ASSESSMENT OF THE FEASIBILITY OF USING A DUAL WATER RETICULATION SYSTEM IN SOUTH AFRICA

Report to the

WATER RESEARCH COMMISSION

by

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EXECUTIVE SUMMARY

Introduction

Many communities in South Africa struggle to access reliable and adequate quantities of good quality water for potable and non-potable water requirements. Although ideally, different water qualities are needed for potable and non-potable water requirements, in practice in South Africa, potable water of the highest quality is often used for non-potable applications (e.g. toilet flushing and landscape irrigation) where water of much lower quality would be acceptable. This practice is unsustainable if the South African government is to assure immediate and long-term water supply goals, and requires the assessment of various options especially in light of the aridity of the region and limited freshwater resources. The use of different non-potable water qualities to supply non-potable water requirements conveyed through dual water reticulation systems presents one of such options.

Internationally, dual reticulation systems of diverse design specifications and configurations, conveying different non-potable water qualities for non-potable water requirements domestically and non-domestically, have been implemented. Examples can be found in the United Kingdom, Australia, Namibia, United States of America, Singapore, Japan, China, the Caribbean nation of Trinidad and Tobago, the Netherlands, Israel, and the Republics of Kiribati and the Marshall Islands.

The use and application of dual reticulation systems were investigated in the past by Botha and Pretorius (1998). The study concluded that dual systems offer new possibilities for maintaining adequate water supply and encouraging the appropriate use of the available water resources in South Africa. However, uptake of the recommendations of the study in especially many water-scarce areas of South Africa has been limited. This is despite the fact that the technology surrounding dual systems and non-potable water use/reuse has evolved since then, with great strides made on the subject. This study therefore emanated from the need to re-visit this subject and evaluate its current applicability within the South African context.

The main aim of this study was therefore to assess the feasibility of implementing dual water reticulation systems in South Africa based on local and international experience.

Methodology

The objectives of this study were achieved through undertaking five tasks: a detailed literature survey, which attempted to garner local and international experiences on dual systems; collection and analysis of perceptions of both decision-makers and current consumers of some non-potable water resource; a detailed case study analysis of an existing dual system; the development of a framework for assessing the feasibility of implementing dual water reticulation systems in South Africa; and the utilization of the framework to assess the feasibility of implementing a dual system within an existing community.

The perception surveys were carried out across a spectrum of technical and non-technical water decision-makers (i.e. water and wastewater services managers and technical personnel, and DWAF officials). Perception surveys were also carried out in Emalahleni, which is a community currently benefiting from recycled mine water supplied by the Emalahleni Mine Water Reclamation Project. The surveys were carried out prior to the commissioning of the reclamation project and sought to determine perceptions regarding the use of non-potable water domestically and the implementation of dual reticulation systems. The case study analysis was carried out in the City of Cape Town (CoCT) which houses a dual system that has been operating for several decades. Thirteen percent of the treated effluent currently produced within the city is reused for certain non-domestic applications, e.g. landscape irrigation, and certain industrial processes, and there is potential for increased reuse within the city. The framework was developed using the different aspects of the triple bottom lines of sustainability (i.e. economical, social and environmental) while the modelling exercise, using the framework, practically assessed the feasibility of implementing a dual reticulation system within the Goldfields gold mine in Driefontein.

A summary of key findings from the study is presented below:

Key findings

- The extent of the aridity of an area is a major driver for non-potable water reuse and the implementation of dual systems in South Africa. In the literature and perception surveys, communities that had experienced water scarcity (e.g. Emalahleni, Garies and CoCT), were generally more willing to reuse non-potable water, even despite the potential risks to public health, than communities in areas of water abundance;
- Water reuse decreases the consumption of potable water. International literature indicates that reuse may save between 30-60% of potable water utilised for domestic non-potable water requirements (e.g. toilet flushing and garden irrigation). The water balance exercise undertaken in the CoCT (section C.4.2) shows that by recycling all treated effluent produced within the city, the total water supply will increase by about 118%. Currently, the CoCT reuses about 13% of the total treated effluent produced within the city;
- The longevity and sustainability of dual water reticulation systems in many parts of the world (e.g. the CoCT, Majuro, Tarawa, Windhoek and Hong Kong) prove that dual systems are feasible water supply options. As long as regulations and guidelines are adhered to, and fundamental precautions and practice (regarding materials, system implementation and operation) are made, a dual system is no more difficult to implement than a traditional potable water supply system. An aggregated score of 8.7 was calculated during the modelling exercise to assess the feasibility of implementing a dual system within the Goldfields gold mine in Driefontein. The score of 8.7 represents a '*high potential for the designed dual system to be viable*' and supports the statement that dual systems are feasible water supply options;
- Wide-area urban/agricultural, district and industrial dual systems are only feasible in areas where a sewer system already exists or is to be implemented. Individual dual systems which are also feasible

where sewer systems exist, have also been implemented in low-income communities/households where sewers don't exist and dry sanitation is commonly practised (e.g. Carnavon). In these communities, dual systems are profitable in reducing pollution due to indiscriminate discarding of domestic wastewater in the environment and for garden irrigation and toilet flushing;

- Colour coding and clear identification/labelling of a dual system played a significant role in encouraging (from 50% to 63%) the acceptance of dual systems amongst surveyed respondents;
- It makes economic sense for sources of non-potable water to be in proximity to the potential uses. This naturally occurs for all dual system scales except the wide-area urban/agricultural dual system which is not inherently designed to be close to potential uses. Therefore, due to the high cost of long distance pipelines, some potential consumers of treated effluent have not been served by the existing dual systems within the CoCT. The study determined that the optimal economic distance between participating WWTWs and existing non-domestic consumers within the CoCT was about 500 metres;
- Tariffs for non-potable water conveyed via dual water reticulation systems are usually lower than potable water tariffs and this has encouraged non-potable water reuse. In the CoCT, treated effluent tariffs in 2007 ranged from 7% to 40% of the potable water tariffs and this has encouraged several large users of non-potable water (e.g. the Chevron oil refinery) to reuse treated effluent. The percentage of willing respondents in the perception survey increased from 36% to 71% if tariffs for non-potable water were lower than for potable water. In the modelling exercise where a treated effluent system replaced the existing potable water supply system for toilet flushing, landscape irrigation, paving and masonry production, cost savings of about 67% (R17 150 048) were achieved over 20 years;
- The literature and perception surveys show that it is critical that community perceptions are well-known and understood prior to the detailed planning of domestic dual systems. Numerous reuse projects have failed in the past (e.g. in California and Florida, United States of America) as a result of negative community perceptions or the failure of decision-makers to determine whether potential users or the public will accept such systems;
- The closer non-potable water is to human contact or ingestion, the more opposed people are to using the water. In the perception surveys, domestic respondents generally preferred reusing non-potable water for toilet flushing, landscape irrigation and car washing than more personal items such as laundry. In support of these perceptions, most non-potable water reuse in South Africa at the current time, is for domestic and non-domestic irrigation and industrial non-potable water processing;
- One prominent area of concern from the perception survey of domestic respondents was the safety of children when exposed to non-potable water used for irrigation;
- The perception survey showed that the trust respondents had in their local authorities determined their willingness to accept a dual system. High performing local authorities attracted higher levels of trust from respondents. This is because respondents associate a level of risk to using dual systems and therefore, will feel the risks are lower when the local authority operating the dual system has proven over time to be reliable;
- Inefficient institutional arrangements and relationships between different units managing or operating

one or more aspects of the treated effluent system (especially in WWTWs) have proven to be detrimental to the optimal operation and sustainability of the dual systems in the CoCT;

- There are no current and detailed South African regulations or guidelines pertaining to non-potable water reuse and dual systems. The DNHPD (1978) guideline is an outdated guideline that needs to be revised in light of current local and international experience. Many of the dual systems that have been implemented in the country have used these outdated guidelines and regulations or those used internationally;
- A significant number of the wide-area urban/agricultural and industrial dual systems that have been implemented in South Africa are driven by private sector and/or community initiatives, with irrigation, mining and industrial processing being the main uses for the non-potable water (especially treated effluent). Since many of these initiatives are not primarily driven by local authorities, no formal operational or tariff agreements are in place.

Based on the findings from the study, some recommendations to facilitate the efficient implementation and sustainability of dual systems in South Africa are proffered below:

Recommendations emanating from the study

- In order to ensure the economic feasibility of dual systems, a careful life cycle cost-benefit analysis needs to be carried out within context of other water resource alternatives and a full appreciation of the true costs of water supply provision. There are potentially large savings in avoiding treating water to potable standards for non-potable domestic and non-domestic uses;
- To guarantee a high level of service for treated effluent reuse, a program of regular control and monitoring of influent from various sources (especially industries) should be developed by local authorities. In addition, many local authorities need to be equipped with qualified personnel that will undertake control and monitoring tasks and enforce regulations/by-laws. Dual systems must not be implemented where the qualified institutional capacity is deficient;
- There is urgent need for the Department of Water Affairs and Forestry to develop a national regulatory document that sets out government's policies regarding non-potable water reuse and dual systems;
- In order to implement dual systems that are technically safe, it is vital that a guideline that proposes uniquely designed and standardised engineering materials (i.e. pipes, meter boxes, valves, taps, tanks, etc.) and specifications (e.g. sizes, thickness, colour, labelling) for non-potable pipe networks be developed for South Africa;
- A pre-requisite for the sustainability of dual systems is efficient institutional arrangements and relationships between the relevant units (e.g. potable water services, wastewater services, sanitation services, bulk stores, billing services and maintenance services) housed within local authorities. This is especially critical in wide-area urban dual systems that utilise treated effluent. Efficient institutional arrangements and relationships will, in addition, assist in the development of integrated water resources and services plans that will ensure the optimal utilisation of an area's available water resources;

- If wide-area urban/agricultural dual systems are to be implemented, local authorities must first consistently produce high performance service. This will increase consumers' trust in their ability to implement dual systems and reduce any potential risks to public health and safety. It is fruitless for local authorities to consider implementing dual systems when service levels and public confidence in their services are low.

In conclusion, dual water reticulation systems are feasible water supply options especially for communities located in arid areas. Provided there is an enabling environment (i.e. regulations, guidelines, institutional capacity, non-potable water resources and qualities, tariffs, decision-maker and potential user perceptions and willingness, appropriate non-potable water uses, public health and safety, and trust in service providers), large users of non-potable water in arid areas will immensely benefit from the implementation of dual systems. This study shows that if all treated effluent produced within an area is recycled, total water supply to the area will increase by about 100%. Tariffs for supplying non-potable water are also shown to be considerably lower than potable water tariffs – the CoCT billed consumers of treated effluent between 7% and 40% of potable water tariffs in 2007. From the perception surveys, it was clear that non-potable water requirements requiring minimal human contact (e.g. toilet/urinal flushing and landscape irrigation) were preferable for domestic respondents. Hence, it would be wise for decision-makers to target these uses when domestic dual systems are to be implemented. Based on the findings from this study, a framework for assessing the feasibility of implementing a dual system was developed. The framework incorporates multiple aspects from the triple bottom lines of sustainability (i.e. technical/engineering, economics, social, institutional, regulations, environment and public health and safety).

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GLOSSARY

Black water	The heavy and solid part of wastewater that contains animal or food wastes. Black water consists of faeces plus flush water, grey water, and urine.
Desalination	One of the processes used to remove salts and most other impurities from saline water by distillation or electrochemical and/or physical means.
Dual water reticulation system	A system consisting of separate pipes that supply drinking and non-drinking water respectively to the end consumer. In many instances, the pipe delivering non-drinking water is colour-coded.
Effluent	Water that flows out of treatment plants or industrial processes.
Grey water	This is household wastewater (i.e. water from showers, baths, hand basins, laundry tubs, washing machines, dishwashers and kitchen sinks) which does not include water from toilets.
Lilac-pipe schemes	Internationally, lilac/purple-coloured pipes are dedicated for non-potable/reused water transport to ensure that reused water mains are NOT confused with potable water mains for delivering drinking water. In Australia, all buried pipes conveying reused water are also mandatorily labelled: ‘non-potable or reclaimed water – Do Not Drink’.
Non-potable water	Non-drinkable water, e.g. non-treated or partially-treated black water, grey water, saline water, surface water or rain water.
Potable water	Water that is considered safe for human consumption.
Reuse/recycle	The process of treating, storing, distributing, and the actual reuse of non-potable water.
Salinity	Soil and water environments are vulnerable to soluble salts, of which sodium chloride is the most common. Salinity refers to the total concentration of all salts in the water or soil. Soil sodicity represents the relative amounts of sodium ions compared to others like calcium, magnesium and potassium. See definition of desalination.
Wastewater/sewage	Black water and non-domestic water.

1. INTRODUCTION

1.1. Background to the study and motivation

South Africa, like many other countries, views water as one of its most fundamental and indispensable natural resources – fundamental to life, the environment, food production, hygiene, industry and power generation. Water, although renewable, is also a finite resource, distributed unevenly both geographically and through time. Several water supply- (e.g. the Lesotho Highlands Water Project) and demand- (e.g. reduction of illegal connections, unmetered connections, unaccounted for water, and pipe leakage) driven initiatives have been implemented in South Africa to ensure the adequate supply of water. Yet, many communities still struggle to access reliable and adequate quantities of good quality water for potable and non-potable water requirements. Even where water is abundant in some areas, there is often serious inequality in its distribution and availability.

Although ideally, different water qualities are needed for potable and non-potable water requirements, in practice in South Africa, potable water of the highest quality is often times used for non-potable applications (e.g. toilet flushing and landscape irrigation) where water of much lower quality would be acceptable. This practice is unsustainable if the South African government is to achieve immediate and long-term water supply goals, and requires the assessment of various options especially in light of the aridity of the region and limited freshwater resources.

The use of different non-potable water qualities to supply non-potable water requirements conveyed through dual water reticulation systems presents one of such options. This option is particularly promising for arid South African communities with limited access to fresh water sources, still in the process of developing their basic infrastructure, in proximity to saline (i.e. brackish or sea) waters, and/or that generate significant volumes of rain water, storm water runoff, sewage, and/or mine effluent. Some factors that have been cited as driving forces behind the need to encourage non-potable water use/reuse in South Africa are:

- Drought and prediction of further droughts from climate change in many arid areas;
- Increased competition for freshwater resources and therefore, the need to conserve higher quality water for suitable uses;
- Growing industrial, agricultural and domestic water needs;
- Growing demands for greener water strategies and water conservation;
- Heightened awareness of the potential benefits of using suitably treated non-potable water in the agricultural industry;
- The high costs of supplying sufficient quantities of potable water to arid areas. This is especially true for communities distant from urban centres and currently with very limited access to public water infrastructure;

A dual water reticulation system is a system consisting of separate pipes that supply drinking and non-drinking water respectively to the end consumer. Internationally, dual reticulation systems of diverse design specifications and configurations, conveying different non-potable water qualities for non-potable water requirements domestically and non-domestically, have been implemented. Many of these systems can be found in countries with similar freshwater challenges and aridity as South Africa, e.g. United Kingdom, Australia (Dimitriadis, 2005; Po et al., 2003; Sydney Water, 2001; Gold Coast Water, 2004), Namibia (Menge, 2006), United States of America (Po et al., 2003), Singapore (Po et al., 2003), Japan, China (Tang et. al., 2007), the Caribbean nation of Trinidad and Tobago (Business and Economy, 2003), Netherlands (UNESCO, 1991; Health Stream, 2003; Leder, 2006), and Republics of Kiribati and the Marshall Islands (Smith et al., 1996; Parr et al., 1997). Detailed descriptions of many of these systems are documented in Chapter 3 of this report.

The use and application of dual reticulation systems were investigated in the past by Botha and Pretorius (1998). The study concluded that dual systems offer new possibilities for maintaining adequate water supply and encouraging the appropriate use of the available water resources in South Africa. However, uptake of the recommendations of the study in especially many water-scarce areas of South Africa has been limited. This is despite the fact that the technology surrounding dual systems and non-potable water use/reuse has evolved since then, with great strides made on the subject.

With the current and future water supply challenges facing South Africa, it has become necessary to revisit this subject area in order to determine the current state of knowledge and experience in using different non-potable water qualities for non-potable water requirements, dual water reticulation systems, and the potential application of dual systems in South Africa.

1.2. Objectives

The objectives of this study are as follows:

a) To determine the current state of knowledge in the use of different non-potable water qualities for a variety of non-potable domestic and non-domestic water requirements;
b) To determine the current state of knowledge and experience in dual water reticulation systems;
c) To investigate the different parameters that influence the feasibility of implementing dual systems within South African communities, e.g. regulations and guidelines, economics, consumer and decision-maker perceptions, technical feasibility, environmental sustainability and institutional capacity;
d) To develop a robust framework that may be used to effectively assess the feasibility of implementing a dual system within a South African community.

1.3. Methodology

a) Literature review:

Extensive literature review was undertaken in order to determine the status of knowledge and/or experience locally and internationally regarding the use of different non-potable water qualities and the implementing dual reticulation systems. Specifically, the literature review sought to accomplish the following:

i. To understand different non-potable water qualities (i.e. grey water, rain water, saline water, mine effluent, and storm water runoff) and to investigate their use for non-potable domestic and non-domestic water requirements;
ii. To locate locally and internationally, implemented dual water reticulation systems that supply different water qualities, and to determine the parameters underpinning their use;
iii. To understand the impacts usage of different non-potable water qualities have had and could potentially have on the implementation and operation of dual water reticulation systems;
iv. To investigate applicable South African and other regulations and guidelines pertaining to different non-potable water qualities and dual water reticulation systems;
v. To investigate the impact(s) use/reuse of different non-potable water qualities may have on public health and safety;
vi. To investigate the economics (i.e. capital, operating and maintenance costs) of implementing dual water reticulation systems;
vii. To document experiences and perceptions expressed by decision-makers and consumers of different non-potable water qualities in communities where such usage has been implemented.

b) Perception surveys:

i. Perception surveys were carried out across a spectrum of technical and non-technical water supply decision-makers (water and wastewater services managers and technical personnel, and DWAF officials). The perceptions of these decision-makers will ultimately decide the feasibility of implementing dual reticulation systems in South Africa. Hence, the surveys, using structured questionnaires and interviews, attempted to mine and document the perceptions of these decision-makers;
ii. Perception surveys were also carried out within a South African community (i.e. Emalahleni) currently requiring water supplementation. The surveys sought to assess a sample of the community's perceptions regarding the use of different non-potable water qualities domestically and the implementation of dual reticulation systems. These perceptions were also generated using structured questionnaires and interviews.

c) A detailed case study:

The findings from the literature review provided significant input into the nature of the case study. The case study sought to determine experiences and the impacts (i.e. costs, benefits, risks, etc.) of a functional dual water reticulation system within the CoCT. The CoCT currently reuses about 13% of its treated effluent for primarily industrial and irrigation purposes;

d) Development of an assessment framework:

In order to assess the feasibility of implementing dual systems in South Africa in the future, a framework was developed using the triple bottom line approach and based on the literature survey, perception survey results and case study. The framework encapsulates the different aspects needed in order to conduct a holistic assessment of dual system implementation vis-à-vis economic and technical; social, institutional and legislative; and environmental, public health and safety.

e) A modelling exercise:

A modelling exercise to assess the feasibility of implementing a dual reticulation system was carried out within the Goldfields gold mine, Driefontein. This mine employs more than 16,000 people and houses several high and medium density residential areas, a golf course, several rock crushing industries and a paving and masonry manufacturer. The mine also operates four wastewater treatment works (WWTWs) and reuses about 10% of its treated effluent from one of its WWTWs for limited landscape irrigation, and communal toilet flushing. The modelling exercise investigated the possibility of implementing a separate treated effluent system from second WWTWfor toilet flushing, paving and masonry production and landscape irrigation. The modelling exercise was of particular benefit in practically assessing the economical, social and environmental parameters influencing the feasibility of implementing a dual reticulation system based on the assessment framework developed;

1.4. Structure of this report

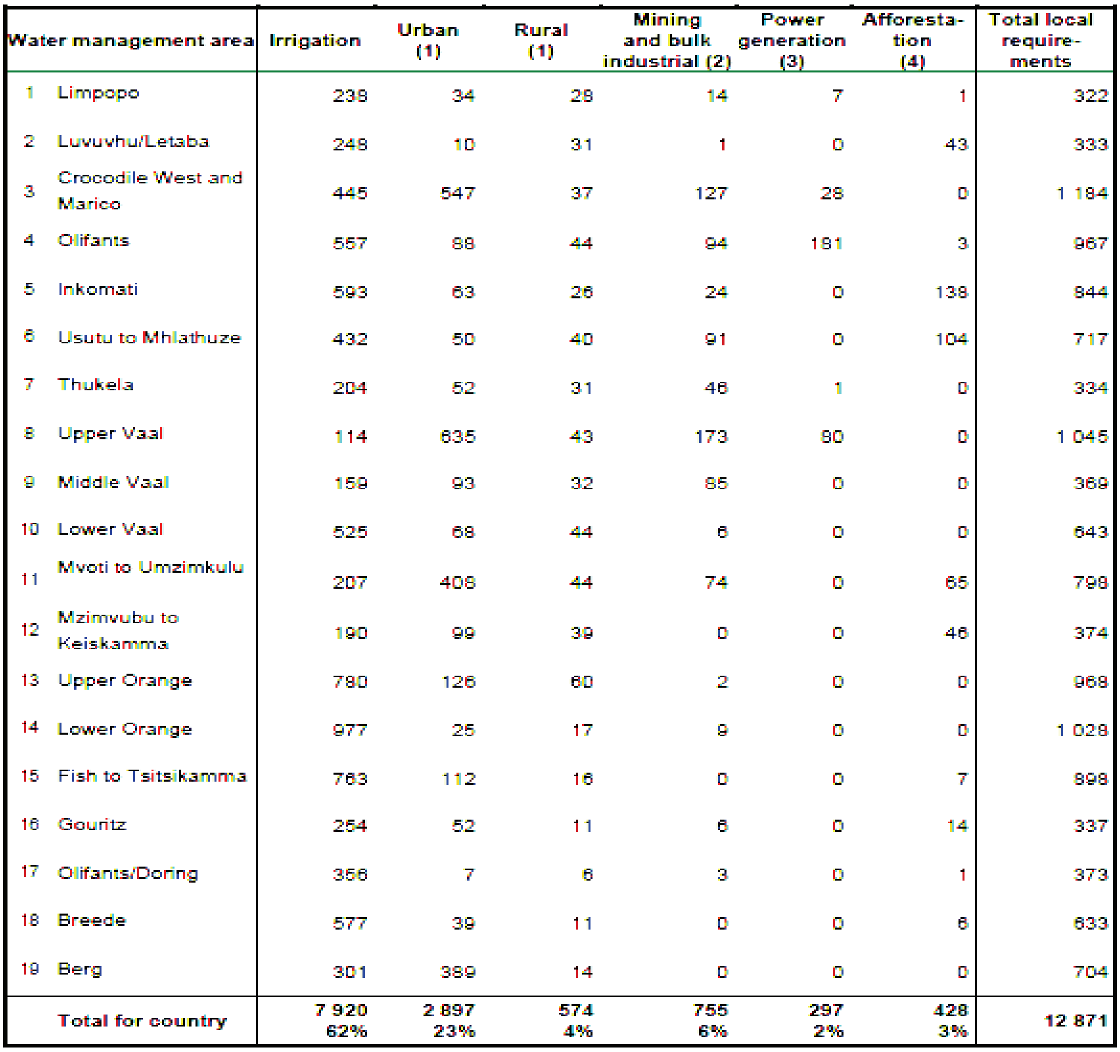
Chapter 1 presents the background, motivation, objectives and methodology employed in this study. Literature and international experiences pertaining to dual water reticulation systems and non-potable water use/reuse are presented in Chapters 2 and 3 respectively while South African experiences on this subject are presented in Chapter 4. A detailed case study of the City of Cape Town dual water reticulation system is presented in Appendix A. Perceptions relating to dual systems and non-potable water use from a variety of respondents are presented in Chapter 5. The questionnaires used in collecting these perceptions are presented in Appendix B (I to V). The assessment framework presented in Appendix C is employed in Chapter 6 to assess the feasibility of implementing a dual system within the Goldfields gold mine in Driefontein. Summaries of key findings pertaining to the assessment of the feasibility of implementing a dual system in South Africa, as well as recommendations and conclusions are presented in Chapter 7.

2. LITERATURE REVIEW

2.1. Overall water availability and requirements in different sectors

Table 1 presents estimates of water requirements for the different sectors within the different water management areas in South Africa for the year 2000 (DWAF, 2004a).

Table 1. Estimates of water requirements for the year 2000 in South Africa (DWAF, 2004a).



Water management area		Irrigation	Urban (1)	Rural (1)	Mining and bulk industrial (2)	Power generation (3)	Afforestation (4)	Total local requirements
1	Limpopo	238	34	28	14	7	1	322
2	Luvuvhu/Letaba	248	10	31	1	0	43	333
3	Crocodile West and Marico	445	547	37	127	28	0	1 184
4	Olifants	557	88	44	94	181	3	967
5	Inkomati	593	63	26	24	0	138	844
6	Usutu to Mhlathuze	432	50	40	91	0	104	717
7	Thukela	204	52	31	46	1	0	334
8	Upper Vaal	114	635	43	173	80	0	1 045
9	Middle Vaal	159	93	32	85	0	0	369
10	Lower Vaal	525	68	44	6	0	0	643
11	Mvoti to Umzimkulu	207	408	44	74	0	65	798
12	Mzimvubu to Keiskamma	190	99	39	0	0	46	374
13	Upper Orange	780	126	60	2	0	0	968
14	Lower Orange	977	25	17	9	0	0	1 028
15	Fish to Tsitsikamma	763	112	16	0	0	7	898
16	Gouritz	254	52	11	6	0	14	337
17	Olifants/Doring	356	7	6	3	0	1	373
18	Breede	577	39	11	0	0	6	633
19	Berg	301	389	14	0	0	0	704
	Total for country	**7 920 62%**	**2 897 23%**	**574 4%**	**755 6%**	**297 2%**	**428 3%**	**12 871**

1) Includes the component of the Reserve for basic human needs at 25 litres/person/day.
2) Mining and bulk industrial that are not part of urban systems.
3) Includes water for thermal power generation only, since water for hydropower, which represents a small portion of power generation in South Africa, is generally also available for other uses.
4) Quantities given refer to impact on yield only. The incremental water use in excess of that of natural vegetation is estimated at 1 460 million m³/a.

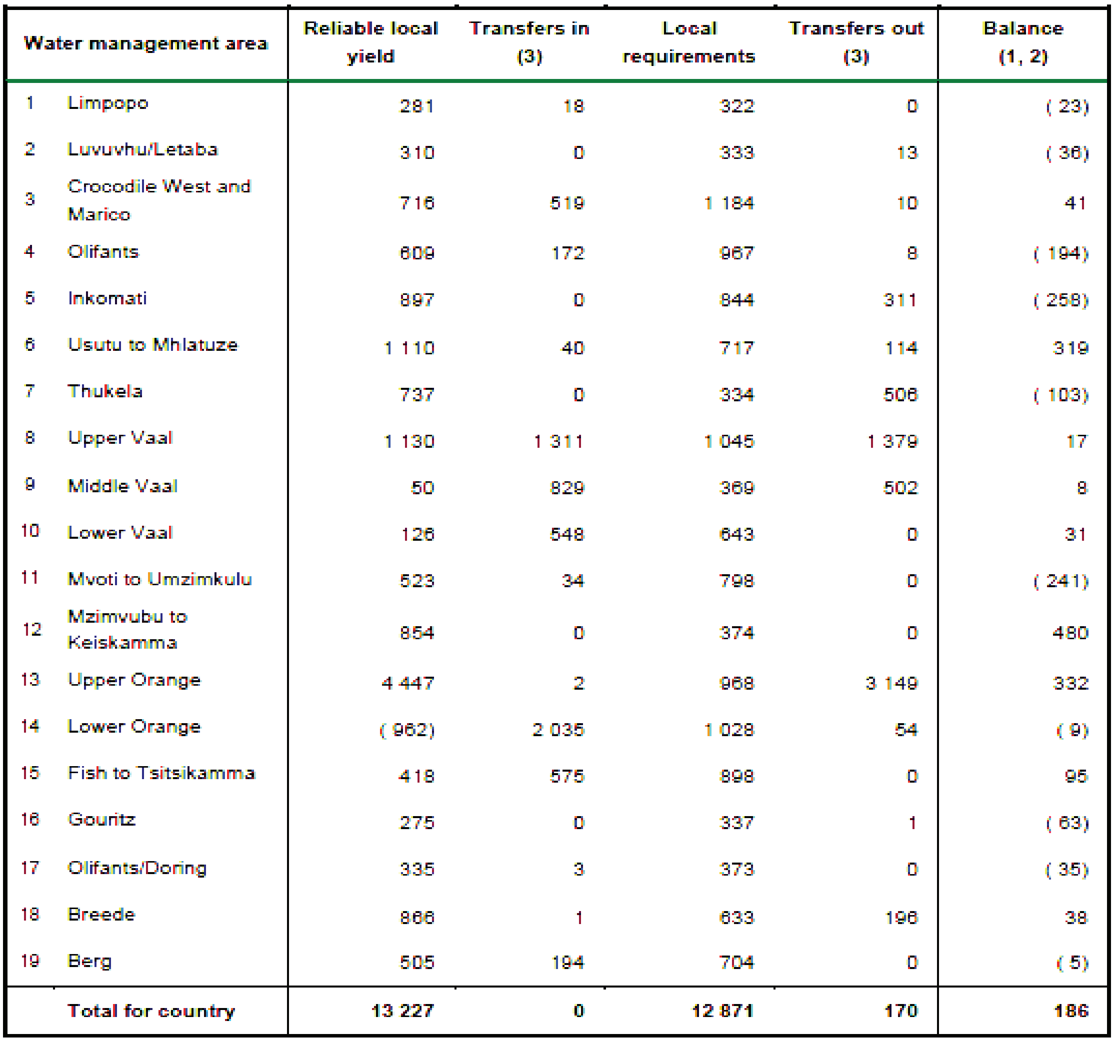
The largest volume of water requirement occurs in the agricultural irrigation sector (62%). The distribution of the volume of irrigation amongst different schemes is estimated to be 59% for private irrigation, 22% regulated by irrigation boards and 19% for State regulated irrigation schemes (DWAF, 1986). Agriculture in southern Africa is a very important activity in terms of poverty eradication and economic development, but is also identified as one of the major inefficient water users in the region – about 45% of the water delivered for irrigation is believed to reach the crop root zone (Stevens and Stimie, 2005). Irrigation also plays a disproportionally important role in the water supply sector because irrigated crops are generally two to three times more productive than rain-fed ones. Irrigation is therefore largely reserved for high value crops such as fruit, vegetables, sugarcane and horticulture (Rothert, 2000). Others include wheat, maize, cotton, coffee, tea, and tobacco. Water requirement for agricultural irrigation is expected to more than double by 2020, but its relative share of the total is expected to decrease, as urban water requirement is expected to outgrow all other sectors (Pallet, 1997). Any savings therefore from this sector may likely make a big difference in water allocation for other users. Table 2 presents estimates of local water yield versus local water requirements for the year 2000 within the different management areas. The estimated total water requirements comprise about 97% of available local yield. The estimated balance between yield plus transfers in and local requirements plus transfers out, highlights the urgent need for effective water resources management and alternative water supplementation schemes.

Indirect reuse of wastewater forms an integral part of water resources management in South Africa. Treated wastewater is extensively reused in the inland parts of South Africa. Return flows from domestic and non-domestic activities typically occur as point discharges of treated effluent into a watercourse or as diffuse seepage that may occur from irrigated areas to a river. In Table 3, a summary is given of the largest return flows as well as whether or not these return flows are indirectly reused within the different water regions within South Africa.

Direct reuse of wastewater for non-potable water requirements is increasingly become viable as a supplement to existing supplies and this is further discussed from Section 2.2.

Table 2. Estimated local yield versus local requirements for the year 2000

(DWAF, 2004a).



Water management area		Reliable local yield	Transfers in (3)	Local requirements	Transfers out (3)	Balance (1, 2)
1	Limpopo	281	18	322	0	(23)
2	Luvuvhu/Letaba	310	0	333	13	(36)
3	Crocodile West and Marico	716	519	1 184	10	41
4	Olifants	609	172	967	8	(194)
5	Inkomati	897	0	844	311	(258)
6	Usutu to Mhlatuze	1 110	40	717	114	319
7	Thukela	737	0	334	506	(103)
8	Upper Vaal	1 130	1 311	1 045	1 379	17
9	Middle Vaal	50	829	369	502	8
10	Lower Vaal	126	548	643	0	31
11	Mvoti to Umzimkulu	523	34	798	0	(241)
12	Mzimvubu to Keiskamma	854	0	374	0	480
13	Upper Orange	4 447	2	968	3 149	332
14	Lower Orange	(962)	2 035	1 028	54	(9)
15	Fish to Tsitsikamma	418	575	898	0	95
16	Gouritz	275	0	337	1	(63)
17	Olifants/Doring	335	3	373	0	(35)
18	Breede	866	1	633	196	38
19	Berg	505	194	704	0	(5)
	Total for country	**13 227**	**0**	**12 871**	**170**	**186**

1) Brackets around numbers indicate a negative balance.

2) Surpluses in the Vaal and Orange water management areas are shown in the most upstream water management area where they become available (that is, the Upper Vaal and Upper Orange water management areas.)

3) Transfers into and out of water management areas may include transfers between water management areas as well as to or from neighbouring countries. Yields transferred from one water management area to another may also not be numerically the same in the source and recipient water management area. For this reason, the addition of transfers into and out of water management areas does not necessarily correspond to the country total.

Table 3. Estimated volumes of major return flows in South Africa

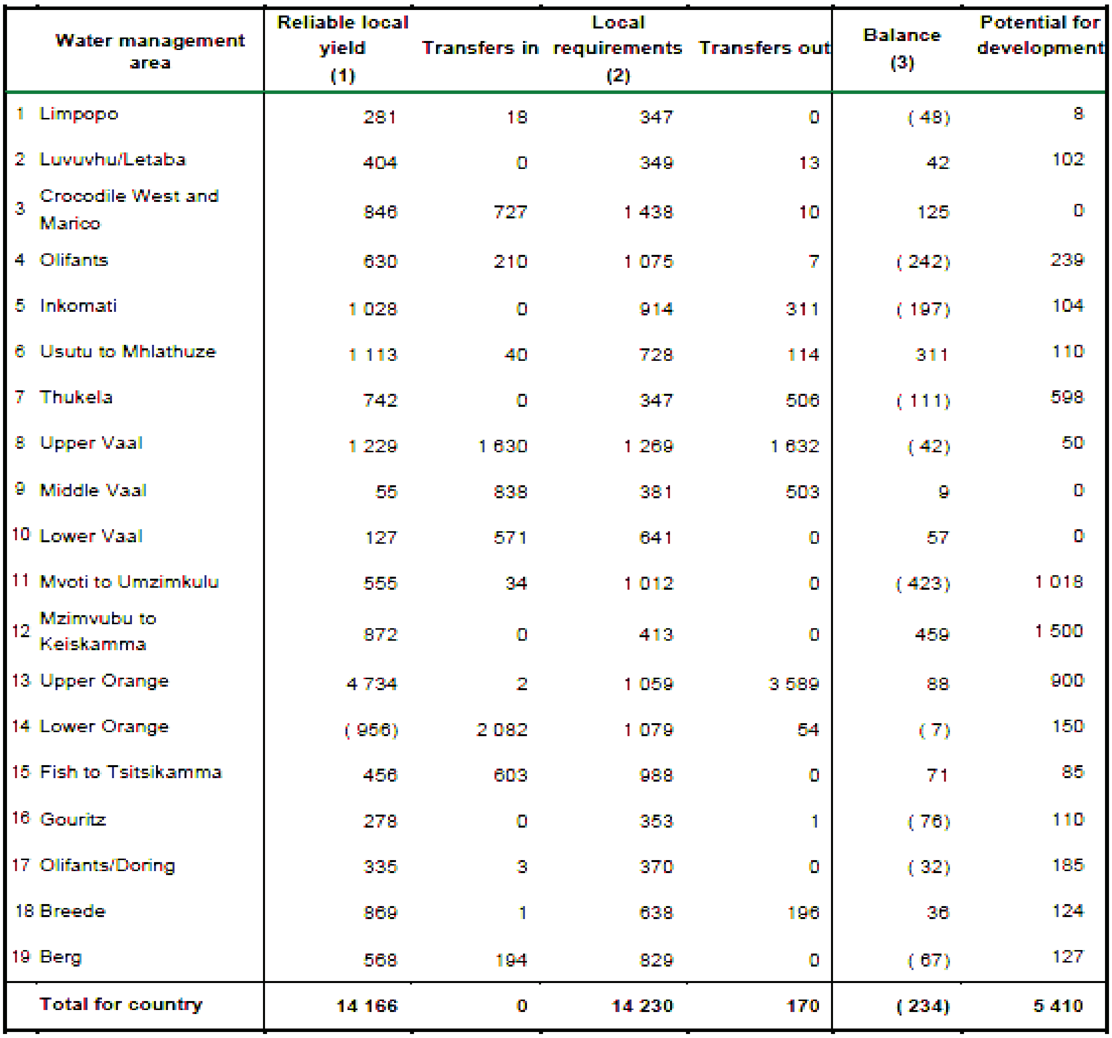
(Basson, 1997).

Region	***Volume of return flows* (10^6 m^3/a)**	***Reuse/No Reuse***
Northern	650	Re-use
Central	14	Re-use
Eastern Coastal	51	Re-use
	124	No re-use
Southern Coastal	51	No re-use
South Western	146	No re-use
Total	**1036**	**715x10^{6}m^3: Re-use (69%)** **321x10^6 m^3: No re-use (31%)**

By far the largest growth in water requirement is foreseen in the urban and industrial areas. This is largely due to population growth, urbanisation, increase in standards of living, increase in services, and associated economic growth and industrialisation. In this respect it is estimated that, should current trends and usage prevail, the total requirement for water in these sectors will approximately double over the next 30 years (i.e. by 2030), or will grow at roughly 3% per annum. Thus, in three decades, South Africa's water resources will be fully utilised. In the future, limited development in agriculture and afforestation is foreseen, due to the limited resources available. However, this does not imply a reduction in the volume of these requirements, rather a reduction in their proportion in relation to other major water use sectors (IUCN et al., 2005). Tables 4 and 5 present estimated future reconciliation of water requirements and water availability in South Africa within the different areas.

