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AUGMENTING CAPE TOWN'S WATER SUPPLY

An Alternative Solution

By Willem Botes (Pr. Tech Eng.) and Dr. Johann van Wyk

Introduction

Decreasing water availability due to climate change and increasing population resulted in an **urgent need for augmenting Cape Town's water supply**

All possible alternatives/proposed solutions need to be considered in terms of **benefits and risks**:

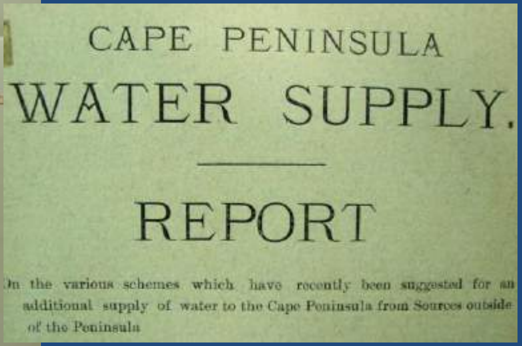
- Environmental
- Financial
- Social (including legal and political)
- Practical

These factors ultimately influence the **feasibility and sustainability** of the chosen solution(s)

Introduction

Did we plan for the future ?

1906: Cape Town population: **< 170 000**



CAPE PENINSULA

WATER SUPPLY.

REPORT

On the various schemes which have recently been suggested for an additional supply of water to the Cape Peninsula from Sources outside of the Peninsula

3 of the present **5** dams

to meet the demand.

1980: Cape Town population: **1.6 million. Last effort to meet demand.**

2017: Cape Town population: **> 4 million. ?**

Current Options Being Considered

(derived from various media reports)

- **Groundwater extraction**
  Cape Flats and Table Mountain Aquifers
- **Desalination plant (400 000 m^3/day)**
  West Coast
- **Augmentation of Voëlvlei Dam**
  From Berg River
- **Re-use of Waste Water**
  Zandvliet WWTW

Groundwater Extraction: Implications

To supply the needed 400 000 m³/day:

Abstraction cannot be from one point

An optimistic yield of 10 l/s (864 m³/day) from a borehole will result in

460 boreholes

If theoretically spaced at 500 m, it will require an area >10 km x >10 km

Also a labyrinth of new pipelines for collection at one/few points before transferring to a WTW – given the highly dense built-up area on the Cape Flats

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Groundwater Extraction: Implications

Quality of the Cape Flats aquifer:

Due to the deterioration of ground water quality, significant upgrades at the current WTW will be required (for advanced treatment processes)

An example of the spatial variation of water quality in the Cape Flats
(Water SA vol.36 n.4 Pretoria Jul. 2010.)

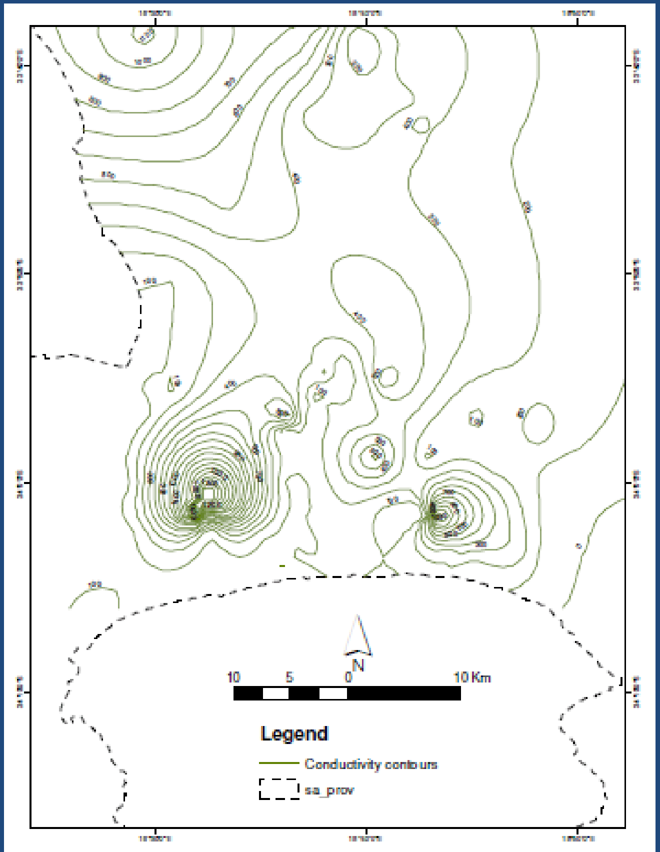

Figure 14
Water quality map based on electrical conductivity distribution in the Cape Flats

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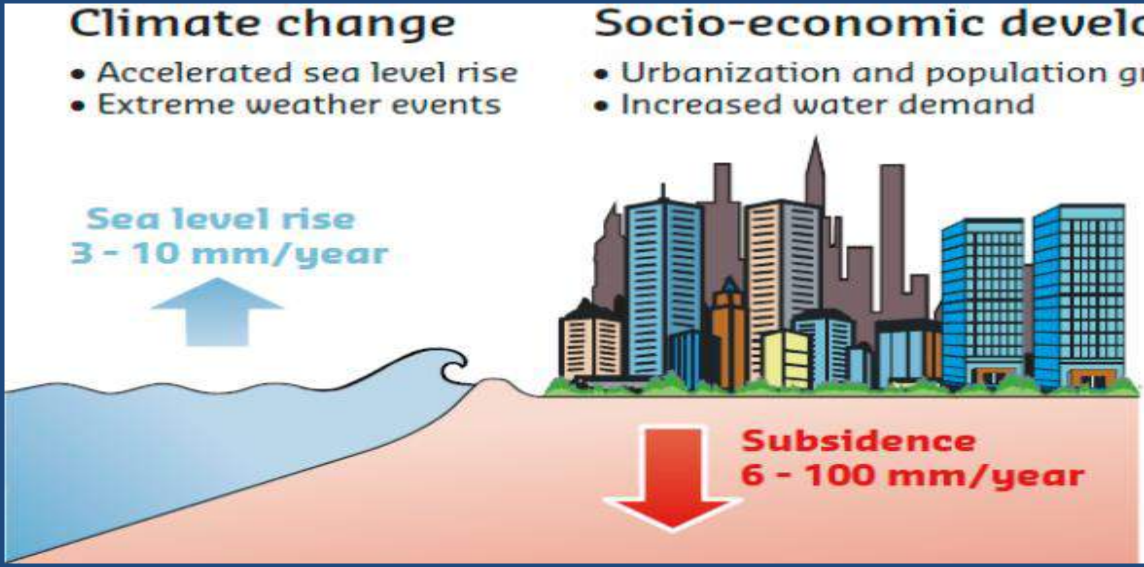
The SINKING Coastal Cities of the World



Causes
- Groundwater extraction
- Oil, gas mining
- Tectonics

Sinking coastal cities

G. Erkens, T. Bucx, R. Dam, G. de Lange, and J. Lambert

Published: 12 November 2015

Proc. IAHS, 372, 189–198, 2015

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The SINKING Coastal Cities of the World

1 **New Orleans, Louisiana, US**

14.5 inches of sea level rise by 2040

Groundwater pumping and dewatering are believed to be the primary reasons.

