Water Desalination: Arizona, California, Nevada and Mexico

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Water Desalination: Arizona, California, Nevada and Mexico

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4/19/2012

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WATER DESALINATION: ARIZONA, CALIFORNIA, NEVADA AND MEXICO

By
Clinton P. Kennedy

A dissertation submitted in partial fulfillment
of the requirements for the degree
of
INTERNATIONAL MASTER OF BUSINESS ADMINISTRATION
in
International Food and Agribusiness
Awarded by the Royal Agricultural College
in cooperation with Utah State University

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Major Professor        Committee Member

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UTAH STATE UNIVERSITY
Logan, Utah
2012
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I declare that this dissertation embodies the results of my own research or advanced studies and that it has been composed by myself. Where appropriate, I have made acknowledgement to the work of others.

Signed,

Clinton P. Kennedy

Dated April 19, 2012
Water Desalination: Arizona, California, Nevada and Mexico

by

Clinton P. Kennedy, International Master of Business Administration
Utah State University, 2012

Major Professor: Dr. Eric Thor
ASU College of Technology and Innovation

This was a study on the history of the Colorado River, the water challenges of the Lower Basin states and the international water laws that govern the United States and Mexico concerning the Colorado river. The main purpose of this study was to determine possible long-term solutions to the growing water needs of the Lower Basin states and how Mexico could help.

After discussing some concerns that the Lower Basin states had, research was done on the different types of desalination. This research included the different methods and their processes. MSF, MED, RO and MVC methods are discussed mentioning their different strengths and limitations.

Next different possible solutions are discussed. These possible solutions include current practices and their successes. The solution that is discussed in length is water desalination as it offers another method of obtaining water. This part also discusses different ways to power the plant. As Mexico was already going to build nuclear power plants one idea was to build a plant in Mexico and use their power to run a desalination plant.
This is one possible solution, to have a desalination plant desalinate water out of the Sea of Cortez in Mexico for the Southwest to use using the Mexico’s nuclear power plant to run the system. The economics of a desalination plant are discussed. The cost of building a plant, cost of desalinating the water, and water transportation costs are examined.

After an examination on these different costs are completed it is discussed on who would pay for the desalination plant and who would receive the water. One possibility discussed is that Arizona, California and Nevada all pay an equal share in the cost of building the desalination plant in Mexico. California would then receive the water from the plant and thus would cut back on their consumption from the Colorado River allowing both Arizona and Nevada to increase theirs.

A PEST analysis is done at the end of this study. It covers Political, Economical, Socio-cultural and Technological categories associated with this study. It covers different concerns and possible legislations that would need to be amended in order to continue with international desalination.
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Introduction:

The topic of this thesis is “Water Desalination: Arizona, California, Nevada and Mexico.” Desalination; as will be the definition for this thesis, is the process of removing salts, or other dissolved substances from water so that it can used for drinking or irrigation. In many countries such as Saudi Arabia and Australia desalination has been a great help in solving their water needs. The main objective of this study is to evaluate if desalination can be a long-term solution to the rising water needs of Arizona, California, Nevada and Mexico.

It is prevalent that the Colorado River play an important if not crucial role in the development and survival the Lower Basin states which consist of Arizona, California and Nevada. Also there are laws and regulations; such as the Mexican treaty of 1944 and minute 242, that determine how much water can be used from the Colorado River, and how much is needed to flow across international borders to Mexico. In an effort to meet international water standards with the Colorado River a desalination plant was built in Yuma Arizona in a effort to capture water runoff, desalinate or clean it, then return it to the Colorado River for the use and consumption of Mexico.

There are 2 desalination categories, thermal desalination and membrane desalination. Thermal desalination refers to the use of heat to accomplish the desalination process
while membrane desalination refers to the use of a membrane. There are several desalination processes the majority of which are thermal processes. The major membrane process is Reverse Osmosis (RO) while the major thermal processes are Multi-Stage Flash Distillation (MSF), Multi-Effect Distillation (MED) and Vapor-Compression Desalination.

Chapter one covers a history of reclamation projects on the Colorado River in an attempt to control the river and the precious water that flows through it including the use of the Yuma Desalination plant. It concludes with a brief overview of the Lower Basin area and its need for more water. Chapter two covers types of desalination and their processes. Chapter three is the body of the thesis, it covers the problems and possible solutions to the Lower Basin’s water crisis and a possible solution. Chapter four is a PEST (Political, Economical, Social, Technological) Analysis which is used by organizations to chart long-term plans and possible problems.

The main objective of this study is to evaluate if desalination can be a long-term solution to the rising water needs of Arizona, California, Nevada and Mexico. The significance of this study is to examine a possible solution to the Lower Basin’s water crisis problems while working with Mexico. If desalination is possible can it be done without adding to Mexico’s water problems?
Chapter 1: Colorado River, Yuma Desalination Plant and The Lower Basin

1902 Reclamation Act:
The Reclamation Act (also known as the Lowlands Reclamation Act or National Reclamation Act) of 1902 is a United States federal law that funded irrigation projects for the arid lands of 20 states in the American West. Prior to the adoption of the 16th amendment the Federal Government could not tax the citizens directly. Much of the government was then funded by the sale of public lands. The Reclamation Act was set up to facilitate the sales of these public lands by putting in infrastructure to facilitate irrigation on these previously arid lands and then sell them with the surplus going back to the Federal Government. Within this act the Secretary of the Interior created the US Reclamation Service within the US Geological Survey to administer the program. The US Geological Survey held onto this program for a short while until 1907 when the Reclamation Service became a separate organization within the Department of the Interior and was subsequently renamed the US Bureau of Reclamation (usbr.gov 2009).

1905 Laguna Dam:
Laguna Dam was the first attempt by the United States to divert water from the Colorado River (McDanial 2009). The construction of this Dam, which started in 1905 and finished in 1909, subsequently ended boat travel up the Colorado River. The construction of this dam was in response to the 1902 reclamation act passed by congress. The main purpose of this dam was to divert Colorado River water into canals
stretching into both Arizona and California. The web of canals which were built during the same time as the Laguna Dam was to take water from the Colorado River and irrigate arid lands. The construction of this dam allowed for year round farming in Arizona and California without completely stopping the flow of the Colorado (usbr.gov 2009). Laguna Dam was the first dam on the Colorado River that diverted water making irrigation possible.

1922 The Colorado River Compact:

In the early twentieth century, western states were experiencing a boom in growth. Interest in developing the Colorado River as an environmental resource was increasing dramatically during this time. In 1916 the state of Wyoming, in partnership with the now Bureau of Reclamation (then the US Reclamation Service), conducted a study of the Green River, a major tributary of the Colorado River. The study was intended to find possible uses of this major water source and eventually prompted the other western states of follow Wyoming’s example and conduct studies on what can be done with the Colorado River.

