orange County), Huntington Beach Desalination Facility (City of Huntington Beach), Long Beach Seawater Desalination Project (City of Long Beach), El Segundo Power Generating Station, (West Basin Municipal Water District) and Scattergood Desalination Plant (City of Los Angeles). This initial research highlighted the relevant environmental, energy and economic impacts that served as the basis of a more focused analysis of the Carlsbad Desalination Plant.

WATER SUPPLY SOURCES IN SOUTHERN CALIFORNIA

Locally derived water supply sources in Southern California come from surface water and groundwater which in turn, are fed by infrequent precipitation and to a greater extent on storm water and runoff. (LADWP 2005) According to California's Department of Water Resources Water Plan, many water agencies have recently made a more concerted effort to capture and store surface runoff. (CADWR 2005) Surface water which usually is stored in local reservoirs serves as a short term, emergency supplement to imported water, aids in flood control and replenishes groundwater.

Groundwater is another important local water resource, but it is highly variable in Southern California. San Diego and South Orange Counties are dominated by vast granite monoliths with only narrow and shallow river-hugging aquifers criss-crossing them. (Dettinger, pers. comm.) Oppositely, Los Angeles has large sediment-filled basins extending from roughly San Bernadino to the coast. (Dettinger, pers. comm.) As a result, groundwater is more abundant in the greater Los Angeles area and north and central Orange County than in South Orange and San Diego Counties. Local groundwater provides approximately 15 percent of the total water supply for Los Angeles, and has provided nearly 30 percent of the total supply in drought years. (LADWP 2005)

To a lesser degree, three groundwater basins underlying North-Central Orange County provide the majority of local water supply for 2.3 million citizens. (MWDOC 2005) Half of Orange County's water demand is met by local supplies--primarily groundwater, followed by recycled wastewater and surface water. (MWDOC 2005)

In contrast, San Diego is substantially limited in terms of groundwater basins—a mere two percent of San Diego's water supply in 2007 was derived from groundwater (SDCWA 2007); in essence, compared to North Orange Counties and Los Angeles Counties, San Diego has much less groundwater.

IMPORTED WATER IN SOUTHERN CALIFORNIA

The Metropolitan Water District of Southern California (MWD) is the most important regional water distributor and the nation's largest supplier of drinking water. (MWD 2009) This agency services close to 19 million residents and businesses in parts of Ventura, Los Angeles, Orange, San Bernadino, Riverside and San Diego counties, routing water from Northern California via the State Water Project and the Colorado River to 26 member agencies. (MWD 2009) The Sacramento/San Joaquin Bay-Delta is the principle reservoir for California surface water flows originating from the Western Sierra snow pack.

In Southern California the main water agencies that receive water from the MWD and serve as wholesalers and distributors for smaller water are: Los Angeles Department of Water and Power (LADWP), the Metropolitan Water District of Orange County (MWDOC) and the San Diego County Water Authority (SDCWA). These agencies will be referred to frequently in this document.

San Diego is the most dependent on imported water (80-90% of its supplies) due to the lack of local supplies and groundwater aquifers, followed by Orange County (53%) and the city of Los Angeles, which varies annually (between 1995 and 2004 it relied on the MWD for 35% of its water). (LADWP 2005) Internally, South Orange County is one hundred percent reliant on imported water, while North Orange County receives about twenty-five percent of its supply from imported water. (MWDOC 2005)

San Diego

Fifty percent of San Diego's imported water originates from the Colorado River while the Bay Delta provides roughly thirty four percent through the State Water Project (SWP). (SDCWA 2008) Due to the high salinity of the Colorado River water, the MWD first dilutes it with water from Lake Skinner before delivery to San Diego. San Diego as well as other water authorities is actively augmenting supplies from agriculture to urban transfers. The Imperial Irrigation District is an example of one such transfer that San Diego is utilizing-- this agricultural water is from the Colorado River. (SDCWA 2008)

Threats to Supply (*Increasing scarcity, decreasing reliability)*

Droughts are common in California and will always be an unpredictable variable in the water supply dilemma of the desert southwest. Presently, California is in its third year of drought and since record keeping began over a century ago, it has experienced three significant droughts. The first was from 1929 to 1934, followed by the shortest, but most severe drought in 1976-77 and the third most notable dry period in California in 1987 to 1992. (CADWR 2008) Three common indicators that are used to determine drought and gauge water conditions are snow pack, precipitation, and reservoir storage. Seasonal averages of these three factors for the present drought most closely resemble those of the

1987-1992 drought. (Lucy Co. 2009) While droughts are an inevitable part of the climate scenario, additional pressures on water supply in California include a decreasing Sierra snow pack and climate change.

The Sierra snow pack is the one of the major sources of freshwater statewide. Southern California relies on the snow melt in spring for the drier summer and fall months. While snow pack amounts fluctuate annually, a report from the California Climate Change Center predicts that global warming will decrease the Sierra snow pack resulting in more rain and less snowfall; somewhere between 30 to 80% of the snow pack amounts that were typically available historically will be no longer available during the warm seasons by the middle of the 21^{st} Century. (CA Climate Change Center 2006) Increased temperatures are also expected to cause early melting of the snow pack along with more intense and frequent flood and drought conditions. (CADWR 2008)

Decreasing Reliability

"If the State's first fifty years of water development was about the construction of dams and aqueducts to meet LA's and California's growth needs, the latter fifty years has been focused on the environmental problems created by those projects." (Davis 1998) This statement was part of a talk on water at a UCLA environment symposium in the late nineties. The speaker was referring to widespread demands for new or restored allocations of water for environmental uses in recent decades. After a half century of securing water, California is now in the process of rerouting it back to the original watersheds and ecosystem. A recent federal mandate for increased water to protect the endangered Delta Smelt in the Sacramento Delta has cut the northern supply of freshwater to Southern California by thirty percent. Similarly, Sonoma County has been ordered to decrease diversions from the Russian River by twenty-five percent to protect Chinook salmon. (SCWA 2009) These are two examples of reallocating water for in-stream use—a trend that is expected to increase in the future.

Droughts, environmental reallocations and climate change all translate into increased water scarcity and decreased reliability of imported water for Southern California. The synergistic effects of these challenges to water supply form positive feedback loops that aggravate the scarcity and decrease the reliability of Southern California's main water resources. Adding climate change to the already complex challenges to existing of water supplies will further complicate water management decisions and response strategies.

Rising Population, Rising Demand

Population is the key driver of future demand. The following table summarizes the populations of Southern California's metropolitan counties that are pursuing ocean desalination. Population is expected to increase, creating more demand for water. This information was derived from the US Census Bureau and the Southern California Association of Governments (SCAG). (US Census Bureau 2008, SCAG 2008) One significant trend not noted is that although San Diego's population is projected to continue increasing, the *growth rate* is expected to decline.

Table 1. Current and Projected Population Rise in Southern California

Location	2007	2030	Change
California	36 million	60 million	40%
Los Angeles County	9.8 million	12.2 million	20%
Orange County	3 million	3.5 million	14%
San Diego County	3 million	4 million	25%

(US Census Bureau 2008, SANDAG 2008, SCAG 2008)

California's population growth and economic expansion have wholly depended on the availability of water. Just under half of California's economy and 55% of its population are based in the southern part of the state. In addition to population, demand is also influenced by land use, water use efficiency and the economic conditions. The following table outlines the major water wholesalers and distributors in Southern California, their current use and their total projected demand (thousand acre-feet/year), assuming a season with normal precipitation and conservation included from 2010-2030. (SDWA, MWDOC & LADWP 2005) The rising demand for water caused by increasing population in Southern California will inevitably add to scarcity which will in turn, drive up water rates.

