WATER REUSE IN DROUGHTS AND DESERTS

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ABSTRACT

Water reuse, particularly reuse of treated wastewater, has been in discussion for a number of decades as municipalities and farmers have viewed a valuable resource flowing back into the river after going through two or three levels of treatment. Resistance in reuse comes from a cultural idea of not reusing treated wastewater for drinking or growing edible crops, probably from the fear that it will transmit diseases from the water or contaminate foods grown with the water. There is also an objection to having animals grown for food drink the treated wastewater, fearing that they may catch diseases, or transmit diseases, from the water.

This paper will present the experience of the Buckeye Water Conservation and Drainage District ("BWCDD" or the "District") in using treated wastewater from the largest wastewater treatment plant ("WWTP") in Phoenix, AZ. Approximately 65% of the water supply for the District comes from the WWTP. Agricultural crops using the water are restricted to fiber and animal feed. The area supports a large health dairy industry with nearly 20 operations and is one of the premier areas for growing fine Pima cotton. We will not argue for using WWTP water for food crops but rather address how water reuse from this source may substitute for scarce supplies of stored, ground or pumped water. BWCDD also uses its water resource for generation of electricity at a drop on one of its weirs, providing further reuse of its canals and water.

INTRODUCTION

The BWCDD has a rich history, one filled with pioneering and an enduring spirit.

When a site was identified in 1885, the founders of the original Buckeye Canal Company went about constructing a canal and diversion, and the first water was turned into the canal in 1887. Having foresight, the founders listed the canal's purposes to be "agricultural, milling or mechanical enterprises."

Although ahead of their time in foresight, the owners of the canal were ill prepared to wrestle with the turbulent Gila River. The canal changed hands five times from 1887 to 1907, finally ending up in the hands of the Buckeye Irrigation Company ("BIC"). The BIC was made up of a group of local farmers with a personal stake in the success of the canal.

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During the late 1910's, the farmers and operators of the canal saw signs of waterlogging on land next to the river because of excess irrigation on the higher ground. In 1922, the Buckeye Water Conservation and Drainage District was formed to finance a new dam and attempt to correct the waterlogging problem. The BWCDD overlaid the lands already being irrigated by the BIC.

While the BWCDD was formed to dewater the lands along the river, it has assisted in the operation of the Buckeye Canal since 1922. In 2000, the District assumed overall responsibility for the canal and acquired title to the canal and the South Extension in 2008. It continues to dewater the District lands with 10 drain wells, pumping approximately 30,000 AC-FT annually.

BWCDD is an irrigation district with the power of drainage, and under Arizona statutes, it is a municipal corporation of the State of Arizona. The District occupies approximately 22,000 acres, with 16,000 acres irrigated. The canal stretches through the towns of Avondale, Goodyear and Buckeye, all located within Maricopa County. The Main Canal is 23.5 miles in length and the South Extension is another 7.5 miles in length.

FIRST STEPS TOWARD SUSTAINABILITY

With the growth of the Phoenix Valley in the early 1920's, a decline of stream flow from the Gila River was seen at the District's headgates even when the river was flowing abundantly. BIC was able to offset the losses with wells, but the water came at a much higher cost.

Looking for a stable and cost effective option, in 1971 the District contracted with the City of Phoenix to take treated wastewater effluent from the 91st Avenue wastewater treatment plant. This was in recognition of the need to conserve water, in all of its conditions, to meet the growing demands of an expanding population. Knowing that effluent reuse would require a shift in types of crops grown but would also provide a more reliable water supply, the District began receiving water from the WWTP later that year. Originally the District began receiving 30,000 acre-feet per year. As the population of the City expanded, as did the WWTP, the amount of water received from this source was expanded to 65,000 acre-feet per year. While effluent provides a significant volume for the District, they still incur large electrical bills for the water pumped to meet seasonal demands.