In 1920 Governor Emmet Boyle from Nevada created the Commission on Colorado River Development. The purpose of this commission was to gather information on plans being considered for water storage and generation of electrical power at Boulder Canyon. While this commission was gathering information other state officials were discussing the potential allocation of the Colorado River water among participating states. Eventually these discussions turned into a plan for the Colorado River Compact of 1922 (Walker 2006).
The Colorado River Compact is an agreement among 7 of the southwest states that the Colorado River runs through. This compact divides the river and all tributaries into an Upper and Lower Basin. The boundary of these two basins is Lee Ferry in Northern Arizona. The Upper Basin consists of Wyoming, Utah, Colorado and New Mexico. The Lower Basin consists of Arizona, Nevada and California. Arizona, Utah and New Mexico all have lands within both basins; however the majority of the states are separated as previously explained.

The compact requires that Upper Basin states not to deplete the flow of the river below 75,000,000 acre feet during any period of ten consecutive years. This means that the average annual flow needs to be 7,500,000 acre feet of water annually. The States in

*Wolter, K Colorado River Compact Presentation*
the Lower Basin need to then split up this annual allotment evenly. The specific annual allotments to the States in the Lower Basin were established in 1928 as part of the Boulder Canyon Project while annual allotments to the States in the Upper Basin were established in the Upper Colorado River Basin Compact of 1948. The annual allotments can be seen in Table 1:

<table>
<thead>
<tr>
<th>States</th>
<th>Share</th>
<th>Allotment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado</td>
<td>51.75%</td>
<td>3.88 Million acre ft/yr</td>
</tr>
<tr>
<td>Utah</td>
<td>23.0%</td>
<td>1.73 million acre ft/yr</td>
</tr>
<tr>
<td>Wyoming</td>
<td>14.0%</td>
<td>1.05 million acre ft/yr</td>
</tr>
<tr>
<td>New Mexico</td>
<td>11.25%</td>
<td>.84 million acre ft/yr</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>States</th>
<th>Share</th>
<th>Allotment</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>58.7%</td>
<td>4.4 million acre ft/yr</td>
</tr>
<tr>
<td>Arizona</td>
<td>37.3%</td>
<td>2.8 million acre ft/yr</td>
</tr>
<tr>
<td>Nevada</td>
<td>4.0%</td>
<td>.3 million acre ft/yr</td>
</tr>
</tbody>
</table>


**Boulder Canyon Project:**

From about 1900 the Black Canyon and nearby Boulder Canyon had been investigated for their potential to support a dam. The mouth of the Black Canyon is where the Hoover Dam is now located. It is about 20 miles East of Boulder City and separates Nevada from Arizona. Boulder Canyon is 20 miles north of Black Canyon. Placing a dam in one of these canyons would allow for flood control, irrigation water and produce hydroelectric power. In 1922 the Reclamation Service (later to be renamed the Bureau of Reclamation) developed a report asking for the development of a dam on the
Colorado River at or around Boulder Canyon. Soon after investigations began it became apparent that Boulder Canyon was not a suitable location due to a geologic fault and spaces that were too narrow to support the construction of a dam. The Reclamation Service then investigated Black Canyon and found that spot to be the ideal construction zone (Stevens 1988). Despite the site change, the dam project was referred to as the “Boulder Canyon Project” and later renamed to The Hoover Dam (Billington 2005).

In order to start and complete this project it had to be approved by congress. With Congress’ approval the Boulder Canyon Project became the Boulder Canyon Act. This Act actually authorized the Boulder Canyon Dam (Hoover Dam), the All American Canal and it re-approved a compact among the Lower Basin states which solidified the water distribution for California, Nevada and Arizona. This Act gave the Lower Basin the exclusive rights and use of their tributaries and limited water to Mexico to the mainstream (Colorado River) not the tributaries. In 1931 Arizona filed a law suit which would be the first of several Arizona verses California Cases. California had been exceeding their consumption allocations forcing Arizona to reduce theirs. The 1963 Supreme Court ruling on Arizona verses California relied heavily on the Boulder Canyon Act in its decision which upheld the water allocations from 1931 and forced California to cut back on the amount of water that it was consuming from the Colorado River (Wolter 2004).
**Imperial Diversion Dam:**

The Imperial Diversion Dam is located about 18 miles north of the Yuma Desalination plant, and about 2 miles north of Laguna Dam. Construction of this dam began in 1936 and opened two years later in 1938. The dam made the Laguna dam redundant as about 90% of the Colorado water is diverted into canals here at the Imperial Dam. The purpose of this dam was to divert water into the All-American Canal, the Gila River and the Yuma Project aqueduct. The dam raises the water by about 25 feet that allows for gravity to flow the water into the canals and aqueducts. Another important feature of this dam is that it allows for the sediment that the river carries to be removed prior to diverting the water to keep the canals from clogging and causing extensive damage and maintenance costs. At the construction of this dam the salinity was not important. Salinity levels did not become important until the 1960’s when Mexico filed a formal protest against the US claiming that the water coming out the US was too poor. As a result Minute Number 242 of the International Boundary and Water Commission was adopted in 1973. Within this minute it requires that the US ensure that the delivery of water into Mexico be no more than 115 (+/- 30) parts per million (ppm) total dissolved substance (TDS) than that at Imperial Dam (usbr.gov 2009).
The Mexican Treaty of 1944:

This is just one of many water treaties between the US and Mexico. The 1944 Treaty; however, is considered one of the most important and the turning point for all future US/Mexico water treaties (Treaty 1946). This treaty distributed between the two countries the waters of the Rio Grande, Colorado River and the Tijuana River. From the Colorado River it allocated 1,500,000 acre feet of water annually to flow into Mexico (Treaty 1946).

This Treaty allows for the diversion and damming of the rivers under “certain understandings.” These understandings include the costs to each respective country for their own water projects and repayments to respective countries if the water projects cause damage or flooding across international border lines (International 2011).

Yuma Desalinating Plant:

In order to comply with the 1944 Water Treaty between Mexico and the US the US had to deliver at least 1,500,000 acre feet of water from the Colorado River to Mexico. In the 1960’s Mexico filed a formal complaint against the US claiming that the water quality was too poor. As a result a special commission on the quality of the Colorado River was established in 1973. From the complaints that Mexico filed with the US and the commission that was formed to follow the quality of water headed into Mexico minute number 242 was established. Within minute 242 it was agreed that the water quality could not rise above 115 (+/- 30) TDS than that of Imperial Dam. It was around this same time that the Yuma Desalting Plant was proposed as a possible solution to the poor water quality that Mexico was complaining about (usbr.gov 2009).
Construction of the Yuma Desalting Plant began in 1975 and ended in 1992. Since that time the Yuma desalination plant has been in operation only twice. Once in 1992 as a 6 month test run and again in 2010 for an 11 month pilot run to extrapolate actual operating costs if the plant needed to be in operation. Neither runs actually desalinated water straight from the Colorado River, but instead desalinated irrigation run off from water pumped out of the Colorado River and used for agricultural purposes (Wolfe 2011). The rest of the time the Plant is used as an onsite water research facility.

At the start of the 2010 pilot run the Yuma desalination facility had already spent $150 million on the facility and management alone. The cost increased during the pilot run which operated at a 33% capacity and cost an additional $23.2 million making it “far from clear [if the plant] will ever operate full bore” (Davis 2010). According to the U.S. Bureau of Reclamation it may even be cheaper to pay farmers in Yuma and surrounding areas not to grow crops, allow the water to flow to Mexico then purchase the same crops from Mexico at a reduced price. Doing this would reduce the need for desalination in the US (McCloskey 2009). In Mexico the cost for water, power, labor and land is cheaper than that in the US. Paying farmers in the US not to grow crops, allowing more water to flow, then purchasing those same types of crops from Mexico could potentially lower the costs of those goods grown in Mexico for US consumers.

