INVESTIGATION INTO THE COST AND WATER QUALITY ASPECTS OF SOUTH AFRICAN DESALINATION AND REUSE PLANTS

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ABSTRACT
Augmenting water supplies to meet water demand is now being considered as on option both on local/regional levels in the Integrated Development Plans of city councils and municipalities, as well as in national strategies such as those of the Department of Water Affairs in South Africa. The Southern Cape has exhausted its terrestrial water resources, especially in times of drought whilst the Western Cape is fast approaching the limits of its terrestrial water resources. Other parts of South Africa are in similar situations.

Six existing plants have been identified and will be investigated in this research project. The selection was to cover a range of plant and process configurations, various product end uses, as well as a number of contractors and equipment suppliers. The selected plants are Mossel Bay 15 Mℓ/d SWRO plant (desalination – direct potable), Beaufort West 2 Mℓ/d reclamation plant (Reuse – direct potable), George 10 Mℓ/d UF plant (reuse – indirect potable), Mossel Bay 5 Mℓ/d UF/RO plant (reuse – direct industrial), and the Albany Coast SWRO plant in the Eastern Cape.

The project entails gathering and evaluation of capital and operational costs, taking into account the quality and quantity of water used as well as the various technology applied. Various institutional models used to finance and operate desalination plants with the view of minimising risk to the end user will be evaluated. This project will assist with the providing of best operating practices to maximise production and unsure sustainability of the technology in terms of cost minimisation, and assist with the resolution of technical and implementation challenges of desalination and reuse plants.

Finally, an integrated database of all operating parameters for the desalination and reuse plants mentioned above will be established. The information gathered during the project will be of beneficial use to municipal engineers and the water community as a whole to define real costs for desalination and reuse. This may be used for more effective future planning and comparison of different water supply options.

1. INTRODUCTION

The SADC region spans an area of approximately 7 million square kilometres; this encompasses large climatic differences which include desert, temperate, savannah and equatorial climates. The variation in climate also sees differential rainfall distribution in the region with the split being distributed as follows: 3% of the region receives over 1 500 mm/yr of rainfall; the moist sub-humid regions (which make up 40% of the area) receive an average rainfall in the range 1 200 – 1 500 mm/yr; 19% is dry sub-humid climate with an average precipitation of 600 – 1 200 mm/yr; 16% of the region is semi-arid with an average rainfall of 400 – 600 mm/yr and finally the remainder of the region receives less than 100 mm/yr. On average, South Africa receives an annual rainfall of 450 mm/yr.

Namibia and South Africa are some of the countries exhibiting arid and semi-arid climates. With Namibia as the driest country in sub-Saharan Africa with low and unpredictable precipitation patterns, this poses a major threat to the development of the country in the face of a high urbanisation rate.

A further threat to terrestrial water resources in South Africa, and other SAC countries, is the deterioration of water quality in certain catchments due to the failure of waste water treatment. The increase in pollution discharged to rivers leads to eutrophication and algal blooms which result in waters which are extremely difficult to treat without highly sophisticated and expensive technologies. This element of water resource depletion appears to be being ignored at present. The problem with this approach is the legacy effect of water pollution which means that problems will continue long after the wastewater treatment processes have been restored, as can be observed at Hartbeespoort Dam. At present, of the 223 river ecosystem types, 60% are threatened with 25% of these critically endangered (DWA, 2012).

South Africa, which receives an average annual rainfall of 450 mm/yr, and Namibia have adopted strategies to provide potable water by applying desalination and water reuse to meet the demand by consumers (DWA, 2011). The cases in South Africa where desalination and water reuse are currently being applied are found in the Southern and Western Cape where water resources have either been exhausted or are fast approaching the limits of their terrestrial water resources. Other parts of South Africa are in similar situations.

Six existing plants have been identified and will be investigated in this research project. The selection was made to cover a range of plant and process configurations, various product end uses, as well as a number of contractors and equipment suppliers.

The selected plants are indicated in Table 1 below.

Table 1: Water reuse and desalination plants to be focused upon

Description	Capacity (Mℓ/d)	Technology
Mossel Bay	15	Desalination – SWRO
Albany Coast	1.8	Desalination – SWRO
Mossel Bay	5	Reuse – direct industrial (UF/RO)
Beaufort West	2	Reuse – direct potable (UF/RO/AO)
George	10	Reuse – indirect potable (UF)
Windhoek	21	Reuse direct potable (PAC/O3/ DAF/Filt/O3/GAC/Cl)
Namwater (under construction)	60	Desalination – SWRO

A typical process flow diagram for desalination is shown in Figure 1 below.