2 **Tokyo, Japan**

Up until the 1960s, the city was sinking by almost 4 inches every year. The rate went down after regulations were imposed on groundwater use.

The SINKING Coastal Cities of the World

3 Ho Chi Minh City, Vietnam

Many parts of the city are sinking by 0.2-0.4 inches per year.

The main reasons cited were over-exploitation of underground water

4 Dhaka, Bangladesh

The city has been sinking due to extensive groundwater extraction, leading to increased flooding.

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The SINKING Coastal Cities of the World

5
Shanghai, China

In the last 100 years, the country's biggest city has sunk by over 2.5 meters due to pumping of groundwater.

6
Manila, Philippines

The capital city is sinking by about 4 inches each year due to over-pumping of groundwater.

The SINKING Coastal Cities of the World

7

Jakarta, Indonesia

One of the fastest sinking cities in the world (9.8 inches/year)

The main reason - residents rely heavily on wells extracting water from aquifers.

8

Houston, Texas, US

Extensive extraction of groundwater and oil have led to the city sinking by around 2 inches per year.

Desalination at West Coast: Implications

Technical, environmental and financial considerations:

To deliver 450 000 m^3/day by reverse osmosis will require an abstraction of **> 1100 000 m^3/day** (12 700 l/s) - massive pump facilities and intake structures will be required

Each day **11 700 tons** dissolved solids (salt) will be returned to the sea as a “heavy” brine effluent with a density of 1045 g/l (compared to an ambient of 1027 g/l)

Considering the ecological sensitive inshore marine environment along the West Coast, **an offshore outfall in at least 10 m water depth** will be required, which will also require extensive pumping facilities

Massive capital investment: **R15 billion**

Desalination at West Coast: Implications

Huge operating costs:

A desalination plant is an energy hog. It takes most reverse osmosis plants about **3 to 10 kilowatt-hours** (kWh) of energy to produce **one cubic meter** of freshwater from seawater

Thus to produce 450 Ml/day (450 000 m^3) will require between **1.4 million and 4.5 million kWh.** At R 2.00 per kWh this will result in an electricity cost of between **R2.8 million and R9 million per day** (or R84 to R270 million per month)

With energy costs an estimated 55 percent of plants' total O&M costs, total monthly costs will be between **R152 million and R490 million per month**

Excluding capital investment **(interest/pay back of R 15 billion)**

Desalination at West Coast: Implications

Costs (examples):

Sydney Desalination Plant chief executive Keith Davies said maintenance of the plant in 2012/13 cost \$194.9 million, in 2013/14 it cost \$192.7 million (R1.9 billion). Without any production – size 250 000 m^3/day)

South Africa's largest desalination plant has virtually come to a halt and is costing the **Mossel Bay** Municipality **R4 million** a year to maintain (size **15 kl/day – 30 000 times smaller** than the proposed plants for Cape Town)

Transfer Water from Berg River to Voëlvlei Dam: Implications

This is not a viable alternative (especially long-term) at all – as it will result in increase abstraction from the already stressed Great Berg River

Any further abstraction will have adverse effects on the water quality and ecology of the system

The ecology depends on the water quality and flow volumes. Water quality is the concentration of substances:

- Physical (TDS, suspended solids, BOD, conductivity, etc.)
- Nutrients (Nitrates, Nitrites, Phosphates)
- Toxic substances (heavy metals, carbon hydrogen substances, pesticides, herbicides)
- Microbiological substances

Transfer Water from Berg River to Voëlvlei Dam: Implications

The concentration of substances are determined by loads of substances and the flow rates (run off) of the river

Consider the following:

- **Increasing loads due to expanded WWTW**
- **Poorly performance of existing WWTW**
- **Increasing stormwater loads due to riparian developments (residential, commercial, industrial, agricultural)**

The abstraction of "surplus winter flows" will have major effects, as these winter flows contribute to flushing and temporarily relief by reducing concentrations

Zandvliet WWTW: Re-use effluent: Potable Water

Advance treatment of waste water effluent to meet potable water standards, will require advanced treatment processes…

Consider the present poor performance of most waste water treatment works, mainly because of maintenance problems due:

- **Lack of staff (technical, administration & management):**
- **Insufficient funding.**

The more advance treatment processes are, the more advanced and costly maintenance actions are required !

Zandvliet WWTW: Re-use effluent: Potable Water

Refer to recent problems at Zandvliet…

The dunes at Monwabisi beach, used by tens of thousands of Cape Flats residents, are covered in large patches of sewage. Normally treated upstream at the Zandvliet Waste Water Treatment Works, the treated sewage flows along a stream through the dunes before being piped out to sea. But on either side of the stream are large, thick patches of stinking untreated sewage. During an inspection at the site on Tuesday last week **(February 9, 2017)**, City of Cape Town Utility Committee member Bertus Van Dalen said he was unsure of the exact cause for the sludge polluting the dunes, but it was likely due to overflows from the **Zandvliet** treatment works. **This happened because the infrastructure was not maintained, he said.**

The volume which can be recovered will also < 20 times the normal water demand for Cape Town.

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Other Alternatives?

Cape Town = Winter Rainfall Area

An ultimate solution will therefore be to source from another climatic region

(summer rainfall area)

Given its size and current use, as well as potential positive impact on the water security of a much larger area, the Vanderkloof Dam would be the best option

Are there more alternatives ?

