ENERGY RECOVERY FOR SUSTAINABILITY

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ABSTRACT

Electricity is one of the principal operating costs for irrigation districts. Moving water from the source of supply to the fields to be irrigated requires constant energy. The design of irrigation canals often provide for drops that are used to dissipate increments of excess energy as water accelerates along the canal due to elevation drops in the terrain. Generating electricity at these drops can provide an excellent, and generally unused, opportunity to recover some of the excess gravitational kinetic energy in moving water.

Until now technology has not been available to economically recover energy from drops that of less than about 5 m. The Buckeye Water Conservation and Drainage District ("BWCDD") and NatEl Energy are installing a 20 kW capacity demonstration unit of the Schneider Linear HydroEngine ("SLH") in an irrigation canal in Buckeye, Arizona. This installation has as its purpose the provision of data around reliability and durability of the SLH engine. With O&M data, BWCDD can evaluate other sites for installation of larger generating units to provide sustainable and renewable energy for the District' operation. The SLH is the only technology the District has found that provides economical and efficient recovery of the energy dissipated in irrigation canal drops

In the longer term, the objective for the SLH technology is to provide large dam benefits in hydro generation with significant environmental attributes not available with high dam construction. This would involve multiple installations of the SLH in a stair-step configuration. Meanwhile, BWCDD should benefit economically with sustainable operations using its own infrastructure to generate a large portion of its electrical requirements.

BUCKEYE IRRIGATION DISTRICT — A HISTORY OF PIONEERING

19th Century Pioneering

It was opportunity, not the thought of being pioneers that took the original founders of the old Buckeye Canal west out of Phoenix in the spring of 1885. They chose a location at the junction of the Gila and Agua Fria rivers to locate a dam that would supply a canal for the purpose of "agricultural, milling or mechanical enterprises." Mr. Malin Jackson, one of the founders provided the name "Buckeye Canal" in honor of Ohio, his native state. Original plans were to bring over 120,000 acres under irrigation. This was 19th Century pioneering.

The decades after its founding saw several floods and rebuilding efforts for the Buckeye Canal including change in ownership. One of those changes in ownership came in 1906

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when several farmers wanted to improve service and water supply and purchased the Buckeye Canal Company, renaming it the Buckeye Irrigation Company (BIC). The BIC was set up as a cooperative so that only adjacent land owners could own stock. Later in 1906 the BIC took over the South Extension canal and in1908 assumed operation of the White Tank Canal, bringing the total length of the main canal to 23 miles with the South Extension adding another 7.5 miles.

The drainage district part of the Company came into existence in later years as excess irrigation on higher grounds caused water logging on some of the lower land areas. In 1922, the “Buckeye Water Conservation and Drainage District” (“BWCDD” or the “District”) was formed to finance a new dam, install pumps and attempt to correct the water logging problem. To supplement water supply from the river, the District drilled water wells, tapping the aquifer of the Hassayampa River Basin which lies below the Town of Buckeye. In 1950, they started a lateral lining program to reduce the amount of water lost to seepage. 1950 also brought celebration as the District became debt free, paying off the bonds issued for the new dam and improvements beginning in 1922.

BWCDD is an irrigation and drainage district and under Arizona statutes is a municipal corporation of the State of Arizona. The District occupies approximately 22,000 acres with 16,000 acres irrigated and lies within the towns of Avondale, Goodyear and Buckeye, all within Maricopa County. The Buckeye or Main canal is 23.5 miles in length and the South Extension is another 7.5 miles in length.[2]

20th Century Pioneering

In 1966 another pioneering decision was made that proved to be very forward looking. In that year the District contracted with the City of Phoenix to take effluent from the 91st Avenue wastewater treatment plant (“WWTP”). The District recognized the growing need to conserve water, in all of its conditions, and the additional demands that an expanding population would make on fresh water supplies. Knowing that this additional supply would require a shift in types of crops grown, but perhaps a more reliable water supply, the District began receiving WWTP water diverted from the Gila River into the Buckeye canal in 1971. Originally the District began receiving 30,000 acre-feet per year. The amount of effluent received has expanded to 65,000 acre-feet per year as the population of Phoenix has grown and the WWTP has expanded to meet the needs of the larger population. BWCDD pays the City of Phoenix at a rate substantially below the cost of potable water in the area. Currently the District receives or pumps approximately 180,000 acre feet per year with an estimated 50,000 acre feet returned to the Gila River.