Table 2. Projected Demand of Water Wholesalers in Southern California in Thousand Acre-Feet/Year

Water Agency	Projected Demand 2010*	Projected Demand 2015*	Projected Demand 2020*	Projected Demand 2025*	Projected Demand 2030*
SDCWA	767,650	795,970	825,560	848,610	883,030
MWDOC	534,257	547,739	563,274	573,724	583,771
LADWP	683,000	705,000	731,000	755,000	776,000

* Data extracted from the following water agencies:

SDCWA = San Diego County Water Authority

MWDOC = Metropolitan Water District of Orange County

LADWP = Los Angeles Department of Water and Power

MANAGEMENT STRATEGIES

The primary focus of this report is ocean desalination as a water response strategy. Many detailed publications and reports have addressed desalination as a largely isolated alternative. This document concentrates on ocean desalination more broadly in comparison to imported water, water conservation and water reuse or water recycling campaigns. Hence, it is proper to briefly examine the roles of water reuse and conservation efforts in enhancing Southern California's water supplies.

Water Conservation

Conservation is a drought proof response strategy that offers an array of benefits. It negates the energy requirements for treating and transporting water, decreases the need for added sewer and water infrastructure and increases water reliability. (Ca Urban Water Conservation Council 2009) In addition, more source water is available for environmental needs and water customers save on water costs.

A leading proponent for California water conservation is the California Urban Water Conservation Council. It comprises of partnerships among urban water agencies, public interest organizations, and private entities with the objectives of increasing efficient water use statewide and to integrating urban water conservation through Best Management Practices (BMP's). (California Urban Water Conservation Council 2009)
In recent years, all of the major water wholesalers and several water districts have signed a Memorandum of Understanding (MOU), agreeing to integrate the Council's recommended BMP's in their water planning.

Governor Schwarzenegger's water conservation goal of equates to a twenty percent reduction in per capita use statewide by 2020. This is in direct response to improving the health of the Bay-Delta ecosystem which serves as the State Water Project's water. (CA SWRCB 2009) Water agencies and water districts are increasing their conservation efforts—the San Diego County Water Authority projects a nine percent increase in conservation for its 2010 supplies and a fifteen percent increase for its 2020 supplies. Whether or not San Diego and other water agencies in Southern California can achieve

these benchmarks is uncertain. Historically, Los Angeles has been proactive in water conservation since the beginning of the century with water meters and instituting mandatory drought restrictions during the 1976-77 drought. (LADWP 2005)
The largest user group of water has been single and multi- family residential use, with over half of the water consumed by outdoor use. Consequently, most water agencies have focused on water conservation education and awareness campaigns and water saving technologies for its residential and business users.

Water Reuse (Recycling)

Most water agencies in Southern California have non-potable water reuse programs. For the most part these comprise less than ten percent of agencies' water portfolios. This water is not used as drinking-water supply, but rather it provides water for agriculture, irrigation, groundwater recharge, and industrial use. Currently, only two percent of SDWA supply comes from non-potable recycled water that is used for irrigation projects and municipal landscaping.

North Orange County's Groundwater Replenishment System (GWS) recycles to produce potable water has been extensively developed since 1976. This system provides north ad central Orange counties with fifteen percent of its supplies and treats wastewater (originally derived from both imported and local sources) using a combination of reverse osmosis, UV light and peroxide. Afterwards, the treated water is pumped into an aquifer to prevent saltwater intrusion and to augment potable water sources. Water reuse offers both greater local control and increased reliability for water planners.

OCEAN DESALINATION

Reverse Osmosis

Desalination has been used for thousand of years to produce potable water in arid regions like North Africa and the Middle East where freshwater resources are extremely limited. Desalination involves the removal of salt and other dissolved solids from sea or brackish water to produce potable water. There are several ways that desalination can occur—these include vapor compression, multi-effect distillation, multi-stage flash distillation, and electro-dialysis. Reverse osmosis is the most common method used in the United States and regionally in Southern California.

In the United States, reverse osmosis (RO) and other membrane systems account for nearly 96 percent of U.S. online desalination capacity and 100 percent of the municipal desalination capacity. (Desalination 2008) RO extracts salt and other unwanted dissolved substances by forcing the source water through a porous membrane; the larger salt particles are absorbed by the filter as water molecules pass on unimpeded. The original membrane technology was developed in the sixties by a UCLA researcher, Samuel Yuster and two of his students, Sidney Loeb and Srinivasa Sourirajan. (UCLA Engineering 2008) As a result of improved membrane technologies and increased energy efficiencies in recent decades, desalination has become more cost effective and more economically competitive with other water supplies.

Status of Desalination in CA

Sixty-seven percent of desalination in the US is used for municipal water supply while industrial uses constitute 18 percent. (Desalination 2008) Most desalination source water is brackish rather than seawater. One of California's largest desalination plants was constructed in Santa Barbara during the 87-92 drought. However, the plant was never operational because shortly after construction, more favorable hydrologic conditions resumed, demand dropped and conservation campaigns mitigated the need for more costly desalinated water.

California water agencies are keen to invest in desalination to buffer against a decrease in reliability of imported supplies coupled with increases in scarcity. The Santa Barbara case offers water agencies who are considering desalination valuable insights. One of the most lessons was that once facilities are constructed, they are by design, meant to be in constant operation. In other words, desalination plants are costly to episodically start up and shut down and should not be used as short term remedies.

Co-location Benefits/Challenges

Seven desalination plants in Southern California are in various planning and permitting stages. Five of the seven plan to "co-locate" which means they will be constructed within power stations to take advantage of existing infrastructure. The benefits of this arrangement may allow for upgrading unsightly infrastructure, are an efficient use of land, provide easy access to the electricity needed for desalination, allow the use of power stations' water intake systems and cooling water for desalination. The water that is used by power plants' that will be used for desalination is referred to as "once through cooling" (OTC) water.

The use of power plants intake systems results in the mortality of numerous marine organisms from small fish, larvae and eggs to larger marine mammals and turtles. In order to protect the internal mechanics of power stations, two lines of defense prevent unwanted organisms and debris in the source water from entering the plants. First large tracks racks represent the first line of defense trapping large debris and organisms. Once past the trash racks, traveling screens are the second protective measure. The mesh sizes of these screens are smaller than the gaps in the trash racks. Organisms and smaller debris are either pinned against racks or screens (impingement) or die as a result of the physical and chemical factors of the industrial process (entrainment). Impingement and entrainment are two of the largest disadvantages of co-location and will be discussed further in the environmental impacts section of this report.

Proposed Ocean Desalination Plants in Southern California

The following sections will discuss the site specific characteristics of Southern California's proposed desalination plants. This literature review was a key component of this project since it served to highlight the most relevant concerns for a more focused environmental and economic analysis of the Carlsbad Desalination Plant.

Carlsbad Desalination Plant Poseidon Resources

Poseidon Resources is a private corporation that finances and develops water projects such as treatment plants and seawater desalination (Poseidon Resources 2009); it has been working with the City of Carlsbad since 2000 to establish an ocean desalination facility co-located with the Encina Power Station (EPS). When completed, the plant will supply the residents of Carlsbad with 50 million gallons million gallons a day (mgd) of freshwater per day (sufficient for the 300,000 residents) while supplementing the supplies of eight local water agencies. (Poseidon Resources 2009) It will be the largest ocean desalination plant in the western hemisphere.

Encina Power Station's withdraws on average, 621 mgd of surface water from the Agua Hedionda Lagoon for its cooling purposes. (Ferry-Graham et al. 2008) The western-most part of the lagoon receives direct flushing with nearby coastal waters of Carlsbad State Beach and this water contains a myriad of coastal marine life. The lagoon serves as a nursery for small fish, a stopover for birds and habitat for a variety of benthic organisms. The coastal waters surrounding the intake jetties are host to kelp forest communities and include a diverse group of residents. Kelp bass, sand bass, and spiny lobsters are some of the main local inhabitants. The discharge is conveyed out of the plant first to a self-contained pool within the lagoon before flowing out to the Pacific Ocean.