During the pilot run the plant desalinated about 48,000 acre feet of water at a cost of $484 per acre foot. The current cost of water per acre foot from the Central Arizona
Project (CAP) which runs the majority of the canals in Arizona is about $120. The cost to desalinate the water and use it is about 4 times as high as pumping ground water from sources around Arizona. As water needs increase the cost of pumping ground water will go up as ground water that was previously abundant begins to diminish. It is estimated that those costs could diminish if the plant operates at full capacity (Davis 2010).

**Colorado Basin Growth:**

For the past about 15 years the Colorado River Compact has been under increased scrutiny from citizens, politicians, water agencies and the media. There are many reasons for this scrutiny. First, Arizona and Nevada have had phenomenal growth in the past two decades, they are two of the fastest growing states in the nation with Nevada’s population growing by over 25% from 2000-2010 (www.census.gov). This massive amount of growth has had many considering changing the agreement and allocating more water to these states that have higher growth. Second, in the last few years there has been an increase attention to the environment and water allocations by the agreement. Some of these water allocations include siphoning off water that was initially intended for agricultural use to be used for other environmental purposes (Dellios 1992). Last, the lower basin states are in a drought alert status. This alert status directly impacts the amount of water allocated by the agreement. One of the biggest concerns with the drought alert status is what is going to happen to the agribusiness in these states with large population growth and diminishing use of the Colorado River for agricultural purposes?
Arizona:

Arizona uses about 7.7 million acre feet of water every year and harvests nearly 900,000 acres of land. Cotton lint, cottonseed, hay, wheat, barley, corn, sorghum, potatoes, lettuce, onions, cauliflower, broccoli, carrots, honeydews, cantaloupes, watermelons, grapefruit, oranges, lemons, tangerines, and grapes are all among the many different crops grown (CRWUA 2011). 15% or 1.2 million acre feet of Arizona’s water needs come from state’s rivers. 41% or 2.8 million acre feet come from the Colorado River. Ground water and pumps account for between 40-41%, or about 2.8 million acre feet of Arizona’s water. The use of reclaimed water meets between 3-4% (Arroyo 2011). According to Arizona Department of Water Resource only about 24,000 acre feet of water is replenishing aquifers annually (2011). Less than 1% of that water that is being pumped out of underground aquifers is being replenished annually.

Relative to the amount of water Arizona uses little is consumed by residents but rather used by agriculture, private industry or hydro energy projects. It is estimated that the average person consumes between 80-100 gallons of water each day. According to the 2010 census the population in Arizona was 6,595,778 persons. This would mean that persons would use between 60 and 74 thousand acre feet of water annually, or about 9% of all of Arizona’s water needs. The census bureau’s projection for Arizona show that the population will increase by 61% to over 10.7 million persons by 2030. Even though a relative small amount is being used for residential consumption there still needs to be adequate access to water sources for places like the Chino Valley.

The Chino Valley is a geographical area of Arizona located in the north western part of the state. This area is in dire need for more water as it is estimated that this part of the
state will run out of water by 2050 (McGavock 2008). There is enough water under this area to sustain a growing populous in this region for the next 200 years; however, the residents cannot drill wells here as the underground aquifer supplies water to the Verde River. There are 7 dams on the Verde River and the fear is that any disruption to the tributaries to the Verde will result in a disruption of power and irrigation to crops.

**California:**

The state of California uses just over 43.1 million acre feet of water annually. 8.9 million acre feet of water is used for residential consumption, showers, lawns, municipalities etc. The other 34.2 million acre feet are used for industrial and agribusiness purposes (Hanak 2006). California’s annual allowance from the Colorado River is 4.4 million acre feet of water. It harvests over 7,500,000 acres of crop land, more than 1 million of those acres within the Imperial Irrigation District, which is the largest user of California’s share of the Colorado River water. An estimate on the percentage of acre footage of water use from the Colorado River here in this valley is difficult to determine as they receive water through the canal from other water sources (USDA 2011). Some of the water is used for agriculture while the rest can be moved through a web of canals to be used for municipalities, residents or industry.

**Nevada:**

Nevada uses about 3.1 million acre feet of water annually. Of this amount, 75.03% is used for agricultural purposes. Nevada only receives about 9 inches of precipitation per year for much of the State, so irrigation is essential for most vegetation to survive in this environment. With Nevada farming almost 6,000,000 acres of farm land every year with a population of only 2.6 million people it’s not so surprising that such a high amount of
their water is used for agricultural purposes (agclassroom.org 2010). About 694,000 acre feet annually go to public water supply, or about 22.4 percent of the annual water use. Thermoelectric power accounted for 40,000 acre feet annually, or about 1.3 percent. Other categories, such as domestic and industrial, were about 1 percent of total water used in Nevada (Strobel 2001).
Chapter 2: Types of Desalination and Their Processes

Types of Desalination:

Multi-stage Flash Distillation (MSF):

Multi-stage flash Distillation (MSF); also known as a “once-through” process, is a water desalination process that distills sea water by “flashing” a portion of the water into steam in multiple stages of heat exchangers. MSF distillation plants produce 85% of all desalinated water in the world (water-technology.net 2011).

*Figure 1 Basic process of MSF desalination (sidem-desalination.com 2011)

Figure 1 shows a basic process of MSF desalination. In a MSF desalination plant there are a series of spaces called stages, each containing a heat exchanger and a
condensates collector which potable water flows out through. The sequence has a cold end and a hot end while intermediate stages have intermediate temperatures. This is important to remember as relatively little heat/energy is lost through the process. The stages have different pressures corresponding to the boiling points of water at the stage temperatures. At the hotter end there is a container called the brine heater.

When the plant is operating in a steady state, feed water at the cold inlet side flows; or is pumped, through the heat exchangers in the stages and warms up. When it reaches the brine heater it is nearly at the maximum temperature. In the heater a small amount of additional heat is added getting the water up to about 112 degrees Celsius. This 112°C mark is debated between plants; some say an optimal temperature is 120° while others use a variation between 110 and 120°. For this paper we will use the 112° temperature. After the heater, the water flows through valves back into the stages which have lower pressures and temperatures than the previous stage. In each stage, as the brine enters, its temperature is above the boiling point at the pressure of the stage, and a small fraction of brine water boils (flashes) to steam thereby reducing the temperature until equilibrium is reached. The resulting steam is slightly hotter than the feed water in the heat exchanger. The steam cools and condenses against the heat exchanger tubes, thereby heating the feed water as described earlier. The resulting condensate is collected as potable water. The total evaporation in all the stages is approximately 20% of the water flowing through the system, depending on the range of temperatures used (Zactruba 2009).