The irrigated land around the Canal is used to grow alfalfa, barley, corn, cotton, oats, sorghum and wheat. Because of the restrictions on use of effluent for food crop irrigation, the grain crops are primarily feed for cattle. The area supports a very healthy industry of dairy and cattle feeding operations. Also, the largest supply in the U. S. of quality Pima Cotton comes from the farms along the District’s canals.[2]

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[2] BWCDD provided all water supply and area descriptions.

21st Century Pioneering

In early 2007 the managers of the BWCDD saw that controlling electricity costs was going to become a bigger issue in the Districts operating budget. The General Manager of the District, Ed Gerak, began to research the alternatives for generation at the three existing drops on the BWCDD canals. In discussion with the District's electrical consultant, K. R. Saline and Associates, which had long been retained to advise on the District's Hoover Dam power allocation, the consultant provided several alternative methods of generation, including the SLH. After discussions with the management of NatEl, Mr. Gerak and his Board of Directors approved a joint project by BWCDD and NatEl to construct a demonstration project for a nominal 20 kW capacity SLH engine at a drop site on the South Extension of the main canal.

Exhibiting the same pioneering spirit of the previous owners and managers of BWCDD, Mr. Gerak crafted a partnership of site owner, machinery supplier, and civil designer and electrical consultant to design, build and operate a pilot operation on at the South Extension drop. The District would provide the site and modifications of the drop to accommodate the SLH engine: NatEl would contribute the engine as a demonstration of its low cost, low impact, low head hydro generation capability; Stantec, Inc., wanting to be part of the development of a unique green technology would contribute the civil design and K. R. Saline and Associates would contribute the permitting and electrical connection consulting, as well as the Federal Energy Regulatory Commission ("FERC") request for exemption from licensing. The pilot would allow a demonstration of technology that could be implemented at other sites in the District that may have the potential to generate between 200 – 300 kW of additional capacity for the District.

At the end January of 2009 the engine has been designed, manufactured and assembled. The civil design has been completed and the FERC request for exemption has been filed. At each stage of the process, the partners have learned how to deal with the technology and the regulations for bringing about a methodology of providing a low cost option for electrical generation in low head environments. The District is currently (April 15, 2009) waiting for notification of the granting of an exemption from FERC to complete the project.

Beyond Buckeye, the initial applications of the SLH are scheduled to be in irrigation canals and water supply conduits. Smaller machines may be economical in wastewater treatment plant outfalls. While this market is being cultivated, NatEl will begin to work with developers that wish to add generation to the approximately 75,000 non-powered existing dams in the U. S.