Figure 1. Proposed site of the Carlsbad Desalination Plant

San Diego County Water Authority (SDCWA)/ Camp Pendleton

The Authority initially proposed a desalination plant using San Onofre Nuclear Generating Station One which has recently been decommissioned. This plan was thwarted by complex regulatory uncertainties between the nuclear power and desalination. The Authority is now proposing a desalination plant to be located near the mouth of Santa Margarita River and that would produce between 50 to 100 mgd for the San Diego County Water Authority, the Municipal Water District of Orange County, and Camp Pendleton. (Naiman 2009) Intake structures would be located slightly offshore close to the sea floor thereby minimizing effects environmental impacts such as entrainment and impingement. The proposed plant is much larger in scale, will not co-locate and is expected to operational in 2018.

Municipal Water District of Orange County (MWDOC)/Dana Point

The Municipal Water District of Orange County is planning a 25 MGD plant in Dana Point. This plant will not be collocated and instead use vertical intake wells. These wells are located on the beach and avert the impacts of surface and subsurface intake systems. Another advantage is that the seawater is filtered by sediments before entering the wells. The low intake yield of the wells does not allow for a large scale desalination operation, but this project will provide greater reliability and increased local control for south Orange County which is one hundred percent dependent on imported water.

Huntington Beach Desalination Facility/Poseidon Resources

This proposed desalination facility will be co-located with the Huntington Beach Generating Station Power Station in Huntington Beach and provide 50 MGD to its residents. (HBDF 2009) It will use the OTC water from the power plant and existing intake system for desalination purposes. Instead of the drawing water from a lagoon, subsurface intake and discharge pipes will be located in offshore coastal ocean. Besides the intake and discharge location and design, this is most similar to the CDP in scale and design.

Figure 2. Proposed Site of the Huntington Beach Desalination Facility (Huntington Beach Sea Water Desalination Facility)

Long Beach Water Department (LBWD)

Long Beach Water, along with the Los Angeles Department of Water & Power and the United States Bureau of Reclamation, has constructed a 300,000 gallon-per-day prototype desalination facility, the largest seawater desalination research and development facility of its kind in the United States. (Long Beach Water 2009) This plant will utilize vertical wells on the ocean surface to produce a capacity of 8.9 MGD to be used by the City of Long Beach. (Long Beach Water 2009)

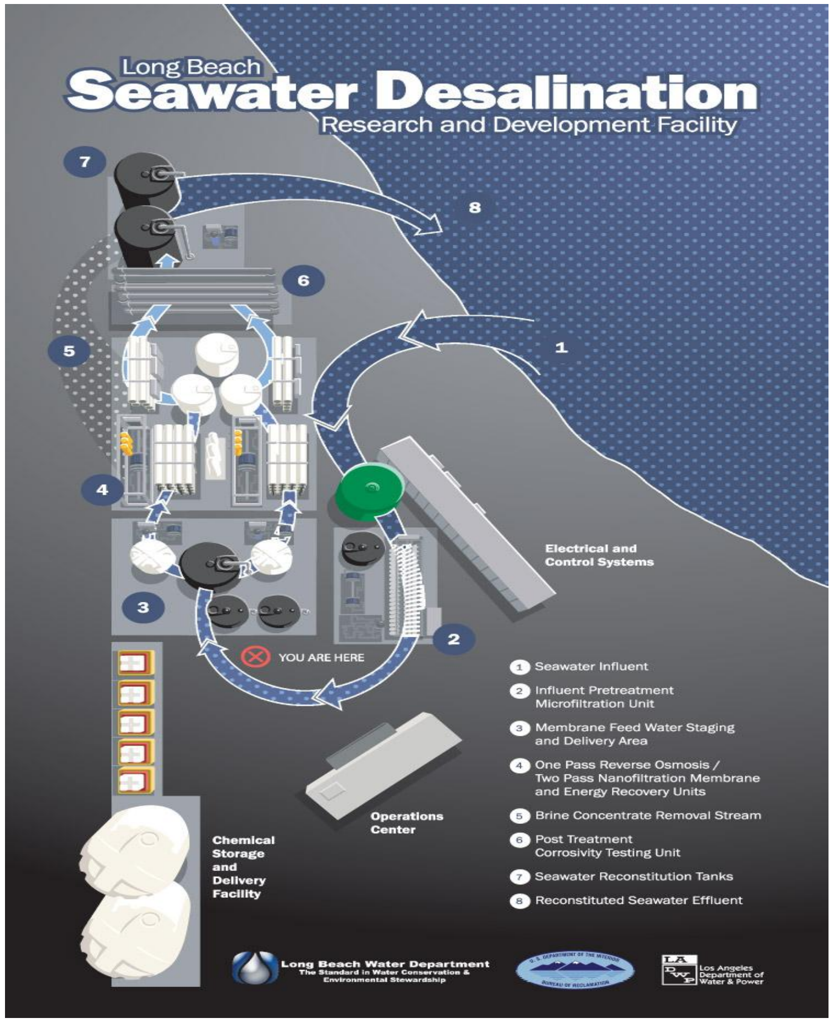

Figure 3. Long Beach Water Seawater Desalination R&D Facility (Long Beach Water 2009)

West Basin Municipal Water District (WBMWD)

Co locating with the El Segundo power plant, this desalination plant would offer 20 MGD to its recipients in the West Basin area. It would use the existing surface water intake system from the El Segundo plant for desalination and brine discharge. (LAWDP 2009)

Figure 4. The Scattergood power plant in El Segundo, CA, owned by the LADWP. (California Coastal Records Project)

Los Angeles Department of Water and Power (LADWP)

This desalination facility would be co-located with the Scattergood Power Plant in Playa del Rey with the ability to produce between 12-25 MGD. It would use the existing surface water intake system and OTC water from the Scattergood plant for desalination and brine discharge. (LADWP 2009)

Figure 5. The Scattergood power plant in El Segundo, CA, is owned by the LADWP (California Coastal Records Project)

Table 3. Summary of key characteristics of the aforementioned desalination plants in Southern California.

Plant	Location	Co-Location	Capacity (MGD)	Intake	Discharge
Carlsbad Desalination Plant/Poseidon Resources	Carlsbad	Yes	50	Surface	Surface
SDCWA Camp Pendleton	Camp Pendleton	Yes	50	Surface	Surface
MWDOC	Dana Point	No	25	Sub-surface	Mixed with WW
Poseidon Huntington Beach Desalination Facility	Huntington Beach	Yes	50	Surface	Surface
Long Beach Water	Long Beach	No	8.9	Subsurface	Subsurface
West Basin MWD	El Segundo	Yes	20	Surface	Surface/OTC Water
LADWP	Playa del Rey	Yes	12-25	Surface	Mixed w/ OTC water or WW

OTC= Once Through Cooling

WW= Wastewater

PART II. ENVIRONMENTAL IMPACTS

The environmental issues of ocean desalination fall into four categories: (1) impacts from the acquisition of the source water, (2) impacts from the management of waste products and concentrate from the desalination process, (3) issues with desalinated product waters, and (4) the impacts of greenhouse gas emissions from the treatment process. (Desalination, A National Perspective, pg.108) The most controversial environmental impacts of ocean desalination in Southern California are impingement and entrainment from intake systems, the hypersaline discharge and the carbon footprint. For the purposes of this project I will examine impingement and entrainment in addition to the energy intensities. These impacts will be applied in an economic analysis in part four of this report.

Focus Questions

Two questions served as the basis of my research:

1. How do fish mortality losses from impingement at the Encina Power Station compare with the commercial landings in California and San Diego?
2. How does the energy demand of ocean desalination compare to that of imported water and other water supply options such as water reuse?

Source Water

Five out of the seven desalination plants in Southern California will use power stations' existing intake systems. "A significant portion of California's generation capacity, approximately 45 percent, is represented by facilities located along the state's coast and estuaries that use once through cooling technology, where the ocean water is passed by the condenser and then discharged back into a water body. This cooling design withdraws approximately 17 billion gallons of seawater per day when all plants using this technology are fully operational." (Ferry-Graham, et al. 2008) This water houses millions of fish, eggs, larvae and invertebrates. Occasionally marine mammals such as seals and turtles are captured in this water as well. According to their size these organisms are either impinged on bar racks or traveling screens or entrained as they pass through these protective intake barriers.