THE WATER POWER NEXUS

The recovery of energy from moving water has existed throughout modern history. From water wheels for grinding grain to powering the machines of the early industrial revolution, converting moving water to useful power was also the natural selection of energy to provide the first large scale generation of electricity. Consequently, electricity became the most effective way to move water to population centers, treat and condition the water for human consumption, and then to collect, move and treat waste water after it had been used. This interdependence of water to make power-whether for hydro generation or water used in the cooling towers at gas, coal or nuclear power generation plants, and the use of power for the delivery and conditioning of water and wastewater-has only become more intense as the population has expanded to the suburbs and regulation of both water and wastewater has become stricter. Stricter regulations have required more power to treat both fresh water and wastewater, and expanding areas have required more power to move water further and further.

The importance of turning water into power can be illustrated by the fact that 75% of the renewable energy for electricity production in the United States in 2005 came from hydroelectric resources. The International Energy Agency estimates that 19% of the world's electricity was generated by hydropower in 2005. Norway gets 95% of its electricity from hydropower.

As to the use of power for water, California estimates that 20% of the power consumed in the state was used to supply, distribute, collect and treat water. California is on the high end of electricity use for water because of the movement of water from the North part of the state to the Los Angeles basin. Within the United States, EPRI estimates that just under 4.0% of electricity is used in water and wastewater treatment applications.

As attention has shifted to renewable resources, not only to offset the ultimate decline in fossil fuels, but also to mitigate the potential impacts of climate change, the potential for a renewal in hydropower development is being given a lot of study. The U. S. Department of Energy has estimated that there is a potential to double the capacity for hydropower generation in the United States, primarily through previously undeveloped low head hydropower resources. This could add from 30,000 to 70,000 MW of capacity to the approximate 70,000 MW of existing capacity, but without building another high dam.

SUSTAINABILITY II – GENERATE OUR OWN POWER

In 1889, a survey by Major Edward H. Wilton recorded a drop of 40 feet over three sections of the canal. Was this the prescience to think of generating electricity? In the 1980's the canal was surveyed again, looking for potential sites to harness the power of the flowing water. However, a viable technology was not found based on the survey results.

In early 2007, management at the BWCDD again began to consider ways to use its moving water to generate electricity. Management was concerned with the potential for escalating rates of purchased power, but just as important, they were aware of a wasted resource, the energy in the drops at the check structures in the canal system. Irrigation or water supply canals are designed with a certain slope to let the water flow down to its destination. If the water flows too fast it can damage the walls of the canal. Periodically, check structures and drops may be installed to dissipate the excess energy or to accommodate changes in the level of the terrain. Check structures also maintain a pool level in the canal so that water can flow by gravitation into laterals that irrigate the crops.

In the exploration of alternative methods of generating power we came across the Schneider Linear Hydroengine ("SLH"). The promise of this technology was that it could generate electricity efficiently and economically in low head environments that had not been economically practical with standard turbine machinery.

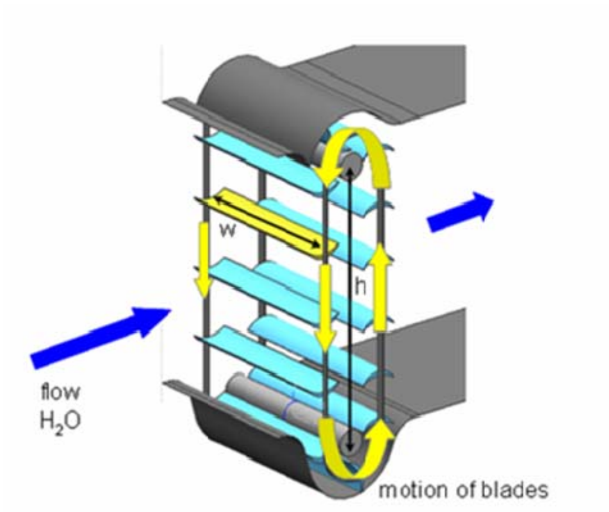

Figure 1. Foil configuration of the SLH

The SLH had been installed in an irrigation canal during a previous energy crisis, as well as having been operated in a remote mountain setting and stream diversions. The developer of the technology, Natel Energy, Inc., was looking for a site with which to demonstrate its latest evolution of design and materials of construction.

