WIN-SA

WATER INFORMATION NETWORK
- SOUTH AFRICA -

"Making knowlege work for us"

LESSON SERIES
September 2014

REUSEDSM & REUSECOST

Tools for the Selection and Costing of Direct Potable Reuse Systems from Municipal Wastewater

WATER RESEARCH COMMISSION

NOTE

This lesson is compiled from the Water Research Commission **Report No: K5/2119//3**, by Chris Swartz, Water Utilization Engineers, and Stellenbosch University.

To obtain the full report, contact:
Water Research Commission
Private Bag X03, GEZINA 0031.
Tel: 012 3301340
Email: orders@wrc.org.za or download from www.wrc.org.za

1 INTRODCUCTION

Water Service Authorities (WSAs) in South Africa currently face a challenge with sustainable supply of sufficient quantities of good quality potable water to the population, due to the highly variable availability of raw water. This is mainly due to changing weather patterns, resulting in increased droughts (spatially and temporally) and flooding events. To address the raw water shortages, WSAs are increasingly investigating alternative raw water resources, of which water reclamation and reuse (from treated wastewater) and desalination (both brackish and seawater) are the most important. This series only focuses on direct potable reuse as a water supply option to augment conventional water sources in water scarce areas.

The overall objective of this guide is to provide decision-makers with a decision-support model (DSM) for municipalities and water boards to identify, evaluate, compare, and select appropriate water reclamation and reuse options, REUSEDM, which can produce sufficient quantities of safe drinking water from available secondary treated wastewater sources. Because the cost of reuse schemes forms one of the main selection criteria, there was also a need to incorporate a more comprehensive reuse costing model to inform the development of the DSM. The guide therefore includes a reuse costing model, REUSECOST.

Both tools are based on a number of drivers, such as technical, water quality, and costing, environmental, social and cultural aspects. In addition, both models only consider raw water feed was limited to secondary treated effluent from municipal domestic wastewater treatment plants, mine effluent and industrial effluents were therefore excluded. While many of the selection criteria considered in developing the REUSEDSM decision support model could equally apply and be used for evaluating indirect potable reuse options, the indirect reuse schemes were not considered due to the additional drivers and considerations that are involved, such as receiving water quality management (dam, river or aquifer), environmental and institutional aspects, to name but a few.

This document is a summary of the factors affecting selection of water reclamation technologies, and the key elements of the Decision Support Model (REUSEDSM), and the Reuse Costing Model (REUSECOST) developed by the Water Research Commission.

2 SELECTION OF WATER RECLAMATION TECHNOLOGIES

The National Strategy for Water Reuse (DWA, 2011) lists five key considerations related to water reuse as an option for water supply and augmentation, namely: water quality aspects, water treatment technology, cost relative to other water supply alternatives, social and cultural perceptions, and environmental considerations. Another important consideration to be added is operation and maintenance of direct potable reuse plants.

a) Water quality aspects

Both the quality of the raw water source and the required final water quality strongly affect the cost of reuse systems, as it determines the treatment requirements of the plant. Reuse of water becomes attractive when the water quality requirements are relatively low (for example for irrigation or secondary industrial use). For direct potable reuse, however, the required water quality relates to public health, and should never be compromised in an attempt to reduce the capital or operating costs of a treatment system needed to achieve the required health-related water quality targets. Furthermore, while the costs for direct potable reuse may be higher than other alternatives, the security (reliability) of supply may also make reuse more attractive.

b) Water Reclamation Technologies and Process Configurations

i) Water Reclamation Technologies

Locally, conventional as well as advanced treatment technologies for water reclamation have in most instances already been tested and proven for South African conditions. A summary of treatment technologies used in water reclamation appears in Table 2.1.

Table 2.1: Applicable water treatment technologies for water reuse (DWA, 2011)

Category of Pollutants	Applicable Technologies
Macro-organics, COD and BOD_5	• Biological treatment (activated sludge, trickling filtration, fixed film reactors, membrane bioreactors) • Chemical coagulation/flocculation and clarification
Particulate and suspended solids	• Chemical coagulation/flocculation and clarification • Granular media filtration • Membrane filtration
Nutrients – Nitrogen	• Biological nitrogen removal (nitrification/ denitrification) • Air stripping (ammonia) • Chemical coagulation/flocculation and solids separation

Category of Pollutants	Applicable Technologies
Nutrients – Phosphorus	• Biological phosphorous removal (enhanced biological phosphorus uptake) • Chemical precipitation (typically metal salt addition)
Microbiological Agents: • Bacteria • Viruses • Parasites	• Membrane filtration • Chemical disinfection (chlorine, bromine compounds etc.) • Ultra Violet (UV) radiation
Salinity, inorganic salts	• Precipitation • Ion exchange • Membrane desalination (nanofiltration /reverse osmosis)
Metals	• Precipitation • Chemical adsorption • Membrane separation
Micro-organics: • Volatile Organics • Pesticides • Pharmaceuticals • Endocrine Disruptors	• Advanced oxidation (H2O2/UV) • Adsorption by activated carbon (granular/powder) • Membrane separation (nanofiltration /reverse osmosis) • Biologically enhanced adsorption (BAC)
Disinfection byproducts	• Modify disinfection agent in upstream processes • Advanced oxidation • Adsorption by activated carbon (PAC/GAC) • Membrane separation (nanofiltration /reverse osmosis)

ii) Process Configurations

A number of different process configurations are possible in which the water reuse treatment technologies listed in Table 2.1 can be applied, and examples are given below.

Example 1 – Old Goreangab Water Reclamation Plant

Chemical treatment – Phase separation – filtration – disinfection

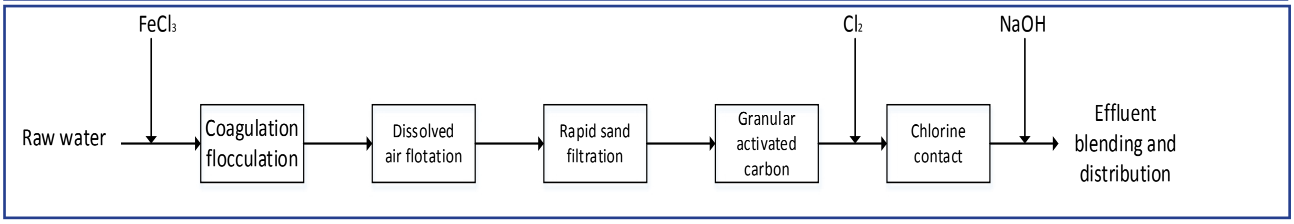


Figure 2-2: Configuration of the Old Goreangab Water Reclamation Plant

Example 2 - New Goreangab Water Reclamation Plant (NGWRP)

Chemical treatment – Phase separation – filtration – membrane filtration – disinfection

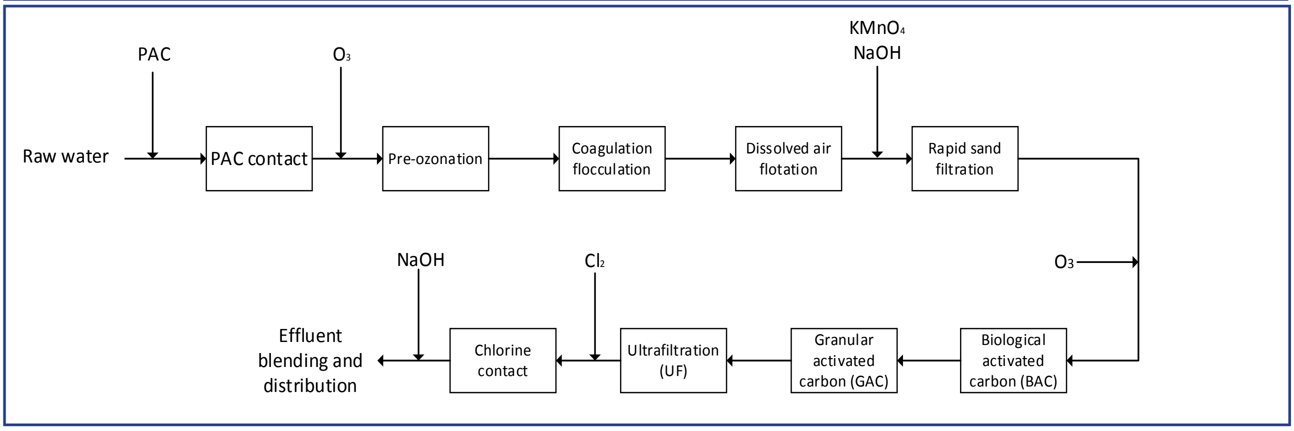


Figure 2-3: Configuration of the New Goreangab Water Reclamation Plant (NGWRP)

Example 3 - Cloudcroft, New Mexico

Reverse Osmosis – Advanced Oxidation – Blending – Membrane filtration – UV disinfection – Activated Carbon – Disinfection

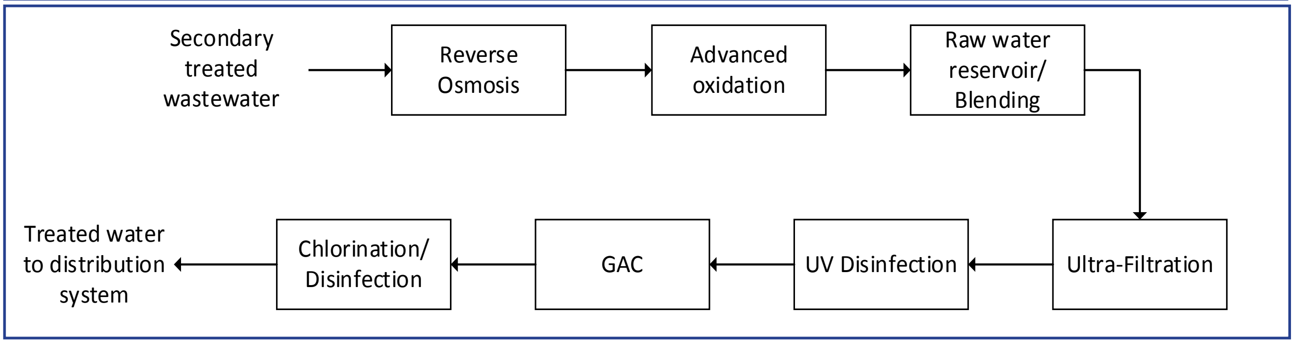


Figure 2-4: Configuration of the Cloudcroft Water Reclamation Plant

Example 4 – Big Springs, Texas

Membrane filtration – Reverse Osmosis – Advanced Oxidation – Blending – Flocculation – Sedimentation – Filtration – Disinfection