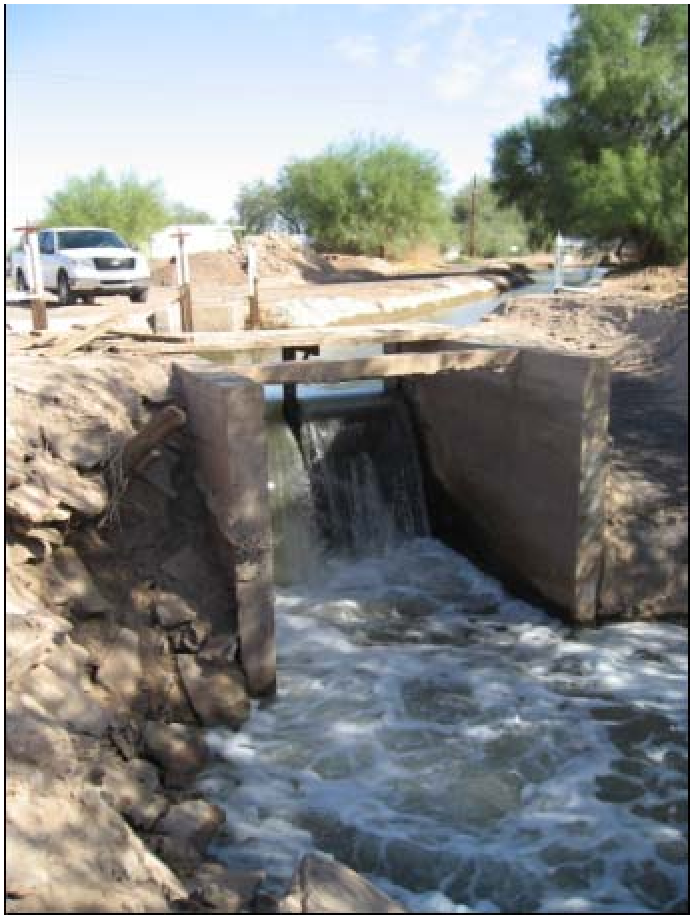

Figure 1. South Extension canal drop

PROOVING THE HARD SCIENCE — MACHINERY DESIGN AND ELECTRICAL GENERATION

The design of the SLH engine, as well as its materials of construction, methods of manufacture and assembly are a matter of established engineering and design. These designs provide for efficiency of operation as well as durability and reliability. The design of the BWCDD demonstration unit is such that it is scalable from 20 kW up to 1,000 kW of nominal capacity. The cost estimates from the current design effort for the SLH system, which includes the engine, generator, inlet gates, penstock, draft tube and PLC (essentially a system ready for installation), are indicated at a capacity cost of between $1,000 and $1,500/kW. The generator is off the shelf, and the other parts lend themselves to stamping, bending and simple milling that does not require expensive multi-axis CNC machines. The PLC is a special design that will meet SCADA requirements and can be adopted for automated and remote operation as well as control of multiple units in series.

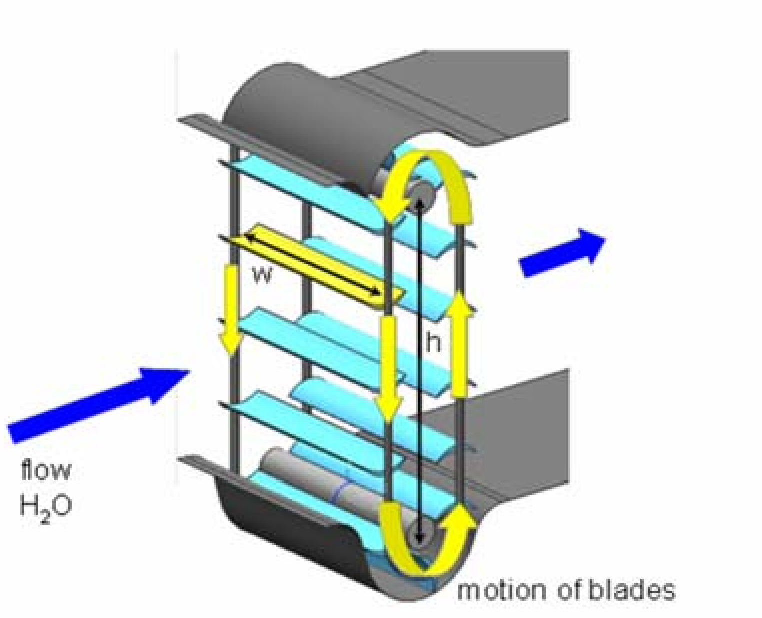

Figure 2. Working Configuration of the SLH machine

The SLH operates in a significantly different manner than a rotary turbine. Water impacts a series of foils that are linked by chain or belt. The foils travel in a linear direction up and down and over the bottom and top shafts. The upper shaft is connected to a speed increaser and generator, providing the electrical output. The significant difference between this design and a rotary turbine is that the SLH can handle large volumes of slow moving water and convert the kinetic energy to electricity with efficiencies of over 80% across a broad range of heads and flows.

