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Low Emissions Development Program

CASE STUDY
Lessons from Small-scale Hydropower Development in eThekwini

Hydropower represents a nexus of water and energy. Municipalities and water utilities have several locations where a feasible conduit-hydropower scheme could be implemented. A significant untapped opportunity for small hydropower development in South Africa lies in capturing power from municipal water and wastewater or conduit infrastructure. Such potential hydropower sites are in the range of the micro, mini, and small (<10 MW). Environmental impacts associated with these projects are also low. This approach allows for reduced construction costs and accelerated project completion compared with construction at undeveloped sites.

Interior of the eThekwini Water and Sanitation hydropower plant at Ashley Drive.

The SA-LED Program, launched in 2015, has strengthened the capacity of the of the public sector to plan, finance, implement, and report on low emissions development projects and to accelerate the adoption of low emissions technologies in South Africa.

The USAID South Africa Low Emissions Development (SA-LED) Program acted as the transaction advisor for the combined mini- and- small-scale hydropower projects to be procured as a Public Private Partnership (PPP) under the National Treasury prescribed processes. This case study document lessons learnt while providing technical assistance to the development of hydropower projects at eThekwini Metropolitan Municipality and provides recommendations to improve hydropower projects within existing municipal water infrastructure. The hydropower project was conceived as a single project made up of a portfolio of small and micro hydropower plants to be financed, designed, built, owned, and operated by a private sector partner—the PPP partner/Independent Power Producer (IPP).

POTENTIAL CONDUIT SITES FOR HYDROPOWER DEVELOPMENT

ETHEKWINI SMALL-SCALE AND MINI HYDROPOWER

The eThekwini Metro Municipality's Water and Sanitation Unit (EWS) has allowed and supported the evaluation of hydropower potential within its water infrastructure network since 2008. EWS owns, operates and maintains the water supply and distribution infrastructure within its Central, Northern, Southern, and Western operational areas. eThekwini's steep topography and resultant

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high-water pressure in its water distribution system provide ideal opportunities for conduit hydropower. Several potential conduit sites were identified as far back as 2008, particularly within the Western and Northern operational areas.

ABOUT THE WESTERN AQUEDUCT

Pipe at reservoir at Wyebank next to building with break pressure tank

The Western Aqueduct (WA) is a large water supply system providing potable water to distribution networks in the Inanda, Ntuzuma, KwaMashu, and Conubia urban areas. The WA is supplied from the Umgeni system, which receives its raw water from the Midmar and Spring Grove dams. Flow in the WA operates by gravity alone and the aqueduct consists of 58 km of steel pipelines, with diameters of 1,600 mm and 1,400 mm, running between the highest point at the Umlaas Road reservoir and the lowest point at Ntuzuma Reservoir.

The main purpose of the project is to generate electricity from small-scale hydropower plants installed at two locations: the break pressure tanks (BPTs) at Ashley Drive, and Wyebank Road on the municipality's Western Aqueduct. The BPTs were constructed to limit the Western Aqueduct pressures in the aqueduct to a 250 meter of Western Aqueduct column, i.e., 25 bar. The BPTs were necessary to step down the pressure in the pipeline, as it became uneconomical for the pipeline to carry pressures more than 25 bar due to that high pressures damage the pipelines and require constant maintenance at a high price.

Conduit projects commonly use a turbine to perform the function of a Pressure Reducing Valve (PRV). As with a PRV, a hydropower turbine reduces pressure. However, instead of dissipating the excess energy like a PRV, the turbine converts it to usable power. The BPTs consist of PRV that reduce pressure before discharging the water into a tank that supplies water to the water system downstream.

ABOUT THE NORTHERN AQUEDUCT

The Northern Aqueduct operated by EWS is a network of bulk water supply pipelines that serves the northeastern portion of their area of supply, which include north of the Umgeni River, to the south of the Ohlanga River and east of Ntuzuma. This pipeline carries water under gravity flow from Durban Heights Water Treatment Works to a large number of terminal reservoirs and PRVs in the system that in turn supplies water to residents and businesses in the respective reservoir and PRV supply zones.

> A significant untapped opportunity for small hydropower development in South Africa lies in capturing power from municipal water and wastewater or conduit infrastructure. Such potential hydropower sites are in the range of the micro, mini and small (<10 MW).