After touring different site possibilities, Natel and the District selected a site on the South Extension that could meet the needs of both parities. The District then solicited other critical partners to make the installation of the SLH a joint effort that could enhance the business prospects of each. The benefit of this effort was that the District could end up with a facility that contributed to its sustainability by lowering purchase power costs and decreasing carbon emissions. In the partnership, the District would provide the site and modifications of the drop structure to allow installation of the SLH. Natel would provide the engine, along with the inlet gates, penstock, draft tube, generator and electronic controls. The District's civil engineering firm, Stantec, Inc., contributed design of the civil structure and powerhouse. A fourth partner, K. R. Saline and Associates contributed the siting and permitting with the Federal Energy Regulatory Commission ("FERC"). At the end of the demonstration period, BWCDD will own the generation facility, but more importantly can assess its viability to install additional units at as many as five more sites within the District's canals.

THE SOUTH EXTENSION SITE

BWCDD and Natel selected a site on the South Extension canal that would accommodate a nominal 20 kW capacity machine. The site is very accessible, has a moderately consistent flow and was across the road from a connection to an electrical distribution line. The site had a 9.5 foot drop while the SLH is rated at 20 kW at 15 feet of drop and 23 ft^3/s flow.

Figure 2. South Extension canal drop

The desirable feature of access near the intersection of two roads also requires that the installation have good security. To enclose the SLH, Stantec selected a pre-cast vault to house the SLH. A by-pass chute was installed alongside the SLH to carry water when the engine was being serviced or to carry excess water flow. To improve the operating characteristics of the SLH, the District was able to add about two feet of drop by lowering the down stream pool as the site was being prepared for installation. The installation of the power house took place during the District's normal dry period in November of 2009, after receiving the exemption from permitting from FERC in September of 2009. A photograph of the installed power house is shown in Figure 3.

Figure 3. Installed Powerhouse – South Extension

To calculate the revenue potential for the SLH, data requirements are the system head, flow and duration of the flow. A review of the record of water flows over a drop for one or two years will provide sufficient data to calculate a duration curve. With this data, along with efficiency of conversion, the calculation of the annual amount of electricity generated can be made. Revenue is determined by the kWh production and the feed-in tariff at the utility.

The flow duration curve shown in Figure 4 provides the basis for a pro forma operating statement for the demonstration unit at BWCDD. The engine capacity design is for 20 kW of capacity at 15 feet head and flow of 23 ft^3/s. The actual drop is 9.7 feet and average flow is 11 ft^3/s. With the duration curve providing time and flow, the calculation of capacity utilization of the Buckeye pilot is approximately 25%. Under these conditions the projected production is 38,000 kWh/yr against a design capacity of 158,000 kWh/yr based on a 90% availability.