The seven largest dams in South Africa

Dam	Completed	River	Capacity (mil. m^3)
Gariep	1971	Orange	5,343
Vanderkloof	1977	Orange	3,188
Sterkfontein	1980	Nuwejaarspruit	2,616
Vaal	1938	Vaal	2,536
Pongolapoort	1973	Pongola	2,446
Bloemhof	1970	Vaal	1,269
Theewaterskloof	1980	Riviersonderend	480

Vanderkloof Dam Specifications

The Vanderkloof Dam (Orange River) is the second largest dam in South Africa. Capacity: 3187.5 million m^3.

50% of capacity can supply 29 million people for one year at a consumption of 150 liter/person/day

The Vanderkloof Dam is augmented by the Gariep Dam, 50 km upstream, the largest dam in South Africa. Capacity: 5343 million m^3.

These dams are in the summer rainfall area. During winter (low rainfall) the effect of additional abstraction will be limited.

Are there more alternatives ?

Capacity of Vanderkloof compared to:

- Theewaterskloof Dam: 6.6 x larger
- Voëlvlei Dam: 19 x larger
- Bergrivier Dam: 25 x larger
- Wemmershoek Dam: 55 x larger

Are there more alternatives ?

Difference in elevation between Theewaterskloof Dam:

> 1000 m

Distance between Voelvlei Dam and Vanderkloof as the crow flies:

700 km

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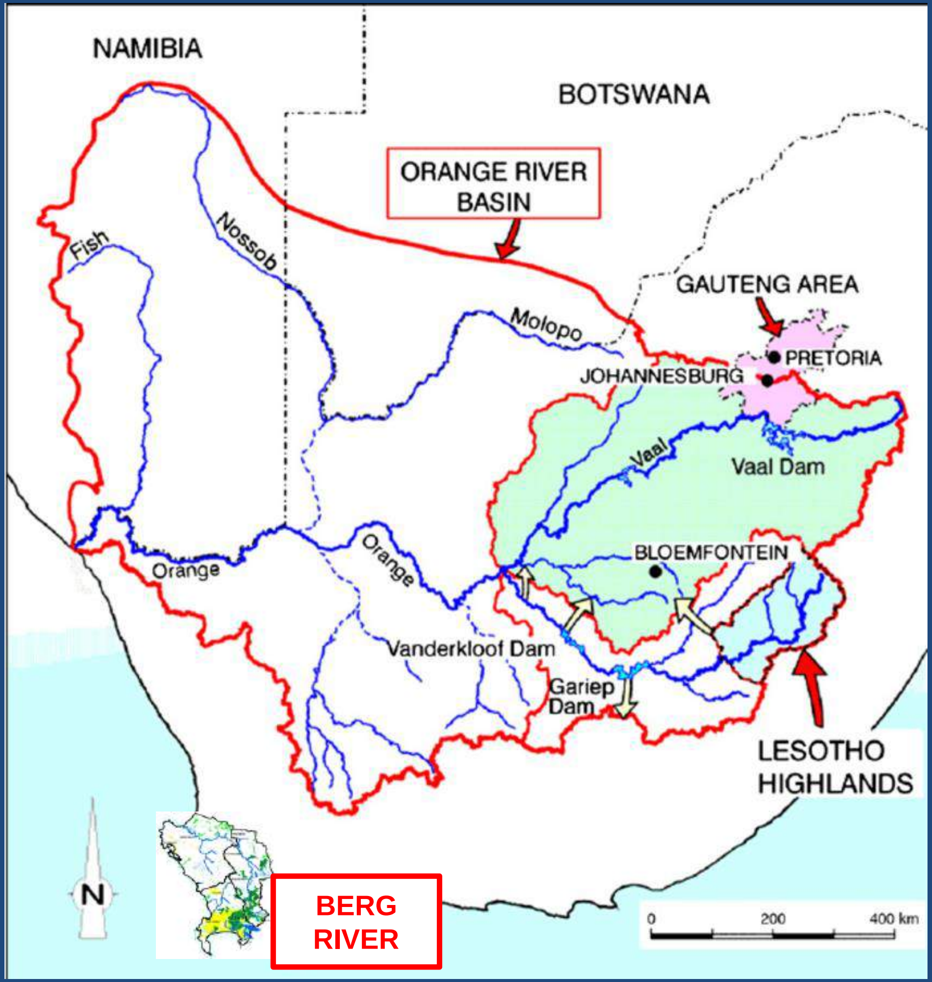
Are there more alternatives ?

Compare the Orange River catchment to the Berg River catchment.

Of the 6 main metropolitan areas in South Africa only 2 are supplied by a portion of the Orange River Basin.



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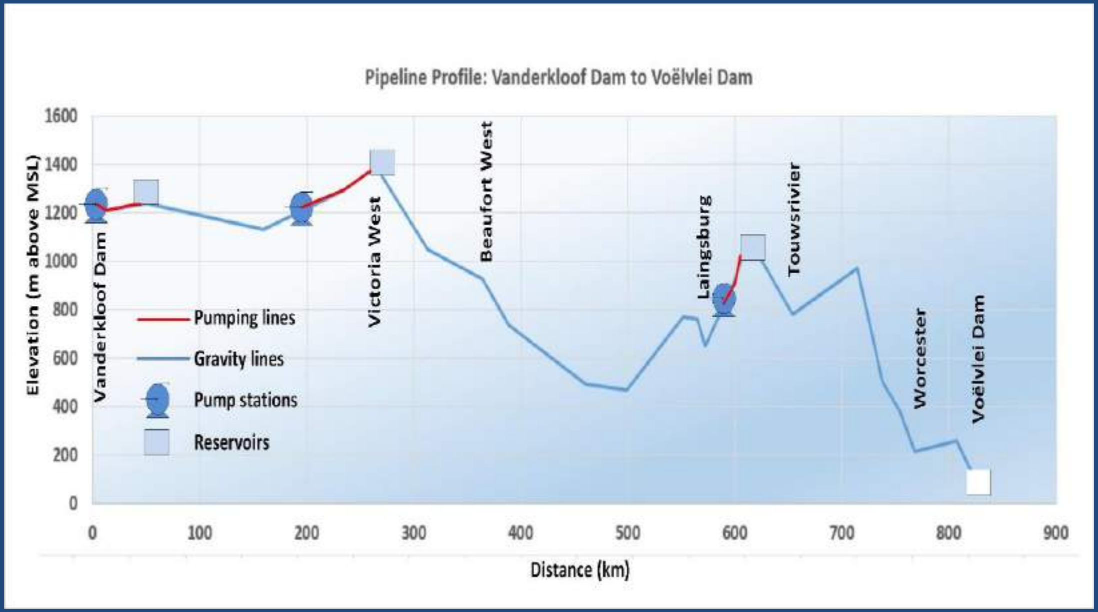
Pipeline(s) to the Western Cape

Preliminary optimized route between Vanderkloof and Voëlvlei is 824 km

Are there more alternatives ?