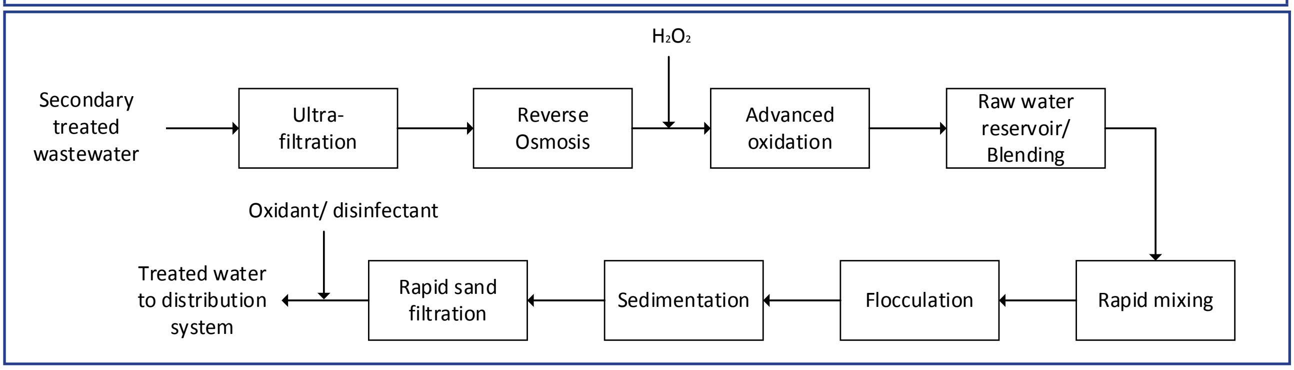


Figure 2-5: Configuration of the Big Springs Water Reclamation Plant

Example 5 - Beaufort West, South Africa

Rapid sand filtration – Membrane filtration – Reverse Osmosis – Advanced Oxidation – Disinfection

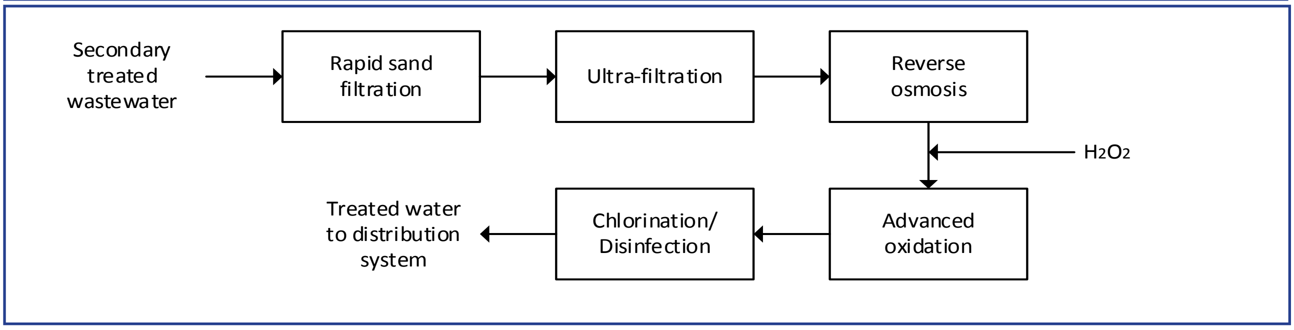


Figure 2-6: Configuration of the Beaufort West Water Reclamation Plant

c) Environmental Considerations

i) South African Environmental Legislation

While South Africa is facing serious problems with the delivery of adequate services to its citizens as required by the Constitution, the same Constitution also put an obligation on different organs of state to ensure that the environment needs to be protected to the benefit of mankind. Section 24 in Chapter 2 of the Constitution of South Africa (Act 108, 1996) stated that:

“Everyone has the right: (a) to an environment that is not harmful to their health or well-being; and (b) to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that: (i) prevent pollution and ecological degradation; (ii) promote conservation; (iii) secure ecological sustainable development and use of natural resources while promoting justifiable economic development.”

The Constitution, in Section 152 of Chapter 7, further states that: (1) The objective of local government are: (c) to promote social and economic development; (d) to promote a safe and healthy environment…”.

From this fundamental piece of legislation it is clear that local government and specifically municipalities in South Africa need to find ways to balance development against the environment to ensure sustainability. The environment therefore needs to be an integrated part of the decision making process when considering the development or the upgrade of water treatment facilities. The Environmental Impact Assessment (EIA) procedure provided for a systematic approach towards finding the balance between developments and the protection of the environment.

Based on the obligation provided in the Constitution, various pieces of legislation have been developed to enable the implementation of these requirements. The following legislations are applicable:

- National Environmental Management Act (NEMA) (Act 107 of 1998)
- The National Environmental Management: Waste Act (NEM: Waste Act) (Act 59 of 2008)
- National Water Act (NWA) (Act 36 of 1998)
- National Heritage Resource Act (NHRA) (Act No. 25 of 1999)

ii) Residuals management

The proper disposal and treatment of concentrate and residuals will be needed if non-destructive processes are used. Therefore, the following actions are recommended:

- Identify the need for additional treatment (a regulatory framework is needed to manage concentrate).
- Define the proper disposal.
- Understand public health considerations.
- Consider heat recovery in wastewater.
- Consider cost issues.

Note that this issue pertains to all recycled water types (and not only direct potable reuse), and is related to source control efforts (residuals management starts at the source). Managing salinity is also important. The reader is also referred to WRC publications on "Guidelines for the Utilisation and Disposal of Wastewater Sludge", a series of five volumes (WRC Report No. TT 349/09, June 2009) for more information on residuals management and disposal.

iii) Brine disposal options

A number of alternatives exist for the disposal of brine, and the choice of which to use is influenced by environmental considerations (legislation; permits by regulating authorities), location of the desalination plant, and cost. The most generally used treatment and disposal options are discussed by Schutte (2005).

d) Operation and Maintenance Aspects

The following are important considerations when drawing up an operational monitoring program for a reclamation and reuse plant:

- Evaluate current wastewater treatment plant monitoring (important parameters are COD, pH, ammonia, nitrate, phosphate, suspended solids, total dissolved solids and faecal coliforms in the final effluent).
- Minimize the potential for fouling during advanced treatment. Here aspects such as the occurrence of algae in maturation ponds, increased organic loadings and ammonia is especially important.
- Develop a list of constituents to be measured for operational monitoring, including: total organic carbon, characterization of organics, and other parameters that may provide comparison of treatment effectiveness.
- Make sure that allowance is made for measurement and monitoring of pollutants and chemicals that may be present in industrial effluent streams that are discharged to the wastewater treatment works.
- For membranes, include membrane integrity monitoring for pathogens and chemicals (which is dependent upon the expectations of process performance).

- Evaluate the removal of EDCs and other CECs by membranes and advanced oxidation processes (AOPs).
- Incorporate online monitoring, where possible.
- Optimize AOPs through monitoring for performance and reliability.
- For testing membrane performance and integrity, consider using dye as a surrogate for viruses.
- Examine the use of sidestream treatment rather than returning the untreated waste stream to the head of the plant and recycling constituents.
- Develop a rationale for regulators and the public as to why agencies are treating recycled water to a greater degree than other sources (because the source is from wastewater rather than surface water).

e) Social and Institutional Aspects

The importance of public acceptance of any water supply scheme is widely recognised. It is in particular a crucial consideration where potable reuse of wastewater is one of the alternative or supplemental supply options. This is also the case where treated municipal wastewater is used for irrigation of food crops. Public perceptions and cultural or religious taboos may create obstacles to certain water reuse applications. Water users attach religious, cultural and aesthetic values to water and any water reuse project must remain sensitive to these values.

i) Public perceptions and public involvement in decision-making

The following important aspects are critical to consider as part of public perception: Public participation; Public engagement; Public acceptance; Subjective or perceived norms and values; Social capital; Economic implications; Institutional aspects.

ii) Institutional aspects

Water reuse projects have many sophisticated technical, engineering, financial, operational and maintenance aspects. A key consideration to any such project is the fact that the water typically has to be treated to improve/upgrade its quality, before it is fit for reuse by a downstream user. The downstream user must be guaranteed an appropriate quality of water to protect designated use of the water. Reuse projects therefore require a high level of confidence in the implementation and operating agencies. A public sector agency, such as a municipality or water board must have a minimum threshold of capacity and competency, (in terms of technical expertise, planning ability, project management capability, financial strength and rating), be a trusted water services deliverer and be accepted by the community and stakeholders as a reliable organization, before it can be considered as capable of implementing a water reuse project.