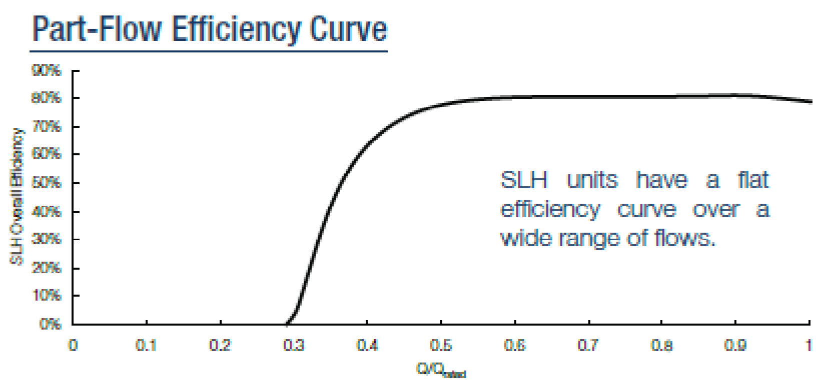

Figure 3. Efficiency curve of the SLH engine

CONVINCING THE SOCIAL SCIENCES — ECONOMIC, REGULATORY AND ENVIRONMENTAL ASPECTS

Economics of SLH in Low Head Hydro

Favorable economic results generally are when there is a net monetary income. For the regulatory community, favorable economics means all rules are complied with. And for the environment, a project must look at life cycle effects to be sure that air, water, soil, plants and animals are not adversely impacted, in addition to considering human safety factors, productive land use and the recycling of all construction materials.

In the U. S. there has been very little development in low head hydro over the past 50 years. Some of this may be attributed to the social forces that have put hydro development in the environmentally unfriendly category, but a great deal has to do with the fact that using the standard turbine technologies was too expensive to design, build and install. Generally, an installation of a turbine meant design for a specific application and then manufacturing one unit on a multi-axis CNC machine. The civil works had to be designed to carry the heavy loads of the machinery as well as the constant force of falling water.

In the initial phases the SLH will not escape some unfavorable attitudes held about hydro generation. Attitudes will change only after favorable environmental benefits are demonstrated. As to the economic feasibility, design and cost estimates have confirmed a realistic opportunity to again look at low head hydro as a means of meeting the renewable energy needs of the nation. Since the engine can be produced by standard stamping, forming and machining methods and the engine housing, penstock and draft tube are fabricated of heavy steel, the cost of capacity can be competitive with coal fired plants and nearly as competitive as combined cycle gas turbines. With low capital cost and renewable flowing water providing low or no cost fuel, the overall cost of electricity can be very competitive.

To determine the cost competitiveness 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.

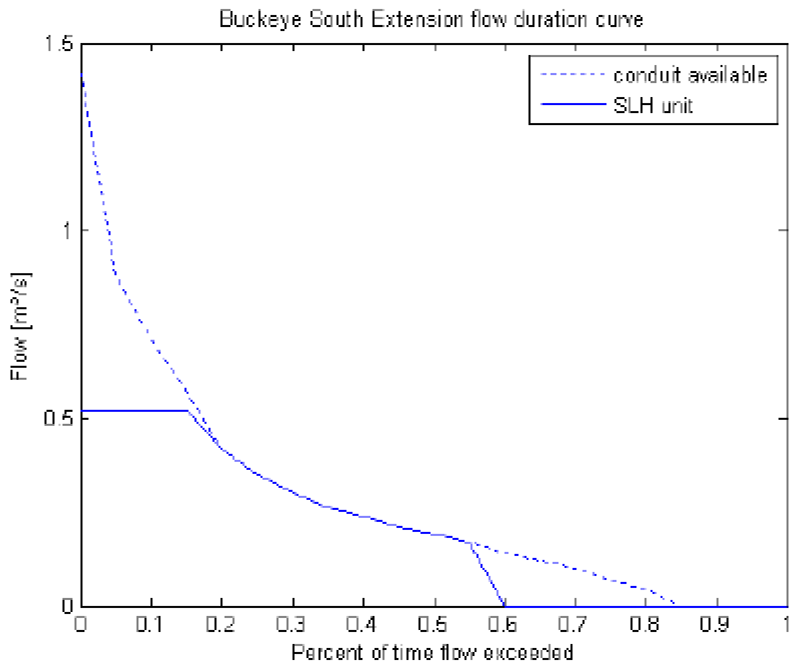

Figure 4. Flow Duration Curve for South Extension Drop

The flow duration curve (Fig. 4) provides the basis for a pro forma operating statement for the demonstration unit at BWCDD. The engine design is for 20 kW of capacity at 4 m of head and flow of 0.52 m^3/s. The actual drop is 2.74 m and average flow is 0.29 m^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.