Length of pumping lines: **120 km**. This is a conservative estimate as detailed surveys will result in a more optimized route.

Length of gravity lines: **704 km**

Three pump stations

Headloss due to friction: **412 m** (> 1000 m available)

Pipeline(s) to the Western Cape: Some technical aspects

Requirements to convey 400 million liters of water (1/2 the daily consumption of Cape Town and adjacent towns in the Cape Winelands and Berg River municipalities):

- Flow of 2.1 m^3/s in 2 x 1.7 m diameter pipelines.
- Flow of 1.5 m^3/s in 3 x 1.4 m diameter pipelines.

Why 2 or 3 pipelines ?

- More sustainable option with regard to maintenance and shut downs.
- More pump alternatives (smaller pumps)
- Route preparation the same.
- Project can be phased over time as the demand increase.

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Pipeline(s) to the Western Cape: Some technical aspects

Abstraction of 400 000 m³/day for one month is < 0.4% of the total capacity of the Vanderkloof Dam.

Environmental impact: Limited to construction (temporary) as for most of the line existing servitudes for roads, rails or power lines can be followed. Insignificant when compared to alternative new resources (groundwater extraction, new dams or brine discharges to the surf zone).

No new treatment plants (or additional process plant) are required.

Immediate and long term solutions to frequently drought stricken Karoo towns (e.g. Victoria West, Beaufort West, Laingsburg, etc.) saving millions of Rands.

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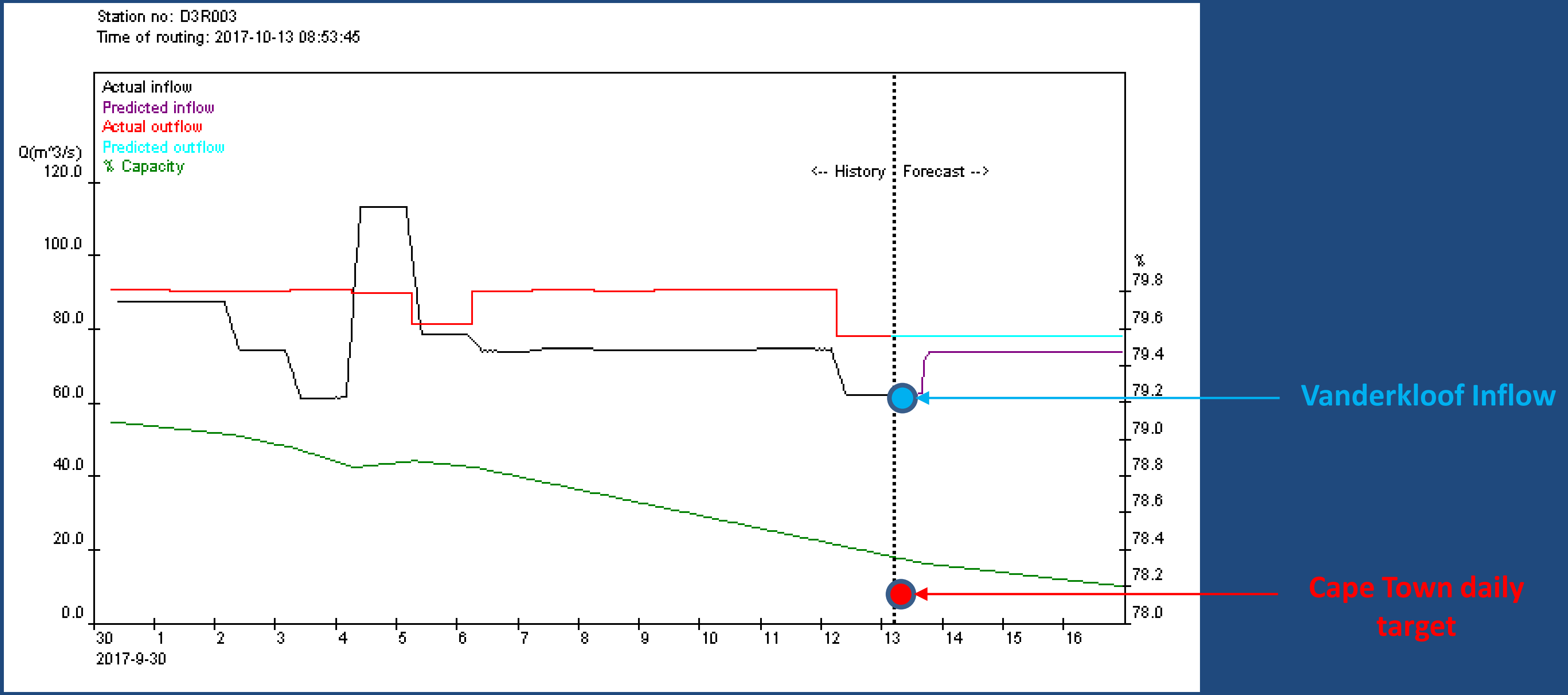
Pipeline(s) to the Western Cape: Some technical aspects

Present inflow to Vanderkloof (13/10/2017) is > 60 cumec (or 6.9 million m³/day) which is > 10 times the present daily target of Cape Town (500 000 m³).



Project Benefits

Cost: Preliminary estimates:

< 50% of estimated cost for desalination plant

Employment: Preliminary estimates include:

> 200,000 man days

Local/national work force: All expertise and facilities are locally available – South African companies.

Available gravity head: Possible generation of electricity – turbines in pipelines.

