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Western Cape Reconciliation Strategy Support

Strategic Assessment of Water Re-use Potential to Augment the Western Cape Water Supply System



FINAL REPORT

February 2010

CONSULTANTS

Milkwood in association with Aurecon

Milkwood COMMUNICATIONS (Pty) Ltd
We Change Minds, not ours, but the minds of those that you would like to see changed.

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**STRATEGIC ASSESSMENT OF WATER RE-USE POTENTIAL
TO AUGMENT THE WESTERN CAPE WATER SUPPLY SYSTEM**

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EXECUTIVE SUMMARY

1. INTRODUCTION

Milkwood Communications was requested by the Department of Water Affairs (DWA) to undertake a strategic assessment of the water re-use potential within the Western Cape Water Supply System (WCWSS) as part of the Reconciliation Strategy. The assessment would propose a way forward to utilise the City of Cape Town's (CCT's) effluent discharges, which are a potentially valuable resource. The results were presented at the Strategy Steering Committee (SSC) meeting held on 11 March 2009. This report highlights the main findings of the study.

The purpose of the study was to assess the potential for the re-use of water (treated effluent) as a water augmentation option for the City of Cape Town, specifically as an extension to the existing Western WCWSS. The study consisted of the following components:

- A review of previous water re-use studies undertaken by the CCT.
- A review of the latest information available on water re-use practice nationally and internationally.
- Obtaining up-to-date information on the availability and quality of treated effluent, as well as existing and potential re-use schemes.
- Identifying barriers to implement water re-use schemes and to put forward strategies to address these barriers.
- Conceptualising potential water re-use schemes and doing conceptual costings for them.
- Formulating a recommended strategic approach towards water re-use for augmentation of the WCWSS.

2. REVIEW OF PREVIOUS STUDIES

Water re-use has been studied as part of numerous different projects undertaken for the City of Cape Town and DWA over the years. These were reviewed, and the main conclusion is that in each case the re-use of water was found to have significant potential as a water resource, and in each case it was recommended that further studies be done to investigate this potential in more detail. The more specific main conclusions are summarised below:

- In all studies, it was found that direct re-use of treated effluent for irrigation and some industrial applications was cost-effective, and it was recommended that this be actively pursued to maximise its potential.
- It was found that there is considerable scope for direct re-use for non-potable purposes if some form of tertiary treatment could be undertaken to improve the quality slightly.
- Re-use for potable purposes was found to be too expensive still, but the recommendations were to continue with the necessary investigations to keep this as a potential future option.

3. REVIEW OF NATIONAL AND INTERNATIONAL PRACTICE

The latest information available on water re-use practices nationally and internationally were reviewed.

Case Studies

Ten case studies from South Africa and internationally were identified and assessed.

International Best Practice

The publication entitled *Best Practices for Indirect Potable Re-use: Phase 1 Report* by the Water Re-use Foundation (2004) was obtained from the USA. This study identified best practices that should be implemented to ensure that well-planned, indirect, potable re-use projects receive fair consideration in water supply decisions. Some valuable insights were provided, which are detailed in the main text of this report.

Water Quality Risks Associated with Water Re-use

One of the reasons that direct potable re-use does not find favour internationally is because of the many unknown factors that exist relating to the quality of the water, even after it has been through an advanced treatment process. Some examples of these factors are the higher pollutant loads due to increased population and industrialisation and the presence of contaminants of a complex chemical nature that could have damaging effects, for example Nitrosodimethylamine (NDMA), 1,4 Dioxane and endocrine disrupting compounds (EDCs).

Conclusions and Recommended Approach

It is proposed that, for augmenting the supply to the WCWSS, the focus should be on investigating planned, indirect, potable and non-potable schemes using advanced treatment processes such as reverse osmosis (RO), to be in line with international best practice. Direct potable and non-potable schemes should be included for comparative purposes, and to allow them to be brought to the fore, should direct potable re-use be favourably accepted in South Africa and within the supply area of the WCWSS. As a result of this approach, no new direct potable options were conceptualised as part of this strategic investigation.

4. CURRENT STATUS OF RE-USE IN CAPE TOWN

Volume of Effluent Available

Approximately 600 M³/d (218 Mm³/a) of treated effluent was discharged from the 16 wastewater treatment works (WWTW) in the City of Cape Town in 2007/2008. Most of the effluent (90%) is discharged from the eight largest works, with about half (53%) being treated at the two largest WWTW, namely Cape Flats and Athlone.

Seasonal Availability of Effluent

The effluent discharged varies seasonally, with the bulk of the effluent being available in the winter months (especially June, July, August), due to stormwater ingress into the sewers. Therefore to maximise the use of the treated effluent resource, this study focuses on all-year-round use.

Effluent Quality

The City does not comply with the current standards for effluent on a consistent basis. This lack of compliance can be attributed to the financial, operational and technical constraints being experienced by the CCT.

This study is proposing that only advanced treatment processes such as reverse osmosis (RO) be used. This level of processing will deal with most potential contaminants that may still be in the treated effluent, so for the purposes of this study, effluent quality is not of strategic importance. Should RO not be the preferred means of treatment, a detailed quantitative assessment will have to be undertaken of the water treatment process to ensure that the product water complies with the required water quality standards.

Quality constraints are, however, relevant for the local re-use proposed as part of the CCT's Effluent Re-use Master Plan, and need to be addressed in order to maximise the potential identified in the Master Plan.

Current and Planned Future Re-use of Treated Effluent in Cape Town

Currently, approximately 80.5 Mℓ/d (21.1 million m³/a) of treated effluent is used (10% of the total annual volume available). Of this, it is estimated that approximately 32.8 Mℓ/d (7.3 million m³/a, which is 35% of the annual volume re-used) replaces potable use; i.e. would contribute towards demand reduction.

The CCT has a Master Plan (CCT, 2007) in place for treated effluent use (as discussed in **Section 4.6** of the main text), and this has identified an additional 74.8 Mℓ/d (10.3 million m³/a) from April 2007. Approximately 56.5 Mℓ/d (7.0 million m³/a, which is 68% of the current annual volume used) replaces existing potable use.

This gives a total future re-use of 155.3 Mℓ/d (31.4 million m³/a) (14% of the total annual volume currently available). Of this, it is estimated that 89.3 Mℓ/d (14.3 million m³/a, or 46% of the current annual volume used) will replace existing potable water use in the City.

Most of the existing and potential re-use takes place in Summer. Of the current volume of effluent re-used (21.1 million m³/a), approximately 77% (16.38 million m³/a) is estimated to be Summer re-use, and the remaining 23% (4.9 million m³/a) is estimated to be Winter re-use.

The Master Plan set a limit on the cost of supplying treated effluent of R2.50/kℓ, which is approximately half the price of potable water.

The location of the existing and potential future pipeline networks for the distribution of treated effluent from the Master Plan is included in this report as **Appendix C** (A0 sheet at the back of the report). Existing pipelines are shown in red and potential future pipelines in green).

Surplus Effluent Available

It is estimated (Reconciliation Strategy Study) that the volume of effluent which would be discharged in the year 2020 will be 705 Mℓ/d (257 million m³/a). Assuming the Master Plan will be fully implemented by then, the total estimated surplus effluent available after proposed re-use in 2020 is 549 Mℓ/d (226 million m³/a). Most of this surplus is available in Winter. **Table 6.3** in the main text contains details of these estimates. Pie charts showing the surplus effluent available are given in **Figure 6.1** in the main text.

Of the eight largest works, treated effluent from Potsdam will be almost fully utilised by 2020, so this works was excluded from further consideration in this study. The estimated surplus from the remaining seven larger works is approximately 545 M³/d (200 million m³/a). This volume was considered to be available when conceptualising and costing the various potential schemes in this study.

5. POTENTIAL SCHEMES (COSTINGS)

The potential schemes put forward as part of this study are listed in **Table E.1** below in the appropriate categories of re-use. Each potential scheme is described in **Sections 7.1 to 7.6** of the main text of this report, and the locations are shown on **Figure 7.1** in the main text.

Table E.1 Potential Water Re-use Schemes put forward as part of this study

Category of re-use		Potential re-use scheme	
Planned direct	non-potable	CCT's Master Plan – re-use by industry and urban irrigation	
	potable	Blending option costed in Reconciliation Strategy Study (UWP) (integrated into WCWSS) (Schemes 4a and b)	
Planned indirect	non-potable	Berg River irrigation exchange	
		Irrigation Exchange (Stellenbosch) (Scheme 5)	
	potable	Discharge into existing dams / aquifers and integrate with the WCWSS	Steenbras Dam – existing (Scheme 1a)
			Steenbras Dam – raised (Scheme 1b)
			Berg River Dam (Scheme 2)
			Cape Flats Aquifer recharge (Scheme 3)
	Discharge into new dam (not costed)	Diep River (Platrug Dam)	
Benchmark against desalination (integrated into WCWSS) (Scheme 6)			

During the investigation it became evident that substantial increases in electricity costs were likely in the near future and this would influence the operating costs of the potential schemes. In order to make allowance for this, a cost of 31.4 c/kWhr was assumed to double in real terms by 2016.

Summary of Costs

The results of the costing exercise undertaken are summarised in **Table E.2** below, where unit reference values (URVs) for each scheme are given.

Table E.2 Comparison of URVs of Development Options

Options		Potential yield of scheme (million m ³ /a)	URV (real electricity increase) (R/m ³)	URV (no electricity increase) (R/m ³)
Scheme 1a	Return treated effluent to Steenbras	83	5.8	4.3
Scheme 1b	Return treated effluent to Steenbras (raised)	83	6.0	4.5
Scheme 2	Return treated effluent to Berg River Dam	83	5.8	4.4
Scheme 3	Recharge Cape Flats Aquifer	83	4.5	3.5

Options		Potential yield of scheme (million m ³ /a)	URV (real electricity increase) (R/m ³)	URV (no electricity increase) (R/m ³)
Scheme 4a	Planned direct potable use – Faure (blending ratio 1:4)	24	4.6	3.4
Scheme 4b	Planned direct potable use – Faure (blending ratio 1:2)	39	4.3	3.2
Scheme 5	Irrigation exchange (Stellenbosch)	5	-	3.0
Scheme 6a	Desalination	83	11.9	6.9
Scheme 6b	Desalination (into system)	83	13.1	7.7

Conclusions

The following conclusions can be drawn from the investigation into the comparison of the development options:

1. The development option where the treated water is pumped back to Steenbras Dam is technically feasible, but would place limitations on the operation and optimisation of the water resources within the WCWSS. The primary reason for this is that the additional water which is pumped into Steenbras Dam has to be pumped back to Faure and utilised to supply Winter demand, as no additional storage capacity is provided in the Steenbras Dam.
2. Pumping the treated water into the Berg River Dam or into a raised Lower Steenbras Dam would both be technically feasible options and would also not impact significantly on the operation of the WCWSS.
3. The cost of planned indirect use of treated water for potable supply is significantly cheaper than the desalination of sea water.
4. The cost and URVs of all of the development options are sensitive to real electricity tariff increases. The reason for this is that both desalination and the planned indirect use of treated effluent are energy-intensive processes.
5. Desalination of seawater is especially sensitive to real electricity tariff increases. This is due to the high total dissolved solids (TDS) of seawater and the high pressure required for the reverse osmosis process.
6. The development options proposed need to be modelled in the system model in order to ensure that the yields proposed are realised and that the proposed development options do not negatively impact on the operation and optimisation of the water resources in the WCWSS.

6. RECOMMENDED STRATEGIC APPROACH FOR THE FUTURE USE OF TREATED EFFLUENT

The overall conclusion which can be drawn from this strategic investigation is that significant potential exists for the large-scale re-use of water in the City of Cape Town, and that this resource can be integrated into the WCWSS.

The main recommendations are given below.

6.1 Investigate Planned Indirect Potable and Non-Potable Re-Use

In line with international best practice, it is recommended that indirect potable and non-potable re-use development options are pursued. Initial cost estimates for these indirect re-use options are promising, indicating that planned indirect re-use of water may compare favourably against other water resource development options. The planned indirect use of water is significantly cheaper than desalination.

6.2 Feasibility Study

It is recommended that CCT, in conjunction with DWA, initiate a feasibility study on both indirect planned re-use and direct planned re-use as a water augmentation scheme for the WCWSS. By comparing both planned indirect or planned direct water re-use from a technical, financial, environmental and social acceptability perspective, the CCT and DWA should be able to take a decision on the most acceptable way forward. The results of this feasibility study should be compared with those of the feasibility studies currently underway, such as the Mitchell's Pass Diversion, Voëlvelei Augmentation Phase 1, etc.

6.3 Best Practices

Recommendations from the publication on "*Best Practices for Implementing Indirect Potable Re-use Projects*" should be implemented, specifically:

- Create a perception of improvement
- Communicate all the benefits of indirect potable water re-use
- Understand and avoid environmental justice issues
- Understand and use track records
- Break source-to-tap connection
- Establish the Water Agency and investment as the sources of water quality (including the establishment of a separate monitoring body)
- Rename the water quality.

6.4 Local Re-Use

For those WWTW that are not candidates for supply to a large development option, local re-use options should be maximised. The focus for local re-use should be on those users who require year-round supplies as well as where the re-use would replace existing potable water use. The potential and cost-effectiveness of localised post-treatment to provide the required quality of water should also be investigated. This would involve the review of the threshold charge of R2.50/kℓ for treated effluent by the CCT.

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1. INTRODUCTION

Milkwood Communications was requested by the Department of Water Affairs (DWA), following a Western Cape Water Supply System (WCWSS) Strategy Steering Committee (SSC) Meeting held on 18 September 2008, to undertake a strategic assessment of the water re-use potential within the WCWSS, based on the City of Cape Town's (CCT's) effluent discharges, and to propose a way forward to utilise this potentially valuable resource. The results were presented at the SSC meeting held on 11 March 2009. This report highlights the main findings of the study.

2. TERMS OF REFERENCE OF STRATEGIC ASSESSMENT

The purpose of the study was to assess the potential for the re-use of water (treated effluent) as a water augmentation option for the City of Cape Town, specifically as an extension to the existing Western Cape Water Supply System (WCWSS). The study consisted of the following components:

- A review of previous water re-use studies undertaken by the CCT.
- A review of the latest information available on water re-use practice nationally and internationally.
- Obtaining up-to-date information on the availability and quality of treated effluent, as well as existing and potential re-use schemes.
- Identifying barriers to implement water re-use schemes and to put forward strategies to address these barriers.
- Conceptualising potential water re-use schemes and doing conceptual costings for them.
- Formulating a recommended strategic approach towards water re-use for augmentation of the WCWSS.

3. CATEGORIES OF WATER RE-USE

Water can be re-used in a number of different ways. **Table 3.1** summarises the three main categories of water re-use.

Table 3.1 Categories of water re-use

PLANNED Use is pre-planned to occur through an engineered system	DIRECT Treated effluent returned directly into the potable water supply system	POTABLE Use for potable purposes, eg. drinking water
		NON-POTABLE Use by industry, irrigation, domestic dual reticulation
	INDIRECT Treated effluent returned into a receiving water body, eg. dam, lake or aquifer, from where the water is abstracted again and treated for potable water supply	POTABLE
		NON-POTABLE
UNPLANNED Effluent is discharged into a river or water body and abstracted downstream for potable water supplies. Common worldwide	DIRECT	POTABLE
		NON-POTABLE
	INDIRECT	POTABLE
		NON-POTABLE

Many water supply projects around the world actually fall into the unplanned indirect potable re-use category, since towns in the upper reaches of catchments discharge treated effluent into the river, and towns downstream abstract water from the river, treat it, and supply it as potable water. The Thames River in England is often quoted as an example of this, but the Vaal River in South Africa is another example.

4. REVIEW OF PREVIOUS STUDIES

Water re-use was studied as part of numerous different projects undertaken for the CCT and DWA over the years. The studies are summarised in **Table 1** below, and reviewed in the sections that follow.