An agency/organisation must be able to demonstrate the capability to implement water reuse projects. It is therefore likely that the agencies and organisations with an acceptable capability and capacity profile to implement water reuse projects would be limited to metropolitan municipalities, water boards, some larger local municipalities, private companies specialised in the water sector and public private partnerships. Private sector management, engineering and financing capacity related to water reuse, as demonstrated by several successful water reuse projects in mining and industry is well established in South Africa. International interest in local water reuse projects has been expressed. The substantial private sector capacity must be leveraged in the implementation of water reuse projects.

f) Cost Considerations

Apart from water quality requirements and the source of supply, the costs of water supply schemes are also determined by the geographical location (topography, climate, distance from supply sources) and the water supply costs (raw water costs, abstraction costs and bulk transport costs (pumps and pipelines)). Where the costs of the raw water supply are becoming increasingly higher, the cost-efficiency of water reclamation schemes are making such schemes more competitive with other alternatives. DWA (2011) points out the important premise that the economic value/cost of water must always be seen in the broader context of affordability, reliability and responsible use of a limited resource.

i) Factors influencing the cost of technologies

A number of factors have an influence on the cost of technologies that may be used for water reclamation or reuse projects. The following are factors that influence the cost of technologies that are used in water reclamation projects:

- Plant and technology costs - The actual cost of the equipment may vary significantly for different processes and manufacturers.
- Energy sources - Because energy is one of the largest O&M cost components, water reclamation costs are also very sensitive to changing energy prices. Consideration of various energy sources is therefore important to reduce the overall cost of the water supply system.
- Feed water intake - Large distances from the feed water source increase the capital costs of the reclamation plants.
- Feed water quality- The composition of the feed water has a direct influence on the capital and operating cost, especially where pre-treatment is required. The poorer the feed water quality, the more advanced treatment technologies are required, resulting in higher capital and operating costs.
- Disposal of waste streams - The disposal of waste streams (sedimentation residuals, filter backwash water, membrane backwash and brine streams) can have a significant impact on the total capital and operating cost of the reclamation system. New waste disposal legislation requires treatment and disposal facilities that are costly and greatly determines the feasibility of various options.
- Plant life - The amortisation period, which is determined by the plant life, affects the capital costs and the unit treatment costs.
- Interest rates - The interest rates affect the capital costs, performance ratio, total investment and selection of the preferred plant.
- Site costs - Land costs are a major determinant of the location preference. An important factor is the cost of transporting the water to this location. Water transport over long distances will increase the unit cost of the treated water.
- Product water quality requirement - This criterion determines the number of stages

of the final treatment steps, but the cost implication is considerably less than for the feed water quality influence.

- Pre-treatment - This relates to the quality of the feed water (see above) and can have a substantial effect on the overall cost of the process configuration.
- Chemical costs - Chemicals may be required for pre-treatment, coagulation, cleaning of membranes and post-treatment, and can add to the operating costs of the technologies. The local availability and price are important considerations.
- Availability of skilled labour - Skilled labour for operation and maintenance of the treatment technologies, and in particular for the more advanced technologies, is not always readily available. To source these skills and/or to provide specialized training will increase the O&M costs of the treatment plant.
- Storage and distribution of the final water - This is not a part of the treatment system, but does influence the overall project cost.

ii) Costing criteria

- Capital costs - Swartz et al (2013) lists cost estimating and economic criteria that can be used in the development of water supply facilities and infrastructure. The capital costs of water supply projects consist of the following:

  - Construction Capital Cost - the total amount expected to be paid to a qualified contractor to build the required facilities at peak design capacity.
  - Non-construction Capital Cost - an allowance for the following elements associated with the constructed facilities: Facilities planning, Engineering design, Permitting, Services during construction, Administration, etc.

- Land Cost - The market value of the land required to implement the water supply alternative.
- Land Acquisition Cost - The estimated cost of acquiring the required land, exclusive of the land cost.
- Total Capital Cost - Total capital cost is the sum of construction cost, non-construction capital cost, land cost, and land acquisition cost.
- Equivalent Annual Cost - Total annual life cycle cost of the water supply alternative based on service life and time value of money criteria established herein. Equivalent Annual Cost accounts for: Total Capital Cost, Operations and Maintenance (O&M) costs (with the facility operating at average day capacity), Time value of money (annual interest rate), Facilities service life, etc.
- Unit Production Cost - Equivalent Annual Cost divided by total annual water production.

iii) Treatment Facility Cost

Public perception and effluent quality standards in water reclamation projects demand advanced water reclamation facilities, and back-up systems to provide additional reliability. It should also include the cost of well-equipped laboratory facilities.

iv) Operating costs

Operating costs include the following: Human resources (personnel), Chemicals, Energy, Maintenance cost, Management cost, Safety, Raw water cost, Plant residuals disposal (including brine disposal), Monitoring (including Blue and Green Drop costs), Training costs, etc.

v) Distribution System Cost

The cost components of a reclaimed water distribution system are similar to that of a potable water supply system. The cost of a reclaimed water distribution system is project-specific, depending on the type of reuse. In general, indirect potable reuse is less expensive than the direct potable reuse applications due to additional system redundancies and treatment processes required for direct potable reuse. Non-potable reuse can be more expensive than indirect potable reuse because it requires a separate distribution system to convey the reclaimed water to the end users, and may also require the installation of irrigation systems and seasonal storage reservoirs.

g) Example of a South African cost comparison study

This section introduces the costing data of nine plants that were analysed in this study. The procedures performed on the various components of the costing data of these plants are described and the final present value unit costs to produce potable water at each of these plants are presented. The percentage contributions of the components to the cost of each plant are displayed in graphical format to allow for ease of comparison in the discussion of results. A comparison was made of the capital and operating costs of a number of water reclamation plants. It includes a comparison with the costs of local desalination plants, as well as with the costing figures supplied by some of the large water boards in South Africa (as presented in Swartz et al, 2006).

i) Raw data collection

The general information of the data collected from the various plants analysed in this study is displayed in Table 2.2. Amatola Water and Umgeni Water do not have values for their capacity as it was never known how much treated water the costing data was accounting for. The colour-coding of Table 2.4 allows for simple general comparison of treatment procedures.

ii) Data manipulation

This section describes the various manipulation procedures applied to the raw data obtained for the nine plants.

iii) Consumer Price Index

The Consumer Price Index (CPI) is an indication of the changes in price level of goods and services purchased urban consumers. The CPI can be used as a measure of inflation for items such as the value of wages and for regulating the prices of general products. Therefore, in this study the CPI of South Africa has been used to project the costs of personnel at various plants where the data is outdated from the present value. The general costs incurred at plants have also been projected to present value using the CPI. Courtesy of (Statistics South Africa, 2012a), Table 2.3 shows the annual South African CPI values that were used to calculate the new annual personnel and general costs of a plant each year, from the given year to 2012.

Table 2.2: General information of treatment plants analysed in this study

PlantType	Plant name	Location	Capacity (ML/d)	Year of data	Source of costing data
Conventional	**Rand Water**	Gauteng	5260	2004	(Swartz *et al.*,2006)
	Amatola Water	Eastern Cape	NA	2004	(Swartz *et al.*, 2006)
	Umgeni Water	KwaZulu-Natal	NA	2012	(Umgeni Water, 2010)
Desalination	**Bitterfontein**	Western Cape	0.288	2004	(Swartz *et al.*, 2006)
	Sedgefield	Western Cape	1.5	2010	(Civil designer, 2010)
Water reclamation	**NGWRP**	Windhoek, Namibia	21	2003	(du Pisani, 2006:79)
	Beaufort West	Western Cape	2	2012	(Marais and von Durckheim, 2012)

The formula used to perform this calculation is shown in equation 2.1:

$$P_{n+1} = P_n \times (1+CPI) \quad \text{[Equation 2.1]}$$

where:

P_{n+1} = *personnel cost at year n+1*

P_n = *personnel cost at year n*

CPI = annual increase of CPI as a percentage (%)

This formula is used consecutively until n+1 = year 2012. The value of P_{n+1} will then be equal to a good approximation of the cost of personnel in the year 2012.

Table 2.3: CPI annual average percentage increase (adapted from (Statistics South Africa, 2012a))

Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Average	5.8%	1.4%	3.4%	4.6%	7.2%	11.5%	7.1%	4.3%	5.0%	5.7%

Table 2.4: Treatment train and capacity of each advanced treatment plant analysed

PLANT	WATER RECLAMATION				DESALINATION	
	NGWRP	**NEWater**	**GWRS**	**Beaufort West**	**Sedgefield**	**Bitterfontein**
CAPACITY (ML/d)	21	273	265	2	1.5	0.288
TREATMENT TRAIN	PAC	Micro-filtration	Micro-filtration	Phosphate removal	Direct intake	
	Coagulation/ flocculation	Reverse osmosis	Reverse osmosis	Settling	Pre-disinfection	Reverse osmosis
	Dissolved air flotation	Advanced oxidation	Advanced oxidation	Rapid sand filtration	Reverse osmosis	
	Rapid sand filtration	Chlorination	Chlorination	Ultra-filtration	Chlorination	
	Ozonation			Reverse osmosis		
	BAC + GAC			Advanced oxidation		
	Ultra-filtration			Chlorination		
	Chlorination					

iv) Energy tariff index

In order to project outdated energy cost fractions of a plant's annual cost it was necessary to obtain the energy tariff annual percentage changes from ESKOM, South Africa's leading electricity public utility. The values shown in Table 2.5 were used to project the Energy component of a plants cost to 2012 wherever applicable. The formula used to perform these projections is similar to Equation 2.1, however, the CPI percentage is replaced by the Eskom tariff increase percentage.

Table 2.5: Eskom energy tariff annual percentage increases (adapted from (Eskom, 2012))

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Average (%)	8.4	2.5	4.1	5.1	5.9	27.5	31.3	24.8	25.8	16.0

v) Producer Price Index

The Producer Price Index (PPI) measures the average change in prices received by domestic producers for their output. As seen in the business plan of Umgeni Water for 2010/11 – 2014/15 (Umgeni Water, 2010) the South African PPI was used to project the chemical cost component and the maintenance cost component of each plant, wherever applicable. Table 2.6 contains the annual average South African PPI percentages that were used in this study. This index is applied in the same way that the CPI and Energy tariff index were applied. The formula used to perform the projection was again Equation 2.1 except the CPI percentage was replaced by the PPI percentage. Due to the negative value of the PPI percentage in the year 2009, the cost of chemicals and maintenance will drop slightly in the projection of the year 2009 in comparison to the year 2008.