There are several things that will change the actual economic outcome of the BWCDD installation. The District has the opportunity to lower the level of the down stream pool to make the elevation change larger. Another change would be to alter the schedule of water directed through the drop to have a longer period of flow through the SLH. Either of these would impact the actual results to make the installation more favorable than in the forecast.

Economic considerations for SLH sizes above 20 kW are more favorable. A scaling study has provided system cost estimates for all sizes up to 1000 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 amount of capacity utilization experienced. NatEl estimates of lifecycle cost per kWh based on a 20 year life, 8% cost of capital and $0.02 O&M is shown in Fig. 5.

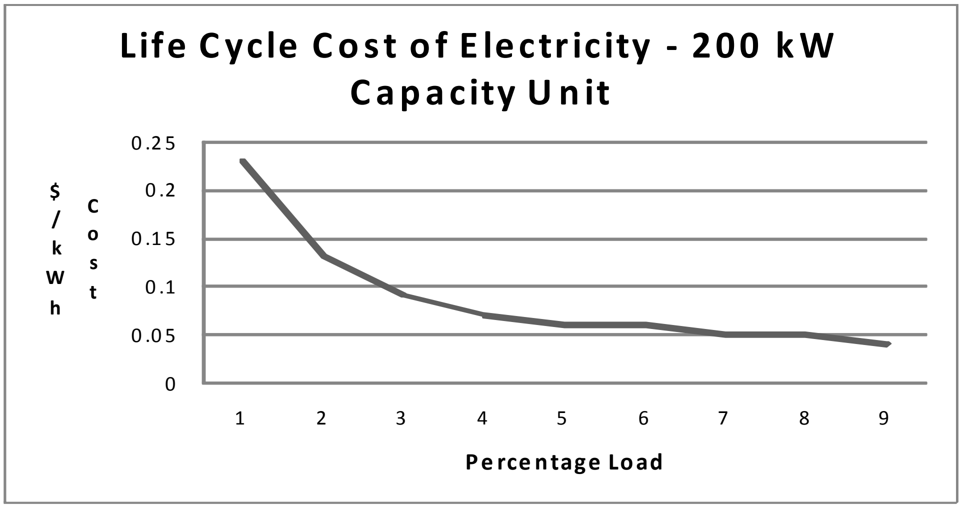

Figure 5. Estimated SLH kWh lifecycle cost based on percentage load

Beyond the price-cost relationship cost of electricity, the 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 10%, 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 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 become 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 ten cents ($0.02 - $0.10) per kWh in RECs over the coming years.

Regulatory Considerations

Regulations tend to reflect the social considerations in the community in which we live. Regulation of hydro electric generation reflects society's attitudes about the environmental effects of generation using high dams that have caused river obstructions to fish passage or riparian ecological impacts. These concerns are reflected in the factors required for an application for the FERC exemption for a low head hydro exemption. An Environmental Impact Statement is not required by statute for a low head hydro exemption. However, FERC does require an Environmental Assessment and notification of potentially impacted agencies and organizations of the intent to build a facility in a waterway, even a conduit such as an irrigation canal or aqueduct.

This number of parties to be notified in a FERC exemption request illustrates the lengths to which regulations allows participation in the approval process. The process also can provide potential delays and alterations as comments and/or objections come from any of the notified parties. In addition to the U. S. Fish and Wildlife, State Game and Fish departments and state permitting agencies, archeological discoveries and historical agencies may have effect the schedule. Consideration for Native American lands must also be taken into account. A requirement by FERC is a GIS map of the site, with ownership of attached parcels identified to reflect neighborhood impacts. Under normal circumstances, the cost of the preparing the FERC exemption request as well as the time required for FERC approval and post approval conditions could make a facility as small as the one at Buckeye too expensive for a reasonable economic return.

Regulation of projects to prevent environmentally damaging events is a concept we approve of. What is required is for the process to work efficiently and timely to realize the full benefits of a project's possibilities. For the small hydro construction process, obtaining the FERC exemption is **THE** critical path element in going from conception to operation.

Before January of 2009 there were only ten exemptions for low head hydro generation issued nationally over the past four years[3.] An analysis shows only four of those as Conduit exemptions. However, two Conduit exemptions have been issued in January of 2009[3]. One of the 2009 issued projects took over nine months from application to granting of an exemption. The second took five and a half months which is what is expected if there are no protests or motions to intervene. In addition to the processing time, a condition of approval is filing of final construction drawings 60 days prior to beginning construction.