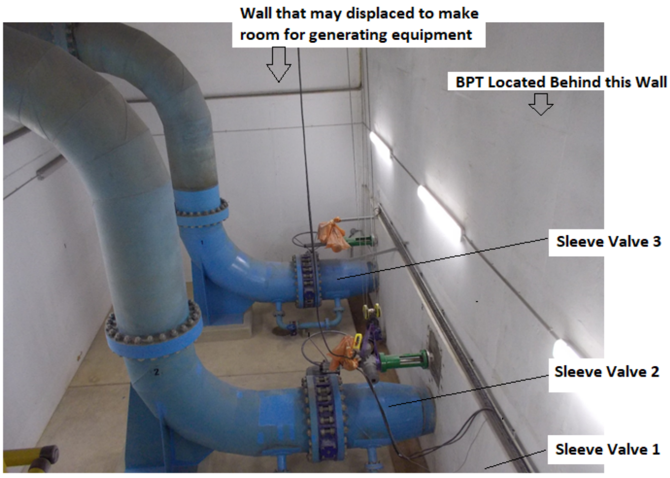
ESTIMATING HYDROPOWER POTENTIAL: PROCESS, PRIORITIES AND PARTNERSHIPS

HYDROPOWER POTENTIAL ANALYSIS

In conventional hydropower system development, resource assessments are completed by identifying dams or topography with sufficient drop for hydropower potential. A hydrologic analysis can be completed to understand the patterns of available flows and the potential risk of high flows that could endanger the structures at the intake. On this basis, a project layout is developed and ultimately power and energy estimates can be completed. This approach estimates power potential based on the natural features, such as topography and geology, and publicly available data. However, this approach cannot be used for pressurized pipelines due to their artificial, engineered characteristics and the fact that the water has already been captured as needed to meet water demands, with the turbines located where the BPT are located. The power generation equipment is designed on the basis of available flow and head (pressure). In the case when the equipment needs to be retrofitted into an existing water supply network, however, the flow and pressure are likely to change as water demand fluctuates and therefore the flows are expected to vary substantially during the day as water demand changes. The design of a conduit hydropower project is therefore constrained by existing conditions that focus entirely on power generation rather than the capture and transport of water to the site.

To estimate the head and flow available for generation within a pipeline, site-specific information must be available for analysis. The information required to complete estimates of potential hydropower generation includes:

- ✓ Historical flow data
- ✓ Historical pressure/elevation data
- ✓ Detailed understanding of the entire conveyance system to ensure that sufficient resources remain after generation for the primary system to function properly
- ✓ Existing system drawings to physically identify if a suitable installation location exists



Pipes and valves at Ashley Drive.

Ideally, the required information would be available from the municipality, but often municipalities lack the necessary data collection systems. For example, SA-LED found that there was no metering data available from EWS of the flows and pressures, particularly for the Northern Aqueduct. While the City had initiated the metering of flows on some pipelines, and was considering hydropower development at several sites, the proposed sites on the Northern and Western Aqueducts were not yet metered. Therefore, essential data on flows and pressure were unavailable.

The City installed data-loggers that are connected to software (EWS uses a software called *PMAC Lite*) at some of its outflow pipelines from a select few reservoirs. As the metering is done on the outflows, instead of the inlet pipes, the data was of more use in monitoring water consumption than for hydropower analysis. For the purpose of estimating hydropower potential, meters should be placed in the inlets to the water storage reservoirs as water pressure and flows are higher at these points. Hydropower generation turbines would need to then be located upstream or inline of the inlet pipes as these are the ones that experience high pressures than the outflows.

> The level of effort required to estimate hydropower potential is often greater for conduit systems than conventional ones. In some cases, it is costly to obtain data, which can add complexity to conducting the assessment.

Third-party engineering firms contracted by the City were another potential source of data and information. EWS had been under the impression that the data from the firms was available and that its quality was sufficient to conclude the feasibility assessment, which was not the case. The firms had some of the data needed, but that data was not always accessible to SA-LED. Also, some data and information from the firms were available for the Western Aqueduct sites, but not the Northern Aqueduct.

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Overall, data gathering and technical investigation during the feasibility study were challenging due to lack of availability and access to data, and lack of clarity around ownership of data.

DEFINING THE PROJECT AS A HYDROPOWER PPP PROJECT

EWS prefers to enter into a public private partnership (PPP) arrangement for the development of its hydropower plants. The main reason for this decision is that the City does not have funds internally to develop the hydropower projects, nor is hydropower development a municipal function. The City also does not have the relevant expertise in-house to develop or operate these projects. It is therefore best to find a private sector entity to develop the plants, operate them, and potentially transfer them to the City after at least seven years, or at which time the City plans to have the internal capacity is built to manage and operate the plants once transferred. Often, most renewable energy developers or financiers prefer longer contracts of up to 20 years, however, in order to recover their capital. Due to the use of municipal land (the BPTs or reservoirs) and the effective partnership between the City and the private sector in the provision of renewable electricity, the project was deemed a potential PPP.