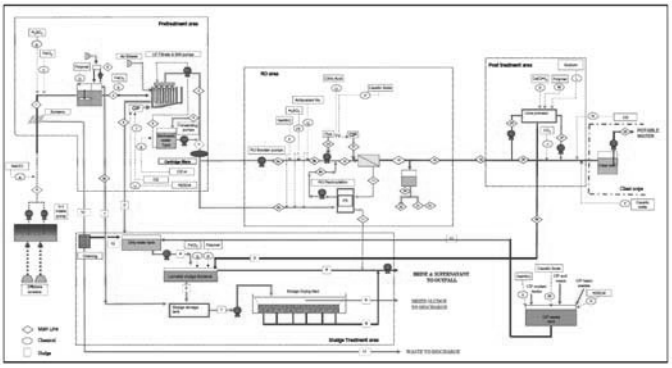

Figure 1: Desalination process flow diagram (acknowledgement: Veolia Water)

There are many possible process flow diagrams for water reuse. A process flow diagram mooted for water reuse in another WRC research project is shown in Figure 2 below.

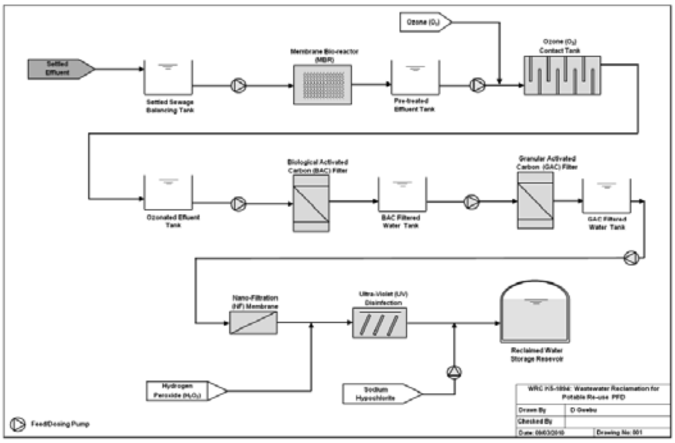

Figure 2: Water reuse process flow diagram (Acknowledgement: Umgeni Water)

2. AIMS OF THE WRC PROJECT

The aims of this Water Research Commission (WRC) funded project are:

- Establish an integrated database of all the operating parameters for the five desalination plants mentioned previously. This should include the feed, product and rejection water quantity, quality and temperature, power consumption, consumables consumption, and operating and maintenance costs.
- Include in the above database parameters relevant to the re-stabilisation of the product water before reticulation.
- Evaluate and report on the various costs of the desalination plants as a function of the quantity of water produced and the various technologies used.
- Evaluate and report on the various costs of the re-stabilisation plants as a function of the quantity of water produced.
- Report on the technical, and operations and maintenance, challenges experienced in operating the desalination and re-stabilisation plants, and water reuse plants. This would include factors such as declining flux through the membrane and "Cleaning in Place" frequency and efficiency.
- Report on factors which affect the cost of operating desalination plants and how to optimise them.

A previous project funded by the Water Research Commission and Department of Water Affairs and Forestry resulted in the publication of "A Desalination Guide for South African Municipal Engineers" (Du Plessis et al. 2006), which currently serves as a resource for desalination. This report will update and supplement the above report, while providing a new resource for water reuse decision making.

The information gathered during the project will be of beneficial use to municipal engineers and the water community as a whole to define real costs for desalination and reuse. This may be used for more effective future planning and comparison of different water supply options.

3. COST COMPARISON

When normal terrestrial water resources run out due to any of a number of reasons then alternative water resources must be evaluated. These range from the use of boreholes, reuse of treated final effluent from wastewater plants, to sea water desalination. Prior to this, steps such as leakage minimisation, water saving devices and water restrictions should have been implemented.

According to normal decision making processes, all options should be listed, compared and then the best option chosen. This would usually be the best value (not cheapest) option; however, depending upon the urgency or crisis level being experienced, a more expensive option may be chosen. In the case of water other factors such as safety and palatability will also come in to play, with safety generally being a non-negotiable.

One of the biggest problems that were experienced in the past was the "paucity of cost data on the ground" in South Africa, with figures having to be estimated rather than based on actual tender prices. Estimates typically lead to higher cost scenarios as no professional is prepared to be seen as being imprudent. One of the chief aims of this project is to obtain accurate built costs for different technologies, as well as accurate O&M costs to allow accurate cost predictions.

In order to properly compare the project costs of the different options, use has to be made of project finance evaluation techniques.