Referring to Table 2, with the exception of the Long Beach and Dana Point desalination projects, the remaining plants are planning to co-locate with power stations whose source water for desalination will originate from surface and subsurface seawater.
Table 3 below outlines the generation capacity and the water requirements of power stations and desalination plants in Southern California.

Table 4. Southern California Power and Co-located Desalination plants using once-through cooling (OTC) systems. (Steinbeck)

Power Plant	***Avg. Intake Volumes (2000-2005) (MGD)***	***Max. Permitted Intake Volumes (MGD)***	***Desalination Requirements (MGD)***
1. Encina	621	857	304
2. San Onofre	2293	2438	Planning
3. Huntington Beach	179	514	304
4. Long Beach	577	261	Planning
5. El Segundo	334	706	Planning
6. Scattergood	309	495	Prototype

Entrainment and Impingement

A large part of the ocean's pelagic biomass consists of plankton. These organisms include eggs and larvae that represent the early life stages of fish and shellfish. Entrainment is mortality that occurs as a result of exposure to the physical, chemical and thermal stressors during the intake process. Impingement is mortality that results when marine organisms are pinned against intake protection hardware such as screens and racks. Losses from entrainment include small fish and plankton and far exceed the number of species lost by impingement.

Sampling and modeling are used to estimate loss of species numbers via entrainment--enumerating mortality from impingement is less complex and entails counting the organisms left intact on intake screens. (Ferry-Graham 2008) Assessing the ecological impacts on nearby populations and communities is complex for both. In general effects from impingement are more localized than those of entrainment. (Ferry-Graham 2008)

Considerations of Entrainment and Impingement

Size of intake screens and marine organisms

The pore size of the intake screens and the size of marine organisms are the two basic parameters that determine species entrainment and impingement. In order to prevent fouling of the intake systems by biological and anthropogenic sources, trash racks are the first line of protection followed by traveling screens. The distance between bars is typically 8.75 cm (3.5 inches) and traveling screens' pore sizes range from 1.56cm (5/8", 3/8") to 0.94cm. (Steinbeck) The mortality of pelagic marine organisms smaller than these dimensions and cannot overcome the intake flow is assumed to be one hundred percent. On the other hand, benthic organisms that live near or on the bottom are less prone to entrainment. ((Ferry-Graham 2008)

Measuring mortality from impingement is a straightforward process while estimating entrainment is more entailed. In addition there are numerous questions underlying both the sampling protocols and the modeling used to estimate mortality. Some of the major concerns are: sampling frequency, type of collecting gear, and the mesh sizes of plankton nets and according to Ferry-Graham, all can introduce bias into the results. Although a variety of models are used to estimate impacts on species populations, these provide limited information due to lack of life history data and baseline data sets of natural variability in space and time. (Ferry-Graham 2008)

Impingement and entrainment monitoring data at power stations in Southern California is limited; addressing ecological impacts from co-located desalination plants is site specific due to differences in source water, scale and intake design of both the desalination and power plants. Therefore, the following calculations were performed for the Carlsbad Desalination Plant in Carlsbad, California to evaluate the impacts on commercial fisheries.

Carlsbad Desalination Plant (CDP) Species-Specific Impingement Calculations

The following discussion of impingement is based on monitoring data collected by Tenera Environmental for the Encina Power Station. The report documents losses from impingement by individual species and enumerates number of individuals and total mass. Without a measure of comparison such as the species population numbers in the source water, the evaluation is limited. Therefore, I chose to compare the loss by impingement of four, site-specific fish (California halibut- *Paralichthys californicus,* Northern Anchovy- *Engraulis mordax*, Pacific Sardine- *Sardinops sagax* and White Sea Bass- *Atractoscion nobilis* to the commercial landings in California and San Diego. This analysis offers a practical tool to evaluate environmental impacts from impingement of these fish species.

Calculations were performed using the impingement data (from Poseidon's *Updated Impingement and Entrainment Assessment Attributed to Desalination Plants* (Poseidon 2007)), age of recruitment, and various mortality coefficients. Losses to fishers were calculated using a range of natural mortality scenarios from most conservative of no natural mortality to 10 y^{-1}. Impingement data was collected by Tenera Environmental for the Encina Power Station (EPS) over fifty-two week period during 2004-2005. The foregone loss in biomass (pounds) of the aforementioned fish species to commercial fisherman was calculated as a percent of the total landings in California and San Diego. The following equation was designed to quantify the loss with the variables explained below:

$$N_{R} = N_{I} \cdot e^{-m\Delta t}$$

N_R = Mass (g) of recruited individuals* (REPRESENTS THE MAXIMUM LOSS TO FISHERS)

N_I = Mass (g) of individuals impinged

m= exponential mortality coefficient

$\Delta t=$ Age of recruitment – Age of impingement (yrs.)**

*Recruitment is defined as the product of survival of individuals in space and time that could be landed by fishers.

**Age of impingement estimated by using weight at length function W= a (L^b) (derived from various fisheries management plans) followed by estimating age from length.

Results

Table 5- The calculations represent the loss to commercial fishers due to impingement in one year.

Species	**Number of fish impinged**	**Loss to fishers in (lbs.)**	**CA Landings (lbs.)**	**San Diego Landings (lbs.)**	**Percent of CA Landings**	**Percent of San Diego Landings**
Northern Anchovy	573	1.18 lbs.	24,646,691	40,050	4.79E-08	2.95E-05
Pacific Sardine	268	0.59 lbs.	76,173,217	47,420	7.75E-09	1.24E-05
White Sea bass	70	0.15 lbs.	293,049	52,565	5.12E-07	2.85E-06
California Halibut	95	.21 lbs.	924,216	30,748	2.27E-07	6.83E-06

For the fish considered, the percent losses are far less than one thousandth of one percent of the total loss of both the California and San Diego landings. The loss to fishers even with the most conservative mortality coefficient-- 0/yr. (i.e., none of the fish impinged would have suffered natural mortality, survived to an age and all were caught by fishers) was minimal.

Conclusions and Challenges of Calculations

At first glance, Tenera's impingement numbers seemed unusually low for a year period. Also, because this is one sampling event, the losses are not accurate; more data sets are needed for more rigorous testing.

The impingement data set is an obvious weakness in enumerating the percent loss since they represent a one time sampling event lasting a year. Multiple sampling events establishing long term data sets over time are needed to obtain more accurate estimates. Other points of concern include: the location, method and frequency of capture between impingement and fishers. (Ferry-Graham 2008) Impingement data was recorded at one point (the Encina Power Station) in space and time whereas commercial landings originated from numerous vessels fishing in various coastal and open ocean locations—this is a another source of variability.

In terms of determining significance we assume that the landings represent an acceptable benchmark of loss by society. This point of view may not be warranted by all and is subject to debate. We also assume that the landings data are accurate and efforts to cull them are legitimate. These calculations cannot serve as proxies for other organisms not surveyed in detail such as invertebrates and shellfish nor does it consider pertinent ecological attributes traits like species density and richness that may impact local and regional fish populations or communities. Finally, the results do not reflect the ecosystem services that fish and other impinged organisms provide. These factors are much more complex to adequately address in the scope of this report, but might offer a unique perspective. Despite the shortcomings in the collecting the impingement data, the results signify a very minor loss to the commercial fisheries of the four species.

Caveat to Analysis

The Carlsbad Seawater Desalination Project's Flow, Entrainment and Impingement Minimization Plan includes a daily loss of total biomass impinged from Carlsbad's Desalination Plant (CPS). According to the report, the projected estimated impingement associated with the stand-alone operation (desalination is operating independently) ranges from 1.57kg/day (3.5 lbs./day) to 7.16 kg/day (15.75 lbs./day). Using the most detrimental figure of 15.75 lbs. per day, the total yearly loss would equate to 5,750 lbs. of lost biomass. The total commercial fish landings in San Diego were 2.1 million lbs. in 2007 and include some invertebrates and shellfish. Assuming that *all* of these fish could potentially be commercially available for harvest, the annual mortality from impingement would still be well below one percent of the commercial landings in San Diego.

