Sustainably Covering the Central Arizona Project

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Abstract

The Central Arizona Project is second largest and expansive aqueduct system in the entire United States. It moves more than 1.5 million acre feet of water annually which is only half of its capacity. This engineering marvel is truly incredible that supports millions of people in the state as well as well as millions of people around the United States that are in need of crops year-round. The Southwest is one of the fastest growing regions in the country. With climate change affecting yearly temperatures and water needs in this region increasing, infrastructure of the Central Arizona Project needs to be retrofitted with new technologies to combat against the water loss that comes from evaporation due to the open aired canal. This study was designed to look at three different technologies with the capability of covering the Central Arizona Project canal and reduce the amount of water that is lost annually.

Introduction

The Colorado River is one of the most important commodities in the United States for supplying water to millions of people. In the early 1900's the states of Arizona, California, Colorado, Nevada, New Mexico, Utah, Wyoming and Mexico negotiated shares to the fresh water from the Colorado River under the Colorado Compact (CAP, 2018). This fresh water is supplied to over 30 million people that occupy this area and in the past the river used to flow south of the United States into Mexico. This freshwater serves various different purposes which includes drinking water, irrigation, and generating billions of kilowatt hours' worth of energy. With increasing population in the arid Southwest, the river has been and is currently being over allocated, reserves are beginning to fall, and water shortages for millions of people is looming. Coupling with these issues is climate change, with it brings projections of hotter temperatures and drier weather. With shortages increasing, and stream flow decreasing, current infrastructure delivering water throughout the Southwest must be considered for an update.

With population of the Southwest increasing at approximately 1,500 percent over the last 90 years (Chourre and Wright 2012). Water supply needs to be tightly managed in terms of being able to supply freshwater and ever rising energy needs to millions of people. Assuming that growth will resemble patterns of the past, sustainable and new technological measures need to take place in order to insure the well-being of its inhabitants. The current infrastructure in use to supply water to the state of Arizona is by the Central Arizona Project. The Central Arizona Project is a 336-mile-long uncovered canal that stretches from Lake Havasu, Arizona and ends in the southern part of the state 14 miles past the city of Tucson, Arizona. It is designed to lift water over 2,900 vertical feet over its journey and deliver an average of 1.5 million acres of water to central and southern Arizona (Snyder, 2017). This water is channeled into large uncovered reservoirs around the state, which is then pumped to the millions of residents inhabiting these metropolitan areas.

