Bloemwater Conduit Hydropower Plant launched

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On 31 March 2015 the Minister of Water and Sanitation, Nomvula Mokonyane, unveiled Bloemwater's conduit hydropower facility at the Brandkop Reservoir, and celebrated the major scientific and engineering achievements made by the team of researchers.

INTRODUCTION

South Africa is currently facing an energy crisis which places additional importance on harvesting all available and feasible renewable energies. While the country is not particularly endowed with hydropower conditions, large quantities of raw and potable water are conveyed daily under either pressurised or gravity conditions over long distances and elevations.

Figure 1: Jacques van Delft, Bloemwater electrical technician, helps Nomvula Mokonyane, Minister of Water and Sanitation, to open the water supply valve at the launch to get the turbines running

The University of Pretoria (UP), supported by the Water Research Commission (WRC) and collaborating organisations such as the City of Tshwane Metropolitan Municipality, Bloemwater and the eThekwini Municipality, was engaged in a research project to investigate and demonstrate the potential of extracting the available energy from existing and newly installed water supply and distribution systems.

The aim of the project was to enable the owners and administrators of bulk water supply and distribution systems to install small-scale hydropower systems to generate hydroelectricity for use on site and, in some cases, to supply energy to isolated electricity demand clusters, or even to the national electricity grid, depending on the location, type and size of installation. It taps into a previously unutilised source of hydropower by using excess energy in pressurised conduits to produce clean and renewable hydroelectric power.

This type of energy generation, referred to as conduit hydropower, is different to conventional hydropower generation where large dams are used to store river water in a reservoir. Its simplicity is what makes this solution so elegant – harnessing energy that is already present within the existing infrastructure and that would usually be lost through a pressure reducing valve. As part of the research project two reports detailing the entire process were compiled: Conduit Hydropower Development Guide (WRC Report No TT597/14) and Conduit Hydropower Pilot Plants (WRC Report No TT596/14).

BACKGROUND

An initial scoping investigation by the WRC and UP highlighted the potential of hydropower generation at the inlets to storage reservoirs (Van Vuuren 2010). In South Africa there are 284 municipalities, and several water supply utilities and mines, all owning and operating gravity water supply distribution systems which could be considered for small-, micro- and pico-scale hydropower installations. The WRC and Bloemwater entered into a partnership to install the first full-scale demonstration unit for conduit hydropower in South Africa.

The Caledon–Bloemfontein potable water supply system is responsible for supplying most of the water to the Bloemfontein area and was commissioned in the late 1960s. The supply system has a design capacity of 141 Mℓ/day (1.632 m^3/s).