Table 4.1 Summary of previous studies

Date	Name of Study	Report Title and Reference in this Report	Undertaken by
1979	Masters Thesis for the University of Stellenbosch	An investigation into the reclamation of sewage effluent as a source of water supply to the Cape Metropolitan Area (Kapp, JF, 1979)	JF Kapp
1992	Western Cape System Analysis	Utilisation of less conventional water sources (WCSA Report Volume 27) (DWA, 1992)	DWA
1999	Strategic Evaluation of Bulk Wastewater	Water reclamation, a strategic guideline (CMC, 1999)	CMC
2001	Integrated Water Resources Planning Study	Main report (CTCC <i>et al</i> , 2001a), and Potential for the use of treated wastewater within the CMA (CTCC <i>et al</i> , 2001b)	CTCC
2002	Re-use of Treated Wastewater within the City of Cape Town	Re-use of treated wastewater within the City of Cape Town (City of Cape Town, 2002)	CTCC
2007	City of Cape Town Water Re-use Master Plan. Treated	Treated effluent re-use strategy, and Master planning within the City of Cape Town (City of Cape Town, 2007)	CTCC
2007	Western Cape Reconciliation Strategy Study	Treatment of effluent to potable standards for supply from the Faure Water Treatment Plant. June 2007 (DWA, 2007a), and Overview of water re-use potential from wastewater treatment plants (DWA, 2007b)	DWA

4.1 MASTERS THESIS

An Investigation into the Reclamation of Sewage Effluent as a Source of Water Supply to the Cape Metropolitan Area. November 1979

This investigation was undertaken for the purposes of a Masters Degree for the University of Stellenbosch by J F Kapp. The re-use of treated sewage effluent in the Cape Metropolitan Area was investigated with a view to establish a time-relationship for the introduction of water re-use in the area. The various forms of water re-use practiced globally were summarised, available technology was reviewed and health aspects considered. A sample of public opinion with regard to water re-use was presented and the overall position of water supply and demand as well as of sewage works in the Cape Metropolitan Area were reviewed. The conclusion reached was that there was no immediate need to re-circulate reclaimed water, both from a demand and supply and an economic point of view.

4.2 WESTERN CAPE SYSTEM ANALYSIS

Western Cape System Analysis – Utilisation of Less Conventional Water Sources. (WCSA Report Volume 27) (DWAF, 1992)

This study was undertaken by Ninham Shand for DWAF, and looked at direct potable re-use, direct non-potable re-use and desalination of seawater. The study also investigated using groundwater from the Cape Flats Aquifer, but this is not reported on now or in the previous study because the option involving artificial recharge of the aquifer directly with treated effluent (i.e. with no tertiary treatment) was considered too high a risk.

Direct potable re-use

This development option considered taking treated effluent from the four WWTWs along the False Bay coast, reclaiming it to potable standard using a physico-chemical process (i.e. not reverse osmosis) and blending it with water at the Faure Water Treatment Works. The costing of this scheme was based on the report on a pilot plant operated by the Water Research Commission (WRC) and the Cape Town City Council, which treated effluent from the Cape Flats Wastewater Treatment Works (WWTW) for 4½ years (WRC, 1990). The cost of water from this scheme was found to be high, but still lower than the desalination of seawater.

Direct non-potable re-use

This option involved exchanging treated effluent directly (i.e. with no further treatment) for 20 million m³/a of fresh water allocated to irrigators in the Stellenbosch area. The potential scheme was based on obtaining water from WWTWs along the False Bay coast and pumping it via a pipeline to a convenient distribution point. This would involve a pipeline some 45 km long, pumping against a head of about 350 m. The scheme that was costed was based on summer delivery only to a small balancing dam near the exit of the Stellenboschberg Tunnel. This scheme was re-costed in the Integrated Water Resource Planning (IWRP) Study, as described in **Section 4.4**.

Desalination of sea water

This option was based on taking cooling water from the Koeberg nuclear power station discharge canal and using the reverse osmosis process to purify it to potable standard. This was found to be the most expensive option, but it had the lowest health risks.

The yields, unit reference values and unit costs obtained in the study for the schemes described above are summarised in **Table 4.2** below.

Table 4.2 Yields and Costs of Sources Considered (portion of Table 27.4.1, DWA,1992)

Description	Yield		Unit Reference Value (R/m ³)	Unit Cost (R/m ³)
	(Ml/d)	million m ³ /a		
Irrigation Exchange Scheme (effluent for irrigation)	83 – 165	20	0.61 – 0.83	1.01 – 1.40
Direct potable re-use (at Faure WTW)	100 (module)	36 (module)	1.52	1.86
Desalination of sea water	140 (module)	50 (module)	3.02	5.56

Note: Costs in the above table are base dated 1991. A discount rate of 8% p.a. was used for the unit reference value (URV), and 17% p.a. for the unit costs.

The following conclusions were reached in that study:

- Exchange of irrigation water – this has possible merit but the extent to which it could be economically adopted is limited.
- Direct potable water re-use - could make a large contribution to augmenting the urban water supply, but the unit cost of water would be high. Also, despite the strictest precautions, there would remain some health risk and possibly also aesthetic and religious objections.
- Desalination of sea water was the most expensive source, but it is unlimited, involves little health risk, and is unlikely to raise objections from the public.

The overall conclusion was that, compared with the surface water sources that have been exploited so far, all the options are expensive and involve uncertainty, and (except for desalinated seawater) have significant health or other risks.

4.3 STRATEGIC GUIDE FOR WATER RECLAMATION

Water Reclamation: A Strategic Guide. (CMC, 1999)

This study was undertaken by Cape Wastewater Consultants for the (then) Cape Metropolitan Council (CMC) as part of the project entitled 'Strategic Evaluation of Bulk Wastewater'. Various development options were conceptualised and costed for direct potable and non-potable (commercial irrigation and industrial use) use, and indirect non-potable use (aquifer recharge). The costings of three of these schemes (commercial irrigation, direct potable use at Faure WTW and dual reticulation) were based on the costings done in the WCSA (DWAf, 1992), as described in **Section 4.6** of this report. It should be noted that the direct potable use scheme did not include treatment by reverse osmosis. The urban irrigation/industrial schemes were for proposed distribution of effluent from the Potsdam WWTW (Ninham Shand, 1998).

The costs of the various schemes, compared to the Skuifraam Dam and Supplement Scheme (now Berg River Project) are summarised in **Table 4.3** below.

Table 4.3 Comparison of Water Reclamation Options
(repeat of Table 5.17 from CMC, 1999)

Scheme	Yield (million m ³ /a)	Capital Cost (Rm)	Operation and Maintenance Costs (Rm/a)	Unit Reference Value (URV) (R/m ³)	Comment
Skuifraam Dam and Supplement	81	723	8.5	1.06	Excluding water treatment and distribution costs
Urban irrigation/ industrial*	1.1	19	0.14 – 0.19	0.30 – 0.41	
Commercial irrigation*	20	150	3.8	0.96 – 1.45	
Dual reticulation (new erven)*	28	218	2.9	1.19	-
Reclamation to potable standard (direct potable use)	35.5	248	43.3	2.18	Excluding water treatment and distribution costs

Note: Costs in the above table are base-dated February 1997

* indicates those costs that were based on costings in the WCSA (DWAf, 1992)

The conclusions drawn from the study were that:

- Urban irrigation/industrial use of reclaimed water based on local distribution networks is financially attractive and should be actively pursued.
- A more detailed study of the commercial irrigation option should be undertaken.
- A more detailed investigation of the possibility of installing dual reticulation networks should be undertaken.
- There is a considerable marginal premium for reclamation to potable standard before this becomes financially attractive relative to other options.

The main conclusion from this study was that water re-use has considerable potential and should be implemented.

Study Recommendations

The main recommendations from the study are summarised below:

Non-potable water re-use has considerable merit and should be actively pursued immediately.

The strategy for water reclamation needs to be structured around a long-term goal of “zero effluent discharge”. Since industrial and irrigation use would be insufficient to achieve this goal, it will be necessary to introduce potable re-use in the future, and this should be planned for. The following aspects will need to be considered to ensure that the introduction of potable re-use is a future option:

- a) **Institutional arrangements:** The management structures of the water and wastewater sectors need to acknowledge that they are dealing with the same resource.
- b) **Planning and design of wastewater treatment works:** The need to separate the domestic and industrial waste streams entering WWTWs was emphasised. This is currently done at the Atlantis WWTW, and the feasibility of establishing two separate waste streams in other existing WWTWs (for example Athlone WWTW) should be investigated. This should be standard practice for all new WWTWs that are planned.
- c) **Setting a medium-term goal for water reclamation:** It was suggested in the report that a medium-term goal of “zero effluent discharge” at mid-summer (at least for all effluent of domestic origin) be set. The basis for this goal was that there are water re-use options already available which are financially attractive and which would be beneficial to the environment. These are the opportunities for increasing the scale of irrigation with reclaimed water, and increasing the industrial use of water. The following steps were identified to achieve this medium-term goal:
 - Reclaimed water should be used for municipal watering of parks, gardens, roadside verges and islands.
 - A reticulation system should be installed on a planned and progressive basis in order to achieve this.
 - Industries should be surveyed to establish their water quality and quantity requirements and persuaded whenever possible to accept reclaimed water.
 - A more detailed, focused study of industries is recommended, with a view to establishing a comprehensive database which can be used as a planning tool on an ongoing basis.

- Municipalities should be encouraged to develop more detailed and rigorous records of their categories of water users.
- The feasibility of providing reclaimed water to areas with high garden/sports field watering use should be investigated in greater detail.
- The feasibility of providing reclaimed water to irrigation farmers in the Helderberg/Stellenbosch areas to replace fresh water supplies currently being used, should be investigated in greater detail.
- The introduction of some form of incentive should be considered to encourage developers to install dual reticulation systems.

It was recommended that the following specific studies be implemented:

- Project 1: Analysis and prioritisation of wastewater treatment works in the (then) Cape Metropolitan Area (CMA), with regard to the potential for water reclamation from the works.
- Project 2: Detailed studies for water reclamation from the Athlone and Cape Flats WWTW
- Project 3: Determine the implications of water reclamation for water demand management: and redefine water use scenarios for the CMA

Shortly after this report was completed, the six separate municipalities making up the CMC merged to form the CCT. Consequently, the recommendations from this report were not a high priority and were not implemented at that stage. Since then, the recommendations for further studies have been largely taken forward in the City of Cape Town's Masterplan (discussed in **Section 4.6**), and the Western Cape Reconciliation Strategy (discussed in **Section 4.7**).

4.4 INTEGRATED WATER RESOURCE PLANNING STUDY

Integrated Water Resource Planning (IWRP) Study: Main Report (CTCC et al, 2001a) and Potential for the Use of Treated Wastewater within the CMA. (CTCC et al, 2001b)

This study was undertaken by Ninham Shand and Arcus Gibb for the City of Cape Town as part of the Integrated Water Resource Planning Study. Three possible options were investigated, namely: reclamation to potable standard, irrigation exchange, and the potential for local use for irrigation and industry. The objective of the study was to ensure that all the major issues relating to each option were identified so that they might be addressed timeously.

Option 1: Direct potable re-use

This option is similar to that proposed in the Western Cape System Analysis (WCSA) (DWAF, 1992), and later in the Strategic Guide for Water Reclamation (CMC, 1999), but the design and costing was done in more detail, based on information from the (then) recent upgrade to the Windhoek reclamation plant. Treated wastewater will be pumped from the four WWTWs along the False Bay coast to a 125 Ml/d treatment works at the Faure WTW. The processes used are similar to those used at Windhoek, and exclude reverse osmosis.

It was recommended that a public participation process be used when the time comes for this option to be implemented.

Option 2: Direct non-potable re-use - Irrigation exchange

This option was originally put forward in the WCSA (DWAF, 1992) (described in Section 4.6 of this report), and later in the Strategic Guide for Water Reclamation (CMC, 1999) (Section 4.5) as having a yield of 20 million m³/a. During workshops that were held as part of the IWRP study, it was found that farmers would be unwilling to exchange more than 5 million m³/a of their

20 million m³/a allocation. Therefore design and costing of this alternative was based on a yield of 5 million m³/a.

It was envisaged that water would be pumped at a rate of 60 Ml/d from the Zandvliet and Macassar WWTW to a small balancing dam (0.5 million m³ capacity, i.e. 9 days storage capacity) near the exit of the Stellenboschberg Tunnel. This would entail a pipeline some 45 km long, pumping against a head of 350 m. From the balancing dam, the treated effluent would be distributed through the existing infrastructure. The scheme would only operate in summer for approximately 5 months.

Option 3: Direct non-potable re-use – local industrial and irrigation use

This study focused in detail on irrigation and industrial users close to the Athlone, Borchers Quarry and Bellville WWTWs. Areas which could be irrigated and industrial users were identified, and a reticulation scheme was designed and costed which would supply 12 million m³/a. No further treatment would be done on the wastewater.

The main features of the three options are summarised in **Table 4.4** below.

Table 4.4 Main Features of Options
(repeat of portion of Table 5.16.1 from CTCC *et al*, 2001)

Scheme	Yield (million m ³ /a)	Capital Cost (Rm)	Annual Costs (Rm/a)	Unit Reference Value (URV) (R/m ³)	Comment
Irrigation exchange	5	96	2	1.62	Yield low, cost very high, and very long to implement. Some environmental implications. Might have some resistance from farmers
Treated wastewater to potable standard (direct potable re-use)	46	864	71	3.10	Yield very high, cost very high, very long to implement. Some environmental, social and health concerns
Treated wastewater for local urban irrigation and industrial use	11	96	1	0.80	Yield reasonable, cost high, moderately quick to implement. Some environmental implications and health risk. Might have some consumer resistance

Note: costs in the above table are base-dated 2000

The study found that the costs of Option 1 and Option 2 were too high for immediate implementation, but that the potential for local use be pursued immediately. The following actions were recommended:

- undertake a detailed survey of all the industries, and consumers with potential local irrigation needs, whereafter this option should be re-assessed.
- carry out a further study to assess the quality required by industries and the quality produced at the WWTW.

The recommended investigations were undertaken in the form of the Master Plan implemented by the CCT (CCT, 2007), which is discussed in **Section 4.6** of this report.

A further recommendation was that reclamation should be taken seriously and in future when WWTWs are extended, or new works implemented, the final end-use should be identified and planned for in the design, taking into account the treatment objectives and standards needed.

4.5 RE-USE OF TREATED WASTEWATER WITHIN THE CITY OF CAPE TOWN

Draft Report: Re-use of Treated Wastewater within the City of Cape Town. December 2002

This is a report prepared for the City of Cape Town by GLS (City of Cape Town, 2002). The aim of the study was to get a better understanding of the potential for re-using treated wastewater for industrial/irrigation purposes within the CMA, and to refine the pre-feasibility wastewater re-use proposals contained in the Integrated Water Resource Planning (IWRP) Study.

A survey was undertaken to establish the actual demand for treated wastewater by irrigation and industrial users in close proximity to the Athlone, Borchers Quarry and Bellville WWTWs. Supply schemes to these users were then conceptualised and costed. It was found that the actual demand for the scheme was far less than what was assumed for the IWRP Study (3.1 million m³/a for this study, compared to 12 million m³/a in the IWRP Study). That meant that the URV was considerably higher (R1.01/m³ compared to R0.80/m³ for a 6% discount rate). Despite this, it was still economically worthwhile to implement the schemes, since the URV of additional bulk water, if supplied from the planned Skuifraam Scheme (now Berg River Dam) was estimated at R1.39/m³ for a 6% discount rate.