3.1 Project finance

Project finance is the art of representing the costs of a number of different project options in such a way that they may be compared directly. Costs should be at least partly matched with the income to be derived from the project, and these can be included if different or omitted if the same. In the private sector, where the return on capital is all important, a normal rate of return is also included to assess the overall viability of the project.

Costs are usually separated into two different categories:

- Capex or capital expenditure, where a long lasting asset is purchased such as a pipeline or civil structure. The amortisation period for the capital expenditure should be the same as its expected useful lifetime, although in practice this is frequently limited to 20 years, which skews the cash flows to later in the project. Thus the capex needs to be itemised under civil works, mechanical and electrical components with an expected useful life for each of these items and the capex amortised accordingly.
- Opex or operational costs, which represent the operational and maintenance costs of a project option. These include staff costs, electricity, replacement of membranes, chemicals, parts, etc. While capex costs do not incur inflation as they are purely a function of the capital amount and interest rate, opex expenses will increase annually by the inflation rate and must thus be escalated accordingly. Care must be taken to ensure that major expense items such as the replacement of membranes are correctly priced and inserted into the correct time period. A further complication is that the price of membranes, for instance, tends to drop with time as competition improves.

The two sets of costs are then compiled into a table of costs for each financial year and the net cash inflows or outflows derived. These are then reduced to a net present value (NPV) by means of a formula. It is important to note that the first year is not subjected to the NPV formula – only year two onwards. Table 2 below indicates a typical NPV input spreadsheet.

Table 2: NPV input spreadsheet

		Capital Cost	Expected Useful Life	Cashflows Per Financial Year																			
		Rm	EUL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Capital																						
1.1	Civil																						
1.2	Mechanical																						
1.3	Electrical																						
2	O&M Expenditure																						
2.1	Staff - operational																						
2.2	Staff - idling																						
2.3	O&M - not RO membranes																						
2.4	Electricity																						
2.5	Water																						
2.6	RO Membranes																						
2.7	CIP solutions																						
2.8	Post conditioning chemicals																						
2.9																							
3	Water Production																						
3.1	Desalinated Water Production																						
3.2	Sale price of desalinated water R/m3																						
3.3	Income - Desalinated Water																						

In order to calculate the NPV of each of the project options, certain assumptions need to be made and used across all the project options. The assumptions which need to be made are indicated in Table 3 below.

Table 3: Financial Assumptions

Description	Value	Comment
Rate of inflation	6.7%	Average CPIX for previous 5 years
Rate of inflation – electricity	14%	Higher than CPIX – value ex Eskom statement
Interest rate	10.8%	Average interest rate for previous 5 years
Period	Varies	Varies according to expected useful life (EUL)
Rate of return	N/A	Not a commercial project

3.2 The implications of electricity inflation

Water reuse and more so sea water desalination are energy intensive technologies and the cost of operating them will be increasingly affected by the increase in cost of electricity. South Africa has traditionally had very cheap electricity, but this is now changing rapidly due to the upgrades in electricity production capacity and reticulation infrastructure which requires extensive capital expenditure. Eskom has also changed to borrowing directly as opposed to borrowing via government guarantee and this has necessitated them indicating a price increase of 14% per annum for the foreseeable future.

Thus the more energy intensive a process is the more marked the increase in energy costs and the higher the NPV of the project option. The effect of the electricity inflation at 14% can be seen in Figure 3 below.

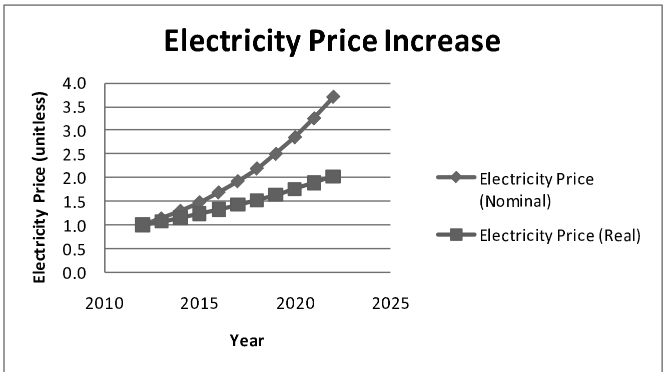

Figure 3: Forecast of increase in electricity price

4. WATER QUALITY

An important part of the cost comparison is the evaluation of the water quality of both the feed and product water. It is fairly obvious that in a process such as RO the costs will be much lower for water reuse where the salinity is relatively lower, as compared to the desalination process. Not only are the energy costs for pumping across the membrane lower, but there is also a lower rejection rate than for desalination.

The water quality data gathered will be collated and presented in a manner useful to the end user in decision making when considering different technologies.