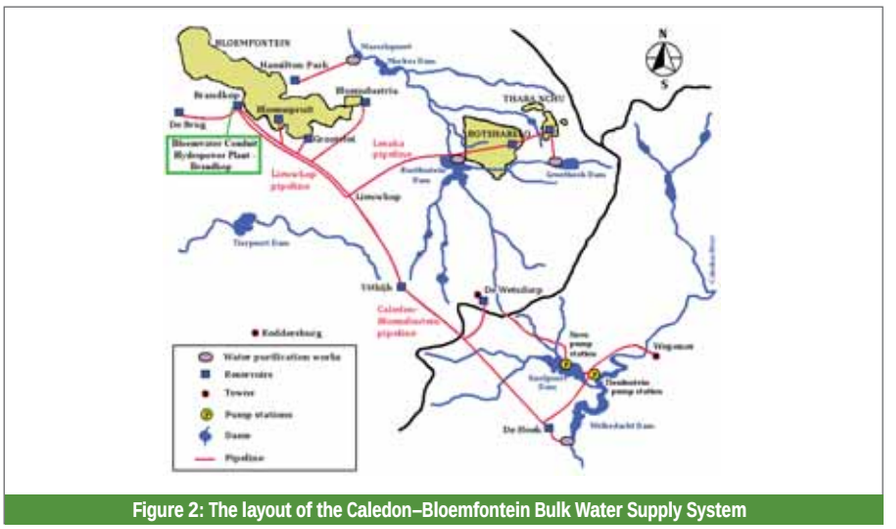

Figure 2: The layout of the Caledon–Bloemfontein Bulk Water Supply System

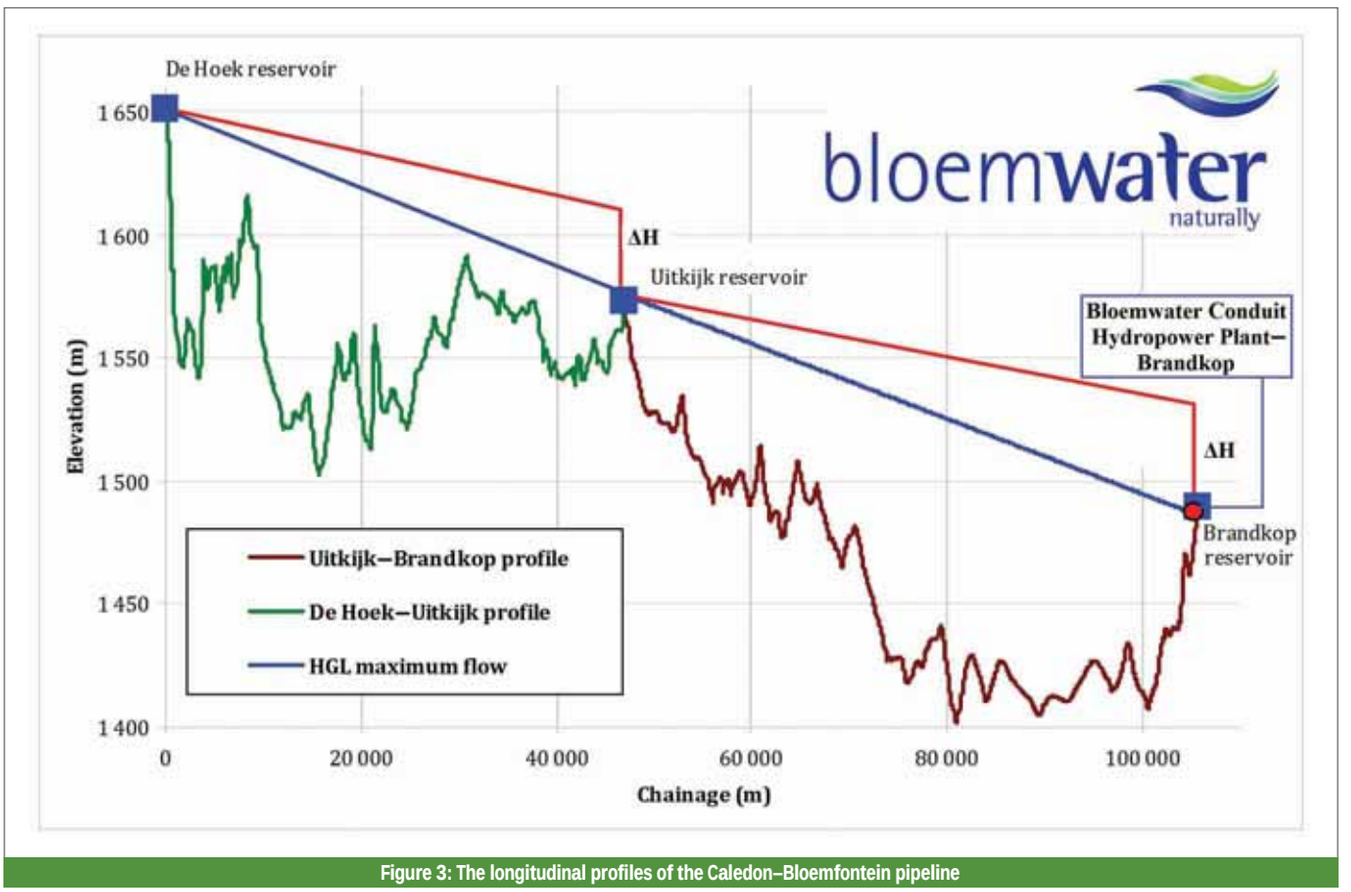

Figure 3: The longitudinal profiles of the Caledon–Bloemfontein pipeline

Figure 4: A pictorial view of the development of the Bloemwater Conduit Hydropower Plant at the Brandkop Reservoir

With the exception of the Welbedacht Dam, the Department of Water and Sanitation (DWS) transferred the assets to Bloemwater in 1991.

The Caledon–Bloemfontein pipeline supplies potable water from the Welbedacht Dam in the Caledon River to Bloemfontein. The treated water is pumped a distance of 6.7 km with a high-lift pump station to the De Hoek Reservoir (22.7 Mℓ). From here it gravitates through a 1 168 mm Ø pre-stressed concrete gravity main 47 km to the Uitkijk Reservoir (9.1 Mℓ) and a further 58.8 km to the Brandkop Reservoir (136 Mℓ). See Figure 2 for the layout of the Caledon–Bloemfontein Bulk Water Supply System.

Excess energy is dissipated through pressure control valves upstream of the Uitkijk and Brandkop Reservoirs before being discharged into the reservoirs (see longitudinal profiles in Figure 3). In order to determine the energy potential at the inlets into the two reservoirs (Uitkijk and Brandkop) the pipelines were hydraulically assessed and the available pressure head and flow rate recorded for a number of months. This assessment indicated that there were approximately 350 to 400 kW available at each of these sites.