The following recommendations were made from that study:

- Maximise those re-use opportunities that would be the most economical, ie. those for which the treated wastewater effluent can be used directly with no additional post-treatment.
- Ensure that all WWTWs comply with the General Standard for Effluent.
- Implement a comprehensive monitoring programme to monitor the quality of effluent on an ongoing basis and provide remedial mechanisms.
- Address the problems at existing effluent re-use schemes such as Bellville, so that the current available potential is achieved.
- Investigate the potential of irrigation of municipal parks, public open spaces, reserves and islands with treated effluent on a city-wide level.
- Set up a live city-wide large water user database which can provide relevant information and assist the engineer in the decision-making process.
- Categorise the users in the large water user database and investigate the different categories for their potential for use of treated effluent.
- Design and cost new processes to treat effluent to a level suitable for use by the relevant large-user categories. Use this information to investigate the economic viability of re-use by each category.
- Evaluate the viability of on-site pre-treatment to required standards at various industries/categories.
- Design and implement a pilot project.
- Design and implement the main project.

4.6 CITY OF CAPE TOWN WATER RE-USE MASTER PLAN

Treated Effluent Re-use Strategy and Master Planning within the City of Cape Town. April 2007

This study was undertaken for the City of Cape Town (Water and Sanitation, Water Demand Management and Strategy) by BVI Consulting Engineers. The study is described in general terms in this section, and more detailed information, for example the estimated potential volumes for re-use and locations of new re-use pipelines, is given in **Section 6.4**.

Investigations were conducted into the re-use practices of 13 individual WWTW over the period 2003 to 2005. The investigations involved the following three components:

- Status of the infrastructure (pumps and pipelines) of the existing re-use scheme at each WWTW (where applicable).
- Quality of treated effluent being distributed, current level of service, and problems experienced by end-users.
- Investigation into the potential for expanding the distribution of treated effluent from each WWTW.

A series of 13 separate reports was produced in which recommendations were made regarding the potential for expansion of water re-use from these WWTW. These were later summarised into a single report (City of Cape Town, 2007).

The proposed expansions were designed at feasibility level and consisted of layout plans and costings. The designs were based on supplying potential large users within an economical distance of each WWTW. Industrial and irrigation users were identified, but the study did not look at supplying residential dwellings. As most of the users are irrigators, the bulk of the water re-use takes place in summer. The costings were based on a unit cost of R2.50/kℓ. The capital was discounted over the expected demand over a 20 year period at 6% interest. The Total Capital Cost required to develop the full potential is R222 million.

The proposed expansions of the water re-use reticulation schemes from each WWTW are being implemented in a phased manner, as the necessary funds become available. There is considerable pressure on capital expenditure budget, within the City of Cape Town, which makes it difficult to obtain the necessary budget approval for capital projects. Significant progress was made on Athlone WWTW in 2008/2009, when the CCT spent R35 million on installing the proposed northern pipeline, which is now complete. The CCT plans to install the southern pipeline from Athlone WWTW during 2010. Other plans for 2010 include a minor extension to the re-use pipeline from Kraaifontein WWTW, and major upgrades of the water re-use facilities at Belville WWTW and Macassar WWTW.

Barriers

It was found that the main barriers to developing the full potential for water re-use are the poor quality of the treated effluent produced by the WWTWs, and the lack of management structures to oversee the distribution of the treated effluent to end-users. These two points are interlinked, and require an integrated solution, as described below.

The quality of effluent provided by the WWTW is an important factor impacting on the effective distribution of treated effluent. A high level of control and monitoring is required to ensure the necessary standards are achieved. At present, not all the WWTWs treat effluent to the required

DWAF licence standards, and some provide no general disinfection. This has negative impacts on the end-users, who then reduce their use of re-used water in favour of treated water from the potable supply. The consultants found that there would be increased interest in making use of treated effluent if the quality could be ensured, and especially if the quality could be improved, even slightly (L Pienaar, pers comm.). In order to achieve the necessary level of control and monitoring, and to maintain the infrastructure adequately, the current management and reporting structures need to be modified.

Study Recommendations

- **Establish the current status.** It is recommended that the following be determined and actioned before any further expansions are undertaken:
 - Accurately determine the existing status of all infrastructure
 - Understand and address all existing delivery problems
 - Enter into contract agreements with all existing-users: enter them on the City's database (SAP) and ensure they are billed for water use before any further expansions are undertaken.

- **Modify the current management and reporting structures.**
 - Establish a dedicated management and control section for Treated Effluent
 - Set-up adequate lines of communication between the maintenance teams from Reticulation and the Treated Effluent management structure
 - Conduct workshops and information sessions to ensure that role players are informed of and support all proposals
 - Set-up a single line of reporting problems, statistical data and suggested improvements
 - Establish minimum Levels of Service (LOS) policy
 - Implement emergency measures to upgrade existing works to required LOS.

- **Establish a water re-use policy.** The study also identified a need to establish a policy for expansion of the water re-use network, based on the following aspects:
 - Quality of treated effluent available
 - Financial feasibility of schemes
 - Priority and need of end-users
 - Balanced development between large gains and social responsibility
 - The potential for private capital to be utilised.

- **Formulate an appropriate tariff policy.** It is proposed that this tariff policy be based on a cost recovery model, where the cost of the effluent treatment at the WWTW is excluded, as these costs are recovered under normal billing systems by the CCT.

- **Investigate Funding Alternatives**

One of the challenges faced in the maintaining and expansion of the re-use of treated effluent is to secure budget allocations in an ever-increasing competitive environment within the City's budget limitations. The various options are:

 - receiving normal budget allowance
 - ring-fenced unit within the City to utilise income (or a portion) from billing to improving and expanding the service
 - utilising private Capital by means of Public Private Partnerships.

Recent Accomplishments

The Water Demand Management (WDM) unit has been actively busy setting-up the basic management infrastructure for an effective treated effluent supply and monitoring service. Some of the main items put in place are:

- a single cost and profit centre for treated effluent
- 3 dedicated staff members appointed to assist with treated effluent supply
- all users visited and issued with standardised agreements
- signed agreements collected and kept on record
- all users entered into SAP for invoicing purposes
- all unmetered users are currently having meters installed
- all bulk supply lines are also receiving meters and data loggers to enable the collection of management information
- contracts for small remedial works such as filter repairs at various plants are also being set-up
- negotiations for possible Public Private Partnerships for the development of infrastructure are also underway, eg. Grand West Casino/Old Mutual for a project from the Athlone Works and Hartland Properties for a project through AECl properties in Somerset West from the Macassar Works.

4.7 RECONCILIATION STRATEGY STUDY

Reconciliation Study: Treatment of Effluent to Potable Standards for Supply from the Faure Water Treatment Plant. June 2007. (DWAF, 2007a), and Overview of Water Re-use potential from Wastewater Treatment Plants (DWAF, 2007b)

This was the most recent study undertaken and it formed part of the Western Cape Water Supply System: Reconciliation Strategy Study. The study made use of the City's Master Plan to provide an overview of the status of water re-use at the time. A potential development option for direct potable re-use was conceptualised and costed. This proposed development was a refinement of the scheme proposed during earlier studies, the main difference being the inclusion of reverse osmosis in the treatment of the effluent.

The proposed development option entails the use of the treated effluent from the Cape Flats, Mitchell's Plain, Zandvliet and Macassar WWTWs. The treated effluent will be pumped to and treated at a reclamation plant to be constructed at the site of the existing Zandvliet WWTW. The reclaimed water would then be pumped to the Faure WTW, where it could either be treated again, or be fed directly into the main distribution reservoirs. The main option costed involved full utilisation of the amount of treated effluent available in Summer, as detailed below:

Option 1:

Summer yield	=	166 Mℓ/d
Winter yield	=	166 Mℓ/d
Scheme yield	=	60.6 million m ³ /a

A second option involved using only 60 Mℓ/d in winter, giving a scheme yield of 41.2 million m³/a. The URVs for the above options were R1.29/m³ to R1.94/m³.

This was compared against the costs of other potential developments, including desalination, as shown in **Table5**.

Table 4.5 Summary of URV results obtained in the WCWSS Reconciliation Study (from pg ii, DWA 2007b)

Intervention	URV (R/m ³)	Source/Comment
Treated effluent to potable standards using reverse osmosis (direct potable re-use)	1.29 – 1.94	DWA 2007a. Includes costs of water and treatment
Treated effluent for commercial irrigation	2.77	URV updated from IWRP Study
Dual Reticulation	1.25	URV updated from IWRP Study
WC/WDM	0.3 – 0.7	URV updated from IWRP Study
Desalination	9.8	URV updated from IWRP Study. The actual URV would be location specific (includes water treatment and distribution infrastructure)

The conclusions from the study are summarised below:

- Treated effluent is a valuable water resource and should be considered in all future water-resource planning studies. There is a demand for treated effluent, especially for local irrigation, agricultural and industrial use. The re-use options investigated to date, particularly some of the non-potable use options, are cost competitive.
- The use of treated effluent for non-potable use is viable and should be aggressively pursued.
- The use of treated effluent for potable use, although appearing viable, requires further investigation before it can be considered for implementation because of uncertainties with regard to the social acceptability and the potential health risk.

The following recommendations were made:

- a strategic review of treated effluent as a water source to meet future supplies needs to be undertaken at both a national and municipal level.
- Identify those WWTW that produce higher quality effluent and are therefore better suited to service potable use schemes. Ring fence these works for the future.
- Investigate possible industrial re-use schemes and provide incentives if necessary.
- Investigate opportunities for using treated effluent to meet riverine reserve requirements.
- Investigate extending "local irrigation with treated effluent schemes, and to provide supplies for domestic gardening and/or toilet flushing.

4.8 CONCLUSIONS FROM STUDIES

The main conclusion from this review of past studies is that in each case the re-use of water was found to have significant potential as a water resource, and in each case it was recommended that further studies be done to investigate this potential in more detail. The more specific main conclusions are summarised below:

- In all studies, it was found that direct re-use of treated effluent for irrigation and some industrial applications was cost-effective, and it was recommended that this be actively pursued to maximise its potential.

-
- It was found that there is considerable scope for direct re-use for non-potable purposes if some form of tertiary treatment could be undertaken to improve the quality slightly.
 - Re-use for potable purposes was found to be too expensive still, but the recommendations were to continue with the necessary investigations to keep this as a potential future option.

5. REVIEW OF NATIONAL AND INTERNATIONAL PRACTICE

The latest information available on water re-use practices nationally and internationally were reviewed. Case studies are reviewed in **Section 5.1**, followed by a summary of international best practice in **Section 5.2**. Some of the potential water quality risks associated with water re-use are discussed in **Section 5.3**, and conclusions and a recommended approach are put forward in **Section 5.4**.

5.1 CASE STUDIES

Projects that have been implemented in South Africa and internationally were identified and assessed as to how they are performing. The major water re-use schemes in operation around the world today are listed in **Table 5.1** below in order of implementation date. More detailed descriptions of these projects will be given in the sections which follow.

Table 5.1 Case studies of water re-use

No	Scheme	Implementation Date	Category of re-use	Description	RO?
1	The Montebello Forebay Ground Water Recharge Project, Los Angeles, California, USA	1962	Planned indirect potable re-use	Recharge to an aquifer	No
2	Windhoek, Namibia	1968	Planned direct potable re-use and planned indirect potable re-use	Direct supply to water supply system and recharge to an aquifer. 26% - 36% of drinking water supply to 240 000 people	No
3	Orange County, California	1976 (current upgrade approved 2003 – completed 2007)	Planned indirect potable	Effluent treated at Water Factory 21 using RO, and used for aquifer recharge and as a seawater barrier. Capacity is 63 M/d and supplies 2 million people	Yes
4	Upper Occoquan Sewage Authority, Washington DC, Virginia	1978	Planned indirect potable	Conceived as a water quality improvement programme for Occoquan Reservoir, which is the principal water source for >1 million people. Capacity of scheme is 120 M/d. Occoquan Watershed Monitoring Laboratory was established at the outset	No
5	Atlantis, South Africa	Stormwater recharge – 1980. Treated effluent recharge – 1987	Planned indirect potable re-use	Recharge 4.5 M/d of treated effluent to the aquifer. 15 M/d is abstracted from this aquifer to supply 70 000 people. In addition, treated industrial wastewater is used as a barrier against saltwater intrusion near the coast	No
6	Hueco Bolson Recharge Project, El Paso, Texas, USA	1985	Planned indirect potable re-use	Supply to 250 000 people	No
7	Scottsdale Water Campus, Arizona, USA	1999	Planned direct non-potable and planned indirect potable	Water Campus consists of a 45 M/d WT plant for non-potable use, and a 38 M/d advanced WT plant (microfiltration and reverse osmosis) for groundwater recharge for potable use	Yes
8	Singapore's NEWater, Singapore	2003	Planned indirect potable and non potable re-use	Supply to industry and a dam. 1% of drinking water to 4.2 million people	Yes
9	Roodeplaas Dam, City of Tshwane, South Africa	2005	Planned indirect potable re-use	Supply to a dam	No

No	Scheme	Implementation Date	Category of re-use	Description	RO?
10	Queensland's Western Corridor Recycled Water Project, Brisbane, Australia	starting 2008	Planned indirect potable and non-potable re-use	Supply to industry, power station cooling water, and Lake Wivenhoe, the region's principal storage reservoir, from which water is abstracted for potable supplies. Three advanced Water Treatment plants with a total capacity of 232 M/d. About half will go to indirect potable use	Yes

Figure 5.1 below shows the various major milestones in water re-use since the direct re-use scheme started operation in Windhoek, Namibia in 1968, including the various technological advances that have been made since then.

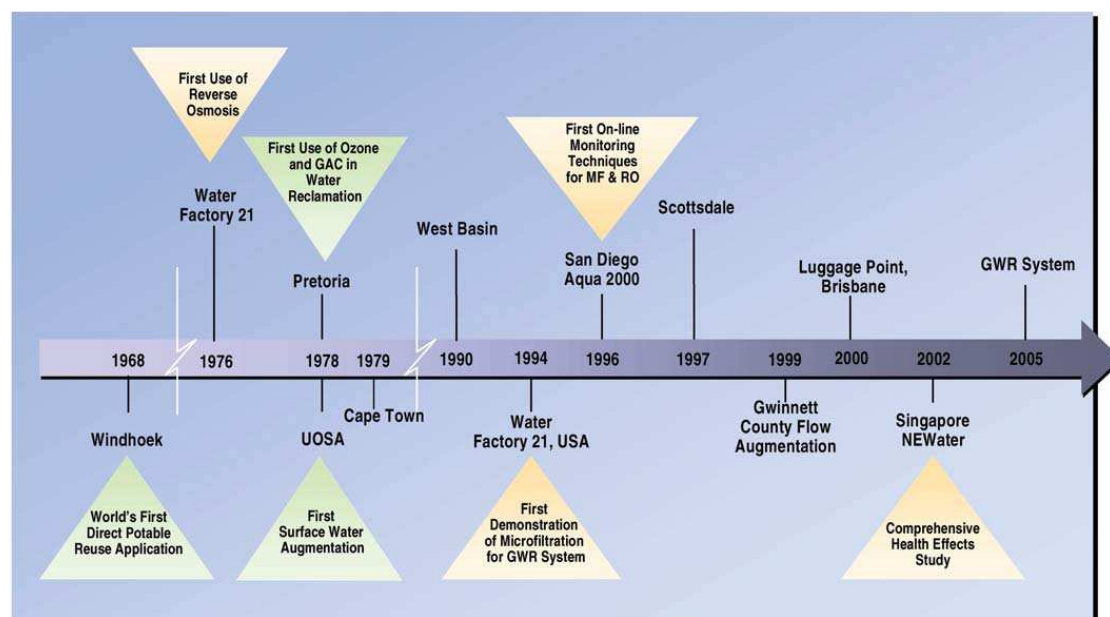


Figure 5.1 Salient milestones in advanced re-use applications (after Law, 2003)

Information given in this report regarding water treatment processes and water quality comes directly from the studied literature.