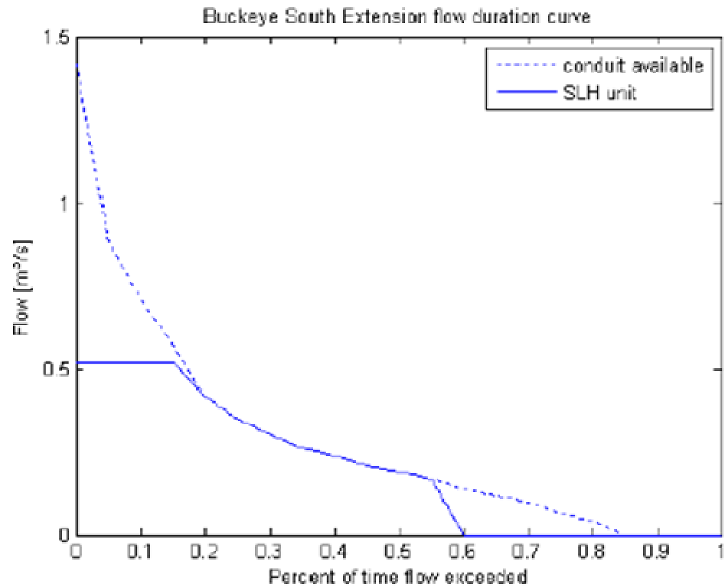

Figure 4. Flow Duration Curve for South Extension Site

By lowering the down stream pool of the South Extension site the District has improved the economic potential of the SLH, so that the capacity utilization will probably be closer to 35%.

The 20 kW SLH installation at the South Extension would not be profitable as measured by standard monetary inputs and outputs. However, because of the contributions of all of the partners, the system will provide a payback to the District. For the other partners there are the prospects that this installation will lead to commercial installations from 100 kW to 1,000 kW in size. Natel has calculated the system cost for SLH sized ranging from 20 kW to the 1,000 kW size. To scale from the small size to the large, Natel can increase the throat dimension by making it taller or wider, or both. The engine components are made larger accordingly.

Economic considerations for SLH sizes above 20 kW are more favorable. A scaling study has provided system cost estimates for all sizes up to 1,000 kW. The lowest cost per kW for the machinery is estimated to be in the 200 kW – 400 kW range. Adding in civil design, construction and permitting the all-in estimates for a 200 kW capacity installation is likely to range from $1,850 - $2,000 per kW of capacity. Operation and maintenance cost is estimated to be approximately $0.02 kW/h. The biggest variable will be the capacity utilization experienced. Natel's estimated of lifecycle cost per kWh based on a 20 year life, 8% cost of capital and $0.02 O&M is shown in Figure 5.