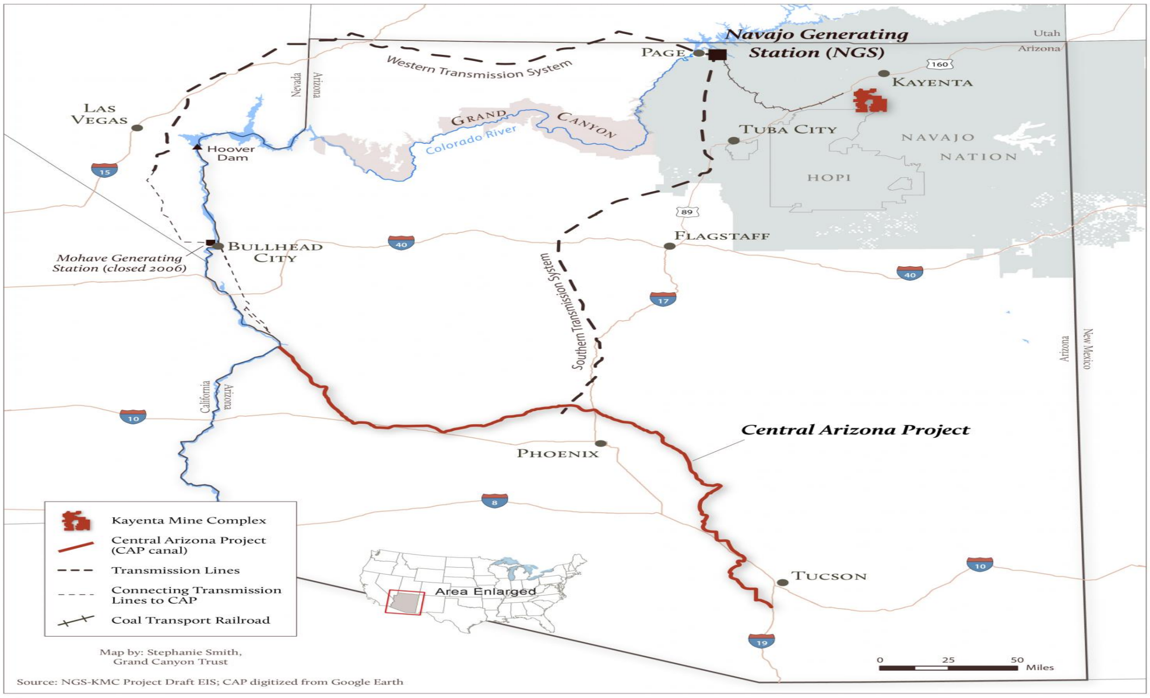

Figure 1: Outlining CAP Canal Path

With a multitude factors contributing to the demise of the Colorado River water supply, this report will explore the advantageous possibilities of sustainable technologies being implemented into the current infrastructure that makes up the Central Arizona Project. The infrastructure that will be looked at specifically is the uncovered canal that transports nearly 1.5 million acre feet of water annually for consumption. These sustainable technologies are options that could be implemented efficiently on the current infrastructure, resulting in hundreds of thousands of acres of water that can be saved and used to save energy as well.

Three such approaches are a plausible for the current infrastructure that makes up this large-scale project: utilization of floating shade balls, a floating cover, and floating voltaic cells. Shade balls are currently being implemented in the city of Los Angeles reservoir. This technology is simple, cost effective, and boasted some success in its small trial run. This method involved dumping a vast amount of black floating balls (shade balls) into the reservoirs which combats against debris landing in the water and most importantly UV exposure. Secondly, floating covers which have been extremely popular internationally and in projects domestically. A floating cover is more permanent option compared to shade balls. These covers are typically anchored physically to the infrastructure offering total coverage of the water, as well as combats UV exposure. The third and final option is floating solar voltaic technologies that combats against UV exposure and debris but correspondingly generates electricity. These floating solar voltaic covers (floating solar), is a way in which the Southwest United States could effectively increase the water supply as well as improving the current energy infrastructure. This study sets out to answer three questions: a.) what is the most cost effective sustainable covering technology out of floating solar, floating covers, and shade balls? b.) why they should be implemented? And c.) which out of three is ready to be implemented currently? To achieve this study, a cost benefit analysis will be conducted on the three sustainable technologies mentioned to determine which is more cost effective. As well as an in-depth case study on previously completed projects using these technologies and their outcomes.

This study is significant because it provides an opportunity for cities to move toward a more sustainable built environment before necessities such as water become an issue that cannot be fixed. While people view natural resources as things that have always been available and will continue to be so studies have shown that they are decreasing at a rapid rate more and more each year as population continues to grow. The current CAP infrastructure in the Southwest has worked great; however, there comes a point in time when updates must be made to ensure water safety for generations to come.

Figure 2: CAP Canal Outside Phoenix

Methodology

A variety of methods will be used to conduct this study of researching an economic and sustainable procedure to cover sections of the Central Arizona Project canal. For this studies research, there will be a mixture of qualitative and quantitative methodologies taking place. There will be a mixture of site observations, an extensive amount of literature review, and a cost benefit analysis between three different sustainable covering options.

The observations for this study will be conducted throughout the progression of writing for this capstone. These observations will show the physical topography and landscape of the project as well as how plans may take place to conduct the covering of the Central Arizona Project canal, depending on the statistical valuation of where structure would be more beneficial to cover. Past pictures of the site will be observed to better portray the proposed ideas from this capstone.