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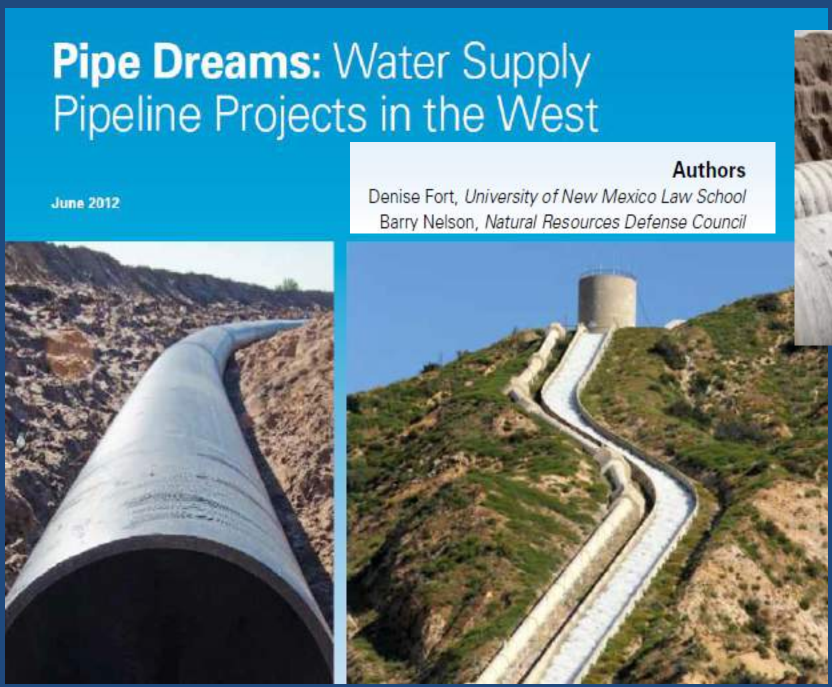
Is this a far fetched idea (Pipe dream)?

Water conveyance systems in the USA – Coastal Cities



California State Water Project:

> 1100 km

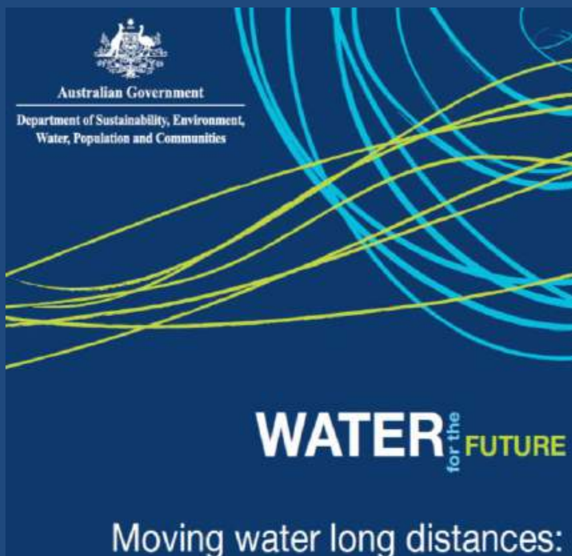
Los Angeles Aquaduct:

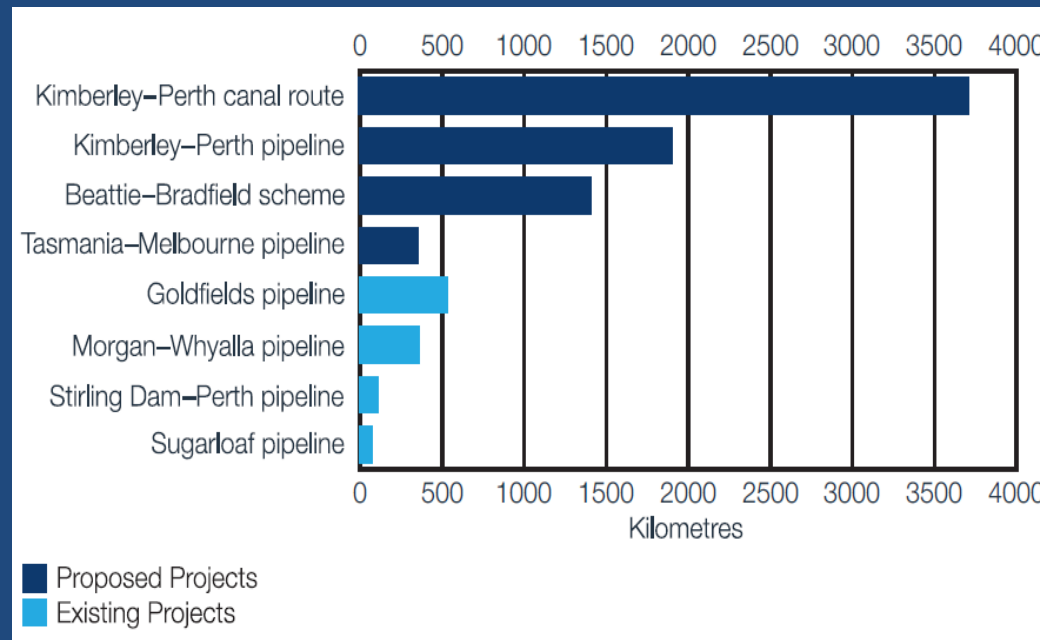
> 350 km

Transbasin diversions: Source from other climate region

Is this a far fetched idea (Pipe dream)?

Australia – Coastal Cities





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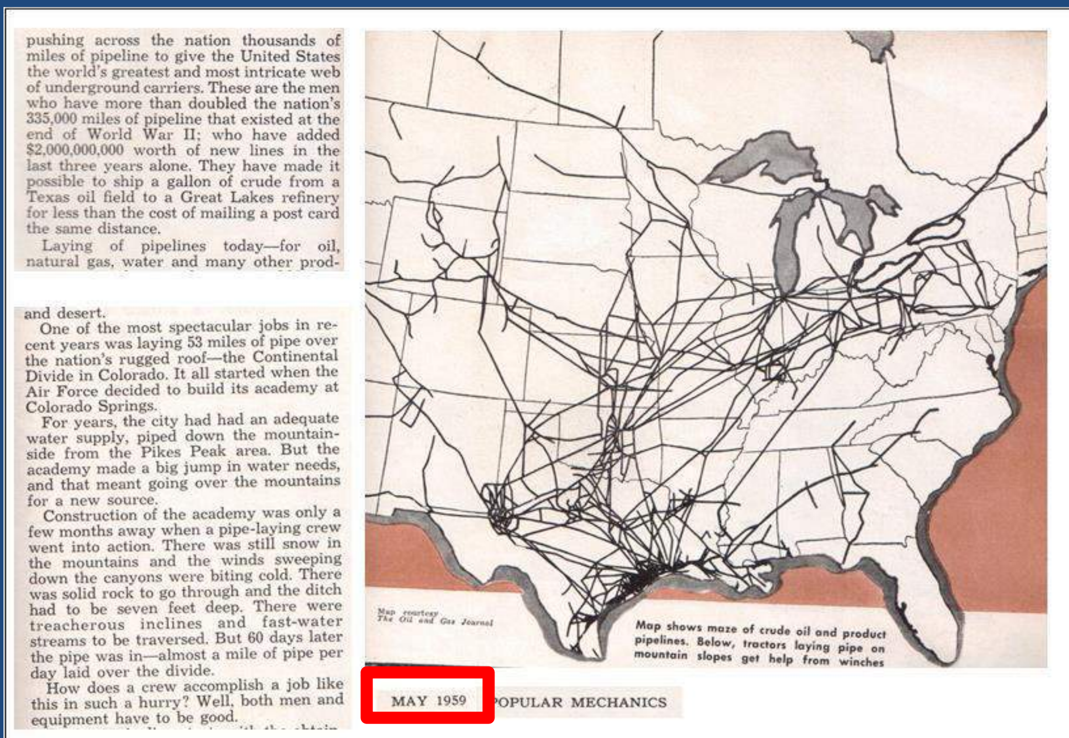
Is this a far fetched idea (Pipe dream)?