Table 2.6: South African PPI annual average percentages (adapted from (Statistics South Africa, 2012b))

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Average	2.2%	2.3%	3.7%	7.7%	10.9%	14.2%	-0.1%	6.0%	8.4%	6.0%

vi) Capital redemption

Most projects have a capital redemption plan set up in order to pay off the capital cost of the project. The capital redemption is broken into annual or monthly payments which make the total amount easier to comprehend and manipulate. As the capital of a water treatment plant is often included as a component of its annual cost (and as allowance has been made for it in this study) each plant analysed in this study requires the initial capital to be broken into annual components. In most cases the data obtained on plants already contained a component of annual capital cost/redemption. Where the capital cost of a plant was only available as a lump sum, assumptions had to be made. The assumption, which was observed in a Desalination Guide for South African Municipal Engineers (Swartz *et al.*, 2006) is that the capital redemption period runs for 25 years at an interest rate of 12%. To make sense of these values equation 2.2 has been presented below. The equation gives an annuity factor which can be multiplied to the total capital expenditure of a project to determine the annual cost of capital over those 25 years.

$$\alpha = \frac{i(1+i)^n}{(1+i)^n - 1} \qquad \text{[Equation 2.2]}$$

where:

α = annuity factor (0< α <1)

i = annual interest rate (%)

n = number of compounding periods (years).

In this study, where i = 12% and n = 25 years, then α = 0.1249997. This annual capital cost, whether as a unit cost per kilolitre or as a total annual cost, will remain constant for every year of projection to present value as it has been calculated with an annuity factor which already incorporates an interest rate.

vii) Prime interest rate

The prime interest rates for South Africa are used to project the true value of capital from a given year to a wanted year. Therefore, the total capital cost of a plant, or a process within a plant, was projected to 2012 using the prime interest rates for each year. This was done in order to compare whole costs of technologies, regardless of annual operating and maintenance (O&M) costs. This method is thus not used for the calculation of the capital cost component in a plant's annual cost. Equation 2.1 is again used to perform these projections however the CPI value is replaced by the prime interest rate percentage for each year. The prime interest rates from 2003 to 2012 of South Africa can be found in Table 2.7 below.

Table 2.7: South African prime annual average interest rates (adapted from (Viljoen, 2012))

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Average(%)	13.4	11.0	10.5	15.67	13.75	15.17	12.5	9.5	9.0	8.5

viii) Exchange rates

The plants from other countries that were analysed presented data which was of foreign currency to South Africa. It was therefore necessary to obtain the appropriate exchange rate between those currencies and the South African Rand at the correct period. Specifically, these countries were the USA and Singapore with the currencies of the US Dollar (USD) and Singapore Dollar (SGD) respectively. These currencies were necessary to manipulate the data of the GWRS in the Orange County of USA and the NEWater plants in Singapore. Table 2.8 shows the two average annual exchange rates that were necessary for this study and the year from which they were taken. The year for exchange was chosen according to the most recent year of which data could be obtained.

Table 2.8: Exchange rates used for the GWRS and NEWater plants (XE Corporation, 2012)

Exchange	ZAR /USD	ZAR/SGD
Year	2010	2007
Average annual rate (ZAR / currency)	7.54	4.70

After the foreign currency has been exchanged into ZAR terms, the remainder of the calculations for these two plants could continue in the same manner as the local plants, using the abovementioned indexes.

ix) Final results

The steps and equations mentioned in the section above were applied to the available data wherever necessary. A spread sheet format was utilized to complete the calculations. Table 2.9 shows the typical calculations for the GWRS plant that were performed to arrive at a present value.

Table 2.9: Data calculations for GWRS to determine the present value of cost components

	USD annual total	ZAR annual total	R/kL (2010)	R/kL (2011)	R/kL (2012)
Personnel	$6,966,873.00	R 52,530,222.42	R 0.59	R 0.62	R 0.66
Energy	$6,347,318.00	R 47,858,777.72	R 0.54	R 0.68	R 0.78
Chemicals	$4,152,496.00	R 31,309,819.84	R 0.35	R 0.38	R 0.40
Maintenance	$3,540,947.00	R 26,698,740.38	R 0.30	R 0.33	R 0.34
Total O&M	$21,007,634.00	R 158,397,560.36	R 1.78	R 1.78	R 1.78
Capital	$19,666,513.00	R 148,285,508.02	R 1.67	R 1.67	R 1.67
General	$8,600,232.00	R 64,845,749.28	R 0.73	R 0.77	R 0.81
TOTAL	**$49,274,379.00**	**R 371,528,817.66**	**R 4.17**	**R 4.21**	**R 4.25**

In order to explain these results shown in Table 2.9, the manipulation of component of energy is explained below.

a. The annual total cost of energy in USD was multiplied with the exchange rate from the table to yield the total annual energy cost in ZAR:

$$\$6,347,318.00 \times 7.54 \text{ R/\$} = \text{R } 47,858,777.72$$

b. The ZAR value was divided by the annual production of the plant in m^3/year to determine the unit cost of the plant :

$$\text{R } 47,858,777.72 \div 89000000 m^3/y = \text{R } 0.54$$

c. This unit cost was then increase according to the index value of energy tariffs in Table 4.4, for the year 2011:

$$\text{R } 0.54 \times (1+ 25.8\%) = \text{R } 0.68$$

d. The 2011 unit cost is increased again using the index value of energy tariffs in Table 4.4, for the year 2012:

$$\text{R } 0.68 \times (1+ 16\%) = \text{R } 0.78$$

e. This value is then the final present value of the unit cost of energy use in the production of potable water at the GWRS in Orange County.

The present values of personnel, chemicals, maintenance and general cost components for this plant were determined in a similar manner to the energy component, except the appropriate indexes were used in steps 3 and 4 above. These indices were explained earlier. It must be noted that the capital value does not increase each year. This is because the interest has already been incorporated into the plant's annual capital cost so it will remain a constant value until the plant's redemption period is complete. The total unit cost of producing potable water at the GWRS plant is thus the sum of all the components mentioned. This value is R4.25/kL. Table 2.10 displays the final unit costs (in Rand per kilolitre) that were determined for each conventional, desalination and water reclamation plant. Appendix C contains the full spread sheet of the calculations for each plant.

Table 2.10: Summary of present value unit costs (R/kL) for various water plants

	Rand water	Umgeni Water	Amatola Water	Sedgefield	Bitter-fontein	Goreangab	Beaufort West
Capacity (ML/d)	5260			1.5	0.288	21	2
Cost components (R/kL)							
Personnel	0.67	0.71	1.31	0.44	5.10		2.88
Energy	0.85	0.23	0.74	2.77	3.39		1.88
Chemicals	0.17	0.08	0.24	2.18	1.10		3.06
Maintenance	0.40	0.26	0.50	0.46	1.64		2.61
Total O&M	2.09	1.28	2.80	5.86	11.22	6.44	10.43
Capital	0.11	0.25	0.39	3.73	1.50	1.84	4.43
General	0.22	2.15	0.45	0.00	0.93		1.39
TOTAL(R/kL)	**2.42**	**3.69**	**3.63**	**9.59**	**13.65**	**8.28**	**16.25**

In order to build up a form of comparison between the plants, a stacked column chart is presented to show the different plant unit costs and the proportion of each of the six components within each unit cost (Figure 2.7).

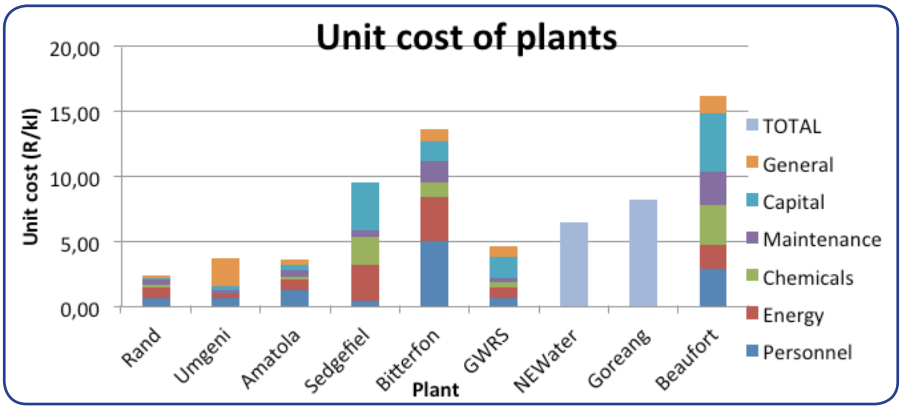


Figure 2 7: Stacked column chart of plant unit cost and component contribution

For ease of comparison, pie charts showing the percentage of each of the six abovementioned cost components were created for each plant (Figures 2.8 and 2.9). Due to the nature of the NEWater data, it does not qualify to be displayed as a pie chart.