The feed water carries away the excess heat of the condensed steam, maintaining the temperature of the stage at a constant rate. The pressure in the chamber remains
constant as an equal amount of steam is formed when new warm brine enters the stage and steam is removed as it condenses on the tubes of the heat exchanger. The equilibrium is stable, because if at some point more vapor forms, the pressure increases thereby reducing evaporation and increasing condensation.

In the final stage the brine and the condensate has a temperature nearly the same as the inlet temperature. Then the brine and condensate are pumped out from the low pressure in the stage to the ambient pressure. The brine and condensate still carry a small amount of heat that is lost from the system when they are discharged. The additional heat that was added in the brine heater makes up for this loss.

The energy that makes possible the evaporation is all present in the brine as it leaves the heater. The reason for letting the evaporation happen in multiple stages rather than a single stage at the lowest pressure and temperature, is that in a single stage, the feed water would only warm to an intermediate temperature between the inlet temperature and the heater, while much of the steam would not condense and the stage would not maintain the lowest pressure and temperature. Therefore desalinating in stages becomes more economical and efficient.

In addition, MSF distillation plants, especially large ones, are often paired with power plants in a cogeneration configuration. Waste heat from the power plant is used to heat the seawater, providing cooling for the power plant at the same time. This reduces the energy needed by one-half to two-thirds, which drastically alters the economics of the plant, since energy is by far the largest operating cost of MSF plants. Reverse osmosis, MSF distillation's main competitor, requires more pretreatment of the seawater and
more maintenance, as well as energy in the form of work (electricity, mechanical power) as opposed to cheaper low-grade waste heat (McCann 2002).

**Multi-Effect Distillation Process:**

The Multi-Effect Distillation (MED) process is very similar in concept to the MSF process. There are, however, some very important variation to the processes. Below in *figure 2 we can see the basic MED process.

*Figure 2 Basic MED process (sidem-desalination.com 2011)*

There are some similarities between the MSF process and the MED process. For example, both capture and reuse the heat throughout the process. Another example is that there are multiple stages where there is a decreasing pressure and temperature in
each stage (or effect). There are also many differences between the processes. To find the major differences between these processes it is important to know how a MED distillation process works.

A MED evaporator consists of several consecutive cells maintained at a decreasing level of pressure and temperature from the hot to cold. Each stage (effect) contains a horizontal tube bundle. The top of the bundles are sprayed with sea water that flows down from tube to tube gravitationally. Heating steam is introduced inside the tubes. Since tubes are cooled externally by the sea water the heated steam inside the tubes condenses into fresh water. This is the first major difference between MSF and MED. MSF uses a “flash” process by moving the heated water from one pressure to another.

The second major difference between these two processes is the use of heat. MSF processes heat the incoming water to between 110 and 120°C, MED processes use a significantly lower temperature, typically around 60°C for the first effect. The access heat from the first effect of a MED process heats the second effect and so the latent heat from the second effect heats the third and so on until the brine is collected, mixed with new sea water and passed through the process again. Though the temperature in each process varies, they both use pressurized stages or effects to gain the maximum advantage from their respective temperatures.

The heat released by the condensation warms up the sea water outside the tubes and partly evaporates it. Due to evaporation, sea water slightly concentrates when flowing down the bundle and gives brine at the bottom of the effect. The vapor created by the sea water evaporation is at a lower temperature than the first heating system, but can
still be used as the heating system in the second effect where the same process repeats. The process repeats several times until the last effect where after the water condenses it is cooled by sea water. The brine is then collected and cooled by seawater where part is rejected and part is mixed with new sea water and ran through the system again. This is the third major difference between MSF and MED processes. While MSF are also called “once through” processes the MED process; mixed with new sea water, can pass through the system many times (Zactruba, 2009).

There are many advantages to using a MED process compared to other processes such as MSF or Reverse Osmosis (RO). One such advantage is that MED uses very little electrical consumption when compared to the other processes. MED operates at a low temperature and at a low concentration so corrosion and scaling are avoided or reduced. The water that comes into the MED systems does not need to be pre-treated and the system is tolerant to variations in total dissolved solids (TDS) in sea water conditions. This is a simple system to operate and is highly reliable. Since there are very few rotating parts, corrosion and scaling are reduces and it operates at a relatively low temperature this type of a system is ideal to couple with a power plant (Entropie 2010).

**Vapor-Compression Desalination:**

There are a number of different types of vapor-compression distillation, but the most common is mechanical vapor compression or MVC. This is the process in which mechanical energy is the main driving force instead of steam or membranes. With this process there is basically a heat pump that pumps in heat from a low-temperature to a higher temperature (Aguirre 2010). When the heat is pumped in a turbine compresses the heat into steam which produces vapor. The
vapor is used to heat up incoming water as well as to produce more vapors. Since the vapor is being compressed, the energy is being recycled and the only heat added is the initial heat used to create the initial vapor. As the vapor is generated it passes over to a heat exchanging condenser which returns the vapor to water. The fresh water is then moved to storage while the heat removed during condensation is transmitted to the remaining feedstock. In terms of energy consumption and water recovery ratio the vapor-compression distillation system is the more efficient. The turbine can even be directly hooked up to a wind turbine where all the energy used is clean and renewable. The major problem with this type of desalination is that it requires a large initial capital cost, an inventory for parts and constant maintenance. Due to the large capital costs this type of distillation is not economical for large scale desalination projects, it is more suitable for smaller personal, residential or individual business usage (Thye 2010).

Figure 3: MVC Distillation Process. (Heins 2007).
Reverse Osmosis (RO):

Reverse Osmosis (RO) is a membrane process of desalination. In this process water from a pressurized saline solution is separated from the dissolved salts by being forced through a water-permeable membrane. The water flowing through the membrane is forced through by pressure created between the pressurized feed water and the ending potable water. The remaining feed water will continue through the pressurized side as brine. Typically the feed water passes through multiple membranes to extract the maximum amount of water. As the feed water passes through each phase of membranes it becomes more and more concentrated. Eventually the brine will need to be discharged and removed from the process. Without discharging the brine the concentration of dissolved salts would cause damage to the membranes the subsequently require ever increasing energy inputs with relatively little output and high maintenance costs. No heating or phase change take place in the RO process (lenntech.com 2011).

Before the RO process can take place there has to be pretreatment process where the larger particles can be screened and removed before entering into the membranes. In the Yuma Desalination Plant in Arizona this is done by gravity. Water is pumped in to giant tanks which fills up the middle section first. As the water levels increase the solids settle on the

Figure 4: RO membranes (Cook, 2009)
bottom of the tanks and the water is then collected from the top to pass through the same process again. After the water passes through this gravity tank it is pumped into storage tanks where the PH levels can be adjusted and a threshold inhibitor to control scaling can be added (Wolfe 2011). Below is a picture of the gravity tank used at the Yuma Desalination Plant.

*Picture taken by Clinton Kennedy Oct 28th 2011.

After the PH levels are adjusted and inhibitors have been added the feed water is then pumped through membranes similar to the ones shown in figure 4. Through each membrane potable water is collected and the brine discharge is left to be sent through another membrane until the concentration gets too high and the brine needs to be rejected into evaporation ponds. This access water is typically transferred by canal to
the evaporation ponds. According to June Wolfe, a program analyst at the Yuma Desalination plant, RO technology can only recover about 73% of the available water (Wolfe 2011).