One significant difference between a conduit hydropower PPP and other PPPs where municipal property is used, in a conduit hydropower PPP a private partner installs a turbine at the reservoir, which is municipal property, for power generation while the reservoir must also continue to be owned and operated by the municipality to provide municipal water supply.

DATA/METHODOLOGY INCONSISTENCIES

There are different approaches for estimating hydropower potential in conduit hydropower systems and conventional hydropower development. The lack of a standardized assessment methodology on conduit hydropower can lead to varying results.

Past investigations by some international and local firms had produced optimistic estimates for hydropower potential, primarily within the Northern Aqueduct's potential sites. SA-LED realized that previous evaluations did not make use of the full asset data, e.g., incorrect information on the type of materials the pipelines were made of, year of construction, friction, roughness, or growth of biofilm.

In considering energy losses in a pipeline, a distinction should be made between **secondary** (local) losses, which relate to a secondary loss factor and the velocity squared, and **friction** losses, which are influenced by the roughness parameter (wall roughness and fluid viscosity), the length of the pipeline and the inverse of the diameter and the gravitational acceleration. Determining the last two parameters, in some instances, would require digging up the pipelines to inspect their condition. While it is acknowledged that as water infrastructure ages, the absolute roughness of the pipe will change, and it is common that roughness increases.

However, there is another argument that depending on the water quality – flowing through – some pipelines increase with age, i.e., the growth of biofilm[1] that reduces friction losses. It is recommended that municipalities conduct field verification tests of the hydraulic performance of water conveyance systems as part of their infrastructure management of their water infrastructure. South Africa's Water Research Commission (WRC) recommends that there should be a national effort to monitor the growth of biofilm in pipelines that would lead to the compilation of a "National biofilm growth production map for pipelines,"

[1] Biofilm is defined as an accumulation of microscopic animals, plants and bacteria attached at an interface such as a liquid and a fixed boundary, also known as "slime, "biological deposits", "microbial mat", and "organic glue" or by many other descriptive names.

Lack of a defined methodology for estimating hydropower potential in conduit system can lead to large discrepancies across assessments. To resolve this issue, a tool was developed by the University of Pretoria to standardize the approach.

In assessing the hydropower potential on the Northern Aqueduct sites, SA-LED made use of the WRC funded conduit hydropower tool and manual for estimating hydropower potential in conduit systems developed by the University of Pretoria's Civil Engineering Department. This tool was found to be useful as it has been applied in a number of pilot projects in South African municipal water infrastructure. SA-LED recommends following the WRC's assessment methodology for typical hydropower schemes, such as installing turbines in pipelines, as this will allow municipalities to obtain consistency in approach and the end result of the assessment. It will also allow the local hydropower industry to have a systematic approach in harvesting the energy wasted in existing conduits.

BEYOND THE DATA: OTHER FACTORS TO CONSIDER

USAGE OF ELECTRICITY GENERATED BY THE HYDROPOWER SITES

The electricity generated at each hydropower site is intended to be fed into the municipal distribution network, with minor use on-site as the reservoirs are mainly gravity fed and do not require electricity for pumping water. The only energy consumption at these sites is for security, alarm systems, and communications. eThekwini has a well-defined structure/process for interconnection of small-scale hydropower generators. The City's policy states that power can only be bought at Eskom MegaFlex rates, and not more than or less than these rates. This represents a direct offset of Eskom electricity.

DEFINING THE COSTS OF THE HYDROPOWER INSTALLATIONS

The economics of a micro/mini/small hydropower developments are crucial in determining the overall project feasibility (van Vuuren et.al, 2014). As EWS intends to enter into a PPP arrangement for the development of the hydropower installations, it is important that the project(s) pass the three tests for a municipal PPP.

- ✓ Value for money
- ✓ Risk transfer – transfer of risks from the municipality to the private party who is well placed to manage the risks
- ✓ Affordability – capacity of the municipality to afford the deal

The above requirements call for a detailed economic analysis of the project. A lesson learned by SA-LED, particularly in the case of the Western Aqueduct, was that while the technical feasibility of the small hydropower project was more readily established, determining the financial viability of the project could be challenging, partly due to the wide range of costs of turbines based on the source (U.S. versus Europe versus China versus India Original Equipment Manufacturers (OEM) manufactured turbines). Also, past local studies had varying costing figures, which created a wide gap in the costing figures. A Chinese manufacturer provided costing figures that, when applied, led to a more economically viable project when also considering that the municipality's electricity department could only purchase power from the IPP/PPP partner at Eskom MegaFlex rates, per municipality policy.