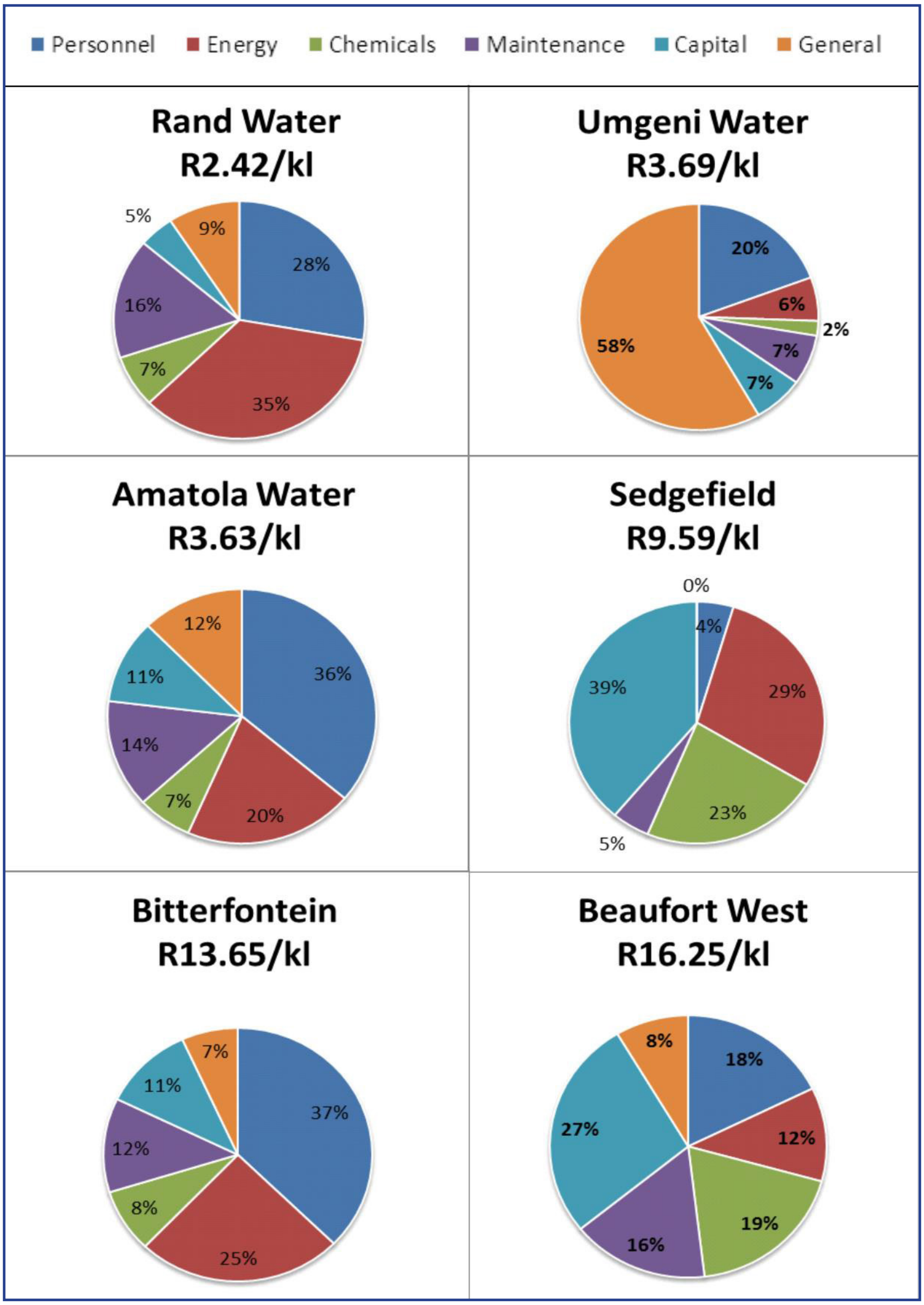


Figure 2 8: Pie charts of plant unit costs showing contribution of each component

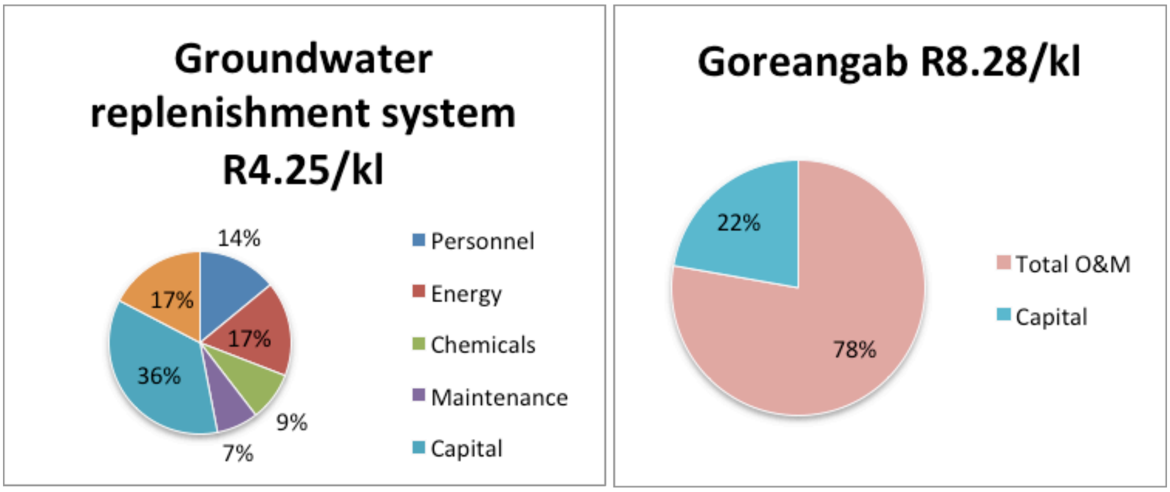


Figure 2 9: Pie charts of plant unit costs showing contribution of each component

A valuable graph of the relationship between the capacity of water reclamation plants and their unit cost is presented below (Figure 2.10). A logarithmic trend line shows the strong relationship between the variables. As the capacity of the plants increase, the unit cost decreases.

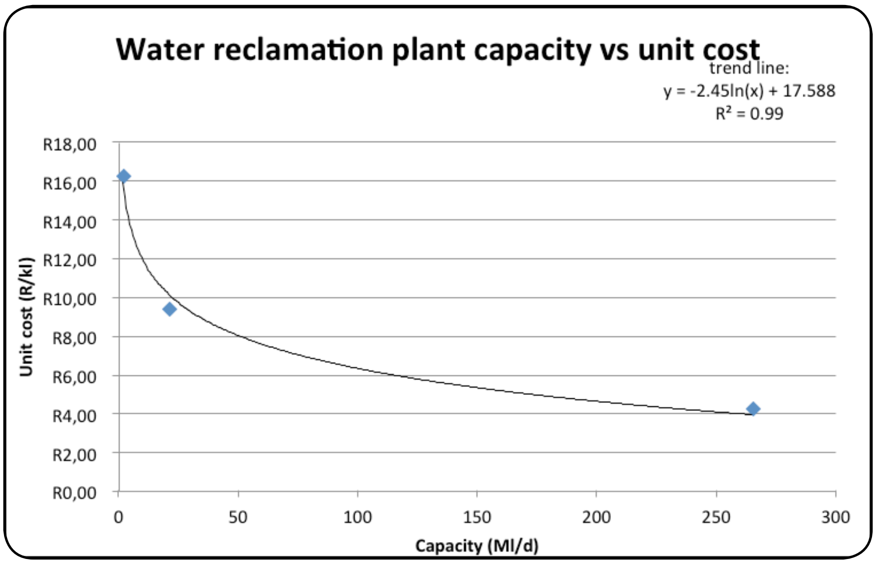
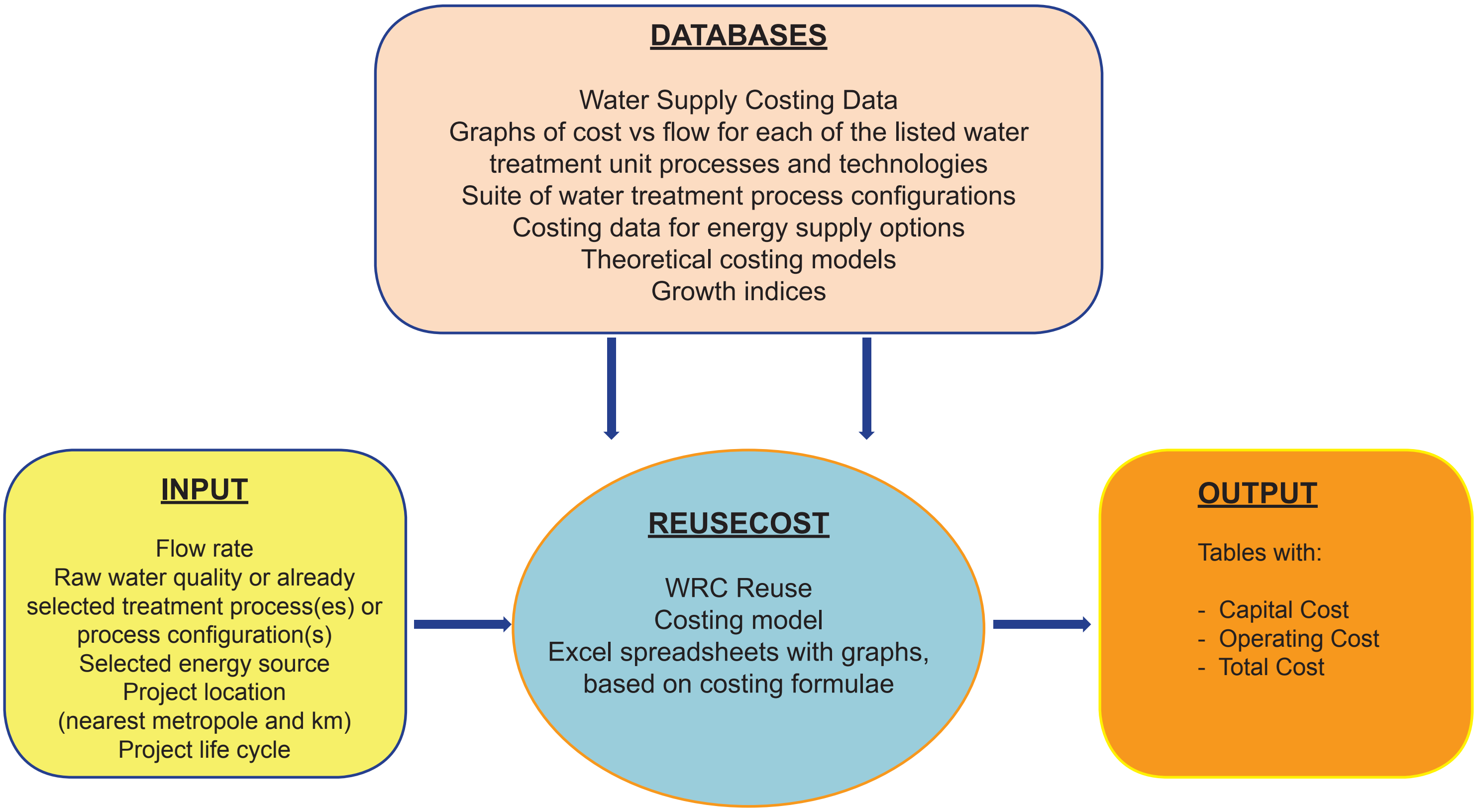


Figure 2 10: Water reclamation plant capacity and unit cost

3 COSTING MODEL FOR WATER RECLAMATION SCHEMES

Figure 3.1: Schematic representation of the WRC Water Reuse Costing Model (hereafter referred to as REUSECOST).