Table 4. Reconciliation of requirements for and availability of water for the year 2025 (base scenario)

(DWAF, 2004a)

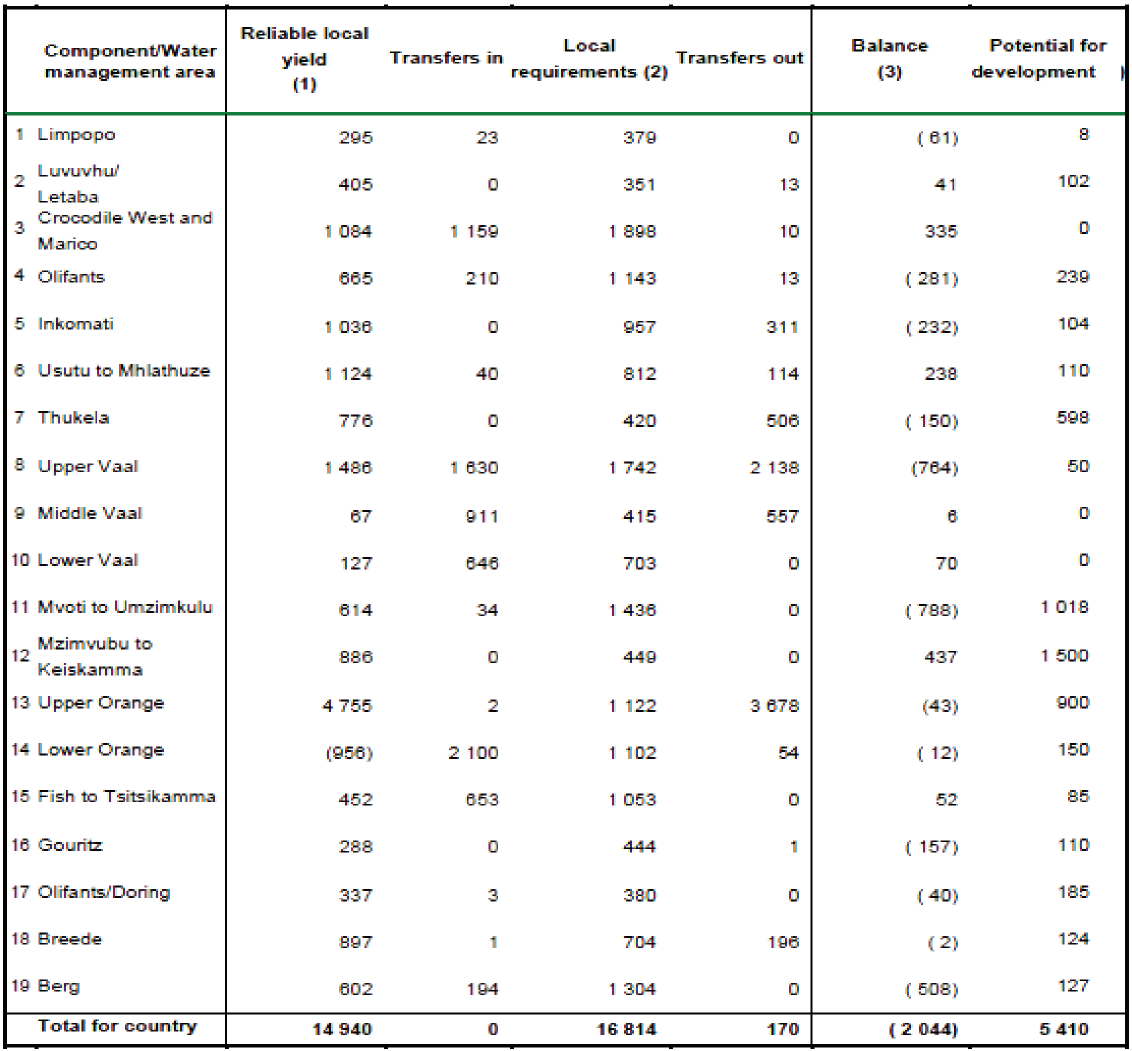


Water management area	Reliable local yield (1)	Transfers in	Local requirements (2)	Transfers out	Balance (3)	Potential for development
1 Limpopo	281	18	347	0	(48)	8
2 Luvuvhu/Letaba	404	0	349	13	42	102
3 Crocodile West and Marico	846	727	1 438	10	125	0
4 Olifants	630	210	1 075	7	(242)	239
5 Inkomati	1 028	0	914	311	(197)	104
6 Usutu to Mhlathuze	1 113	40	728	114	311	110
7 Thukela	742	0	347	506	(111)	598
8 Upper Vaal	1 229	1 630	1 269	1 632	(42)	50
9 Middle Vaal	55	838	381	503	9	0
10 Lower Vaal	127	571	641	0	57	0
11 Mvoti to Umzimkulu	555	34	1 012	0	(423)	1 018
12 Mzimvubu to Keiskamma	872	0	413	0	459	1 500
13 Upper Orange	4 734	2	1 059	3 589	88	900
14 Lower Orange	(956)	2 082	1 079	54	(7)	150
15 Fish to Tsitsikamma	456	603	988	0	71	85
16 Gouritz	278	0	353	1	(76)	110
17 Olifants/Doring	335	3	370	0	(32)	185
18 Breede	869	1	638	196	36	124
19 Berg	568	194	829	0	(67)	127
Total for country	**14 166**	**0**	**14 230**	**170**	**(234)**	**5 410**

1) Based on infrastructure in existence and under construction in the year 2000. Also includes return flows resulting from a growth in requirements.
2) The assumed growth in urban and rural water requirements results from the anticipated high population growth and current ratios of domestic to public and business water use. Allowance has been made for known developments in urban, industrial and mining sectors only, with no general increase in irrigation.
3) Brackets around numbers indicate a negative balance.

Table 5. Reconciliation of requirements for and availability of water for the year 2025 (high scenario)

(DWAF, 2004a)



Component/Water management area	Reliable local yield (1)	Transfers in	Local requirements (2)	Transfers out	Balance (3)	Potential for development
1 Limpopo	295	23	379	0	(61)	8
2 Luvuvhu/ Letaba	405	0	351	13	41	102
3 Crocodile West and Marico	1 084	1 159	1 898	10	335	0
4 Olifants	665	210	1 143	13	(281)	239
5 Inkomati	1 036	0	957	311	(232)	104
6 Usutu to Mhlathuze	1 124	40	812	114	238	110
7 Thukela	776	0	420	506	(150)	598
8 Upper Vaal	1 486	1 630	1 742	2 138	(764)	50
9 Middle Vaal	67	911	415	557	6	0
10 Lower Vaal	127	646	703	0	70	0
11 Mvoti to Umzimkulu	614	34	1 436	0	(788)	1 018
12 Mzimvubu to Keiskamma	886	0	449	0	437	1 500
13 Upper Orange	4 755	2	1 122	3 678	(43)	900
14 Lower Orange	(956)	2 100	1 102	54	(12)	150
15 Fish to Tsitsikamma	452	653	1 053	0	52	85
16 Gouritz	288	0	444	1	(157)	110
17 Olifants/Doring	337	3	380	0	(40)	185
18 Breede	897	1	704	196	(2)	124
19 Berg	602	194	1 304	0	(508)	127
Total for country	**14 940**	**0**	**16 814**	**170**	**(2 044)**	**5 410**

1) Based on infrastructure in existence and under construction in the year 2000. Also includes return flows resulting from a growth in requirements.
2) Urban and rural requirements based on high growth in water requirements as a result of population growth and the high impact of economic development. Allowance has been made for known developments in urban, industrial and mining sectors only, with no general increase in irrigation.
3) Brackets around numbers indicate a negative balance.

2.2. Non-potable water uses

Below are some of the non-potable water uses that do not require potable water quality:

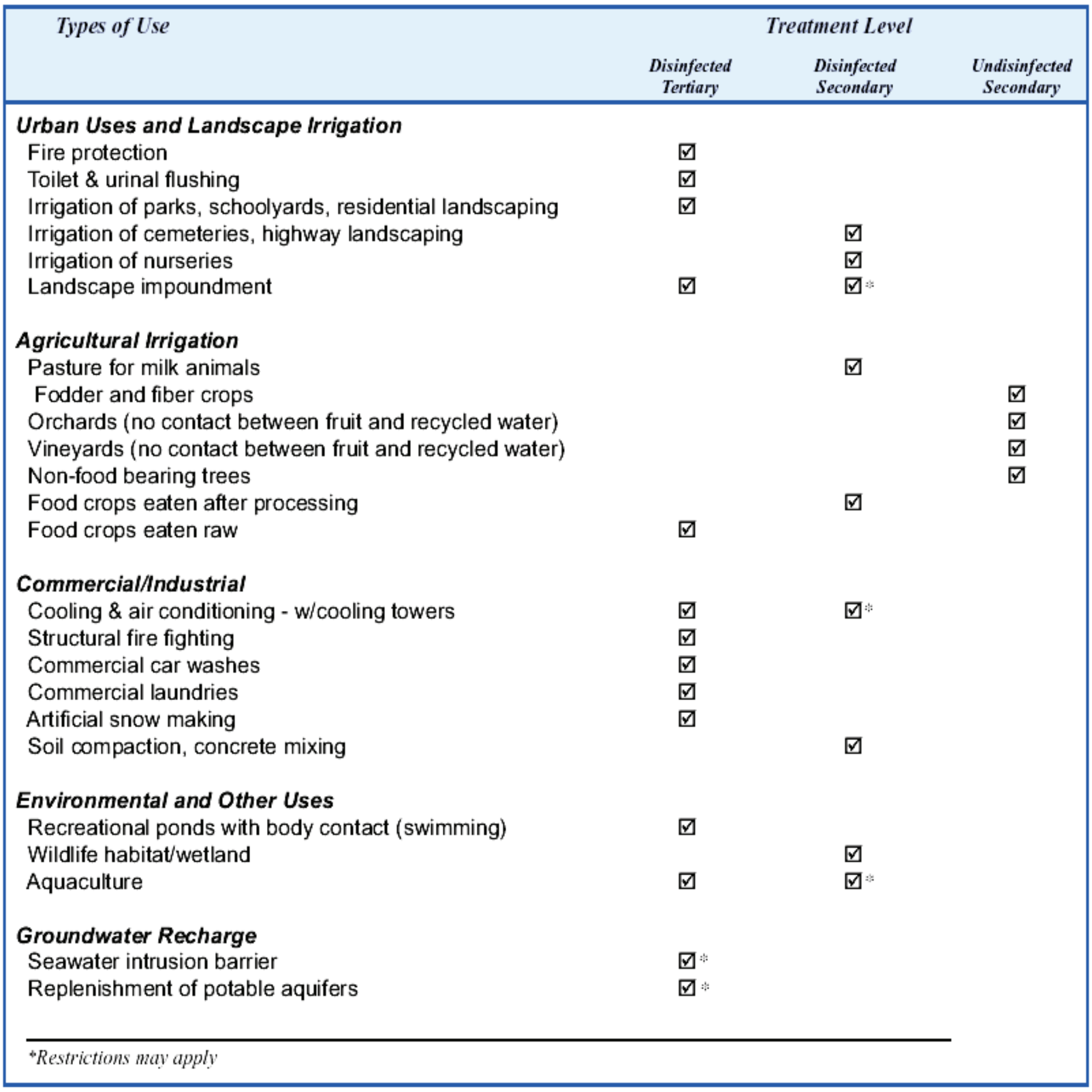
- Landscape irrigation of golf courses, parks, playgrounds, sports fields, freeway medians, commercial, office buildings and residence lawns;
- Industrial uses, e.g. air-conditioning, laundry, car washing, heat dissipation, power generation, and processing;
- Agricultural uses, e.g. irrigation of produce, pastures for animal feed, and nurseries;
- Emergency use in dust suppression and fire-fighting;

- Toilet and urinal flushing in both domestic and non-domestic buildings;
- Aquaculture (the cultivation of aquatic organisms like fish);
- Ground water recharge; and
- Construction (dust control, concrete mixing, soil compaction and aggregate washing).

Many of these uses require some degree of treatment to be suitable for use (see Table 6).

Table 6. Non-potable water uses and estimated minimum treatment levels

(Water Facts, 2004)



Types of Use	*Treatment Level*		
	Disinfected Tertiary	*Disinfected Secondary*	*Undisinfected Secondary*
Urban Uses and Landscape Irrigation			
Fire protection	☑		
Toilet & urinal flushing	☑		
Irrigation of parks, schoolyards, residential landscaping	☑		
Irrigation of cemeteries, highway landscaping		☑	
Irrigation of nurseries		☑	
Landscape impoundment	☑	☑*	
Agricultural Irrigation			
Pasture for milk animals		☑	
Fodder and fiber crops			☑
Orchards (no contact between fruit and recycled water)			☑
Vineyards (no contact between fruit and recycled water)			☑
Non-food bearing trees			☑
Food crops eaten after processing		☑	
Food crops eaten raw	☑		
Commercial/Industrial			
Cooling & air conditioning - w/cooling towers	☑	☑*	
Structural fire fighting	☑		
Commercial car washes	☑		
Commercial laundries	☑		
Artificial snow making	☑		
Soil compaction, concrete mixing		☑	
Environmental and Other Uses			
Recreational ponds with body contact (swimming)	☑		
Wildlife habitat/wetland		☑	
Aquaculture	☑	☑*	
Groundwater Recharge			
Seawater intrusion barrier	☑*		
Replenishment of potable aquifers	☑*		

**Restrictions may apply*

Reuse of domestic and industrial wastewater, rain water, saline water and storm water presents a viable substitute for potable water in many non-potable applications listed above and therefore, has a potentially important role to play in helping to meet future requirements for water in especially arid South African cities. Wastewater reuse could potentially supply about 50 percent of the water needs of urban users and a significant proportion of the water needs for irrigation (Dimitriadis, 2005).

2.3. Non-potable water sources

2.3.1. Rain water harvesting

Rain water is drops of fresh water that fall as precipitation from clouds. Since ancient times, the only sources of natural water that were recognized as safe to drink were rain water and water from deep wells. Rain water must however be carefully handled so that it does not become contaminated. Once it runs along a surface, it has potential to pick up pollutants (e.g. soil, plant parts, insect parts, bacteria, algae, and sometimes radioactive materials that have been washed out of the air). Hence, because of the health risks of consuming contaminated rain water, it is with reluctance that communities are encouraged to directly consume it. However, with some filtration and the proper infrastructure, rain water can be harvested and used for non-potable uses, e.g. irrigation, toilet flushing, laundry, and car washing.

2.3.2. Storm water

Storm water is water from rain or melting snow that doesn't soak into the ground but runs off into waterways. It flows from rooftops, over paved areas, bare soil and through sloped lawns. The quality of runoff is affected by a variety of factors and depends on the season, local meteorology, geography and activities which lie in the path of the flow. As it flows, storm water runoff collects and transports soil, animal waste, salt, pesticides, fertilizers, oil and grease, debris and other potential pollutants. Transported soil clouds the resource and downstream waterway and interferes with the habitat of fish (by depleting the amount of oxygen in the water) and plant life (by reducing light for photosynthetic organisms and encouraging weeds and toxic algal blooms). Common chemicals found in storm water are detergents, coolants, petroleum products (oil), fertilizers, paints and nitrogen (Speers and Mitchell, 1999).

Storm water can be collected for potable and non potable use. This water may be suitable for most non-potable uses but, because it gathers a variety of pollutants as it runs off on different surfaces, it will likely require treatment prior to use. Storage and conveyancing systems are also required for harvesting rain water in a catchment area. An example of a storm water harvesting and dual system can be found at the Millennium Dome (Lazarova et al., 2003).

2.3.3. Surface water

This is water which exists on the surface of the earth in different forms such as streams, oceans, rivers, lakes and ponds. The major source of surface water is precipitation. This is either directly from storm water or from underground seepage. Fresh surface water accounts for about 0.27% of the world's fresh water volume. Surface waters are highly susceptible to pollution from its immediate environment in the form of waste effluent from domestic, non-domestic or natural activities.

2.3.4. Sea water

Sea water is water from a sea or ocean. 97% of the total volume of water on the earth is sea water. On average, sea water in the world's oceans has a salinity of between 3.0-3.5%. This means that for every 1 litre of sea water, there are between 30-35 grams of salts (mostly, but not entirely, sodium chloride) dissolved in it. Sea water, with this level of salinity, is not potable. The salinity of sea water does vary, and the combination of salinity and temperature has a major influence on ocean currents and behaviour. Inclusive of weight, other ways to characterize the average salinity are 35 ppt (parts per thousand), and 35 psu (practical salinity units). There are other salts (e.g. Magnesium, Sulphur, Calcium and Potassium) dissolved in sea water, with ordinary sodium chloride constituting about 90% of the dissolved salts (Nave, 2005).

Several countries currently use seawater in their industrial processes. This is mainly for cooling, and hence there is generally no treatment prior to disposal. Some other countries (e.g. Hong Kong, China) make use of seawater for domestic uses (mainly toilet-flushing), with treatment ranging from none to secondary.

2.3.5. Brackish water

Brackish water is water that is saltier than fresh water, but not as salty as sea water. It may result from the mixing of seawater with fresh water, especially as is found in estuaries. Technically, brackish waters contain between 0.5 and 30 grams of salt per litre. Thus, brackish waters cover a range of salinity regimes and are not considered a precisely defined condition.

An estuary, a common location for brackish waters, is the part of a river where it meets the sea. Typically, estuarine waters are slow and sluggish, and often salty and fertile. As a result, they are not always as attractive to look at as the clear waters of a mountain stream, but they are productive. One characteristic of estuarine water habitats in general, is that while productivity (the amount of aquatic organisms) is high, diversity (the number of species) can be quite low compared with rivers or the sea. This apparent contradiction is because relatively few fish and invertebrates can tolerate the fluctuations in salinity. On the other hand, those animals that can live there do so in enormous numbers.

Brackish waters can also be found in the form of ground water from aquifers. To be usable, brackish water needs to be treated (desalinated). Without treatment, brackish waters can cause scaling and corrosion problems in water wells and piping and cannot be used in many industrial processes (Warner, 2001).

2.3.6. Mine water

Mine water refers to the mostly saline wastewater discharged from mining operations. Most mines are required to handle large quantities of water. To obtain the water needed by their operations, some mines pump water over great distances, while others use nearby river water. Many South African mines which have operated over a long period of time in an area, have dug large volumes of empty spaces below ground surface. Many of these empty spaces have become storage spaces for large volumes of mine water which are difficult to discharge into surface water courses due to the complex and expensive wastewater treatments required. See Table 7 for an example of mine water quantities at the Emalahleni catchment area.

Table 7. Mine water available at the Emalahleni Catchment

(Gunther, 2006)

Source	*Available 2005 (m^3/day)*	*Available 2015 (m^3/day)*	*Available at closure > 2020 (m^3/day)*
Anglo	18 000	20 000	28 000
Ingwe Collieries	17 800	26 400	29 300
Others	2 800	3 800	14 400
Total	38 600	50 200	71 700

2.3.7. Black water

Black water is water generated from bathtubs, showers, hand basins, laundry, kitchen, and any water flushed down the toilet or urinals. Black water requires a detailed treatment process before being released to the environment or made available for use.

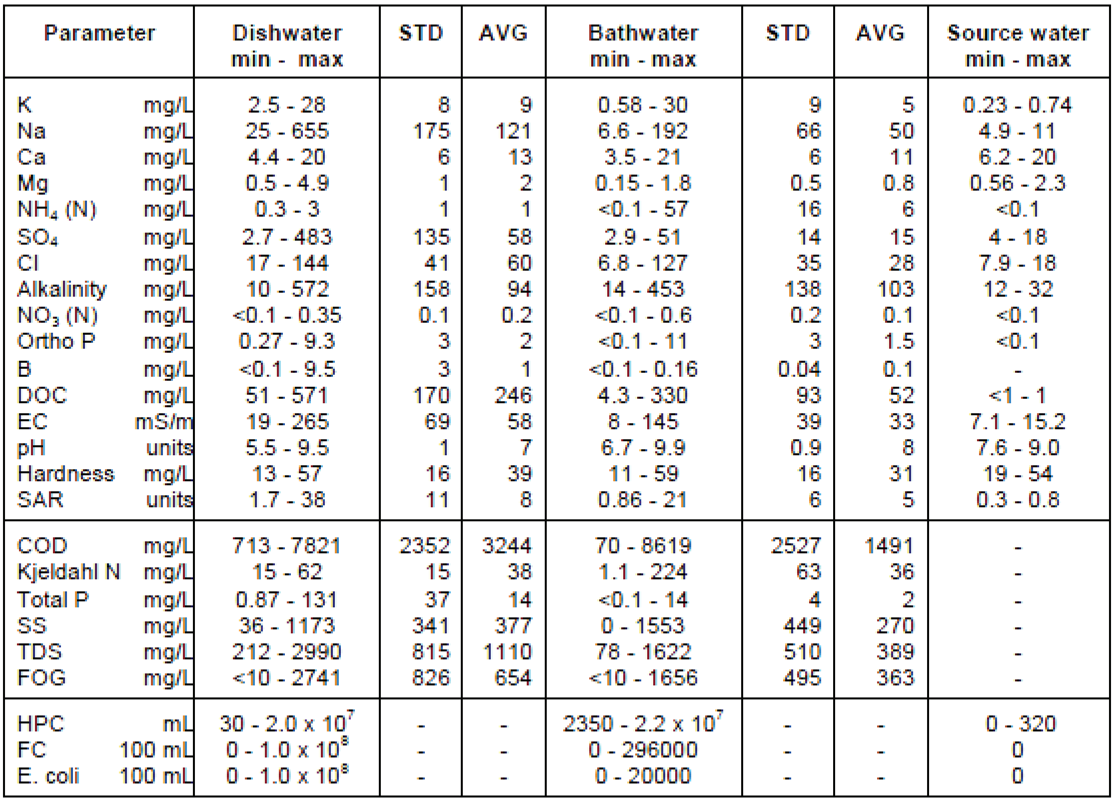
2.3.8. Grey water

This represents household wastewater (i.e. water from showers, baths, hand basins, laundry tubs, washing machines, dishwashers and kitchen sinks) and does not include water from toilets. In Australia and the USA, grey water refers to only water from bathtubs, showers, hand basins, laundry tubs and washing machines – kitchen wastewater is excluded.

Engelbrecht and Murphy (2006) undertook an analysis of dish water, bath water and source water from a selection of respondents. The respondents were selected based on their residential location, economic and social status. A summary of the analysis results are presented in Table 8.

Table 8. Summary of results from analysis of dish water, bath water and source water

(Engelbrecht and Murphy, 2006)



Parameter	Dishwater min - max	STD	AVG	Bathwater min - max	STD	AVG	Source water min - max
K mg/L	2.5 - 28	8	9	0.58 - 30	9	5	0.23 - 0.74
Na mg/L	25 - 655	175	121	6.6 - 192	66	50	4.9 - 11
Ca mg/L	4.4 - 20	6	13	3.5 - 21	6	11	6.2 - 20
Mg mg/L	0.5 - 4.9	1	2	0.15 - 1.8	0.5	0.8	0.56 - 2.3
NH_4 (N) mg/L	0.3 - 3	1	1	<0.1 - 57	16	6	<0.1
SO_4 mg/L	2.7 - 483	135	58	2.9 - 51	14	15	4 - 18
Cl mg/L	17 - 144	41	60	6.8 - 127	35	28	7.9 - 18
Alkalinity mg/L	10 - 572	158	94	14 - 453	138	103	12 - 32
NO_3 (N) mg/L	<0.1 - 0.35	0.1	0.2	<0.1 - 0.6	0.2	0.1	<0.1
Ortho P mg/L	0.27 - 9.3	3	2	<0.1 - 11	3	1.5	<0.1
B mg/L	<0.1 - 9.5	3	1	<0.1 - 0.16	0.04	0.1	-
DOC mg/L	51 - 571	170	246	4.3 - 330	93	52	<1 - 1
EC mS/m	19 - 265	69	58	8 - 145	39	33	7.1 - 15.2
pH units	5.5 - 9.5	1	7	6.7 - 9.9	0.9	8	7.6 - 9.0
Hardness mg/L	13 - 57	16	39	11 - 59	16	31	19 - 54
SAR units	1.7 - 38	11	8	0.86 - 21	6	5	0.3 - 0.8
COD mg/L	713 - 7821	2352	3244	70 - 8619	2527	1491	-
Kjeldahl N mg/L	15 - 62	15	38	1.1 - 224	63	36	-
Total P mg/L	0.87 - 131	37	14	<0.1 - 14	4	2	-
SS mg/L	36 - 1173	341	377	0 - 1553	449	270	-
TDS mg/L	212 - 2990	815	1110	78 - 1622	510	389	-
FOG mg/L	<10 - 2741	826	654	<10 - 1656	495	363	-
HPC mL	30 - 2.0 x 10^7	-	-	2350 - 2.2 x 10^7	-	-	0 - 320
FC 100 mL	0 - 1.0 x 10^8	-	-	0 - 296000	-	-	0
E. coli 100 mL	0 - 1.0 x 10^8	-	-	0 - 20000	-	-	0

From Table 8, it can be seen that there are significant distinctions and notably large chemical ranges between grey water generated from dishes and baths. Hence, the justification in Australia and the USA to separate kitchen water from the other sources of grey water. Grey water obtained from the kitchen is contaminated with oils, animal fats, chemical detergents and food particles. Kitchen water promotes and supports the growth of micro-organisms. Chemical detergents used for dish washing may be very alkaline and fats can solidify causing blockages in the natural drainage systems of soils. Kitchen water should therefore not be used for irrigation unless it is treated because it has the potential to alter the characteristics of the soil. Whilst grey water generated from hand basins, showers and baths do not normally contain human waste, it may contain similar micro-organisms. It is however safe to say that grey water from the bathroom contains much lower numbers of these organisms and is considered safe to use on the garden if done responsibly and within a prescribed period from collection.

There are significant distinctions between grey water and black water. These distinctions tell us how these wastewaters should be treated and managed in the interests of public health and environmental protection. Some of these distinctions include:

- Grey water contains far less nitrogen than black water. Nine-tenths of the nitrogen contained in combined wastewater comes from black water. Nitrogen (as nitrite and nitrate) is the most serious (cancer causing) and difficult-to-remove pollutant affecting drinking water;

- Grey water contains fewer pathogens than black water at the point of discharge. Medical and public health professionals view faeces as the most significant source of human pathogens. However if grey water is left untreated for a few days, it will develop the characteristics of black water, i.e. it will become malodorous (anaerobic) and contain a large number of bacteria;
- Grey water decomposes much faster than black water. The most significant difference between black water and grey water lies in the rate of decay of the pollutants in each. Black water consists largely of organic compounds that have already been exposed to one of nature's most efficient "treatment plants" – the digestive tract of the human body. The by-products from this process do not rapidly decompose further when placed in water; therefore the rate of decay of grey water is higher than that of black water;
- Contrary to black water, grey water does not stink immediately after discharge. However, if it is collected in a tank, it will very quickly use up its oxygen and will become anaerobic. Once it reaches the septic state, grey water forms sludge that either sinks or floats depending on its gas content and density. Septic grey water can be as foul-smelling as black water and will also contain anaerobic bacteria, some of which can be human pathogens. Consequently, a key to successful grey water treatment lies in its immediate processing before it turns anaerobic. The simplest, most appropriate treatment technique consists of directly introducing freshly generated grey water into an active, live topsoil environment.

Grey water may be used for irrigation and watering of gardens as these uses do not necessarily require potable water. Black water from toilets and urinals should not be reused in the domestic environment without the installation of specialized treatment equipment. When using grey water on the garden, the type of soap and washing powder used must be considered. Many soap products contain ingredients that may affect plants and soil negatively such as phosphorus, pH, bleaches and disinfectants. Grey water contains impurities and micro-organisms that may cause a health risk and therefore should be applied at the roots of the plants being irrigated to avoid contact with humans on the soil surface. The bio-accumulation of potentially toxic elements in plants is also an issue of concern as this may have long term health effects on humans. Grey water should be prevented from overflowing into storm water drains, rivers, streams and ground water as it may contaminate these sources of water.

Potential benefits associated with the use/reuse of grey water are that it will reduce the demand for potable water. This should in turn, reduce the load on potable water and WWTWs and hence, reduce the cost of water treatment. It can also reduce the cost of irrigation by reducing the application of plant nutrients that may be present in grey water (Engelbrecht & Murphy, 2006).

2.4. Non-potable water reuse

Non-potable water reuse involves the process of treating, storing, distributing, and the actual reuse of non-potable water. Treated effluent reuse therefore involves the treating of wastewater at a wastewater treatment works and the redirection of the treated effluent into a water system for further use. There are two types of treated effluent reuse: direct and indirect. Indirect re-use refers to raw water that is taken from a river, lake, or aquifer which has received treated effluent. Direct reuse is the planned use of treated effluent for some beneficial purpose, including drinking. Figure 1 shows a schematic conventional water supply and treated effluent reuse loop.

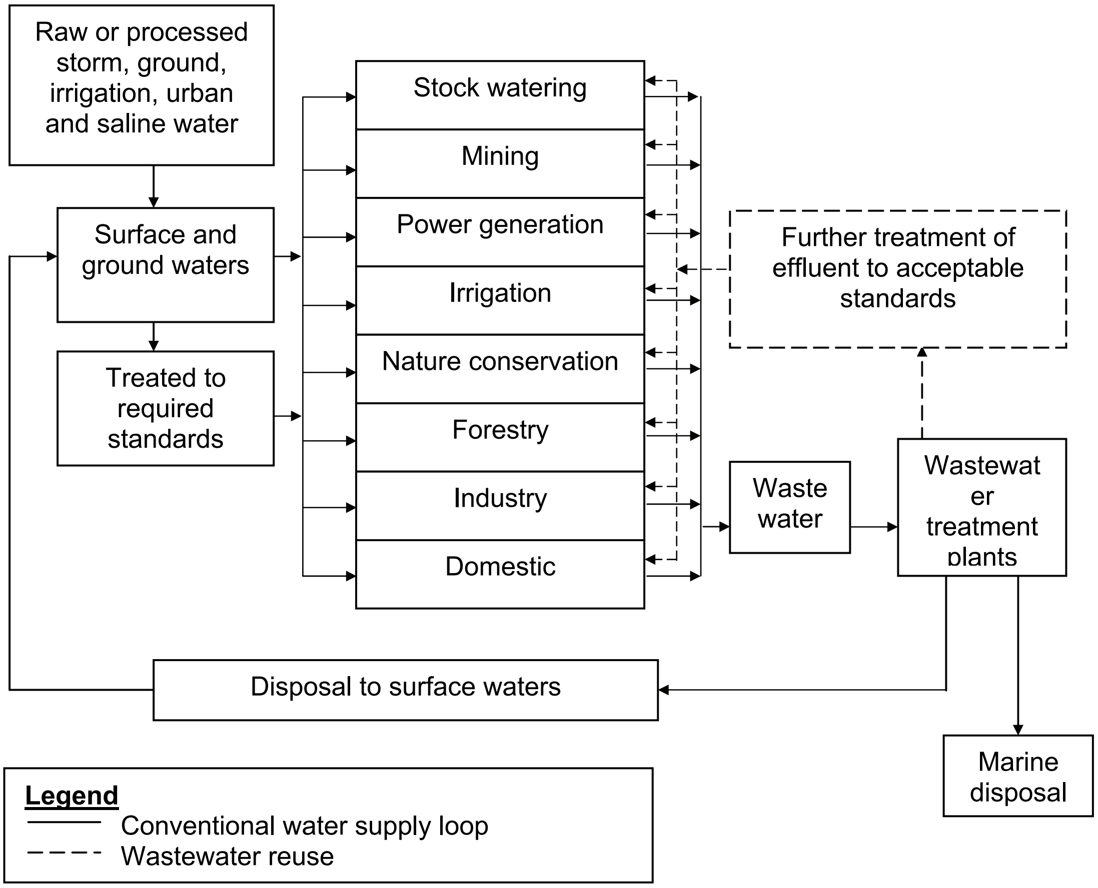


Figure 1. Schematic conventional water supply and treated effluent reuse loop

(Grobicki and Cohen, 1999)

Grobicki and Cohen (1999) estimate that between 35-65% (about 1 086 x 10^6 m^3/a) of the total urban and industrial water consumed in South African towns and cities are return flows. Less than 3% of this is however reused. Find in Table 9 data pertaining to treated effluent reuse in South Africa (Grobicki and Cohen, 1999).

Table 9. Treated effluent reuse in South Africa

(Grobicki and Cohen, 1999)

Application	***m³/a***
Aquifer storage and recharge (Atlantis)	2×10^6
Industrial water (paper making)	9.6×10^6
Industrial water (other)	data not available
Cooling in municipal power stations	4.2×10^6
Irrigation in urban areas	data not available

2.4.1. Advantages and disadvantages of treated effluent reuse

In addition to those listed in section 1.1, It is now more widely recognised that the benefits of water reuse include the following (Dimitriadis, 2005, McKenzie et al., 2003):

- In areas without water borne sewerage, grey water use improves the performance of septic tanks;
- Grey water use reduces the hydraulic, biological and nutrient load on the WWTWs which can have several additional benefits such as deferring new capital works.

Some disadvantages/ constraints include (Dimitriadis, 2005, McKenzie et al., 2003):

- Community perceptions of risk may arise to discourage the reuse of wastewater. Perceptions mostly relate to food safety and the long-term sustainability of such schemes, as well as the costly management of salinity, sodicity, or nutrient levels;
- Wastewater reuse would likely involve additional pipe work, pumps and storage tanks, which can be expensive. These costs may not be recovered from the potable water tariff savings from the consumer’s perspective. In some instances, the water supplier provides grants to encourage consumers to reuse;
- Reused water use can pose a health hazard in some cases, especially if it is not implemented correctly. In hot climates, where germs breed faster than in cooler climates, this can be a hazard;
- Water reuse is not always necessarily the low technology solution to water conservation that many consumers believe. To be implemented properly and safely, water reuse is based on a number of simple concepts, which require a certain level of technology if the process is to operate properly;
- In many areas, the effluent from the WWTWs is discharged into surface waters or even supplied to industries or irrigation schemes. The overall impact of household water reuse on the overall water resources of an area will therefore depend on the situation applicable to the area under consideration;
- Users downstream of the surface water resource may be ill-affected by the reduced surface water flow quantities due to treated effluent reuse upstream;
- Where treated effluent reuse results in sewer flows drastically reducing, solid waste may be deposited within the sewer causing blockages.

2.4.2. Treated effluent reuse categories and potential constraints

Table 10 lists specific wastewater reuse categories and potential constraints that can result in each category:

Table 10. Treated effluent categories and potential constraints

Wastewater reuse category	***Potential constraints***
Agricultural irrigation: ➢ Crop irrigation ➢ Commercial nurseries	➢ Effect of water quality, particularly salt, on soil and crops ➢ Marketability of crops and public acceptance ➢ Public health concerns, especially for unprocessed food crops
Landscape irrigation: ➢ Park ➢ School yard ➢ Freeway median ➢ Golf course ➢ Cemetery ➢ Greenbelt ➢ Residential	➢ Surface and ground water pollution if not properly managed ➢ Public health concerns related to pathogens ➢ Effect of water quality, particularly salt on soils and plants
Industrial reuse: ➢ Cooling ➢ Boiler feed ➢ Process water ➢ Heavy construction	➢ Reclaimed water constituents related to scaling, corrosion, biological growth and fouling ➢ Public health concerns, particularly aerosol transmission of organics and pathogens in cooling water and pathogens in various process waters
Ground water recharge: ➢ Ground water replenishment ➢ Salt water intrusion ➢ Subsidence control	➢ Trace organics in reclaimed wastewater and their toxicological effects ➢ Total dissolved solids, metals and pathogens in reclaimed wastewater

2.5. Dual water reticulation systems

A dual water reticulation system is a system consisting of separate pipes that supply drinking and non-drinking water respectively to the end consumer. In many instances, the pipe delivering non-drinking water is colour-coded. The non-drinking water system would be used to augment potable water supplies by providing non-drinking water (e.g. untreated or partially treated black, grey, saline or wastewater) for non-drinking purposes such as fire-fighting, toilet/urinal flushing, and irrigation. The different forms and scales of dual systems are presented in the sections below.

2.5.1. Dual water reticulation system forms

Dual water reticulation systems exist in different forms (see below) – the main difference being the source or quality of the non-potable water supply:

2.5.1.1. Dual (rain/surface/storm and potable) water reticulation systems

Dual (rain and potable) water systems have become an option for many poor communities with limited access to fresh water sources. The rain water system collects rain water from roofs or pavements in order to replace potable water used for irrigation, toilet or urinal flushing.

Germany alone has over half a million dual (rain and potable) water systems in homes and workplaces. Political and cultural drivers appear to have a strong influence on uptake in Germany. Subsidies from local government of up to USD $100 are available in some areas to help with the initial cost of these systems. In addition to this, the higher cost of potable water in Germany is a good incentive for homeowners to install dual (rain and potable) water systems. Japan has strict regulations that ensure that buildings with a total space of over 300,000 m^2 have dual (grey and potable) water or dual (rain and potable) water systems installed. Large new buildings, such as hotels, now have dual systems fitted as standard practice. In England and Wales, more than 100 dual (rain and potable) water systems are currently in place.

Although in some parts of Africa (e.g. Botswana, Togo, Mali, Malawi, South Africa, Namibia, Zimbabwe, Mozambique, Sierra Leone and Tanzania), the rapid expansion of rain water harvesting systems has occurred in recent years, uptake has been slower than expected. This is due in part to the lower rainfall volumes and its seasonal nature, the smaller number and size of impervious roofs, and the higher costs of constructing catchment systems in relation to typical household incomes. The lack of availability of cement and clean graded river sand in some parts of Africa and a lack of sufficient water for construction in others, add to overall cost. Despite the advances made in rainwater harvesting, dual (rain and potable) water systems are few. Most communities that use rainwater do not employ dual systems but rather, manually collect in buckets for household use.

Figure 2 shows an example dual (rain and potable) water reticulation system. In the figure, rain water is collected from the roof area or pavement by down pipes. A filter(1) stops leaves and other large solids from getting into the holding tank. The water enters the tank through a smoothing inlet(2), which stops sediments at the bottom of the tank from being disturbed by heavy rainfall. A suction filter(3) prevents the uptake of floating matter when the water is drawn up for use. As the water is non-potable, it travels through a separate set of pipes. A pump(4) pressurises the water. In the figure, the pump is a submersible one, although other systems may use suction pumps. The control unit(5) monitors the water level(6) in the tank and can display this information to the user. If the water level in the tank drops too low, the control unit will trigger an automatic change over(7) to the mains water supply. The system must have an air gap(8) installed in order to prevent back flow of rain water into the mains. When the water in the tank reaches a certain level, an overflow trap(9) allows floating material to be skimmed off into the storm drain. A non-return valve should be fitted to prevent contamination of the tank by backflow, together with a rodent barrier (A device on the holding tank overflow pipe to prevent rodents entering into the holding tank). Water soaking through a permeable pavement(10) can also be collected, although an oil trap(11) as well as filter should be fitted. Collecting water from the pavement increases the potential for oil and animal faeces to contaminate the tank water. Therefore, depending on how the water is to be used, disinfection should be considered.

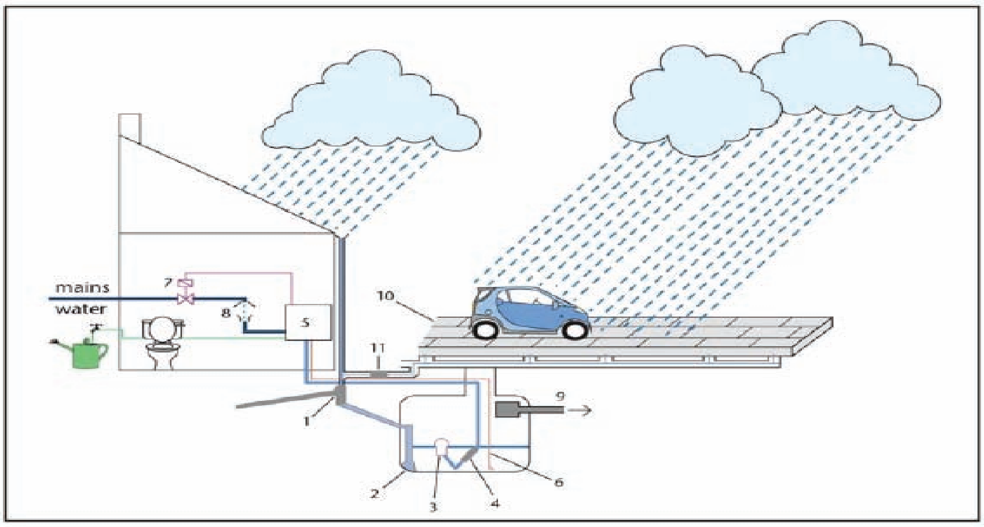


Figure 2. Schematic of a dual (rain and potable) water reticulation system

(Environment Agency, 2003)

2.5.1.2. Dual (saline and potable) water reticulation systems

Several locations around the world utilise saline water for diverse uses. Saline water may refer to sea, brackish or mine water. Table 11 lists some of the locations using saline water and the level of treatment used before application.

Table 11. Some locations using saline water and treatment employed

(Smith et al., 1996 & Parr et al., 1997)

Country	***Level of Treatment***
Cayman Islands	Secondary[1]
Gibraltar	None
Hong Kong	Preliminary
Hong Kong	Secondary[2]
Kiribati	None
Marshall Islands	None
US Virgin Islands	primary

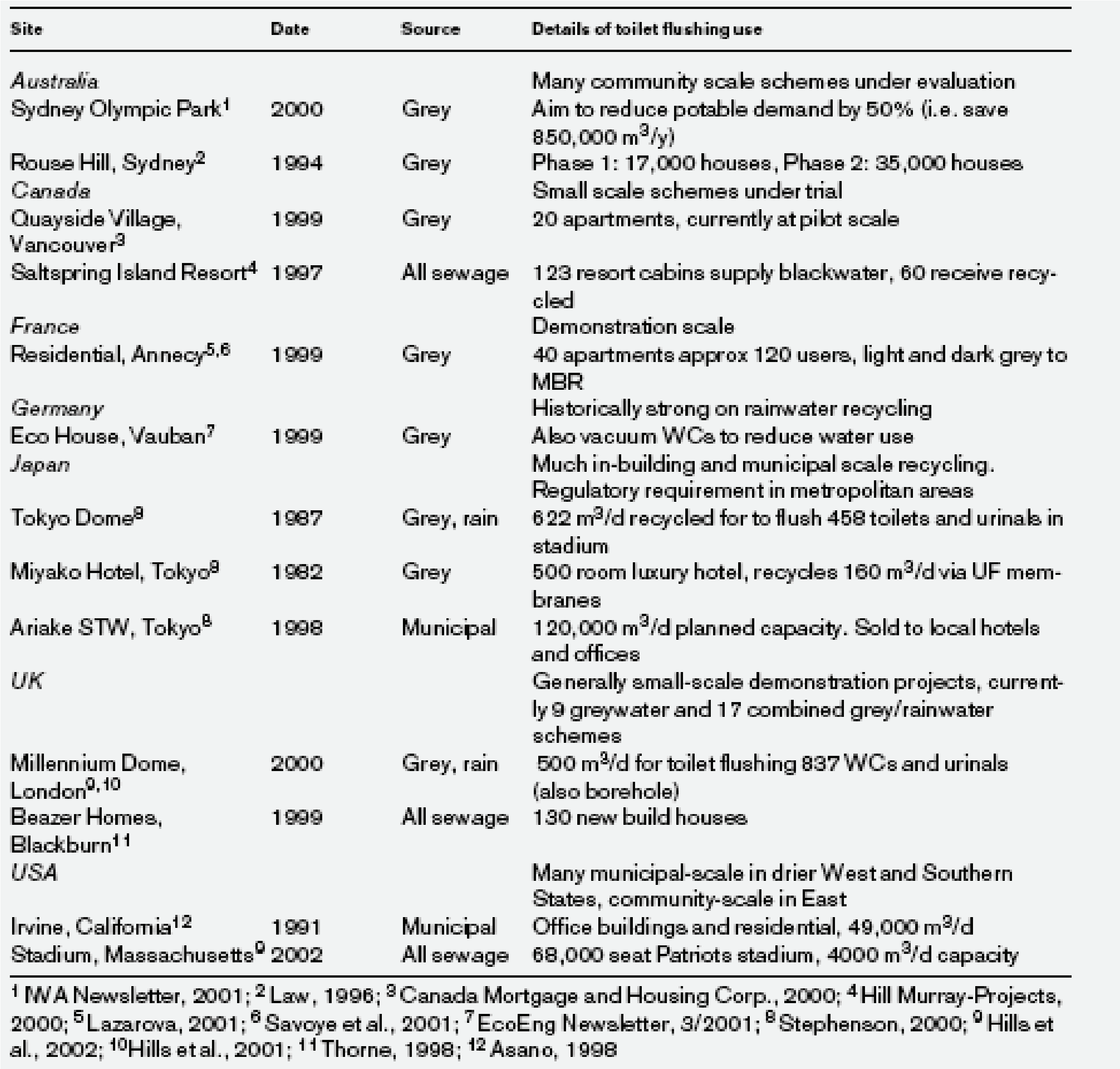
[1] *Mixed with municipal wastewater*
[2] *Salinity arises from the use of highly saline well water.*

2.5.1.3. Dual (grey/effluent and potable) water reticulation systems

Dual (grey/effluent and potable) water reticulation systems are also extensively used all over the world. Table 12 presents examples of dual systems with the non-potable supply specifically for toilet flushing.