5.1.1 The Montebello Forebay Groundwater Recharge Project, Los Angeles, California, USA

Implementation date

The Montebello Forebay Groundwater Recharge Project replenishes the groundwater basin underlying the greater Los Angeles metropolitan area and has been in operation since 1962.

Category of re-use

Planned indirect re-use, through recharge to an aquifer. Water is reclaimed from wastewater at three reclamation plants through treatment to tertiary level and is then allowed to soak into the aquifer for storage for later use, using shallow 3.1 m deep spreading dams, as shown in **Figure 5.2**.



Figure 5.2 The Montebello Forebay Ground Water Recharge Project's Rio Hondo spreading grounds (after http://toxics.usgs.gov/highlights/ndma_biodegradation.html, accessed 17 November 2008)

Capacity and population supplied

The reclamation plants range in capacity from 49 MI/d to 380 MI/d. The quantity of reclaimed water now being recharged each year is equivalent to the water needs of a 250 000 people (AWWA, 1993).

Treatment process

According to http://www.cmhc-schl.gc.ca/en/inpr/su/waco/inpoware/inpoware_005.cfm (accessed 17 November 2008), the water reclamation plants were originally built as secondary treatment facilities, but inert media filtration was added in the mid-1970s as an additional measure for public health protection because of unrestricted body contact that was occurring in receiving streams. Wastewater is drawn from areas where there are strict controls on wastewater, and efforts are made to limit the inflow of industrial wastewater.

The first stage of treatment involves sedimentation with optional coagulation. Approximately two-thirds of the wastewater suspended solids (SS) are removed at this stage and returned to the sewer system for further treatment and disposal at the sanitation districts' joint water pollution control plant.

The second stage of treatment is biological oxidation using activated sludge, with polymer coagulation in the final clarifiers, if needed. Coagulation with alum and direct gravity filtration using either dual-media sand/coal or mono-media anthracite coal follow secondary treatment. Disinfection by chlorine is done before and after filtration, with 90 minutes of contact time following filtration.

Monitoring and quality control

Reclaimed water, as it leaves the treatment plant, is clear, colourless, and odourless, and meets the numerical standards for heavy metals, pesticides, trace organic compounds, minerals, micro-organisms, and radionuclides established for drinking water. The Montebello Forebay project combines extensive sampling and analysis of effluent from its three water reclamation plants and provides similar monitoring of six shallow monitoring wells within the confines of the spreading grounds and 19 production wells located upstream, downstream, and in the spreading grounds. Results of the combined monitoring program indicate that there has been no degradation of groundwater quality in terms of total dissolved solids (TDS), nitrogen, trace organics, heavy metals or micro-organisms despite the fact that historically up to 30% of the water recharged to this basin in a given year has been reclaimed water.

Substantial savings have been realised from the use of reclaimed water (AWWA, 1993). There has been absolutely no degradation of the groundwater quality, and the health of those people indirectly ingesting reclaimed water has not been adversely impacted in any detectable way. AWWA concluded that there was a significant amount of further replenishment that could utilize reclaimed water in Los Angeles and Orange Counties, if certain environmental, engineering, technical and regulatory considerations could be successfully addressed, thereby helping to alleviate the growing water supply problems in Southern California.

A number of studies have been undertaken over the years to determine if there were any possible health effects from the purified recycled water. These include:

- a five-year toxicological study started in 1978 (Nellor *et al*, 1984). The level of mutagenic activity was highest in storm runoff followed by dry weather runoff, recycled water, groundwater and imported water. The results from this study were used in 1987 to support the increase of the annual quantity of recycled water that was used to replenish the groundwater.
- The first epidemiological study was undertaken between 1969 and 1980. No consistent relationship was found between exposure to water that contained purified recycled water and illness rates (National Research Council, 1998).
- Another study examined adverse birth outcomes (Sloss *et al.*, 1999). The study examined the years 1982 through to 1993 and found no consistent association between residence in an area receiving recycled water and higher rates of these outcomes or any dose-response relationship between recycled water and the rate of these outcomes.

Other aspects of particular interest

It is said to be the first project that added purified recycled water to an underground aquifer in the USA.

5.1.2 Windhoek, Namibia

Implementation

Planned direct potable re-use has been taking place in Windhoek since 1968, when the original Old Goreangab Water Reclamation Plant (OGRP) was constructed. A photograph of the OGWRP is shown in **Figure 5.3**. Since then the plant has been graded regularly as technology has improved with time, and an additional reclamation plant was built in 2002 – the New Goreangab Water Reclamation Plant (NGRP).



Figure 5.3 The Old Goreangab Water Reclamation Plant, adjacent to the Goreangab Dam in Windhoek, Namibia. (after US EPA, 2004)

Category of re-use

Planned direct potable and non-potable re-use and planned indirect potable and non-potable re-use, (26% - 36% of drinking water).

Capacity and population supplied

Windhoek is the capital city of Namibia. It is located in an arid environment and all water resources within a radius of 500 km have been fully exploited. The population in 2007 was 240 000 people, with a growth rate of 5%/a, and a corresponding water requirement of 57.5 Mℓ/d or 21 million m³/a in 2007.

The OGRP had an initial production rate of 4.8 Mℓ/d in 1968. It now only supplies water for irrigation of sports fields and parks (direct non-potable re-use). The NGRP has a capacity of 21 Mℓ/d, which is 36% of the demand in 2007 (Menge, undated). It supplies the city with reclaimed water (direct potable re-use).

Historically, reclaimed water was only used during drought periods, but since 1980 and with increasing volumes since 1995, reclaimed water has become a permanent source of supply for the city. Projections are that direct reclaimed water could comprise more than 27% of supply by 2011, up from 15.4% in 2005 and 26% in 2007 (Lahnsteiner and Lempert (2007)). According to Du Pisani (2005), at present the maximum proportion of water supplied to Windhoek on an annual basis by the NGRP is 35%. According to Lahnsteiner and Lampert (2007) the maximum

portion of reclaimed water fed into the distribution system at any one time is 50% in times of water scarcity and low water demand (winter season). Originally, after commissioning of the NGRP, it was decided to limit the maximum percentage of reclaimed water to 35% of the total potable water released into the distribution network, but this was later raised to 50% because the NGRP constantly achieves low DOC values. Reclaimed water is generally introduced into the water supply system from the NGRP through blending with water from the Von Bach surface water scheme at a ratio of 1:3.

The City of Windhoek has very recently begun to direct some of the excess reclaimed water to recharge wells located in the aquifer that lies below and around the city, for storage of water for dry years. Before being pumped into the wells the water is treated even further to avoid contamination of the aquifer using granular activated carbon, filtration and chlorination (Van der Merwe, undated). Artificial recharge to aquifers could supply 39% of the annual water demand in dry years by 2019 (Van der Merwe, undated).

Treatment process

There have been four technology changes/upgrades at Windhoek since 1968, with the most recent being in 2000 when, amongst other changes, an ultrafiltration (UF) membrane filtration system was installed. As stated by Law (2003) it is unlikely that the treatment train that was initially implemented at Windhoek will ever be used again for potable re-use; it was considered appropriate at the time but would not be acceptable today.

Wastewater for reclamation at the NGRP is received from residential and commercial areas only via the Gammams wastewater treatment plant (WWTP). Wastewater from industrial areas is treated at another wastewater treatment plant and used for irrigation of pastures or discharged to a river. Wastewater is first treated at the Gammams WWTP to a high standard from where it is piped to the NGRP for further advanced treatment to drinking water standards.

The treatment process at the Gammams WWTP includes trickling filters (6 M³/d capacity) and activated sludge (12 M³/d capacity), with enhanced phosphorus removal. The effluents from each of these processes go to two separate maturation ponds for 4 to 12 days of polishing. Only the polished effluent from the activated sludge system is directed to the Windhoek reclamation facility from the Gammams WWTP. Water from the Goreangab Dam is also treated at the NGRP. The water quality of the Goreangab Dam varies and according to Lahnsteiner and Lempert (2007), the quality has deteriorated in recent years to the point where water is no longer abstracted from the dam for treatment in the NGWRP. After tertiary treatment at the NGWRP, reclaimed water is blended again with bulk water from different sources.

The treatment processes employed at the NGRP include (Lahnsteiner and Lampert (2007)) powdered activated carbon (PAC) dosing, pre-oxidation and pre-ozonation, flash mixing, enhanced coagulation and flocculation, dissolved air flotation, dual media rapid gravity sand filtration, ozonation, biologically active carbon (BAC), filtration, granular active carbon (GAC) filtration, ultra-filtration (UF), disinfection and stabilisation.

According to Lahnsteiner and Lampert (2007) the multiple barrier approach in place means that the treatment processes employed ensure that at least two (in many cases three or more) unit processes are provided for removing each crucial contaminant that could be harmful to the human body or aesthetically objectionable. For example, complete and/or partial barriers for one of the most resistant pathogens, *Cryptosporidium*, include ozonation, enhanced coagulation, dissolved air flotation (DAF), dual media filtration, ultrafiltration and chlorination. Similarly, five barriers have been included for organic substances, viz. enhanced coagulation, ozonation, BAC,

GAC adsorption and ultrafiltration. This ensures both micropollutant removal and degradation and results in a substantial reduction of the tri-halomethane (THM) formation potential.

The salinity of the potable water supply has increased by approximately 50% over the past 50 years. Partial desalination is being considered as a future process step for the NGWRP to stop or even reverse this trend (Lahnsteiner and Lempert (2007)).

Monitoring and quality control

According to Menge (undated) a rigorous monitoring and quality control system is in place in Windhoek covering the entire water cycle. Routine tests including physical, inorganic and organic chemistry, microbiology and viral indicators are performed. The health risk programme includes all the advanced tests such as virology, parasites, toxicity, mutagenicity, pharmaceutical substances, endocrine disruptors, pesticides, algae toxins and taste and odour compounds.

Water samples are taken every four hours at various points throughout the plant and analysed in the plant laboratory for basic quality control purposes. Refrigerated composite samples are taken twice per week and used for extensive analyses of all major water quality parameters as defined for guarantee values. Plant operation shows that the specified guarantee parameters can be easily met and a high quality drinking water is provided. These guarantee values that the final water produced by the plant must adhere to were based on World Health Organization (WHO) Guidelines (1993), Rand Water (South Africa) Potable Water Quality Criteria (1996) and the Namibian Guidelines for Group A water (NamWater, 1998) (Lahnsteiner and Lampert (2007)).

Risk studies and evaluations of toxicity and carcinogenicity have demonstrated that reclaimed water produced at the Windhoek facility is a safe and acceptable alternative water resource for potable purposes. Treatment capacity at the Windhoek treatment plant was increased to 40 Ml/d in 2004. According to Lahnsteiner and Lempert (2007), since the beginning of potable re-use in 1968 in Windhoek, no outbreak of waterborne disease has been experienced and no negative health effects have been attributed to the use of reclaimed water. This forms a prerequisite for acceptance by the population and an indication for the trust by the latter in potable re-use is the fact that less than 5% of the population uses additional point source treatment in their homes.

Costs

Unit reference values according to Van der Merwe (undated) in 2005 for the various supply options included costs of R5.55/m³ for potable direct re-use and R6.72 for injection of reclaimed water into the aquifer for later re-use.

Other aspects of interest

Windhoek is still the only place in the world where direct potable re-use takes place, i.e. where purified recycled water is provided directly as drinking water to the customer rather than added into an environmental buffer where the recycled water is mixed with groundwater or water from dams.

Research was carried out in Windhoek, Namibia during the 1970s and 1980s (Isaacson and Sayad, 1988). The study compared the occurrence of diarrhoeal disease in residents from an area receiving recycled water with one that did not. No statistically significant difference was found over the full six years of observation. For a two-year period of the study, the incidence of diarrhoea among those receiving conventional supplies was actually statistically significantly higher than those receiving recycled water.

No adverse effects have been noted from consumption of water that consists of the highly treated recycled water.

Sources

The information discussed in this section was sourced from the following references accessed via the internet, which are acknowledged with thanks: USEPA (2004), Law (2003), Lahnsteiner and Lempert (2007), (Menge, undated), (Van der Merwe, undated).

5.1.3 Orange County, California, USA (also termed Water Factory 21)

This project is also termed the Water Factory 21, and the more recent expansion is called the Ground Water Replenishment (GWR) System project.

Implementation

Water Factory 21 was implemented in 1976, and the GWR project in 2004.

Category of re-use

Planned indirect potable re-use by means of aquifer recharge. Aquifer recharge is also used to prevent seawater intrusion into the aquifer.

Capacity and population supplied

Water drawn from the Orange County aquifer is treated and provides drinking water for 2 million people.

Treatment process

The treated sewer water undergoes an advanced treatment process that includes two membrane filtration systems - microfiltration and reverse osmosis, and treatment by ultraviolet light and hydrogen peroxide. In fact Water Factory 21 was the first case of reverse osmosis used for water re-use when it was opened in 1976 (Law, 2003). Once purified, the water is sent to spreading basins. The newly purified water seeps into the ground, like rain, and blends with groundwater. Water is later pumped out of the aquifer for supply to the water treatment plant, for potable supply.

Injection of treated wastewater into aquifers for later supply is practised in the USA, especially in the drier western states. According to Law (2003), Water Factory 21 was being upgraded in 2004 using a treatment train similar to the one used in Singapore, using dual membranes followed by disinfection.

Monitoring and quality control

The Orange County Water Department (OCWD) has always implemented an aggressive water quality monitoring programme for the Water Factory 21 and the aquifer. Through this, and their appropriate responses to water quality problems as they have arisen, they have built trust in their ability to manage the scheme.

Other aspects of particular interest

Another goal of the GWR project is to reduce the volume of wastewater discharged into the ocean in order to reduce pollutant loads and ensure that beaches remain open. This has significant economic value for the region, as was highlighted by beach closures in the Summer of 1999.

Sources

Information in this section was sourced from the Orange County website (<http://www.gwrssystem.com/about/overview.html>), as well as the publication entitled 'Best Practices for Developing Indirect Potable Re-use Projects' (Water Re-use Foundation, 2004).

5.1.4 Upper Occoquan Sewage Authority, Washington DC, Virginia, USA

Implementation

In 1978, eleven small secondary wastewater treatment plants were replaced with one large advanced treatment works called the Upper Occoquan Service Authority (UOSA) Water Reclamation Plant, pictured below as **Figure 5.4**.



Figure 5.4 UOSA Regional Water Reclamation Plant
(source: <http://www.uosa-construction.org/index.asp>)

Category of re-use

Planned indirect re-use. Highly treated output from the UOSA Water Reclamation Plant supplies about 20% of the inflow into the Occoquan Reservoir.

Capacity and population supplied

Water from the reservoir is a source of drinking water for 1.2 million people. The capacity of the works is currently 159 M³/d average flow.

Treatment process

The water reclamation plant receives raw wastewater as an influent flow. It is treated initially by conventional wastewater treatment processes (screening, grit removal, primary and secondary clarification), which removes over 90% of most incoming pollutants and provides a high-quality effluent for subsequent advanced waste treatment polishing steps. Chemical advanced treatment includes the high-lime process to reduce phosphorous to below 0.10 mg/ℓ. This process also serves as a barrier to viruses, captures organics leaving secondary treatment, and precipitates heavy metals. Physical advanced treatment includes multimedia depth filtration and activated

carbon, aiming to reduce TSS to below 1 mg/ℓ and COD to below 10 mg/ℓ. Disinfection is provided in the form of a chlorination and dechlorination process.

Monitoring and quality control

An independent agency known as the Occoquan Watershed Monitoring Laboratory (OWML) was established to monitor water quality of the watershed. For over 25 years, the Upper Occoquan Sewage Authority (UOSA) has discharged recycled water to the Upper Occoquan Reservoir with no public health issues.

Other aspects of particular interest

The UOSA was the first planned indirect re-use scheme worldwide using a reservoir when it opened in 1978 (Law, 2003). The primary reason the scheme was implemented was to improve the quality of the water in the Reservoir, since the area has sufficient water supply from other sources.