The WRC Water Reuse Costing Model (hereafter referred to as REUSECOST) is shown diagrammatically below. The REUSECOST Costing Model is available electronically on a CD in the back-page sleeve. The electronic copy of the model on CD contains the following: user Instructions; input Component (where the user will enter required information); eExcel programming that does the cost calculations – the Model Component; output Component (that will provide the tables and graphic costing results) and Database of costing information (not accessible to the user, only for doing cost calculations).

The model is an adaption from the WATCOST model that was developed in the WRC project TT 552/13 "Development of a costing model to determine the cost-efficiency and energy efficiency of water treatment technologies and supply options" (Swartz et al, 2013). The REUSECOST model was developed by extending the WATCOST model to include costing data and process configuration for water reclamation facilities. A number of requirements were set for the model, and both models have the following features:

- The models focus on the water treatment and water reclamation components of the water supply system, but include estimates for the following: raw water or raw wastewater transport (feedwater); clean water storage (reservoirs) and distribution networks (various levels of service)
- The models produce outputs for capital costs, operating costs and total costs (in costs per annum and per kilolitre of water produced).
- The costs are based on life-cycle costing.
- Data used for calculating costs were obtained from local water supply and reuse projects of the past ten years, converted to present value using appropriate growth indices.
- The databases are structured in such a way to enable easy, annual updating.
- The model is spreadsheet based (Excel).
- The model attempted to be user friendly, unambiguous and easy to operate, requiring minimal data inputs from the user (drop down menus are used).
- The databases contain a suite of proposed treatment processes, so that the user can compare costs of different treatment units for a given raw feedwater quality range and flows.
- The WATCOST model is not a decision support tool, but will be designed in such a way that a decision-making functionality can be added seamlessly at a later stage. The REUSECOST model has been integrated with the Water Reuse decision-support model developed in this project and presented in Chapter 4 of the guidebook.
- The models include for variations in costs for undertaking water supply and water reclamation projects in different geographic areas.
- The models allow for cost escalation by updating unit costs and tariffs on an annual basis.
- It includes the costs of soft issues such as training, monitoring and control, compliance and management.
- The costs include the establishment and maintenance of security systems for protecting all the components of the water supply systems, i.e. catchments, water sources (surface water, ground water, and alternative water sources), abstraction facilities and raw water supply pipelines, water treatment plants, clean water reservoirs, distribution networks and consumer points.
- The models were designed in such a way that it can be modified at any time by the project team, and later by a designated administrator.

a) Components and Elements of the REUSECOST Model

i) REUSECOST

The model consists of the following four main components: INPUT, MODEL, OUTPUT and DATABASES

Each of these components and the elements contained in each are shown below.

INPUT

1. **Flow rate**
   a. Estimated quantity of water to be produced at the end of the design period of the project or current phase of the project, in megalitres (thousand cubic meters) per day
   b. The model will assume that the reclamation plant will be in operation for 24 h/d. (Should the required number of operational hours per day be less (say 8 h/d), then the plant design size will be increased proportionally to provide the same required volume of water per day).

2. **Raw water quality or already selected treatment process(es) or process configuration(s)**
   a. Turbidity (range and average, but preferably normal distribution).
   b. Organics (measured as colour, DOC, COD or UV254)
   c. Electrical conductivity.
   d. Chlorophyll a (where applicable).
   e. Iron.
   f. Nutrients (ammonia, nitrates, phosphates)
   g. Any other relevant macro- or micro-determinands which may dictate the type of treatment process to be used (for guidance, refer to WRC Report 1443/1/07).
   h. Microbiological quality (faecal coliforms or E.coli).

3. **Project location**
   a. Name of the nearest large city (metropole).
   b. Distance in km from this metropole.
   c. Exact location of plant (GPS coordinates if possible).

4. **Supply of abstracted raw water to the treatment plant**
   a. Distance of raw water source from the treatment plant
   b. Terrain (topography)

5. **Clean water storage**
   a. Number of reservoirs.
   b. Required storage time.

6. **Distribution networks**
   a. Estimated number of consumers.
   b. Proposed number and types of connection points.
   c. Terrain (topography).

7. **Project life cycle (normally design period, in years)**

MODEL

1. Process Configurations

The model will access the chosen process configuration from the database of process configurations. Each process configuration will then route the program to each of the unit processes contained in that configuration. There may be more than one technology that can be opted for in most of the unit treatment processes, and the model will calculate costs for each of these, so that the user can compare costs for different options.

If the user does not provide a preferred process configuration(s), then the user will be able to select process from a list provided by the model, based on input data on raw water quality provided by the user. The selection of applicable process configuration options is based on the knowledge base of applicable treatment processes for given raw water qualities).

2. Cost calculations for unit treatment processes

The model will then calculate costs for the required flow rate for each unit treatment process (and each technology option that it may comprise) based on the formulae and graphs derived from and contained in the costing data database of the model (see the DATABASE component below for more details on how the costing data will be obtained and organized).

3. Cost calculations for raw water transport

Based on the hourly flow rate provided in the input component, or selected pipe size if the raw water conveyance pipe already provide for later phases of the project, the topography of the route and the distance in km of the abstraction point from the treatment plant, a cost will be calculated for the raw water transport to the plant.

A link will be provided to the model of Prof SJ van Vuuren as contained in the WRC Report TT278/06 “Life Cycle Costing Analyses for Pipeline Design, with supporting software”. This model can also be used for calculation of pipe costs for final water distribution (see Cost calculations for the treated water distribution on the next page).

4. Cost calculations for clean water storage

The required storage period for clean water and the daily flow as provided in the input component will allow the calculation of reservoir size(s), based on standard free board and inlet/outlet arrangements.

5. Cost calculations for the treated water distribution

Only a rough cost estimate will be provided, as this would require a more detailed design by the user to do a more accurate cost calculation. The rough cost estimate will be based on the number of connection points and km of distribution network piping.

8. Cost calculations for operational management

Costs will be calculated for all activities related to operational management of the water supply system, and the water treatment plant in particular, over the project life time (i.e. life cycle costs). This will be based on the DWA classification of the treatment plant, which in turn will be based on the capacity of the treatment plant (in ML/d) and the process configuration.

9. Cost calculations for other items

Any further cost items that will become apparent during the development of the model will be added to the total costs, and will be based on either the total calculated cost or on some other item(s) related to the characteristics and capacity of the treatment plant.

10. Allowance for project location

Adjustments will be made to certain cost items for water supply projects that are situated in remote locations and that will, for example, result in increased delivery costs, technical back-up and skills shortages.

OUTPUT 1

1. Table with Capital Cost

The table with Capital Cost will contain the following elements:

Element	Applicable range		Design quantity	Design unit	No of items	Cost per item	Cost per element
	Min	Max					
WASTEWATER FEED							
Raw water intake tower							
Raw water pumps							
ADVANCED WATER TREATMENT (WATER RECLAMATION/DIRECT POTABLE REUSE)							
Unit Process 1							
Unit Process 2							
Unit Process 3							
Unit Process 4							
Unit Process 5							
CLEAN WATER STORAGE							
Reservoir 1							
Reservoir 2							
DISTRIBUTION							
Distribution network (total amount)							
Sub Total Capital Cost							
Treatment Plant Yard Piping (* %)							
Landscaping and Rehabilitation (* %)							
Site Electrical and Controls (* %)							
TOTAL CONSTRUCTION COST							
Professional Fees (Planning, Design, Engineering, Legal)							
TOTAL CAPITAL COST							

OUTPUT 2

2. Table with Operating Cost

The table with Operating Cost will contain the following elements:

Element	Unit	Unit cost	No of units per day	Cost per day (Million)	Cost per year (Million)	Cost per kilolitre (R/kL)
Electricity	kWh					
Human Resources						
Chemicals						
Safety						
Total Maintenance						
TOTAL OPERATING AND MAINTENANCE COST						

OUTPUT 3

3. Table with Total Cost

The table with Total Cost will contain the following elements:

Total Capital Amortization

TOTAL CAPITAL COST: Present value	
TOTAL CAPITAL COST: Future value (Amortized over x years at y% interest)	

Total Cost Summary	Cost per day (Million)	Cost per year (Million)	Cost per kilolitre (R/kL)
Total capital costs (Based on future value)			
Total operating and maintenance costs			

ii) REUSECOST costing database

Process Configurations

The Process Configurations database contains a comprehensive number of possible process configurations that are currently used in the production water for drinking purposes by water reclamation. Examples are shown in Table 3.1 .

Table 1.1: Examples of configurations

Configuration	Treatment Processes
1	Chemical treatment – Phase separation – filtration – disinfection
2	Chemical treatment – Phase separation – filtration – membrane filtration – disinfection
3	Reverse Osmosis – Advanced Oxidation – Blending – Membrane filtration – UV disinfection – Activated Carbon – Disinfection
4	Membrane filtration – Reverse Osmosis – Advanced Oxidation – Blending – Flocculation – Sedimentation – Filtration – Disinfection
5	Rapid sand filtration – Membrane filtration – Reverse Osmosis – Advanced Oxidation – Disinfection

Costing Data

Costing data were obtained for current water supply or water reclamation projects or projects that were completed in the past ten years. The costs are broken down as far as is possible to produce costs per unit treatment process for a wide range of treatment capacities, from small-scale treatment plants (community scale: for a number of households) to large water treatment plants (for the large cities or Water Boards). The costs are plotted for treatment cost versus unit treatment process capacity. Lines are fitted and formulae established (for acceptable line fits), which are then used to calculate costs in the model for the flow rate that was entered in the input by the user. Graphs should have as many data points as possible (depending on availability of data), but at least 5. Correlation coefficients (r^2–values) are indicated on the graphs to give an indication on the accuracy of local cost estimation of that particular unit treatment process. Data covers a wide range of treatment plant sizes (capacities), and it was endevoured to ensure that data-points are not centered around one size (capacity).