Due to rapid urbanization and industrial developments there was in 1959 already 353,000 miles of WATER, gas and oil pipelines in the USA and pipelines worth > $ 2 milliard were added in 3 years time.


pushing across the nation thousands of miles of pipeline to give the United States the world's greatest and most intricate web of underground carriers. These are the men who have more than doubled the nation's 335,000 miles of pipeline that existed at the end of World War II; who have added $2,000,000,000 worth of new lines in the last three years alone. They have made it possible to ship a gallon of crude from a Texas oil field to a Great Lakes refinery for less than the cost of mailing a post card the same distance.

Laying of pipelines today—for oil, natural gas, water and many other prod-

and desert.

One of the most spectacular jobs in recent years was laying 53 miles of pipe over the nation's rugged roof—the Continental Divide in Colorado. It all started when the Air Force decided to build its academy at Colorado Springs.

For years, the city had had an adequate water supply, piped down the mountainside from the Pikes Peak area. But the academy made a big jump in water needs, and that meant going over the mountains for a new source.

Construction of the academy was only a few months away when a pipe-laying crew went into action. There was still snow in the mountains and the winds sweeping down the canyons were biting cold. There was solid rock to go through and the ditch had to be seven feet deep. There were treacherous inclines and fast-water streams to be traversed. But 60 days later the pipe was in—almost a mile of pipe per day laid over the divide.

How does a crew accomplish a job like this in such a hurry? Well, both men and equipment have to be good.

Map courtesy The Oil and Gas Journal

Map shows maze of crude oil and product pipelines. Below, tractors laying pipe on mountain slopes get help from winches

MAY 1959 POPULAR MECHANICS

These were trans-state and trans-basin lines to provide for water scarce urban developments.

How can WAMTech Contribute?

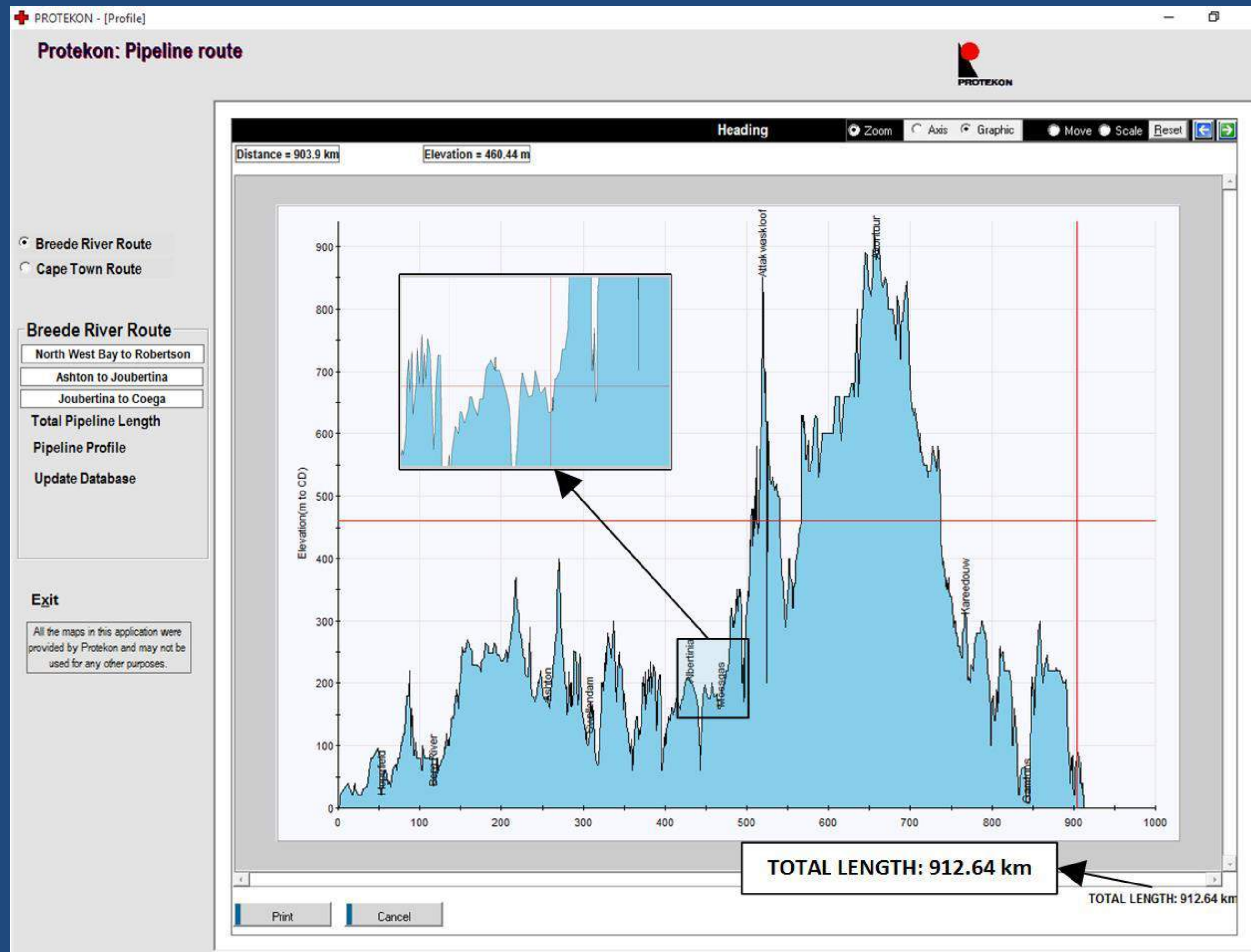
Experience.....