Secondly, extensive literature review will be conducted to provide the correct information of how much water is annually lost due to evaporation throughout the freshwater journey from the Colorado River to its final destination in Tucson, Arizona. Once the amount of evaporation loss is established in the canal, research will be conducted on a few different sustainable ways so this structure can effectively and efficiently be covered. They will range from floating solar voltaic technologies as well as suspended devices that are not meant for energy generation. Devices such as shade balls, single sheet films, as well as fixed structure coverings. These different devices will vary widely in cost and functionality in terms of deterring evaporation, which will be taken into evaluation for future implementation of these technologies.

Lastly, a cost benefit analysis will be conducted to better support the above issues of which of the options will be better in terms of the environment and economically sustainable in present time but most importantly in the future. A large point of this cost benefit analysis is to provide additional information that affordable technologies currently exist and are continually evolving that would directly benefit the water supply of the Central Arizona Project and why its relevant now. Furthermore, this cost benefit analysis will be supported by conducting further research in already completed projects in other countries around the world, and how they effected the quantity and quality their water supply by preventing mass evaporation loss.

After these methods are conducted, the results will be further assessed on whether or not these techniques can be put to practice on a large scale in selected areas for pilot use. Specifically, in areas that receive the highest quantity of evaporation each year. These research methods will supply information for the consideration for the state of Arizona and surrounding states to look at sustainable methods to cover their canal and or reservoirs to combat the effects of evaporation on the current fresh water supply.

Literature Review

Before carrying out the necessary cases studies on the use of reservoir covers and their effectiveness in mitigating evaporation and debris, it is necessary to understand the need and relevance of covering reservoirs in areas such as Arizona through a literature review. The goal of this section is to examine the history of these covers as well as existing projects that have been completed in the past and current projects that are in progress. By doing so an understanding can be better developed about the topic, in why this study is important and if there is a necessity for one of these technologies to be implemented.

This study aims to answer the questions a.) what is the most cost effective sustainable covering technology out of floating solar, floating covers, and shade balls? B.) why they should be implemented? and c.) which out of three should be implemented currently, within the guidelines of the definition that is water sustainability. Sustainability follows three pillars that include environmental, social, and economic factors. In reclaiming the definition of sustainability, it is defined modestly as, "sustainability simply implies that a given activity or action is capable of being sustained (i.e. continued indefinitely) (Santillo 2007). The covering systems that will be reviewed in the study are deemed sustainable due to the fact that they are cost effective, contribute to water security for the public, and also do not degrade the environment due to implementation.

The Colorado River Basin

As stated above the Colorado River Basins is considered one of the most important water systems in the United States. Headwaters of the Colorado begin in Wyoming as well as Colorado, this river has helped shape the economic growth of the West as well as the Southwest. Not only does this basin supply majority of the water to seven western states, it also is vital economic system to these states. According to The Nature Conservancy agency, "the Colorado

River supports 1.4 trillion in annual economic activity and 16 million jobs in Wyoming, Colorado, Nevada, Utah, California, and New Mexico." To quantify that, 1.4 trillion worth of economic activity is equivalent to one-twelfth of the United States domestic product, this basin is vital to its local states but also the entire nation. With this primary water resource being over allocated and the flow rate of the river is dramatically decreasing. Very simply, this river is a fundamental lifeline to millions of people and its must protected to guarantee its future for centuries to come.

Figure 3: Colorado River Basin Map

Colorado River Compact

The Colorado River compact was a document that was designed to allocate the high valued Colorado River water to the seven basin states. This compact was now known as the "Law of the River" was signed and activated in 1922 by the states as well as the federal government (USBR, 2008). From article one of the document it states, "is to establish the relative importance of different beneficial uses of water, to promote interstate comity; to remove causes of present and future controversies; and to secure the expeditious agricultural and industrial development of the Colorado River Basin, the storage of its waters, and the protection of life and property from floods" (USBR, 2008). This compact was huge for the state of Arizona even though terms were not agreed upon until the early 1940's. With the agreement that Arizona would receive a portion of the Colorado River water each year the negotiations with the federal government for the Central Arizona Project commenced.