Sources

Information in this section was obtained from the following websites:

www.toowoombawater.com.au and <http://www.uosa-construction>, and the following publication:

Water Re-use Foundation, 2004.

5.1.5 Atlantis, South Africa

Implementation

Recharging the sand aquifer with stormwater commenced in about 1980, and recharge with treated effluent commenced in about 1987 (King, 2009).

Category of re-use

Industrial and domestic wastewater are kept separate and are treated in two separate WWTW. The treated industrial wastewater is used as a barrier against saltwater intrusion near the coast (planned, indirect, non-potable re-use). The treated domestic wastewater is used to recharge the aquifer that is used for potable purposes (planned indirect potable re-use).

Capacity and population supplied

This scheme is located in the Atlantis area (70,000 people), situated 50 km north of Cape Town, South Africa. Two infiltration basins augment the aquifer storage capacity with 4.5 M/d (2 million m³/a) of treated wastewater. High-quality stormwater is also discharged to the aquifer. This water is subsequently abstracted after an underground residence time of about 1 year as part of a 15 M/d groundwater supply project.

Treatment process

Conventional tertiary treatment of wastewater.

Monitoring and quality control

There are 97 observation boreholes and wellpoints available to monitor the effect of the recharged water on the surrounding aquifer. Water levels and quality are monitored, and boreholes yielding poor quality water are avoided.

Other aspects of particular interest

According to US EPA (2004), this is the largest aquifer storage and recharge project in South Africa.

At present, the yield from the boreholes is lower than the potential yield because of clogging by iron bacteria. Rehabilitation of the boreholes would restore the full yield from the aquifer. The availability of imported surface water from Voëlvele Dam in recent years has led to the increase in the use of surface water in preference to spending the money on borehole rehabilitation in order to maximise the yield from the aquifer (Bishop, 2009).

5.1.6 Hueco Bolson Recharge Project, El Paso, Texas, USA

Implementation

The Hueco Bolson Recharge Project began operating in 1985.

Category of re-use

The project makes use of planned indirect re-use via the re-charge to an aquifer.

Capacity and population supplied

The Hueco Bolson Recharge Project involves treating wastewater to potable water quality standards and injecting it directly into the Hueco Bolson aquifer, which is the primary drinking water source for the city of El Paso, Texas.

Most of the wastewater collected for treatment at the Fred Harvey Water reclamation plant (FHWRP) is domestic, with less than 0.01% generated by industrial dischargers. Reclaimed water from the FHWRP is pumped from the clear well at the plant via a pipeline to the 11 injection wells for recharge. Production wells in the recharged well field pump water to the El Paso Water Utilities (EPWU) water supply system, where it is blended with other well water, chlorinated, and delivered to a population of more than 250 000 people. The capacity of the FHWRP is 38 Mℓ/d.

Treatment process

The ten-step treatment process includes screening, degritting, primary clarification, equalization, flow equalization, two-stage powdered activated carbon (PAC) treatment, lime treatment, two-stage recarbonation, sand filtration, ozonation, GAC filtration, chlorination, and storage. The 38 Mℓ/d system has two parallel 19 Mℓ/d systems.

The backbone of the overall treatment process is the two-stage biophysical PAC process. This process, which combines a conventional aerated biological treatment system with the use of PAC, provides most of the removal of organics and all of the removal of nitrogen compounds. The first-stage treatment consists of a reactor and clarifier, similar to an activated-sludge system, and provides carbonaceous removal and nitrification as well as adsorption of non-biodegradable organics. The second stage of the PAC treatment system uses methanol and denitrifying bacteria to remove nitrates and continue the adsorption of the organics.

High-lime treatment is used for wide-band heavy metals removal, high viral kills, and phosphorous removal. A two-stage recarbonation system using liquid carbon dioxide provides calcium carbonate equilibrium. After recarbonation comes sand filtration using automatic backwashing, traveling-bridge-type filters. Ozone is then used for primary disinfection, because of its advantages over chlorination in disinfection performance and in trihalomethane formation. GAC (granular activated carbon) filters are used as a polishing process for removal of residual organic compounds and reduction of taste- and odour-producing compounds, pesticides, synthetic organics, trihalomethane precursors and trihalomethanes.

Monitoring and quality control

To protect the Hueco Bolson aquifer, the EPWU goal is to produce water at the FHWRP that meets the U S Environmental Protection Agency's drinking water standards.

The existing FHWRP monitors the water for regulatory compliance and monitors other unregulated but important water quality parameters such as pathogens, heavy metals, and

organics. Bacteriological tests, conducted to make sure there are no disease-causing organisms in the effluent water, have shown an average total of 0 coliforms per 100 ml of effluent water. The average reduction for TOC is approximately 96%. The existing priority pollutant monitoring of the injection well system has detected only trihalomethanes, at levels well below the U.S. EPA limit of 100 µg/ℓ. Based on analysis of a special five-day sampling program, the FHWRP is effective in removing the priority pollutants that enter the plant.

Sources

The information in this section was sourced from the following website:

http://www.cmhc-schl.gc.ca/en/inpr/su/waco/inpoware/inpoware_008.cfm

5.1.7 Scottsdale Water Campus, Arizona, USA

Implementation

The design of the Water Campus began in 1995, construction began in 1996, and the first water was delivered in 1999.

Category of re-use

Planned direct non-potable re-use, and planned indirect potable re-use via recharge to an aquifer.

Capacity and population supplied

Water Campus consists of a 45 Mℓ/d water treatment plant for direct non-potable use, and a 38 Mℓ/d advanced water treatment plant for groundwater recharge for potable use.

Treatment process

The water used for non-potable purposes is treated to a tertiary level, and is safe for body contact. The majority of this water is used for irrigation of golf courses, parks and road medians. The water used for potable purposes undergoes advanced treatment, including microfiltration and reverse osmosis. The resulting water exceeds Federal drinking water standards. It is injected via dry wells into the aquifer from which the City of Scottsdale obtains its drinking water.

Monitoring and quality control

The water quality laboratory is located within the main building of the Water Campus and analyses water samples to ensure compliance with water quality standards.

Other aspects of particular interest

This project contributes towards satisfying the legal requirement of the State of Arizona's 1980 Groundwater Management Code, which requires that groundwater aquifers be recharged to replenish what is withdrawn. It was approved by more than 70% of those that voted on the project in 1989.

Sources

The information in this section was sourced from the following publication: Water Re-use Foundation, 2004.

5.1.8 Singapore's NEWater, Singapore

Implementation

Water re-use was first implemented in Singapore in 2003. It is part of a strategy by the Public Utilities Board (PUB) to provide Singapore with a diversified and sustainable water supply. The term NEWater has been adopted to describe the water, which is one of four sources in the 'Four National Taps' strategy. The other sources of water are local supplies, imported water (from Malaysia) and desalinated water.

The first NEWater plants were officially opened in 2003 at the Bedok and Kranji water reclamation plants (similar to South African wastewater treatment plants). A visitor's centre was also opened at this time to educate the public about NEWater. A third NEWater plant was opened at the Seletar water reclamation plant in June 2004. A fourth NEWater plant was opened in March 2007 in Ulu Pandan. This plant is privately designed, built, owned and operated (DBOO) and is designed to supply 120 M ℓ /day (32 million gallons per day) of NEWater for 20 years. The fifth, and largest NEWater plant is currently being constructed at the Changi water reclamation plant, as shown in **Figure 5.5**. It is also privately DBOO. It currently supplies 69 M ℓ /day, but will supply 188 M ℓ /d (50 mgd) when it is completed in 2010.

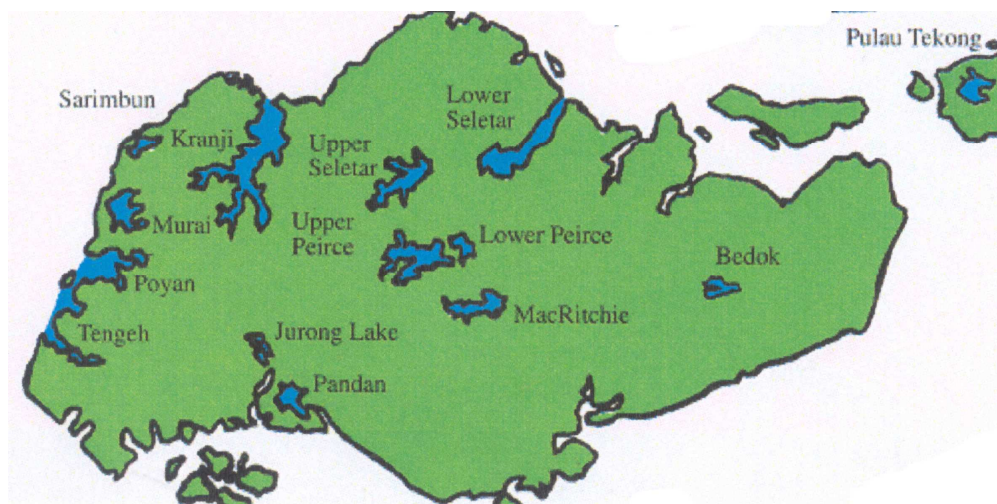


Figure 5.5 Sembcorp Changi NEWater Plant (Source: <http://www.channelnewsasia.com/stories/singaporelocalnews/view/446564/1/.html>)

Category of re-use

NEWater is used for planned direct non-potable uses in the industrial and commercial sector, for example in electronics factories and power generation plants, in the air-conditioning cooling systems of commercial and institutional complexes, and for landscaping. It is also used for planned indirect potable use by being discharged to reservoirs.

Until recently, Singapore had 14 reservoirs with a total storage capacity of 142 million m³, covering approximately half the land area of the country. The location of these reservoirs is shown in **Figure 5.6**. Some of the reservoirs are impoundments of natural runoff only, while many of them also act as storage for stormwater runoff collected elsewhere and pumped into the reservoir. The recently completed Marina Barrage (the first urban reservoir) brings the number of reservoirs in that country to 15, with plans to build two more urban reservoirs in the next few years increasing the land area covered to two thirds.



Source: Map from Public Utilities Board cited in <http://homepage.mac.com/voyager/NoPlace/ctlb.html>

Figure 5.6 Map of Singapore's Reservoirs

The retention time of recycled water from the Bedok NEWater plant in the Bedok Reservoir was estimated to be three to six months (Membrane and Separation Technology News, March 2003). **Table 5.2** below lists the five existing NEWater plants and the name and capacity of the adjacent reservoirs (Lee, 2005).

Table 5.2 NEWater Plants and adjacent Reservoirs

Name of NEWater plant	Date completed	Adjacent Reservoir	
		Name	Capacity (million m ³)
Bedok	2003	Bedok Reservoir	23.2
Kranji	2003	Kranji Reservoir	22.5*
Seletar	2004	Upper and Lower Seletar Reservoirs	24.1
Ulu Pandan	2007	Pandan Reservoir	22.5*
Changi	2009/2010	Not known	-

* indicates the combined capacity of Kranji and Ulu Pandan reservoirs

Capacity and population supplied started

In February 2003, the PUB started pumping 7.5 Mℓ/d (2mgd) of NEWater into reservoirs for indirect potable use. This equated to about 1% of the drinking water for 4.2 million people. The aim is to increase this progressively to 38 Mℓ/d (10 mgd), or an estimated 2.5% of total potable water consumption by 2011.

The NEWater provided directly to non-potable users is in addition to the abovementioned amounts.

The four existing NEWater plants currently supply more than 15% of Singapore's total (potable and non-potable) water requirements. The aim is that 30% of Singapore's water requirements will be supplied by NEWater by 2010, once the Changi NEWater plant is fully operational.

Treatment process

NEWater is the product of a multiple barrier water reclamation process:

- The first barrier is the conventional wastewater treatment process whereby the used water is treated in the Water Reclamation Plants.
- The second barrier, and first stage of the NEWater production process, uses microfiltration/ultrafiltration to filter out suspended solids, colloidal particles, disease-causing bacteria, some viruses and protozoan cysts. The filtered water that goes through the membrane contains only dissolved salts and organic molecules.
- The third barrier, and second stage of the NEWater production process, utilises reverse osmosis (RO). In RO, a semi-permeable membrane filters out undesirable contaminants such as bacteria, viruses, heavy metals, nitrate, chloride, sulphate, disinfection by-products, aromatic hydrocarbons, and pesticides that cannot pass through the membrane. Hence, NEWater is free from viruses and bacteria and contains very low levels of salts and organic matter. At this stage, the water is of a very high quality.
- The fourth barrier, and third stage of the NEWater production process, acts as a safety precaution. UV disinfection is used to ensure that all organisms are inactivated and the purity of the product water guaranteed. With the addition of some alkaline chemicals to restore the pH balance, the NEWater is ready for use.

Monitoring and quality control

According to Lee (2005), the prototype NEWater plant had to undergo a sampling and monitoring programme for two years before an expert panel concluded on its robustness and reliability. Not only did the plant pass the physical and engineering tests but the quality of NEWater was found to be in line with parameters and standards set by the US Environmental Protection Agency and the World Health Organisation. This verdict was arrived at after some 20,000 comprehensive chemical and microbiological tests and analyses were conducted (PUB Annual Report 2002). It was found that the quality of the water produced was purer than that of potable water now produced by the PUB.

The most recent audit of the quality of NEWater in July 2009 found the quality to be consistently high, "even with additional parameters to be monitored and lower levels of detection through more sensitive instrumentation". Currently the water is tested for 290 physical, chemical and microbiological parameters. (http://www.desalination.biz/news/news_story.asp?id=4939)

Costs

Lee (2005) estimated that NEWater would cost RM 3.71/4.546/m³ in 2005, which at December 2005 exchange rates would be about R2.60/m³.

Other aspects of particular interest

Singapore's Environment and Water Industry Council (EWI) is responsible for growing the water and environment industry in Singapore. It aims to promote Singapore as an R&D base for water technologies, so that these skills can be marketed globally.

The PUB has won two Global Water Awards to date. In 2006, the agency was named Water Agency of the Year, and in 2008, NEWater was awarded the title "Environmental Contribution of the Year", for a water or wastewater plant leaving a small environmental footprint. In 2002, NEWater also won the "Environmental Contribution of the Year" award from the National Water Research Institute of the United States for the NEWater Demonstration Plant. The "Award of Excellence" was given in recognition of the PUB's outstanding contributions to microfiltration technology. (source: <http://www.wateronline.com/article.mvc/NEWater-Wins-Its-Second-International-Award-0001>)

Sources

The information in this section was sourced from the following websites:

<http://en.wikipedia.org/wiki/NEWater>, http://infopedia.nl.sg/articles/SIP_1555_2009-08-11.html,
http://www.ecologyasia.com/news-archives/2003/feb-03/straitstimes_030222_1.htm,
<http://www.pub.gov.sg/mpublications/Pages/PressReleases.aspx?ItemId=42>

5.1.9 Roodeplaat Water Treatment Works, Roodeplaat Dam, City of Tshwane, South Africa

Implementation

This WTW began operating in 2005.

Category of re-use

The scheme makes use of planned indirect potable re-use. The City of Tshwane commissioned a 60 Mℓ/d WTW which draws water from the Roodeplaat Dam. The Roodeplaat Dam in turn receives a relatively large proportion of its inflows from effluent from WWTWs located a few kilometres upstream.

Capacity and population supplied

The WTW has a capacity of 60 Mℓ/d. Water produced by the plant supplies the areas to the north of the Magaliesberg such as Montana and Wonderboom.

Treatment process

The treatment process includes the following components:

- dissolved air flotation (DAF)
- sedimentation
- rapid gravity sand (RGS) filtration
- UV disinfection
- chlorination.

The plant is part of the Roodeplaat Temba Water Services Trust and features a high level of automation with SCADA and remote communication systems.

Monitoring and quality control

Roodeplaat Dam experiences severe eutrophication and algal growth problems due to the high nutrient loads from the WWTW effluent discharged into the dam. This poses a challenge to the WTW to produce water of a suitable quality, particularly with respect to taste and odour.