First feasibility study for gas pipeline from Saldanha Bay via Mossgas to Coega in the Eastern Cape.

Two routes:

- **Via Cape Town**
- **Via Breede Valley**

> 900 km



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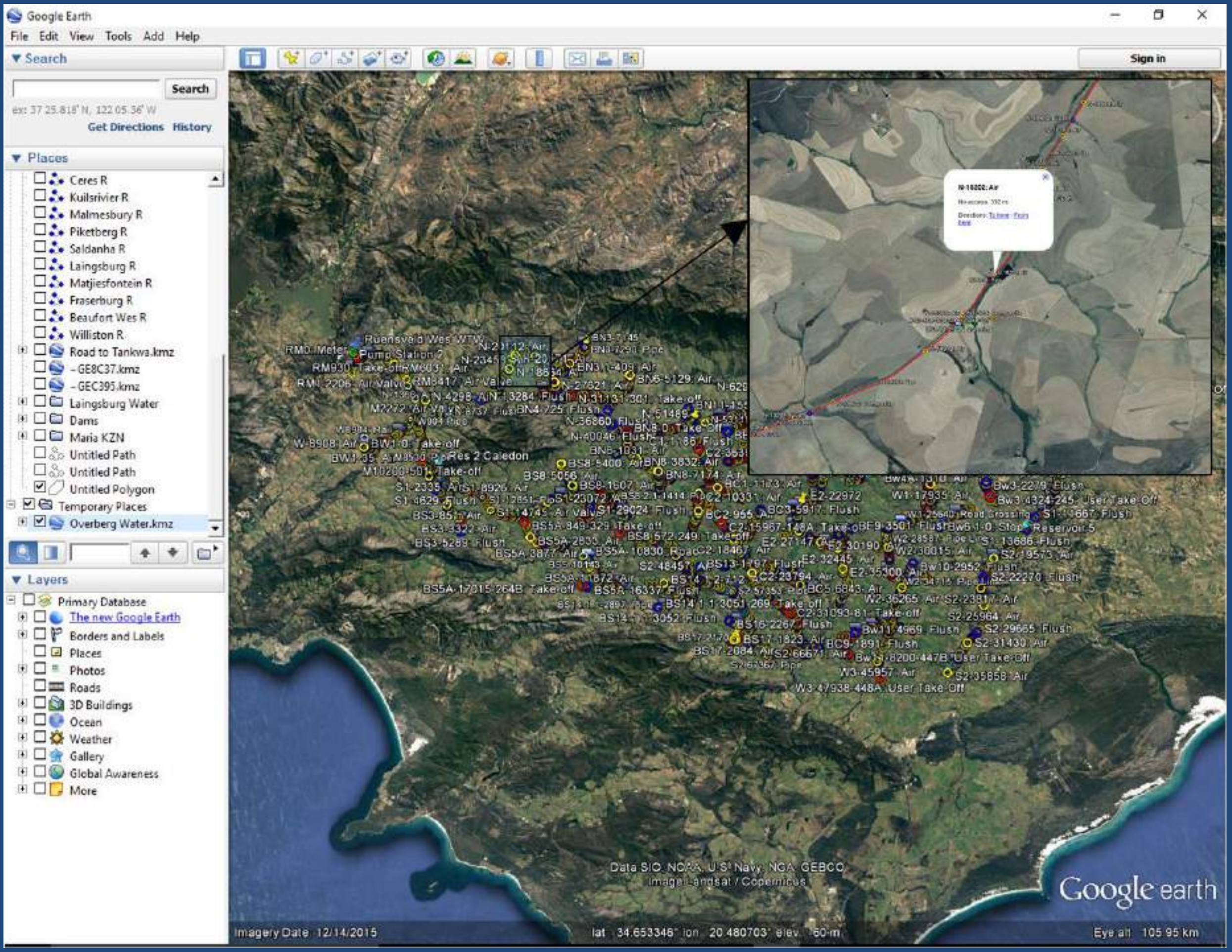
How can WAMTech Contribute?

Experience…..