The Central Arizona Project

With the Colorado River basin being one of the most vital systems in the United States, the infrastructure to move this water is also extremely intricate. The Central Arizona Project (CAP), is the second largest and most expensive water transfer project in the United States. The aqueduct has the capacity to transfer 1.5 million acre-feet of Colorado River water from Lake Havasu down to southern Arizona (Hanemann, 2002). Construction of the project was completed in November of 1992, which consists of fourteen pumping plants lifting the water over 2900 feet and after completion approached the cost of 5 billion dollars. Moving this amount of water per year the CAP used 2,921,590 Megawatt hours in the year of 2014 (CAP, 2018). The Central Arizona Project is a fundamental component for the survival of central and southern Arizona. Since its completion in November of 1992, infrastructure updates need to take place in order to achieve optimal functionality for current and future use.

Climate Change is Occurring

According to many scientist's climate change is occurring all around the world and at a rapid pace that was not anticipated. These changes to our climate is increasing the surface temperature on the earth, natural disasters are more frequent, and ocean levels are rising. Of these changes, the one that is going to be most drastic are the rising temperatures on earth's surface. According to Global Water Resources, "Numerical experiments combining climate model outputs, water budgets, and socioeconomic information along digitized river networks demonstrate that (i) a large proportion of the world's population is currently experiencing water stress and (ii) rising water demands greatly outweigh greenhouse warming in defining the state of global water systems to 2025” (Vorosmarty, Science pg. 210). Currently, Arizona has an average temperature of 70.9 degrees year-round but an average temperature of 100 degrees in the summer months and only averages 11.92 inches of rainfall per year (U.S. Climate Data). With current trends rising of global temperature, Arizona will become increasingly hotter, hotter temperatures will increase water demand as well as increase evaporation off of the uncovered infrastructure of the Central Arizona Project.

Continuing, the Southwest is becoming steadily more vulnerable to hazardous and costly weather and climate events. The greatest social and environmental impacts come from drought, winter storms, floods, thunderstorms, and temperature extremes (Southwest Climate Change Assessment Report, 2013). In which case Arizona’s water supply would be affected by each hazardous event. For instance, drought would mean tapping into groundwater supplies that could sustain the area for years but not decades, decreasing snow fall in Rocky Mountain Range would decrease Colorado River water levels, and extreme temperatures would result in a higher volume of water usage across the state. As stated earlier, a very high percentage of people are beginning to move to the Southwest region which in turn take more water and resources to maintain a specific lifestyle and results in the ever-decreasing water supply of Lake Mead (a large reservoir created for the Colorado River). Lake Mead has enough capacity to hold the entire average annual flow of the Colorado River for two years (Chris Holdren And Kent Turner 2010). At full pool, Lake Mead extends 65 miles from Hoover Dam to Pearce Ferry. Its greatest width is 9.3

miles, and the highly irregular shoreline is 550 miles in length (Chris Holdren and Kent Turner, 2010).

In the year of 2010 at the elevation of 1,082 the lake is almost 140 feet below full pool elevation. Meaning at the time when Lake Mead was nearly at full capacity in 1999 at the elevation level of 1,215 but has continued to drop which in theory will turn into a large issue for the surrounding states. Especially for Arizona, once the reservoir water level is below a certain point water will then begin to be rationed in specific amounts to the state. Which would be the most detrimental to the agricultural industry. According to Rose Davis, spokeswoman for the U.S. Bureau of Reclamation. "The southern part of California and the southern part of Arizona, are the vegetable breadbasket of this country," she says. "If you eat a salad for dinner tonight, chances are that salad came from California or the Yuma, Ariz., area" (Siegler, 2015). With that being said, if water levels continue to drop, Arizona will suffer from a smaller water supply as well as lose an extensive generator to their economy.