For the first phase, Bloemwater decided to develop a hydropower plant with sufficient capacity to meet the electricity demands of its head office, which is situated at the Brandkop Reservoir. Pressure head and flow were measured for the hydraulic assessment, and electricity consumption data was recorded to determine the correct turbine for the demand. The turbine and generator are housed in a turbine room located next to the Brandkop Reservoir. On average, approximately 30% of the water supplied via the Caledon–Bloemfontein pipeline is diverted through the turbine (350 ℓ/s at 40 m pressure head). After passing through the turbine generator, the water is discharged through a constructed opening in the roof of the southwest corner of the reservoir.

Based on the available pressure head range and fixed flow rate of 350 ℓ/s, it was decided to select a 96 kW crossflow (Banki) turbine. The type of turbine selected was the IREM ECOWATT Micro hydroelectric power plant type TBS 4-0.5 with synchronous generator. Electronic regulators are connected to provide the dissipating capability – 9 x RMP 12000/B with a total capacity of 108 kW. The regulators keep the voltage and frequency stable as the absorption of the electricity produced by the turbine generator group remains constant, providing clean, stable electricity at the correct voltage and frequency of 50 Hz. Sufficient renewable electricity is generated to supply the peak demand of Bloemwater's head office, as well as to meet the electricity requirements of the reservoir terrain. The theoretical annual energy that can be generated with this plant is 837 500 kWh, based on average flow and pressure values.

THE HYDROPOWER PLANT

A pictorial view of the development of the Bloemwater Conduit Hydropower Plant is shown in Figure 4.

FINANCIAL VIABILITY OF THE PROJECT

The feasibility study conducted for this installation made some assumptions

regarding the design life (40 years), anticipated electricity escalation (8%) and the discount rate (7%) on the investment made by Bloemwater. It also looked at the current monthly spending of the Bloemwater head office on electricity, which resulted in a payback period of 72 months. The aim was to make this system viable without receiving special subsidies or tariffs. The success and short payback period have given Bloemwater the confidence to start planning the next phase and conducting feasibility studies for other potential conduit hydropower sites. The total cost for this project was R3 500 000 or R36 500/kW.

The plant is not utilised to its full potential, as the peak 96 kW is only required during the peak demand hours of the day. After hours and during weekends the plant will only operate at 30% of its capacity. Thus the potential is there to utilise this more efficiently.

SUCCESS OF THE PROJECT

The plant has now been operational since the launch, supplying Bloemwater with hydroelectric power even when other parts of town are left in the dark during load shedding. This is an example of basic innovative research being implemented practically. It is believed that the research which provided this working demonstration plant has inspired the uptake of conduit hydropower in South Africa. Already several other potential conduit hydropower sites have been identified, investigated, put out to tender and constructed, or are operational at Rand Water, Mossel Bay Municipality, George Municipality, Lepelle Water, Amatola Water, Bloemwater, eThekwini Municipality, City of Tshwane, Johannesburg Water, City of Cape Town and Eskom, amounting to 38.6 MW. This has a monetary generating value of R220 million/annum. Further estimates point to an additional 59.8 MW of untapped potential in the larger metropolitan areas alone, with monetary generating value of R340 million/annum excluding all the mines.

This will provide temporary employment during the construction stage, and direct employment opportunities in operation and maintenance at some of these power plants.

Conduit hydropower uses the available water supply and distribution infrastructure and thus, as long as there is a demand, hydroelectric energy can be generated. As conduit hydropower 'piggybacks' on existing water infrastructure, it also has minimal negative environmental impact.

Hydropower schemes generally have very long lifespans with low operating and maintenance costs (USBR 2008). Furthermore, hydroelectric energy technology is a proven technology that offers high efficiencies, as well as reliable and flexible operation (ESHA 2009).

Conduit hydropower requires a relatively small capital investment and has a short return on investment period. As long as society uses water, renewable hydroelectricity can be generated. At the Bloemwater Conduit Hydropower Plant the water supply system and the electricity consumption were carefully monitored for a number of months before selecting the most suitable turbine and installation configuration for optimal operation.

From the start the Bloemwater Board gave its full support to this new endeavour. South Africa only has a handful of conventional hydropower schemes, but Bloemwater took the bold step by investing in conduit hydropower, and also assisted in knowledge dissemination and showcasing the application of this new technology.

To operate the system effectively a better understanding of the whole system is required. On this project, the supply of water from the WTW, the capabilities and characteristics of the pipeline system, the demand for water from the Brandkop supply reservoir and the electricity requirements for head office are now working as an integrated system. There is also a greater synergy between the various components, as they need to be operated and regulated collectively.

Bloemwater has successfully exploited this productive synergy between the water and energy systems.

Please also visit www.youtube.com/watch?v=um4aIk53hrs to view the YouTube video of this project – *The Power of Hydro: Bloemwater Conduit Hydropower Plant Project*.

ACKNOWLEDGEMENT

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