Table 12. Examples of dual (grey/effluent and potable) systems

(Lazarova et al., 2003)



Site	Date	Source	Details of toilet flushing use
Australia			Many community scale schemes under evaluation
Sydney Olympic Park[1]	2000	Grey	Aim to reduce potable demand by 50% (i.e. save 850,000 m^3/y)
Rouse Hill, Sydney[2]	1994	Grey	Phase 1: 17,000 houses, Phase 2: 35,000 houses
Canada			Small scale schemes under trial
Quayside Village, Vancouver[3]	1999	Grey	20 apartments, currently at pilot scale
Saltspring Island Resort[4]	1997	All sewage	123 resort cabins supply blackwater, 60 receive recycled
France			Demonstration scale
Residential, Annecy[5,6]	1999	Grey	40 apartments approx 120 users, light and dark grey to MBR
Germany			Historically strong on rainwater recycling
Eco House, Vauban[7]	1999	Grey	Also vacuum WCs to reduce water use
Japan			Much in-building and municipal scale recycling. Regulatory requirement in metropolitan areas
Tokyo Dome[8]	1987	Grey, rain	622 m^3/d recycled for to flush 458 toilets and urinals in stadium
Miyako Hotel, Tokyo[8]	1982	Grey	500 room luxury hotel, recycles 160 m^3/d via UF membranes
Ariake STW, Tokyo[8]	1998	Municipal	120,000 m^3/d planned capacity. Sold to local hotels and offices
UK			Generally small-scale demonstration projects, currently 9 greywater and 17 combined grey/rainwater schemes
Millennium Dome, London[9,10]	2000	Grey, rain	500 m^3/d for toilet flushing 837 WCs and urinals (also borehole)
Beazer Homes, Blackburn[11]	1999	All sewage	130 new build houses
USA			Many municipal-scale in drier West and Southern States, community-scale in East
Irvine, California[12]	1991	Municipal	Office buildings and residential, 49,000 m^3/d
Stadium, Massachusetts[9]	2002	All sewage	68,000 seat Patriots stadium, 4000 m^3/d capacity

[1] IWA Newsletter, 2001; [2] Law, 1996; [3] Canada Mortgage and Housing Corp., 2000; [4] Hill Murray-Projects, 2000; [5] Lazarova, 2001; [6] Savoye et al., 2001; [7] EcoEng Newsletter, 3/2001; [8] Stephenson, 2000; [9] Hills et al., 2002; [10] Hills et al., 2001; [11] Thorne, 1998; [12] Asano, 1998

2.5.1.4. Dual (combined – rain/storm/grey/saline water and potable) water reticulation systems

Dual (combined and potable) water reticulation systems are systems that allow the non-potable supply to be feed from a combination of different non-potable sources.

2.5.2. Dual water reticulation system scales

Broadly, there are four scales of dual systems (Dimitriadis, 2005; McKenzie et al., 2003):

2.5.2.1. Individual systems

Non-potable water which is collected on-site, is treated and reticulated via a separate pipe network to a building on-site. Dual systems in this category serve a single building whether these buildings contain single or multiple units.

2.5.2.2. District systems

Non-potable water which is collected within an area, is treated and reticulated via a separate pipe network to multiple buildings within the same area. Dual systems in this category serve large housing developments.

2.5.2.3. Wide-area urban/agricultural systems

Non-potable water which is collected within a wide area (e.g. a city), is treated and reticulated via a separate pipe network to a variety of users (urban and/or agricultural). Dual systems in this category include centralised schemes such as the reticulation of treated effluent from a WWTWs.

2.5.2.4. Industrial systems

Non-potable water which is collected within an industrial enterprise, is treated and reticulated via a separate pipe network to various uses within the industrial enterprise.

3. INTERNATIONAL EXPERIENCES IN DUAL WATER RETICULATION SYSTEMS

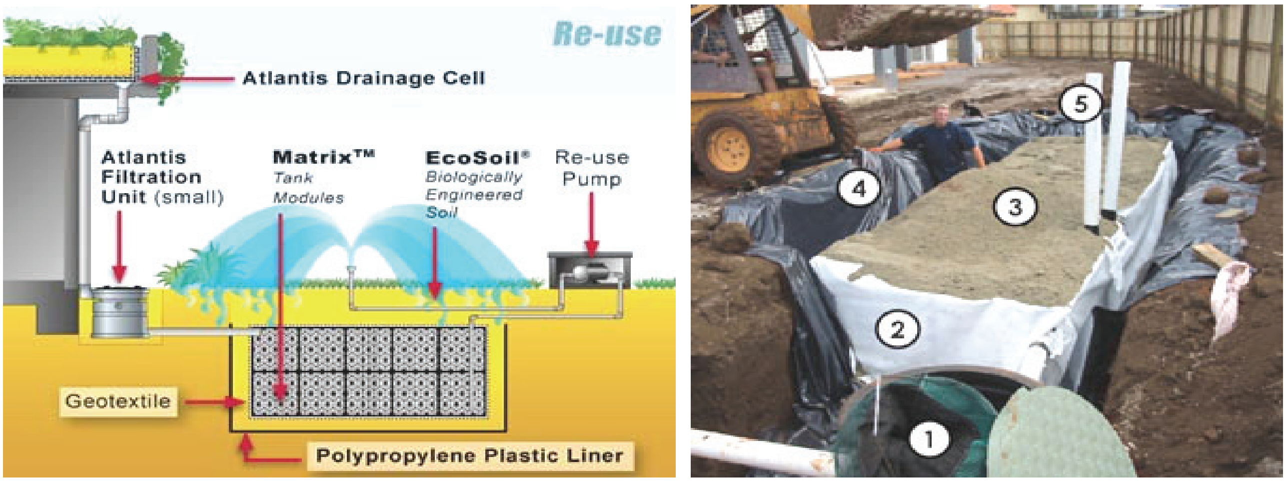
3.1. Individual dual water reticulation systems

3.1.1. The Clagg Hall Community Centre, United Kingdom

Clagg Hall community centre in Derby has installed a dual (rain and potable) water network to supply water for flushing in two urinals and four toilets. The community centre collects water from the roof and permeable pavement in an adjacent car park. The rain water which is collected and reused, supplies about 75% of the centre's non-potable water needs (Environment Agency, 2003).

3.1.2. The Atlantis System, Australia

In domestic applications, the Atlantis rain water reuse system (Figure 3) utilises filtration units to filter all storm water run-off from roofs prior to entering the storage tanks. The system also uses ecosoils to purify highly contaminated storm water. Typical applications for the system are toilet flushing, washing machine water and garden watering (Atlantis, 2005).



Legend

1. Atlantis® Filtration Unit
2. Atlantis tank wrapped in geotextile
3. Washed river sand
4. Polypropylene liner
5. Pump outlet

Figure 3. Schematic of the Atlantis rain water reuse system

3.1.3.. The Healthy Home®, Australia

Gardner, T. (2002)

The Healthy Home® layout is shown schematically in Figure 4 where 120m^2 of the 167m^2 roof area supplies roof runoff to a 22kl concrete cistern installed under the house. First flush devices located on each down pipe ensure that the first 1mm of roof runoff goes to waste. The rainwater is reticulated through the house using a 0.7kW pump after first passing through a 20 micron filter and 40W UV disinfection system. The rainwater cistern is supplemented from the potable main supply, after passing through a backflow prevention device.

The grey water system houses a recirculating sand filter contained within a partially buried 6kl concrete tank. The tank compartments form a septic/surge tank, two pump wells and a 1.5m^2 by 800 mm deep sand filter. The potable and grey water systems are intensively monitored to measure flow rate and volume using 16 pulse generating water meters; the rainfall and cistern water level are measured with a tipping bucket rain gauge and pressure transducer respectively; the grey water system is regularly connected to an automatic water sampler to collect pumped-out samples over a 24 hour period. These sand filtered samples, along with septic tank samples, are analysed within 24 hours for a suite of chemical and microbiological characteristics.

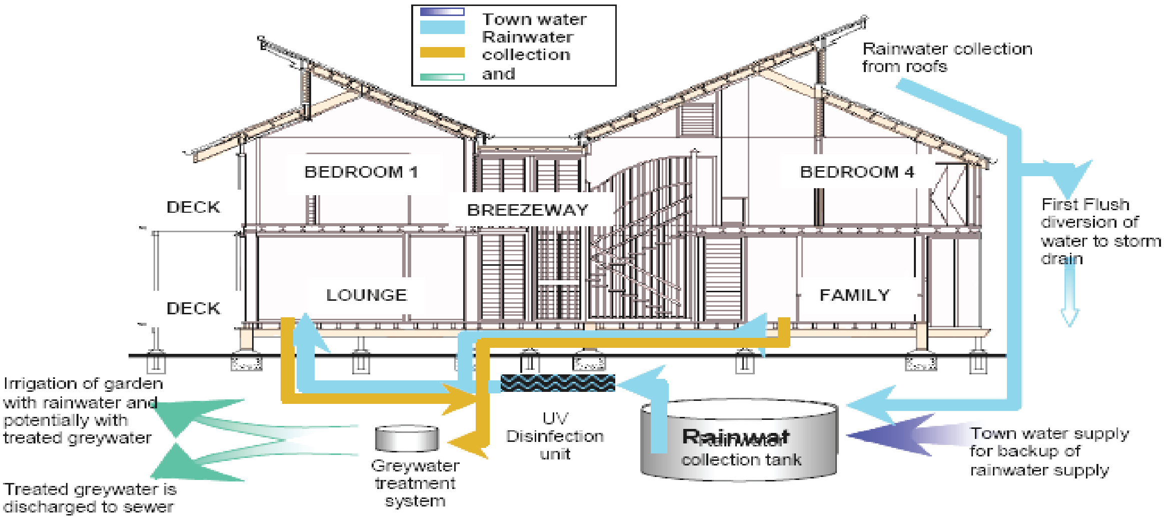


Figure 4. Schematic of the dual (rain and grey, and potable) water system in the Healthy Home®

3.2. District dual water reticulation systems

3.2.1. The Hockerton Housing Co-operative, United Kingdom

(Environment Agency, 2003)

In 1998, the Hockerton Housing Co-operative in Nottinghamshire built five homes designed to minimise water and energy use. The site has been designed to allow the occupants to be independent of the potable mains water supply. Water from the road, other pavements and surrounding fields is collected via a series of dykes and channelled to a sump, from where it is pumped to a 150m^3 reservoir. This water is used for everything apart from drinking. It is passed through a sand filter, which removes particles and has some bacterial action. Tables 13 and 14 summarise capital and operational costs for the rain water collection and storage system for these five households. The costs exclude pipe reticulation to each of the five homes.

Table 13. Initial outlay costs for the Hockerton housing rain water system (excluding pipe reticulation)

Item	*Unit cost (£)*	*Total capital cost (£)*	*Labour installation cost (£)*
Foul and rain water drainage	-	1 776	1 017
Fresh water collection and pumps (incl. reservoir)	-	9 000	2 231
Conservatory drainpipes and gutters	1 737	500	-
Total cost	1 737	11 276	3 248
Cost per household		**2255.20**	**649.60**

Table 14. Annual maintenance costs for the Hockerton housing rain water system (excluding pipe reticulation)

Item	*Time taken (man days)*	*Cost (£)*
Management of reed beds	2	150
Emptying of septic tanks	0.5	35
Change of filters	1	75
Maintenance of sand filters	2	150
New filters	-	40
Total cost	5.5	450
Cost per household		**90**

The benefits of this project were significant: savings on water supply and sewerage charges for the five households were GBP £1,000 in the first year alone. There are no external labour costs for the development, as occupants carry out their own maintenance.

3.2.2. The Beddington Zero Energy Development, United Kingdom

The Beddington Zero Energy Development (BedZED) is a housing development in South London. The development comprises 82 homes, with a mix of one, two, three and four bedroom properties for outright sale, shared ownership and affordable rent. Flexible workspaces and live/work units are also available. BedZED aims for water use one third of that of a normal housing development by installing amongst other things, rain water harvesting from roofs and car parks. It is predicted that nearly a fifth (18%) of daily water consumption at BedZED will be met from rain water and reused water, stored in large tanks incorporated into the foundations and conveyed into the homes using dual pipe systems. The spaces in the car park are made from porous paving laid over gravel. Run-off from roofs, roads and pavements drains to a dry ditch, which has been made into a water feature (Environment Agency, 2003).

3.2.3. The Sydney Olympic venue and Newington village, Homebush Bay, Australia

(Dimitriadis, 2005; Po et al., 2003)

A well-known reuse project in Sydney is the Water Reclamation and Management Scheme at Homebush Bay, the site of the Sydney 2000 Olympics. Highly treated wastewater and storm water generated from the

Olympic venue facilities and Newington village is collected, treated and reused for toilet flushing, watering lawns, gardens and parks around the Olympic venues and facilities and at the Newington Village.

3.3. Wide-area urban/agricultural dual water reticulation systems

3.3.1. Majuro, Marshall Islands and Tarawa, Republic of Kiribati

(Smith et al., 1996 and Parr et al., 1997)

Majuro atoll is the capital of the Marshall Islands and lies approximately half way between Hawaii and Papua New Guinea in the Western Pacific Ocean. Given the lack of any major potable water sources, the unpredictable rainfall and a rapidly increasing population, the authorities in Majuro have had to install a dual (saline and potable) water reticulation system to meet most of the non-potable needs of the island – such as toilet flushing and fire fighting.

Tarawa has many similarities with Majuro, being a Pacific atoll of similar size, population resources and climate. Like Majuro, Tarawa has an established dual (saline and potable) water system. For administrative purposes, the atoll is split into two districts – North and South Tarawa. South Tarawa is the most populated and developed area, and has the dual system – references to Tarawa generally refer to South Tarawa.

The dual (saline and potable) water systems of Majuro and Tarawa are very similar in that they both:

- serve only the most populous areas of the atolls;
- use saline ground water, not sea water, as the sewage medium; and
- discharge untreated sewage into the ocean via a short sea outfall.

The systems differ in that:

- the majority of the potable water supply is made up from ground water in Tarawa as opposed to surface run-off in Majuro;
- there is less aid money available for operation and maintenance tasks, and for extensions to or upgrading of the infrastructures in Tarawa.

Table 15 presents summaries of the two dual systems and associated services.

Table 15. Summaries of the two dual (saline and potable) water systems and associated services

(Smith et al., 1996 & Parr et al., 1997)

	Majuro	***Tarawa***
Population (1996)	25500	25000
population served by dual system	13000	20000
Supply hours:		
➢ potable supply	24 hrs on, 24 hrs off	7 hrs per day
➢ saline supply	not at low tides	24 hrs per day
Saline supply completed	1988	1982
Connection charges ($USD):		
➢ potable supply		
◘ domestic	100	15.75
◘ commercial	400	79
➢ saline supply	100	79
➢ sewerage	100	79
Tariffs ($USD):		
➢ **potable water**		
◘ **domestic**	1.6/m^3	0.79/m^3
◘ **commercial**	1.6/ m^3	3.94/m^3
➢ **saline water**	7/month	no tariff
➢ **sewerage**	part of rates	no tariff

In both atolls, saline sewerage was only possibly viable in situations where sewerage was a realistic option. This generally discounted the poorest communities that traditionally had no access to sewerage facilities. The corrosive effects of the saline sewage on pipelines, pumps and valves were not found to be of major concern because the supply and sewerage networks had been designed to avoid corrosion problems by the use of plastic pipes and stainless steel fittings. However, corrosion in consumers' properties was a problem because the toilet cisterns in individuals' houses had not been designed to avoid corrosion problems. It was believed that wear and tear occurred due to abrasive sand particles in the saline supply network.

There were no significant odour problems at either location (over and above any usual sewage odour). This may have been due to the continual flushing of the sewers with saline water as a result of cistern flushing system failures which allowed water to flow constantly. This continuous flushing caused an extra problem of high energy costs associated with pumping. This problem could have been minimised by introduction of a tariff to recover costs for the quantity of saline water used, which would encourage proper maintenance of toilet cisterns.

Neither of the authorities in the atolls treated their saline sewage before discharging it to the ocean.

Two main conclusions about the applicability of dual (saline and potable) water systems to developing urban coastal areas emerged from this study, supported by secondary conclusions:

a) *Dual supply systems are technically viable options.*

Dual (saline and potable) water systems operate satisfactorily in several locations world-wide and there is no reason to assume that, on a technical level, they cannot work elsewhere. As long as fundamental precautions regarding choice of materials are made, a saline supply and sewerage system is technically no more difficult than a potable supply system since it requires similar levels of operation and maintenance. However, leakages from saline pipelines may be more problematic than those from potable water pipelines as there is greater potential for ground water contamination.

b) *Dual systems can be considered as an option for implementation, with decisions being made on a full and equitable local comparison of alternatives.*

- Dual systems are often perceived as being insufficiently established to warrant large investment. Hence, there is need to raise the awareness of decision-makers about the potential of dual supplies;
- Wide-area urban and industrial dual systems can only be applicable in situations where sewerage exists and is therefore not applicable in low-income developing areas;
- Dual systems will only be viable if the cost of the infrastructure and subsequent supply costs are less than those of alternative schemes.

3.3.2. Hong Kong, China

(Tang et al., 2007)

Dual systems have been implemented in Hong Kong since the 1950s. Sea water (the non-potable resource) is mainly used for toilet flushing. The sea water supply system consists of pumping, treatment, storage and reticulation and is operated in similar fashion as the potable water supply system. There are about 40 seawater pumping stations situated at various locations with a total pumping capacity of 1.5 Mm^3/day. Treatment involving only screening and disinfection, takes place inside the pumping stations. There are also about 45 seawater service reservoirs with a total capacity of about 0.2 Mm^3. Total length of the sea water reticulation network is 1400 km. These pipes are usually made of polyethylene or polyvinyl chloride.

Some of the challenges encountered in operating the extensive Hong Kong dual (seawater and potable) water reticulation system include the treatment of saline wastewater, which is difficult to treat in WWTWs, complaints regarding odour and colour, sudden deterioration of seawater quality, deposits and biological growth inside pipelines, and the corrosion of pipelines and equipment.

3.3.3. The Virginia Pipeline Scheme, Australia

The largest horticultural reuse scheme in Australia can be found at Bolivar, South Australia. This project, commonly known as the Virginia Pipeline Scheme, is expected to supply over 20 billion litres of irrigation water a year for more than 120 market gardens. Associated with this scheme was a preliminary analysis of stakeholder perceptions of risks. Public concerns included (1) the source and quality of the water used; (2) the effect of using recycled water to irrigate edible food crops and; (3) possible negative environmental impacts of the aquifer recharge technique and the overall scheme itself to the region. The analysis concluded that the likelihood of major public concerns to emerge as a result of the scheme was relatively low. The scheme was formally launched in October 2003 (Po et al., 2003).

3.3.4. Rouse Hill, Australia

The largest residential dual (grey and potable) water system can be found in the Rouse Hill development area, Sydney. Since 2001, more than 16 000 properties in the development have been supplied with about 1.7 billion litres annually of high quality recycled water for toilet flushing, garden watering and fire fighting. This initiative resulted from an agreement between landholders and the New South Wales government to pursue the concept of integrated water cycle management. Its aim was to reduce the export of sediment and nutrients to the Hawkesbury/Nepean River System. Sydney Water conducted two separate studies to understand the Rouse Hill community's views on recycled water before and after commissioning the system. Most residents surveyed were aware of the system when they took up residence in the area. However, there was uncertainty amongst some of the residents as to whether human waste was being recycled or not, and what was actually involved in the treatment of the recycled water. Residents were generally aware of the appropriate uses of recycled water and had used the water accordingly. They regarded the dual water system with a sense of pride. As a result of this scheme, demand for drinking water in homes reduced on average by about 40% (Dimitriadis, 2005; Po et al., 2003; Sydney Water, 2001).

3.3.5. Pimpama Coomera, Australia

(Po et al., 2003; Gold Coast Water, 2004)

Pimpama Coomera is the fastest growing region on the Gold Coast. The current population of 5,000 residents is expected to grow to 150,000 over the next 50 years. In recognition of this expected growth, Council introduced a dual (grey and potable) system in 2003 that allows residents access to an alternative water source. The system uses the latest technologies to provide high quality recycled water for reuse in the local areas, and treats up to 13 megalitres of wastewater per day.

At the front of each property are two water meters. One in a green/brass coloured box (for drinking water supply) and the other in a lilac/purple coloured box (for recycled water supply). Drinking water from the green/brass meter supplies all areas inside the home except the toilet(s) and two external taps. Recycled water from the lilac/purple meter supplies water to the toilet(s) for flushing, as well as to two external taps for car washing and garden watering. All recycled water pipes, materials and fittings are lilac in colour and clearly labelled for ease of identification, eliminating any confusion between the two supplies and reducing the risk of recycled water being used for potable water purposes.

The drinking water meter is installed with an integral dual check valve – this is an added safety measure to ensure that public health is protected. The dual check valve plays an integral part in minimising the possibility of backflow through the system.

Recycled water is treated to high standards and is monitored to ensure it meets or exceeds State Government guidelines which reflect the water quality criteria required to protect public health. Table 16 identifies the appropriate uses of recycled water and outlines where recycled water should not be used in Pimpama Coomera.

Table 16. Uses and non-uses of recycled water

(Gold Coast Water, 2004)

Uses	***Non-uses***
➢ **Toilet flushing** ➢ **Garden watering and irrigation** ➢ **Filling ornamental ponds** ➢ **Car washing** ➢ **Construction purposes**	➢ Drinking ➢ Cooking or other kitchen purposes ➢ Personal washing (baths, showers, hand basins and bidets) ➢ Evaporative coolers ➢ Clothes washing ➢ Household cleaning ➢ Swimming pools ➢ Recreation involving water contact (e.g.: children playing under sprinklers) ➢ Irrigation of fruit trees and crops that are eaten raw or unprocessed ➢ Filling pets water bowls

3.3.6. Windhoek, Namibia

(Van der Merwe, 2006)

Namibia is the most arid country south of the Sahara Desert. The capital, Windhoek is situated in the Central Highlands of Namibia, approximately 1 600m above MSL. Average annual rainfall is 360mm, while average evaporation is 3 400 mm/a. Namibia's water resources are unevenly distributed over the country and there are no perennial rivers within the borders of Namibia.

The non-potable supply is exclusively for irrigation and was constructed between 1991 and 2003. By the end of 1991, the Windhoek Golf Course (a major consumer of non-potable water) was linked to the dual system through a series of temporary pump stations. The dual system also provides water for landscaping of parks, sport fields (including sports fields at schools), cemeteries, nurseries and large hotel gardens. Since completion, the dual system supplies approximately 5-7% of Windhoek's annual water demand.

The dual system operates by supplying non-potable water through three storage reservoirs from four pump stations. Non-potable water supply is scheduled so that day-time users are generally small consumers who utilise manual irrigation systems, and night-time users are generally the larger consumers who have automated irrigation systems. Approximately 107 consumers are currently connected to the dual system. All connections are metered. Meters are read and consumers are charged on a monthly basis. Quotas are calculated at 1 m^3 per m^2 of irrigation area per annum in seasons without water shortages and 0.7 m^3 per m^2 per annum during seasons of drought depending on the availability of treated effluent. Provision is also made for peak demands during the dry summer months. Rising block tariffs are applied if a quota is exceeded. The tariff system makes provision for a higher tariff for commercial users such as nurseries and hotels while institutions pay the same tariff with a reduction in tariff if they need to use pressure pumps for irrigation (to allow for energy cost and maintenance of irrigation pumps). The system is operated on a full cost recovery basis.

The non-potable supply is only suitable for *restricted irrigation*. To avoid human consumption, no potable water taps are allowed to be connected to the dual pipe system. Strict guidelines have been applied for irrigation, i.e. ponding on sport fields are discouraged, and irrigation is scheduled for times when there is very limited human exposure. Despite these guidelines, the use of clearly marked pipelines, and the regular inspection of premises using irrigation water is employed.

3.3.7. The Irvine Ranch Water District, Orange County, United States of America

(IRWD, 2006)

The Irvine Ranch Water District in Orange County has been recycling water for nearly 30 years. Recycled water makes up 20% of IRWD's total water supply, reducing the need to import expensive water and helping to keep water rates low. Eighty percent of all business and community (parks, school grounds, etc.) landscaping in the District is irrigated with recycled water. The recycled water supply includes more than 245 miles of pipeline, 8 storage reservoirs and 12 pump stations. The system provides recycled water to approximately 1,000 acres of fields and orchards planted with a variety of fruits, vegetables and nursery products. Recycled water is also used to irrigate landscapes including parks, schools, golf courses, streetscapes, and open spaces managed by community associations. A few estate-sized residential lots also use this water for front and backyard irrigation. Many water features such as fountains and the lake at Mason Park are filled with recycled water.

In 1991, IRWD became the first water district in the US to obtain Health Department permits for the interior use of recycled water from a community system. Recycled water is currently used for toilet and urinal flushing in IRWD's facilities as well as in several high rise office buildings. For new buildings over seven stories, the additional cost of providing a dual system was found to add only 9% to the cost of plumbing. Drinking water demands in these buildings dropped by as much as 75% due to the recycled water supply.

3.3.8. St. Petersburg, Florida, United States of America

(ASTE, 2004)

The St Petersburg dual distribution system, which uses highly treated recycled water for irrigating 8000 homes, 46 schools, 66 parks and 6 golf courses, is one of the most widely known reuse systems in the USA. It has been operating since 1977. The scheme prohibited the use of hose connections until 1995, with garden irrigation previously being limited to in-ground sprinkler systems.

3.4. Industrial dual water reticulation systems

3.4.1. The Irvine Ranch Water District, Orange County, United States of America

(IRWD, 2006)

In 1997, a local carpet manufacturer in the Irvine Ranch Water District in Orange County retrofitted carpet dyeing facilities to use recycled water. The new process is effective, saving up to 500,000 gallons of potable water per day.

3.4.2. The Walt Disney Resort and Curtis Stanton Energy Centre, Florida, United States of America

(ASTE, 2004)

The Walt Disney World Resort Complex uses recycled water from Reedy Creek Utilities for five golf courses, highway medians, a water park and a 110 acre tree farm growing horticultural produce for the Complex. Also in Florida, the Curtis Stanton Energy Centre uses recycled water for cooling coal-fired boilers.

3.5. Negative/controversial international experiences in dual water reticulation systems

3.5.1. The Netherlands

(Health Stream, 2003)

Dual water supply systems in the Netherlands suffered a setback following an outbreak of gastrointestinal illness attributed to an accidental cross-connection in a dual (grey and potable) water reticulation system. In the Netherlands, the term grey water refers to surface waters which are partially treated but not to a potable standard. The water supply in this incident was drawn from the Rhine river and subjected to coagulation, flocculation, sedimentation and rapid sand filtration before distribution to households as grey water.

The outbreak took place in a new housing development that had the dual water supply system, with grey water being supplied for garden watering, toilet flushing and laundry use. No problems were detected for over a year after the estate was occupied, however in early December 2001, a number of complaints of disagreeable taste and odour of the potable water supply were received by the water supply company. Investigations showed unusually high counts of Total Coliform bacteria in the potable water supply, with *E.coli* and *Enterococci* also detected. Also, an accidental cross-connection between the potable and grey water networks was discovered. The grey water system normally operated at a lower pressure than the potable supply as a safety measure to prevent potential cross-connections. However, at the time of the incident, the grey water system was operating at elevated pressure. This permitted grey water to enter the potable water reticulation system since the cross-connection between both systems had been in place for about one week before it was discovered. A boil water notice was issued and health authorities, after investigation, concluded that an outbreak of gastroenteritis affecting about 200 people had occurred.

As a result of this incident and examination of data on occurrence of Noroviruses and other viruses in contaminated source waters, Dutch regulators have decided that more treatment steps will be required in addition to the current water treatment train for grey water in order to adequately protect public health. This requirement has impacted on the economic feasibility of grey water schemes, and it is expected water suppliers in the Netherlands may decide to abandon many planned schemes of this nature and terminate some existing operations. The incident has resulted in a reappraisal of risk assessments carried out prior to approval of dual reticulation systems of this nature, with regulators concluding that risks for some enteric viruses had been underestimated in their initial calculations.

3.5.2. United States of America

(Po et al., 2003)

Two indirect potable reuse projects (one in California and the other in Florida) involving surface water augmentation were postponed indefinitely because of public or political pressure and/or health concerns. A headline in a local paper that dubbed the Dublin County's Clean Water Revival Project in California as "Toilet to Tap" halted the whole project. This groundwater replenishment project was proposed to augment the local water supply, to reduce salt levels in existing groundwater aquifers and to reduce the need for wastewater discharges to San Francisco Bay. With strong support from local environmental groups however, the county resorted to using potable water instead.

3.6. Regulations and Guidelines guiding reuse and dual water reticulation systems

3.6.1. Regulation regulating grey water reuse in Arizona, United States of America

Box 3.6.1. shows a section of the Arizona grey water law pertaining to grey water reuse.

BOX 3.6.1. TIER 1 ARIZONA GREY WATER LAW – APPLIES TO SYSTEMS UNDER 400 GPD (OASIS DESIGN, 2006)**.**

ARTICLE 7. DIRECT REUSE OF RECLAIMED WATER

Historical Note

New Section adopted by final rulemaking at 7 A.A.R. 758, effective January 16, 2001 (Supp. 01-1).

R18-9-711. Type 1 Reclaimed Water General Permit for Grey Water

"Grey water" means wastewater that originates from residential clothes washers, bath tubs, showers, and sinks, but does not include wastewater from kitchen sinks, dishwashers and toilets.

A. Type 1 Reclaimed Water General Permit allows private residential direct reuse of grey water for a flow of less than 400 gallons per day if all the following conditions are met:

1. Human contact with grey water and soil irrigated by grey water is avoided;
2. Grey water originating from the residence is used and contained within the property boundary for household gardening, composting, lawn watering, or landscape irrigation;

3. Surface application of grey water is not used for irrigation of food plants, except for citrus and nut trees;
4. The grey water does not contain hazardous chemicals derived from activities such as cleaning car parts, washing greasy or oily rags, or disposing of waste solutions from home photo labs or similar hobbyist or home occupational activities;
5. The application of grey water is managed to minimize standing water on the surface;
6. The grey water system is constructed so that if blockage, plugging, or backup of the system occurs, grey water can be directed into the sewage collection system or onsite wastewater treatment and disposal system, as applicable. The grey water system may include a means of filtration to reduce plugging and extend system lifetime;
7. Any grey water storage tank is covered to restrict access and to eliminate habitat for mosquitoes or other vectors;
8. The grey water system is sited outside of a floodway;
9. The grey water system is operated to maintain a minimum vertical separation distance of at least five feet from the point of grey water application to the top of the seasonally high groundwater table;
10. For residences using an onsite wastewater treatment facility for black water treatment and disposal, the use of a grey water system does not change the design, capacity, or reserve area requirements for the onsite wastewater treatment facility at the residence, and ensures that the facility can handle the combined black water and grey water flow if the grey water system fails or is not fully used;
11. Any pressure piping used in a grey water system that may be susceptible to cross connection with a potable water system clearly indicates that the piping does not carry potable water;
12. Grey water applied by surface irrigation does not contain water used to wash diapers or similarly soiled or infectious garments unless the grey water is disinfected before irrigation; and
13. Surface irrigation by grey water is only by flood or drip irrigation.

3.6.2. United States Environmental Protection Agency (USEPA) guidelines for dual pipe connections

(USEPA, 2004)

Efforts to control cross-connections involve the maintenance of a separation between potable and non-potable pipelines. While the specific requirements often vary from US state to state, common elements typically include colour-coding requirements as well as minimum vertical and horizontal separations. Excerpts from the State of Washington, “Reclaimed Water – Potable Water Separation Standards,” are provided below as an example of these requirements.

Policy requirements: Potable water lines require protection from any non-potable water supply, including all classes of reclaimed water. For buried pipelines, proper pipe separation must be provided.

General Requirements: Standard potable and non-potable pipe separation standards should be observed at:

- *Parallel installations:* Minimum horizontal separation of 10 feet (3 meters) pipe-to-pipe.
- *Pipe crossings:* Minimum vertical separation of 18 inches (0.5 meters) pipe-to-pipe, with potable lines crossing above non-potable lines.

Special conditions: Special laying conditions where the general requirements above cannot be maintained may be addressed as shown in the following examples.

Special Condition 1 – Pipeline separation for irrigation and potable pipes: Minimum pipeline separation between any potable water line and reclaimed water irrigation laterals shall be 4 feet (1.2 meters) pipe-to-pipe separation (Figure 5).

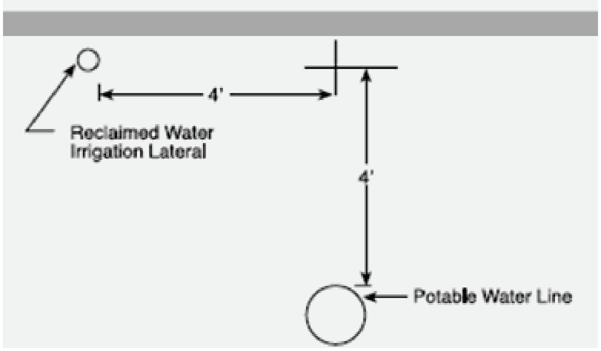


Figure 5. Special condition 1 – Pipeline separation for irrigation and potable water pipes

(USEPA, 2004)

Special Condition 2 – Inadequate Horizontal Separation: Site limitations will likely result in parallel pipe installations with less than 4 feet (1.2 meters) of pipe-to-pipe separation. In these instances, a minimum pipe-to-pipe separation of 18 inches (46 cm) shall be provided, and the reclaimed water irrigation lateral shall be installed a minimum of 18 inches (46 cm) above the potable water pipeline. An impervious barrier, such as PVC sheeting, installed between the irrigation lateral and the potable line for the length of the run is recommended (Figure 6).

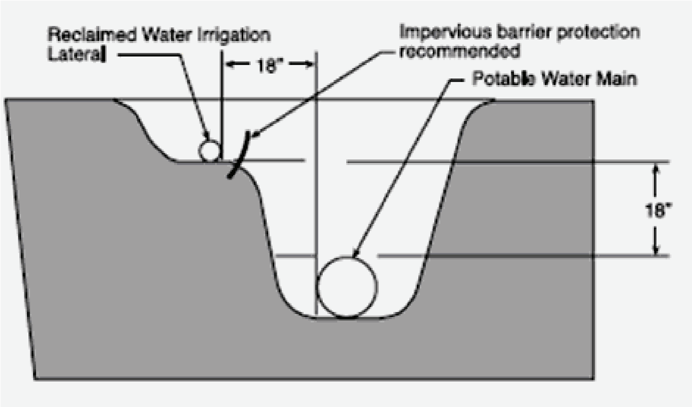


Figure 6. Special condition 2 – Inadequate Horizontal Separation

(USEPA, 2004)

3.6.3. Pimpama Coomera guidelines for dual water systems, Australia

3.6.3.1. Pipes

- Pipe sizing, flow rates and pipe material types must comply with Australian Standard AS/ New Zealand Standard NZS 3500.1.2.

- Construction and installation of supply service pipes to the first two fixture outlets shall be DN Nominal size 20mm. DN 15mm branches shall not exceed 3 metres in any length and may supply only one fixture outlet

3.6.3.2. Proximity to other services:

- Below ground – recycled water pipe (lilac/purple) must be installed a minimum of 300mm away from any drinking water pipes.
- Above ground – recycled water pipes (lilac/purple) must be installed a minimum of 100mm away from any drinking water pipes.

3.6.3.3. Marking and labelling

Authorised lilac/purple coloured pipes and materials (plastic or metal) must be clearly labelled to AS 1345. All buried pipes must have identification tape attached to the top of the recycled water pipe running along it, and this tape must be attached in intervals of no more than 3 metres. The tape must be at least 75mm wide (or 25mm for smaller diameter pipes) and state “Non-potable” or “Recycled Water – Do Not drink” continually along its length. Pipe work installed in concealed areas (e.g. behind cavity walls) must be lilac/purple coloured or equivalent.

3.6.3.4. Hose taps

Hose taps connected to the recycled water service (Figure 7) are different to normal hose taps. Features of these hose taps include:

- Left hand hose connecting thread.
- Removable tap handle (anti-vandal type).
- Hose taps to be either 15 nominal sizes or 20 nominal sizes.
- Lilac/purple coloured identification on tap.
- Hose tap backflow prevention device.
- Two external hose taps must be connected to the recycled water reticulation service (one at the front and one at the rear of the dwelling).
- Where the Overflow Relief Gully (ORG) is located, adjacent to the sewerage jump-up connection point, at least one of the non-potable hose tap outlets should be positioned at this point.

3.6.3.5. Signage above hose taps

- Metallic safety signs are to be permanently fixed above all recycled water outlets, in accordance with AS 1319.
- Signs and warning notices must comply with the requirements of Australian Standard AS 1319. Signs shall have yellow background with black letters. Options for wording are “Water not suitable for drinking” (Figure 7) or “Warning – not for drinking”.

Figure 7. A recycled water tap

(Gold Coast Water, 2004)

3.6.3.6. Others

- All recycled water pipes, materials and fittings must be lilac/purple in colour.
- The recycled water main will be generally located in the same trench as the drinking water main.
- The recycled water main will be the main closest to the property.
- The recycled water main is generally Polyethylene or UPVC pipe, but can also be ductile cast iron pipe wrapped in a lilac/purple plastic sleeve.
- Water pressure in the recycled water main is similar to the pressure in the drinking water main.
- Once plumbing installations have been completed, a testing procedure is to be undertaken by the plumbing contractor to ensure that there are no cross connections on the property. The proposed testing procedure may also be carried out by the property owner and is outlined below.

3.6.3.7. Cross connection testing

Once plumbing installations have been completed, the plumbing contractor should undertake the following testing procedure for the recycled and drinking water supplies.

The proposed testing procedure is as follows:

i. Turn off the drinkable water supply to the property at the brass dual check valve meter. Leave the recycled water supply on.

ii. Turn on all sink, bath and shower taps (both hot and cold) one by one. All taps should run dry after a short period of time.

iii. After taps have run dry, flush all toilets. The toilets should refill as normal provided they are connected to the recycled water supply.

iv. Turn on all outside taps. The external drinkable water tap should run dry. Taps that continue to run are connected to the recycled water supply and should be clearly identified with appropriate warning signs.

v. To check appliances within the home such as the washing machine, turn off the recycled water supply and turn the drinking water supply back on. Run the recycled water supply dry via the outside taps or toilet flushing. Turn on the internal appliances. If the appliances do not fill, they are connected to the incorrect supply.

vi. Turn the recycled water supply back on at the meter. Turn on the tap connected to the recycled water supply that is located furthest away from the meter.

Note: Turn back on all taps slowly so that all air will be purged from the pipeline while it is being recharged.

Should any part of this test indicate a possible cross connection, the problem should be identified and repaired before undertaking the above testing process again.

Figure 8 shows an example dual reticulation system within a house. The dual system is connected to a Wide-area urban system.