Adaptive Capacity

Adaptive capacity is as defined by Intergovernmental Panel on Climate Change as, "a measure of society's ability to adjust to the potential impacts of climate change, sometimes characterized in relation to social vulnerability and represented in regional statistics through the use of socioeconomic indicators" (Climate Change 2014 pg. 1142). Arizona needs to begin looking at options to building infrastructure that is resilient to climate change. The first step to achieve resiliency is to take the initiative of changing for the better in terms of development and resource security. As stated above, climate change is occurring around the world and it will be felt equally in the Southwest and coupling that with a growing population it needs to be identified that new practices must start emerging before the issue is unable to be fixed. Arizona needs to begin by achieving greater water security throughout for following generations, and this could be achieved by updating the Central Arizona Project canal infrastructure.

Three Existing Technologies

Shade balls

The first sustainable technology that will be looked at for this project is the use of a new technology that has been implemented in the state of California specifically in the Los Angeles Reservoir. This specific technology is being looked at due to its cost effectiveness as well as the balls malleability to float on any structure no matter the shape or size. By them using shade balls in their reservoir it holds potential to be effective in the Central Arizona Project Canal. Shade balls are specifically designed to float on top of lagoons, reservoirs, and larger bodies of waters. They are cheaper than a custom built floating cover, allow rain water to seep through to the water below but are extremely effective in deterring algae growth and other contaminants from entering the covered water supply. From Advanced Water Treatment Technologies, “High surface area coverage is achieved by placing a sufficient amount of balls on the surface of the liquid. The balls arrange themselves to provide coverage of up to 91%. The result is a thermal insulation barrier which combines the insulation factor of the air held in each ball with the poor heat conductivity of plastic. While the air pockets between the balls are not sealed, they also contribute to this insulation system, which dramatically reduces heat loss and light transfer” (AWTT, 2017). As stated above, the shade balls will arrange themselves and there is no need to anchor them down to the sides of the canal. This is why shade balls are so appealing for Central Arizona Project, if cracks need to be fixed or a water pump repaired this type of covering does not pose an issue to the construction teams that need to make repairs, and there is no added pressure not to damage the million-dollar cover while removing it from the canal. Shade balls can be simply moved to the side away from the area that needs to be worked on and once finished the balls will form back in the area seamlessly as if never disturbed.

Figure 4: Shade Balls

Floating Covers

The second technology that will be looked at is similar to shade balls in terms of material, but floating covers are typically much more expensive and have more amenities. Floating covers could be a great option for a canal like the Central Arizona Project but they do pose the issue of being a more permanent structure and not as easily moved as shade balls would be. Typically, floating covers offer 95 percent to 99 percent coverage of the body of water that they are sitting on, significantly reduces UV rays that penetrate into the water, and do a significantly better job than shade balls do in terms of wind protection. There are a multitude of different covers that could potentially be used to cover the canal ranging from fixed structure and modular floating covers. Each boast specific attributes that the other cannot, and come at many different price points. A fixed structure makes it so the canal would be physically sealed and has little to no maintenance that comes along with it. Once it was in place it could be left alone whereas modular floating covers would have to be checked on to make sure they are fixed in the right position in the canal. Nevertheless, with a modular cover, it can be tested in multiple places throughout the canal and moved freely. There would not be the pressure of developing a fixed structure that could not be modified, moved, or removed in the future. As well as if maintenance and surveying needed to be done on the section that was covered a modular covered could easily be removed and then placed back after maintenance was completed. With that being said a fixed cover would mean less work after installation but would not be economically or easily usable for the Central Arizona Project canal.