The challenge for an IPP in aiming to deliver power at MegaFlex rates is that applying the levelized cost of electricity (LCOE[2]) to a **new build** (in this case, renewable hydropower energy) versus an

[2] The levelized cost of electricity (LCOE) is a measure of a power source that attempts to compare different methods of electricity generation on a comparable basis. It is an economic assessment of the average total cost to build and operate a power generating asset over its lifetime divided by the total energy output of the asset

existing coal power plant is not a good comparison. The current stated MegaFlex tariffs are based on *existing* installations, while *new-build* prices focus on plants whose operating lives were to start today.

The current pricing of electricity imposed by the City also does not factor in the economic, environmental and social costs of greenhouse gas emissions. The costs of other factors not taken into consideration include the health effects of air particle pollution, deaths arising from coal mining, and the savings from building transmission infrastructure compared to localized hydropower production.

There is a risk that there might be no appetite within the private sector bidders to offer tariffs below the target MegaFlex level.

KEY TAKEAWAYS FROM THE EWS EXPERIENCE

SUMMARY OF PROJECT LESSONS LEARNED

The micro/mini/small-scale hydropower potential within existing water supply infrastructure is a good way to generate clean energy without having to undergo the more stringent processes that comes with larger projects, particularly as experienced in the development of "greenfield" projects.

CATEGORY	CHALLENGE/IMPACT	RECOMMENDATION
Technical	Difficulties in accessing the required data for estimating hydropower potential caused delays	Municipalities considering developing conduit hydropower should aim to have annual metered pressure and flow data in place and up to date in asset registers.
Resources and Relevant Skills	Hydropower is not a municipal core competency and the relevant skills and resources are not easily or readily available from a given municipal department. This can result in delays in processes such as if one tries to obtain information from other departments, such as from the supply chain management, electricity and energy, or finance departments.	A multidisciplinary municipal team should be established with members drawn from the relevant municipal departments, and an engineering expert hired/contracted to help clarify project needs from the outset.
Data Availability from Contractors	Difficulties in accessing the required data on from contractors that have previously worked on municipal projects and lead to delays in feasibility studies.	Municipalities must ensure that they can access data or are furnished with all data from previous work that contractors have done for the municipality.
Data Availability in Asset Registers	Unreliable or incomplete asset registers result in significantly more work required to obtain necessary information for feasibility studies.	Municipalities must work on their asset registers to make sure this information is accessible to project officials.
Municipal Data Availability	Data is a significant challenge, as municipalities often do not have or monitor the required or appropriate data.	As part of planning processes, data availability must be looked at carefully and time and effort

over that lifetime. The LCOE can also be regarded as the minimum cost at which electricity must be sold in order to break-even over the lifetime of the project.

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CATEGORY	CHALLENGE/IMPACT	RECOMMENDATION
	Assumptions made in the planning phase affected the project timeline and the ability to follow the legislated PPP project cycle.	for data collection must be included in planning.
Executive Decision Making	Lack of commitment or involvement from executive decisionmakers can lead to confusion in decision making on scope and process as well as delays.	It is important that the advice and information provided by the transaction advisor is officially recognized by senior management. It is therefore important to make use of the formal transaction advisor contract that the city manager signs.
Scope	Scope creep can be a challenge that contributes to project delays	An agreement on the scope of support should be agreed upon and signed to by senior management and then communicated across the municipality and among decisionmakers so that proper buy-in and coordination is established.
Resources	Resources required for estimating technical inputs into the feasibility studies are often higher than expected and should only include consultant time for technical studies.	Budgets should be made with contingencies or allowances for technical or engineering tests or data monitoring, for example, which are often required for municipal projects.
PPA Tariff	Municipalities may have policies that mean all power must be bought at Eskom MegaFlex tariffs. A municipality's mean effective tariff may be different. If higher, then a municipality may be leaving a percentage of the tariff to the benefit of the PPP partner.	Municipalities should try to ensure effective or real tariffs are used in their projects as an accurate reflection of cost.

To ensure that the Northern Aqueduct potential hydropower sites are developed alongside the Western Aqueduct it was recommended that the former sites "piggyback" on the main tender process for the Western Aqueduct. Given the small size of potential installed power generation on the Northern Aqueduct there are concerns that if not developed with the main project the potential that exists on these sites might be ignored. However, due to the rising profile of embedded generation, it is hoped that municipalities will be able to develop renewable resources available to them especially within their infrastructure.

RECOMMENDATIONS FOR CONSIDERING HYDRO DEVELOPMENTS WITHIN WATER SUPPLY SYSTEMS

There are several actions that could improve the prospects for future development of hydropower projects considered for water conduits, including applied research, policy analysis, and technology development and testing as well as establishing the priorities in the maintenance of water supply systems and rigorous implementation.

Flow meters and pressure transducers should be installed to determine the maximum and minimum flow rates and corresponding pressures at each site. These meters should be installed over long periods to get better long-term flow data, as longer record sets would lead to better estimations of hydropower potential.

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