Estimating Entrainment

According to California's Energy's Entrainment report, "only seven of the 21 OTC plants in California have conducted studies of entrainment effects that meet current scientific standards. (Ferry-Graham 2008) Sampling data is scarce as policy requirements regarding impingement and entrainment have been inconsistent and costs for such studies are high.

According to Raimondi, potential entrainment is estimated using: the intake flow volume (N) and the number of larval organisms in the water (V). One hundred mortality is assumed and estimates are calculated by N x V. Measuring flow does not pose as difficult of a challenge as determining the number of larval in a square meter of source water. This is estimated using fisheries management models.

"Sampling is usually conducted with a 300 - micron mesh plankton net targeting larvae of a particular size or larger and occurs at the intake and at locations away from the intake. (Ferry-Graham 2008) Most studies are conducted over a one year period. To allocate samples in space and time, researchers consider the site specific characteristics at the power plant's location such as intake design and source water. (Ferry-Graham 2008) There are many challenges with entrainment sampling design. The most notable are: duration and frequency of sampling coupled with the appropriate gear. (Ferry-Graham 2008) Other factors include: a lack of baseline assessments of population densities in source waters as well as, complicated species' life histories and behavior. (Ferry-Graham 2008)

Ecological Entrainment Modeling

Once potential entrainment has been estimated, modeling is introduced to assess the loss. There are a variety of different modeling techniques that are used to estimate the ecological impacts of entrainment. Each model produces a specific outcome and the choice of model is determined by the type of information available. (Ferry-Graham 2008) Some ecological considerations when examining effects depends on where the intake is located, how much water is taken in by the plant, its velocity and at what time of day or season intake occurs.

The Agua Hedionda Lagoon will serve as the source water for the CDP; it is important to note its unique ecosystem services and connectivity to the Pacific Ocean. The western most section of the lagoon lies adjacent to coastal waters and experiences daily tidal flushing. This influx carries an assortment of estuarine fish, shellfish and marine mammals. The habitat is serves as a nursery for juvenile fish which may spend part or all of their life cycle foraging, developing and reproducing here. According to the Flow, Entrainment and Impingement Minimization Plan (Poseidon 2009), the three most susceptible fish to entrainment are the blennies, gobies and white croakers.

Assessing Loss using the Empirical Transport Model

Since accurate source population estimates are not available, the empirical transport model (ETM) was used to estimate the impacts of the CDP. This model "provides an estimate of incremental (a conditional estimate in the absence of other mortality) imposed on local larval populations by using an empirical measure of proportional entrainment rather than relying solely on demographic calculations."(Ferry-Graham 2008) In simplest terms, impacts were based on the estimated number of larval organisms in the entrainment volume compared to the estimated number of larval organisms present in the source water volume on a given day. This equation is expressed as:

PE (potential entrainment) = $\frac{\mathbf{N_{Ei}}}{\mathbf{N_{Si}}}$

where,

$\mathbf{N_{Ei}}$ = estimated density of larvae in **entrained water x design cooling water intake**

N_{Si} = estimated density of larvae in **source water on survey day x source water volume**

For the CDP, the ETM Model data estimated a combined twelve percent loss for gobies, blennies and hysopops. (Poseidon 2009) This means that a total of twelve percent of these fish combined in the lagoon will be lost to entrainment daily.

Comments

Does desalination cause an added impact in terms of entrainment or impingement or simply exacerbate a pre-existing problem?

No, the Carlsbad Desalination Plant does not add additional significant impact in terms of impingement and entrainment collocating alongside of the EPS. The existing intake systems are destructive to marine life and losses cannot be disputed. Losses to commercial fishers from impingement were minimal. On the other hand, if desalination plants are going to co-locate and use the existing intake technology they are warranted to more rigorously monitor impingement and entrainment losses.

Therefore, it is my recommendation that continuous yearly sampling is conducted as part of the mitigation requirements to establish more robust data sets in conjunction with restoring wetlands as currently mandated. This would provide policymakers with a more accurate reference to determine the significance of the impingement impact.

PART III. ENERGY AND SOCIAL COST ANALYSIS

Energy Considerations and Costs

Energy use is a major indirect environmental impact of ocean desalination—the reverse osmosis process is energy intensive due to the high pressures required to extract the salt and organic components from seawater. Two major considerations that affect energy use are the temperature and salinity of the source water. Since seawater contains higher total dissolved solids than its counterpart, brackish water, consequently it requires four times the amount of energy to process. (Desalination, 2008) Carlsbad Desalination Plant's use of the warm, once through effluent water from EPS will reduce energy input by 5-10%. (Voutchkov, 2007)

Energy accounts for the majority of the variable costs of desalinated water second only to amortization costs. (Desalination 2008) Therefore, the cost to desalinate seawater is highly dependent on the price of energy. For example, a six cent rise per kilowatt hour in energy use will increase total cost of seawater desalination by over 35%. (Desalination 2008) Clearly small fluctuations in the price of energy have dramatic effects on the total costs. Reducing the costs of desalinated water will depend in large part, on the ability to develop more efficient membranes that can function at lower pressures.

In addition to the private costs (paid for in the energy bill of the desalination plant), energy use also imparts several indirect effects on the environment and society. When society bears the cost of an additional unit beyond the private costs, this is known as an externality. The "total social cost" of the energy is the sum of the private cost (which reflects real resources that could have been used elsewhere) and the externality imposed. One of the main externalities associated with energy use stems from greenhouse gas emissions that, in turn, contribute to indirect environmental issues such as global warming, melting of the ice caps and sea level rise.

Problem

Both ocean desalination and imported water from the State Water Project are highly energy intensive. The cost of polluting from greenhouse gas emissions and the environmental losses (that result from securing these water supplies) impart costs to society not reflected in the cost of water. In order to achieve efficiency in the pricing of desalinated water it is necessary to include these non-market costs. Further, consideration of the external costs can also be a tool for determining an efficient water supply allocation from the different response strategies available.

In this analysis ocean desalination was compared with imported water from the State Water Project and the Colorado River, along with conservation and water-reuse. The energy use, fish mortality, and carbon footprint of each category were ranked in a matrix. These externalities were selected since they were the main environmental impacts examined in the project. In the second part of the analysis, each water response was then ranked according to the following scenarios:

SCENARIO A: Severe environmental impacts from energy or significant increase in mitigation costs

SCENARIO B: In stream values of water increase

The purpose of this exercise is to demonstrate how these negative externalities influence the marginal social costs of water in scenarios A and B.

Focus Question:

How do external costs of ocean desalination (indirect environmental impacts from energy use and the reallocation of water to in stream uses) affect the allocative efficiency of water response measures in Southern California?

Methods

We assume that the marginal social costs are equal for all response strategies representing the social optimum. Restated, there is no advantage in choosing a particular water response strategy over another when substituting one acre-foot from any source with an acre-foot from another is equal. This is only the case if all sources have the same social cost on the margin.

The energy use, fish loss (from impingement and entrainment and lack of in-stream water) and carbon footprint of ocean desalination, water reuse, conservation and imported water in Southern California were qualitatively enumerated on a scale of one to four (lowest to highest). The water supplies were then ranked as the most (5) and least favorable (1) under the aforementioned scenarios (A&B).

These scenarios serve as an economic extension of the impingement exercise of ocean desalination in part two of this report and the energy intensities. Although they are stylized examples, they represent likely changes in the future. For example, the allocation of water for in-stream uses is a trend that is expected to increase in western water supplies to protect endangered fish-both freshwater and marine.

Rankings

The following negative externalities were qualitatively ranked for the aforementioned water supplies: energy costs, carbon footprint, and environmental losses (specifically losses of marine fish from impingement and entrainment and endangered freshwater fish from lack of in-stream water).