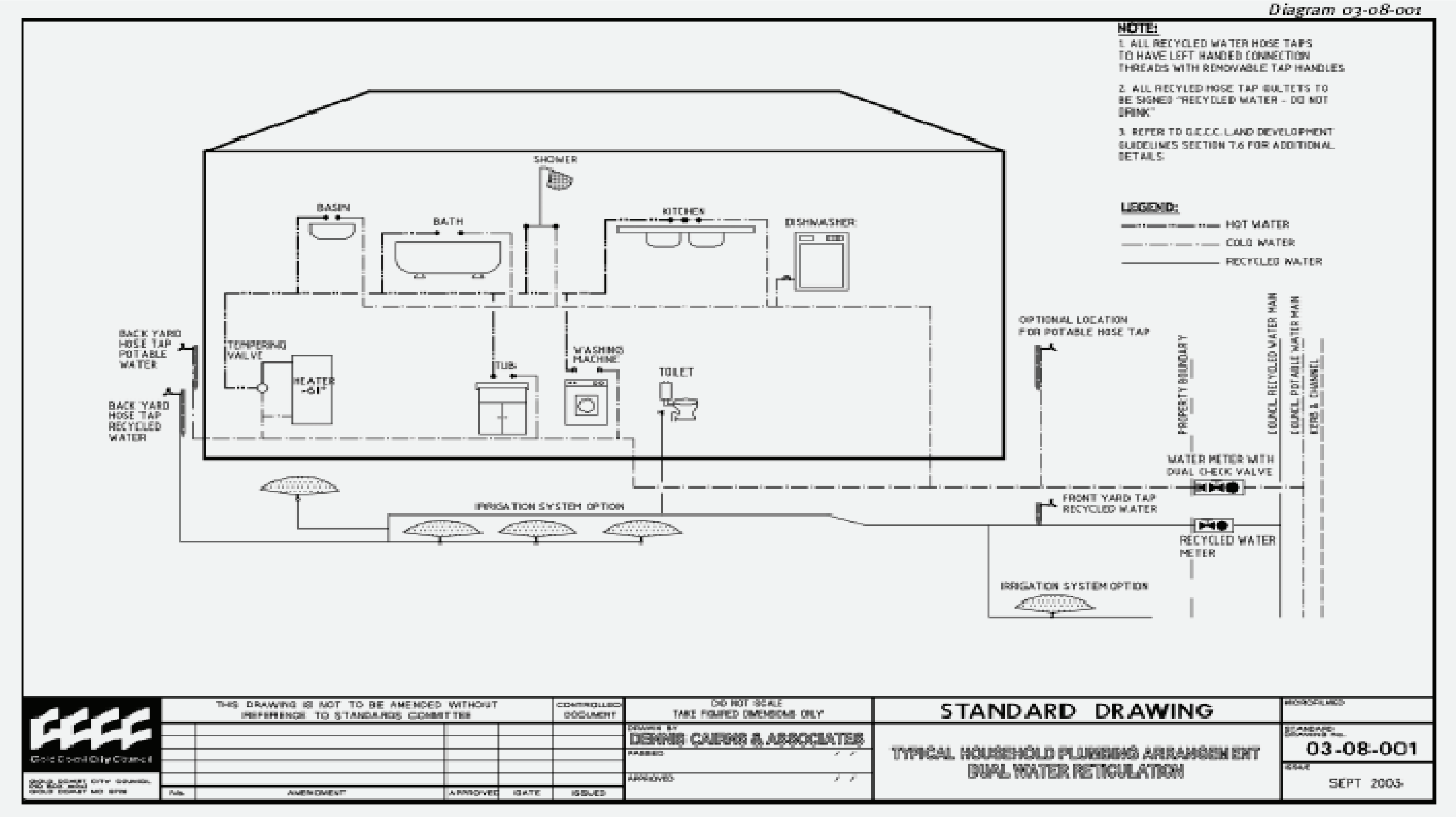


Figure 8. A Pimpama Coomera example dual (grey and potable) water system

(Po et al., 2003; Gold Coast Water, 2004)

3.6.4. Melbourne guidelines for dual water systems, Australia

(WSA, 2002)

The Water Services Association of Australia published a comprehensive guideline document (WSA, 2002) for the implementation of dual systems in Australia. The document incorporates planning and design guides for the different areas of dual system implementation.

3.7. Summary of findings and observations

A summary of the salient findings and observations from the international review are presented below:

- The extent of the aridity of an area stands out as one of the main drivers for non-potable water reuse and the implementation of dual systems;
- Domestic non-potable water reuse for garden irrigation and toilet/urinal flushing has been proven to significantly decrease the volume of potable water consumed. This especially applies to middle- to high-income households where a significant volume (ranging from 30-60%) of the potable water consumed is utilised for non-potable water requirements (e.g. toilet flushing and garden irrigation);
- Tariffs for non-potable water conveyed via dual water reticulation systems are often lower than potable water tariffs (e.g. Tarawa and Kiribati, United Kingdom and Australia). This may result from non-potable waters not treated to potable standards. In areas where wastewater is the non-potable water, existing WWTWs assist in lowering the cost of non-potable water production. In other instances, local authorities have introduce subsidies to reduce tariffs for non-potable water supply;
- Wide-area urban/agricultural, district and industrial dual systems can only be financially viable in areas where sewer systems have been implemented. These scales of dual systems are therefore not suited for low-income communities. Individual and district dual systems on the other hand, can be extensively employed by low-income communities where sewer systems have not been implemented and where dry sanitation is practised, and they can also be implemented where sewer systems exist;
- Dual systems have been proven to be technically viable water supply options in especially communities that have housed these systems over a long period of time (e.g. Majuro and Tarawa);
- Colour coding and clear identification/labelling of the non-potable pipes of the dual system have played a significant role in safe guarding and facilitating public health and safety by ensuring (i) consumers utilise the non-potable water for appropriate uses and (ii) operational and other infrastructure personnel can distinguish the two sets of pipes;
- Dual water reticulation systems of varied forms and scales exist. Broadly, four forms, dependent on the source of the non-potable source, and four scales, dependent on the size of the dual system, are defined (see section 2.5);
- Guidelines for the design, implementation and operation of dual systems are often based on local needs and circumstances whereas regulations generally conform to tried and tested international standards;
- Wastewater reuse demands stringent control and monitoring measures in order to protect public health and safety. Negative experiences as a result of cross-connections and accidental ingestion

have proven fatal to the sustainability of some dual systems (e.g. in the Netherlands);

- It is critical that community perceptions are well-known and understood prior to the detailed planning of especially domestic dual systems. Numerous water reuse projects have failed in the past (e.g. in California and Florida in the United States of America) as a result of negative community perceptions.

4. SOUTH AFRICAN EXPERIENCES IN NON-POTABLE WATER USE AND DUAL WATER RETICULATION SYSTEMS

4.1. National regulations and guidelines regarding non-potable water use

In relation to non-potable water use/reuse in South Africa, there exist some regulatory clauses addressing grey water and treated effluent quality and reuse in the following documents:

- Government Gazette No. 9225, Regulation 991: Requirements for the purification of wastewater or effluent (EAF, 1984);
- the latest revision of the Water Services Act of 1997 relating to grey water and treated effluent (DWAF, 2001) (see Box 4.1);
- the latest revision of the National Water Act of 1998, 37(1) (DWAF, 2004b) relating to irrigation of any land with waste or water containing waste generated through any industrial activity or by a water works.

In these documents, there is no objection in principle to the reuse of grey water or treated effluent for different non-potable uses as long as it is permitted and controlled by the relevant Water Services Authority.

Box 4.1. **GOVERNMENT GAZETTE** (DWAF, 2001)
Regulation Gazette **No. 7079**
Vol. 432 Pretoria. 8 June 2001. No. 22355

GOVERNMENT NOTICE
No. R. 509
DEPARTMENT OF WATER AFFAIRS AND FORESTRY

WATER SERVICES ACT, 1997
REGULATIONS RELATING TO COMPULSORY NATIONAL STANDARDS
AND MEASURES TO CONSERVE WATER

The Minister of Water Affairs and Forestry has under sections 91() and 73(I) (j) of the Water Services Act, 1997 (Act No. 108 of 1997), made the Regulations in the Schedule.

Disposal of grey water

7. A water services institution may impose limitations on the use of grey water if the use thereof may negatively affect health, the environment or available water resources.

Use of effluent

8. (1) A water services institution must ensure that the use of effluent for any purpose does not pose a health risk before approving that use.

(2) Any tap or point of access through which effluent or non-potable water can be accessed, must be clearly marked with a durable notice indicating that the effluent or non-potable water is not suitable for potable purpose.

(3) A notice contemplated in sub regulation (2) must be in more than one official language and must include the PV5 symbolic sign for non-potable water as described in SABS 11 86: Symbolic Safety Signs: Part 1 : Standards, Signs and General Requirements.

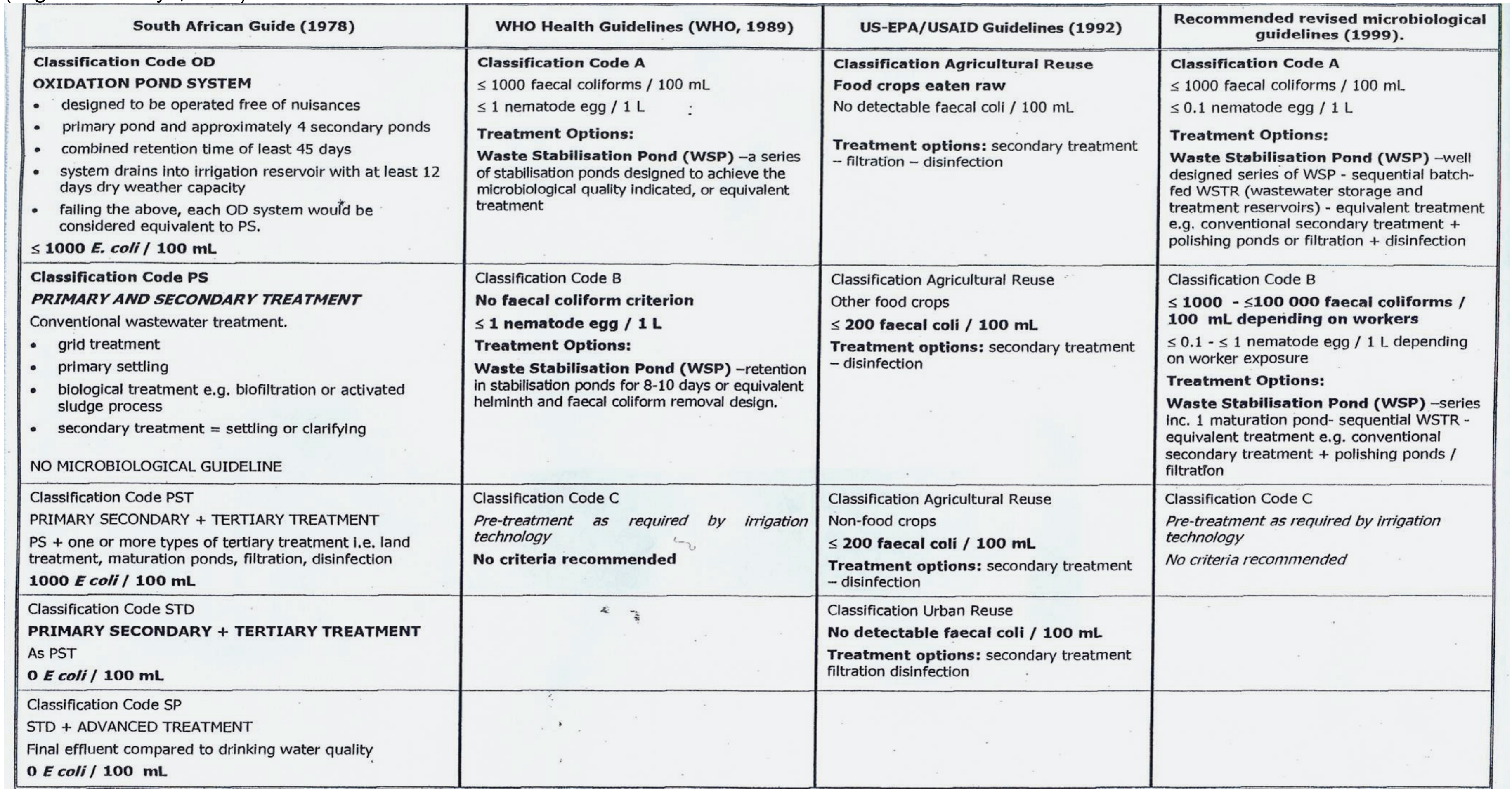
There are some guidelines pertaining to non-potable water use/reuse. Specifically, The South African guide for the permissible utilisation and disposal of treated effluent (DNHPD, 1978) and The South African water quality guidelines (DWAF, 1996). The DWAF (1996) guidelines recommend the different water quality parameters required for various industrial, agricultural (irrigation, livestock watering, aquaculture) and aquatic eco-system applications irrespective of the water source, while the DNHPD (1978) guideline, is specific to the permissible use and disposal of treated effluent.

In terms of guidelines, different countries have developed different approaches to protect human health and the environment from both microbiological and chemical risks. Provided industrial discharges are properly controlled, microbiological risks are usually the dominant risk for non-potable applications of treated effluent (Anderson, 2001 in Jagals and Steyn, 2002). With the emphasis on a public health risk more than an environmental risk, international guidelines for the recycling of wastewater focus more on the health-related microbiological quality of the water (Jagals, 2000 in Jagals and Steyn, 2002). Tables 17 and 18 (extracted from Jagals and Steyn, 2002) compare three international guidelines on wastewater reuse (according to treatment and reuse types) with the DNHPD (1978) guideline.

International guidelines generally follow two basic approaches, i.e. guidelines for *no potential risk (NR)* and for *attributable risk (AR)* based on circumstances in the particular area or population. These guidelines would include specification of crops to be irrigated, treatment requirements, effluent quality standards, as well as epidemiological status of the user population. In developed countries, guidelines tend to follow a conservative high technology / high cost / low risk (NR) approach, especially towards health sensitive crops, while in developing countries, guidelines follow a more practical and affordable approach of controlling infection risk with low cost control measures such as irrigation techniques, consumer exposure control and health and hygiene awareness education – measures which are within the economic means of the particular country or community (Jagals and Steyn, 2002). The DNHPD (1978) guideline is very similar to the US-EPA/USAID guidelines which classify water for health-related recycling according to conventional treatment system methods. These guidelines are a stricter format of application and in many respects can be considered to be high technology / high cost, *NR* approaches towards achieving low risk. In the current South African context, this might not be generally achievable. Jagals and Steyn (2002) present recommendations in their report for the review of the DNHPD (1978) guideline. Many of their recommendations fall in line with the guidelines proposed by Blumenthal et al. (1999). Blumenthal et al. proposed quality guidelines to the WHO based on their reviews of epidemiological, microbiological and risk assessment studies. If their guidelines are strictly applied, this approach provides a measure of infection risk control in the face of lacking epidemiological and/or risk assessment evidence (most often experienced in a developing community). By implication, communities that do not have the capacity to conduct epidemiological studies or to assess risks attributable to the particular recycled wastewater application need only use the conditions and criteria thresholds prescribed in the guideline (Jagals and Steyn, 2002). The recommendations put forward by Blumenthal et al. (1999) were recently incorporated into the WHO guidelines (2006).

Table 17. Wastewater classification according treatment: South African guidelines (1978, 1999), WHO (1989) and US-EPA (1992)

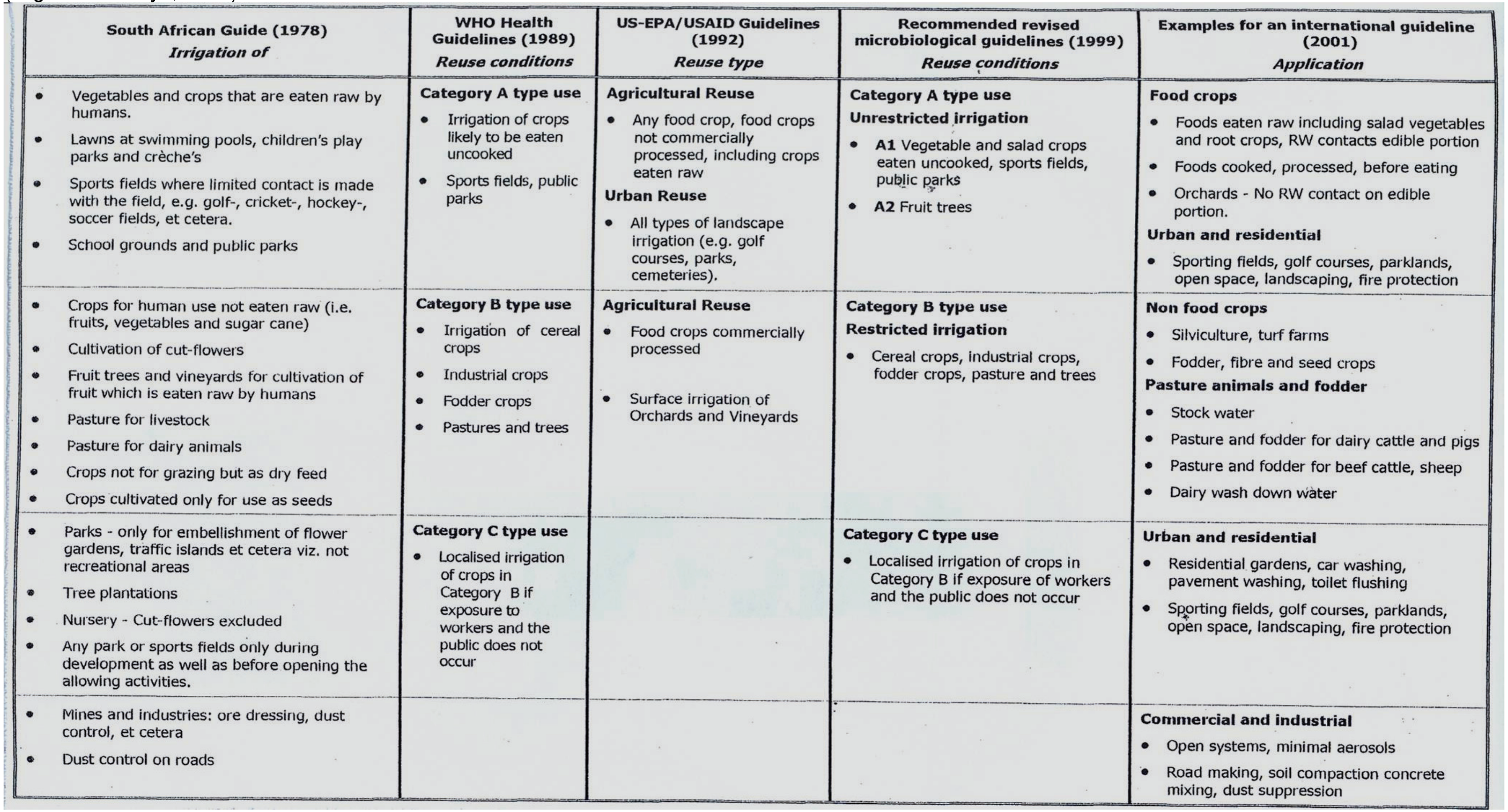
(Jagals and Steyn, 2002)



South African Guide (1978)	WHO Health Guidelines (WHO, 1989)	US-EPA/USAID Guidelines (1992)	Recommended revised microbiological guidelines (1999).
Classification Code OD **OXIDATION POND SYSTEM** • designed to be operated free of nuisances • primary pond and approximately 4 secondary ponds • combined retention time of least 45 days • system drains into irrigation reservoir with at least 12 days dry weather capacity • failing the above, each OD system would be considered equivalent to PS. **≤ 1000 *E. coli* / 100 mL**	**Classification Code A** ≤ 1000 faecal coliforms / 100 mL ≤ 1 nematode egg / 1 L **Treatment Options:** **Waste Stabilisation Pond (WSP)** –a series of stabilisation ponds designed to achieve the microbiological quality indicated, or equivalent treatment	**Classification Agricultural Reuse** **Food crops eaten raw** No detectable faecal coli / 100 mL **Treatment options:** secondary treatment – filtration – disinfection	**Classification Code A** ≤ 1000 faecal coliforms / 100 mL ≤ 0.1 nematode egg / 1 L **Treatment Options:** **Waste Stabilisation Pond (WSP)** –well designed series of WSP - sequential batch-fed WSTR (wastewater storage and treatment reservoirs) - equivalent treatment e.g. conventional secondary treatment + polishing ponds or filtration + disinfection
Classification Code PS ***PRIMARY AND SECONDARY TREATMENT*** Conventional wastewater treatment. • grid treatment • primary settling • biological treatment e.g. biofiltration or activated sludge process • secondary treatment = settling or clarifying NO MICROBIOLOGICAL GUIDELINE	Classification Code B **No faecal coliform criterion** **≤ 1 nematode egg / 1 L** **Treatment Options:** **Waste Stabilisation Pond (WSP)** –retention in stabilisation ponds for 8-10 days or equivalent helminth and faecal coliform removal design.	Classification Agricultural Reuse Other food crops **≤ 200 faecal coli / 100 mL** **Treatment options:** secondary treatment – disinfection	Classification Code B **≤ 1000 - ≤100 000 faecal coliforms / 100 mL depending on workers** ≤ 0.1 - ≤ 1 nematode egg / 1 L depending on worker exposure **Treatment Options:** **Waste Stabilisation Pond (WSP)** –series inc. 1 maturation pond- sequential WSTR - equivalent treatment e.g. conventional secondary treatment + polishing ponds / filtration
Classification Code PST PRIMARY SECONDARY + TERTIARY TREATMENT PS + one or more types of tertiary treatment i.e. land treatment, maturation ponds, filtration, disinfection **1000 *E coli* / 100 mL**	Classification Code C *Pre-treatment as required by irrigation technology* **No criteria recommended**	Classification Agricultural Reuse Non-food crops **≤ 200 faecal coli / 100 mL** **Treatment options:** secondary treatment – disinfection	Classification Code C *Pre-treatment as required by irrigation technology* *No criteria recommended*
Classification Code STD **PRIMARY SECONDARY + TERTIARY TREATMENT** As PST **0 *E coli* / 100 mL**		Classification Urban Reuse **No detectable faecal coli / 100 mL** **Treatment options:** secondary treatment filtration disinfection	
Classification Code SP STD + ADVANCED TREATMENT Final effluent compared to drinking water quality **0 *E coli* / 100 mL**			

Table 18. Reuse types: South African guidelines (1978, 1999), WHO (1989) and US-EPA (1992)

(Jagals and Steyn, 2002)



South African Guide (1978) ***Irrigation of***	**WHO Health Guidelines (1989)** ***Reuse conditions***	**US-EPA/USAID Guidelines (1992)** ***Reuse type***	**Recommended revised microbiological guidelines (1999)** ***Reuse conditions***	**Examples for an international guideline (2001)** ***Application***
• Vegetables and crops that are eaten raw by humans. • Lawns at swimming pools, children's play parks and crèche's • Sports fields where limited contact is made with the field, e.g. golf-, cricket-, hockey-, soccer fields, et cetera. • School grounds and public parks	**Category A type use** • Irrigation of crops likely to be eaten uncooked • Sports fields, public parks	**Agricultural Reuse** • Any food crop, food crops not commercially processed, including crops eaten raw **Urban Reuse** • All types of landscape irrigation (e.g. golf courses, parks, cemeteries).	**Category A type use** **Unrestricted irrigation** • **A1** Vegetable and salad crops eaten uncooked, sports fields, public parks • **A2** Fruit trees	**Food crops** • Foods eaten raw including salad vegetables and root crops, RW contacts edible portion • Foods cooked, processed, before eating • Orchards - No RW contact on edible portion. **Urban and residential** • Sporting fields, golf courses, parklands, open space, landscaping, fire protection
• Crops for human use not eaten raw (i.e. fruits, vegetables and sugar cane) • Cultivation of cut-flowers • Fruit trees and vineyards for cultivation of fruit which is eaten raw by humans • Pasture for livestock • Pasture for dairy animals • Crops not for grazing but as dry feed • Crops cultivated only for use as seeds	**Category B type use** • Irrigation of cereal crops • Industrial crops • Fodder crops • Pastures and trees	**Agricultural Reuse** • Food crops commercially processed • Surface irrigation of Orchards and Vineyards	**Category B type use** **Restricted irrigation** • Cereal crops, industrial crops, fodder crops, pasture and trees	**Non food crops** • Silviculture, turf farms • Fodder, fibre and seed crops **Pasture animals and fodder** • Stock water • Pasture and fodder for dairy cattle and pigs • Pasture and fodder for beef cattle, sheep • Dairy wash down water
• Parks - only for embellishment of flower gardens, traffic islands et cetera viz. not recreational areas • Tree plantations • Nursery - Cut-flowers excluded • Any park or sports fields only during development as well as before opening the allowing activities.	**Category C type use** • Localised irrigation of crops in Category B if exposure to workers and the public does not occur		**Category C type use** • Localised irrigation of crops in Category B if exposure of workers and the public does not occur	**Urban and residential** • Residential gardens, car washing, pavement washing, toilet flushing • Sporting fields, golf courses, parklands, open space, landscaping, fire protection
• Mines and industries: ore dressing, dust control, et cetera • Dust control on roads				**Commercial and industrial** • Open systems, minimal aerosols • Road making, soil compaction concrete mixing, dust suppression

4.2. National guidelines pertaining to the implementation of dual water reticulation systems

In South Africa, there are no national guidelines documenting best practice in the detailed design, implementation, and operation of dual water reticulation systems. The CoCT seems to be the only local authority currently developing guidelines for their dual (treated effluent and potable) system.

The sections below showcase some dual systems that have been implemented in South Africa.

4.3. Individual dual water reticulation systems

4.3.1. Carnarvon, Northern Cape

(Van der Merwe and Le Grange 2007)

The village of Carnarvon is located south of the Karee Mountains. Carnarvon is set among flat-topped hills and is one of the region's busiest farming centres. The economy of the district is based on merino sheep farming. Before 2005, the management of grey water (bath, shower and kitchen water) had previously placed a heavy financial burden on the Kareeberg Municipality and residents of Carnarvon. At the time, 800 of the households within the community collected and stored their grey water in containers on a daily basis, as infrastructure for the discarding of grey water did not exist. Municipal workers then collected this grey water twice a week using a truck, and disposed it at the existing sewer treatment plant site. Different grey water recycling systems were then investigated and a suitable system was identified. The preferred system (Figures 9-15) requires residents to pour (or channel via a pipe) their household grey water into a 50 litre drum via a filter trap and sump. A submersible pump in the drum kicks in automatically as the sump fills up. The water is then pumped through a hose and sprinkler onto the garden. When the sump is almost empty, the pump turns itself off.

After a satisfactory pilot phase involving 2 units, 110 grey water recycling units were ordered and a local contractor appointed to assist with the installation. Awareness workshops on operation and maintenance of the grey water recycling units were conducted, and households are committed to the proper operation and maintenance of the systems.

4.3.1.1. Estimated costs for the Carnarvon grey water systems

a. Capital costs

ITEM	QUANTITY	UNIT COST (R)	TOTAL COST (R)
Purchase of 40 No. grey water reuse units (50 litre drum, pump, filter trap and sump, pipes, and hose)	40 No.	2,964	118,560
Conveyance, installation, training, and signing maintenance agreements for 40 units	40 No.	3,800	152,000
COST		**6,764 PER HOUSEHOLD**	**270,560 TOTAL**

b. Operation & Maintenance costs: Each household maintains their units

Figure 9. Grey water filter and sump

Figure 10. An example grey water reuse system where no drainage previously existed

Figure 11. A submersible pump in the 50 litre drum

Figure 12. Crop and landscape irrigation using grey water

Figure 13. Inline tap to regulate flow to garden

Figure 14. Drainage pipe connections to filter and sump

Figure 15. An example where plumbing for an existing household drainage is retrofitted into the grey water reuse system

4.3.2. Hull Street, Kimberley. Free State

(WASE Africa, 2006)

Each double-storey house on Hull Street houses a dual water system. The grey water from the washing machine is channelled using an above surface PVC pipe to irrigate the lawn (Figure 16) while grey water from the kitchen sink is channelled using a rock-filled trench to also irrigate the lawn but below the surface. The rock-filled trench contains fat trap containers, a mulch layer from gravel, sisal and saw dust, removable plastic baskets to catch large particles, and geotextile material (Figure 17).

Figure 16. Above surface irrigation using washing machine grey water

Figure 17. Below surface irrigation using kitchen grey water

4.4. District dual water reticulation systems

4.4.1. Garies, Northern Cape

(Garies, 2000, Mvula Trust, 2006)

Garies is a small town in the Western Coastal Region of the Northern Cape. It has a population of about 1,680 people. The people are poor with 27% of the 441 households earning less than R500 per month, and only 9% earning above R3 500. It is a dry area. The soil is shallow, with hard granite rock beneath, making it difficult to sink boreholes. The ground water is generally salty and not fit for human consumption.

During the WSDP process pre-2000, community members raised a number of issues that they wanted prioritised. These included using salt water throughout the sewage system (to ensure that scarce fresh water was saved for drinking purposes) and expanding entrepreneurial projects using salt water, e.g. brick making. Since then, Garies has adopted a dual (saline and potable) system. Saline water is used for toilet flushing and treated effluent is used to water the Garies golf course.

4.4.1.1. Estimated costs for the saline supply systems in Garies

(Field data, 2007)

a. Capital costs (2006 figures): these costs were carried by external institutions

ITEM	QUANTITY	UNIT COST (R)	TOTAL COST (R)
Borehole drilling for saline water for toilet flushing	1 No.	13,000	13,000
Laying pipe mains			74,000
Others			229,000
TOTAL COSTS			**316,000**

b. Operation & Maintenance costs (2006 figures): these costs were carried by the consumer

ITEM	QUANTITY	UNIT COST (R)	TOTAL COST (R)
Equitable share allocation for water			4,000
Bad debts			26,000
Cost recovery			304,000
Fixed monthly tariff	➢ R25 per household or yard tap connection ➢ R84 per non-residential connection in addition to R2.25/kl volume charge		

4.4.2. The Lynedoch Eco-village, Western Cape

(Sustainability Institute, 2006)

Lynedoch is a small emerging hamlet located in the heart of the Cape Wine lands some 15 km south of the historic town of Stellenbosch. Government authorities have planned for the Lynedoch hamlet to eventually develop into a small, rural, socially mixed, town comprising several hundred families. Within the Lynedoch hamlet is the Lynedoch Eco-Village development which is situated on a 7 ha property that is owned by a non-profit company called the Lynedoch Development Company (LDC). The Lynedoch Eco-village is a pilot sustainability project in South Africa (Figure 18) with ‘zero waste’ as one of its targets. At the inception of the project, the strategic objective behind sewage treatment and reuse was “to create an effluent that would retain its nutrient load (especially phosphates and nitrogen) for reuse as fertilizer for irrigation purposes”. The justification for this objective not just in Lynedoch, but world-wide, is the need to provide a sustainable replacement for chemical fertilizers which worldwide, are declining in availability. This, in the long term, is expected to promote food security.

An engineered micro-ecology WWTW was installed on site (Figures 19 and 20). The facility consists of a peat filter inoculated with earth worms which deals with effluent solids within an aerobic environment. The output from the treatment facility (i.e. treated effluent loaded with nitrogen and phosphorus) is profitable for reuse as a natural organic fertilizer for irrigation (Figures 22 and 23). Before the effluent is used for irrigation, it is first passed through an ultraviolet apparatus (Figure 21) for pathogenic disinfection. The treated effluent is expected to generally reduce potable water used for irrigation. In richer households, a 60% reduction is expected. Test results from the on-site boreholes (Figure 24) indicate that the borehole water is not suitable for potable purposes. Hence, water pumped from these boreholes is used to supplement irrigation water supplied from the treatment facility.

The total quantity of effluent expected from the Lynedoch community during summer is profitable for irrigation purposes. In winter however, a significant proportion of the effluent would be wasted. This is because Lynedoch experiences its rainfall season during winter and most of the effluent will be swept away with storm water runoff. Based on the target to achieve ‘zero waste’ in this regard, and the DWAF (1996) guidelines concerning effluent disposal in natural water courses, this situation presented a challenge. Amongst many, the preferred solution thus became reducing the capacity of the treatment facility and as a result, reducing the effluent quantity entering and exiting. Currently, the treatment facility only collects sewage from the Sustainability Institute offices, Lynedoch primary school and guest house. Sewage from households within Lynedoch is channelled to a second WWTW – a Vertically Integrated Wetland (VIW) (Figures 25, 26 and 27).

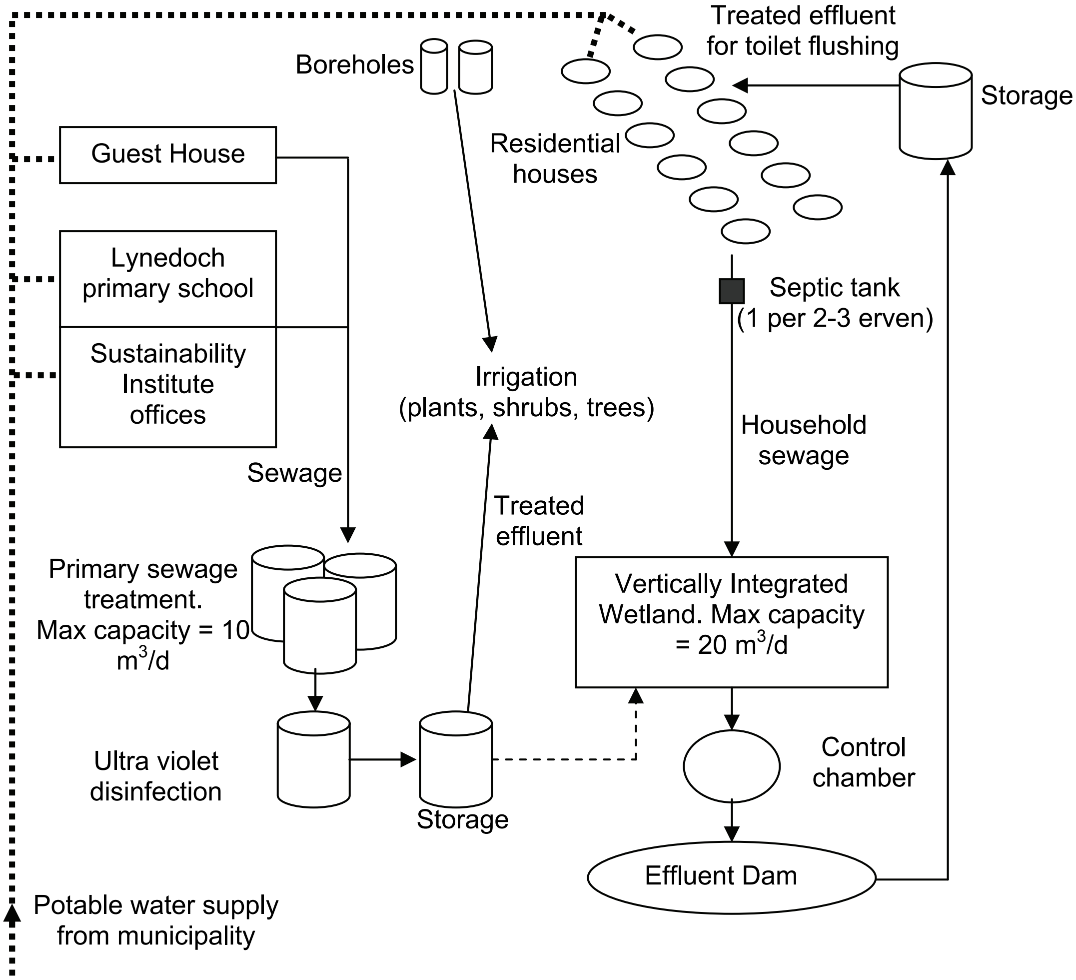


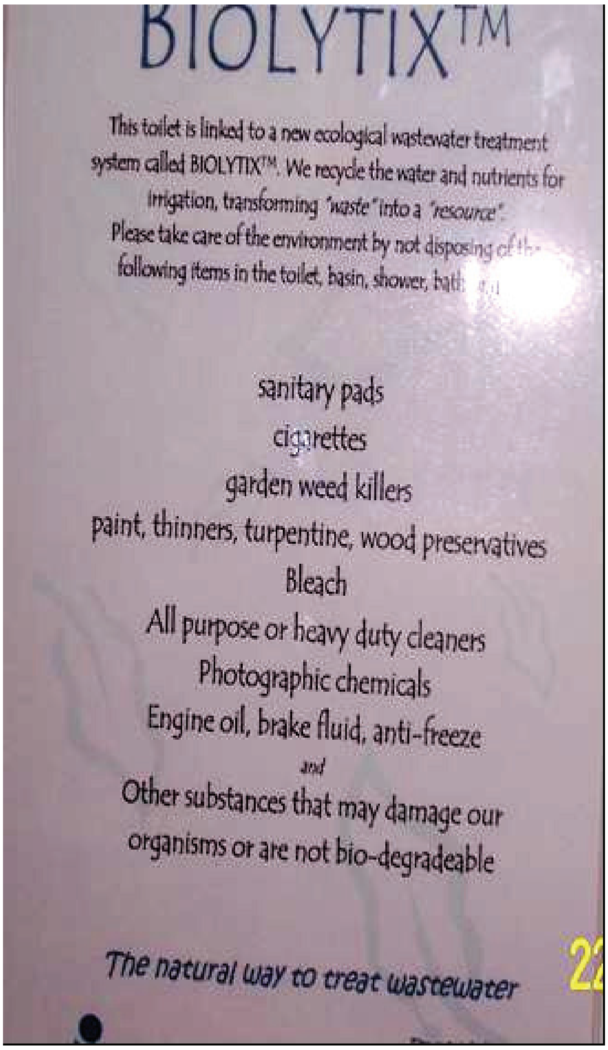
Figure 18. Schematic of the Lynedoch Eco-village dual system

Figure 19. The primary treatment facility

Figure 20. The treated effluent storage tank

Figure 21. The ultraviolet unit

Figure 22. Irrigation with effluent



BIOLYTIX™

This toilet is linked to a new ecological wastewater treatment system called BIOLYTIX™. We recycle the water and nutrients for irrigation, transforming *"waste"* into a *"resource"*.
Please take care of the environment by not disposing of the following items in the toilet, basin, shower, bath

sanitary pads
cigarettes
garden weed killers
paint, thinners, turpentine, wood preservatives
Bleach
All purpose or heavy duty cleaners
Photographic chemicals
Engine oil, brake fluid, anti-freeze
and
Other substances that may damage our organisms or are not bio-degradeable

The natural way to treat wastewater

Figure 23. An awareness notice pasted in the restrooms of the Sustainability Institute

Figure 24. Boreholes on site supplying supplemental water for landscape irrigation

The treated effluent from the VIW is aimed at household toilet flushing. Toilet flushing water, in contrast to irrigation, must be of a very low nutrient (i.e. phosphorus and nitrogen) load due to the toilet plumbing facilities installed on site. The objective of this second treatment facility was "*to generate an effluent with low nutrient load for toilet flushing*". In contrast to the primary treatment facility, the VIW achieves this second objective.

Effluent from all the households passes through septic tanks (one per two or three erven) where the solids from the effluent are deposited. The fluid then proceeds on to the VIW at the bottom of the site where treatment is aerobic on top of the Wetland (which is where the effluent enters) and anaerobic at the bottom (as the effluent sinks down). After exit from the VIW, it goes into a dam via a control chamber (layered with iron filings that magnetize phosphorus) (Figure 26), from where it gets pumped into storage tanks at the top of the site for gravity feed into the households for toilet flushing. This reuse is expected to reduce potable water consumption by at least 40% per house. Halophytes (plants that are adapted to growing in saline conditions) are planted on the wetland (Figure 27). These plants achieve two objectives – they feed on the nitrogen from the effluent and provide beauty on the surface of the wetland.

