Conduit hydropower gaining momentum in South Africa

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South Africa
• What is conduit hydropower?

• What opportunities do we have in South Africa for conduit hydropower?

• Feasibility of conduit hydropower – It is a really profitable investment
Presentation Layout

• Introduction
• What is conduit hydropower?
• Where would you find conduit hydropower opportunities?
• Technology - Turbines
• Who has been looking in SA?
• Examples of opportunities
• Summary
Introduction

• “Low hanging fruit”
• Easy renewable to develop
• In US FERC – adopted legislation which provides exemption
• Fits into SA being a water scarce country
What is conduit hydropower?

Hydropower is often referred to as water power. The simplest definition of hydropower would be the power that derives from the force of energy of the moving water.

“Conduit hydropower” – energy generated from pressurised conduits
What is conduit hydropower?

Available WRC studies

- KV238/10 - A High Level Scoping Investigation into the Potential of Energy Saving and Production/Generation in the Supply of Water Through Pressurized Conduits
- TT596/14 - Conduit Hydropower Pilot Plants
- TT597/14 - Conduit Hydropower Development Guide

www.wrc.org.za
What is conduit hydropower?

Pipelines are usually controlled at the downstream end
# Finding sites

<table>
<thead>
<tr>
<th>Operational category</th>
<th>Type</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveyance</td>
<td>Open channel</td>
<td>Convey fluid from one point to another</td>
</tr>
<tr>
<td></td>
<td>Tunnel / conduit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Aqueduct</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drops (vertical and chutes)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Culverts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Water distribution systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bulk sewer lines</td>
<td></td>
</tr>
<tr>
<td>Regulatory and diversions</td>
<td>Sluice gates</td>
<td>Control water level upstream side of structure. Navigation, Storage, Hydro.</td>
</tr>
<tr>
<td></td>
<td>Weirs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Barrages</td>
<td></td>
</tr>
<tr>
<td>Flow measurement</td>
<td>Parshall flume</td>
<td>Measure flow</td>
</tr>
<tr>
<td></td>
<td>Crump weir</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Broad crested weir</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sharp crested weir</td>
<td></td>
</tr>
<tr>
<td>Dams</td>
<td>Outlet works</td>
<td>Reserve flow releases, domestic or irrigation releases, spill/overtopping flows</td>
</tr>
<tr>
<td>Water treatment works</td>
<td>Inlet works</td>
<td>Treatment facility with specific opportunities at both in- and outlet</td>
</tr>
<tr>
<td></td>
<td>Outlet works</td>
<td></td>
</tr>
<tr>
<td>Waste water treatment works</td>
<td>Inlet works</td>
<td>Treatment facility with specific opportunities at both in- and outlet</td>
</tr>
<tr>
<td></td>
<td>Outlet works</td>
<td></td>
</tr>
<tr>
<td>Energy dissipation</td>
<td>Drop structure</td>
<td>Dissipate energy associated with big elevation change, or velocity head</td>
</tr>
<tr>
<td></td>
<td>Kinetic structure</td>
<td></td>
</tr>
<tr>
<td>Industrial flows</td>
<td>Conduits and channels</td>
<td>Water utilized in industrial activities/processes</td>
</tr>
<tr>
<td>Rivers/channels</td>
<td>Kinetic</td>
<td>Convey fluid from one point to another</td>
</tr>
</tbody>
</table>
Finding sites

Pressure Reducing Stations
Turbines

Impulse turbines

Cross flow turbine

Pelton wheel

Turgo turbine
Turbines

Reaction turbines

Francis turbine

Axial flow turbine
Turbines

Reaction turbines

Pump-as-turbine

Powerpipe™
(spherical turbine)
Who’s looking in SA

• Department of Water and Sanitation
  – As an example new Gariep Bloemfontein pipeline

• Water utilities
  – Rand Water Board (4 sites total 13 MW); At PRS
  – Bloemwater (2 x 350 kW + more); At PRS
  – Umgeni Water (various); At PRS
  – Lepelle Northern Water (120 kW); At WTW
  – Johannesburg Water (7 sites total 5 MW); At PRS and in-line

• Municipalities (Local authorities)
  – City of Tshwane (5 sites total > 2.3 MW + 3 existing sites 180 kW); At PRS
  – Ethekwini Municipality (various); At PRS
  – City of Cape Town (?); at WTW

• ESKOM
  – Orange Fish Tunnel outlet at Teebus (10 MW); At PRS
Examples of opportunities

• City of Tshwane
  – Pierre van Ryneveld Reservoir
  – Garsfontein Reservoir
  – Heights High Level Reservoir