**Conclusion:**

Of all the different desalination processes that were covered in the section the most efficient and economical for large scale potable water desalination would be the Multi-Effect Distillation process (MED). The reason for this is that the cost to desalinate water using this method is consistently lower than that of the MSF method. Though MSF is more popular MED is more efficient for water usage as the brine or rejected water is mixed with new water thus eliminating the need for brine water disposal. Without the need to deal with brine water the real estate cost diminish as well. All these reasons are why a MED plant is proposed to be built in Mexico to desalinated water for the Lower Basin area.
Chapter 3: Problem/Solutions For Arizona, California and Nevada

Problem: What to do to increase water supplies to California, Arizona and Nevada?

There is a limited supply of water to California (CA), Arizona (AZ) and Nevada (NV). With populations rising in all 3 states, industry needing more water, environmental projects wanting more water and agriculture needing and wanting more water for production what is to be done? How can more water be allocated to these states without taking it from someone else? When the 1922 River compact was signed NV was not in need of a large amount of water. Las Vegas was not there, Boulder city was not there and the Hoover Dam had not been built yet. Since that river compact was put into effect only 0.3 million acre feet per year has been available to NV from the Colorado River (Hiltzik 2010). The population of Las Vegas alone uses that much water annually, and that doesn’t account for farming, business or municipalities (power production). In fact it is estimated that the populous in NV accounts for about 22.4% of all the water use in Nevada (Strobel 2001).

Nevada isn’t the only state needing more water just for the growing population, Arizona’s north western part of the state is in a dire need for more water. According to Ed McGavock; a lead water resource consultant for Montgomery and Associates (M&A), the Chino area of AZ will run out of water by the year 2050 (McGavock 2008). The Chino area covers the towns of Flagstaff, Prescott and Camp Verde with a combined
estimated populous of almost 250,000 persons (Census 2010). The major issue that the residents of this area is having is that there is a law in AZ stating that no new wells can be drilled or pumped from any aquifer that adds to the Verde River. According to McGavock there is a large aquifer of water directly under the Chino area that has enough water to supply to the populous of this area for the next 200 years, but it cannot be pumped. There are 7 dams on the Verde River and the fear is that any disruption from the tributaries to the Verde will result in a disruption of power and irrigation to crops. How can AZ solve this water problem in the next few years?

California is a state that has been riddled with problems in the recent years. One major problem is the regulation of water usage throughout the state. In 2008 a law was enacted that had passed 7 years earlier requiring all new developments to have a 20-year water supply plan. Part of this law also required every municipality to have some sort of water treatment in place to clean the water and put it back into tributaries. The result was a $1.3 billion dollar investment from the state and a reduction in development (Steinhauer 2008). In terms of the environment California may place more of an emphasis on this category than do other states. One example of this is in 1992 California enacted a law to pump out almost 80,0000 acre feet of water from the Delta of Sacramento and the San Joaquin Rivers in order to preserve endangered salmon rather than to water farms for production which was the original intent for the water. The result was an increase in production cost for food and utility cost for residents with relatively little effect on the endangered salmon (Dellios 1992). How can California both protect the environment and supply water to farmers?
The way consumption is calculated is a process by which they first calculate how much of the Colorado river is diverted plus how much local ground water is pumped which will equal total supply. Then they take the ratio of ground water pumped to total supply and multiply that ratio by the return flows. The resulting number is then subtracted from the return flow, the remaining return flow is then subtracted from the total diverted water from the Colorado River.

Sample Calculation:

<table>
<thead>
<tr>
<th>Colorado River Water Diverted</th>
<th>500,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Water Pumped (GW)</td>
<td>50,000</td>
</tr>
<tr>
<td>Total Supply</td>
<td>550,000</td>
</tr>
<tr>
<td>Ratio of GW to Total Supply (50/550)</td>
<td>9%</td>
</tr>
<tr>
<td>Total Return Water (TRW)</td>
<td>250,000</td>
</tr>
<tr>
<td>GW Portion</td>
<td>22727</td>
</tr>
<tr>
<td>Return flow credits (TRE - GW portion)</td>
<td>227,273</td>
</tr>
</tbody>
</table>

This example calculation is how all the states calculate how much they use from the Colorado River. According to Chuck Cullom; from the Central Arizona Water Conservation District, the fear is that eventually ground water pumping will stop which
will increase the amount each states wants to divert from the Colorado river (Cullom 2011). At the rate each state is going it is possible to see moratoriums on drilling and pumping wells very soon. Arizona is currently going through this problem in the Chino area and California is starting to ration the number of well drilling permits (McGavock 2008).

97% of the water on the Earth is salty or brackish water, 2.5% is locked up in either the polar ice caps or glaciers, the remaining .5% is the accessible water that we have and use today. That .5% is either from lakes, rivers, tributaries or underground aquifers (Manning 2011). When compared to how much water there is in the world .5% is not a large amount. How can access be gained to the 97% and have enough water for the world to use?
**Solution 1: Water Storage**

Nevada tried to solve some of its water problems back in 2004 by paying Arizona to store water for them. How this works is that Nevada would pay Arizona a sum of $230 million over a 10 year period and Arizona stores available water from the Colorado River in its underground aquifers for Nevada to use. These available waters could come from runoff returns, increased treated waters from drilled wells or treated waters from sources such as lakes and streams that do not connect to the Colorado River. When Nevada needs more water it simply draws it directly from Lake Mead and Arizona can draw the same amount from the underground aquifers. The thought was to make it a savings account for water. The reason for the payments is that Arizona is supplying the water, storing the water and purifying the water for Nevada’s usage. This is only a short term solution as if there should be a water crisis declared in the Southwest then neither Arizona or Nevada can draw more from the Colorado River or Lake Mead (snwa.com 2012). As the threat of moratoriums increases, drilling permits are rationed and the states wanting to draw more water from the Colorado; something more needs to be done than just this. If water storage was combined with desalination then this could become a long-term solution.

**Solution 2: Water Conservation**

Since water flows out of the tap so easily in the US, water conservation is something difficult to teach people. There are organization that are trying to educate people on how to use water more efficiently. Sites like wateruseitwisely.com, bewatersmart.net and eartheasy.com are some national resources designed to help people conserve water at home. Other agencies, such as the Arizona Department of Water Resources
(ADWR) are trying to make water conservation a top priority in agriculture. They have teamed up with other agencies such as Arizona Department of Environmental Quality and the Department of Agriculture. The EPA (Environmental Protection Agency) published a paper which talks about some successful cases of water conservation in July of 2002. In this document it cited specific example where water conservation has saved thousands of acre feet of water annually. One such case study preformed in Phoenix showed that water conservation practices accounted for 45,000 acre feet of water saved annually (2002). Water conservation is another possible solution to the Lower Basin’s water problems.

**Solution 3: Desalination**

A long term solution to the water problems facing California, Nevada and Arizona is salt water desalination. As mentioned in Chapter 2, desalination is the process by which salt is taken out of a water supply and made into potable, or usable water. Is it possible to desalinate enough water for the Lower Basin to use? Is the technology there and accessible? Is it economical?