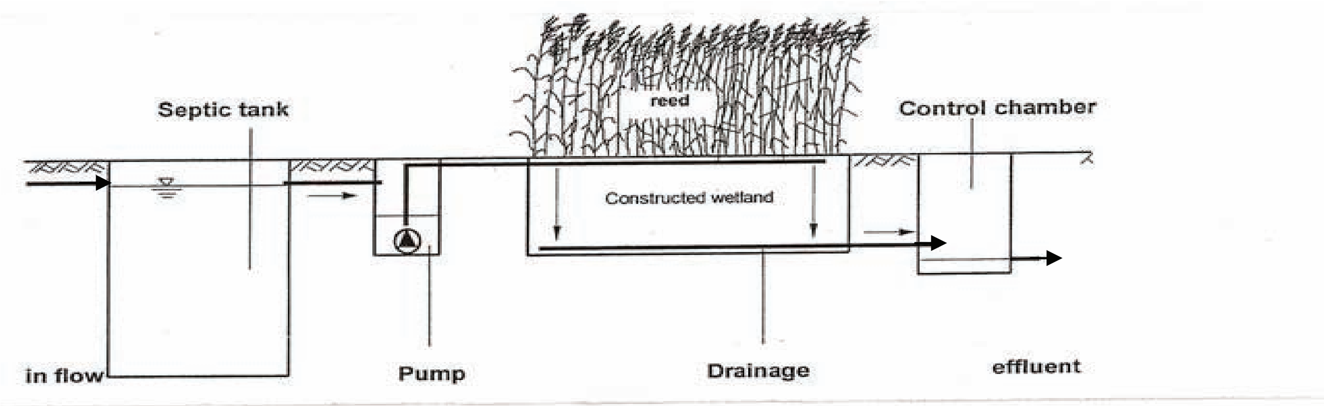


Figure 25. Cross-section of the Vertically Integrated Wetland

(Bart Senekal Inc, 2003)

Figure 26. The Vertically Integrated Wetland and control chamber

Figure 27. Halophytes growing on the VIW

In the Lynedoch Eco-village, potable water is to be supplied to each of the planned 45 units (currently 12 units have been built) from a municipal potable water line. Two water meters are installed per household, one for potable water and the other for treated effluent. The fee for potable water used is paid to the municipality and the fee for treated effluent used goes towards the operation and maintenance of the on-site treated effluent reuse system. As a result of the dual system, low-income households are estimated to save about 90% of their normal monthly water bill and middle-income households around 70%.

4.4.2.1. Estimated costs for the Lynedoch Eco-village dual system

Estimated costs of the two treatment systems are presented below. The primary treatment facility was installed in the year 2000 while the VIW was constructed in 2004.

a. Capital costs for the primary treatment facility (capacity = 10 m^3/day)

ITEM	QUANTITY	UNIT COST (R)	TOTAL COST (R)
5 kl cylindrical tanks	8	4,625	37,000
Pre-fabricated Concrete sump	3	15,000	45,000
Purchase of Pumps	3	15,000	45,000
Labour			10,000
Pipe work & others			63,000
TOTAL COST			**200,000**
AVERAGE COST			**20 per litre**

b. Capital costs for the VIW (capacity = 20 m^3/day)

ITEM	QUANTITY	UNIT COST (R)	TOTAL COST (R)
Excavation, stones, Geo-fabric, worms, halophytes, 8 mm diameter irrigation pipes			300,000
TOTAL COST			**300,000**
AVERAGE COST			**15 per litre**

c. Operation & Maintenance costs for the primary treatment facility and VIW

ITEM		UNIT COST (R)	TOTAL COST (R)
O & M for the primary treatment facility and VIW (i.e. labour for cleaning filters, pump servicing, manual removal of debris from sewage)	Non-subsidized households	% of household levy	% of R240
O & M for the primary treatment facility and VIW (i.e. labour for cleaning filters, pump servicing, manual removal of debris from sewage)	Subsidized households	% of household levy	% of R120

4.5. Wide-area urban/agricultural dual water reticulation systems

4.5.1. Mining in Rustenburg, North West

The Rustenburg Local Municipality recently established the Rustenburg Water Services Trust, a ring fenced company, to manage some of its water services. One of the services is treating industrial and domestic effluent at the recently upgraded Rustenburg Municipality WWTWs and conveying the effluent via a network of pipes to three users: the Anglo Platinum mine (10 Ml/d), the Implat Platinum mine (15 Ml/d) and the Rustenburg Municipality (2 Ml/d). The mines utilize the treated effluent as process water, while the Municipality uses some of the effluent for irrigating its public parks and sells the rest of the effluent (0.5 Ml/d) to some smaller mines (Marx, 2007)

4.5.2. Mining, aquifer recharge and aquaculture in Lephalale, Limpopo

In the Limpopo Province where development of mineral deposits is limited by scarce water resources, several mining houses are investing in potable water supply systems and WWTWs in the form of Pubic Private Partnerships with municipalities in exchange for treated effluent to be used as process water. One example is Anglo American's Mokopane Platinum mine, which is currently using treated effluent from both the Mokopane and Polokwane WWTWs. Another example is the Potgietersrus Platinum Mine that is to extract about 14Ml/d of treated effluent from the Polokwane/Seshego City WWTWs.

Polokwane's WWTW also currently supplies about 67% (approximately 25.20 Ml/day) of its total treated effluent to the Sand River and Pou River aquifers through groundwater recharge. Although Polokwane is largely dependent on surface water, the town also has an elaborate groundwater abstraction infrastructure that has the ability to supply domestic water in times of surface water shortages and during periods of peak demand (e.g. during the 1992-1994 drought).

Another initiative in the reuse of treated effluent is the crocodile-breeding farm by a private company from Thohoyandou WWTW in the former Venda district of the Limpopo Province. In this project, a portion of the treated effluent, some of which is discharged into the Luvuvhu River, is pumped in to disused maturation ponds where crocodiles are being bred. Crocodiles are bred for the leather, which is sold locally and internationally.

4.5.3. Kelvin power station, Gauteng

The Kelvin Power station has used about 3×10^6 m^3/a of treated effluent from a WWTW in the Northern Suburbs of Johannesburg for its operations (e.g. cooling) for a number of years. Kelvin, at the time, provided about 20% of Johannesburg's power needs (Grobicki and Cohen, 1999).

4.5.4. MONDI Paper production in eThekwini Municipality, KwaZulu-Natal,

(Anglo American, 2005)

In May 2001, the Durban Water Recycling Works (a Public Private Partnership between the eThekwini Unicity Council and investors) started production of near-potable water and the sale of this water to industrial clients for direct re-use in their processes. The plant is designed to treat 47.5Ml/d of domestic and industrial wastewater with about 35 Ml/d supplied to MONDI Paper. Some positive aspects of the project include:

- Conservation and sustainable development of Durban's water resources;
- Reduced pollution loading on the marine environment by means of recycling previously sea-discharged wastewater;
- Reduction of Durban's potable water demand. At operational capacity (47.5 Ml/day) the Durban Water Recycling plant will meet 7% of the city's 2005 potable water demand and will reduce the city's treated wastewater output by 10%. The potable water previously drawn by industrial consumers is available for redistribution to previously disadvantaged peri-urban communities without the need to invest in major bulk potable water supply and treatment infrastructure. If eThekwini Water Services' innovative water supply schemes to the urban poor are utilised, the volume of potable water saved on a daily basis can be used to extend water supply to up to 220 000 households in the greater Durban area;
- Public Private Partnership – an innovative contractual and financial model for providing capital for new infrastructure;
- Innovative use of water treatment technologies to produce near potable standard water from domestic and industrial wastewater. The recycled water produced by the plant meets or exceeds the South African potable water standards in 95% of the potable parameters measured;
- Significant economic benefits for all role players:

  For eThekwini Water Services, the project had the following significant economic advantages:

  - Delayed capital investment for increased marine outfall pipeline capacity;
  - Delayed capital investment for future bulk potable water supply infrastructure;
  - No capital investment for the construction of the recycling plant;
  - Creation of long-term revenue from a levy raised on the production of recycled water;
  - Consequent reduced cost of water services to Durban's citizens.

  For Durban Water Recycling (Pty) Ltd, the project, as an investment opportunity, has been financially attractive and sustainable in the long-term.

  For MONDI Paper, the project had the following significant economic implications:

  - 44% reduction in water tariff (2001) representing a significant cost saving for MONDI Paper.
  - The likelihood that the price of recycled water will escalate at a lower rate than potable water, given the current water environment in Durban.

4.5.5. The City of Cape Town, Western Cape

For several decades, the CoCT has provided treated effluent from some of its' WWTWs to meet some non-potable water requirements within the CoCT. Wastewater is collected and treated by the participating WWTWs, further filtered and disinfected, and then pumped through reuse pipe networks to mostly large users of non-potable water. A detailed case study was carried out on the CoCT dual (treated effluent and potable) system and this is presented in Appendix A.

4.6. Industrial dual water reticulation systems

4.6.1. The Goldfields gold mine, Driefontein

The Goldfields gold mine in Driefontein uses treated effluent produced at one of its WWTWs for toilet flushing at the Masizakehle high density residence and landscape irrigation at several locations. Further details about this dual system are presented in Chapter 6.

4.7. Summary of findings and observations

A summary of the salient findings and observations from the South African review are presented below:

- Similar to international experience, the extent of aridity of an area (e.g. in the provinces of the Western Cape, Limpopo and the Northern Cape) has driven non-potable water reuse and the implementation of dual systems in South Africa;
- At the current time, non-potable water reuse is mostly targeted at satisfying domestic and non-domestic irrigation and industrial non-potable water requirements;
- The water balance exercise undertaken in the CoCT (section C.4.2) shows that by recycling all treated effluent produced within the city, the total water supply will increase by about 118%. Currently, the CoCT reuses about 13% of the total treated effluent produced within the city;
- A significant number of the dual systems that have been implemented in the country are driven by private sector and/or community initiatives and minimally controlled by relevant local authorities;
- There exists no current and detailed South African regulation or guideline pertaining to non-potable water reuse and the planning, implementation and operation of dual systems. The DNHPD (1978) guideline is an outdated guideline that needs to be revised in light of current local and international experience;
- A source of non-potable water that is sited within proximity of the use(s) makes economic sense from both a supply and demand perspective. A distance of 500 metres between treated effluent source and users seemed to be the optimal distance within the CoCT;
- An important factor impacting the growth of treated effluent reuse in the CoCT is the inconsistent treated effluent qualities flowing out of the different WWTWs. Due to the inconsistent qualities of influents from different domestic and non-domestic return flows, and the deterioration of infrastructure, several CoCT WWTWs struggle to produce treated effluent qualities that consistently conform to national regulations. This has resulted in many treated effluent users further treating the effluent before reuse;
- Another challenge to the growth of treated effluent reuse in the CoCT is the limited synergistic relationships between the different units managing one or more aspects of treated effluent production (i.e. treatment, distribution, quality monitoring, maintenance, and metering). Because many of these units are managed independently, this has resulted in inefficiencies in treatment, supply, billing, etc.

5. NATIONAL PERCEPTION SURVEYS

Surveys were administered to the following categories of respondents who are, in one way or another, involved with, influence, or are influenced by non-potable water use and reticulation in South Africa:

- Consumers / users: (a) Domestic consumers of drinking water produced from unconventional sources and (b) Institutional consumers of non-potable water. Efforts at surveying domestic users of non-potable water failed.
- Decision makers: (a) DWAF officials involved with non-potable water use and reticulation in South Africa (b) Service Providers of non-potable water, and (c) Service Providers of drinking water.

5.1. Questionnaire structure

The Department of Water Affairs and Forestry, DWAF (2004c) has set a number of objectives against which strategies by water institutions or consumers (to influence water demand/use) should be measured vis-à-vis economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability. Po et al. (2003) also recommend some factors that may influence the acceptance of a water reuse project, i.e. the Disgust or "Yuck" factor, perceptions of risk associated with using recycled water, the specific uses of recycled water, the sources of water to be recycled, the issue of choice, trust and knowledge, attitudes towards the environment, environmental justice issues, the cost of recycled water, and socio-demographic factors

In order to garner the relevant perceptions of respondents towards non-potable water reuse and dual systems, the questionnaires were developed using the objectives and factors above as a guide. Each questionnaire therefore required information and perceptions relating to the key issues below as they relate to existing non-potable water reuse and dual systems:

- Economical efficiency
- Technical feasibility
- Social acceptance
- Organisational capacity
- Availability of appropriate regulations
- Public health and safety
- Public education

5.2. Background and profile of respondents

5.2.1. Domestic consumers of drinking water produced from unconventional sources

Emalahleni (Witbank), located within the Mpumalanga Highveld Coalfields, is a mining community that produces 60% of SA's saleable coal. The intense mining activities in Emalahleni over the past century have resulted in significant quantities of surface waters gradually draining into the mined-out voids and mixing with polluted waters from production and mining processes. Anglo Coal, in conjunction with Ingwe collieries, has developed the Emalahleni Mine Water Reclamation Project which abstracts and treats these polluted mine effluents for drinking water use in the Emalahleni municipality. The project has been designed to provide about 20 Ml/d of potable water to the community. The water is distributed to consumers via the current potable water reticulation networks.

The Emalahleni community provided the opportunity to evaluate people's perceptions on the consumption of potable water from an unconventional source, the use of non-potable water for non-potable water uses, and willingness to adopt dual reticulation systems in homes. Four areas, i.e. Klipfontein (a suburban area), and Lynville, Ackerville and Extension 14 (3 townships), were selected and surveyed.

The questionnaire utilised in this section is presented in Appendix B.I.

i) Klipfontein

Questionnaire administration in Klipfontein was difficult for several reasons including high fences, dogs, hostility, lack of interest, and the presumption of some residents who thought questionnaire administrators were job seekers.

ii) Lynville, Ackerville and Extension 14

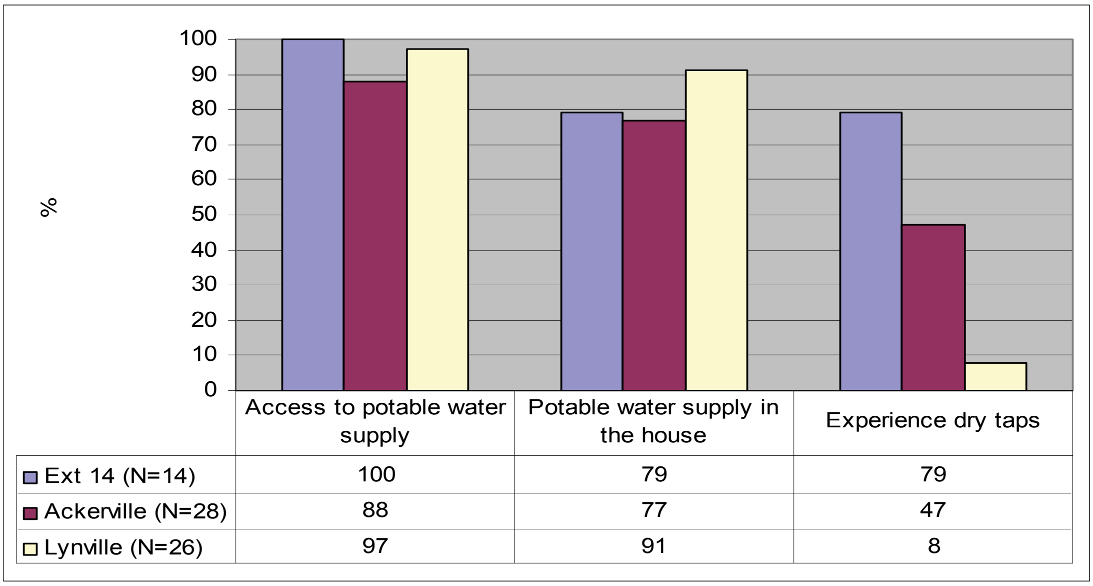
Residents were generally accommodating. The men were generally reluctant to participate, often directing the responsibility to the women. Many of the respondents were initially suspicious, thinking the questionnaire filling process was a ploy to expose those defaulting in paying for services or involved in unauthorised water consumption. Some respondents presumed the administrators were government officials who could provide solutions to their problems hence, some time was spent conveying their problems.

A profile of the respondents is as follows:

Table 19. Profile of Emalahleni township respondents

RESPONDENT	AREA	NUMBER OF RESPONDENTS	AVERAGE HOUSEHOLD INCOME PER MONTH (R)	AVERAGE HOUSEHOLD SIZE
A	Extension 14	14	< R2000	3.5
	Ackerville	28	< R2000	5.0
	Lynville	26	R2000-R5000	3.5

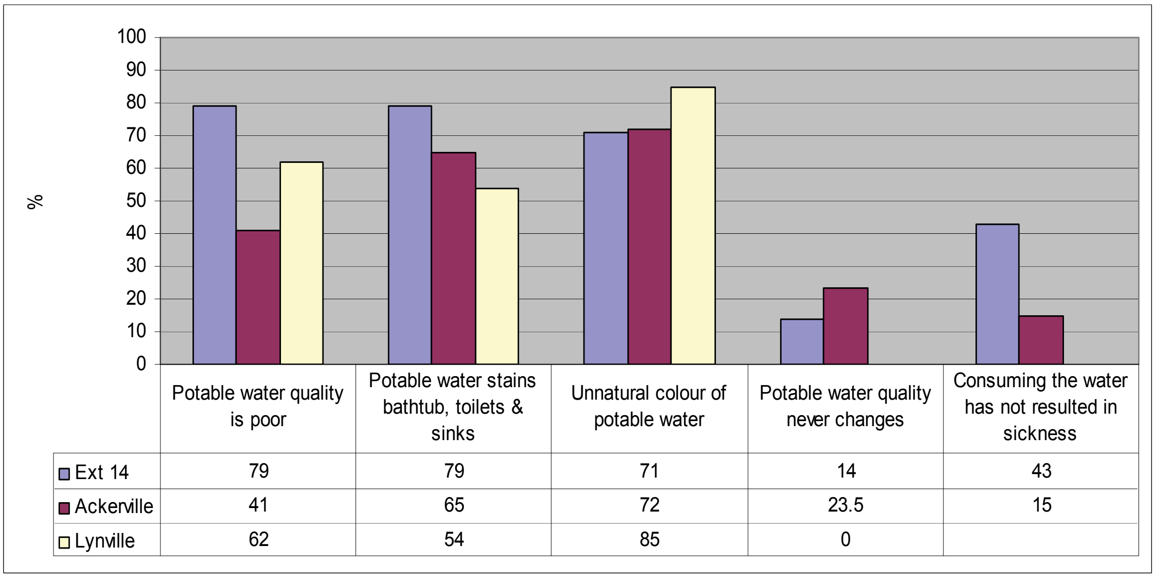
Most respondents benefit from the municipal potable water supply, with majority receiving potable water supply in their homes (Figure 28). About 12% of the respondents in Ackerville get their potable water from other sources. Residents in these three areas experience dry taps with frequencies ranging from once a week to once a year – Extension 14 records the most incidents. Reasons for this include maintenance inefficiencies and the low levels of water in the Emalahleni dam.



	Access to potable water supply	Potable water supply in the house	Experience dry taps
■ Ext 14 (N=14)	100	79	79
■ Ackerville (N=28)	88	77	47
□ Lynville (N=26)	97	91	8

Figure 28. Potable water supply to the Emalahleni township respondents

Figure 29 attests to the dissatisfaction of respondents with regards to the quality of potable water supplied to domestic households in 2006. Generally, respondents perceived the potable water quality to be poor, with the water taking on different colours at different times, and with the associated staining of plumbing fittings. A very high incidence of water related sickness (especially typhoid) was reported in the questionnaires. It was however difficult to determine whether this perception was correct or not, as other vectors may have contributed to the incidence of water-related sickness. From the information given during the questionnaire administration, the prevalence of water-related sicknesses affected about two thirds of the population at any given time in Emalahleni.



	Potable water quality is poor	Potable water stains bathtub, toilets & sinks	Unnatural colour of potable water	Potable water quality never changes	Consuming the water has not resulted in sickness
■ Ext 14	79	79	71	14	43
■ Ackerville	41	65	72	23.5	15
□ Lynville	62	54	85	0	

Figure 29. Water quality in the three Emalahleni townships

5.2.2. Institutional consumers of non-potable water

The questionnaire utilised in this section is presented in Appendix B.II. A profile of the respondents is as follows:

Table 20. Profile of institutional consumers (respondent C) of non-potable water

RESPONDENT	AREA	RESPONDENT CATEGORY	QUESTIONNAIRES ADMINISTERED	RESPONSES RECEIVED
C	City of Cape Town	Irrigation: ➢ Education (school fields) & professional sport fields ➢ Landscape (Public use) ➢ Agriculture	19 4 1*	9 2 1
		Industries:		
		➢ Petroleum	1	1
		➢ Pulp and paper	2	1
		➢ Textile	1	0
		➢ Construction	2	2
	Lephalale	Industries: Petroleum	1	1
		Total	**31**	**17**

** represents a group of about 30 farmers*

Approximately 88% of the respondents sampled have uninterrupted potable water supply.

5.2.3. Decision makers

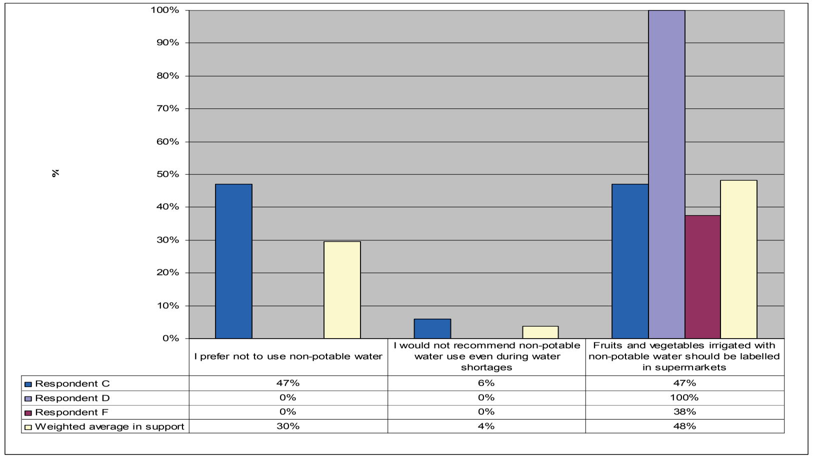
A profile of the respondents in this category is as follows:

Table 21. Profile of decision makers involved in non-potable water use

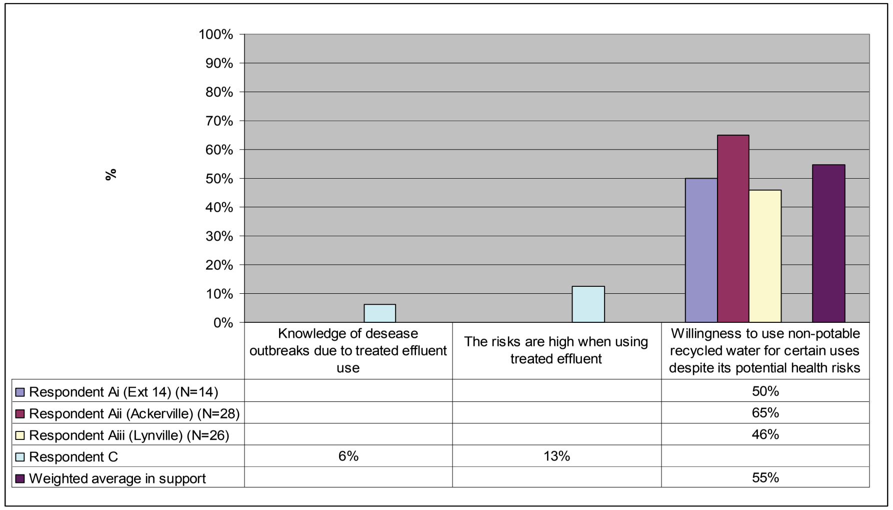
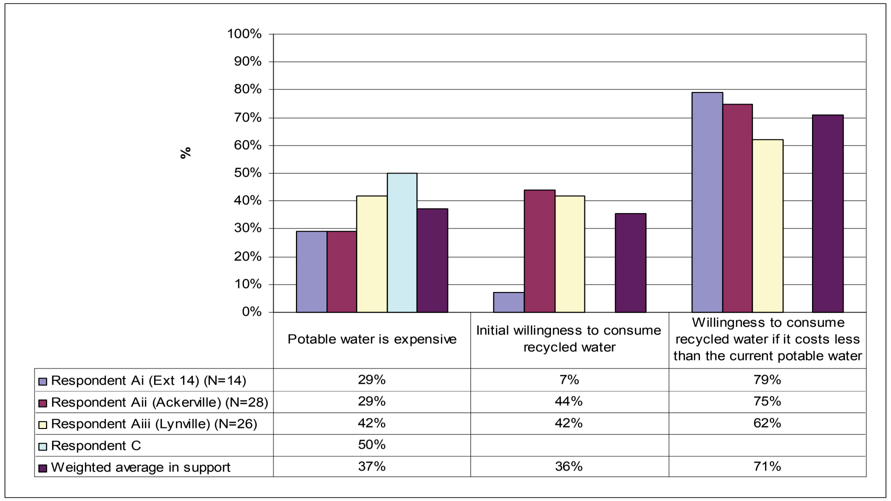
RESPONDENT	DESCRIPTION	QUESTIONNAIRE REFERENCE	QUESTIONNAIRES ADMINISTERED	RESPONSES RECEIVED
D	DWAF officials involved with non-potable water use and reticulation in South Africa	Appendix B.III	3	2
E	Service providers of non-potable water (WWTWs and wastewater services managers)	Appendix B.IV	16	1
F	Service providers of drinking water (water treatment works and water services managers)	Appendix B.V	10	8
Total			29	11

5.3. Perception results

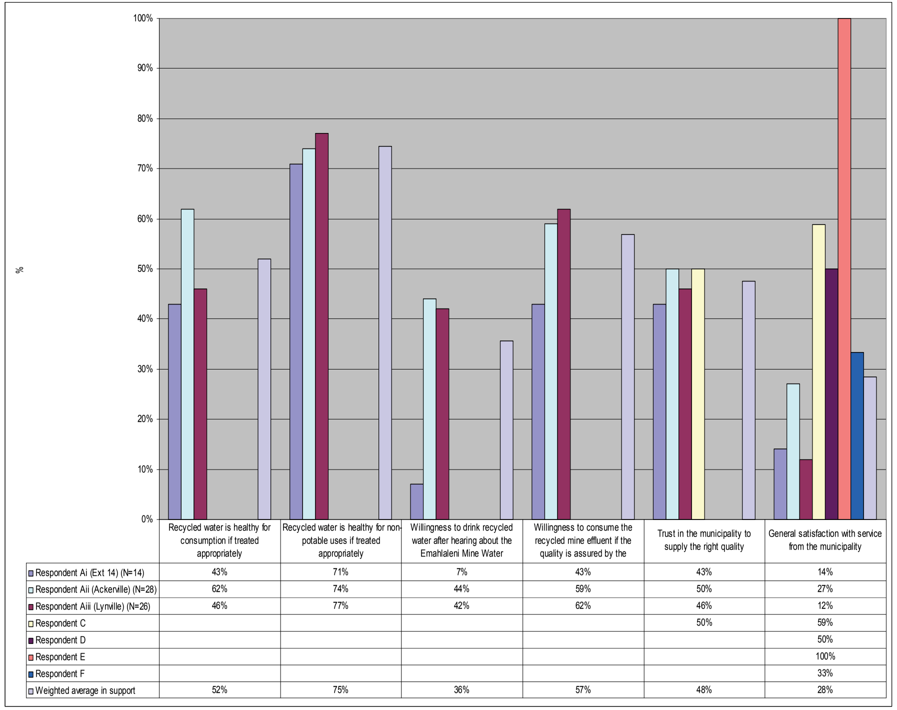
Respondents' perceptions were collected using the key issues listed in Section 5.1 and are presented below:

<table>
<tr><th>Key issues</th><th>Statement</th><th>Perception results</th><th>Summarised comments</th></tr>
<tr><td>Ranking of key issues</td><td>Rank in order of priority from 1 (most important) to 7 (least important) the critical issues you would consider when planning a dual reticulation system</td><td><table>
<tr><th>Key issues</th><th>Consumers' (Respondents A and C) ranking</th><th>Decision-makers' (Respondents D, E and F) ranking</th><th>Overall ranking</th><th>Overall weight</th></tr>
<tr><td>Public health and safety</td><td>1</td><td>2</td><td>1</td><td>1.00</td></tr>
<tr><td>Economics</td><td>2</td><td>3</td><td>2</td><td>1.16</td></tr>
<tr><td>Technical/ Engineering</td><td>5</td><td>1</td><td>3</td><td>2.09</td></tr>
<tr><td>Regulation</td><td>3</td><td>5</td><td>4</td><td>2.28</td></tr>
<tr><td>Organisational capacity</td><td>4</td><td>6</td><td>5</td><td>2.44</td></tr>
<tr><td>Social acceptance</td><td>7</td><td>4</td><td>6</td><td>2.84</td></tr>
<tr><td>Public education</td><td>6</td><td>7</td><td>7</td><td>2.85</td></tr>
</table></td><td>Public health and safety, economics and technical/engineering are the three most important issues to be considered during the planning of a dual system. It is important to note that social importance (a pre-requisite for planning dual systems in many places) is not considered by all respondents to be amongst the top three.</td></tr>
<tr><td>Public health and safety</td><td>Perceptions of risk</td><td>

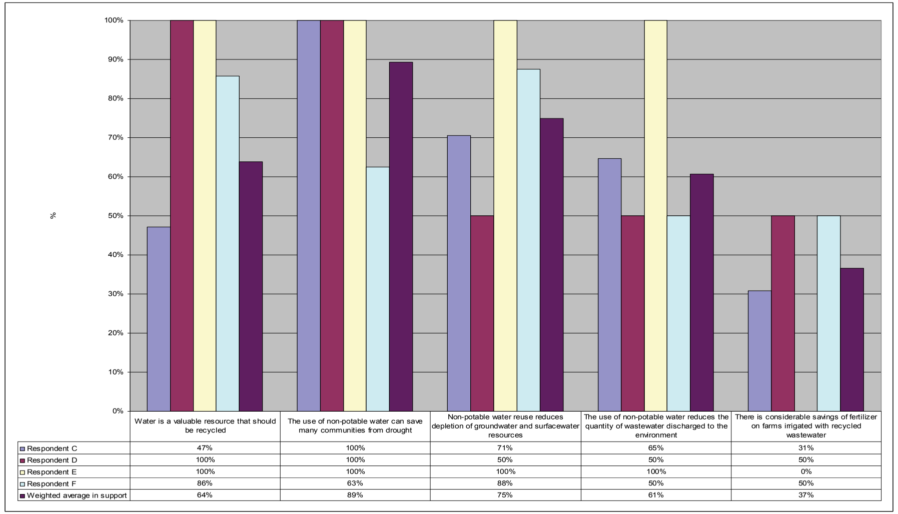
<table>
<tr><td>Weighted average in neutral</td><td>30%</td><td>7%</td><td>33%</td></tr>
</table></td><td>Perceptions of risk are often related to public health issues from reusing water. People may perceive the use of recycled water to be too risky because (i) the use of the water source may not be natural (ii) it may be harmful to people (iii) there might be unknown future consequences (iv) their decision to use the water may be irreversible, and (v) that the quality and safety of the water is not within their control.
➢ 30% of Respondents C prefer not to use treated effluent. This however decreases to 4% if a period of water shortage is experienced.
➢ The 48% response of decision makers to labelling fruits and vegetables in supermarkets is likely indicative of perceived risk associated with consuming fruits and vegetables irrigated with non-potable water. By labelling, consumers who purchase these products, accept the risks involved.</td></tr>
</table>

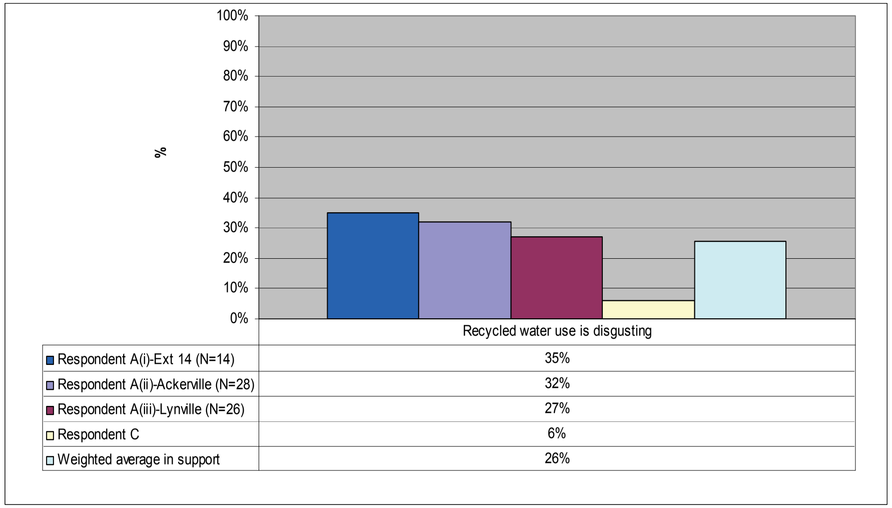
Key issues	Statement	Perception results	Summarised comments
			➢ Percentage response of Respondents C to known incidents of disease outbreak and the evaluation of risks involved when using treated effluent are shown to be low. ➢ There were concerns amongst domestic respondents about the safety of children when exposed to non-potable water. ➢ On average however, 55% of domestic respondents were willing to use non-potable recycled water for certain uses even given its potential health risk in case of accidental consumption.
Economical efficiency	Cost of recycled water		➢ 37% of respondents indicated that their potable water is expensive. ➢ Initial willingness to consume/use recycled mine effluent by Respondent A was 36%. This willingness to consume/use recycled mine effluent increased to 71% if non-potable water tariffs become lower than the potable water tariff. Willingness to consume/use recycled mine effluent decreased to 15% if tariffs become higher than the potable water tariff. ➢ Some respondents were not willing to consume the recycled mine effluent even if it resulted in an increase in the current price of potable water.

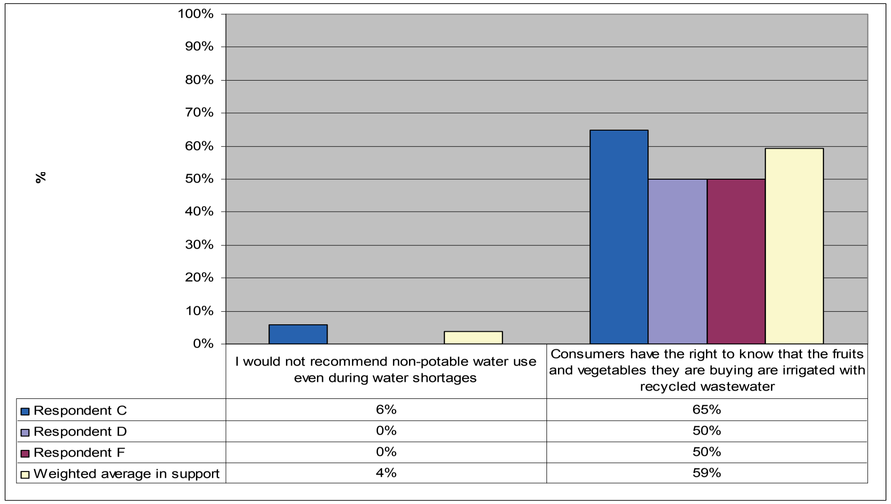
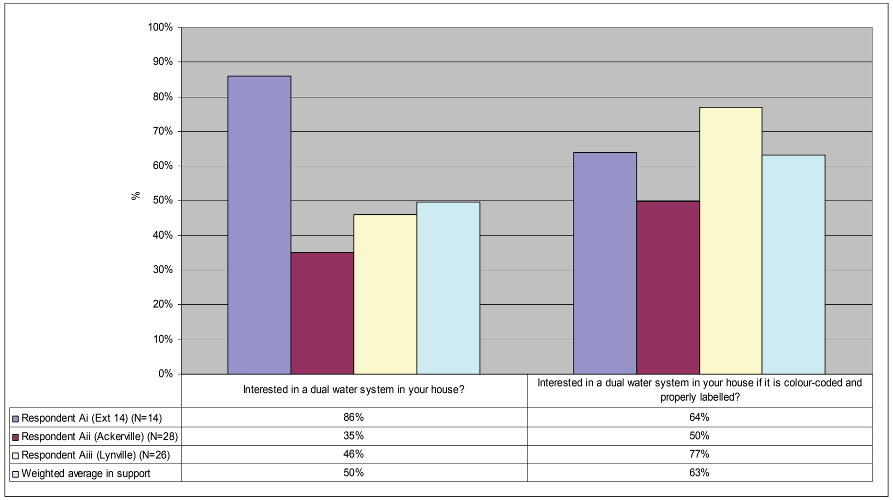
<table>
<tr><th>Key issues</th><th>Statement</th><th>Perception results</th><th>Summarised comments</th></tr>
<tr>
<td>Technical feasibility</td>
<td>Various uses of recycled water</td>
<td>
<table>
<tr><th colspan="4">Current domestic uses (mostly during water shortages)</th></tr>
<tr><td rowspan="2">Respondent A</td><td>Toilet flushing</td><td>Laundry</td><td>Landscape irrigation</td></tr>
<tr><td>Vegetable irrigation</td><td>Car washing</td><td></td></tr>
<tr><th colspan="4">Current non-domestic uses</th></tr>
<tr><td rowspan="2">Respondent C</td><td>Manufacturing</td><td>Refinery processes</td><td>Dust suspension</td></tr>
<tr><td>Landscape & sports field irrigation</td><td>Crop, fruit & vegetable irrigation</td><td></td></tr>
</table>
Activities Respondent A is willing to utilise non-potable recycled mine water for.
<table>
<tr><th></th><th>Ext 14</th><th>Ackerville</th><th>Lynville</th><th>Weighted mean</th></tr>
<tr><td>Toilet flushing</td><td>43</td><td>79</td><td>73</td><td>69</td></tr>
<tr><td>Laundry</td><td>29</td><td>50</td><td>35</td><td>40</td></tr>
<tr><td>Landscape irrigation</td><td>79</td><td>38</td><td>78</td><td>62</td></tr>
<tr><td>Vegetable/crop/fruit irrigation</td><td>43</td><td>32</td><td>35</td><td>35</td></tr>
<tr><td>Car washing</td><td>64</td><td>82</td><td>46</td><td>65</td></tr>
</table>
</td>
<td>➢ The grey water generated in 81% of the domestic households (Respondent A) drains into the sewer system. Hence, landscape irrigation using grey water is not common practice in the three areas. However, about 35% of respondents recycle some household grey water for toilet flushing and general household cleaning when there are water shortages.
➢ Toilet flushing, landscape irrigation and car washing are the most widely accepted domestic options for non-potable recycled mine water.</td>
</tr>
</table>

<table>
<tr><th>Key issues</th><th>Statement</th><th>Perception results</th><th>Summarised comments</th></tr>
<tr>
<td>Organizational capacity & public health and safety</td>
<td>Trust in service providers</td>
<td>


<table>
<tr><th></th><th>Recycled water is healthy for consumption if treated appropriately</th><th>Recycled water is healthy for non-potable uses if treated appropriately</th><th>Willingness to drink recycled water after hearing about the Emahlaleni Mine Water</th><th>Willingness to consume the recycled mine effluent if the quality is assured by the</th><th>Trust in the municipality to supply the right quality</th><th>General satisfaction with service from the municipality</th></tr>
<tr><td>Respondent Ai (Ext 14) (N=14)</td><td>43%</td><td>71%</td><td>7%</td><td>43%</td><td>43%</td><td>14%</td></tr>
<tr><td>Respondent Aii (Ackerville) (N=28)</td><td>62%</td><td>74%</td><td>44%</td><td>59%</td><td>50%</td><td>27%</td></tr>
<tr><td>Respondent Aiii (Lynville) (N=26)</td><td>46%</td><td>77%</td><td>42%</td><td>62%</td><td>46%</td><td>12%</td></tr>
<tr><td>Respondent C</td><td></td><td></td><td></td><td></td><td>50%</td><td>59%</td></tr>
<tr><td>Respondent D</td><td></td><td></td><td></td><td></td><td></td><td>50%</td></tr>
<tr><td>Respondent E</td><td></td><td></td><td></td><td></td><td></td><td>100%</td></tr>
<tr><td>Respondent F</td><td></td><td></td><td></td><td></td><td></td><td>33%</td></tr>
<tr><td>Weighted average in support</td><td>52%</td><td>75%</td><td>36%</td><td>57%</td><td>48%</td><td>28%</td></tr>
</table>
</td>
<td>
➢ If treated appropriately, 51% of domestic respondents conceptually considered recycled mine effluent healthy for human consumption and, significantly more (75%) considered the resource suitable for non-potable uses (e.g. toilet flushing & non-edible food gardening).
➢ After the responses above, a brief of the Emalahleni Mine Water Reclamation Project was presented. The responses, contrary to the conceptual response above, showed discomfort in some of the consenting respondents to consume the recycled mine water. The result is that willingness to consume recycled mine water decreased from 51% to 36%. Some reasons put forward for the decreased willingness include the perceptions of danger associated with mining activities, and the negative health-related experiences in the community perceived by some to be related to mining activities. Some respondents were sceptical about mine water being treated to drinking quality, and the lack of knowledge regarding wastewater recycling made some uneasy.
➢ If quality assurances are provided by the municipality, percentage willingness to consume recycled mine effluent increased from 36% to 57%. This is despite the low level (28%) of general satisfaction with municipal services. A few months prior to the survey, the potable water quality was so poor, people had to buy bottled water. Surprisingly 48% of the community still trusts the municipality to provide good quality water.
</td>
</tr>
</table>

<table>
<tr><th>Key issues</th><th>Statement</th><th>Perception results</th><th>Summarised comments</th></tr>
<tr><td rowspan="2">Social acceptance</td><td>Attitude towards the environment</td><td>

<table><tr><td>Weighted average in neutral</td><td>26%</td><td>7%</td><td>14%</td><td>32%</td><td>27%</td></tr></table></td><td>A positive attitude towards environmental preservation has assisted several non-potable water projects to be successful as the people embrace these projects as their way of contributing positively towards the environment.
➢ There is a generally a positive attitude towards the environment amongst decision makers.</td></tr>
<tr><td>Disgust / 'Yuck'</td><td>
</td><td>A disgust reaction is likely to be generated from people's perceived 'dirtiness' of the water and their fear of contagions or personal contamination from using the water.
➢ 60% of Respondent A knew nothing about water recycling. When provided with a definition for water recycling, 33% of this group considered recycled water disgusting.
➢ 6% of Respondent C considered recycled water disgusting. 35% of these respondents gave a 'neutral' response.</td></tr>
</table>

Key issues	Statement	Perception results	Summarised comments
	The issue of choice		In places where there were water shortages, people have been known to readily accept water reuse because of the heightened awareness of the need to conserve water. However, despite this general trend, a few projects (e.g. the San Gabriel Valley Groundwater recharge project) have failed despite being conceived during a drought. ➢ 96% of decision makers indicate their willingness to use non-potable water especially during a drought. ➢ 59% of decision makers agree that consumers have the right to know that the fruits and vegetables they are buying are irrigated with treated effluent. Hence, it becomes the purchaser's choice to purchase or not.
	Willingness to adopt a dual system		➢ Support for dual systems is average in the three communities (50%). In Extension 14, support for the implementation of dual systems is high at 86%. In Ackerville and Lynville, support for the implementation of dual systems increases as respondents increasingly understand what dual systems are and some of the safety features (e.g. colour coding and proper labelling) used to minimise risks to public health and safety.