• Bloemwater
  – Brandkop Reservoir
  – Uitkijk Reservoir

• Johannesburg Water
Examples of opportunities

**Potential sites in Tshwane**

Geographically speaking the City of Tshwane has a lower elevation than the bulk service Reservoirs of Rand Water which is the main water supply. Water is then distributed through a large water system that includes 160 reservoirs, 42 water towers, 10677 km of pipes and more than **260 pressure reducing installations** (PRV’s) that operates at pressures of up to 250 m.
Examples of opportunities – Pierre van Ryneveld
Examples of opportunities – Pierre van Ryneveld

16 KW crossflow turbine
Examples of opportunities - Garsfontein
Examples of opportunities - Garsfontein

Potential for a week = 82 097 kwh
Annual potential = 4 257 309 kwh

Data since April 2011 and
P\text{avg upstream} = 120 \text{ m}
Q\text{avg} = 0,77 \text{ m}^3/\text{s}

Required turbine capacity 550 kW or 950 kW depending on operational approach adopted
Examples of opportunities – Heights HL
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Examples of opportunities – Heights HL

Potential 455 kW
Examples of opportunities - Brandkop
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Examples of opportunities - Brandkop

30 Minute kW Demand vs % Time

Data Used: From 10:00 on 2012/11/14 to 01:00 on 2013/01/16
Examples of opportunities - Brandkop

- IREM Crossflow turbine and generator
- Nominal voltage: three/single phase 400/230V 50Hz
- Generated electric power: $P = \pm 96$ kW
- Net head axis turbine: $H = \pm 40$ m
- Flow: $Q = \pm 350$ l/s

**ECOWATT Micro hydroelectric power plant type TBS**
- Cross Flow turbine in stainless steel type 4-0.5
- Synchronous generator type AZ 100
- Revolution multiplier by cogged driving belt
- Automatic flow regulation (with electric actuator 230Vac)
- Manual butterfly valve
Examples of opportunities - Brandkop

- **Electric Distribution Board Mod. CT 100.000**
  - a voltmeter, a digital frequency-meter, ammeters indicating the total current distributed by the generator, ammeters indicating the current drawn by the consumers
  - magneto thermal, which protects the generator from possible short circuits on the consumer line
  - electronic voltage relay, operating a warning buzzer and a visual signal in the event the voltage variation exceeds the limits

- **Electronic Regulating System RMP 12000/B with water dissipation resistances**
  - box unit, which include the electronic control board to micro processor and the power control
  - transient voltage protection (TVP)
  - resistors for dissipation equipped with 9 x 12 kW

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Examples of opportunities - Brandkop
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96 kW
Examples of opportunities - Brandkop
Examples of opportunities - Brandkop

- Launched plant - 31 March 2015
- Supplies the entire Bloemwater head office
## Examples of opportunities - Brandkop

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure and flow measurements</td>
<td>The available head versus flow relationship is required to select a suitable turbine.</td>
<td>R25 000</td>
</tr>
<tr>
<td>Electricity consumption data</td>
<td>A monitoring system was installed measuring the electricity consumption of Bloemwater head office. Peak electricity consumption and daily pattern is required.</td>
<td>R20 000</td>
</tr>
<tr>
<td>Dynamic analysis</td>
<td>A dynamic analysis is required to ensure the safe operation of the hydropower plant.</td>
<td>R40 000</td>
</tr>
<tr>
<td>Valve chamber</td>
<td>Modifications to existing valve chamber providing off take and valve chamber.</td>
<td>R40 000</td>
</tr>
<tr>
<td>Pipe and valve work</td>
<td>Supply and installation of off-take pipeline (500 mm diameter) including bends, isolating valve, reducers and pressure control/regulating valve (400 mm control valve).</td>
<td>R445 000</td>
</tr>
<tr>
<td>Cross-flow turbine</td>
<td>Manufacture and supply of cross-flow turbine with bottom outlet, synchronous 3-phase generator, electronic regulator and control panel.</td>
<td>R1 350 000</td>
</tr>
<tr>
<td>Electrical connection to BW offices</td>
<td>Providing and installing electrical cable connecting to BW head office (distance ±200 m). Modifications to electrical panels, switching between municipal and hydroelectric power.</td>
<td>R762 690</td>
</tr>
<tr>
<td>Turbine room</td>
<td>The turbine, generator, electric control panel, monitoring equipment and regulator is housed in a brick walled lockable structure with safety signs, lighting, cameras etc.</td>
<td>R535 000</td>
</tr>
<tr>
<td>Monitoring system</td>
<td>Installing monitoring system of power output from generator, net power to the external load, system voltage, gross and net system current, status of all shutdown functions etc.</td>
<td>R30 000</td>
</tr>
<tr>
<td>Data logging and communication system</td>
<td>Logger with internal modem to capture data remotely installed in the Turbine room. Additional pressure transducers and monitoring equipment was also installed.</td>
<td>R60 000</td>
</tr>
<tr>
<td>Flow measurement &amp; Pressure reducing and solenoid control</td>
<td>An ultrasonic flow meter was installed on the off-take to the turbine connected to the data logger.</td>
<td>R70 000</td>
</tr>
<tr>
<td>Design and implementation</td>
<td>Assistance with design, turbine selection and implementation</td>
<td>R225 000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>R 3 602 690</strong></td>
</tr>
</tbody>
</table>