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6. INSTITUTIONAL ARRANGEMENTS

Water reuse plants or sea water desalination plants would normally be operated under the jurisdiction of the local or district municipality, whoever is the water services provider. The plants can also be designed, constructed operated and even financed by private water service providers who are appointed for this purpose in the form of a public-private partnership, or PPP.

"Private sector expertise and experience has always been utilised in public sector procurement, but, where in traditional procurement, private companies built and then walked away, PFI seeks to ensure that the private sector takes responsibility for the quality of design and construction it undertakes, and for long-term maintenance on an asset, so that value-for-money is achieved." (HM Treasury (UK) 2003)

In South Africa, PPPs are a useful solution for the provision of high technology expensive services where efficiency is a must. The nature of a tender process, provided it is not subverted, is such that it optimises competition and lowers prices. However, the downside of this competition, especially in depressed economic times, is that the service provider may in fact under quote for the service and attempt to recoup their profit by means of the exploitation of grey areas in the PPP contract. A typical example of this the breakdown versus maintenance scenario frequently observed in operations and maintenance contracts for water and wastewater works.

The contractor will claim that a broken pump was in an extremely poor state of maintenance before he took over and that as such it is a replacement item rather than a maintenance item and that, as such, an additional amount is to be claimed. Furthermore, the cost involved may be increased to improve the contract profit.

As such, the PPP contract must be extremely carefully drafted and reviewed by a specialist in PPP in order to prevent conflict in the future.

PPPs are a useful delivery model for operating a high technology project for the following reasons:

- PPPs make projects affordable
- PPPs maximise the use of private sector skills
- Under PPPs, the private sector takes life cycle cost risk
- With PPPs, risks are allocated to the party best able to manage or absorb each particular risk
- PPPs deliver budgetary certainty
- PPPs force the public sector to focus on outputs and benefits from the start
- With PPPs, the quality of service has to be maintained for the life of the PPP
- The public sector only pays when services are delivered
- PPPs encourage the development of specialist skills, such as life cycle costing
- PPPs allow the injection of private sector capital
- PPP transactions can be off balance sheet

PPPs are also not without their dangers, which can be listed as follows:

- Does sufficient private sector expertise exist to warrant the PPP approach?
- Does the public sector have sufficient capacity and skills to adopt the PPP approach?
- It is not always possible to transfer life cycle cost risk
- PPPs do not achieve absolute risk transfer
- PPPs imply a loss of management control by the public sector
- PPP procurement can be lengthy and costly
- The private sector has a higher cost of finance
- PPPs are long-term relatively inflexible structures

How can PPP risks be mitigated against?

- Build national PPP centres of excellence
- Balance sheet treatment should not drive the decision to undertake a PPP
- Develop shadow private sector bid models at the outset
- Streamline speed and cost of procurement
- Share refinancing benefits
- The South African government should provide guidance on PPPs for the public sector which includes guidance on procurement procedures
- Create a Treasury Knowledge Unit

7. BEST PRACTICE

This aspect of the project will report on the technical, and operations and maintenance, challenges experienced in operating the various plants and include factors such as declining flux through the membrane and "Cleaning in Place" frequency and efficiency. It will also report on factors which affect the cost of operating plants and how to optimise them.

The two most obvious items of concern will be the longevity and Trans Membrane Flux (TMF) of the various membranes used, and how these can be optimised and the energy costs of the various treatment processes. Factors affecting the above include the pre-treatment of the feed water, the frequency of CIP and the extent to which the TMF is allowed to decline before instituting CIP.

Other important practices include the remineralisation of the product water in order to ensure that it is stable and will not damage the reticulation network, and the introduction of the product water into the rest of the town's water.

With regards to water reuse, an important factor is careful consideration of the socio-political factors involved and the manner in which the product water is "shared" amongst the community.

Lastly, it is important to keep abreast of the latest developments in membrane technology and the increasing longevity of membranes which will affect the feasibility of these technologies. An example of this is the development of new RO membranes, which require lower feed pressures and hence less energy than before due to surface effects incorporated into them (Offringa, G, 2010).

8. CONCLUSION

The aims of this project are fairly comprehensive and should provide a useful resource to the municipal and industrial sector in terms of assessing different technologies and their associated actual costs rather than estimated costs.

The project should also provide assistance in the development of successful PPPs for the provision of services relating to the technologies, highlighting potential pitfalls and suggesting ways in which these can be resolved.

Lastly, the best practices section will be useful in learning from errors made by others in the past and preventing them being made in the future. This will ensure that plants provide the best value for money.

9. REFERENCES

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