5.4. Summary of findings and observations

A summary of the salient findings and observations from the perception survey are presented below:

a. Ranking of key issues

- The ranking of the key issues that influence the planning of a dual water reticulation system have provided numeric weights when aggregating the assessment of each issue within the assessment framework developed in Appendix C;
- Public health and safety, economics and technical/engineering were ranked the three most important of the seven issues. Social acceptance (a pre-requisite for planning especially domestic dual systems in many places) was however ranked low (position 6) by both respondent categories. It is not immediately clear why this is so. However, social acceptance has stood out as one of the reasons why several dual systems where either not implemented or abandoned. It is critical that decision-makers pay adequate attention to whether potential users and the public will accept the implementation of a dual system.

b. Public health and safety

- Respondents indicated knowledge of a few incidents involving the accidental consumption of non-potable water. Despite this, institutional respondents considered the risks to public health due to non-potable reuse, to be low (13%) while 55% of domestic respondents were still willing to reuse non-potable water for certain uses;
- Several domestic respondents were particularly concerned about the safety of children when exposed to non-potable water (e.g. during garden irrigation);
- Perceptions of risk to public health were expressed when asked about the consumption of fruits and vegetables irrigated with non-potable water. 48% of respondents considered it necessary for supermarkets to inform consumers, using packaging labels, when fruits and/or vegetables on shelves had been irrigated with non-potable water.

c. Economics

- Non-potable water tariffs significantly influenced (from 36% to 71%) respondents' willingness to embrace non-potable reuse.

d. Technical/Engineering

- Colour coding and clear identification/labelling of the non-potable pipes played a significant role in encouraging (from 50% to 63%) the acceptance of dual systems amongst some respondents previously negative to the technology.

e. Organizational capacity

- A significant percentage (90%) of decision makers support non-potable water reuse for freshwater conservation, environmental protection and environmental sustainability;

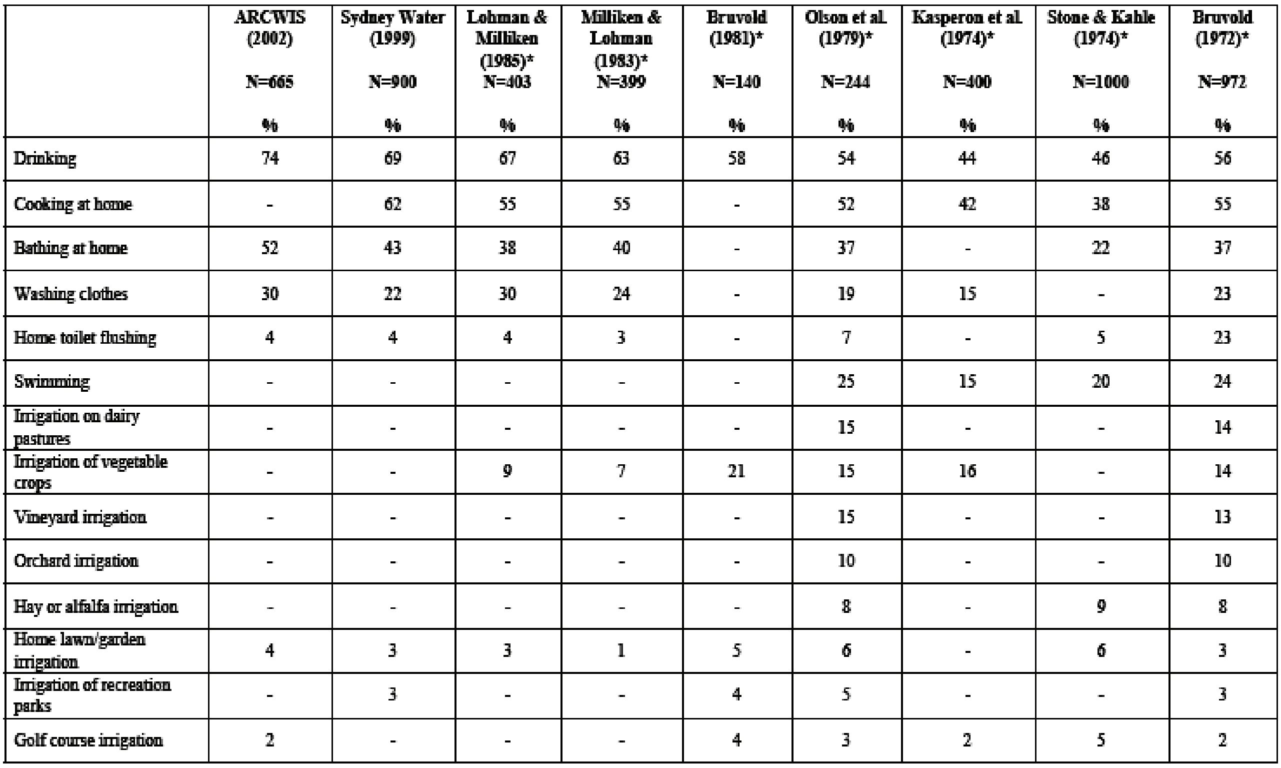
- Percentage increase (from 36% to 57%) in willingness to consume recycled mine effluent from the Emalahleni Mine Water Reclamation Project if quality assurances are provided by the municipality indicate some level of consumer confidence in municipal authorities. This is despite the fact that the level of general satisfaction with municipal services was at 28% at the time of administering the questionnaires.

f. Social acceptance

- Similar to international experience, the closer recycled water is to human contact or ingestion, the more opposed people are to using the water (Table 22). In the surveys, domestic respondents indicated more comfort reusing non-potable water for toilet flushing, landscape irrigation and car washing.

Table 22. Preferred uses of recycled water from different studies

(Po et al, 2003), *N = number of respondents*



	ARCWIS (2002) N=665 %	**Sydney Water (1999)** N=900 %	**Lohman & Milliken (1985)*** N=403 %	**Milliken & Lohman (1983)*** N=399 %	**Bruvold (1981)*** N=140 %	**Olson et al. (1979)*** N=244 %	**Kasperon et al (1974)*** N=400 %	**Stone & Kahle (1974)*** N=1000 %	**Bruvold (1972)*** N=972 %
Drinking	74	69	67	63	58	54	44	46	56
Cooking at home	-	62	55	55	-	52	42	38	55
Bathing at home	52	43	38	40	-	37	-	22	37
Washing clothes	30	22	30	24	-	19	15	-	23
Home toilet flushing	4	4	4	3	-	7	-	5	23
Swimming	-	-	-	-	-	25	15	20	24
Irrigation on dairy pastures	-	-	-	-	-	15	-	-	14
Irrigation of vegetable crops	-	-	9	7	21	15	16	-	14
Vineyard irrigation	-	-	-	-	-	15	-	-	13
Orchard irrigation	-	-	-	-	-	10	-	-	10
Hay or alfalfa irrigation	-	-	-	-	-	8	-	9	8
Home lawn/garden irrigation	4	3	3	1	5	6	-	6	3
Irrigation of recreation parks	-	3	-	-	4	5	-	-	3
Golf course irrigation	2	-	-	-	4	3	2	5	2

- Involving, interacting with and educating communities from inception about different non-potable water qualities and their potential to satisfy certain non-potable water requirements is critical in facilitating social acceptance.

6. MODELLING OF A DUAL WATER RETICULATION SYSTEM USING THE PROPOSED ASSESSMENT FRAMEWORK – CASE OF THE GOLDFIELDS GOLD MINE, DRIEFONTEIN.

A modelling exercise, using the assessment framework presented in Appendix C, was undertaken in this section. The exercise aimed to assess the feasibility of implementing a dual water reticulation system within the Goldfields gold mine in Driefontein.

The Goldfields gold mine, Driefontein is located in South Africa's West Wits Line goldfield, about 70km south west of Johannesburg and on the outskirts of Carletonville (Figure 30).

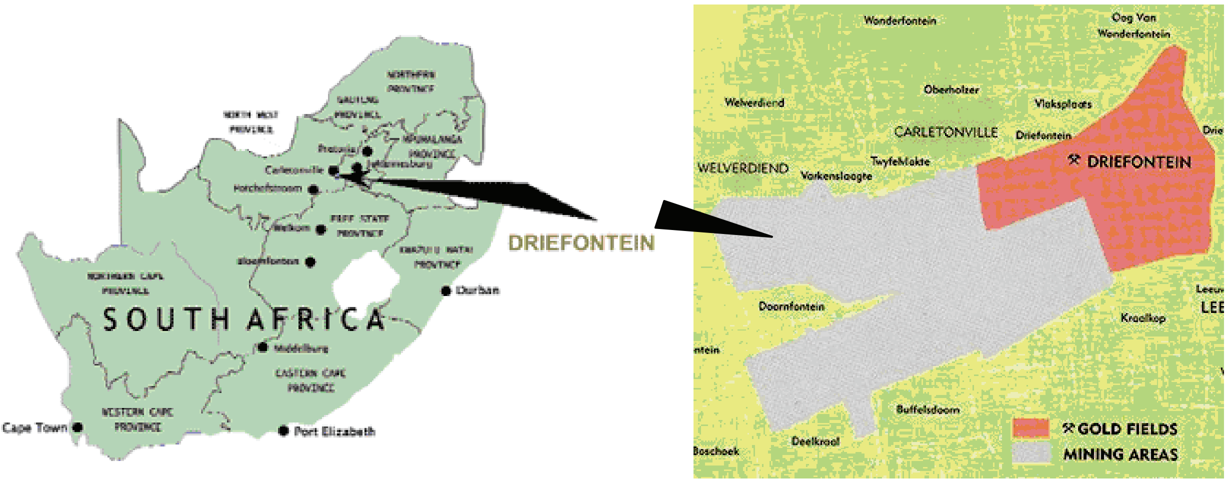


Figure 30. Location of the Goldfields gold mine, Driefontein

The mine (Figure 31) houses 4 WWTWs producing about 10.36 Ml/d of treated effluent. 1 Ml/d of this effluent (from WWTW 1 alone) is used for flushing communal toilets at the Masizakehle high density residence (Figures 32 and 33) and for landscape irrigation at the West Village residential area, the Golf Course and the Training Centre (Figures 34 and 35). Dewatering and treatment of dolomite waters also takes place within the several mining shafts underground for specifically mining processes. The excess of the dolomite water and unused treated effluent sums to about 36 Ml/day and this is discharged into the Wonderfonteinspruit (Figures 36).

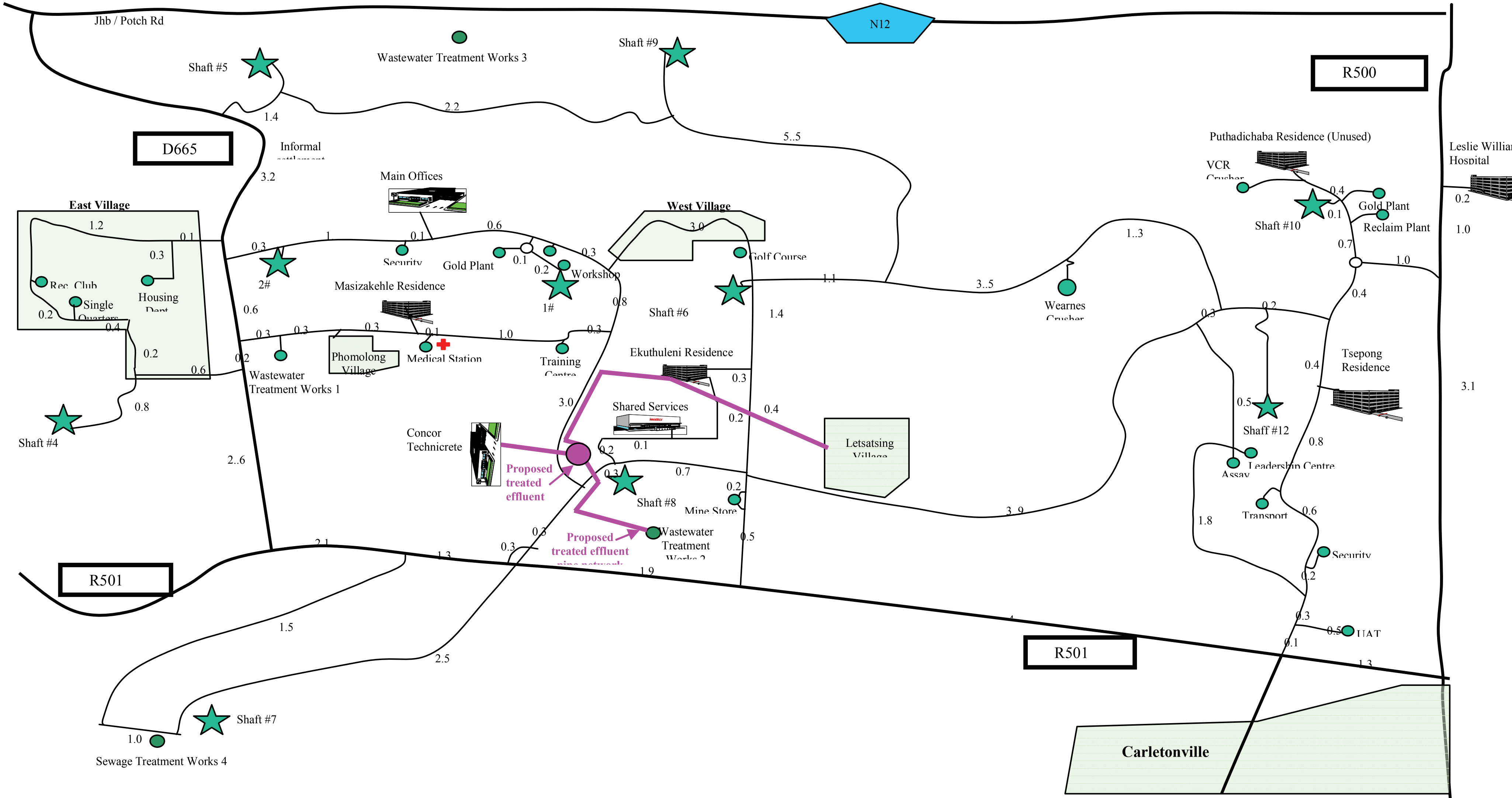


Figure 31. Layout of the Goldfields gold mine, Driefontein

Figure 32. A communal toilet cistern supplied with treated effluent[*]

Figure 33. Pipes supplying communal toilets[**]

Note:

**Cistern braces are employed to prevent access to the effluent for any reasons which may pose a threat to public health and safety;*

***Green colour on pipe flanges represents pipes conveying treated effluent. Yellow colour on pipe flanges represents pipes conveying treated dolomite water.*

Figure 34. Green colour pipes conveying treated effluent for irrigation at the Training Centre.

Figure 35. A dual treated effluent (green pipes) and potable (blue pipes) water reticulation within the Training Centre.

Figure 36. Discharge of dolomite water

Potential uses for the unused treated effluent include:

i. Toilet flushing in the other high density residences (i.e. Tsepong and Ekuthuleni);
ii. Toilet flushing and/or garden irrigation in the medium density residential areas (i.e. East Village, Letsatsing and Phomolong);
iii. Toilet flushing in some of the non-residential buildings (i.e. Main offices, Medical Station, Training Centre, Workshop, Security, Shared Services centre and Mine Store);
iv. Paving and masonry production at the Concor Technicrete facility (which houses 2 concrete mixing plants and 80 personnel) within the mine area (Figure 37).

Figure 37. The Concor Technicrete facility

The modelling exercise presented below was undertaken to investigate the various aspects of implementing a treated effluent system within an existing community. Hence, the modelling exercise was of benefit in practically determining the economical, social and environmental parameters influencing the feasibility of implementing a dual reticulation system based on the assessment framework developed and presented in Appendix C.

The modelling exercise involved the use of treated effluent from WWTW 2 which has a capacity of 2.5 Ml/d. The treated effluent system incorporating a treated effluent storage tank, new pumps at WWTW 2 and piped reticulation, will be implemented to convey the treated effluent from WWTW 2 to Ekuthuleni residence (for toilet flushing and irrigation), Concor Technicrete (for toilet flushing, paving and masonry production) and Letsatsing village (for toilet flushing and irrigation).

The proposed system, which will be implemented in phases, is shown in purple colour on Figure 31 and described below. As indicated earlier, treated effluent will be supplied from WWTW 2.

i. Phase 1 – Construction of a storage tank and installation of pipes to supply treated effluent from WWTW 2 to Ekuthuleni residence (for toilet flushing and irrigation) and Concor Technicrete (for toilet flushing, paving and masonry production);
ii. Phase 2 – Purchase and installation of new pumps for WWTW 2 and installation of pipes to supply treated effluent to Letsatsing village for toilet flushing & irrigation;
iii. Phase 3 – Electrical and mechanical infrastructure replacement and major repairs;
iv. Phase 4 – Electrical and mechanical infrastructure replacement and major repairs.

Assumptions:

i. The quality of treated effluent to be supplied by WWTW 2 would be appropriate for toilet flushing, landscape irrigation and concrete mixing;

ii. There is minimal upgrade currently required at WWTW 2;
iii. Implementation of this project would commence in 2009 and will have an expected 20 year design life;
iv. Existing potable water service pipes to the potential uses will be used;
v. The Rand Water Board potable water tariff of R4.80 per kl does not change over the 20 year design period for the treated effluent system.

The modelling exercise involved assessing the feasibility of implementing the dual system in three areas – technical and economic (Section 6.1.), social, institutional and regulatory (Section 6.2.) and environmental and public health and safety (Section 6.3.). Details of the exercise are presented below:

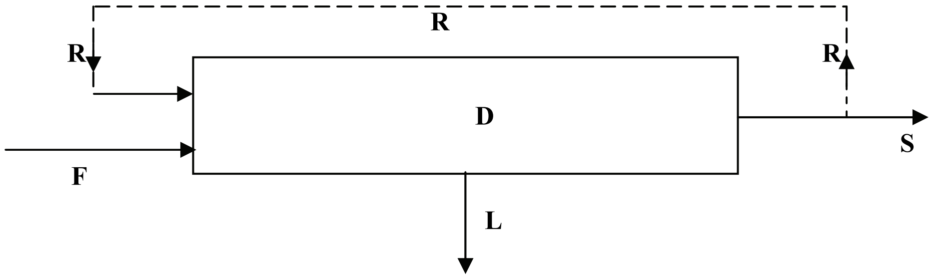
6.1 Technical and economic bottom line assessment

Table 23. Framework for assessing technical and economic bottom line criteria – modelling exercise

GOAL	CRITERIA	EVALUATION QUESTION / STATEMENT	SCORE			WEIGHT	REAL SCORE
			1	2	3		
Technical feasibility	Increase in total supply	Percentage increase in total supply due to non-potable water use (*Box 6.1.*)	Significant (> 10%)	Moderate (5-10%)	Insignificant (<5%) ✓	x 2.09 =	**6.27**
	Potential supply to current demand	Ratio of potential non-potable supply to current demand for non-potable water supply *(Table 24)*	Significant (>2) ✓	Moderate (1-2)	Insignificant (<1)	x 2.09 =	**2.09**
	Distance	Average distance between potential supply and demand	Insignificant < 0.5 km	Moderate 0.5-1.0 km ✓	Significant > 1.0 km	x 2.09 =	**4.18**
	Non-potable water use/reuse	Potential for human contact with the non-potable water	Insignificant	Moderate ✓	Significant	x 2.09 =	**4.18**
	Treatment technology	Treatment technology readily available?	Locally available	Nationally available ✓	Must be imported	x 2.09 =	**4.18**
	Retro-fit system	Ease to retro-fit a dual system?	Significant ✓	Moderate	Insignificant	x 2.09 =	**2.09**
	Supply reliability	Reliability of non-potable water supply (51 weeks a year / 98% of the time)?	Significant ✓	Moderate	Insignificant	x 2.09 =	**2.09**
	Treatment quality reliability	Treatment technology meets effluent quality requirements under expected operating conditions?	Significant ✓	Moderate	Insignificant	x 2.09 =	**2.09**
	Operation & Maintenance	Level of skill required to operate and maintain the dual system	Low	Moderate ✓	High	x 2.09 =	**4.18**
	Utilise existing infrastructure	Potential to utilise existing infrastructure (e.g. WWTW)?	Significant ✓	Moderate	Insignificant	x 2.09 =	**2.09**
	Upgradeability	Extent dual system can be readily expanded to supply future flows?	Significant ✓	Moderate	Insignificant	x 2.09 =	**2.09**
Technical sustainability	Long-term applicability	Period of impact of the system? (short to long term)	Significant > 10 yrs ✓	Moderate 3-10 yrs	Insignificant < 3 years	x 2.09 =	**2.09**
	Flexibility	Technology can be adapted to meet more stringent effluent standards in the future?	Significant ✓	Moderate	Insignificant	x 2.09 =	**2.09**
	Future supply to current demand	Ratio of future non-potable supply to future demand for non-potable water supply	Significant (>2) ✓	Moderate (1-2)	Insignificant (<1)	x 2.09 =	**2.09**
Economical feasibility	Cost difference	Difference in the overall cost of supplying potable and non-potable water *(Tables 25 and 26 and Box 6.2.)*	Profitable ✓	Moderate	Not profitable	x 1.16 =	**1.16**

GOAL	CRITERIA	EVALUATION QUESTION / STATEMENT	SCORE			WEIGHT	REAL SCORE
			1	2	3		
	Savings	Extent of cost savings for non-potable use	Significant	Moderate	Insignificant	x 1.16 =	**1.16**
	Financial help	Financial assistance/incentives for non-potable use	[✓ Significant]	Moderate	Insignificant	x 1.16 =	**1.16**
	Job creation	Potential for job creation	Significant	Moderate	[✓ Insignificant]	x 1.16 =	**3.48**
Weighted mean of Real Scores (ΣReal Score/ΣNumber of items) (Range: 1.9-5.7)							**2.7**

Box 6.1. Percentage increase in total supply due to non-potable water use



where F = Potable water supply, R = Recycled water supply, D = Non-potable and potable water demand, L = Losses (e.g. leakage and evaporation) and S = Effluent discharge

A water balance equation of the system above is:
$F + R = D + L + S + R$ 6.1a
Current Rand Water potable water supply, F = 250 Ml/day
Current return flows, S from the four WWTWs = 10.36 Ml/day (i.e. 4.14% of potable water consumption, F)
Therefore, total demand plus losses (D + L) = 95.86% of total supply (F + R).
Assuming all return flows are recycled, i.e. S = 0, equation 6.1a becomes
$R = 0.0432F$ 6.1b
By substituting 6.1b into the left hand side of equation 6.1a, equation 6.1b becomes
$1.0432F = D + L + S + R$ 6.1c

Equation (6.1c) indicates that if the mine achieves zero effluent discharge, S through recycling, R, with D+L equal to the current 95.86% of total consumption, the total available inflow into the system would be 1.0432 times the current potable water supply from Rand Water (an increase of 4.32%).

The percentage of return flow (4.14%) from the total supply is small and below the range expected in such a community (i.e. 30-60%). It is therefore suspected that a portion of the current Rand Water supply, F of 250 Ml/day is diverted to other purpose(s) that are not accounted for in the water balance equation (6.1a).

Table 24. Estimated non-potable water demands for selected areas at the Driefontein mine

End user connection	PHASE 1 (2009)			PHASE 1 (plus 3% annual growth) & PHASE 2 (2014)			PHASE 3 = PHASE 1 & 2 (plus 3% annual growth)			PHASE 4 = PHASE 1 2 & 3 (plus 3% annual growth)		
	Summer daily demand (kl/d)	**Winter daily demand (kl/d)**	**Annual total (kl)**	**Summer daily demand (kl/d)**	**Winter daily demand (kl/d)**	**Annual total (kl)**	**Summer daily demand (kl/d)**	**Winter daily demand (kl/d)**	**Annual total (kl)**	**Summer daily demand (kl/d)**	**Winter daily demand (kl/d)**	**Annual total (kl)**
Ekuthuleni (toilet flushing for 2581 residents and landscape irrigation)	568	340	165722	627	375	182970	692	414	202014	764	458	223040
Concor Technicrete (toilet flushing for 80 staff members and concrete mixing)	2.5	2.5	752	3	3	830	3	3	917	3	3	1012
Letsatsing village (toilet flushing for about 1300 residents and landscape irrigation)				314	189	92000	347	209	101575	383	230	112147
TOTAL	**571**	**343**	**166474**	**944**	**567**	**275801**	**1042**	**626**	**304506**	**1151**	**691**	**336200**
Current WWTW 2 treated effluent capacity	**2500**	**2500**	**600000**	**2500**	**2500**	**600000**	**2500**	**2500**	**600000**	**2500**	**2500**	**600000**
Ratio of potential supply to demand	**4.4**	**7.3**	**3.6**	**2.6**	**4.4**	**2.2**	**2.4**	**4.0**	**2.0**	**2.2**	**3.6**	**1.8**

Table 25. Estimated capital costs for Phases 1, 2, 3 and 4 over a 20 year design life from 2009

S/No.	ITEM			COST/UNIT (R)	TOTAL (R)
	Phase 1 (2009)				
1	Construction of a circular, concrete reinforced, treated effluent storage tank (1.5 Ml, concrete)				1000000
2	Purchase and installation of bulk treated effluent pipes	WWTW 2 to tank	700 m of 200 mm dia	300 per m	210000
		Tank to Concor	600 m of 50 mm dia	150 per m	90000
		Tank to Ekuthuleni	1300 m of 160 mm dia	270 per m	351000
3	Pipe connection chambers		2 No.	12000	24000
4	Telemetry & programmable logic controller				40000
5	Professional fees (including disbursements) 14% of total				240100
				Phase 1 Total (Including VAT of 14%)	**2,228,814**
	Phase 2 (2014)				
1	Installation of new pumps		18 KW	3,000 per KW	54000
2	Modular filters		50 kl/hr		50000
3	Purchase and installation of bulk treated effluent pipes	Ekuthuleni to Letsatsing	1600 m of 160 mm dia	270 per m	432000
4	Pipe connection chambers		1 No.	12,000	12000
5	Professional fees (including disbursements) 14% of total				76720
				Phase 2 Total (Including VAT of 14%)	**712,181**
	Phase 3 (2019)				
1	Major curative maintenance works (pipe, pumps, etc.)				40000
2	Telemetry & programmable logic controller				40000
3	Professional fees (including disbursements) 14% of total				11200
				Phase 3 Total (Including VAT of 14%)	**103,968**
	Phase 4 (2024)				
1	Installation of new pumps		18 KW	3,000 per KW	54000
2	Modular filters		50 kl/hr		50000
3	Professional fees (including disbursements) 14% of total				14560
				Phase 4 Total (Including VAT of 14%)	**135,158**
				NET PRESENT VALUE OF CAPITAL COSTS FOR PHASES 1, 2, 3 & 4 (Incl VAT)	3,180,121.20

Table 26. Estimated operation and maintenance costs over a 20 year design life from 2009

S/No.	ITEM	PHASE	VOLUME PUMPED OVER 5 YRS (kl/a)	COST/UNIT (R)	PHASE 1 (R)	PHASE 2 (R)	PHASE 3 (R)	PHASE 4 (R)
1	Electrical costs	1	166474	0.08	13317.92			
		2	275801	0.10		27580.1		
		3	304506	0.15			45675.9	
		4	336200	0.20				67240
2	Maintenance costs	1% on Civil cost			18527	18527	18527	18527
		4% on Mechanical cost			1448	1448	1448	1448
3	Other costs / Contingencies				20000	20000	20000	20000
Annual cost over 5 years (R)					53293	67555	85651	107215
Present Value of each phase's annual cost (r)					202,023	159,010	125,180	97,296
NET PRESENT VALUE OF O & M COSTS OVER 20 YEARS (R)					**583,511**			

Box 6.2. Costing Summary:

The Net Present Value of Capital, Operation and Maintenance costs for the treated effluent system over a design life of 20 years =

R3,180,121 (Capital) + R**583,511** (O & M) = R3, 763, 632

The Annual Annuity over 20 years based on the NPV at 10% equals R442, 075

Currently, Goldfields pays the Rand Water Board approximately R4.80 per kl for potable water. Consumers do not pay for potable water. The table below summarises the estimated savings/(deficits) as a result of implementing the treated effluent reuse system.

	VOLUME PUMPED EACH YEAR OVER 5 YRS (kl/a)	ANNUAL COSTS FOR RAND WATER POTABLE WATER AT R4.80/kl (R)	COST FOR POTABLE WATER PER PHASE (5 YEARS) (R)	ANNUAL COSTS FOR THE TREATED EFFLUENT SYSTEM (R)	COST FOR THE TREATED EFFLUENT SYSTEM PER PHASE (5 YEARS) (R)	SAVINGS/(DEFICIT) PER PHASE (5 YEARS) (R)
PHASE 1	166474	799,075.20	3,995,376	442,074.79	2,210,373.90	1,785,002.10
PHASE 2	275801	1,323,844.80	6,619,224	442,074.79	2,210,373.90	4,408,850.10
PHASE 3	304506	1,461,628.80	7,308.144	442,074.79	2,210,373.90	5,097,770.10
PHASE 4	336200	1,613,760.00	8,068,800	442,074.79	2,210,373.90	5,858,426.10
20 YEAR OVERALL COST/SAVINGS/(DEFICIT)			25,668,792			17,150,048 (67% SAVINGS)

6.2. Social, institutional and regulatory bottom line assessment

Table 27. Framework for assessing social, institutional and regulatory bottom line criteria – modelling exercise

GOAL	CRITERIA	EVALUATION QUESTION / STATEMENT	SCORE			WEIGHT	REAL SCORE
			1	2	3		
Social feasibility	Disgust	Extent of ‘disgust’ to non-potable water use	Insignificant	Moderate ✓	Significant	x 2.84 =	5.68
	Acceptance**	Acceptance of the dual system by the community	Significant	Moderate ✓	Insignificant	x 2.84 =	5.68
	Aesthetics	Unpleasant sight, noise and/or odour emissions from the system	Insignificant ✓	Moderate	Significant	x 2.84 =	2.84
	Trust/confidence in service provider	Consumers’ level of trust and confidence in the potable water service provider	High ✓	Moderate	Low	x 2.84 =	2.84
Institutional feasibility	Local capacity	Availability of Institutional capacity to operate the system	Significant ✓	Moderate	Insignificant	x 2.44 =	2.44
	Acceptance**	Acceptance of the dual system by decision makers	Significant	Moderate ✓	Insignificant	x 2.44 =	4.88
Regulative availability	Regulation	Municipal Regulations/by-laws available to guide system planning and operation	Significant ✓	Moderate	Insignificant	x 2.28 =	2.28
Weighted mean of Real Scores (ΣReal Score/ΣNumber of items) (Range: 2.7-7.9)							**3.8**

[**] A score of 1 for this variable may likely render the project infeasible

6.3. Environmental and public health and safety bottom line assessment

Table 28. Framework for assessing environmental and public health and safety criteria –modelling exercise

GOAL	CRITERIA	EVALUATION QUESTION / STATEMENT	SCORE			WEIGHT	REAL SCORE
			1	2	3		
Environmental feasibility	Erosion and scouring	Anticipated increase in erosion and scouring in the receiving water course?	Insignificant ✓	Acceptable	Significant	x 1.00 =	1.00
	Flow regimes	Anticipated unnatural alterations to the flow regime in the receiving water course ?	Insignificant ✓	Acceptable	Significant	x 1.00 =	1.00
	Water quality	Anticipated negative changes in water quality in the receiving water course?	Insignificant ✓	Acceptable	Significant	x 1.00 =	1.00
	Wetlands	Extent wetlands will be negatively affected and/or wetland value diminished?	Insignificant ✓	Acceptable	Significant	x 1.00 =	1.00
	Habitats	Extent to which habitats in the downstream water course will be disrupted?	Insignificant ✓	Acceptable	Significant	x 1.00 =	1.00
	Downstream availability	Anticipated decrease in downstream water availability for users due to upstream reuse?	Insignificant	Acceptable ✓	Unacceptable	x 1.00 =	2.00
	Energy efficiency	Application of the technology results in greenhouse gas emissions?	Insignificant	Acceptable ✓	Significant	x 1.00 =	2.00
Public health and safety	Monitoring and control	Monitoring and control systems in place to minimise public health hazards?	Significant ✓	Acceptable	Insignificant	x 1.00 =	1.00
	Risks	Health risks to O&M staff or consumers?	Low	Acceptable ✓	High	x 1.00 =	2.00
	Liability	Insurance cover in case of system failure?	Significant	Acceptable	Insignificant ✓	x 1.00 =	3.00
Public education	Education / Awareness	Current level of education/awareness about non-potable water use	High	Moderate ✓	Low	x 2.85 =	5.70
	Public education	System implementation enables public education opportunities to be maximised	Significant	Acceptable ✓	Insignificant	x 2.85 =	5.70
Weighted mean of Real Scores (ΣReal Score/ΣNumber of items) (Range: 1.3-3.9)							**2.2**

AGGREGATION OF THE WEIGHTED MEAN OF REAL SCORES FOR THE TRIPLE BOTTOM LINES (RANGE: 5.9-17.5)	**8.7**

LEGEND

ASSESSMENT RESULT BASED ON THE AGGREGATED WEIGHTED MEAN OF REAL SCORES FOR THE TBLs

5.9	**-**	**8.6**	**:**	**Very high potential to be viable**	**11.4**	**-**	**14.2**	**:**	**Middle to low potential to be viable**
8.6	**-**	**11.4**	**:**	**High potential to be viable**	**14.2**	**-**	**17.5**	**:**	**Unlikely to be viable**

6.4. Summary of the outcomes from the modelling exercise

The Goldfields gold mine, Driefontein was used to model the assessment of the feasibility of implementing an industrial scale dual water reticulation system. Summaries from the exercise are presented below:

- Treated effluent from WWTW 2 is to be supplied to Ekuthuleni residence (for toilet flushing and irrigation), Concor Technicrete (for toilet flushing and concrete mixing) and Letsatsing village (for toilet flushing and irrigation);
- Four phases over a 20 year dual system design life from 2009 is planned. For the potential uses highlighted above, WWTW 2 is capable of supplying the expected 20 year demand. The ratio of treated effluent supply from WWTW 2 to potential uses over the 20 year design life varies from 3.6:1 to 1.8:1;
- Percentage increase in current supply from reusing the total volume of treated effluent currently generated (10.36 Ml/day) is 4.32%. This percentage is negligible and possibly as a result of the negligible quantity of treated effluent generated by the mine (10.36 Ml/day) in comparison to the total potable supply of 250 Ml/day. It is suspected that a portion of the potable supply is diverted for some other purpose(s) that are not accounted for in the water balance equation used in the calculation of the percentage increase in total current supply;
- Net Present Value of estimated capital, operation and maintenance costs over the dual system's design life was calculated. This is compared with the estimated costs to the mine for potable water supply over the same period. Overall, the modelled dual system achieves estimated cost savings of about R17,150,048 (67% of the cost of potable water supplied by Rand Water) over 20 years;
- The assessment of each triple bottom line produced the following results:

Table 29. Summary of modelling exercise assessment

Bottom line	Range	Weighted mean of Real scores
Technical and economic assessment	1.9-5.7	2.7
Social, institutional and regulatory assessment	2.7-7.9	3.8
Environmental and public health and safety assessment	1.3-3.9	2.2
Aggregated assessment (see the legend in the previous page)	**5.9-17.5**	**8.7**
RESULT		**Implementation of a dual water reticulation system at the Goldfields gold mine, Driefontein for the prescribed potential uses has a '<u>High potential to be viable</u>'**

7. SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

The main aim of this study was to assess the feasibility of implementing dual water reticulation systems in South Africa based on local and international experience. The objectives of this study were achieved through undertaking five tasks: a detailed literature survey, which attempted to garner local and international experiences on dual systems; collection and analysis of perceptions of both decision-makers and current consumers of some non-potable water resource; a detailed case study analysis of the CoCT dual system; the development of a framework for assessing the feasibility of implementing dual water reticulation systems in South Africa; the utilization of the framework to assess the feasibility of implementing a dual system within the Goldfields gold mine in Driefontein.

A summary of key findings from the study is presented below:

7.1. Key findings

- The extent of the aridity of an area is a major driver for non-potable water reuse and the implementation of dual systems in South Africa. In the literature and perception surveys, communities that had experienced water scarcity (e.g. Emalahleni, Garies and CoCT), were generally more willing to reuse non-potable water, even despite the potential risks to public health, than communities in areas of water abundance;
- Water reuse decreases the consumption of potable water. International literature indicates that reuse may save between 30-60% of potable water utilised for domestic non-potable water requirements (e.g. toilet flushing and garden irrigation). The water balance exercise undertaken in the CoCT (section C.4.2) shows that by recycling all treated effluent produced within the city, the total water supply will increase by about 118%. Currently, the CoCT reuses about 13% of the total treated effluent produced within the city;
- The longevity and sustainability of dual water reticulation systems in many parts of the world (e.g. the CoCT, Majuro, Tarawa, Windhoek and Hong Kong) prove that dual systems are feasible water supply options. As long as regulations and guidelines are adhered to, and fundamental precautions and practice (regarding materials, system implementation and operation) are made, a dual system is no more difficult to implement than a traditional potable water supply system. An aggregated score of 8.7 was calculated during the modelling exercise to assess the feasibility of implementing a dual system within the Goldfields gold mine in Driefontein. The score of 8.7 represents a '*high potential for the designed dual system to be viable*' and supports the statement that dual systems are feasible water supply options;
- Wide-area urban/agricultural, district and industrial dual systems are only feasible in areas where a sewer system already exists or is to be implemented. Individual dual systems which are also feasible where sewer systems exist, have also been implemented in low-income communities/households where sewers don't exist and dry sanitation is commonly practised (e.g. Carnavon). In these communities, dual systems are profitable in reducing pollution due to indiscriminate discarding of domestic wastewater in the environment and for garden irrigation and toilet flushing;

- Colour coding and clear identification/labelling of a dual system played a significant role in encouraging (from 50% to 63%) the acceptance of dual systems amongst surveyed respondents;
- It makes economic sense for sources of non-potable water to be in proximity to the potential uses. This naturally occurs for all dual system scales except the wide-area urban/agricultural dual system which is not inherently designed to be close to potential uses. Therefore, due to the high cost of long distance pipelines, some potential consumers of treated effluent have not been served by the existing dual systems within the CoCT. The study determined that the optimal economic distance between participating WWTWs and existing non-domestic consumers within the CoCT was about 500 metres;
- Tariffs for non-potable water conveyed via dual water reticulation systems are usually lower than potable water tariffs and this has encouraged non-potable water reuse. In the CoCT, treated effluent tariffs in 2007 ranged from 7% to 40% of the potable water tariff and this has encouraged several large users of non-potable water (e.g. the Chevron oil refinery) to reuse treated effluent. The percentage of willing respondents in the perception survey increased from 36% to 71% if tariffs for non-potable water were lower than for potable water. In the modelling exercise where a treated effluent system replaced the existing potable water supply system for toilet flushing, landscape irrigation, paving and masonry production, cost savings of about 67% (R17,150,048) were achieved over 20 years;
- The literature and perception surveys show that it is critical that community perceptions are well-known and understood prior to the detailed planning of domestic dual systems. Numerous water reuse projects have failed in the past (e.g. in California and Florida, United States of America) as a result of negative community perceptions or the failure of decision-makers to determine whether potential users or the public will accept such systems;
- The closer non-potable water is to human contact or ingestion, the more opposed people are to using the water. In the perception surveys, domestic respondents generally preferred reusing non-potable water for toilet flushing, landscape irrigation and car washing than more personal items such as laundry. In support of these perceptions, most non-potable water reuse in South Africa at the current time, is for domestic and non-domestic irrigation and industrial non-potable water processing;
- One prominent area of concern from the perception survey of domestic respondents was the safety of children when exposed to non-potable water used for irrigation;
- The perception survey showed that the trust respondents had in their local authorities determined their willingness to accept a dual system. High performing local authorities attracted higher levels of trust from respondents. This is because respondents associate a level of risk to using dual systems and therefore, will feel the risks are lower when the local authority operating the dual system has proven over time to be reliable;
- Inefficient institutional arrangements and relationships between different units managing or operating one or more aspects of the treated effluent system (especially in WWTWs) have proven to be detrimental to the optimal operation and sustainability of the dual systems in the CoCT;
- There are no current and detailed South African regulations or guidelines pertaining to non-potable water reuse and dual systems. The DNHPD (1978) guideline is an outdated guideline that needs to be revised in light of current local and international experience. Many of the dual systems that have been

implemented in the country have used these outdated guidelines and regulations or those used internationally;

- A significant number of the wide-area urban/agricultural and industrial dual systems that have been implemented in South Africa are driven by private sector and/or community initiatives, with irrigation, mining and industry being the main uses for the non-potable water (especially treated effluent). Since many of these initiatives are not primarily driven by local authorities, no formal operational or tariff agreements are in place.