As of 2009 Saudi Arabia is the world’s largest producer of desalinated water. Their desalination projects account for 70% of the country’s present needs through a network of water pipes and desalination plants. Saudi Arabia has nearly 30 desalination plants, most of which are Multi-Stage Flash (MSF) desalination plants. MSF desalination accounts for 85% of the desalinated water in the world, although there are more Reverse Osmosis (RO) plants (Water-technology.net 2011). Saudi Arabia currently have the world’s largest desalination plant which is capable of desalinating 800,000 cubic meters of water daily (Picow 2009). This equates to just about 650 acre feet of
water daily, 237,250 acre feet annually. This Saudi Arabian desalination plant alone has the capacity to almost double Nevada’s annual withdrawal from the Colorado river.

The cost to build such a plant is estimated at about $3.8 billion (water-technology.net 2011). That cost does not include annual maintenance, water transfer costs (canals or pipes) or energy costs. The energy that is needed to run such a large factory is something that needs to be taken into consideration before building one. Saudi Arabia can do it as they are oil rich and can run the desalination plants off of oil and gas. Oil and coal are the main sources for powering desalination plants, but nuclear power should be utilized more often. The cost of nuclear power is very competitive today when based against the cost of coal, natural gas or oil (world-nuclear.org 2011).

Most Desalination today uses fossil fuels which continues to increase the levels of greenhouse emissions. For about 15,000 desalination plants the capacity of desalination is approaching 11.8 million acre feet (40 million m³) of water annually. The energy needed to run so many plants is staggering. It take about 6kW to desalinate 1 cubic meter of water (6kw/m³) with RO systems and between 25 and 200kw to desalinate 1 cubic meter of water (25-200kw/m³) with MSF and MED systems since they require heat (Thye 2010). RO accounts for about 15% of the desalinated water in the world while MSF and MED account for the other 85% (water-technology.net 2011). With these numbers it is estimated that about 17.52 million mega watts (1MW=1000kW) of power is used to desalinate water using an RO system, while between 292 billion and 2.336 trillion MW’s are used to desalinate water using MSF and MED systems. These energy requirements are not going to diminish as much as demand for desalination will
rise. The result should be to diminish the amount of greenhouse emissions emitted to produce the necessary energy requirements (World-nuclear.org 2011).

Renewable energy sources are able to be used for desalination, in fact many foreign desalination projects are either being remodeled or being built around solar farms and wind turbine farms. The limitation comes in the size of the desalination plant and the physical land requirements to build either a solar or wind farm large enough to supply sufficient power to the plant on a regular basis. According to Koussai Quteishat; the former director of the Middle East Desalination Research Centre (MEDRC) the current cost of desalination using renewable energy is estimated to be at least four times greater than that of conventional desalination (Quteishat 2006). This statement is challenged by the National Renewable Energy Laboratory in Golden Colorado. In a paper published in 2011 which claims that solar power has reached the point where it can be economically viable for smaller MSF, MED and RO plants and that wind can run RO plants (Al-Karaghouli 2011). Even though there have been many advancements in both wind and solar energy they are simply not able to produce enough energy on their own to make desalination of a large facility economically viable at this time, as research continues the likelihood of these renewable energy resources running large desalination facilities grows.

With solar and wind power not producing enough energy to operate a large desalination facility we turn to nuclear power as a renewable energy source that will reduce carbon emissions. Today nuclear power is just as competitive at creating energy for desalination plants as fossil fuels. A study done in India and Japan on the economics of nuclear desalination concluded that the costs are between $.70 and $.90 /m³, this was
almost the exact same as fossil-fuelled plants in the same areas (world-nuclear.org 2011). With the cost of fossil fuels rising one possible energy source is nuclear energy.

Mexico announced in February 2011 that they were going to build between 6 and 8 new nuclear power plants in order to have nuclear power supplement up to 25% of Mexico’s power needs by 2028. These plants would range in size from 840MWe to 1400MWe of output. One proposed site for a Nuclear power plant was off the Sea of Cortez in the providence of Sonora (world-nuclear 2011). This plant would supply power to the northern parts of Sonora along with the Baja of California. It is rumored that this plant will be one of the larger ones but as of yet the exact capacity and size has not been officially announced. As a nuclear power plant generates power 24 hrs a day and has no capacity to store any unused power, the proposal is to place a desalination plant in close proximity to the proposed Sea of Cortez nuclear power plant and operate off of the heat emissions and power. Building a desalination plant next to a nuclear power plant makes sense so that the nuclear plant can use desalinated water for cooling.

(Footnote: Just prior to the defense Mexico announced the plan to move away from nuclear power and to retrofit their current power plants to use compressed natural gas. With this information it becomes unclear where a suitable power supply for a desalination plant could come from or even if a desalination plant in Mexico is still a viable option. During the same time as Mexico announced their plan to move away from nuclear power California announced a plan to build a nuclear power plant. A desalination plant next to the California nuclear power plant could be one possibility in the future.)
**Possible Solution: Mexico to Desalinate Water for Southwest to Use**

Nevada, California and Arizona are 3 states around the Colorado River that are experiencing water problems and are paying large amounts of monies to fix these problems. From my research they are simply investing into short term solutions and not long-term. As population grows, average temperature rises and water needs for agriculture and industry increases the long term solution should be the main focus with short term solutions used as a buffer until long term infrastructure can be put in place and running. A desalination plant built on Mexico soil to desalinate the water for US consumption is one possible long-term solution.

**Economics of Desalination:**

Currently Nevada is paying large sums of money to Arizona to simply store water for future usage. Arizona is facing a large water problem in both the Chino Valley area and the Phoenix Metro area with their water needs. California is having problems meeting their large water demands for residential and agricultural use. All three states are paying large sums of money to fix these problems for a short time, I propose that they use that money to purchase land in Mexico, build a desalination plant, use Mexico’s proposed Nuclear Power Plant as energy and pipe the water back up to the US, specifically San Diego and Southern California for their usage.

Nuclear plants produce large amounts of energy potentially available for desalination. With Nuclear power plants there is a higher availability in terms of steam since almost all of the rejected heat of a nuclear plant goes to the steam condensers, while for fossil
fuel plants some 15-20% of the rejected heat is useless, being directed to the atmosphere with the flue gases. Thus, for MED or MSF, the maximum amount of water that can be desalted (per unit of electricity generated) is considerably higher, also, due to economies of scale, if the higher production potential is realized, the average cost of desalted water decreases (International Atomic Energy Agency 2000).

In a study done by the International Atomic Energy Agency in 2000 they calculated the cost of desalination plants using Nuclear power as an energy source. Their conclusion was that the cost of a desalination plant ranged from $1450 per m³/day capacity to $2050 per m³/day capacity for either a MSF or an MED plant. This means that for a 240,000m³/day capacity plant would cost between $348 million and $492 million. This cost then rises exponentially as the capacity increases above 500,000m³/day. One example of this is the 800,000m³/day plant being built in Saudi Arabia for $3.8 billion. The most cost effective size plant for the price is a 480,000m³/day capacity plant costing between $696 million and $984 million (International 2000). I propose that the desalination plant in Mexico be the 480,000m³/day capacity MED plant. Though these states may need more water in the future this could be a good starting point to a long-term solution as it will increase the amount of water available to these states.