According to the Magalies Water Annual Report (2007), the newly constructed Roodeplaat WTW was commissioned in September 2005 but the plant proved from the beginning to pose insurmountable challenges during the commissioning stages, resulting in deteriorating water quality. Magalies Water therefore launched an expanded water quality monitoring program in the reticulation system which assisted Magalies Water in identifying and addressing some of the causes of the poor water quality. By 2007 water quality had improved due to timeous intervention strategies and water quality complied with SABS 241: Class 1.

Other aspects of particular interest

The problems relating to the quality of the water from Roodeplaat Dam have led to the abstraction point for the WTW at the dam wall being modified to enable water to be drawn off at the depth which would supply the best quality water. Two new outlets were added, and it is estimated that this will result in a substantial saving in the cost of chemicals (Pollard *et al*, 2009).

Sources

Information in this section was sourced from the following website:

<http://www.magalieswater.co.za/water%20services.htm>

5.1.10 Western Corridor Recycled Water (WCRW) Project for Brisbane, Queensland, Australia

Implementation

This project is the largest recycled water project in Australia and began operating in December 2008. It involved the construction of three advanced water treatment (AWT) plants, over 200 km of large diameter pipelines, nine major pumping stations, and several balancing and storage tanks.

Category of re-use

The project supplies purified recycled water for indirect potable and non-potable use. Treated water is released into Lake Wivenhoe, where it has an estimated retention time of six months or more. It is later released downstream into the Brisbane River. It flows downstream for approximately 40 km before reaching the intake works of the Mount Crosby Water Treatment Plant, where it is treated and then distributed for potable use. The non-potable application is for cooling water for the Tarong and Swanbank power stations.

Capacity and population supplied

At full capacity, the project is capable of supplying a total of 232 Mℓ/d of high quality reclaimed water in the South East Queensland Water Grid, which supplies potable water to the cities of Brisbane and Ipswich. The Bundamba and Luggage Point AWT Plants each have a capacity of 66 Mℓ/d, and the Gibson Island AWT Plant has a capacity of 100 Mℓ/d. The proportion of purified recycled water that will end up in public supply is estimated to be 10% under 'normal' conditions, but will obviously be higher in drought conditions.

The WCRW Project is currently receiving 165 Mℓ/d of wastewater. The policy is to supply industry and high value uses first, before putting water from the WCRW Project into the drinking supplies. Since the drought conditions in South East Queensland have eased recently, a decision was made to only commence indirect potable supply when the reserve levels reach a level of 40%. Before this, the policy was to continue indirect potable supply regardless of dam storage levels. (Dennien, 2009, personal communication).

Treatment process

Influent treated wastewater to the AWT plants is supplied from six existing wastewater treatment plants in the cities of Brisbane and Ipswich, which receive mixed wastewaters from industry and a combined residential population of one million. All wastewater treatment plants include a biological nutrient removal stage, resulting in nitrogen and phosphorus levels being reduced to less than 5 mg/ℓ and 3 mg/ℓ, respectively.

The treatment process used at all the AWT plants consists of the following components:

- A clarifier pre-treatment stage to remove suspended solids and phosphorus.
- Membrane microfiltration.
- Reverse osmosis.
- An advanced oxidation stage in which hydrogen peroxide is used in combination with UV irradiation to offer additional security against protozoa, viruses and organics. (It is interesting to note that this stage is not used in some other potable re-use schemes (for example Singapore), but is required in terms of recent Australian legislation).
- Before discharge, the water is chemically adjusted and chlorinated.
- Dechlorination is provided where water is discharged to the natural environment.

- At those AWT plants where the incoming feed water is dosed with ferric chloride to aid coagulation and precipitation in the pre-treatment clarifiers, further phosphorus removal takes place. It is estimated that this additional treatment will mean that about 90% of the phosphorus that would have been discharged to receiving waters from the six wastewater treatment plants, will be removed.

Monitoring and quality control

A separate advisory panel has been set up by the Queensland Water Commission (QWC) to deal with water quality issues. Their responsibilities will include monitoring the operating procedures in the AWT plants, and the appropriate validation and verification controls. They will also possibly become involved in controlling the influent to wastewater treatment plants, particularly where it is known that synthetic organic chemicals and other harmful wastes are in use.

Costs

The total cost of the project was US\$2,3 billion.

Other aspects of particular interest

The project was originally intended to focus on conserving raw water by supplying water for irrigation and power station cooling water, with the indirect potable re-use option being a possible future option. The prolonged drought prompted the early implementation of the indirect potable re-use option.

Sources

Information in this section is sourced from an article in the October 2008 issue of Water21, entitled "Australia's largest recycled water project: Queensland's Western Corridor" (pgs 16-18) by Bill McCann, and the project's website: <http://www.westerncorridor.com.au>.

5.2 BEST PRACTICE

The publication entitled *Best Practices for Indirect Potable Re-use: Phase 1 Report* by the Water Re-use Foundation (2004) was obtained from the USA. The goal of the study was to identify best practices to ensure that well-planned, indirect, potable re-use projects receive fair consideration in water supply decisions. Marketing, communication and technical professionals were brought together and came up with 25 best practices.

Six case studies were chosen to compare against this list of best practices. Three of the case studies were successfully implemented, and are the first three examples listed in **Table 5.1** (Orange County California Groundwater Recharge System (USA), Upper Occoquan Sewage Authority (Virginia, USA) and Scottsdale (Arizona, USA)). The other three case studies were not implemented due to negative public opinion. Each case study was compared against the 25 best practices, and the best practices refined accordingly. The list of best practices from the publication are given in **Appendix A**.

A number of the best practises relating to implementation risk are highlighted below (excerpts from the document):

Risk-based best practices

Understand and avoid environmental justice issues

"Don't use minority groups or previously disadvantaged groups as "guinea pigs". Ideally the leaders proposing the project should be in the community that is being supplied. Don't offer lower rates for the water."

Understand and use track records

"The track record of the local water agency should be used to build confidence that the water quality will continue to be of a high standard should the water re-use project be implemented. The health and safety records of existing water re-use projects can also be cited."

Break the source-quality connection

"This can be achieved by using multiple barriers (i.e. ultra filtration, reverse osmosis and UV radiation) and by ensuring a redundancy of barriers. An example of this is returning the purified water back to a water resource and then ultimately treating the raw water again by means of a conventional treatment process. The public should be made aware that the water being returned to the resource will be of a higher quality than the existing water in the resource."

For example: this study was originally called a "Strategic Assessment for the Use of Treated Effluent in the City of Cape Town", but the title of the report has been changed to exclude the words "Treated Effluent", as a first step in this recommendation.

Articulate an ongoing Water Quality Plan

"The public will be more confident if they are shown a plan for increasing knowledge about risks and improving quality over time, as well as an emergency response plan. These will show that the diligence of the water utility is what ensures quality and safety, not the physical source of the water."

Other best practises would include the following:

Establish the Water Agency and Investment as the Sources of Water Quality

"People tend to associate water quality with its physical source. Yet for years, water quality has depended more on the level of investment in treatment and monitoring than the source. Surface water has not generally been "fit to drink" for over a century. The water utility has been protecting the public health and creating safe, potable water from low quality sources throughout this history."

"Establishing the water utility as the trusted source of water quality is an opportunity to enhance the reputation of the water utility and increase support for water and environmental projects."

Communicate all the benefits of indirect potable re-use

"Community leaders will support or consent to indirect potable re-use if they believe that the benefits greatly outweigh the risk. Indirect potable re-use will have to be accurately positioned against the other alternatives in order for it to get fair consideration. The benefits can be stated in terms of the problems that it solves:

- under-utilisation of water
- climate dependency of water supplies
- need for investment in separate infrastructure
- under-utilisation of "potable" storage assets
- "unplanned" indirect potable re-use is already happening
- increases surface water quality.

Water quality is dependent more on treatment and monitoring and less on the physical source of the water. Indirect potable re-use projects typically (and should) lead to higher water quality."

Rename the water quality

"The terms "recycled water" or "reclaimed water" do not have to be used to describe a project. These terms emphasise the source of the water. "Recycled" implies "re-used". How many people buy re-used clothes or re-used tyres? Re-used, recycled and reclaimed imply second class, not the best of class. Choose another term such as "purified", "highly purified" or simply "drinking water" to convey the higher quality of the water. The term purified will be more easily accepted if processes such as reverse osmosis are being proposed and installed. Disapproving slogans can create a negative idea of value. Agencies should consider creating a new idea of value to associate with the new name. In the Scottsdale case study, the water department effectively branded the wastewater effluent as a "valuable resource".

Singapore is using the term "NEWater".

5.3 WATER QUALITY RISKS ASSOCIATED WITH WATER RE-USE

One of the reasons that direct potable re-use does not find favour internationally is because of the many unknown factors that exist relating to the quality of the water, even after it has been through an advanced treatment process. A lot of the concerns also apply to receiving waters, ie:

- Increased population and industrialisation are creating higher pollutant loads on the receiving waters.

- Due to technological advances, many of the contaminants are of a complex chemical nature that could have damaging effects. In most cases, these effects, and the levels at which they occur, are not known.
- Some of the trace organics that have been found in low concentrations in surface and reclaimed waters internationally are compounds such as Nitrosodimethylamine (NDMA), 1,4 Dioxane and those chemicals that are classified as endocrine disrupting compounds (EDCs).
- There is a problem relating to testing for these contaminants because currently only a small fraction of the contaminants present in surface water and groundwater can be identified (Law, 2003).
- Improvements in detection technology now allows for the detection of known contaminants at much lower levels, and has also led to the discovery of new contaminants (Law, 2003).

5.4 CONCLUSIONS AND RECOMMENDED APPROACH

The literature review showed that water re-use is being undertaken in many countries, and that it is becoming more and more widespread. There is a concentration of case studies in the more arid regions where water is especially scarce, for example Windhoek (Namibia), California (USA) and Australia. Other countries where re-use takes place are Singapore, Belgium and Spain. Re-use tends to be mainly for non-potable purposes, for example irrigation of crops, golf courses and urban spaces, industrial use and, to a lesser extent, dual reticulation in households.

Where re-used water is used for potable purposes, it is mainly via planned indirect re-use. The only place in the world that currently practices direct potable re-use is Windhoek, Namibia. All other re-use for potable purposes is indirect, where additional safety is provided in the form of an environmental buffer (eg. river or dam). Indications are that, if a direct potable re-use scheme was initiated now in Windhoek, it would be unlikely to obtain the necessary approval (pers comm. P du Pisani (City Engineer, Windhoek), February 2009). The literature survey indicates that current expert opinion is that planned indirect re-use for potable purposes is viable and safe, but measures have to be put in place to continuously monitor the water quality.

Recent projects in the water re-use field in South Africa have included proposals for direct potable re-use, for example in Dargle (Umgeni Water), Durban (eThekweni Municipality) and Sedgefield. Although these schemes are in the early stages, indications are that direct potable re-use is being favourably received in those areas, and it will be interesting to monitor these projects as they progress.

It is proposed that, for augmenting the supply to the WCWSS, the focus should be on investigating planned, indirect, potable and non-potable schemes making use of advanced treatment processes such as RO, to be in line with international best practice. Direct potable and non-potable schemes should be included for comparative purposes, and to allow them to be brought to the fore, should direct potable re-use be favourably accepted in South Africa and within the supply area of the WCWSS. As a result of this approach, no new direct potable options were conceptualised as part of this strategic investigation. The costs of the direct potable scheme put forward in a previous study (Reconciliation Strategy Study) were updated for comparison purposes.

6. CURRENT STATUS OF RE-USE IN CAPE TOWN

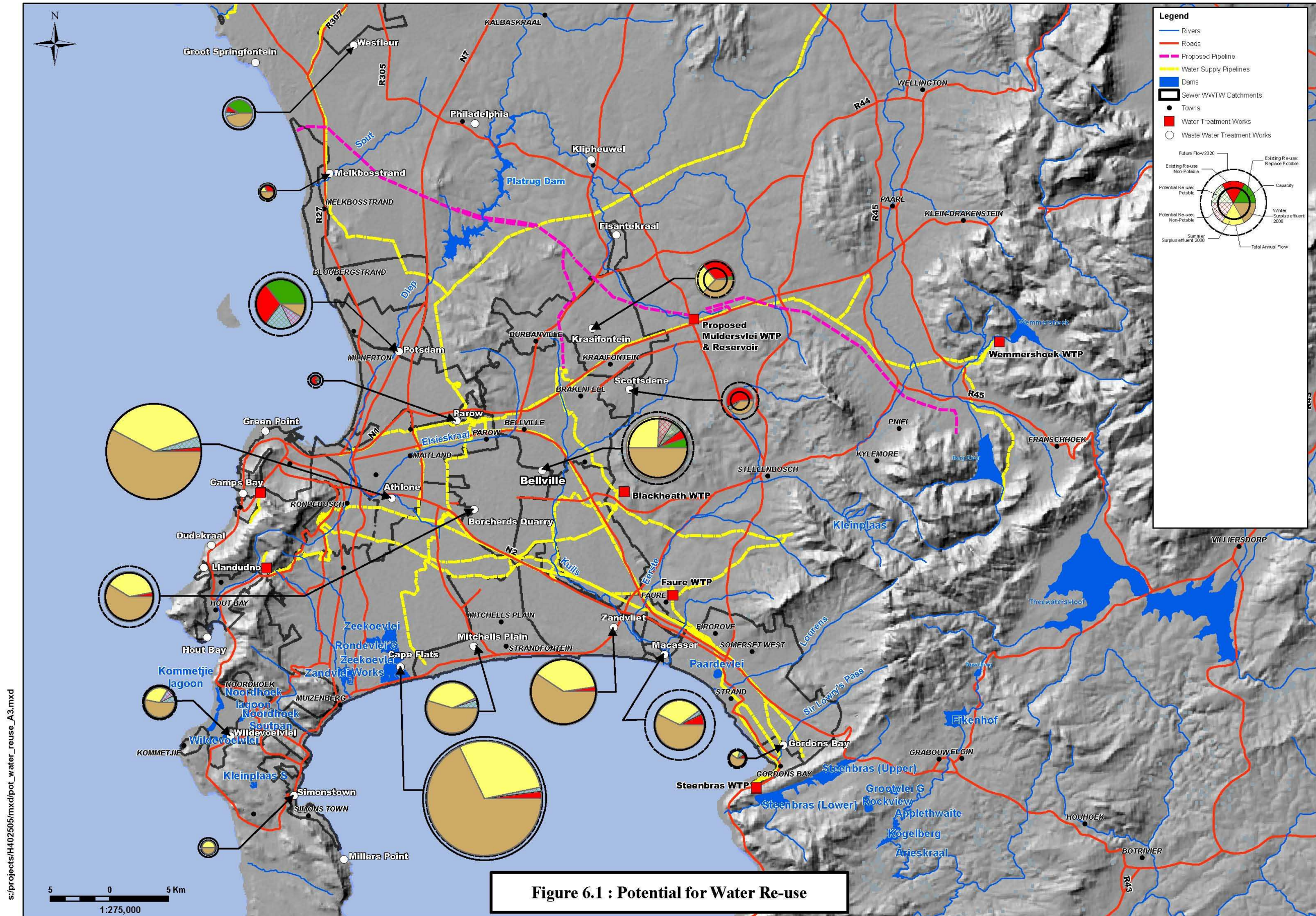
6.1 VOLUME OF EFFLUENT AVAILABLE

There are 16 wastewater treatment works (WWTW) in the City of Cape Town, as well as a number of marine outfalls, the locations of which are shown in **Figure 6.1**. The effluent disposed of via the marine outfalls is not of a suitable quality for re-use, so was not considered in this study.