Based on the findings from the study, some recommendations to facilitate the efficient implementation and sustainability of dual systems in South Africa are proffered below:

7.2. Recommendations emanating from the study

- In order to ensure the economic feasibility of dual systems, a careful life cycle cost-benefit analysis needs to be carried out within context of other water resource alternatives and a full appreciation of the true costs of water supply provision. There are potentially large savings in avoiding treating water to potable standards for non-potable domestic and non-domestic uses;
- To guarantee a high level of service for treated effluent reuse, a program of regular control and monitoring of influent from various sources (especially industries) should be developed by local authorities. In addition, many local authorities need to be equipped with qualified personnel that will undertake control and monitoring tasks and enforce regulations/by-laws. Dual systems must not be implemented where the qualified institutional capacity is deficient;
- There is urgent need for the Department of Water Affairs and Forestry to develop a national regulatory document that sets out government's policies regarding non-potable water reuse and dual systems. The DNHPD (1978) guideline document and the CoCT (CCT, 2006) by-laws may provide some input for this document. From the proposed regulatory and guideline documents, local authorities will do well to develop by-laws for their jurisdictions;
- In order to implement dual systems that are technically safe, it is vital that a guideline that proposes uniquely designed and standardised engineering materials (i.e. pipes, meter boxes, valves, taps, tanks, etc.) and specifications (e.g. sizes, thickness, colour, labelling) for non-potable pipe networks be developed for South Africa. Non-potable pipe networks with these features would be valuable in easily distinguishing non-potable pipe networks from potable networks, and preventing cross-connections;
- A pre-requisite for the sustainability of dual systems is efficient institutional arrangements and relationships between the relevant units (e.g. potable water services, wastewater services, sanitation services, bulk stores, billing services and maintenance services) housed within local authorities. This is especially critical in wide-area urban dual systems that utilise treated effluent. Efficient institutional arrangements and relationships will, in addition, assist in the development of integrated water resources and services plans that will ensure the optimal utilisation of an area's available water resources;

- If wide-area urban/agricultural dual systems are to be implemented, local authorities must first consistently produce high performance service. This will increase consumers' trust in their ability to implement dual systems and reduce any potential risks to public health and safety. It is fruitless for local authorities to consider implementing dual systems when service levels and public confidence in their services are low.

In conclusion, dual water reticulation systems are feasible water supply options for especially communities located in arid areas. Provided there is an enabling environment (i.e. regulations, guidelines, institutional capacity, non-potable water resources and qualities, tariffs, decision-maker and potential user perceptions and willingness, appropriate non-potable water uses, public health and safety, and trust in service providers), large users of non-potable water in arid areas will immensely benefit from the implementation of dual systems. This study shows that if all treated effluent produced within an area is recycled, total water supply to the area will increase by about 100%. Tariffs for supplying non-potable water are also shown to be considerably lower than potable water tariffs – the CoCT billed consumers of treated effluent between 7% and 40% of potable water tariffs in 2007. From the perception surveys, it was clear that non-potable water requirements requiring minimal human contact (e.g. toilet/urinal flushing and landscape irrigation) were preferable for domestic respondents. Hence, it would be wise for decision-makers to target these uses when domestic dual systems are to be implemented. Based on the findings from this study, a framework for assessing the feasibility of implementing a dual system was developed. The framework incorporates multiple aspects from the triple bottom lines of sustainability (i.e. technical/engineering, economics, social, institutional, regulations, environment and public health and safety).

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APPENDIX A: CASE STUDY OF THE CITY OF CAPE TOWN DUAL WATER RETICULATION SYSTEM

Of the several dual water reticulation systems highlighted in the previous section, a case study was carried out on the CoCT dual (treated effluent and potable) water reticulation system. In terms of scale, this dual system is a wide area urban reuse system.

The case study involved an investigation of the CoCT's dual system using the following considerations – technical, economical, social, regulatory, institutional, environmental, and public health. Literature surveys (including the following references – BVI/CCT, 2007; CCT WSDP, 2007; Cape Gateway, 2006; CCT, 2006; Mukheibir and Sparks, 2005; Marud, 2004; Murray et al., 1998; Murray and Tredoux, 1998 in Grobicki and Cohen, 1999) and social surveys (using structured interview and questionnaire instruments) were the primary data generation tools used in the case study. Findings from this study provide significant input to the dual water reticulation system planning tool developed in chapter 7.

Questionnaires were administered to three respondent categories (see Table A1) in order to generate system specific information and perceptions. Some of the information generated will be incorporated into the relevant sections below.

Table A1. Questionnaire administration and responses

CATEGORY	CATEGORY GROUPS	QUESTIONNAIRES ADMINISTERED	RESPONSES RECEIVED
Institutional consumers of treated effluent	**Irrigation:**		
	➢ Education (school fields) & professional sport fields	19	9
	➢ Landscape (Public use)	4	2
	➢ Agriculture	1*	1
	Industries:		
	➢ Petroleum	1	1
	➢ Pulp and paper	2	1
	➢ Textile	1	0
	➢ Construction	2	2
	Sub-total	**30**	**16**
Decision makers in the wastewater service sector	Service providers of non-potable water (wastewater treatment works and wastewater services managers)	16	1
Decision makers in the potable water service sector	Service providers of drinking water (water treatment works and water services managers)	8	2
	Total	**54**	**19**

** represents a group of about 30 farmers*

Twelve out of the sixteen institutional consumers surveyed are from the education, sport, agriculture and public sector (Table A1) and use the effluent for mainly irrigation purposes (Figure A1). Participation by several government owned schools and industries was limited as many of these potential respondents either felt the information was confidential or may be misinterpreted and used against them.

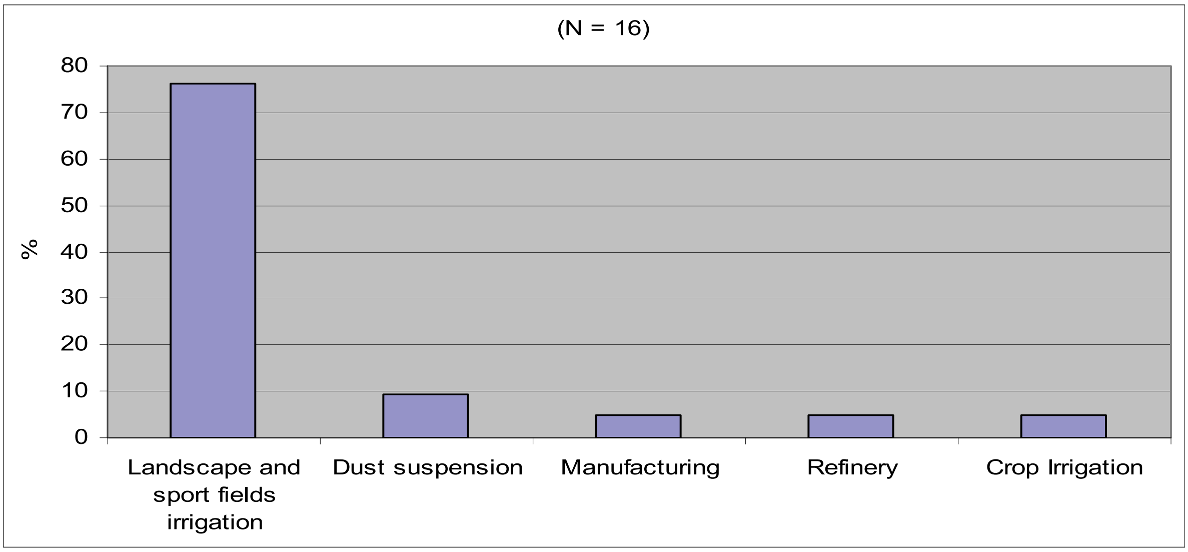


Figure A1. Water use patterns

A.1. Background

For several decades, the CoCT has provided treated effluent from some of its' wastewater treatment works to meet some non-potable water requirements within the CoCT. Wastewater is collected and treated by the participating wastewater treatment works, further filtered and disinfected, and then pumped through the reuse pipe networks to mostly large users of non-potable water.

Some of the reasons put forward for treated effluent reuse include the following (some of the respondents indicated that more than one reason motivated their use of non-potable water) (Figure A2):

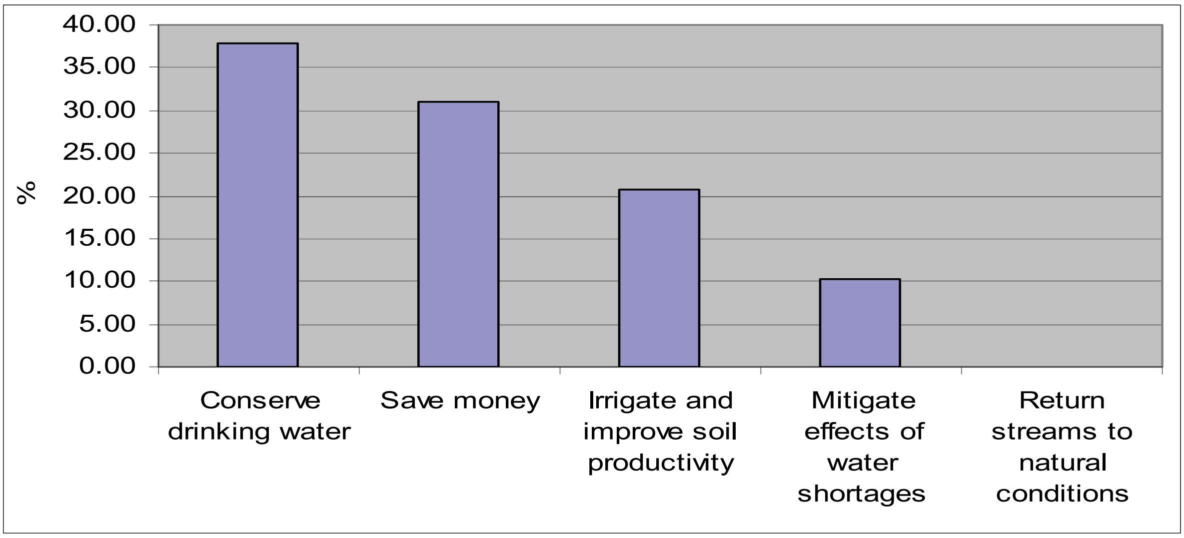


Figure A2. Reasons for treated effluent reuse

i. To conserve drinking water: 37% of all potable water used in the CoCT in 1998 was used by households. Of this, 21.3% was used to irrigate gardens and fill swimming pools. In 1990, high income households consumed 59% of domestic potable water, middle income households consumed 30%, and low income households 11%. 61% of all potable water was used to flush toilets and transport sewerage. This reason dominates the respondent responses received (38%);

ii. To encourage efficient water conservation and demand management strategies (i.e. resource optimization, fiscal efficiency, social equity, environmental conservation and protection, and reducing growth in water demand): This will postpone the costly investment for new water supply sources and/or new wastewater treatment plants. It is understandable that none of the respondents chose this reason as none are water service providers;

iii. To allow for irrigation even during times of water restrictions and improve soil productivity: Average summer irrigation demand is estimated at about 300 Ml/day. 20% of respondents chose this reason. Table A2 summarises the history of water restrictions in the CoCT;

Table A2. History of water restrictions in the City of Cape Town (Source: CCT WSDP, 2007)

YEAR	DETAIL
1872	Waterworks committee reports supply not meeting demand. Temporary suspensions on potable water supply experienced
1881	Daily suspensions of potable water supply experienced
1902	Summer restrictions imposed on potable water supply
1904 (-1921)	Restrictions imposed due to insufficient summer supply. Supply frequently interrupted for up to 15 hours per day
1949	Restrictions imposed on garden irrigation for 2 months preceding completion of the Steenbras 840 mm diameter pipeline
1956	Restrictions imposed preceding the construction of the Wemmershoek Dam
1971-1973	Water restrictions imposed preceding the completion of the Voëlvlei Dam and a severe drought
1993	Water restrictions imposed on garden irrigation for 2 months preceding the completion of the Faure Water Treatment Plant
2000	Water restrictions imposed for 10 months due to low winter rainfall
2004	Restrictions imposed due to low rainfall in the winters of 2003 and 2004

iv. To save money on the water bill: 31% of respondents chose this option. In Figure A3, respondents express their opinion about the price of potable and non potable water. 50% of the respondents indicated that the price of potable water is expensive, hence the attraction for non-potable water for non-potable water uses.

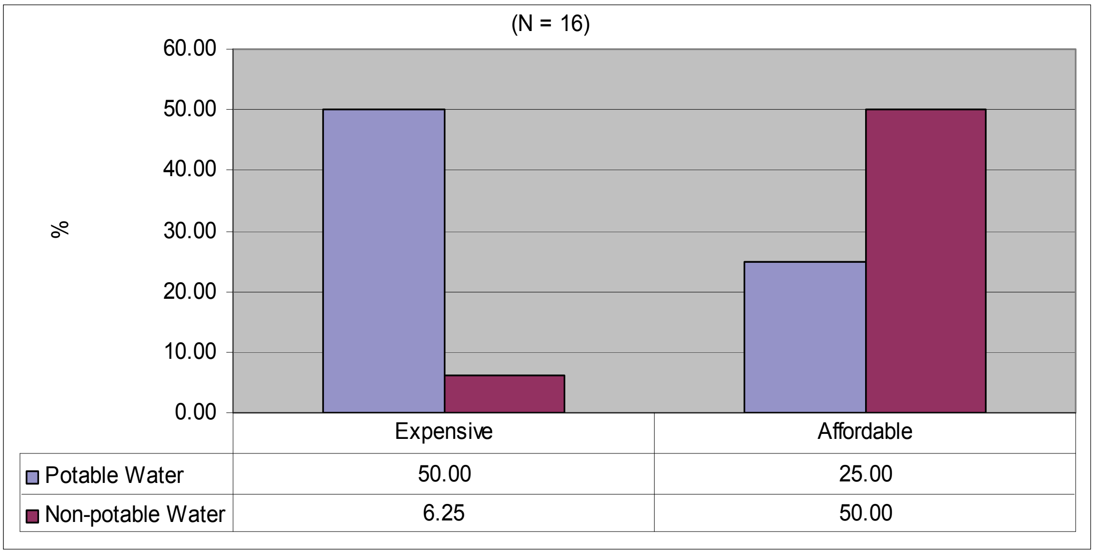


Figure A3. Evaluation of potable and non-potable water tariffs

v. To mitigate the effects of current and future water shortages that have plagued the area by providing a backup water source during drought: About 10% of respondents indicated this reason in Figure A2. As a result, the use of treated effluent increases during periods of water restriction and drought. Table A3 shows the yields of the various potable water sources to the CoCT and the large extractions for usage.

Table A3. Potable water source yields versus usage *(Source: CCT WSDP, 2007)*

SOURCE	YIELD PER ANNUM (Mm^3)	USAGE (Mm^3)	USAGE AS % OF YIELD
Theewaterskloof/ Kleinplaas Dam	219.00	120.00	55
Voëlvlei Dam	105.00	70.50	67
Palmiet River	22.50	22.50	100
Wemmershoek Dam	54.00	54.00	100
Steenbras Upper and Lower Dam	40.00	40.00	100
Lewis Gay Dam, Kleinplaas	1.85	1.85	100
Land en Zeezicht Dam	0.50	0.50	100
De Villiers Dam + Victoria Dam + Alexandra Dam	4.00	4.00	100
Boreholes	6.64	6.64	100
Overall	**453.49**	**319.99**	**71**

Although a coastal city with easy access to sea water, the major source of non-potable water for the institutional consumers is treated effluent (Table A4). One out of the 16 respondents uses a combination of treated effluent and raw surface water.

Table A4. Different non-potable water sources

	USING TREATED EFFLUENT	USING RAW WATER FROM RIVER	USING SEA WATER
No of respondents	16	1	0

vi. To return some streams to their natural flow conditions (i.e. seasonal flow) from their current flow conditions (i.e. non-seasonal) by reducing effluent discharges into surface water: No responses

A.2. Technical considerations

There are 22 wastewater treatment works in the CoCT. Only 10 of these produce treated effluent for mostly summer irrigation and industrial reuse. Although the CoCT currently generates an average daily effluent flow of about 643.57 Ml/d, only about 80.5 Ml/d of effluent is currently reused. This is mostly due to ageing/poor treatment infrastructure unable to treat effluent to required quality, lack of interest/knowledge by large non-potable users resulting in a lack of buy-in, and nominal control and measurement tools. For administrative purposes, each WWTW and current (and potential) users are delineated into a catchment area. With the current infrastructure and some upgrade, a total reuse potential of 155.30 Ml/d is estimated (see Table A5).

Table A5. Current, potential and total potential treated effluent reuse

WASTEWATER TREATMENT WORKS	AVERAGE EFFLUENT VOLUME TREATED (Ml/d)	PEAK DAILY SUMMER REUSE (Ml/d)	POTENTIAL REUSE (Ml/d)	CURRENT AND POTENTIAL REUSE (Ml/d)
Athlone	120.00	3.50	11.80	15.30
Bellville	56.00	7.30	12.20	19.50
Borcherds Quarry	30.00	2.00	No Reuse	2.00
Cape Flats	200.00	6.60	9.50	16.10
Dove	10.00	n/a	n/a	n/a
Gordonsbay	3.50	0.70	1.30	2. 00
Klipheuwel	0.03	No Reuse	n/a	n/a
Kraaifontein	18.80	8.60	0.40	9.00
Llandudno	0.50	No Reuse	n/a	n/a
Macassar	35.00	3.50	7.60	11.10
Melkbosstrand	3.10	2.20	n/a	2.20
Miller’s Point	0.03	No Reuse	No Reuse	No Reuse
Mitchells Plain	37.50	No Reuse	6.10	6.10
Oudekraal	0.03	No Reuse	n/a	n/a
Parow	1.50	1.50	0.40	1.90
Philadelphia	0.08	No Reuse	n/a	n/a
Potsdam	32.00	32.10	12.50	44.60
Scottsdene	7.50	6.20	2.10	8.30
Simon’s Town	5.00	No Reuse	n/a	n/a
Wesfleur (Atlantis)	14.00	4.80	1.60	6.40

WASTEWATER TREATMENT WORKS	AVERAGE EFFLUENT VOLUME TREATED (Ml/d)	PEAK DAILY SUMMER REUSE (Ml/d)	POTENTIAL REUSE (Ml/d)	CURRENT AND POTENTIAL REUSE (Ml/d)
Wildevoëlvlei	14.00	No Reuse	4.80	4.80
Zandvliet	55.00	1.50	4.50	6.00
Total	**643.57**	**80.50**	**74.80**	**155.30**

Treated effluent reuse in the CoCT is divided into four user categories:

i. Formal network distribution users: These represent the CoCT reticulation infrastructure supplying treated effluent (approximately 39.9 Ml/d) to users as a city service. Some irrigation users include Athlone stadium, schools, public open spaces, Old Mutual sports grounds, UWC & Pentech, Strandfontein sports grounds, Langa sports fields, Ajax football club, and Mandela Park sports grounds. Some industrial users include Caltex, Nampak Paper, Sappi, Alpha and Lafarge ready-mix, Athlone power station, and Spoornet Truck washing.

ii. Private supply scheme users: These are privately funded and operated infrastructure to specific users for their own uses (e.g. Century City and Steenberg Golf Estate from Cape Flats). These schemes have formal agreements with the CoCT and withdraw approximately 14.5 Ml/d.

iii. Informal downstream users: These users are unregulated and withdraw treated effluent (approximately 10.5 Ml/d) from downstream points. These include some golf courses from the Athlone treatment works and agricultural users from Kraaifontein and Scottsdene.

iv. Wastewater treatment works reuse: This comprises use (approximately 15.6 Ml/d) within the treatment works for cleaning of screens, irrigation and dewatering plants.

Although not categorised above, aquifer recharge occurs in Atlantis. The Atlantis potable water is supplied primarily from the aquifer, and extensive recharge occurs with treated domestic effluent. Two large infiltration basins, covering an area of approximately 500 000 m^2 exist some 500m up-gradient of the extraction point, recharging to the order of 200 Ml/a. Storm water runoff from the town is also used to recharge. In addition, treated industrial effluent (of greater salinity) is used to recharge an area close to the coast. This creates a mound of water which maintains a balance between the sea and the potable aquifer (Murray et al., 1998 and Murray and Tredoux, 1998 in Grobicki and Cohen, 1999)

Domestic use of treated effluent is not widely practiced in the CoCT and none of the sewage treatment works currently supply treated effluent to domestic users. One of the many treated effluent reuse schemes in the CoCT is described below:

A.2.1. The Potsdam treated effluent reuse scheme

Situated on Koeberg Road in Milnerton, opposite the Chevron oil refinery, Potsdam (Figures 4, 5, 6 and 7), in 2003, provided non-potable water to the Milnerton Golf Course, the Theo Marais sports fields, SAPPI Paper, public open spaces, the Table View beachfront dunes, and four schools in Milnerton and Table

View. The Milnerton primary school is one of these schools. Milnerton primary receives potable and non-potable water supply via a dual reticulation system. The non-potable supply is used to irrigate the school's sports fields.

Amongst many of the planned reuse scheme upgrades across the CoCT, an ultra-modern effluent treatment plant was launched in Potsdam in June 2006. The Potsdam wastewater treatment plant, built at a cost of R19 million, is expected to generate an additional 38 million litres of non-potable water per day for the Blaauwberg area.

The refurbishments at Potsdam include:

- two new pump stations capable of pumping up to 40 million litres per day;
- a highly sophisticated filtration plant to remove all suspended solids;
- a bulk supply pipe network of 4km;
- a 40 million litre storage reservoir (the size of a rugby field) built with environmentally friendly materials and techniques; and
- a new intake chamber with floating skimmer.

Potential new users of the facility include the Chevron oil refinery, Kynoch and local farmers. The scheme also provides the bulk infrastructure for future extensions to other industrial users and residential developments in the area. A new development on the farm De Grendel will also utilise the treated effluent and install a dual water reticulation network for domestic irrigation.

In addition to clause 66 of the CoCT (2006) water by-law (e.g. proper signage (Figure A9) on all reuse appurtenances), other new safety features were installed with the new Potsdam facility. These include orange colour coded treated effluent pipes (Figure A8), pipe markers (Figure A11) and meter chambers (Figure A10). It is hoped that any new or upgraded reuse systems within the CoCT will retain this colour coded convention. In this way, public health and safety is further safe guarded.

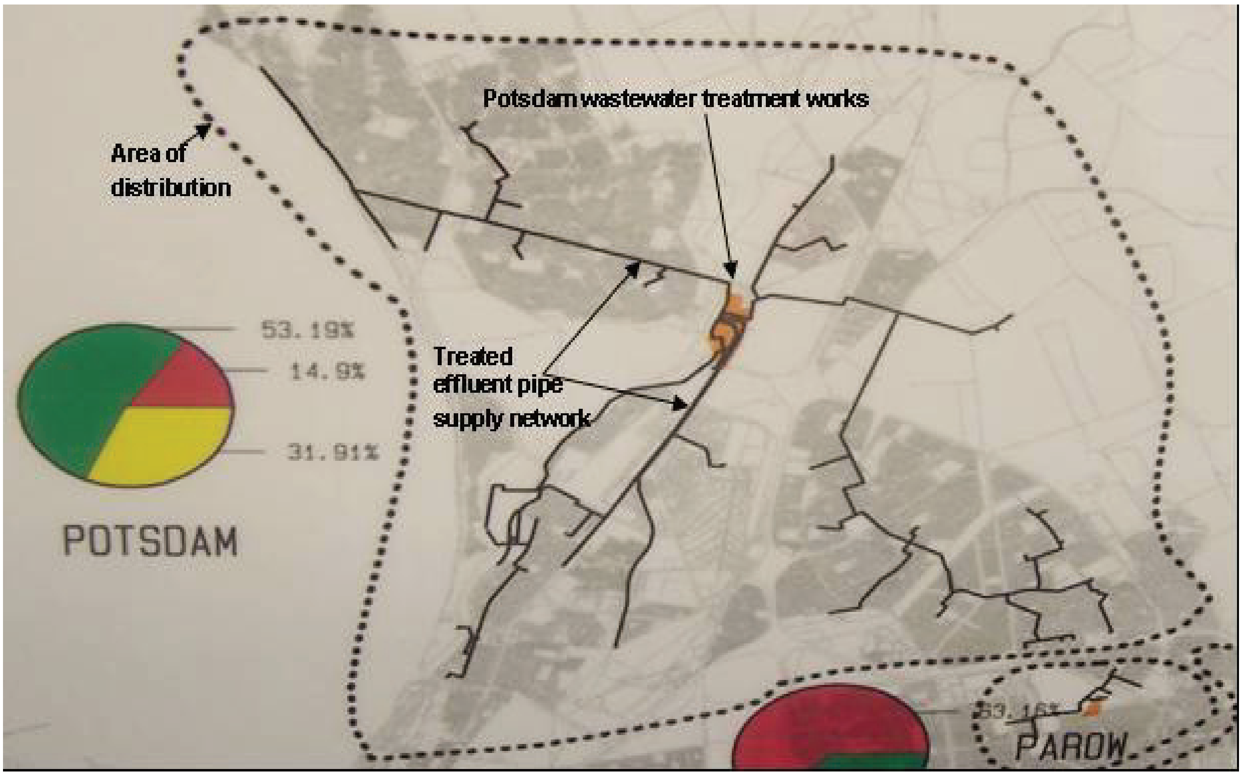


Figure A4. Schematic of the Potsdam wastewater treatment works and treated effluent pipe supply network

Figure A5. Aerial view of the Potsdam wastewater treatment works, new 40 Ml reservoir and treated effluent supply main

Figure A6. A modular filtration unit

Figure A7. New 40 Ml reservoir

Figure A8. Orange colour coded 600 mm GRP treated effluent supply mains through Koeberg road

Figure A9. Treated effluent signage

Figure A10. Orange colour coded treated effluent meter chamber

Figure A11. Orange colour coded pipe marker

A.2.2. Effluent quality

Sustaining the required treated effluent quality in the different wastewater treatment works remains a challenge for several reasons, including finance and influent quality. Due to the limited financial allocations to the different wastewater treatment works, essential maintenance and replacement, source quality monitoring, and treated effluent qualities have suffered. Many of the wastewater treatment works receive highly polluted industrial effluents which they are not designed for. As a result, treatment plant failures (in the order of about 10 per annum) occur often – the most common being blockages in the sludge pipes. To sustainably achieve the recommended effluent qualities (DWAF, 1996; EAF, 1984; DNHPD, 1978), substantial infrastructure and operating capital, and regular quality control and monitoring are required.

Table A6 shows the percentage compliance of four wastewater quality parameters in several of the wastewater treatment works against the EAF(1984) regulation. As can be seen in the table, many of the wastewater treatment works produce effluent qualities that violate some of the EAF (1984) regulations.

Table A6. Percentage compliance of four wastewater quality parameters (De Bruyn, 2007)

WWTW	TSS	COD	Ammonia	*E. coli*
WWTW 1	98	98	98	0***
WWTW 2	78**	82**	62***	2***
WWTW 3	100	98	86**	65***
WWTW 4	49***	47***	49***	83**
WWTW 5	100	98	96	93
WWTW 6	96	60***	38***	89**
WWTW 7	98	92	76**	89**
WWTW 8	96	98	96	42***
WWTW 9	100	90	72***	80**
WWTW 10	100	100	100	94
WWTW 11	69***	29***	76**	95
WWTW 12	98	96	92	48***
WWTW 13	79**	67***	85**	81**
WWTW 14	86**	72***	88**	66***
WWTW 15	86**	26***	20***	26***
WWTW 16	96	89**	96	91
WWTW 17	76**	4***	37***	62***
WWTW 18	100	98	100	100
WWTW 19	88**	45***	88**	60***
WWTW 20	94	94	100	96
WWTW 21	98*	100*	92*	98*

** 75-90% compliance; *** < 75% compliance

A.3. Economic considerations

A common misconception in planning for treated effluent reuse is that treated effluent always represents a low-cost water supply. This assumption is true only when treatment facilities are conveniently located near large agricultural or industrial users and when little additional processing is required. Economic considerations should therefore include transportation of the effluent to consumers, location of treatment operations in relation to effluent source, and the scale of the dual reticulation systems (Dimitriadis, 2005). In the CoCT, treated effluent is typically conveyed from the wastewater treatment works to the industrial and irrigation consumers who are located close by, and the effluent is treated for reuse in the wastewater treatment works thereby eliminating additional treatment costs. As can be seen in Figure A12, as distance from the treated effluent source increases, less and less consumers are willing to use the resource due to pipe network costs (Figure A12).

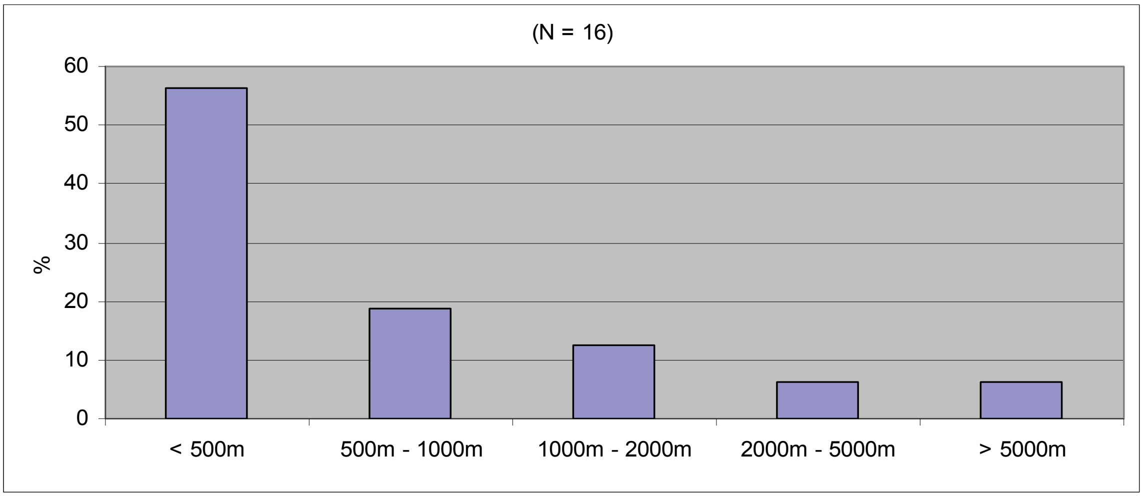


Figure A12. Distance of effluent from users

A.3.1. Unit costs for treated effluent production:

In Table A7, unit costs for producing treated effluent in several of the CoCT's wastewater treatment works is presented.

Table A7. Unit costs for treated effluent distribution

WASTEWATER TREATMENT WORK	CURRENT REUSE (Ml/d)	UNIT COSTS OF PRODUCING TREATED EFFLUENT* (R/kl)
Athlone	3.50	2.30
Bellville	7.30	1.72
Cape Flats	6.60	2.31
Gordon's Bay	0.70	2.58
Kraaifontein	8.60	1.66
Macassar	3.50	1.22
Mitchells Plain	0.00	2.08
Parow	1.50	1.21
Potsdam	32.00	2.00
Scottsdene	6.20	2.34
Wesfleur (Atlantis)	4.80	2.28
Wildevoëlvlei	0.00	2.04
Zandvliet	1.50	2.42
AVERAGE COST		**R2.00**

Cost redeemed at an average interest rate of 6% over 25 years

A.3.2. Tariffs for treated effluent supply

An all-inclusive treated effluent tariff policy that compels all users to pay for the service is yet to be formulated. In addition, cost recovery is not currently effectively coordinated. With the current tariff model, formal network distribution users pay for the service while informal and private users pay a nominal administrative fee. the CoCT's intent however, is to charge all users for the service, improve on cost recovery, and keep effluent tariffs as low as possible to increase use and make it a viable resource for specified uses, even if some users need to treat it further. Find in Table A8 tariffs for 2006/7. As can be observed, effluent tariffs are lower than potable water tariffs.

Table A8. Tariffs for treated effluent supply

TREATED EFFLUENT CATEGORY	TREATED EFFLUENT		POTABLE WATER
	DESCRIPTION	TARIFF (2006/7) (R/kl)	
Industrial/Commercial		2.35	5.83
Municipal, schools, sports fields		2.07	5.15
Government/Departmental		2.07	5.53
Public golf courses	These are courses with historical links to the CoCT Council and which provide a service to the public	0.37	5.15
Bulk users	These are users in excess of 5.0 Ml/d	0.53	Not applicable
Informal and private	Admin fee for metering, chlorination, etc.	0.05	Not applicable
Special Users		By agreement with the Director of Water Services	7.88

A.3.3. Funding considerations

Competition for budgetary allocations for treated effluent capital and recurrent expenditure from the CoCT are stiff. As a result, some alternatives have been proposed, i.e. receiving a normal budget allocation from the CoCT, establishing a ring fenced unit within the CoCT to utilise income (or a portion) from billing; and/or utilizing private capital by means of Public Private Partnerships. To understand the state and potential of treated effluent supply, a number of feasibility studies from 2003-4 were undertaken in several of the treatment works. Presented below is the feasibility costing for the upgrade of the Parow wastewater treatment works and reticulation system.

A.3.4. Feasibility costing for the upgrade of the Parow wastewater treatment works

(BVI/CCT, 2007; Mukheibir and Sparks, 2005)

a. Background:

Although designed for 1.2 Ml/day, The Parow WWTW currently treats an average of 2.2 Ml/day. Effluent conforms to DWAF requirements and approximately 1.5 Ml/day is currently pumped to user *Irrigation 1*.

b. Existing treated effluent infrastructure and demand:
The Parow WWTW discharges treated effluent into a storage/maturation pond. A pumping system (2 No. KSB ETA 65-200, 2900 rpm with 30 kW motor pumps) and Arkal filtration unit on *Irrigation 1*'s premises then extracts effluent from the storage pond (capacity is approximately 6.0 Ml) through a pipe network for Irrigation. Using effluent, an irrigation rate of between 20mm and 30 mm per week is estimated. An overflow links the storage pond with a larger storm water storage dam (approximately 40 Ml) within *Irrigation 1*'s property. The storage pond could, in times of low effluent flow be supplemented from the larger dam. The existing pumps and pipelines have no control or safety features built into them. *Irrigation 1* is currently the only consumer of the Parow WWTW treated effluent. Existing demand is shown in Table A9:

c. Future Infrastructure and demand
Other large potable water consumers were investigated and the upgrade of the Parow WWTW to produce treated effluent would incorporate some of their non-potable water demand. A feasibility study for these large users, estimates an economical distance from the WWTW based on a unit cost of approximately R2.50/kl. Although possible to provide effluent to residential dwellings situated near the existing and planned networks, this possibility was not included in the feasibility study for several reasons including inadequate control measures and inadequate effluent reuse polices. Upgrade is recommended to occur in 3 phases. Summer daily demand forms the basis for the analysis. No winter demand data exists. Table A9 depicts current and estimated potential demand.

Table A9. Current and estimated potential treated effluent demand at the Parow WWTW

End user connection	**EXISTING (INCLUDES PHASE 1)**				**EXISTING & PHASE 2**				**EXISTING, PHASE 2 & PHASE 3**			
	Peak design (kl/hr)		**Summer daily demand (kl/d)**	**Annual total (kl)**	**Peak design (kl/hr)**		**Daily Summer daily demand (kl/d)**	**Annual total (kl)**	**Peak design (kl/hr)**		**Summer daily demand (kl/d)**	**Annual total (kl)**
	day flow	**Night flow**			**day flow**	**Night flow**			**day flow**	**Night flow**		
SCHOOLS												
School 1									13		80	10320
School 2									13		80	10320
School 3					7		40	5160	7		40	5160
SPORTS PARKS												
Irrigation 1		167	1200	216000		167	1200	216000		167	1200	216000
Irrigation 2		30	183	23589		30	183	23589		30	183	23589
Irrigation 3	25		150	19350	25		150	19350	25		150	19350
Irrigation 4					30		180	23220	30		180	23220
Irrigation 5		1	5	645		1	5	645		1	5	645
TOTAL	**25**	**198**	**1538**	**259584**	**62**	**198**	**1758**	**287319**	**88**	**198**	**1918**	**308604**
Current WWTW summer			**1500**				**1500**				**1500**	

flow to effluent users										
Total as % of current WWTW summer flow	**103%**				**117%**				**128%**	

Table A9 indicates that if all the potential users agree to use treated effluent, the current quantity of the WWTW summer flow produced will be inadequate and will need to be increased over time. To achieve this, the upgrade (in 3 phases) of the Parow WWTW is recommended (Figure A13.).