Figure 5: Permanent Cover

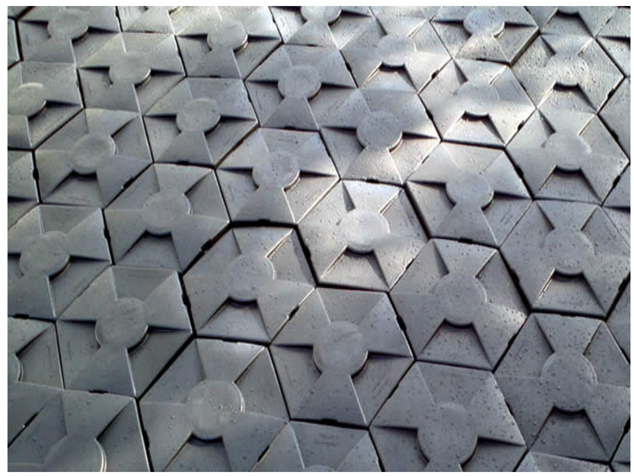

Figure 6: Hex-Protect Modular Floating Cover

Floating Solar Voltaic Cell

Floating solar photovoltaic panels have numerous advantages compared to overland installed solar panels, including fewer obstacles to block sunlight, convenient, energy efficiency, higher power generation efficiency owing to its lower temperature underneath the panels. Additionally, the aquatic environment profits by the solar installation because the shading of the plant prevents excessive water evaporation, limits algae growth and potentially improving water quality (Sahu, Yadav, Sudhakar, 2016). Nevertheless, overland solar panels have many advantages that lack in the floating solar systems. For example, they are cheaper to install, panels are easier to clean and maintain, and larger systems can be linked together to ensure large energy generation. New data has been emerging making a good case that using floating cells compared to land locked cells is the way of the future. It is well known that to produce a great amount of energy in terms of solar energy a large parcel of land must be used. So, floating solar voltaic modules can easily be implemented into large developed parcels of land, in the case of the developed land would be the Central Arizona Project canal. What is being proposed for this project is not entirely covering the entire three hundred miles plus canal with floating solar modules but instead placing these modules near the fourteen pumping stations that as stated earlier must lift water over 2900 vertical feet to its final destination south of the city of Tucson. These floating modules would be able to provide a large source of electricity that can help supply the pumping stations with power, which in return saves power that can be allocated elsewhere in surrounding areas. These floating cells will be mounted into what is known as a pontoon system, which is defined as, “A pontoon is flotation device with buoyancy enough to float by itself as well as with a heavy load. The platform is designed to hold suitable number of modules in series parallel combination according to the requirement and space avail-ability [19,20] (Sahu, Yadav, Sudhakar, 2016). Lastly, canal top solar panels have a few other characteristics that land based solar cannot offer in long term usage. For example, not only do they save canal water from evaporation they generate power with higher efficiency compared to land based solar power plants due to cooling effect on solar panels by evaporating canal water, saves precious land for other uses while also producing a great amount of energy (Sahu, Yadav, Sudhakar, 2016). With the average width of reservoir being eighty-feet across there is huge potential for floating voltaic cells to be placed by the pumping stations and create a vast amount of energy that would eventually pay for the panels as well as bring profits in the future.

The reason this study is not solely focused on the potential that floating solar technology brings to areas such as the Central Arizona Project is the issue of feasibility. The 2.8 million

Mega-watts it took to pump the water from Lake Havasu to the final destination is an extremely large amount of energy to propel the water up-hill so many vertical feet. Solar technology is a growing field in terms of its capability but as of right now it is difficult to make the assumption that it could offset any significant amount of that 2.8 million Mega-watt hours or even remove one of the massive pumping plants along the canal. If the technological capacity behind floating solar increase another study will need to commence solely looking at the potential of floating voltaic cells on the canal. With that being said, the technologies of floating covers/hex-covers and shade balls are being looked at equally throughout this study to which could currently be implemented.