Approximately 600 Ml/d (218 Mm³/a) of treated effluent was discharged from the WWTWs (excluding marine outfalls) in 2007/2008. Most of the effluent (90%) is discharged from the eight largest works, with about half (53%) being treated at the two largest WWTW, namely Cape Flats and Athlone. The volumes discharged for each works are given in **Table 6.1**. This study focuses on the effluent discharged from these eight larger works (Cape Flats, Athlone, Zandvliet, Bellville, Mitchell's Plain, Macassar, Potsdam and Borchers Quarry).

Table 6.1 Volume of effluent treated at WWTW

Name	Capacity of WWTW		Actual Flows 2007/08	
	Capacity of WWTW	Capacity of WWTW	Average Annual Daily Flow	Total Annual Flow
	Mℓ/d	million m ³ /a	Mℓ/d	million m ³ /a
Cape Flats	200	73.0	172.5	63.0
Athlone	120	43.8	119.3	43.6
Zandvliet	55	20.1	59.5	21.7
Bellville	46	16.8	52.3	19.1
Mitchell's Plain	37.5	13.7	33.6	12.3
Macassar	34	12.4	31.3	11.4
Potsdam	32	11.7	35.1	12.8
Borchers Quarry	30	11.0	33.0	12.1
Wesfleur (Atlantis)	14	5.1	9.5	3.5
Wildevölvlei	14	5.1	11.6	4.2
Kraaifontein	7	2.6	20.5	7.5
Simonstown	5	1.8	2.3	0.8
Scottsdene	4.5	1.6	9.8	3.6
Gordons Bay	3.5	1.3	3.3	1.2
Melkbos Strand	2.5	0.9	3.3	1.2
Parow	1.2	0.4	0.8	0.3
	606.2	221.3	597.8	218.2



6.2 SEASONAL AVAILABILITY OF EFFLUENT

The seasonal distribution of the effluent discharged is shown in **Figure 6.2**. The bulk of the effluent is available in the winter months (especially June, July, August), due to stormwater ingress into the sewers. Therefore to maximise the use of the treated effluent resource, this study focuses on all-year-round use.

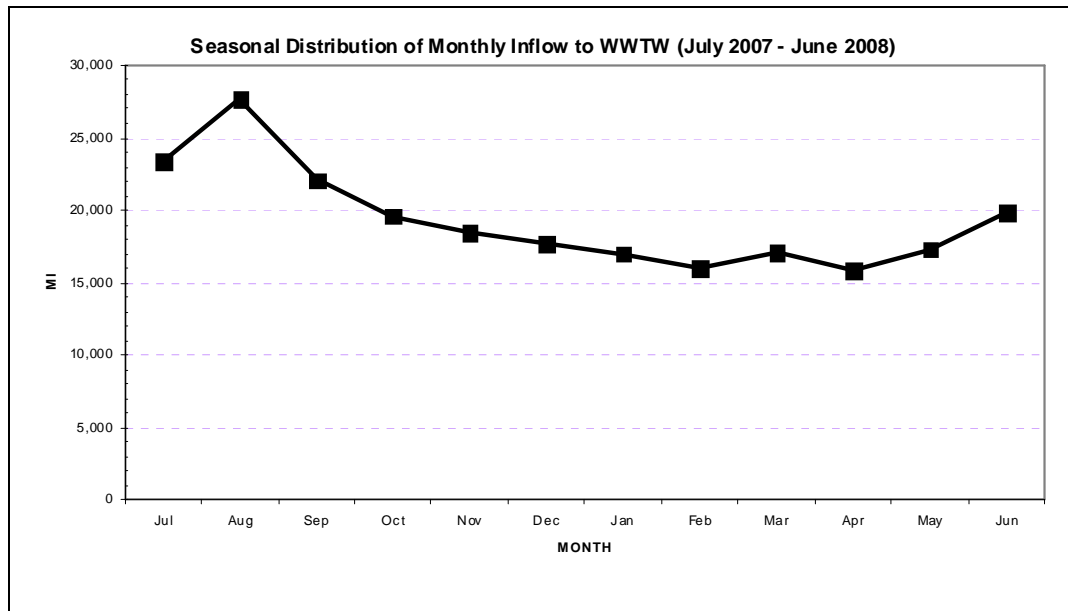


Figure 6.2 Seasonal distribution of treated effluent

6.3 EFFLUENT QUALITY

A number of sets of standards for treated effluent are relevant to the effluent discharged by the WWTW in Cape Town. The existing General and Special Standards that were published in 1984 currently apply, and the updated (more stringent) standards will be applied by DWA from 2010. The City does not comply with the current standards for effluent on a consistent basis. This is illustrated in **Figure**. This lack of compliance can be attributed to the financial, operational and technical constraints being experienced by the CCT.

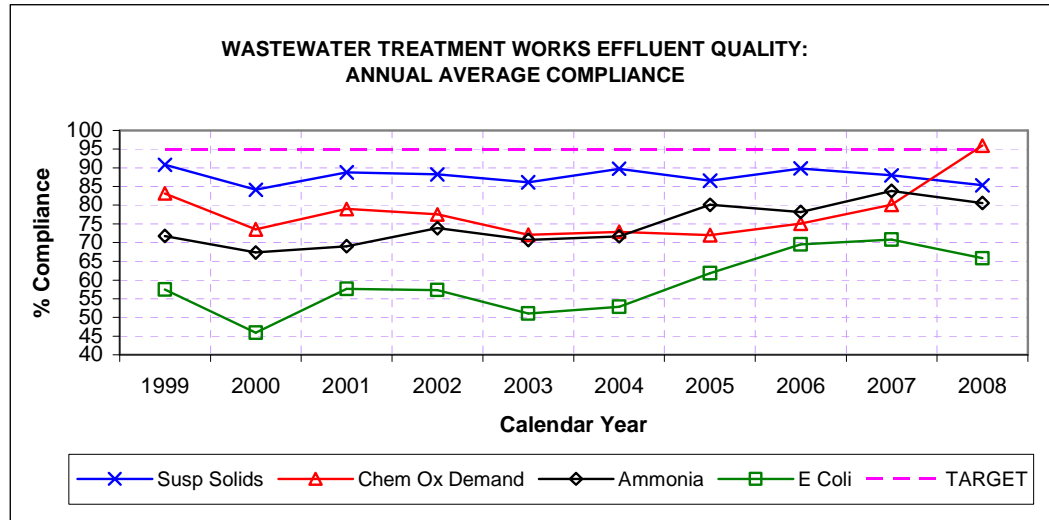


Figure 6.3 Annual Average Compliance of WWTW Effluent Quality

Effluent quality results are given in **Appendix B**. Averaged results for all WWTW for the 2008 calendar year are given in **Appendix B1**, and more detailed results for the eight largest WWTW are given in **Appendices B2-B9**.

As was discussed in **Section 5.4** of this document, this study is proposing that only advanced treatment processes such as reverse osmosis (RO) be used. This level of processing will deal with most potential contaminants that may still be in the treated effluent, so for the purposes of this study, effluent quality is not of strategic importance. Should RO not be the preferred means of treatment, a detailed quantitative assessment will have to be undertaken of the water treatment process to ensure that the product water complies with the required water quality standards.

Quality constraints are, however, relevant for the local re-use proposed as part of the CCT's Effluent Re-use Master Plan, and need to be addressed in order to maximise the potential identified in the Master Plan. As stated previously (in **Section 4.6**), according to BVI Consulting Engineers, it seems that there would be a demand for treated effluent of a slightly better quality, even if the cost per kl was higher than the current rate (L Pienaar, pers comm.).

6.4 CURRENT AND PLANNED FUTURE RE-USE OF TREATED EFFLUENT IN CAPE TOWN

Currently, approximately 80.5 Ml/d (21.1 million m³/a) of treated effluent is used (10% of the total annual volume available). Of this, it is estimated that approximately 32.8 Ml/d (7.3 million m³/a, which is 35% of the annual volume re-used) replaces potable use; i.e. would contribute towards demand reduction.

The CCT has a Master Plan (CCT, 2007) in place for treated effluent use (as discussed in **Section 4.6**), and this has identified an additional 74.8 Ml/d (10.3 million m³/a) from April 2007. Approximately 56.5 Ml/d (7.0 million m³/a, which is 68% of the current annual volume used) replaces existing potable use.

This gives a total future re-use of 155.3 Mℓ/d (31.4 million m³/a) (14% of the total annual volume currently available). Of this, it is estimated that 89.3 Mℓ/d (14.3 million m³/a, or 46% of the current annual volume used) will replace existing potable water use in the City. The estimates of existing and potential re-use volumes for each WWTW are given in **Table 6.2**.

Table 6.2 Estimated current and potential future re-use per WWTW

WWTW	Existing daily re-use		Potential additional re-use		Total potential annual re-use	
	Total	Portion replacing potable	Total	Portion replacing potable	Total	Portion replacing potable
	million m ³ /a	million m ³ /a	million m ³ /a	million m ³ /a	million m ³ /a	million m ³ /a
Athlone	0.648	0.000	1.775	1.609	2.423	1.609
Bellville	1.995	1.019	2.625	1.145	4.620	2.164
Borcherds Quarry	0.360	0.000	0.000	0.000	0.360	0.000
Cape Flats	1.305	0.000	0.472	0.472	1.777	0.472
Gordons Bay	0.100	0.000	0.133	0.133	0.233	0.133
Kraaifontein	2.710	0.226	(0.317)	(0.317)	2.393	(0.091)
Macassar	0.810	0.000	0.326	0.326	1.136	0.326
Melkbos Strand	0.396	0.000	(0.036)	(0.036)	0.360	(0.036)
Mitchell's Plain	0.000	0.000	0.781	0.636	0.781	0.636
Parow	0.259	0.039	0.049	0.049	0.308	0.088
Potsdam	8.276	4.553	3.387	2.289	11.663	6.842
Scottsdene	2.034	0.062	0.200	0.200	2.234	0.262
Wesfleur (Atlantis)	1.680	1.407	0.196	0.196	1.876	1.603
WildeVoëlvelei	0.000	0.000	0.679	0.305	0.679	0.305
Zandvliet	0.540	0.000	0.035	0.035	0.575	0.035
	21.113	7.307	10.305	7.041	31.418	14.348

Most of the existing and potential re-use takes place in Summer. Of the current volume of effluent re-used (21.1 million m³/a), approximately 77% (16.38 million m³/a) is estimated to be Summer re-use, and the remaining 23% (4.9 million m³/a) is estimated to be Winter re-use.

The Master Plan set a limit on the cost of supplying treated effluent of R2.50/kℓ, which is approximately half the price of potable water.

The location of the existing and potential future pipeline networks for the distribution of treated effluent from the Master Plan is included in this report as **Appendix C** (A0 sheet at the back of the report. Existing pipelines are shown in red and potential future pipelines in green).

6.5 SURPLUS EFFLUENT AVAILABLE

It is estimated (Reconciliation Strategy Study) that the volume of effluent which would be discharged in the year 2020 will be 705 Mℓ/d (257 million m³/a). Assuming the Master Plan will be fully implemented by then, the total estimated surplus effluent available after proposed re-use in 2020 is 549 Mℓ/d (226 million m³/a). Most of this surplus is available in Winter. **Table 6.3** contains details of these estimates. Pie charts showing the surplus effluent available are given in **Figure 6.1**.

Table 6.3: Estimated surplus effluent available per WWTW in 2020

Name	Future flow estimates		Total existing and potential re-use		Surplus effluent 2020	
	Projected annual daily average flow 2020	Projected total annual flow 2020	Average annual daily flow	Total annual flow	Average annual daily flow	Total annual flow
	Mℓ/d	million m ³ /a	Mℓ/d	million m ³ /a	Mℓ/d	million m ³ /a
Athlone	120.5	44.0	15.3	2.423	105	41.6
Bellville	68.5	25.0	19.5	4.620	49	20.4
Borcherds Quarry	49.3	18.0	2.0	0.360	47	17.6
Cape Flats	178.1	65.0	16.1	1.777	162	63.2
Gordons Bay	4.7	1.7	2.0	0.233	3	1.5
Kraaifontein	17.0	6.2	9.0	2.393	8	3.8
Macassar	64.9	23.7	11.1	1.136	54	22.6
Melkbos Strand	4.1	1.5	2.2	0.360	2	1.1
Mitchell's Plain	35.1	12.8	6.1	0.781	29	12.0
Parow	2.9	1.1	1.9	0.308	1	0.7
Potsdam	52.9	19.3	44.6	11.663	8	7.6
Scottsdene	18.0	6.6	8.3	2.234	10	4.3
Simonstown	2.8	1.0	0.0	0.000	3	1.0
Wesfleur (Atlantis)	13.7	5.0	6.4	1.876	7	3.1
Wildevoëlvele	15.3	5.6	4.8	0.679	11	4.9
Zandvliet	57.0	20.8	6.0	0.575	51	20.2
	704.8	257.2	155.3	31.418	549	225.8

Of the eight largest works, treated effluent from Potsdam will be almost fully utilised by 2020, so this works was excluded from further consideration in this study. The estimated surplus from the remaining seven larger works is approximately 545 Mℓ/d (200 million m³/a). This volume was considered to be available when conceptualising and costing the various potential schemes in this study.

7. POTENTIAL SCHEMES (COSTINGS)

The potential schemes put forward as part of this study are listed in **Table 7.1** in the appropriate categories of re-use. The locations of the development options are shown on **Figure 7.1**.

Table 7.1 Potential Water Re-use Schemes put forward as part of this study

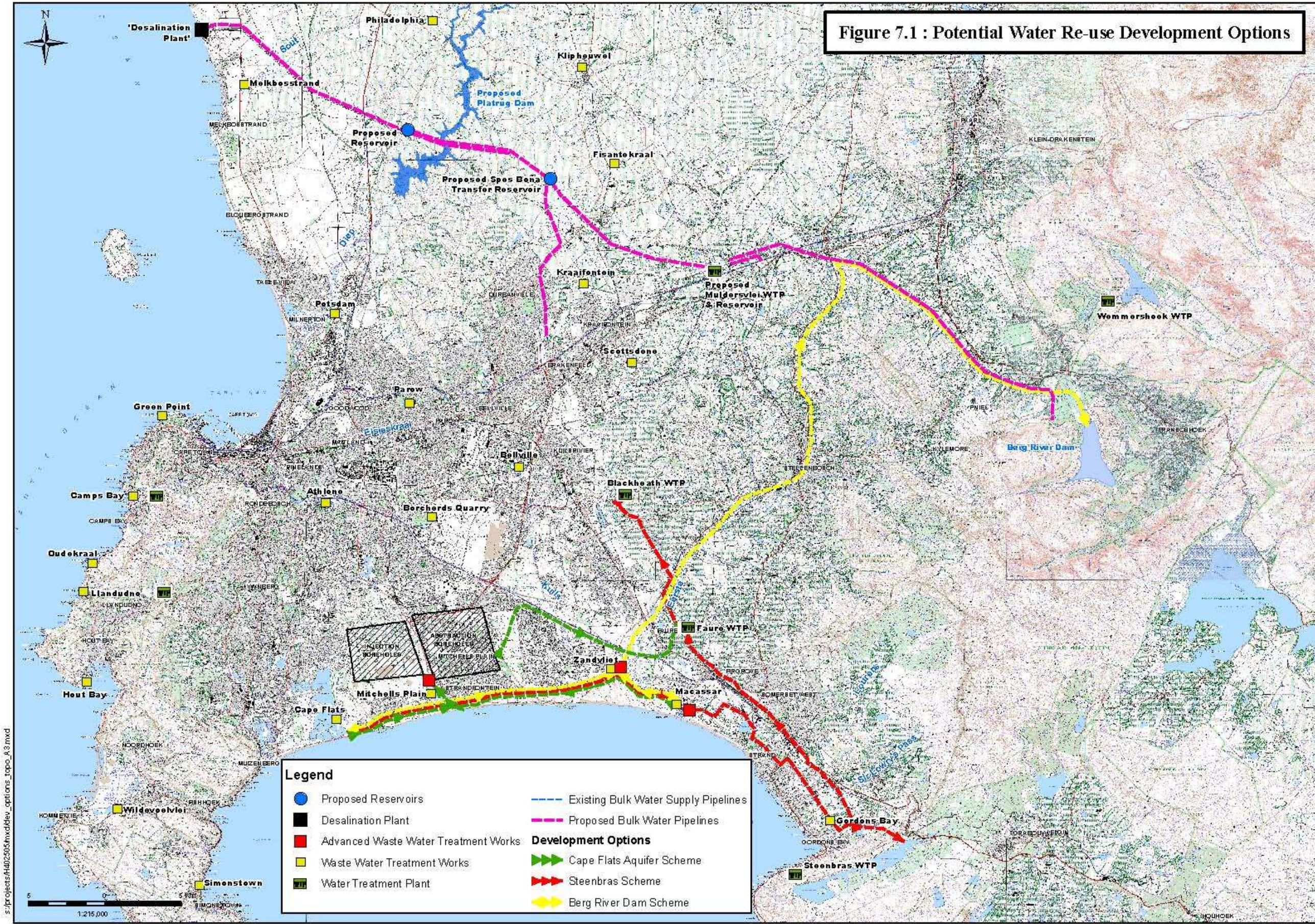
Category of re-use		Potential re-use scheme	
Planned direct	non-potable	CCT's Master Plan – re-use by industry and urban irrigation	
	potable	Blending option costed in Reconciliation Strategy Study (UWP) (integrated into WCWSS) (Schemes 4a and b)	
Planned indirect	non-potable	Berg River irrigation exchange	
		Irrigation Exchange (Stellenbosch) (Scheme 5)	
	potable	Discharge into existing dams / aquifers and integrate with the WCWSS	Steenbras Dam – existing (Scheme 1a)
			Steenbras Dam – raised (Scheme 1b)
			Berg River Dam (Scheme 2)
			Cape Flats Aquifer recharge (Scheme 3)
	Discharge into new dam (not costed)	Diep River (Platrug Dam)	
Benchmark against desalination (integrated into WCWSS) (Scheme 6)			

During the investigation it became evident that substantial increases in electricity costs were likely in the near future and this would influence the operating costs of the potential schemes. In order to make allowance for this, a cost of 31.4 c/kWhr was assumed to double in real terms by 2016.