Indices

A range of indices were entered into this database, and will be hyperlinked to the original indices. Examples are current electricity tariffs, remuneration packages for treatment plant personnel and maintenance personnel.

4 WATER REUSE DECISION SUPPORT MODEL (REUSEDSM)

The REUSEDSM spreadsheet-based decision support system was developed to provide a simplistic method to compare different reuse options using multi-criteria analysis. The model is based on a multi-criteria weighted sum analysis, and evaluates alternative water reuse options against a number of selection (decision) criteria. It is strongly recommended that weighing of the criteria should be done with input from subject field experts in the following disciplines: planners, engineers (all disciplines), decision-makers, managers (water supply; environmental; human resources; financial), estimators, water quality scientists, health practitioners and engineers, and social scientists.

THE WEIGHTED SUM METHOD

The weighted sum model is the simplest multi-criteria decision analysis for evaluating a certain number of alternative options against a number of decision criteria. By way of explanation, when the user want to weigh up three alternative options, namely A1, A2 and A3, against three decision criteria C1, C2 and C3, with each criterion carrying a weighting Ci.1, Ci.2, Ci.3, these weightings are normalised and are summed up to a value of 1.

When the decision (or selection) criteria are grouped under primary decision criteria headings, each consisting of a number of secondary decision criteria, then the matrix can be drawn up in such a way that a primary weighting (AiCi) is given for each of the options (A1, A2, A3), followed by a weighting for each of the secondary decision criteria (numerical values for these are assigned for each criterion in a scale of High (0.75), Medium (0.50) or Low (0.25). The actual weighting for each decision or selection criterion is then the product of the primary weight (AiCi) and the secondary weight (Xci). These actual weights are then totalled to provide a weighted sum for each option (Aiscore). A final weight is then calculated as a fraction of percentage of the total weighted sum.

The table below shows the structure of the matrix developed for the water reuse model. Once the Matrix is populated with the various co-efficients, each alternative weight is then calculated via the weighted sum model.

Primary decision criteria description	**Primary decision criteria weight for Options 1, 2 and 3** (total in each row to add up to 1.0)			**Secondary decision criteria description**	**Primary decision criteria weight for Options A1, A2, A3** (from Table *)		
	Option A1	Option A2	Option A3		Option A1	Option A2	Option A3
C1	A1C1	A2C1	A3C1	C1.1	A1C1.1	A2C1.1	A3C1.1
				C1.2	A1C1.2	A2C1.2	A3C1.2
				C1.3	A1C1.3	A2C1.3	A3C1.3
C2	A1C2	A2C2	A3C2	C2.1	A1C2.1	A2C2.1	A3C2.1
				C2.2	A1C2.2	A2C2.2	A3C2.2
				C2.3	A1C2.3	A2C2.3	A3C2.3

Primary decision criteria description	**Primary decision criteria weight for Options 1, 2 and 3** (total in each row to add up to 1.0)			**Secondary decision criteria description**	**Primary decision criteria weight for Options A1, A2, A3** (from Table *)		
	Option A1	Option A2	Option A3		Option A1	Option A2	Option A3
C3	A1C3	A2C3	A3C3	C3.1	A1C3.1	A2C3.1	A3C3.1
				C3.2	A1C3.2	A2C3.2	A3C3.2
				C3.3	A1C3.3	A2C3.3	A3C3.3
Weighted sum (Ai_{score} = ΣAiCi.AiCi.i)					$A1_{score}$	$A2_{score}$	$A3_{score}$
Final weight (fraction of total weighted sum)					Final weight A1	Final weight A2	Final weight A3

Steps In Using The Water Reuse DSM Spreadsheet

STEP 1:

Choose a main option theme from the list below. If more than one main theme needs to be evaluated, separate model application runs need to be performed for each

Main option theme examples:

- Reclamation and reuse system configurations (wastewater treatment plant and reclamation plant (advanced treatment plant)
- Direct versus indirect potable reuse
- Centralised versus decentralised treatment

STEP 2:

List the different options to be compared. Plant configurations can be selected from a drop-down list that appears in the model, or may be entered manually entered as a new configuration. Descriptions of the five pre-set configurations in the model also appear in the report (section 2.3.2)

STEP 3:

For each option, give a primary weight for each of the primary criteria.
These weights must add to 1.0 (example shown in Table 4.2)

Primary criteria:

- Water quality
- Water treatment technologies
- Cost
- Social and cultural perceptions
- Environmental considerations

STEP 4:
For each option, give a secondary weight for each of the secondary criteria by selecting from the drop down lists in the secondary criteria table (example shown in Table 4.3a).

(Note: There are eight (8) secondary costing criteria. Two of these secondary criteria (brine disposal cost, and foreign exchange rate impacts) should be completed using the drop down lists, while the remaining six (6) should be estimated using the costing model, as performed in Step 5).

STEP 5:
For each option, provide the cost information required to complete the secondary criteria weightings.

Note: Cost comparisons for the remaining costing criteria should be obtained from the REUSECOST model, or the user can enter the cost data if it is available.

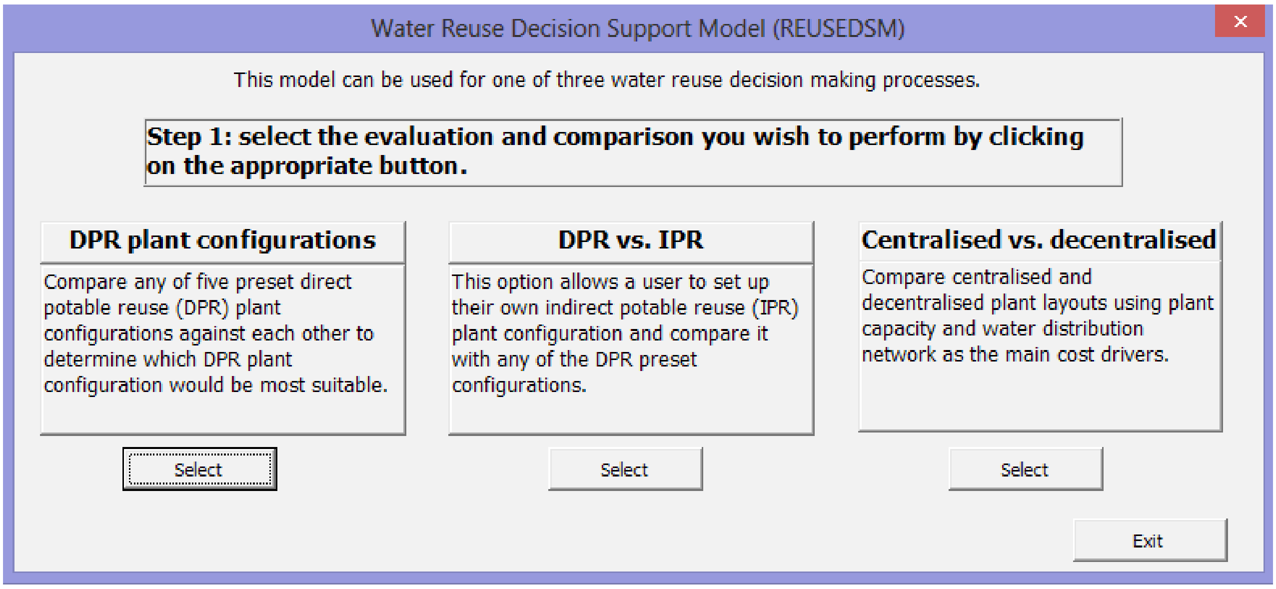
STEP 6:
The water reuse DSM will then calculate the weighted sum for each option, followed by calculation of the final weight (example shown in Table 4.4)

STEP 7:
The DSM will provide a listing of the "best" option, followed by a prioritized list of the other options. The DSM shows which of the selection criteria played the decisive role in the selection process by using a colour code.

Using the REUSEDSM: Example

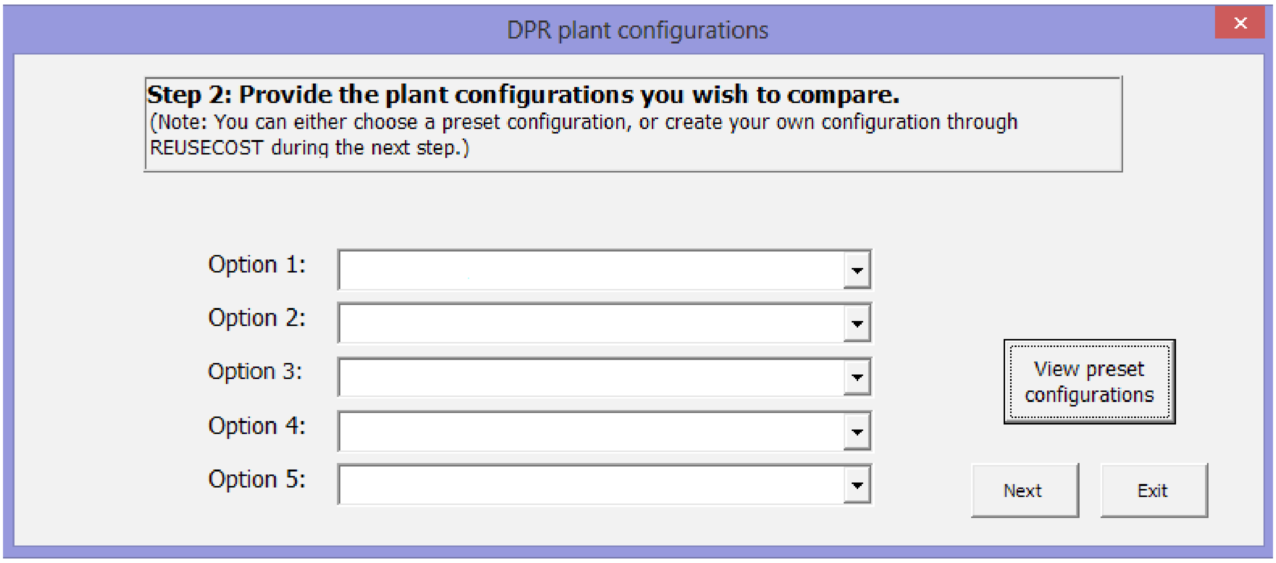
Note: weighting numerical values chosen arbitrarily only for purposes of the example)

STEP 1: Choose a main option theme



<u>Main option theme:</u>
Water reclamation treatment configurations

STEP 2: List the different options to be compared.