Figure 7: Floating Voltaic Cells

Figure 8: Fixed Voltaic Cells Over Canal (Sahu, Yadav, Sudhakar, 2016)

Data and Discussion:

This 336-mile-long canal known as a lifeline to most of the southwest is completely uncovered. Due to the high temperatures that are constant throughout the state of Arizona, although the water is cold from the Colorado River the water is still heated and millions of gallons are lost each year to evaporation. To put this in perspective, one acre foot of water is equal to 325,851.4286 gallons of water according to U.S. liquid gallon measurements. The Central Arizona Project Canal currently loses approximately 4.4 percent of its total carried water to evaporation which is extremely small when broken down into percentages (CAP, 2018). This 4.4 percent lost annually breaks down to approximately 16,000 acre feet per year lost to evaporation which broken down in terms of U.S. liquid gallons, is $5.21362e^{9}$ gallons, which is an extremely large amount of water that is lost. The argument can be made that this water will return back to the water cycle, which is true, but that water that was guaranteed to Arizona in the canal no longer is once its lost to evaporation. Couple this with, rising population, higher temperatures, and less water in the Colorado River there is area of concern that things need to be done to guarantee water security for Arizona's future.

Evaporation Rate & Cost	
Evaporation Rate	**Cost**
4.4 % (1.5 million acre feet)	748 gallons →0.69 CAP Charge
16,000 acre feet (lost to evaporation)	*5,213,616,000 gal / 748 gal = 6970074.87 Ccf*
16,000 acre feet equals (5,213,616,000 Gallons)	*6970074.87 x $0.69=* $8,560,645.95533 (Cost of Water Lost)

Figure 9: Representation of Evaporation Rate and Cost

Technologies	**Cost**	**Coverage Rate**	**Life Expectancy**	**Energy Production**
Shade Balls	$1.90-$2.00 ft^2	91%	25+ years	N/A
Floating Covers	$1.90- $2.00 ft^2	95-99%	20+ years	N/A
Floating Solar	$2.71 and $3.57 per watt	99%	25+ years	15 watts ft^2

Figure 10: Technology Cost, Life Expectancy and Energy Production

The three technologies above have different characteristics that can be useful in terms of combatting against the 4.4 percent evaporation rates that currently affect how much water reaches its final destination. The cost and coverage rate is truly what determines the feasibility of the three technologies and how they could actually be implemented into the Central Arizona Project canal system.

The three sustainable technologies that were reviewed throughout this study are great example of what areas can do to save water from evaporation and contamination. It is evident that these technologies will become more and more popular as time goes on, temperatures rise, droughts become more severe, and water prices increase. Nevertheless, where the technology currently stands to date, it is not financially feasible to cover the Central Arizona Project canal with shade balls, floating covers/hex covers, or the main portion of this project floating solar. It would far too costly per square foot to cover the entire canal with shade balls at $1.90-$2.00 dollars a square foot, as well as floating covers/hex covers at $1.90-$2,00 per square foot. However, if a pilot project were to commence the recommendation would be to look at these technologies to be implemented first prior to floating solar technology. These technologies have an extremely great coverage rate between 91% and 99% and both do not require to be maintained over a period of time. Once they are placed in the water they are fairly self-maintained and have a great life span. Shade balls at 25+ years and the floating covers at 20+ years, if the price of water were to increase an astronomical amount then these technologies could potentially serve to function the Central Arizona Project canal and have a fairly quick payback period. Continuing, the main part of this study was looking at floating solar technology and implementing it into the current infrastructure of the Central Arizona Project canal. As stated above the worry about this study was whether or not any of these technologies were going to be deemed feasible, and although they were not, solar is still a potential option for this system and other systems around the world. The issue that is being dealt with about floating solar is that, the technology behind the actual panel is just not currently advanced enough to be cost effective and produce enough power to offset any of the 2.8 million Mega-watts that is necessary to move the 1.5 million acre feet of water through the canal during the course of a year.