7.1 SCHEME 1: DELIVERY OF EFFLUENT FROM WWTW ALONG FALSE BAY COAST TO UPPER STEENBRAS DAM

This development option is based on using effluent produced by the four WWTW located along the False Bay coast (Cape Flats, Macassar, Mitchell's Plain and Zandvliet). A schematic diagram of this option is given in **Appendix D1.1**. This effluent would be treated at a reverse osmosis plant located near the Macassar WWTW and purified to potable standard. It is estimated that by the year 2020, approximately 118 million m³/a of effluent would be available for treatment. Approximately 30% of the inflow to the plant would be lost in the purification process, therefore supplying approximately 83.2 million m³/a of water before conventional treatment. The purified water would be pumped into the Upper Steenbras Dam at a point some 2.5 km upstream of the dam wall. The water would blend with the natural runoff stored in the dam before being abstracted via the existing Steenbras Pumped Storage Scheme and pumped to the existing Faure and Blackheath Water Treatment Works for normal treatment and distribution to consumers.

The unit reference value of this scheme at a 6% discount rate is estimated to be R5.8/m³. The URV calculation sheet is given in **Appendix D2.1.1**. **Appendix D2.1.2** shows the URV calculation sheet for the same scheme with no allowance for a real electricity increase (URV = R4.3/m³).



A variation of this Scheme was also costed which included the cost of raising the Lower Steenbras Dam. A raised Lower Steenbras Dam would also deliver an additional yield of approximately 20 million m³/a. This additional yield was, however, ignored in the URV calculations, as additional pipelines would then also be required between Upper Steenbras Dam and Faure Water Treatment Works. The investigation into the raising of the Lower Steenbras Dam is being carried out as part of the DWAF's Western Cape Feasibility Study of various supply interventions.

The unit reference value of this scheme, with a raised Lower Steenbras Dam, at a 6% discount rate, is estimated to be R6.0/m³. The URV calculation sheet is given in **Appendix D2.1.3**. A second URV calculation sheet showing a corresponding URV of R4.5/m³ where no real electricity increase is allowed for, is given as **Appendix D2.1.4**.

7.2 SCHEME 2: DELIVERY OF EFFLUENT FROM WWTW ALONG FALSE BAY COAST TO THE BERG RIVER DAM

This development option is similar to Scheme 1 in that it is based on using effluent produced by the four WWTW located along the False Bay coast, but pumps the purified water into the Berg River Dam. A schematic diagram of this option is given in **Appendix D1.2**. This would be done through a new pipeline routed via Stellenbosch and Simondium in order to avoid the mountains. The pipeline would discharge into the dam about 2 km upstream of the dam wall. The water would blend with the natural runoff stored in the dam before being abstracted as part of the normal supply and distributed to the water treatment works supplied from the Berg River Dam, for normal treatment and distribution to consumers.

The unit reference value of this scheme at a 6% discount rate is estimated to be R5.8/m³. This excludes any additional cost of having to pump the additional water from the Berg River Dam to Theewaterskloof Dam. The URV calculation sheet is given in **Appendix D2.2.1**. **Appendix D2.2.2** shows the corresponding URV calculation sheet with no allowance for a real electricity increase (URV = 4.4/m³).

7.3 SCHEME 3: RECHARGE OF CAPE FLATS AQUIFER

This development option would have a lower yield than Schemes 1 and 2. It is also based on using the effluent produced by the four WWTW located along the False Bay coast, but only the Summer flow would be used in this option. A schematic diagram of this option is given in **Appendix D1.3**. It is proposed to pump 50 million m³ in the period from the beginning of November, to the end of April the next year, to a reverse osmosis treatment plant located near the Mitchell's Plain WWTW. The quantity of 50 Mm³ is the estimated total quantity of effluent that will be available by 2020 during the Summer months from the four treatment works. After losses in the reverse osmosis process, about 34 million m³/a purified water would be available. This would be injected into the Cape Flats Aquifer in the area to the west of the Mitchell's Plain residential area. The water would be injected during the Summer months only because the water table is naturally close to the surface during the wet Winter months. Water would be abstracted from the aquifer throughout the year by means of boreholes spread throughout the Mitchell's Plain residential and surrounding area, and pumped to the Faure Water Treatment Works for conventional treatment and distribution to consumers.

The combination of effluent recharge and natural groundwater is expected to give a sustained yield of about 52 million m³/a.

The unit reference value of this scheme at a 6% discount rate is estimated to be R4.5/m³. The URV calculation sheet is given in **Appendix D2.3.1**. **Appendix D2.3.2** shows the corresponding URV calculation sheet with no allowance for a real electricity increase (URV = R3.5/m³).

7.4 SCHEME 4: DIRECT POTABLE RE-USE

A direct potable re-use development option was put forward in the Reconciliation Strategy Study. The costing done as part of that study was reviewed and updated in this study. The cost of additional components necessary to integrate the scheme into the WCWSS were estimated and added to make it comparable to the other schemes costed in this study.

This development option is based on using effluent produced by the four WWTWs located along the False Bay coast (Cape Flats, Macassar, Mitchell's Plain and Zandvliet). This effluent would be treated at a new reclamation plant located near the Zandvliet WWTW, and purified to potable standards using reverse osmosis. The purified water would be pumped to the Faure Water Treatment Works (FWTW), where it would be blended with treated water from the FWTW at a ratio of 1:2 (1 part re-used water: 2 parts conventionally treated water). Based on a demand of approximately 320 Mℓ/day of raw water, the conceptualised scheme can supply approximately 39 million m³/a (106 Mℓ/d all year round) of water at blending ratios of 1:2. If a blending ratio of 1:4 was used, the scheme could supply 24 million m³/a (65 Mℓ/d).

The unit reference value of the scheme based on a 1:4 blending ratio at a 6% discount rate is estimated to be R4.6/m³. The URV calculation sheet is given in **Appendix D2.4.1**. **Appendix D2.4.2** contains the corresponding URV calculation sheet with no allowance for a real electricity increase (URV = R3.3/m³).

The URV of the scheme based on a 1:2 blending ratio at a 6% discount rate is estimated to be R4.3/m³. The URV calculation sheet is given in **Appendix D2.4.3**. **Appendix 2.4.4** contains the corresponding URV calculation sheet with no allowance for a real electricity increase (URV = R3.2/m³).

7.5 SCHEME 5: IRRIGATION EXCHANGE (STELLENBOSCH)

The IWRP Study looked at a scheme to exchange irrigation water with Stellenbosch irrigators. The costing done as part of that study was updated in this study.

This development option is based on using effluent produced at the Zandvliet and Macassar WWTWs. A locality plan of this option is given in **Appendix D1.4** (reproduction of Figure 2.1 from CTCC, 2001b). This effluent would not be treated any further, but would be pumped directly to a small balancing dam (0.5 million m³ capacity) near the exit of the Stellenboschberg Tunnel, during five Summer months (November – March). From this point onwards, existing irrigation scheme infrastructure would be used.

At a meeting held during that study, farmers from the Helderberg and Stellenbosch irrigation schemes indicated that they would only be willing to exchange 5 million m³/a of their present allocation of 20 million m³/a allocation from the Riviersonderend-Berg River Government Water Scheme. The reasons for this were because of the potential health risks associated with using treated effluent directly for irrigation of crops that are eaten raw. It may be that there would be

more interest in such an irrigation exchange if the treated effluent was purified before distribution to the irrigators, and it is recommended that such a development option be investigated.

The unit reference value of this scheme at a 6% discount rate is estimated to be R3/m³. The URV of R1.62/m³ from the IWRP Study (CTC, 2001b) was escalated at 8% for 8 years from the year 2000 to 2008, to obtain this value. No URV calculation sheet is provided for this scheme.

7.6 SCHEME 6: SEAWATER DESALINATION

In order to be able to benchmark the planned indirect use of potable water with desalination of seawater, a scheme was conceptualised to integrate a large-scale desalination plant into the bulk water supply infrastructure of the WCWSS. A 228 Mℓ/d desalination plant to be situated next to the Koeberg Power Plant was costed. The desalinated water was pumped to a 300 Mℓ/d bulk water supply reservoir (Koeberg Hill) at an elevation of approximately 180 masl. The bulk reservoir was linked to the Voëlvlei bulk water pipeline in order to be able to blend the desalinated water with treated water prior to distribution. The proposed reservoir was also linked to the proposed Voëlvlei to Glen Garry Scheme in order to ensure that the new bulk water supply could feed the area's high growth.

The unit reference value of this scheme, at a 6% discount rate, is estimated to be between R12.00 and R13.00, depending on the infrastructure required to integrate the desalination plant into the WCWSS. The URV calculation sheets are given in **Appendices D2.5.1** and **D2.5.2**. **Appendices D2.5.3** and **D2.5.4** show the corresponding URV calculation sheets where no allowance for an increase in electricity is made (URV ranges from R6.9/m³ to R7.7/m³).

7.7 SUMMARY OF COSTS

The results of the costing exercise undertaken are summarised in **Table 7.2** where unit reference values (URVs) for each scheme are given.

Table 7.2 Comparison of URVs of Development Options

Options		Potential yield of scheme (million m ³ /a)	URV (real electricity increase) (R/m ³)	URV (no electricity increase) (R/m ³)
Scheme 1a	Return treated effluent to Steenbras	83	5.8 App D2.1.1	4.3 App D2.1.2
Scheme 1b	Return treated effluent to Steenbras (raised)	83	6.0 App D2.1.3	4.5 App D2.1.4
Scheme 2	Return treated effluent to Berg River Dam	83	5.8 App D2.2.1	4.4 App D2.2.2
Scheme 3	Recharge Cape Flats Aquifer	83	4.5 App D2.3.1	3.5 App D2.3.2
Scheme 4a	Planned direct potable use – Faure (blending ratio 1:4)	24	4.6 App D2.4.1	3.4 App D2.4.2
Scheme 4b	Planned direct potable use – Faure (blending ratio 1:2)	39	4.3 App D2.4.3	3.2 App D2.4.4

Options		Potential yield of scheme (million m ³ /a)	URV (real electricity increase) (R/m ³)	URV (no electricity increase) (R/m ³)
Scheme 5	Irrigation exchange (Stellenbosch)	5	-	3.0
Scheme 6a	Desalination	83	11.9 App D2.5.1	6.9 App D2.5.2
Scheme 6b	Desalination (into system)	83	13.1 App D2.5.3	7.7 App D2.5.4

7.8 CONCLUSIONS

The following conclusions can be drawn from the investigation into the comparison of the development options:

7. The development option where the treated water is pumped back to Steenbras Dam is technically feasible, but would place limitations on the operation and optimisation of the water resources within the WCWSS. The primary reason for this is that the additional water which is pumped into Steenbras Dam has to be pumped back to Faure and utilised to supply Winter demand, as no additional storage capacity is provided in the Steenbras Dam.
8. Pumping the treated water into the Berg River Dam or into a raised Lower Steenbras Dam would both be technically feasible options and would also not impact significantly on the operation of the WCWSS.
9. The cost of planned indirect use of treated water for potable supply is significantly cheaper than the desalination of sea water.
10. The cost and URVs of all of the development options are sensitive to real electricity tariff increases. The reason for this is that both desalination and the planned indirect use of treated effluent are energy-intensive processes.
11. Desalination of seawater is especially sensitive to real electricity tariff increases. This is due to the high total dissolved solids (TDS) of seawater and the high pressure required for the reverse osmosis process.
12. The development options proposed need to be modelled in the system model in order to ensure that the yields proposed are realised and that the proposed development options do not negatively impact on the operation and optimisation of the water resources in the WCWSS.

8. RECOMMENDED STRATEGIC APPROACH FOR THE FUTURE USE OF TREATED EFFLUENT

The overall conclusion which can be drawn from this strategic investigation is that significant potential exists for the large-scale re-use of water in the City of Cape Town, and that this resource can be integrated into the WCWSS.

The main recommendations are given below.

8.1 INVESTIGATE PLANNED INDIRECT POTABLE AND NON-POTABLE RE-USE

In line with international best practice, it is recommended that indirect potable and non-potable re-use development options are pursued. Initial cost estimates for these indirect re-use options are promising, indicating that planned indirect re-use of water may compare favourably against other water resource development options. The planned indirect use of water is significantly cheaper than desalination.

8.2 FEASIBILITY STUDY

It is recommended that CCT, in conjunction with DWA, initiate a feasibility study on both indirect planned re-use and direct planned re-use as a water augmentation scheme for the WCWSS. By comparing both planned indirect or planned direct water re-use from a technical, financial, environmental and social acceptability perspective, the CCT and DWA should be able to take a decision on the most acceptable way forward. The results of this feasibility study should be compared with those of the feasibility studies currently underway, such as the Michell's Pass Diversion, Voëlvlei Augmentation Phase 1, etc.

8.3 BEST PRACTICES

Recommendations from the publication on "*Best Practices for Implementing Indirect Potable Re-use Projects*" should be implemented, specifically:

- Create a perception of improvement
- Communicate all the benefits of indirect potable water re-use
- Understand and avoid environmental justice issues
- Understand and use track records
- Break source-to-tap connection
- Establish the Water Agency and investment as the sources of water quality (including the establishment of a separate monitoring body)
- Rename the water quality.

8.4 LOCAL RE-USE

For those WWTW that are not candidates for supply to a large development option, local re-use options should be maximised. The focus for local re-use should be on those users who require year-round supplies as well as where the re-use would replace existing potable water use. The potential and cost-effectiveness of localised post-treatment to provide the required quality of water should also be investigated. This would involve the review of the threshold charge of R2.50/kℓ for treated effluent by the CCT.

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