Based on current spending of Bloemwater head office on monthly electricity bills will result in a payback period of **±72 months** for this project i.e. **±6 years.**
Examples of opportunities - Brandkop

- To operate the system effectively requires a better understanding of the whole system.
- Energy water nexus - Integration of WTW, pipeline capabilities and characteristics, demand pattern and the electricity requirements from head office.
- Please view the YouTube video of this project: *The Power of Hydro: Bloemwater Conduit Hydropower Plant Project*
Examples of opportunities - Uitkijk
Examples of opportunities - Uitkijk

300 mm Ø control valves
2 in serie

400 mm Ø control valves

600 mm Ø butterfly valve

200 mm Ø air valves

Branch 1

Branch 2

Branch 3

914 Ø
## Examples of opportunities – Jhb Water

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<th>Description</th>
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<td>Erand AH Ext 1 New Road</td>
<td>In-line</td>
</tr>
<tr>
<td>2</td>
<td>Linbro Park PRV station</td>
<td>In-line at PRV</td>
</tr>
<tr>
<td>3</td>
<td>Marlboro Ext 1, Philo Street</td>
<td>In-line at PRV</td>
</tr>
<tr>
<td>4</td>
<td>Northcliff Ext 25, Elm Street</td>
<td>In-line at PRV</td>
</tr>
<tr>
<td>5</td>
<td>Moroko North, Dirane Street</td>
<td>In-line</td>
</tr>
<tr>
<td>6</td>
<td>Jabulani, Ext 1</td>
<td>End reservoir at PRV</td>
</tr>
<tr>
<td>7</td>
<td>Pimville, Ext 2</td>
<td>End Reservoir at PRV</td>
</tr>
</tbody>
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Potential of between 3 and 5 MW
## Examples of opportunities – Jhb Water

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</table>

![Diagram](image)
## Is it Feasible?

<table>
<thead>
<tr>
<th>Site</th>
<th>Generating capacity (kW)</th>
<th>Average annual generated energy (kWh/a)</th>
<th>Total cost (R)</th>
<th>Implementation costs (R/kW)</th>
<th>IRR (%)</th>
<th>Levelised costs (c/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>740</td>
<td>6393600</td>
<td>R 20 793 477</td>
<td>R 28 099</td>
<td>26.84</td>
<td>24.55</td>
</tr>
<tr>
<td>2a</td>
<td>372</td>
<td>3214080</td>
<td>R 12 328 659</td>
<td>R 33 142</td>
<td>24.14</td>
<td>27.34</td>
</tr>
<tr>
<td>2b</td>
<td>267</td>
<td>2306880</td>
<td>R 9 512 085</td>
<td>R 35 626</td>
<td>23.06</td>
<td>28.57</td>
</tr>
<tr>
<td>3</td>
<td>265</td>
<td>2289600</td>
<td>R 8 253 450</td>
<td>R 31 145</td>
<td>25.17</td>
<td>25.66</td>
</tr>
<tr>
<td>4</td>
<td>455</td>
<td>3931200</td>
<td>R 12 806 538</td>
<td>R 28 146</td>
<td>26.85</td>
<td>24.22</td>
</tr>
<tr>
<td>5</td>
<td>275</td>
<td>2376000</td>
<td>R 9 211 814</td>
<td>R 33 498</td>
<td>23.40</td>
<td>27.44</td>
</tr>
<tr>
<td>Total</td>
<td>2374</td>
<td>20511360</td>
<td>R 72 906 022</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Development cost of conduit hydropower R16 to R40 million/MW

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In summary

- It is believed that there are numerous hydro power opportunities in South Africa in urban areas
- Feasible and sustainable solutions without subsidies
- Utilizing existing water infrastructure better ("piggy back")
- As an example, City of Tshwane has linked up with industry and University of Pretoria and:
  - Built a pilot 16 kW plant in Pierre van Ryneveld Reservoir
  - Built a 150 kW plant at Annlin Reservoir
  - Mayoral resolution has been made
  - Feasibility studies for conduit hydropower sites completed and busy with detail design
  - Supports further pico hydropower turbine development
  - Skills development/ student training
The authors wish to thank the Water Research Commission of South Africa for funding the various research projects.