With economy of scale the average cost of desalinating 1m³ of water decreases as the size/capacity of the plant increases. The average cost of desalinating water where nuclear power is available ranges from $1.18/m³ in Egypt to $1.8/m³ in India. The reason for the higher cost in India is due to the increased costs in energy. It is estimated that it would cost the US $1.48/m³ for MSF plants. The cost drops for MED plants to a range of $.79 in Egypt to $.98 in India and an estimated cost of $.86 in the
US (International 2007). MED plants are also ideal to couple with nuclear power plants due to the very few rotating parts, corrosion and scaling reductions and the low temperature operations (Entropie 2010).

The cost to transfer the water ranges from place to place depending on the distance, capacity, gravity, diameter of piping and volume. Averages around the world range from .253/m³/km in Egypt to .67/m³/km in France. Using the higher numbers the estimated cost of transporting desalinated water from the MED plant to San Diego is between $128 million (400km or 250 miles) and $180 million (560km or 350 miles). All of these costs; cost of building the plant, plant operation, cost of desalination and transfer of water, can all be shifted to the end consumer. In terms of actual market price it could rise the cost of goods and utilities.

The ending cost to desalinate and transfer water ranges between $1.05 and $1.65 per m³. There are about 264 gallons in 1 m³ of water and 325,851gallons in an acre foot of water. This means that the cost to desalinate and transfer 1 acre ft of water for agricultural use is between $1,291 and $2,041, and the cost per 1000gal of water for residential use is between $3.96 and $6.27.

$$Total \ cost \ per \ m^3 \ = \ \left( \frac{$/m^3}{m^3/day} \right) + \ cost \ of \ desalination \ per \ m^3 + \ cost \ of \ transportation \ per \ m^3$$

$$Ttl \ cost \ per \ m^3(high) = \left( \frac{2050}{480,000} \right) + .98 + .67$$
It is unknown how much profit margin a utility company would put on its delivery of water, but in California the average cost of a 1000gals of desalinated seawater for residential use is between $3.00 and $8.00 delivered to the customer (www.membranes-amta.org 2004). According to James Fryer in his paper; “An Investigation of the Marginal Cost of Seawater Desalination in California,” it costs between $2000 and $3000 per acre of desalinated seawater. The conclusion is that desalinated water could increase the water costs for both residential and agricultural.

Below is a chart summarizing the different costs that were discussed in this section.

<table>
<thead>
<tr>
<th>Economics of Desalination Summary in $</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Cost of plant /m³ capacity</td>
</tr>
<tr>
<td>Cost of desalinating 1m³ of water</td>
</tr>
<tr>
<td>Cost of Transporting the water</td>
</tr>
<tr>
<td>Ending estimated cost to desalinate and transfer 1m³</td>
</tr>
<tr>
<td>Ending cost to desalinate and transfer 1 acr ft</td>
</tr>
<tr>
<td>Ending cost to desalinat and transfer 1000gals</td>
</tr>
</tbody>
</table>
Who pays for it:

California, Arizona and Nevada all have agencies working on their respective water problems. The proposal is that each of the 3 states equally share the burden of paying the costs of building the desalination plant and either share potential profits or simply sell the water at a breakeven point. As all three states are running out of water and the problem will only get worse the priority should be the implementation of a long-term solution.

If profits are generated from selling the water they would go into an escrow account. This escrow account would then be used to pay the cost of upkeep and operational costs along with any expansion projects that may be anticipated in the future. Putting any potential funds in an escrow account avoids the possibility the states to argue about how potential funds are divided and who pays to keep the desalination plant in operation.

Who gets the water:

It has already been stated that California is the intended recipient of the desalinated water from Mexico, but what is not clear is the reason why. The largest city that is closest to the proposed site is San Diego California. The reason to transfer the water to the largest and closest city is to cut down on transfer costs to make desalinated water more economically viable. California also has desalination plants in every city or town cleaning waste water before it goes back into water sources. With these laws already in place and California already applying them then it can be implicitly concluded that the water being returned back into the Colorado River will be within the TDS rates required in the minute 242.
It seems that California is the only state that is receiving any benefits from the desalination plant but that is not the proposal. The proposal is that all three states share the amount of desalinated water evenly between them. Total annual desalinated seawater could reach as much as 141,000 acre ft, split between each state equals 47,000 acre ft per state increase.

\[
\text{Annual amount of water desalinated} = \left( \frac{480,000 \times 264}{325,851} \right) \times 365
\]

Plant capacity = 480,000 m³

Gallons / m³ = 264

Gallons / acre ft = 325,851

Days of the year = 365

\[
\text{amount to each state} = \frac{\text{Annual amount of water desalinated}}{3 \text{ states}}
\]

The way Arizona and Nevada can receive access to the desalinated water is by California reducing its consumption from the Colorado River allowing Arizona and Nevada to increase consumption by 47,000 acres respectively. Each state can then store the additional water this desalination plant may provide any way they see fit. As population continues to rise in each state it is recommended that they all continue with their short term solutions as a safety net along with water conservation practices.
Conclusion:

Building a MED desalination plant can increase water availability, replenishes aquifers that are drying up and potentially increases revenue for each state. Arizona’s Chino valley will have enough water for its residents thus allowing about 250,000 people the ability to stay where they are and not have to move. Nevada will still be able to store water in Arizona but will also be allowed to increase consumption from Lake Mead if needed. California will receive another revenue stream and also allow farms in the dry Southern parts access to much needed water for crops. This long-term solution has high initial costs, but has a good starting point to increase water availability to these thirsty states.
Chapter 4: PEST Analysis

PEST stands for Political, Economic, Socio-Cultural, and Technological. The PEST analysis is used to get a good overview of those 4 major categories when trying to make a business decision. I believe the PEST analysis to be the best type for this thesis as it covers the main concern when talking about the environment and water issues over international borders. This type of analysis will show a better overall view than does Porter’s 5 forces, SWOT or a BCG Matrix. The Porter’s 5 forces, SWOT and BCG matrixes are industry and business strategy frameworks designed to help companies make critical decisions.

Porter’s 5 forces is used to determine competitive intensity and attractiveness of a market. SWOT analysis is used to evaluate strengths, weaknesses, opportunities and threats that a project involves; although could be used for this proposal it does not directly analyze possible influences such as political influences which drives much of what has happened on the Colorado River and an agreement between the Lower Basin states. A BCG Matrix is used more for analyzing product lines and where resources can be allocated. As a result the PEST analysis was chosen for this proposal.

Political Influences:

Out of all assessments the Political assessment is the most controversial. The proposal includes contributions from 3 states while allowing the water to only travel to one. It includes water being taken from a foreign country, cleaned and desalinated on foreign soil then transported over international boundaries for the benefit of another country. There are current international legislation regulating water usage on the Colorado River not to mention domestic legislation regulating how much water each state can consume.
that would have to be changed or altered. If one or more states do not agree to the proposal or to terms it could cause disruption in a long-term solution for each states’ respective water problems. Another issue that will have to be addressed is foreign exchange rate. As the MED distillation plant will be build and operated in a foreign country with its own sovereign currency the cost of desalinated water would depend on the value of Mexico’s currency compared to the dollar in terms of daily operation costs. All of these problems need to be addressed before going forward with the proposal. These problems can be overcome if all three states work together and are willing to equally share the burden and responsibility.