The preparation, processing and post approval conditions of the FERC exemption can take several times longer than the design, installation and commissioning of a project, particularly if the machine is already manufactured. In economic terms this could mean a delay by several months of revenue received from a project.

Environmental Considerations

The SLH has been designed to mitigate several potentially harmful effects to the environment. For irrigation canals, since no additional dams or impoundments are to be constructed, there may be very little environmental impact to come from installing a SLH. There are no Fish and Wildlife considerations and endangered species concerns should have been cleared in the construction of the canal and its drops. The biggest environmental advantage is the positive benefit to be gained by using existing infrastructure of irrigation canals and non-generating low head dams to offset many of the negative impacts from coal and natural gas fired electrical generators. These benefits come about while recovering energy that is currently being wasted.

As legislation for national renewable energy standards are debated and regional cap-and-trade programs are enacted, the drive for carbon dioxide reduction will become more intense. The ability to accomplish a part of the CO_2 reduction objective by using existing infrastructure, and at the same time derive significant economic benefit will become more appealing. In an attempt to quantify the potential for reducing CO_2 emissions for the in-

[3] www.FERC.gov/industries/hydropower.asp

conduit market of irrigation districts and water supply we examined the carbon dioxide emissions per MWh of a local utility:

> Average CO_2 emissions from existing coal fired units - 0.98 metric tons/MWh
> Average CO_2 emissions from existing gas CC – units – 0.42 metric tons/MWh
> Average CO_2 emissions from existing gas CT units - 0.61 metric tons/MWh[4]

At NatEl, we believe the potential capacity of low head hydro installations in irrigation and aqueducts in the western states regulated by the Bureau of Reclamation to be approximately 4,000 MW. At 50% capacity utilization the annual carbon dioxide reduction may potentially be around 17,520,000 metric tons of CO_2 per year if only coal fired plants are considered. With an average CO_2 emission of Combined Cycle and Combustion Turbine units of 0.50 metric tons/MWh of carbon dioxide emissions, the potential for carbon dioxide reduction may be one-half of coal, or 8,760,000 metric tons of CO_2 per year.

The design considerations for the machinery and surrounding housings, penstock and draft tube encompass a "cradle to cradle" philosophy - make everything recyclable. Of the parts and pieces in the SLH system, we estimate that 98% of the materials of construction can be recycled. Of the cement and mechanics of water control in the surrounding housing and structures, that may be true as well.

THE END GAME — LARGE SCALE BENEFITS, SMALL SCALE IMPACTS

The main attraction for BWCDD in partnering with NatEl for a SLH demonstration plant installation is the availability of a technology that can provide economic generation in several more drops in its canal system, thus offsetting its electrical costs by as much as one third. Another attraction was the District's engrained pioneering vision for adoption of this technology worldwide in a system that could bring environmentally friendly electricity generation too many underdeveloped parts of the world. The technology provides a ready alternative to high dam construction that has so many detrimental environmental effects wherever they are installed. The litany of complaints about hydro power using high dams and impoundments are many: Flooding of human and fauna habitat; uprooting families and destroying farm land and grazing areas; impeding fish passage for spawning and migration; forever altering canyon and valley ecology and geographic attractions, as well as others. From its design inception, NatEl has incorporated physics and aquatic physiology criteria to achieve many of the power generation attributes of high dams with a minimum of environmental disturbances and impacts. Through a method called Linear Reservoir Routing ("LRR"), studies indicate that placement of strategic small dams along a long river path can provide up to 80% of the power of a high dam while flooding as little as 5% of the land.

This conclusion has been developed after studies of a dam already installed as well as with a proposed installation. A study at the University of North Texas compared the cost and effects of a high dam built in Nepal with the estimated economic, ecological and

[4] Arizona Public Service; Resource Plan Report; January 29, 2009; p.34.

social costs if a LRR system of stair-step dams had been constructed.[5] The study of the dam in Nepal concluded that the return on investment in economic measures could have possibly been several times that provided by the actual installed conventional high head structure, and the social, ecological and societal benefits would have been dramatically different based on lower human displacement and sustaining fishing and farming that had occurred for centuries[5].