Total energy intensities of water supply sources in Southern California were derived from Dennen et al. and used to calculate carbon footprints and to rank the water response strategies in the social cost analysis. These calculations incorporate the energy required for the initial extraction from a natural source through conveyance, treatment, distribution, end uses, waste collection, treatment, and discharge. (Dennen et al. 2007)

Carbon Footprint

The carbon footprints of San Diego's 2008 water supply measures were calculated in metric tons per acre foot with one mega-watt hour equal to 0.25 metric tons of carbon. This is San Diego Gas and Electrics' emission factor for carbon used in Poseidon's Climate Action Plan. (Poseidon 2007)

Table 6. This table shows the total water supplies in 2008 of the San Diego Water Authority (SDCWA), the average energy use and the carbon footprints.

Water Supply	Water Supplies Allocation 2008 San Diego (Acre/feet/yr)[1]	Average Energy Use (mega-watt hours/acre-foot)[2]	Carbon Footprint (MT per acre/foot)[3]
*Desalination	56,000	4.0	1.0
State Water Project	244,495	3.8	0.85
Colorado River	382, 415	2.0	0.45
Water Re-Use	25, 213	0.30	0.07

1. SDCWA Annual Report 2008
2. Dennen et al. 2007
3. Poseidon Climate Impacts 2007

* Desalination was not part of the San Diego County Water Authority's 2008 annual use and is included solely for comparison.

Environmental Uses and the Value of In-stream Flows

In the past century efforts to secure freshwater to meet the demand of Southern California's 38 million residents has proceeded with little to no regard for in-stream flows. Thirty percent of the California's water is allocated for environmental uses and by 2020 about 29 million acre feet a year will be required to meet the environmental demand. (Bulletin 161, CADWR 1994) This non-consumptive use has gone virtually unnoticed in California until recent federal action in 2007 mandating water to protect the delta smelt in the Sacramento/San Joaquin Bay- Delta highlighted the value of this often overlooked use of water. As a result of this ruling, the State Water Project cut its allocation to Southern California raising concern among water planners of deceasing reliability of imported water supply.

Examining imported water from the Colorado River, there are a number of freshwater fish species whose populations are threatened by lack of stream flows. Four species of fish native to the Colorado River basin that are in danger of becoming extinct are the Colorado pike minnow, the razorback sucker, the bony tail, and the humpback chub. (USFWS)

Rankings

The following negative externalities were qualitatively ranked for the aforementioned water supplies: energy costs, carbon footprint, and environmental losses (specifically losses of marine fish from impingement and entrainment and endangered freshwater fish from lack of in-stream water). The table below contains the results.

Table 7. Social Cost matrix of San Diego's Water Supply (Lowest (0) to Highest (4)

Negative Externality	Water Re-Use	Conservation	Colorado River	State Water Project	Ocean Desalination
Energy Demand	1	0	2	3	4
Loss of fish	1	0	4	3	2
Carbon Footprint	1	0	2	3	4

Results

Scenario A: Impacts of energy use are more severe or carbon mitigation costs increase significantly

Both scenarios A and B suggest that conservation is the most favorable option and should increase relative to the other strategies however, both scenarios reveal very different results in terms of how much ocean desalination should occur in the optimal mix of water response strategies. As energy costs increase, ocean desalination and imported water especially from the State Water Project, are the least favorable water response measures. Likewise, if carbon mitigation costs rise, ocean desalination will no longer be cost effective.

Scenario B- In-stream Value of water rises

Under this scenario, ocean desalination ranks more favorably and imported water from the Colorado River is the least favorable. This low ranking reflects the number of endangered freshwater fish species found in the six other states and Mexico that share the Colorado River water supply.

Comments

Based on the results of the social cost analysis, ocean desalination will remain favorable and cost effective as long as energy costs and carbon offset costs remain low. These results are supported by Dale examined urban water supply responses and concluded that "if electricity prices are high, conservation is the cheapest option and desalination is the most expensive." (Dale 2001) In addition, should the impacts of energy are much more severe than predicted, then the external costs will be much higher and ocean desalination won't be as favorable. The same applies to imported water especially the supply from the State Water Project.

One factor that was not considered in this analysis was the pricing scheme of water. Average cost pricing is a highly inefficient strategy that grossly undervalues the cost of water. Should the price of water be recalculated to reflect the non-market costs, desalination would be a more efficient response.

Another likely future scenario that will favor ocean desalination is the cost of imported water. This is likely to increase in response to increasing demand from population growth, continued economic expansion and scarcity from the effects of climate change. The marginal cost of ocean desalination will remain stationary as more comes online, while the marginal cost of imported water goes up as more comes on line. Increasing demand alone (and the desire to keep all marginal costs the same) will suggest more desalination as a fraction of total supply.

Variable costs of desalination will likely drop as energy efficiency in desalting water improves. Should energy prices outpace improvements in energy efficiency of reverse osmosis, then ocean desalination will not be a favorable response. However, increases in energy costs will most likely increase the price of imported water which may help offset these conditions.

How much ocean desalination should San Diego implement? In one sense this will primarily depend on how scarce imported water becomes. In an extreme case where imported water becomes very scarce thereby inflating the price of the water, then a moderate to high level of ocean desalination may be warranted. Also, hypothetically speaking should desalination plants desalt brackish water from coastal lagoons, increase the membrane efficiency this would cut energy requirements and decrease the price of desalinated water. Finally, improvements in intake technology may lead to more affordable desalinated water by negating the need to mitigate the losses to marine organisms.

Ultimately, as the reliability of imported water decreases Southern California is examining more efficient water uses such as conservation and water re-use. We will remain reliant on imported water to meet our future water needs. Ocean desalination will accompany conservation and water re-use as one of several methods to increase reliability and grant greater local control of water.

PART IV. COMMUNICATION

Interpretive Display/Presentation

The deliverable for this project consisted of designing and presenting an interpretive display at the Birch Aquarium at Scripps. This media was selected as a result of completing Communicating Ocean Sciences to Informal Audiences (COSIA) course during the winter quarter. I opted to embrace the informal route due to a strong belief in the importance of reaching the non-science audience, some of whom might not ever take an interest in water or ocean desalination. Presenting to informal audiences also requires stronger and more adaptive social skills. As a public school educator, I found that informal education was similar in many ways to classroom teaching. Without a doubt, planning and presenting informal is much more involved mainly due to the range of age groups to consider. Some other profound challenges were:

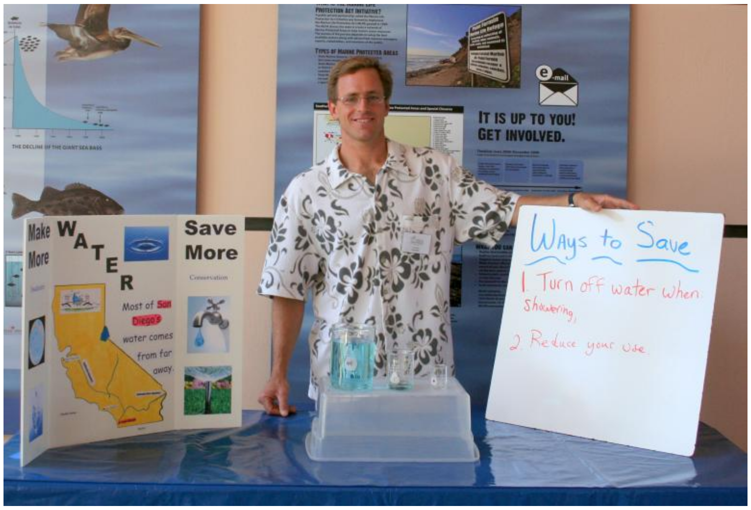

Figure 6. Conservation/Ocean Desalination Display (Briscoe 2009)

1. Conveying a message in a limited timeframe
2. Non-captive audience
3. Design and planning considerations for a diverse audience

The activity was presented on two different occasions—the first was from ten am to twelve on a weekday. The second presentation was done late morning to early afternoon on a Saturday. Each run offered a new opportunity and insight on the strengths, weaknesses and impact of the presentation. These are discussed in detail in the analysis section of this report.