California would be the biggest influence in stopping something like the proposal from happening. During the Boulder Canyon Project Act of 1929 Congress authorized the construction of Hoover Dam and apportioned parts of the Colorado River to the Lower Basin states in which California received the largest share of 4.4 million acres of water annually. From this act on California and Arizona have been arguing over the amount of water each receives, with California claiming that it has more rights to the water and therefore deserves more. In 1963 the Supreme Court ruled in favor of Arizona citing the original 1929 Boulder Canyon Act (Wolter 2004). For over 3 decades California was not content with the amount of water that it was receiving although it was almost twice as much as it’s neighboring state and almost 500,000 acres ft more than any other states the Colorado River and its tributaries run through. After the Supreme Court’s decision California openly opposed the Central Arizona Project (CAP). The CAP controls the canals and water flow throughout Arizona. It took 5 years in the court system until Arizona was able to construct their canals (www.cap-az.com 2012).
Economical:

This assessment talks more about the economic trends, taxations, seasonality issues with trade cycles, distribution trends, exchange rates and international trade. All are of great importance to this proposal.

Currently the cost of a 1000 gals of water is between $1.15 and $2.50 for current methods, while the cost for desalinated water is between $3 and $8. This price difference is significant as a family of 4 using 100 gallons a day average water bill could rise from between $13.8 and $30 respectfully to between $36 and $96 per month (www.membranes-amta.org 2004). While the current cost of water through current methods is lower, this cost could increase as permits become harder to get and aquifers start to run low. Another option is to mix both the desalinated water and the conventional water lowering the overall price of water and distributing it. When both the conventional water and desalinated water are mixed the cost will lower to the customer, but that does not lower the cost to actually desalinate it. Before this water is sold the states would have to come to an agreed price to sell the desalinated water. After a price is agreed upon then any profits could be split evenly between the three states.

Taxes become a problem for this proposal as it would have to follow the Mexican taxation laws. It is proposed that all profits; if there are any, be put into an escrow account to fund any problems that could arise at the desalination plant, taxes for land and energy use along with funding any future expansion projects. This is proposed on the basis that if there are any profits then they can be used to further expand the desalination plant or help fund other projects that could increase the amount of water to these three states.
The exchange rate is another problem that will have to be dealt with. The initial capital costs is where the majority of the exchange rate fluctuation will be the biggest concern. To overcome this obstacle contracts could be written in terms of US dollars switching the risk of fluctuating exchange rates to contractors and builders. If the Mexican Peso increases value against the US dollar than that difference is absorbed by the contractors and builders. After the building is completed and water is flowing to the US the exchange rate will vary depending on when currency is taken out of the escrow account. If the Mexican Peso strengthens or weakens then that could be reflected in the price of water at time of consumption.

**Social:**

There are some concerns about how seawater desalination affect the end user. There are some that are unyielding about building anything that could potentially bring great benefits to large numbers of people if it could harm the environment in any way. The concern is even transmitted to the use of desalinated sea water if it harms marine life. Many would reject the idea of purchasing and using water that has been taken from the ocean, cleaned with nuclear power and transported from Mexico to the United States. Not much can be done to calm those who oppose nuclear power except to show how little impact nuclear power has on the environment compared to other types of power.
In this graph it can be quickly seen that nuclear power has the same environmental impact in terms of CO2 output as does wind or hydro power generation. However; this graph does not account for other environmental factors such as storing nuclear waste. As the US is only purchasing the energy made from the nuclear power plant Mexico will be responsible for any environmental fallout that could occur from a nuclear power plant. For the impact on marine life the first step that can be done to minimize this impact is to put screens on the water intake tubes to filter out any marine life. A netting can also be placed a safe distance around the water intake tubes to ensure that any marine life is not endangered in any way. It is important to have an environmental

expert involved throughout the process to ensure the minimum environmental impact possible.

**Technological factors:**

As technology continues to advance so does the technology of desalination. Reverse Osmosis (RO) was the first most widely accept method of desalination until the mid 1980s when Multi-Stage Flash (MSF) distillation was shown to produce comparable amounts of water while using less real estate, less maintenance and fewer chemicals. From this period on MSF became the dominant method of desalination. A short while later Multi-Effect Desalination (MED) was developed which uses much of the same methods and technologies as MSF but with less energy requirements, and is growing in popularity.

Even though some believe that desalination technology is not going to go much further than what we currently have there is a company in Nevada that is dedicated to finding a more efficient ways to desalinate enough water to become comparable to MSF, MED or RO distillation. Frank Passarelli; lead engineer for Water Desalination International, is developing a system called the Passarell VES. VES stands for Vapor Element Separator. Passarelli believes that his method of desalinating water is the next large movement. Currently his system is capable of desalinating water for small industrial facilities at a rate of 16 to 112 acre feet per year at a rate of $.498 per 1000 gallons. Passarelli believes that with within a couple of years his method of desalination well be capable of desalinating up to 100,000 acre feet per year at that same rate for seawater. If Passarelli is correct then the Passarell VES system would become the most
economical and efficient method of desalination, as of right now it is not capable to
desalinate the capacity of water needed to make this proposal viable (Passarelli 2011).

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<th>Political:</th>
<th>Economical:</th>
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<td>• 3 states influences.</td>
<td>• Current cost of water versus future cost of desalinated water.</td>
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<td>• International boundaries.</td>
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<td>• International legislation.</td>
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<td>• Current water rights of the Colorado River.</td>
<td>• Taxes – International and Domestic</td>
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<td>• Foreign exchange rates.</td>
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<th>Social:</th>
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<td>• Environmentalists and Marine Life</td>
<td>• MED technology versus Passarelli VES method.</td>
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<td>• Nuclear Power</td>
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This chart offers a quick view at the different categories and some of the possible concerns under each one. It is a summary of the different concerns that were addressed previously in this chapter.

**Conclusion:**
Even after all that has been done in an effort to control the flow of water through the Colorado River for consumption for the Lower Basin area there still is not enough water for these states to continue to grow on. The need has arisen for a long-term sustainable method of increasing the water supply to those states. Desalination is one possible long-term solution as it can change seawater into potable water. It is believed
that the MED technology is the most economical and energy efficient method to
desalinate water for consumption and agricultural purposes. With the aid of nuclear
power one 480,000m³/day MED desalination plant in Mexico has the potential to give
California, Arizona and Nevada an additional 47,000 acre ft per state of water annually.
This is just over a 15% increase to Nevada’s water supply from the Colorado River
allowing them to either store more water in Arizona or continue to expand. The
additional 47,000 acre feet of water is almost double what is needed to supply water to
the 250,000 inhabitants of Chino Valley in Arizona. California can gain more in terms of
revenue while supplying farms with much needed water. Desalination is the next long-
term solution to a thirsty world.
References:


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Upper Colorado River Basin Compact, 1948, U.S. Bureau of Reclamation, 1948