Assessment of existing 900 km pipeline – Overberg Water

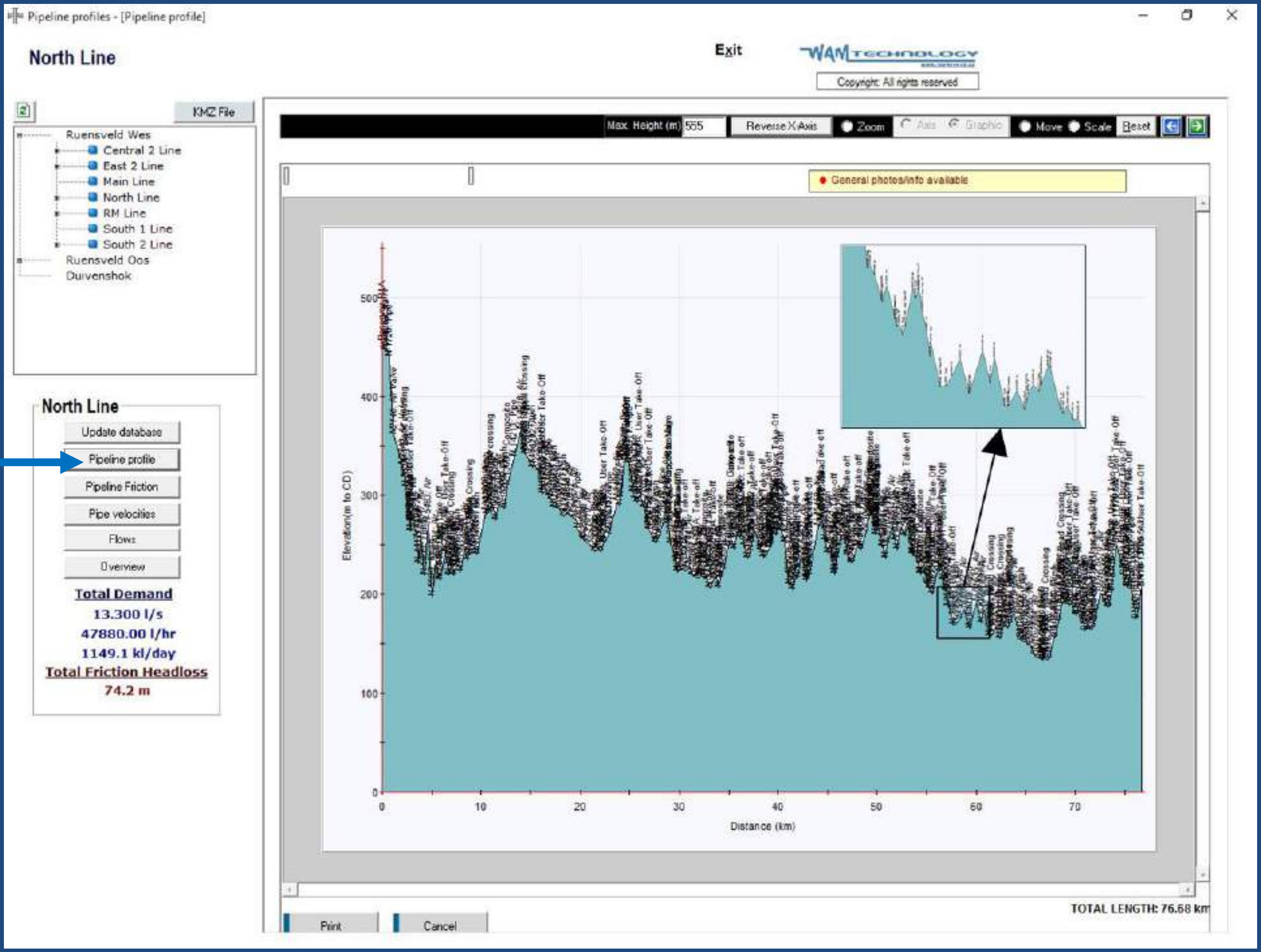
Same tools and technology applied as for Protokon / PetroSA pipeline.



How can WAMTech Contribute?

Experience…..

Assessment of existing 900 km pipeline – Overberg Water



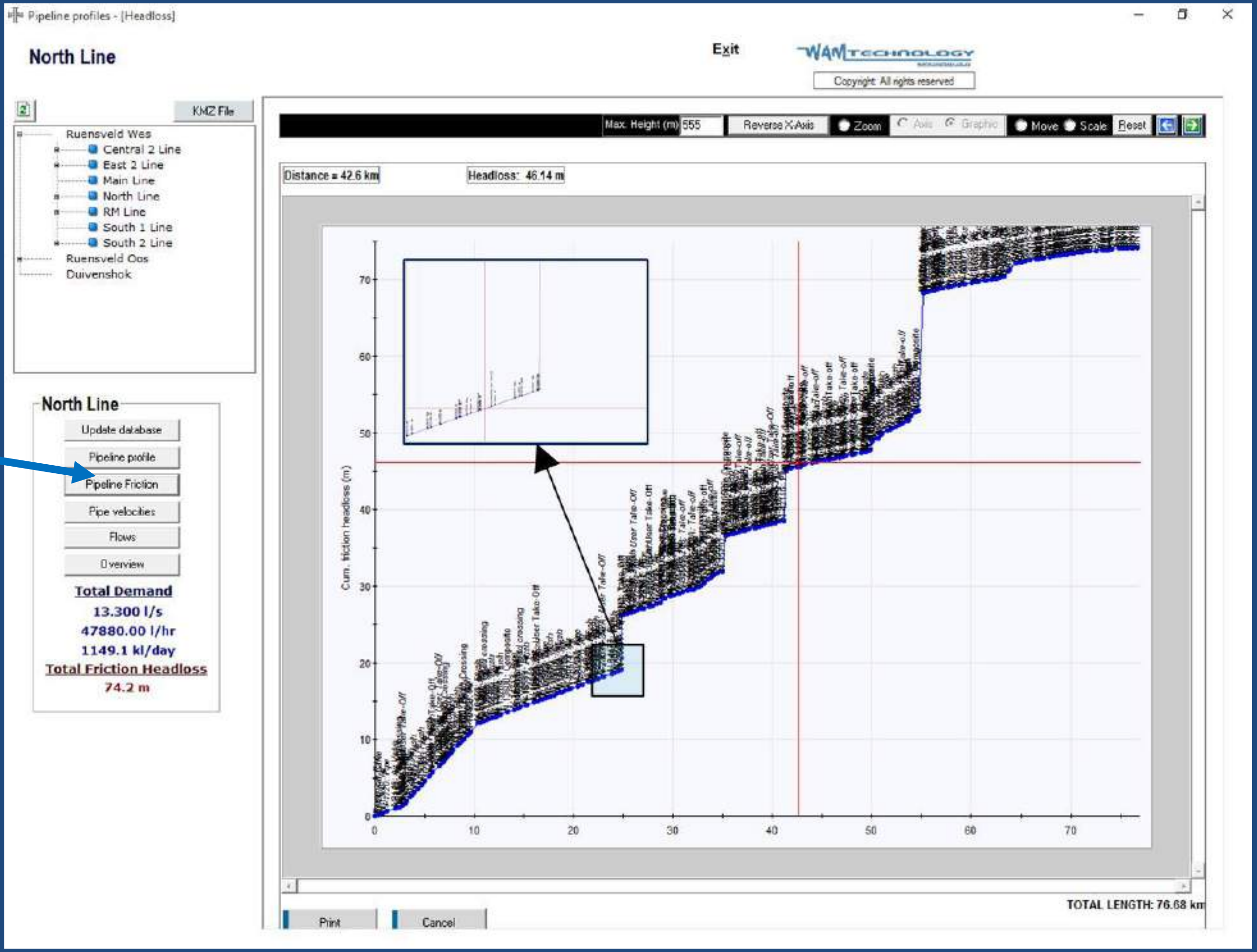
Pipeline Profile

- Pipe details
- Air valves
- Flush valves
- Valve chambers
- Road/Rail crossings
- River crossings
- Take-off points

How can WAMTech Contribute?

Experience.....

Assessment of existing 900 km pipeline – Overberg Water



Pipeline Friction

- **Headloss**
- **Velocities**
- **Flow rates**

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Thank You