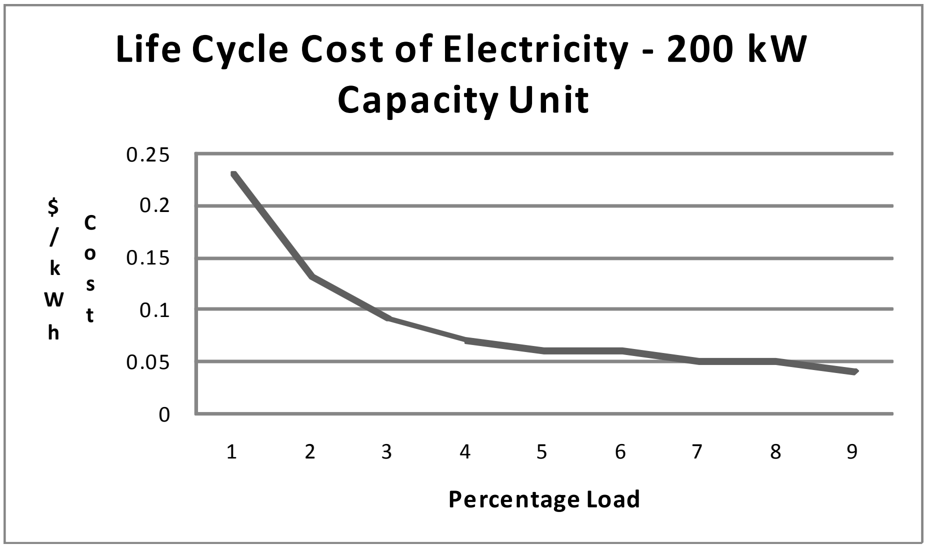

Figure 5. Life cycle cost of Electricity SLH 100

The monetary economic benefits are likely to be enhanced by the incentives that continue to develop around production of renewable energy. For small hydro, the Federal Tax Code allows taxable entities to take an Investment Tax Credit ("ITC") of 30%, or alternatively, an approximate $0.01 kW/hr production tax credit ("PTC") for ten years. For irrigation districts, these incentives will generally not be available, but there may be ways to monetize the ITC and PTC for a portion of the cost of an installation. More readily monetized are the Renewable Energy Credits ("RECs") generally bought by utilities to meet Renewable Energy Standards ("RES"). These REC's will become more valuable as a cap-and-trade program for carbon offsets becomes more prevalent. A cap-and-trade system has been instituted in California and is indicated to be an integral part of the Western Climate Initiative of seven western states. Under the most favorable circumstances, low head hydro may provide between two and six cents ($0.02 - $0.06) per kWh in RECs over the coming years.

REGULATORY CONSIDERATIONS

At the beginning of the project, neither the District nor the developer was aware of the cost and timing of the regulatory requirements, even for a small demonstration unit such as the 20 kW machine to be installed at the South Extension. Although FERC does not require a permit for this type of project, the application for an exemption is still substantial. By requesting an exemption from licensing, there is no requirement for an environmental impact statement. However, an environmental assessment is required and notification to all interested parties, such as state regulatory and environmental agencies. FERC sends notices to the federal agencies to be sure that they have no objections. Under normal circumstances, the cost and time requirement for an application for an exemption to install a project like the South Extension would make it prohibitive. Now that we understand the information and timing requirements, dealing with permits for larger projects will be more efficient and much more cost effective.

FUTURE ENERGY RECOVERY OPPORTUNITIES

As we prepare for the future at BWCDD, our concerns are the escalation of purchased power prices, the availability of water supplies to maintain the irrigated acres of farm production and the societal concerns of global warming and carbon dioxide reduction. We keep close tabs on inputs and outputs to measure the effectiveness of how we operate the District. Table 1 below shows that we reduced power consumption from 2007 to 2008, with the total cost of power declining slightly. However, the cost per kWh of electricity increased by 7% year over year. To improve its sustainability factor, the district has as an objective to cut purchased power by 20% over the next decade. We believe that can be achieved by additional generation capability at current check drop structures and drops to be constructed.

Table 1. BWCDD Water and Power Statistics 2007 – 2008

	2007	2008
Electricity consumed - kWh	13,297,942	12,077,763
Peak Demand during year - kW	2,991	3,046
Total Power Cost	$ 535,829	$ 520,794
Water Demand – Irrigation in acre-feet	128,000	129,000
Water Supply – acre-feet		
WWTP/Gila River diversion	67,400	82,500
SRP Tail Water	35,800	31,400
Pumped Ground Water	79,200	74,200
Drain Water Pumped	31,120	26,950

After operating the SLH unit at South Extension for several months, the District will begin the assessment of future opportunities for electricity generation. We have identified at least five sites that may prove economic and help to reduce purchased power substantially. Two of the sites currently have check structures that can provide quick implementation. The other three are planned structures as we augment supply and direction of water flows. The sites that we have identified are:

Goodyear WWTP inflow
Johnson Road
Gate 67 Drop – Bottom end
Suzy Dean Drain
Watson Drain

These sites offer the potential to add up to 235 kW of capacity. Water flows and drops indicate approximately 50% nameplate capacity utilization. Additional generation from these sites could provide approximately 20% of the District's 2008 electricity consumption.

CONCLUSION

The decision by the BWCDD to work in partnership with Natel to install a small demonstration unit of a unique generation technology will have direct benefit to the District in several ways. By demonstrating the technology we can provide an avenue for our use, as well as providing commercial proof of the technology for adaptation in the United States and around the world. Importantly, we will tap an unused resource of our irrigation system as a method of promoting sustainability. By offsetting electricity purchases from the grid we will reduce our operating cost and hedge against some of our future electricity costs. And, by generating electricity with a renewable resource we will reduce our carbon footprint significantly.

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