The proceeding section includes the planning template used for the presentation, followed by an analysis of the activity. The first outlines the planning process and key considerations involved in design and execution of informal displays. The analysis examines the positive and negative aspects of the presentation and suggests key changes for future use.

Desalination Activity Planning Template for the Birch Aquarium at Scripps

Name of this Activity: Water Conservation and Ocean Desalination

Theme/Main Message of the Activity

Theme: Supplementing San Diego's Water Supply with Conservation and Desalination

Message: The main message is to inform the audience that freshwater can be derived from the ocean but, water conservation is necessary to help ensure water reliability.

Audience

This activity will be designed for student groups K-12.

Activity Objectives

1. The audience will leave knowing that local and regional water supply in San Diego is *scarce* and that conservation of water is necessary to avoid possible future water shortages.
2. The audience will leave with the understanding that the ocean can be used as a new source of freshwater.

Activity Summary/Synopsis

1. Entry Point-**Water Planet**

Tossing an inflatable globe to participants and asking if their hands are touching water or land to show that earth is mostly water and discuss where it is found.

2. **Distribution of Water**

This part of the activity could be delivered either as a demonstration or as a challenge. Starting with a 250 mL beaker of water, the participant removes certain quantities of water that represent how water is distributed on earth first in terms of fresh and saltwater (97%, 3%). Next, from the freshwater beaker, the participant removes a volume equal to one percent from the 3% percent volume to represent the amount of available freshwater for human use. The instructor can either lead the participants through these steps or allow the participant to become more involved in the process. This activity provides the participant with a concrete representation of the amount of available freshwater for human consumption. The presenter's role is to guide the participant through the steps or to perform the demonstration depending on the audience.

3. **San Diego Water Supply, Conservation and Desalination**

The final section of the presentation will be introduced with two pointed questions:

a. Where does our water come from in San Diego?

b. How can we get more water in San Diego?

The objective is to elicit discussion and eliminate misconceptions about water supplies in San Diego. A simple map of California will be used as a reference point and be placed in the middle of a display board describes below. The map will serve as a geographic reference to indicate the sources of imported water (Colorado River Aqueduct, Bay-Delta) and the long distance that the water must travel. One misconception to address in this discussion is that local water supplies are abundant in San Diego and the idea that freshwater will always be available.

The second question will act as a transition point into a discussion of enhancing water supplies through desalination and conservation.

Display Board

This board will be designed as such:

MAKE MORE	**SAN DIEGO'S WATER**	**SAVE MORE**
Desalination	Map of CA	Conservation
Images (Ocean + Cop of water)		Images of conservation practices

TALKING POINTS

Desalination

1. The ocean offers a new, reliable source of water.

2. Desalination is the process of changing saltwater into freshwater. However, it is expensive and requires more energy to clean the water.

San Diego's Water

1. There is not a lot of water in San Diego--most of San Diego's water comes from other places. (Use CA map to prop up talking point)

Conservation

1. Conservation helps to safeguard our water supply.

2. Everyone can help by conserving water.

3. Conservation will become mandatory starting July first.

Materials Needed

Poster board, map of CA, images of ocean and conservation practices, white board and markers, small blow-up globe, 3 beakers of various volumes, eye dropper, graduated cylinder, food coloring

Set-up Procedure

The activity will have the display board on one side of the table with the demonstration equipment out front. I imagine small signage attached to each beaker: ocean, freshwater, available freshwater. It would be more attractive to have the demonstration equipment raised up off the table slightly on a white box in order to see from a distance. Some brochures on water conservation and desalination will be available for those wanting additional information.

Activity Description

The first stage of the activity will introduce the amount of water verses land on earth by tossing the globe around to participants. This is to convey that our planet is mostly water and to inquire where this water is found. This will be followed by a demonstration outlining how water is distributed on earth specifically salt and fresh water and available freshwater available for human consumption. The demonstration will emphasize the limited supply of freshwater and serve as an entry point into water supply in San Diego. The next question will be: Where does our water supply come from in San Diego? After a short discussion among participants and the presenter, the map of California will be used to show that most of San Diego's water is imported.

The last lead question will be: How can we get more water in San Diego? This will allow for use of the display board with an introduction to desalination followed by water conservation measures.

The first activity serves mainly to draw people to the display while reinforcing for many a prior concept that the earth is mostly water. This allows the learner to participate in the learning experience and gives the presenter an idea of their prior knowledge and past experiences.

The second activity is a demonstration that can be manipulated by the presenter of participant based on the size of the audience and/or the skill set demonstrated by the audience demonstrated. This can allow for more or less interaction from the participants (using the graduated cylinder to make measurements, etc.) to develop the concept that the amount of freshwater available for human consumption is very small. Steps can be added or deleted for pacing and attention span to ensure that the conservation and desalination messages receive sufficient attention.

The last phase of the presentation will address the lack of local water supply in San Diego, the reliance on imported water along with the role of conservation and desalination as response strategies to supplement supply in San Diego. This phase will include: assessing prior knowledge about water supply and conservation efforts in San Diego, informing the audience of new water response strategies such as desalination while reinforcing the need to conserve water. In order to adequately address both conservation and desalination, I will inform the younger audiences of desalination by presenting the aforementioned talking points and answering any questions posed. The conservation message will be delivered by asking the participants how we can save water and writing down their responses on a white board. Participants can use the display board visuals as cues to help.

Guiding Questions

Check for prior knowledge, Check for understanding = CPK, CFU

Engagement = E   Discussion = D

Is the earth mostly land or water? (CPK, CFU)

Where is our water found and what type of water is it?

How have you used water today? (E&D)

Can you go for one day without using water? Why or why not? (E&D)

Where does your water come from? (CPK)

Can we use the ocean as a source of water? What would we have to do to get fresh water from the ocean? (E)

Have you ever swallowed saltwater while swimming in the ocean? (E&D)

Would you consider drinking saltwater if the salt was removed and the water cleaned up?

What are some ways you can save water? (D)

Vocabulary

Conservation, scarcity, reliability, desalination, distribution (for older audiences)

ACTIVITY ANALYSIS/DEBRIEF

Name of this Activity: Water Conservation and Ocean Desalination

Theme/Main Message of the Activity

Theme: ***Supplementing San Diego's Water Supply with Desalination***

Message: The main message is to inform the audience that freshwater can be derived from the ocean.

Audience

This activity will be designed for student groups K-12.

Activity Objectives

1. The audience will leave knowing that local and regional water supply in San Diego is *scarce* and that conservation of water is necessary to avoid possible future water shortages.
2. The audience will leave with the understanding that the ocean can be used as a new source of freshwater.

Comments:

For the local visitors the first objective was relatively straight forward and was most likely reinforced by media reports of an impending water shortage. However, I did speak with a group of participants from New York who was completely unaware of water scarcity in Southern California.

The second objective was not quite as familiar as the first and therefore, participants may not have had a more difficult time understanding how this process could provide drinking water. An additional activity strictly focusing on desalination would have help with this objective. I am not sure how many folks would remember just because I told them so.

Activity Summary/Synopsis

1. Entry Point-**Water Planet**

Tossing an inflatable globe to participants and asking if their hands are touching water or land to show that earth is mostly water and discuss where it is found.

Comments

The entry point was a hit and allowed for an easy and comfortable way to draw people into the presentation. It was also easily adaptable for all age groups, a good way to check their background knowledge and augment interest and participation. I would definitely use it again.

2. **Distribution of Water**

This part of the activity could be delivered either as a demonstration or as a challenge. Starting with a 250 mL beaker of water, the participant removes certain quantities of water that represent how water is distributed on earth first in terms of fresh and saltwater (97%, 3%). Next, from the freshwater beaker, the participant removes a volume equal to one percent from the 3% percent volume to represent the amount of available freshwater for human use. The instructor can either lead the participants through these steps or allow the participant to become more involved in the process. This activity provides the participant with a concrete representation of the amount of available freshwater for human consumption. The presenter's role is to guide the participant through the steps or to perform the demonstration depending on the audience.