Conclusion

The Colorado River is one of the most important commodities in terms of economic production, but most importantly it is the life line of the Southwest. The Central Arizona Project is a canal that is responsible for bringing in over 1.5 million acre feet of water to millions of residents that live in the state of Arizona. There is a threat that is taking place in the Colorado River basin in terms of climate change and population growth that could drastically effect the water supply for the state of Arizona. The water levels of the Colorado River have dropped significantly as well as the reservoir that harbors so much of the water known as Lake Mead. The uncovered canal that is the Central Arizona Project needs to be looked at in terms of infrastructure to ensure the water security that Arizona needs now as well as in the future. The three sustainable technologies that were studied for this project are shade balls, floating covers, as well as floating solar voltaic cells. All of which are great ideas and useful technologies that could drastically change the way Arizona secures its water. As stated climate change is occurring and temperatures will increase causing the evaporation rates of the uncovered canal to increase to where more and more water is being lost. As stated in the results and discussion section shade balls and floating covers could potentially work now but are still too expensive to achieve a swift pay-back period. This study most focused on floating solar and its ability to save an enormous amount of energy while also serving as an evaporation shield. Nevertheless, this technology has not advanced to the point where it would be a wise investment to the infrastructure of the Central Arizona Project, it would not sufficiently reduce the amount of energy needed to move the 1.5

million acre feet of water through the canal. With that being said, these technologies need to be studied further so when it does become necessary to cover the canal these systems can be implemented promptly and correctly. If the technological capacity of floating solar drastically changes or the materials for shade balls or floating covers becomes much cheaper these technologies could drastically change the way Arizona receives its water from the Colorado River. Climate change and population growth is already happening and the negative effects of both are going to be felt drastically in the Southwest part of the United States. If water prices were to increase and the Colorado River drop below the benchmark that is set in the Colorado River compact, Arizona would not be drastically affected in the beginning but in the future, would be facing a severe water crisis for the residents of the states. Innovative technologies such as shade balls, floating covers, and floating voltaic cells may not have the capacity now, but bear endless potential for the future amount of water that will travel through the canal.

Appendix A

Calculations:

A.) Average Annual Evaporation of Central Arizona Project:

-4.4% or 16,000 acre feet of water

B.) Annual evaporation rate per square foot in the canal:

There are 696,960,000 square feet of water lost per year due to evaporation

c.) Calculated cost of t lost water per year:
it is 1.78 for every 748 gallons of water.

1 acre ft. = *325851gal.*

-16,000(lost evaporation) x 325851 gal.= ***5,213,616,000*** *(gallons lost per year to evap)*

5,213,616,000 gal / 748 gal ***= 6970074.87 Ccf***

6970074.87 x $0.69= ***8,560,645.955334(Cost of water lost per year to evap)***

d.) Calculated size of solar field needed to offset 50% (100%?) of the pump stations:
It takes 39,114,495 kWh to power twin peaks pumping plant

- *Where solar is currently at, the size of the CAP could not offset 100% nor 50% of the pumping plant.*

e.) Calculated cost of that solar field to build:

- *It cost on average 3 dollars a watt for solar, it took 2.8 million Mega Watts to move the CAP not feasible*

f.) Calculated amount of water saved by it being covered by solar (refer back to b and c):

- *If entire CAP is covered with floating solar nearly all 5,213,616,000 gallons would be saved.*

Ex. Covering 1% of CAP with floating solar.

-336 miles x 0.01 = 3.36 miles

-3.36 → feet = 19,008ft

- 19,008ft x $45ft^2 = $855,360 cost of covering 1% of CAP

- 5,213,616,000 x 0.01 = 52,136,160 (gallons lost from 1% of CAP)

- 52,136,000 x 0.01 = 521,361.6 (gallons lost from uncovered 1%)

- 52,136,000 – 521,361.6 = 51, 614,638.4 (gallons saved by 99% coverage of floating solar)

g.) Calculated amount that would be saved by using solar over use of coal to fire water pumps:

The payback period is far too long for it to be considered a substantial sustainable change instead of using fossil fuels.

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