A controversial river valley program being considered in the 1970s was in the St. John River Basin of Maine. The plan as proposed would build two high dams; Dickey Dam at about 90 meters of head and the Lincoln School Dam at about 30 m of head. From the two dams, 88,240 acres of wilderness, agricultural and habituated land would be flooded for power generation. The installed capacity of these two dams would have been 830 MW. Dr. Daniel Schneider and Emory Damstrom presented a paper at the Waterpower '79 International Conference on Small Scale Hydropower that illustrated a prospective series of eight dams each having a head of 5 to 8 m. Pumped storage reservoirs were added to provide peaking capability and control flooding. This proposal would have flooded approximately 4,500 acres, or 5% of the high dam amount and could produce 80% of the power stipulated in the high dam approach[6]. The dams were not constructed and the area was converted to a national wilderness area.

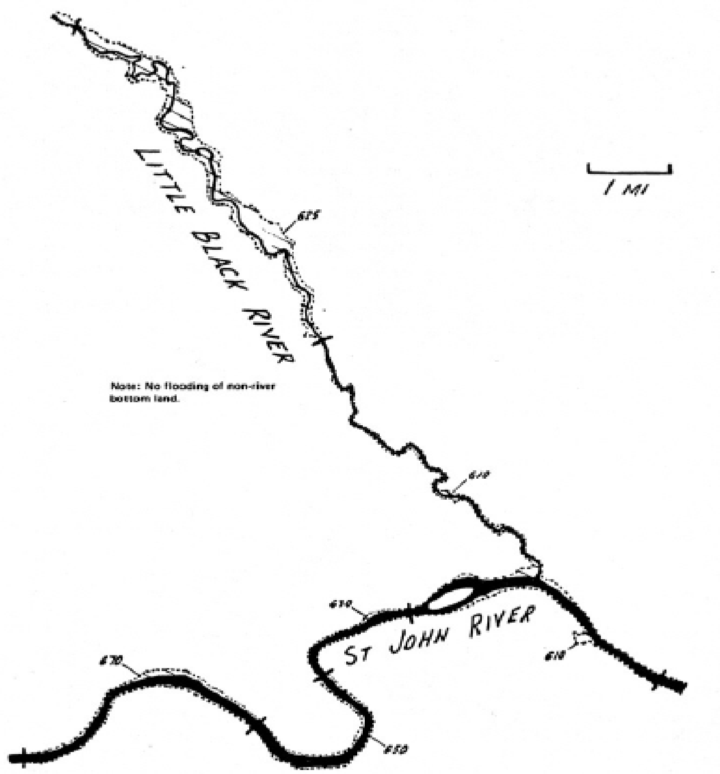

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Figure 6. Illustration of low head reservoirs placed in series.[6]

[5] Nieswiadomy, Dr. Michael; Wang, Hana; "The Benefits of Sustainable Hydropower Using Low-Head Dams in Stair-Step Series"; University of North Texas; Department of Economics; July 17, 2008.
[6] Schneider, Daniel J,; Damstrom, Emory K.; "The Schneider Engine: Performance and Application For Hydropower"; Waterpower '79; October 1-3, 1979.

To obtain high dam benefits with low dam designs requires a programmatic demonstration of the SLH attributes of efficiency, durability, reliability, fish passage, balance of system cost and cost of manufacture and installation. The demonstration site at BWCDD is a small step in the program of demonstration, scaling and implementation of larger size systems.

CONCLUSION — DEMONSTRATION OF THE INSTALLATION BENEFITS TO BWCDD

The data necessary to calculate SLH efficiency in the production of electricity has been gathered in laboratory and pilot plants previously installed. The objectives for the installation at BWCDD of a demonstration of the SLH technology are to provide data on reliability and durability for design components and use machine engineering data of the 20 kW engine to scale the system to larger sizes. By providing access to its site at the South Extension, BWCDD will end up with ownership of the generating plant as well as demonstrated capability for installation of several additional sites.

If all of the potential installations are made at BWCDD, the District may offset up to one-fourth of its electrical costs into the indefinite future. This becomes a permanent hedge of electrical costs for that portion of its operating expense. In the District's pioneering tradition it is using its own resources to provide a long term contribution to systems that support an expanded, sustainable future.

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