Comments

Except for infants, most age groups were able to follow and understand the distribution of water. It was a stand back and watch activity that I decided to turn into a challenge by having the participants guess when they thought I should stop when allocating the freshwater from the saltwater. This encouraged more audience participation and made the demonstration more interactive. Early on I performed the demo for a four year old only to realize afterwards it was completely ineffective. Overall I felt this was a good transition from tossing the globe and lead to discuss the lack of water in San Diego.

3. **San Diego Water Supply, Conservation and Desalination**

The final section of the presentation will be introduced with two pointed questions:

a. Where does our water come from in San Diego?

b. How can we get more water in San Diego?

The objective is to elicit discussion and eliminate misconceptions about water supplies in San Diego. A simple map of California will be used as a reference point and be placed in the middle of a display board describes below. The map will serve as a geographic reference to indicate the sources of imported water (Colorado River Aqueduct, Bay-Delta) and the long distance that the water must travel. One misconception to address in this discussion is that local water supplies are abundant in San Diego and the idea that freshwater will always be available. The second question will act as a transition point into a discussion of enhancing water supplies through desalination and conservation.

Comments

The third section of the presentation proceeded smoothly with the map did work well to reinforce the talking points. The idea that water was piped into San Diego might have been fuzzy since I didn't have pictures of aqueducts and some of the younger participants wouldn't have known what they were. Also, I failed to include questions such as: Have you ever seen the huge waterways along the I-5? Since they might not have known or seen an aqueduct, it might have been difficult for some to believe even after I showed them where San Diego's water came from.

<u>Display Board</u>

This board will be designed as such

MAKE MORE	**SAN DIEGO'S WATER**	**SAVE MORE**
Desalination	Map of CA	Conservation
Images (Ocean + Cop of water)		Images of conservation practices

TALKING POINTS

Desalination

1. The ocean offers a new, reliable source of water.

2. Desalination is the process of changing saltwater into freshwater. However, it is expensive and requires more energy to clean the water.

Comments

The first talking point was reinforced by the demonstration. I made a point of referring back to the beaker when addressing the reliability factor. Rarely did I include the expensive and energy intensive bit for the younger audiences but, this was included in discussions with older, more informed audiences.

San Diego's Water

1. There is not a lot of water in San Diego--most of San Diego's water comes from other places. (Use CA map to prop up talking point)

Conservation

1. Conservation helps to safeguard our water supply.

2. Everyone can help by conserving water.

3. Conservation will become mandatory starting July first.

Comments

These points were made mainly through discussion and offered an easy way to contribute especially for younger audiences since most had been exposed to water conservation at school. I decided to write out most of the conservation tips to speed up delivery. For example, the first sentence read: I can turn off the tap while…. then I would list the responses given. Based on some puzzled looks, the idea of "saving water" did not necessarily correspond to my question of "How do we get more water in San Diego?" Since we are not getting any more water by merely using less trying to link the ideas was an obvious point of confusion. Next time I might refer only to desalination if I were to pose the question.

Set-up Procedure

The activity will have the display board on one side of the table with the demonstration equipment out front. I imagine small signage attached to each beaker: ocean, freshwater, available freshwater. It would be more attractive to have the demonstration equipment raised up off the table slightly on a white box in order to see from a distance. Some brochures on water conservation and desalination will be available for those wanting additional information.

Comments

In terms of space on the table and supplies, the display was appealing and I did not have any trouble moving from one activity to the next. Set-up and tear down was easy, too. The second time I presented I placed the beakers and the graduated cylinder on a small plastic container so that they were off the table and more visible from far away. Also, I set up the display behind the MPA signage on Saturday. It is difficult to determine whether it was strategically favorable in terms of foot traffic.

Activity Description

The first stage of the activity will introduce the amount of water verses land on earth by tossing the globe around to participants. This is to convey that our planet is mostly water and to inquire where this water is found. This will be followed by a demonstration outlining how water is distributed on earth specifically salt and fresh water and available freshwater available for human consumption. The demonstration will emphasize the limited supply of freshwater and serve as an entry point into water supply in San Diego. The next question will be: Where does our water supply come from in San Diego? After a short discussion among participants and the presenter, the map of California will be used to show that most of San Diego's water is imported.
The last lead question will be: How can we get more water in San Diego? This will allow for use of the display board with an introduction to desalination followed by water conservation measures.

The first activity serves mainly to draw people to the display while reinforcing for many a prior concept that the earth is mostly water. This allows the learner to participate in the learning experience and gives the presenter an idea of their prior knowledge and past experiences.

The second activity is a demonstration that can be manipulated by the presenter of participant based on the size of the audience and/or the skill set demonstrated by the audience demonstrated. This can allow for more or less interaction from the participants (by using the graduated cylinder to make measurements, etc.) to develop the concept that the amount of freshwater available for human consumption is very small. Steps can be added or deleted for pacing and attention span to ensure that the conservation and desalination messages receive sufficient attention.

The last phase of the presentation will address the lack of local water supply in San Diego, the reliance on imported water along with the role of conservation and desalination as response strategies to supplement supply in San Diego. This phase will include: assessing prior knowledge about water supply and conservation efforts in San Diego, informing the audience of new water response strategies such as desalination while reinforcing the need to conserve water. In order to adequately address both conservation and desalination, I will inform the younger audiences of desalination by presenting the aforementioned talking points and answering any questions posed. The conservation message will be delivered by asking the participants how we can save water and writing down their responses on a white board. Participants can use the display board visuals as cues to help.

Closing Comments

I did note that most of the participants on Tuesday were school groups from grades two to six with parents and their toddlers on Saturday. I still had a hard time distilling my points for the five and under audience. On a whole though, I felt much more comfortable and confident presenting my topic. This allowed me to observe the reactions of participants and adjust the presentation accordingly instead of solely focusing on my talking points.

If I were to do it again I would repeat steps one and two and instead of talking about San Diego's lack of rain and water supply first, I would go straight to desalination. This would change the theme and main message to address desalination in more detail. I would have a reverse osmosis membrane as a prop and I would start by asking what is in saltwater that we need to get rid of in order to drink. I did discuss the process in

these terms with some groups and they were able to follow fairly well. I would change it to help emphasize the desalination more since a majority of the audience was already familiar with ways to conserve and seemed to be hanging around the display wanting to hear about new information.

The poster would remain the same. It might be more advantageous to have other displays on the floor to help attract people's attention. One of the biggest challenges was being the only display on the floor and in the beginning, it was difficult to attract people to the display—participants draw other participants. Finally I would allow more time for an informal assessment mainly conducted by a question and answer session at the end.

Although I did not collect data to formally assess the effectiveness of the activity, I believe it was well-received. Based on the average time spent at the display, I would say with a high degree of confidence that participants were genuinely interested. Reflecting back I could have allotted more time for expansion on desalination since, as previously mentioned students and older participants were familiar with conservation strategies. The conservation bit offered the opportunity to demonstrate prior learning, however, the participants probably walked away with little understanding of ocean desalination. In other words, the younger students felt good about the experience, but may not have been to recall the messages presented especially water distribution and San Diego's water supply.

With the older, more informed audiences, the opposite was true. The discussion was more focused on ocean desalination and people had some background knowledge of ocean desalination and water supply issues. Conversations also centered alternate uses of water such as agriculture and the equitability of the current allotments of water in California.

Based on the variety of conversations and discussions, I would say the presentation was meaningful since it connected to past experiences and prior knowledge. I would rank impact in terms of time spent at the display station and how much the discussion was controlled by the participant. As I tell my students in a classroom, "the more I talk the less you learn.".

Background and Additional Resources

Water Supply

- SDWA, http://www.20gallonchallenge.com/supply.html
- Water Education Foundation,

  http://www.watereducation.org/doc.asp?id=381&parentID=379

Conservation

- The 20 Gallon Challenge—*Water: Save it or Lose it*

  http://www.20gallonchallenge.com/programs_residential.html

Desalination

- Poseidon Carlsbad Desalination Plant

  http://www.carlsbad-desal.com/default.asp

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