<u>Potential options (for this example only):</u>

Configuration 1:	Conventional processes (e.g. Windhoek)
Configuration 2:	Conventional and RO
Configuration 3:	RO and advanced oxidation

STEP 3: For each option, give a primary weight for each of the primary criteria.

REUSEDSM INPUT

Options Selected:

Option 1:

Option 2:

Option 3:

Option 4:

Option 5:

Note: The total weight fractions for each option should add up to 1.00

Note: Make sure that the tables are empty for options that are not being used.

Step 3: Provide a weighting for each of the primary decision (selection) criteria:

Primary decision criteria description	Primary decision criteria weight				
	Configuration 1	Configuration 2	Option 3	Option 4	Option 5
Water quality					
Water treatment technologies					
Cost					
Social and cultural perceptions (public acceptance)					
Environmental considerations					
Total per option					

OPTION 1: CONVENTIONAL PROCESSES

Water quality	0.15 (15%)
Water treatment technologies	0.25 (25%)
Cost	0.30 (30%)
Social and cultural perceptions (public acceptance)	0.15 (15%)
Environmental considerations	0.15 (15%)

OPTION 2: CONVENTIONAL AND RO

Water quality	0.10 (10%)
Water treatment technologies	0.20 (20%)
Cost	0.35 (35%)
Social and cultural perceptions (public acceptance)	0.10 (10%)
Environmental considerations	0.25 (25%)

OPTION 3: RO AND ADVANCED OXIDATION

Water quality	0.10 (10%)
Water treatment technologies	0.30 (30%)
Cost	0.30 (30%)
Social and cultural perceptions (public acceptance)	0.10 (10%)
Environmental considerations	0.20 (20%)

STEP 4: For each option, select a weighting for each secondary criterion

Step 4: Provide a weighting for each of the secondary decision (selection) criteria:
(Choose from the drop down lists in the shaded cells)

Secondary decision criteria description	Secondary decision criteria weight				
	Configuration 1	Configuration 2	Option 3	Option 4	Option 5
Raw water quality					
Monitoring program					
Water-borne disease					
Product water quality					
Number of barriers					
Maintenance requirements					
Policies and planning					
Public acceptance					
Political interference					
Climate changes					
Rising energy costs					
Legislation					
Forex rates					
Cost of Brine disposal					

STEP 5: Provide cost information for each of the options

Step 5: Provide a cost value (in R/kL) for each of the secondary cost decision (selection) criteria:
(Note: If you do not already have costing information available, click on the button below to make use REUSECOST to do a cost estimation.)

Secondary decision criteria description	Secondary decision criteria weight				
	Configuration 1	Configuration 2	Option 3	Option 4	Option 5
Capital					
Personnel					
Energy					
Chemicals					
Maintenance					
Management					
Total:	R -	R -	R -	R -	R -
	Go to REUSECOST	Go to REUSECOST	Go to REUSECOST	Go to REUSECOST	Go to REUSECOST

Back to Start

Generate Results

Print this Page

In the spreadsheet, the weighted sums for each option are then calculated, followed by a calculation of the final weights.

The results for the example are shown below.

STEP 6: The DSM model performs the calculations and generates the results

"Best" option:	Conventional treatment processes
Second "best" option:	RO and advanced oxidation
Third selection:	Conventional and RO

STEP 7: ‘Best’ option is identified and displayed with the remaining results.

Example of REUSEDSM results

REUSEDSM RESULTS

Ranking:

First: Option 1 (Configuration 1) with a normalized score of 0.55739

Second: Option 2 (Configuration 2) with a normalized score of 0.44261

This section is a visual representation of the product weights. The colours are used as an aid to show how the selected options compare.

Primary decision criteria description	Primary decision criteria weight					Secondary decision criteria description	Secondary decision criteria weight					Product of primary and secondary decision criteria weights				
	Option 1	Option 2	Option 3	Option 4	Option 5		Option 1	Option 2	Option 3	Option 4	Option 5	Option 1	Option 2	Option 3	Option 4	Option 5
Water quality	0.20	0.10				Raw water quality	0.75	0.25	0.00	0.00	0.00	0.15	0.03	0.00	0.00	0.00
						Monitoring program	0.75	0.25	0.00	0.00	0.00	0.15	0.03	0.00	0.00	0.00
						Water-borne disease	0.75	0.25	0.00	0.00	0.00	0.15	0.03	0.00	0.00	0.00
						Product water quality	0.75	0.25	0.00	0.00	0.00	0.15	0.03	0.00	0.00	0.00
Water treatment technologies	0.20	0.20				Number of barriers	0.75	0.25	0.00	0.00	0.00	0.15	0.05	0.00	0.00	0.00
						Maintenance requirements	0.75	0.25	0.00	0.00	0.00	0.15	0.05	0.00	0.00	0.00
Social and cultural perceptions	0.20	0.30				Policies and planning	0.50	0.25	0.00	0.00	0.00	0.10	0.08	0.00	0.00	0.00
						Public acceptance	0.25	0.75	0.00	0.00	0.00	0.05	0.23	0.00	0.00	0.00
						Political interference	0.50	0.75	0.00	0.00	0.00	0.10	0.23	0.00	0.00	0.00
Environmental considerations	0.20	0.30				Climate changes	0.50	0.75	0.00	0.00	0.00	0.10	0.23	0.00	0.00	0.00
						Rising energy costs	0.25	0.75	0.00	0.00	0.00	0.05	0.23	0.00	0.00	0.00
						Legislation	0.50	0.75	0.00	0.00	0.00	0.10	0.23	0.00	0.00	0.00
Cost	0.20	0.10				Forex rates	0.25	0.75	0.00	0.00	0.00	0.05	0.08	0.00	0.00	0.00
						Brine disposal	0.50	0.75	0.00	0.00	0.00	0.10	0.08	0.00	0.00	0.00
						Capital	0.33	0.67	0.00	0.00	0.00	0.07	0.07	0.00	0.00	0.00
						Personnel	0.92	0.08	0.00	0.00	0.00	0.18	0.01	0.00	0.00	0.00
						Energy	0.57	0.43	0.00	0.00	0.00	0.11	0.04	0.00	0.00	0.00
						Chemicals	0.56	0.44	0.00	0.00	0.00	0.11	0.04	0.00	0.00	0.00
						Maintenance	0.38	0.63	0.00	0.00	0.00	0.08	0.06	0.00	0.00	0.00
						Management	0.79	0.21	0.00	0.00	0.00	0.16	0.02	0.00	0.00	0.00
Weighted sum ($Ai_{score} = \Sigma Ai Ci . X_{C1}$)												**2.2603**	**1.79485**	**0**	**0**	**0**
Normalized score (fraction of total weighted sum)												**0.5574**	**0.4426**	**0.0000**	**0.0000**	**0.0000**
Ranking												**1**	**2**	**3**	**3**	**3**

Back to REUSEDSM Input

Go to Capital Cost Output

Print this Page

Note:

The REUSEDSM model was designed, built and tested on a specific computer operating system and using a specific version of Excel. It is therefore recommended that the following requirements are met in order to ensure the optimal operation of the model:

- Operating system: Windows 8 (or any newer version)
- Excel 2013 (or any newer version)
- 2 GB Memory (RAM): if less RAM is used, the model will perform slowly.
- At least 10MB free storage space: this value can vary depending on the amount of files created (for different projects or types of comparison)

These requirements should be met otherwise the model will not perform as intended.

5 CONCLUSION

Decsion support systems present a useful tool to assist water supply authorities and planners to identify, evaluate, compare, and select appropriate reuse. Although it is a relatively simple tool, it requires careful consideration of all the selection criteria against the different options, which ensures thorough planning. Providing weights to the selection criteria should be based on known information and include inputs from stakeholders, authorities and results from costing models. Reliability of the cost estimation with the REUSECOST model will improve as more costing data becomes available (as is the case at present).

NB: Decision-support software for analysing the inter-relationships of multi-factor environments

For more in-depth analysis of the inter-relationships of the multitude of factors involved in the evaluation and selection of water reuse options, the Parmenides Eidos provides decision-support software that provides an innovative approach to managing the entire decision-making process by visualising complex situations, building alignment among decision makers, and supporting the identification of possible courses of action. The software is used by the Centre for Knowledge Dynamics and Decision-making of the University of Stellenbosch. For more information on the software and its application, the main author can be contacted, or contact the Centre directly at: http://www.informatics.sun.ac.za/index.php?page=contact

Compiled and Edited by:

Juliet Mwale & Nonhlanhla Kalebaila

The WIN-SA lesson series aims to capture the innovative work of people tackling real service delivery challenges. It also aims to stimulate learning and sharing around these challenges to support creative solutions. To achieve this, the lessons series is supported by ancillary learning opportunities facilitated by WIN-SA to strengthen people-to-people learning.

To find out more about these and other WIN-SA services go to the WIN-SA portal at www.win-sa.org.za or contact the Network directly.

This document hopes to encourage ongoing discussion, debate and lesson sharing. To comment, make additions or give further input, please visit www.win-sa.org.za or send an email to info@win-sa.org.za.

Our mission is to ensure the body of knowledge in the sector is well managed, readily accessible and applied, leading to improved decision-making and performance, especially of local government.

Address: 491 18th Avenue, Rietfontein, Pretoria
Postal Address: Private Bag X03, Gezina, 0031
Tel: (012) 330 0340 Fax: (012) 331 2565
E-mail: info@win-sa.org.za
Website: www.win-sa.org.za