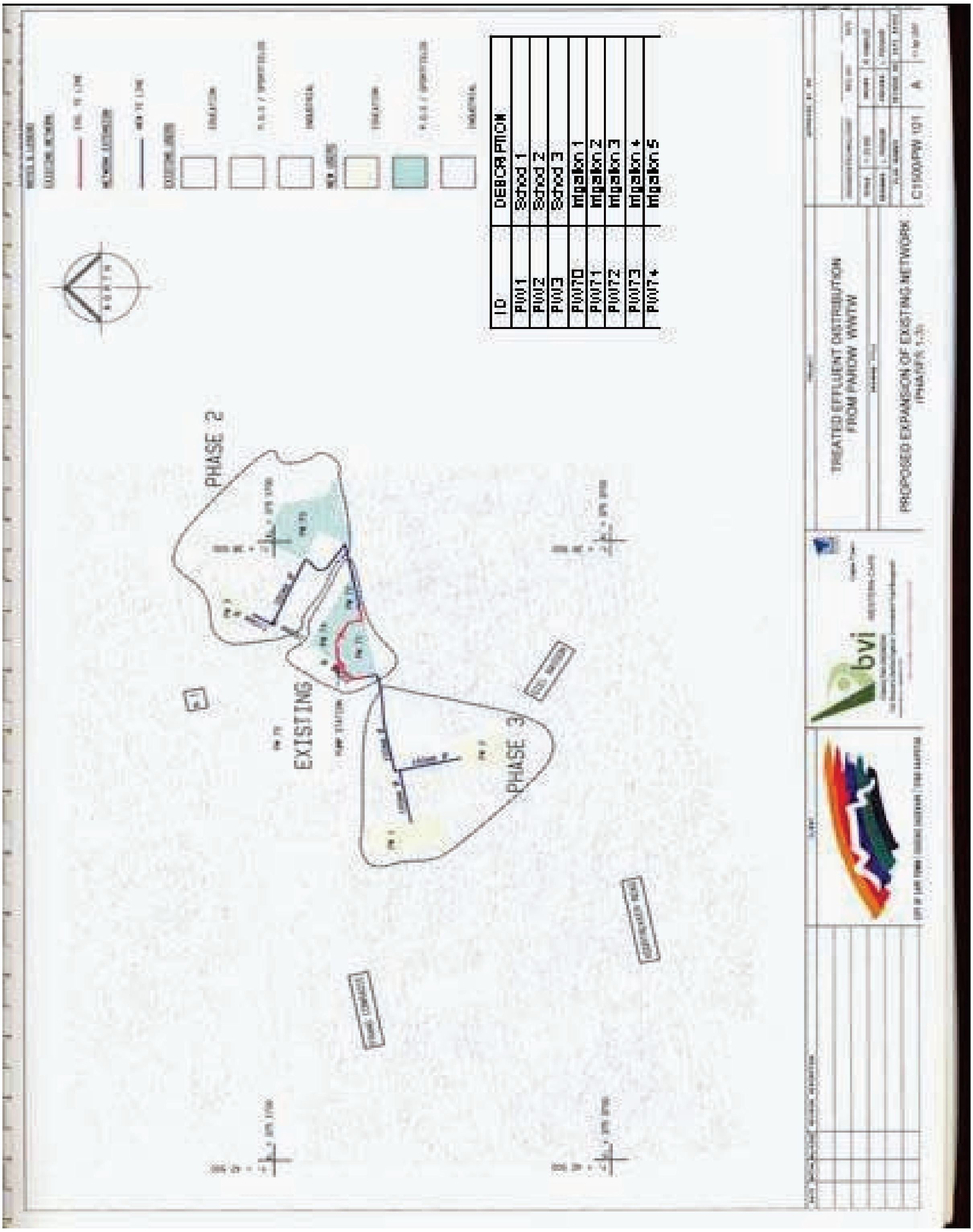


Figure A13. The Parow WWTW and phases of upgrade

Tables 10 and 11 present estimated capital, operation and maintenance costs for the upgrade of the Parow wastewater treatment works and treated effluent reticulation network over a 25 year design life from 2003.

d. Upgrade capital costs:

Table A10. The Parow WWTW upgrade capital costs

S/No.	ITEM		COST/UNIT (R)	TOTAL (R)
	Immediate capital costs			
1	Immediate maintenance (meter reinstallation and demand measurements) (2003)			5,000
2	Pump installation & building	50 KW	6,000 per KW	300,000
3	Modular filters			120,000
4	Pipe work	50 m of 160 mm dia	200 per m	10,000
Total (Excluding VAT)				**435,000**
	Phase 1			
1	Pump installation	18 KW	6,000 per KW	108,000
2	Modular filters	50 kl/hr		50,000
3	Pipe work	320 m of 160 mm dia	220 per m	70,400
		250 m of 200 mm dia	300 per m	75,000
4	Relay overflow pipe linking two storage dams			30,000
5	Pipe connection chambers	2 No.	12,000	24,000
6	Telemetry & PLC			40,000
7	Professional fees (including disbursements) = 14% of total			55,636
Total (Excluding VAT)				**453,036**
	Phase 2			
1	Pump installation	18 KW	3,000 per KW	54,000
2	Modular filters	80 kl/hr		80,000
3	Pipe work	720 m of 160 mm dia	270 per m	194,400
		160 m of 110 mm dia	230 per m	36,800
4	Pipe connection chambers	2 No.	12,000	24,000
5	Professional fees (including disbursements) 14% of total			54,488
Total (Excluding VAT)				**443,688**
	Phase 3			
1	Pipe work	1600 m of 160 mm dia	270 per m	432,000
2	Pipe connection chambers	2 No.	12,000	24,000
3	Professional fees (including disbursements) 14% of total			63,840
Total (Excluding VAT)				**519,840**
TOTAL PRESENT CAPITAL COSTS FOR THE IMMEDIATE AND PHASES 1, 2 & 3 (Exc VAT)				**1,851,564**

e. Operation & Maintenance costs:

Table A11. The Parow WWTW operation and maintenance costs

S/No.	ITEM		COST/UNIT (R)	TOTAL (R)
1	Electrical costs	307 959 kl	R0.08	24,637
2	Maintenance costs		1% on Civil cost	10,000
			4% on Mechanical cost	28,000
3	Other costs			20,000
TOTAL ANNUAL COST				**82,637**
TOTAL ANNUAL COST DISCOUNTED AT 6% OVER 25 YEARS				**1,056,378**

f. Net Present Value (NPV) / Internal Rate of Return:

The Net Present Value of capital, operation and maintenance costs for the upgraded wastewater treatment and reuse system over a design life of 25 years =

R1,851,564 (capital) + R1,056,097 (O & M) = R2,907,942.00

The annual annuity based on the NPV for 25 years at 6% will be R227,478.76

Annual consumption at end of Phase 3: 308, 604 kl (Table A9)

Scenario 1:

With a flat rate treated effluent tariff of R1.75/kl, annual revenue will equal R540,057 at a 17% Internal Rate of Return

Scenario 2:

With a flat rate treated effluent tariff of R3.49/kl, annual revenue will equal R1,074,777 at an above 30% Internal Rate of Return

The annual income of either scenario, if achieved, implies that the upgrade to the Parow WWTW in 2003 was financially viable with benefit (annual revenue from estimated tariffs) minus cost (capital, operation and maintenance) being positive.

A.4. Regulatory considerations

Treated effluent reuse in the CoCT is guided by the following documents: EAF (1984), DWAF (2004a), DNHPD (1978), DWAF (1996), CCT (2006), and CCT (2007). The first two represent national regulations pertaining to effluent quality and reuse, the third and fourth represent national guidelines, the fifth is the CoCT's Municipal potable water By-Law, and the sixth is the Standard Agreement signed by the CoCT and effluent users.

Three clauses in the CoCT's Municipal By-laws for potable water distribution relating to treated effluent reuse are shown in Box A.1.These clauses are currently inadequate and as such, an updated and separate By-Law for treated effluent reuse was recently submitted to the CoCT Council for approval.

Box A.1.

Province of Western Cape: Provincial Gazette 6378
1 September 2006
Water By-Law (CCT, 2006)
To control and regulate water services in the City

Clause 64 (Supply of non-potable water by the municipality):

(1) The Director: Water may on application in terms of section 19 grant a supply of non-potable water to a consumer and at such conditions as he or she may deem fit.

(2) Any supply of water granted in terms of subsection (1) may not be used for domestic or any other purposes which, in the opinion of the Director: Water, may give rise to a health hazard

Clause 65 (Disclaimer in respect of non-potable water quality)

(1) No warranty, expressed or implied, applies to the purity of any non-potable water supplied by the municipality or its suitability for the purpose for which the supply was granted

(2) The use of non-potable water is entirely at the risk of the consumer, and the municipality is not liable for any consequential damage or loss arising directly or indirectly there from.

Clause 66 (Warning notices)

(1) An owner of premises, on which non-potable water is used, must ensure that every terminal water fitting and every appliance which supplies or uses the water is clearly marked with a weatherproof notice indicating that such water is unsuitable for domestic purposes

(2) In an area where treated effluent is used, the consumer shall erect weatherproof notices in prominent positions warning that such water is not suitable for domestic purposes.

(3) Every notice prescribed in terms of subsections (1) and (2) must be in the three official languages used in the province.

The CoCT signs a Standard Memorandum of Agreement (CCT, 2007) with each treated effluent consumer. The Agreements inform users of the regulatory/guideline requirements for treated effluent reuse as spelt out in the five documents above, absolves the CoCT of any liability or claims arising from effluent reuse, and ensures the CoCT has the contact details of all users for several purposes including emergencies. Three standard Memoranda of Agreements were recently formulated for different users and all effluent users (both existing and new) are obliged to sign these agreements.

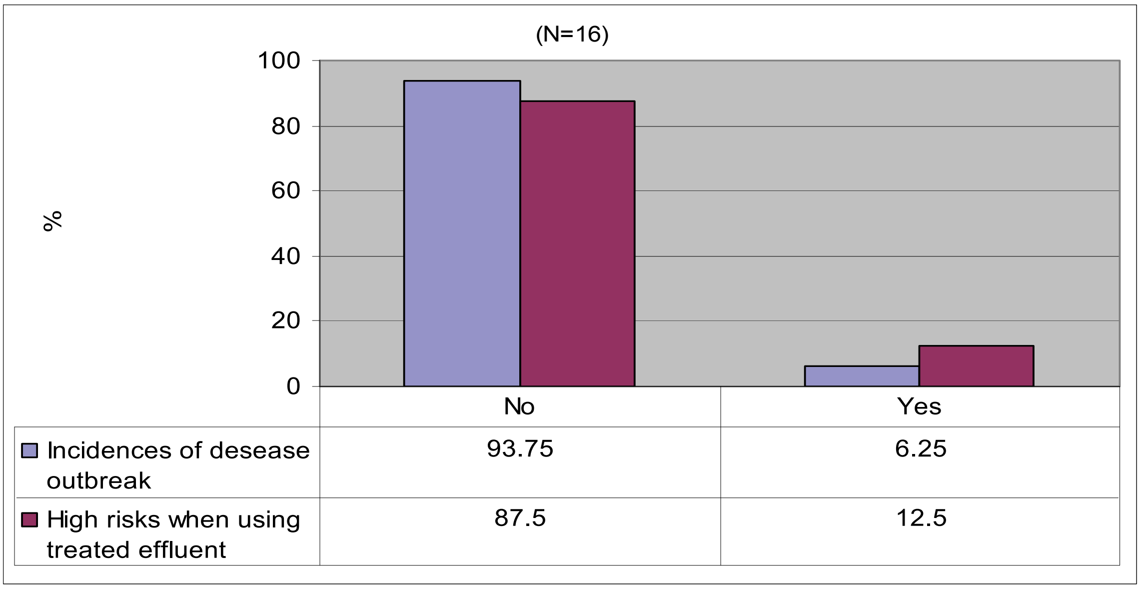
A.5. Public Health considerations

Generally, the level of public concern depends on the nature of treated effluent use. Treated effluent use for non-potable applications is usually associated with a low level of concern, while indirect potable use is of intermediate concern. There is generally greater concern when treated effluent is used for direct potable use (Dimitriadis, 2005). Water quality factors of particular concern include:

- Disease-causing organisms
- Total mineral content (e.g. total dissolved salts)
- Heavy metals
- Pharmaceuticals like antibiotics and pain killers (e.g. paracetamol)
- Radionuclides (e.g. chemotherapy by-products), and
- Concentrations of stable organic substances, pesticides, hormone-affecting and cancer-causing compounds excreted into the sewerage system.

For any dual water reticulation system to gain public confidence and acceptance, the risk of disease outbreak must be minimal. In Figure A14, 94% of the respondents indicated that there had not been any incident of disease outbreak since they began to use treated effluent. This can be attributed to the fact that the use of treated effluent is restricted to non-domestic, outdoor purposes with low human contact and that the necessary precautions stipulated in the regulations and By-Law are adhered to. However, 6% of respondents indicated that there have been cases of people who contracted typhoid when treated effluent was consumed by farm workers who had poor knowledge of the source.

In terms of risk, 88% of respondents indicate that the risks involved in using treated effluent are minimal. This perception is primarily based on the confidence consumers have in their service provider due to the excellent history of good service provided. This is a clear indication of general acceptance of treated effluent by the consumers for the intended purposes. There is however a high tendency for these perceptions to change when treated effluent is considered for indoor usage because of the high contact levels involved (Friedler *et al* 2006).



	No	Yes
🟪 Incidences of desease outbreak	93.75	6.25
🟥 High risks when using treated effluent	87.5	12.5

Figure A14. Risks to public health and safety from treated effluent reuse

The only reported incident in the CoCT which compromised public health due to the accidental consumption of treated effluent occurred in Milnerton in 2004 (see below).

A.5.1. Public health compromised in Milnerton, City of Cape Town

(Marud, 2004)

Milnerton Primary School receives potable water and treated effluent from the CoCT's Potsdam wastewater treatment works via a dual reticulation system. The effluent is used to irrigate the school's sports fields.

On the morning of the 28th of May 2004, a number of residents complained of diarrhoea and vomiting.

Health officials confirmed that *E coli* had been found in the water. Milnerton Primary School was blamed for an illegal connection that was believed to be the source of the contaminated potable water by treated effluent. Milnerton primary school however claimed it was being used as a scapegoat. The Cape Town Council claimed that Milnerton School appeared to have been having a pressure problem with the treated effluent not reaching all the sprinklers on the sports fields and may have connected up the municipal potable water pipeline to the treated effluent pipeline. Whenever there was a pressure problem, the school would open a valve and the stronger pressure from the CoCT 's line would boost the treated effluent supply pressure and allow the treated effluent to reach all the sprinklers. On May 22, the pressure dropped in the municipal potable water pipeline while city workers were conducting repairs in the area. The low pressure permitted some of the treated effluent in the supply pipeline to flow into the CoCT 's potable system because of the illegal connection.

To rectify the contamination, the illegal link was disconnected and the potable water mains flushed and disinfected. The CoCT health directorate was then mandated to tackle owners of facilities with dual reticulated systems to make sure the error was not repeated. Some lessons to proceed from this experience were:

- The need for online monitoring systems in place in the dual system to monitor water quality and to provide early warning signals to consumers on the dual system; and
- The need for better mitigating of such incidents if and when they happen.

A.6. Institutional considerations

Treated effluent infrastructure, management and operation are generally overseen by different sections in the CoCT Water Services Department. Viable working relationships between many of these sections are not currently well established. The result is that treated effluent treatment, distribution, source quality monitoring and metering are administered separately. The proposed By-Law and BVi/CCT (2007) report addresses this deficiency and recommends an integrated approach, i.e.:

- An over-arcing (effluent quality, financial, developmental, social, technical and environmental) policy for treated effluent implementation in the CoCT
- A dedicated management and control section for treated effluent must be established
- Proper communication between the maintenance teams from the reticulation and treated effluent management structures should be established
- All role players to provide total buy-in for all proposals by means of workshops and information sessions
- A single line of reporting problems, statistical data and suggested improvements to be established. It is recommended that a single database containing infrastructure assets, condition of the assets, and users (especially for cost recovery purposes) be developed.

A.7. Environmental considerations

Treated effluent reuse generally poses environmental risks. Possible effects and their relevance depend on each specific situation and how the treated effluent is used. Also, the impact on the environment is influenced by the treated effluent quality with industrial discharges generally containing more toxic substances which can create serious environmental problems.

Since industrial discharges in many areas are mixed with domestic discharges, the toxicity of sewage in the CoCT is generally high. This is problematic since many of the wastewater treatment works are not designed to treat such toxicities. As a result, effluent qualities, in many instances, do not conform to the required standards. However, since the treated effluent reuse in the CoCT is specific to industrial and irrigation uses, there is better control on the environmental impacts with many of the users implementing in-house treatment units to further treat the effluent received.

It is not currently known if any geological/soil investigations have been carried out in order to determine the long-term impact of treated effluent reuse in irrigation.

A.8. Perception considerations

A significant number of the early studies of public perception relating to water reuse were undertaken in the US. Most of these studies were limited in their scope which often aimed to increase public acceptance using applied behavioural methods (e.g. incentives). Indeed, this early approach to implementing water reuse projects often viewed public acceptance as the principal ‘obstacle’ to implementing recycling projects. This approach has been shown to be inadequate. Subsequently, the research following this view involved finding ways to persuade people to accept recycled water. It is now generally accepted that social marketing or persuasion is ineffective in influencing people to use water of less quality than drinking water. The approach, however, of involving community prior to the conception of the project has produced consistent results especially within developing communities. Part of this approach involves the early mining of perceptions relating to the project. Public perceptions and acceptance of water reuse are now recognised as the main ingredients of the success of any water reuse project (Po et al., 2003).

Perceptions generated in the CoCT are discussed in Chapter 5 along with those generated from other decision-makers and consumers.

APPENDIX B.I: QUESTIONNAIRE – DOMESTIC CONSUMERS OF WATER FROM UNCONVENTIONAL SOURCES

UNIVERSITY OF THE WITWATERSRAND

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Introduction

This questionnaire is targeted at consumers of water to assess the willingness or acceptance to use water from unconventional water sources. It is a part of a research project undertaken by 4th year civil engineering students at the University of the Witwatersrand. This questionnaire is anonymous. Your time and patience will be greatly appreciated.

Current water supply information (please tick)

1. Where do you get your water supply?

Well	
River	
Lake	
Rain	
Sea	

Mines	
Tap	
Other	

2. If you get water from the tap, do you know the source from where the water comes from?

River	
Lake	
Sea	

Underground aquifers	
Rain water collected	

3. Where is the tap that you get water from situated?

In the house	
Inside the yard	
On the street	

Other	

4. Do you ever run out of water (Yes/No) and how often does this occur?

At least once a week	
At least once a month	
At least once a year	

Never	

5. Do you know the reason(s) for the water running out?

Yes	

No	

6. If yes to question 5, please list the reasons below

7. Do you think the source of water supply will run out?

Yes	

No	

8. What type of toilet do you use?

Flush	
Chemical	

Pit latrine	

9. Where does your bath and sink water drain to?

A sewer system	
Into the street	
Garden	

Septic tank	

Current water quality (please tick)

1. In your opinion, what is the quality of the water that you use?

Good	
Poor	

Neutral	

2. What is the colour of the water?

Clear	
Brown	
Yellow	

Milky	
Other	

3. Please complete the table about the quality of the water.

(Please tick)	Yes	No
Does the water smell?		
Does the water contain solid particles?		
Are you satisfied with the taste of the water?		
Does the water dirty your bathtub, toilet and kitchen sink?		
Does the water change the colour of your teeth?		

4. Does the quality of water change (Yes/No) and how often does this happen?

At least once a week	
At least once a month	
At least once a year	
Never	

5. Do you ever get sick from drinking the water (Yes/No) and how often does this happen?

At least once a week	
At least once a month	
At least once a year	
Never	

6. Are there any particular diseases that are caused by the water? If Yes, pls list

Current water use habits (please tick)

1. What do you use water for and how often do you use it for these purposes?

Cleaning	everyday	more than twice a week	about once a month	rarely or never
Washing car				
Laundry				
Irrigating landscapes (Grass)				
Irrigating food crops				
Swimming pool				
Dust prevention				
Construction				
Cooking				
Bathing				
Cleaning				
Toilet flushing				

2. Do you know the current tariffs/costs for the supplied water?

Yes	
No	

3. If yes to question 2, kindly provide the current tariff/costs.

4. What do you think about the current water tariff/costs?

It is expensive	
It is acceptable	
It is cheap	
Don't know	

Current water deficiencies (Shortages) (please tick)

1. Do you know anything about water recycling/reclamation?

Yes	
No	

2. Which of the following words best describes your first reaction to water recycling/reclamation?

Yuck/ Sies	
Disgusting	
Unhealthy	
Dangerous	
Ok	
Environmentally friendly	

3. Do you think that recycled/reclaimed water is healthy for drinking and cooking purposes?

Yes	
No	

4. Do you think that recycled/reclaimed water is healthy to use for non-drinking purposes (i.e. toilet flushing and gardening)?

Yes		No	

5. Do you currently use wastewater (bath or kitchen or toilet water or other water) for any uses?

Yes		No	

6. If yes to question 5, please list the uses

The Emalahleni municipality is introducing a project whereby the wastewater from the mines will be purified and supplied to the community for all uses.

7. Do you know about the Emalahleni mine water reclamation project that will supplement your water supply from 2007, if yes how did you learn about it?

Radio		Public Meeting and announcements	
Newspapers and Magazines		A friend/colleague	
TV		Don't know	
Internet			

8. What do you think is the reason for the Emalahleni mine water reclamation project?

To improve the environment		All of the above	
To help the community		Don’t know	
To make a profit			

9. Do you know about the current quality of the mine wastewater?

Yes		No	

10. For which of the uses listed below will you be comfortable using recycled/reclaimed mine water?

Drinking		Gardening (grass, flowers)	
Cooking		Car washing	
Dish washing		Bathing	
Laundry		Swimming	
Gardening (vegetables)			

11. Do you think that using mine water is a danger to the public?

Yes		No	

12. If yes to the previous question, list the possible dangers that you think

13. If you were informed by the Municipality that the mine water is 100% safe, will you be comfortable drinking it?

Yes		No	

14. Are you confident that the Emalahleni local municipality will ensure that the recycled/reclaimed mine water is treated to a satisfactory standard?

Yes		No	

15. Would you use recycled/reclaimed mine water if-

The cost was less than the current water supply	
The cost was higher than current water supply	

16. If the recycled/reclaimed mine water is treated to a quality suitable for non drinking purposes only, would you use it for the following non drinking purposes?

Toilet flushing		Gardening (vegetables)	
Laundry		Car washing	
Gardening (Grass, flowers)			

17. If the recycled/reclaimed water had health risks associated with accidental drinking, would you use it for non drinking purposes?

Yes		No	

18. Would you welcome a two pipe systems in your house where one pipe supplies drinking water quality and the other pipe supplies non-drinkable water quality?

Yes	
No	

19. Would you consider it useful if the two piped water systems were colour-coded and properly labelled for identification (e.g. drinking water pipes are painted blue and non drinking water pipes are painted red)

Yes	
No	

Personal details (Optional – please tick)

Age (yrs)		Income level per month		Household size (people)	
less than 20		none		less than 2	
20-30		less than R2 000		Between 2 and 5.	
30-40		R2 000-R5 000		more than 5	
older than 40		R5 000-R10 000			
		more than R10 000			

APPENDIX B.II: QUESTIONNAIRE – INSTITUTIONAL CONSUMERS OF NON-DRINKING WATER

(ATTENTION: ___________________________)

We would like to request a few minutes of your time to assist this research undertaken by the University of the Witwatersrand and the Water Research Commission. The survey is investigating the feasibility of implementing dual water reticulation systems conveying drinking and non-drinking water qualities in domestic and non-domestic applications in South Africa. Your contribution in this research will immensely help. Your details are not required and your answers will be treated with confidentiality.

__DEFINITION__: *Non-drinking water refers to treated effluent, saline water, treated greywater, raw surface water, etc. suitable for non-drinking purposes, e.g. cooling, paper making, irrigation, etc.*

For each of the following questions, please tick (√) against the option that is most applicable to you.

Section A: Background Information

1. Which of the following sectors can we classify your institution?

   ☐ Domestic ☐ Agriculture ☐ Commerce/ Industry ☐ Sport ☐ Education ☐ Public

   ☐ Others (Specify _________________)

2. If your institution is in Agriculture, what do you use non-drinking water for?

   ☐ Landscape irrigation ☐ Vegetable, fruit and crop irrigation

   ☐ Food processing ☐ Aquaculture

   ☐ Stock watering ☐ Others (specify ____)

3. If your institution is in Commerce/ Industry sector, what do you use non-drinking water for?

   ☐ Power generation ☐ Manufacturing ☐ Non food processing

   ☐ Trade ☐ System cooling ☐ Petroleum

   ☐ Construction ☐ Mining ☐ Others (specify) _____________________________

4. If your institution is Sport, what do you use non-drinking water for?

   ☐ Irrigating golf fields ☐ Irrigating soccer fields ☐ Irrigating rugby fields

   ☐ Irrigating hockey fields ☐ Others (specify) ____

5. If your institution is Education, what do you use non-drinking water for?

   ☐ Irrigating football fields ☐ Irrigating playing grounds

   ☐ Landscape irrigation ☐ Others (specify) ____

6. If your institution is Public, what do you use non-drinking water for?

   ☐ Fire fighting ☐ Street washing ☐ Landscape irrigation (e.g. flowers, grass, trees)

   ☐ Public water features (e.g. water fountains) ☐ Flushing the sewer ☐ Others (specify) __________

Section B: General information and water use pattern

1. When did your institution start using non-drinking water? ___________________________
2. What is the source of your non-drinking water supply?
   ☐ Wastewater/ Sewage
   ☐ Stormwater/ Rainwater ☐ Mine wastewater ☐ Raw water from river, lake or stream
   ☐ Salinewater (☐ seawater ☐ groundwater ☐ brackish water)
   ☐ Greywater (☐ kitchen water ☐ bath/ shower water ☐ laundry water ☐ wash basin water)
3. How far is the non-drinking water source to your institution?
   ☐ <500m ☐ 500-1000m ☐ 1000-2000m ☐ 2000-5000m ☐ > 5000m
4. How often do you get non-drinking water?
   ☐ < Once a week ☐ About two days a week ☐ About three days a week
   ☐ About four days a week ☐ > Four days a week ☐ Always
5. What is the quantity of non-drinking water that your institution receives ______________
6. What is your institution's opinion on the current drinking water bill?
   ☐ Expensive ☐ Affordable ☐ Cheap ☐ Free ☐ Don't know
7. What is your institution's opinion on the current non-drinking water bill?
   ☐ Expensive ☐ Affordable ☐ Cheap ☐ Free ☐ Don't know
8. What are your institution's reasons for using non-drinking water instead of drinking water?
   ☐ To conserve drinking water
   ☐ To postpone the costly investment for a new water supply source
   ☐ To postpone the costly investment on a new wastewater treatment plant
   ☐ To provide a backup water source during drought
   ☐ To reduce effluent discharges into surface water
   ☐ To improve soil productivity as the non-drinking water serves as an additional source of fertilizer
   ☐ To save money on the water bill
   ☐ None of the above
9. Are there any particular diseases that have resulted from the use of your non-drinking water?
   ☐ Yes ☐ No
10. If your answer is Yes, please list them
    ___________________________________ ___________________________________
    ___________________________________ ___________________________________
11. Are there any incidents that have occurred due to non-drinking water use in your institution?
    ☐ Yes ☐ No
12. If your answer is Yes, please list them
    ___________________________________ ___________________________________
    ___________________________________ ___________________________________

From your experience, please rank in the tables below, in order of priority from **1** (most important) to **7** (least important) the critical issues you would consider:

When planning non-drinking water reuse	**Rank**
Economics	
Technical/Engineering	
Public health and safety	
Legislation	
Organisational capacity	
Social/Cultural acceptance	
Public education	

When planning a dual pipe water reticulation system for drinking use and non-drinking reuse	**Rank**
Economics	
Technical/Engineering	
Public health and safety	
Legislation	
Organisational capacity	
Social/Cultural acceptance	
Public education	

Section C: Institutional perceptions

Statement	**Strongly Opposed**	**Opposed**	**Neutral**	**Supportive**	**Strongly Supportive**
The use of non- drinking water has reduced the amount of wastewater discharged to the environment					
Non-drinking water use has reduced the depletion of groundwater and surface water resources					
The use of non-drinking water can save many South African communities from drought					
The quality of the non-drinking water used in this institution is satisfactory					
The non-drinking water this institution uses looks absolutely clear					
The non-drinking water this institution uses is disgusting					
The non-drinking water that this institution uses stains washing					
The non-drinking water this institution uses is odourless					
We trust the health information on non-drinking water provided by the water service provider					
This institution feels personally obligated to do whatever it can do to save water					
Water is a valuable resource that should be recycled					
Fruits and vegetables irrigated with non-drinking water should be labelled in the supermarket					
There is considerable savings of fertilizer on farms irrigated with treated effluent					
This institution would rather not use non-drinking water					
This institution would never use non drinking water even in times of shortages					
This institution would only be prepared to use non-drinking water in times of water shortages					
The government is partly responsible for water shortages					
Every household should be free to choose their source of water supply (e.g. treated effluent, etc.)					
This institution will use non-drinking water if other institutions are using it					
Many institutions affiliated with us support the use of non-drinking water					

APPENDIX B.III: QUESTIONNAIRE – DWAF OFFICIALS

(ATTENTION: ________________________)

We would like to request a few minutes of your time to assist this research undertaken by the University of the Witwatersrand and the Water Research Commission. The survey is investigating the feasibility of implementing dual water reticulation systems conveying drinking and non-drinking water qualities in domestic and non-domestic applications in South Africa. Your contribution in this research will immensely help. Your details are not required and your answers will be treated with confidentiality.

Section A: Organization Profile

1. Name of the organization: _____________________________ Location: ________________________
2. Please give the name of the department in your organisation specifically dealing with non-drinking water for reuse purposes? ____

Section B: Operational Information

DEFINITION: *Non-drinking water refers to treated effluent, salinewater, treated greywater, raw surface water, etc. suitable for non-drinking purposes, e.g. cooling, paper making, irrigation, toilet flushing, etc.*

3. In your department, is non-drinking water reuse a viable water supply option for Industrial/Commercial use?
   ☐ Power generation ☐ Manufacturing ☐ Non food processing
   ☐ Trade ☐ System cooling ☐ Petroleum
   ☐ Construction ☐ Mining ☐ Others (specify) ____________________________
4. In your department, is non-drinking water reuse a viable water supply option for Domestic use?
   ☐ Toilet flushing ☐ Crop/vegetable irrigation ☐ Landscape irrigation
   ☐ Others (specify) _______________________________________
5. In your department, is non-drinking water reuse a viable water supply option for Agricultural use?
   ☐ Landscape irrigation ☐ Vegetable, fruit and crop irrigation
   ☐ Food processing ☐ Aquaculture
   ☐ Stock watering ☐ Others (specify ______________________________________)
6. In your department, is non-drinking water reuse a viable water supply option for Public use?
   ☐ Fire fighting ☐ Street washing ☐ Landscape irrigation (e.g. flowers, grass, trees)
   ☐ Public water features (e.g. water fountains) ☐ Flushing the sewer ☐ Others (specify) ______
7. In your department, is non-drinking water reuse a viable water supply option for Educational use?
   ☐ Irrigating football fields ☐ Irrigating playing grounds
   ☐ Landscape irrigation ☐ Others (specify) ____
8. In your department, is non-drinking water reuse a viable water supply option for Professional Sport use?
   ☐ Irrigating golf fields ☐ Irrigating soccer fields ☐ Irrigating rugby fields
   ☐ Irrigating hockey fields ☐ Others (specify) ____

9. Does your organization give operating licences to Service Providers providing non-drinking water for reuse?

   ☐ Yes ☐ No

10. If your answer is Yes, please list (if any) the different types of non-drinking water for reuse operating licenses that can be applied for:

    a. ______________________ b. ______________________

    c. ______________________ d. ______________________

11. Please list (if any) the Service Providers of non-drinking water for reuse in your area of coverage:

    a. ______________________ b. ______________________

    c. ______________________ d. ______________________

12. Does your organization inspect and certify the facilities of Service Providers of non-drinking water for reuse before they begin their operations? ☐ Yes ☐ No

13. If your answer is No, is there an explanation?

    ____

14. Are there field officers that regularly monitor non-drinking water quality produced for reuse?

    ☐ Yes ☐ No

15. If your answer is Yes, on average, how often are monitoring exercises carried out?

    ☐ Daily ☐ Weekly ☐ Monthly ☐ Quarterly ☐ Bi-annually ☐ Annually

16. If your answer to number 15 is Yes, Do you suppose you have an adequate number of field officers and relevant equipment to carry out non-drinking water quality monitoring exercises? ☐ Yes ☐ No

17. Are there penalties enforceable by law for Service Providers who consistently violate minimum standards for non-drinking water quality for reuse? ☐ Yes ☐ No

18. If Yes, kindly indicate the types of penalties that may be imposed

    ☐ Fines ☐ Service suspension ☐ Service closure ☐ Imprisonment ☐ Others (specify_____

19. On average, what are the typical penalties awarded defaulters?

    ☐ Fines ☐ Service suspension ☐ Service closure ☐ Imprisonment ☐ Others (specify ____)

20. Does your organisation provide/recommend any codes/documents for the installation/maintenance of non-drinking plumbing systems (i.e. dual reticulation systems)? ☐ Yes ☐ No

21. Have you encountered (or heard) of any negative incidents that have occurred from non-drinking water reuse in South Africa. Briefly list (if any).

Date (dd/mm/yyyy)	**Incident**	**Solution**

22. From your experience, please rank in the tables below, in order of priority from **1** (most important) to **7** (least important) the critical issues you would consider:

When planning non-drinking water reuse	**Rank**
Economics	
Technical/Engineering	
Public health and safety	
Legislation	
Organisational capacity	
Social/Cultural acceptance	
Public education	

When planning a dual pipe water reticulation system for drinking use and non-drinking reuse	**Rank**
Economics	
Technical/Engineering	
Public health and safety	
Legislation	
Organisational capacity	
Social/Cultural acceptance	
Public education	

Section C: Consumer Communication and Complaints

23. How often does your organization communicate with non-drinking water reuse consumers?

☐ Not at all (*If Not at all, ignore questions 24-25)*

☐ Daily ☐ Weekly ☐ Monthly ☐ Quarterly ☐ Bi-annually ☐ Annually

24. If applicable, what is the main aim of your communication?

☐ General information ☐ Reporting on non-drinking water quality ☐ Other (Specify_________________)

25. If applicable, how does you organization communicate with these consumers?

☐ Post ☐ Radio ☐ TV ☐ News paper ☐ Internet ☐ Flyers/by hand ☐ Meetings/workshops

26. Does your organisation house any unit where complaints from non-drinking water reuse consumers can be attended to? ☐ Yes ☐ No

27. If Yes, what are the typical complaints received by this unit?

☐ Complaints relating to the physical characteristics (e.g. colour, smell, PH, etc.) of the water

☐ Complaints relating to the chemical characteristics (e.g. chemicals in larger than normal quantities) of the water

☐ Complaints relating to the biological characteristics (e.g. the presence of faecal coliforms) of the water

☐ All of the above

☐ Other

(specify____)

Section D: Organisational perceptions

Statement	Strongly Opposed	Opposed	Neutral	Supportive	Strongly Supportive
The use of non-drinking water has reduced the amount of wastewater discharged to the environment					
Non-drinking water use has reduced pollution to the environment					
Non-drinking water use has reduced the depletion of groundwater and surface water resources					
The use of non-drinking water can save many South African communities from drought					
This organisation is generally satisfied with the non-drinking water service provided by various Service providers					
Water is a valuable resource that should be recycled					
Fruits and vegetables irrigated with non-drinking water (e.g. treated effluent) should be labelled in the supermarket					
There is considerable savings of fertilizer on farms irrigated with treated effluent					
This organisation would rather not recommend non-drinking water reuse					
This organisation would never recommend non drinking water even in times of shortages					
This organisation would only be prepared to recommend non-drinking water reuse in times of water shortages					
Every household should be free to choose their source of water supply (e.g. groundwater, surface water, treated effluent, etc.)					
Consumers have the right to know that the fruits and vegetables they are buying are irrigated with treated effluent					
Many organisations affiliated with us support the use of non-drinking water					

Thank you for your time and information

APPENDIX B.IV: QUESTIONNAIRE – SERVICE PROVIDERS OF NON-DRINKING WATER

(ATTENTION: ________________)

We would like to request a few minutes of your time to assist this research undertaken by the University of the Witwatersrand and the Water Research Commission. The survey is investigating the feasibility of implementing dual water reticulation systems conveying drinking and non-drinking water qualities in domestic and non-domestic applications in South Africa. Your contribution in this research will immensely help. Your details are not required and your answers will be treated with confidentiality.

DEFINITION: *Non-drinking water refers to treated effluent, salinewater, treated greywater, raw surface water, etc. suitable for non-drinking purposes, e.g. cooling, paper making, irrigation, etc.*

For each of the following questions, please tick (√) against the option that is most applicable to you

Section A: Organisation Profile and Operational Information

1. What is the name of your organisation? ____
2. What is the source of your organisation's non-drinking water supply?
   - ☐ Salinewater (☐ seawater ☐ groundwater ☐ brackish water)
   - ☐ Wastewater/ Sewage
   - ☐ Greywater (☐ kitchen water ☐ bath/ shower water ☐ laundry water ☐ wash basin water)
   - ☐ Stormwater/ Rainwater
   - ☐ Mine wastewater
   - ☐ Raw water from river, lake or stream
3. About how much does it cost your organisation to treat your non-drinking water? R _____________
4. Who are the consumers of your non-drinking water?

☐ Domestic	Names of consumers:_____________________________________
☐ Commerce/ Industry	Names of consumers:_____________________________________
☐ Agriculture	Names of consumers:_____________________________________
☐ Education	Names of consumers:_____________________________________
☐ Sport	Names of consumers:_____________________________________
☐ Public (e.g. fire-fighting, street washing, etc.)	
☐ Others (specify _______)	Names of consumers:_____________________________________

5. What is the volume of non-drinking water produced daily? ____________________
6. Is this volume of water rationed among your consumers?

   ☐ Yes ☐ No
7. Please give an approximate number of domestic households using non-drinking water produced by your organisation? ______________

8. What are your organisation's reasons for providing non-drinking water to consumers?
   - ☐ To conserve drinking water
   - ☐ To postpone the costly investment for a new water supply source
   - ☐ To postpone the costly investment on a new wastewater treatment plant
   - ☐ To provide a backup water source during drought
   - ☐ To reduce effluent discharges into surface water
   - ☐ To improve soil productivity as the non-drinking water serves as an additional source of fertilizer
   - ☐ To save money on the water bill
   - ☐ None of the above
9. Are there incentives in place for your organisation to subsidise non-drinking water supply?

   ☐ Yes ☐ No
10. If your answer is Yes, who provides the subsidy and what form of subsidies are provided?

   ☐ Government (☐ Grant ☐ Loans ☐ incentives (e.g. tax exception, reduced interest) ☐ Others (specify ____))

   ☐ NGO's (☐ Grant ☐ Loans ☐ incentives (e.g. tax exception, reduced interest) ☐ Others (specify ____))

   ☐ Community (☐ Grant ☐ Loans ☐ incentives (e.g. tax exception, reduced interest) ☐ Others (specify ___))

   ☐ Intl Agency (☐ Grant ☐ Loans ☐ incentives (e.g. tax exception, reduced interest) ☐ Others (specify ____))

   ☐ Others (specify ____)
11. From your experience, please rank in the tables below, in order of priority from **1** (most important) to **7** (least important) the critical issues you would consider:

When <u>planning non-drinking water reuse</u>	**Rank**
Economics	
Technical/Engineering	
Public health and safety	
Legislation	
Organisational capacity	
Social/Cultural acceptance	
Public education	

When <u>planning a dual pipe water reticulation system</u> for drinking use and non-drinking reuse	**Rank**
Economics	
Technical/Engineering	
Public health and safety	
Legislation	
Organisational capacity	
Social/Cultural acceptance	
Public education	

Section B1: Economic and Technical

Statement	Strongly opposed	Opposed	I don't know	Supportive	Strongly supportive
Our system is cost effective and affordable for the users					
The energy consumption of our system is good (i.e. fuel for pumping, chemicals for treatment, etc.)					
There is a great savings of drinking water due to non-drinking water use					
There is possibility for combining several wastewater treatment works to produce treated effluent for supply					
Our system can be readily expanded to treat and supply higher flows and loads in the future					
The introduction of non-drinking water use created new jobs or economic opportunities					
Using non-drinking water has enhanced the economic growth of our consumers					
Our system's non-drinking water technology is readily available in South Africa					
Installation of the non-drinking water pipe system was easy					
Our non-drinking water system technology can meet the current effluent criteria					
Our non-drinking water system technology can meet future effluent criteria					
Advanced skill is required for normal operation of our non-drinking water system					
Our non-drinking water system has a design life of over 25 years					
The future demand for non-drinking water will keep on increasing					
The O&M staff are not exposed to any risks from the operation of the non-drinking water system					
There is insurance cover in place for both staff of the non-drinking water system and consumers in the event of system failure					

Section B2: Environmental, Public Health and Social

Statement	Strongly opposed	Opposed	I don't know	Supportive	Strongly supportive
Pumps will always be required to supply non-drinking water to consumers					
Currently, all the waste produced from the non-drinking water system is reused					
Non-drinking water use can save many South African communities from drought					
Non-drinking water use has reduced the depletion of groundwater and surface water resources					
There is a regulatory body that regularly monitors non-drinking water quality produced by this organisation					
Our organisation has received health related complaints from consumers of non-drinking water					
The use of non-drinking water has reduced the amount of wastewater discharged to the environment					
We are generally satisfied with the non-drinking water service we give to our consumers					
The non-drinking water that we use/produce looks absolutely clear					
The non-drinking water that we use/produce is disgusting					
The non-drinking water that we use/produce stains washing					
The non-drinking water that we use/produce is odourless					
We feel good when we do something positive to reduce environment pollution					
Water is a valuable resource that should be recycled					
Fruits & vegetables irrigated with non-drinking water (e.g. treated effluent) should be labelled in the shops					
There is considerable savings of fertilizer on farms irrigated with treated effluent					
Public education campaigns have been conducted by us to provide information about non-drinking water					
The non-drinking water system is generally accepted and embraced by the consumers					
The consumers were well mobilized for the non-drinking water project before it was implemented					
Use of non-drinking water does not violate any known cultural, historic or archaeological beliefs in our area					
Non-drinking water supply has tremendously improved the organisational capacity of the local community					
It is mandatory to use non-drinking water in this area					

University
of the Witwatersrand,
Johannesburg

School of Civil and Environmental Engineering

APPENDIX B.V. QUESTIONNAIRE – SERVICE PROVIDEROF OF DRINKING WATER

(ATTENTION ______________)

We would like to request a few minutes of your time to assist this research undertaken by the University of the Witwatersrand and the Water Research Commission. The survey is investigating the feasibility of implementing dual water reticulation systems conveying drinking and non-drinking water qualities in domestic and non-domestic applications in South Africa. Your contribution in this research will immensely help. Your details are not required and your answers will be treated with confidentiality.

DEFINITION: *Non-drinking water refers to treated effluent, salinewater, treated greywater, raw surface water, etc. suitable for non-drinking purposes, e.g. cooling, paper making, irrigation, toilet flushing, etc.*

1. In your organisation, is non-drinking water reuse a viable water supply option for industrial use? If Yes, please tick the appropriate boxes.
   [Paper production ☐ Power generation ☐ Mining ☐ Manufacturing ☐ Petroleum ☐]
   [Construction ☐ System cooling ☐ Other (specify____________________) ☐]
2. In your organisation, is non-drinking water reuse a viable water supply option for domestic use? If Yes, please tick the appropriate boxes.
   [Toilet flushing ☐ Crop/vegetable irrigation: ☐ Landscape irrigation ☐]
   [Other (specify____________________________) ☐]
3. In your organisation, is non-drinking water reuse a viable water supply option for agricultural use? If Yes, please tick the appropriate boxes.
   [Crop/vegetable irrigation ☐ Aquaculture ☐ Stock watering ☐ Irrigating sports fields ☐]
   [Other (specify_____________________________) ☐]
4. In your organisation, is non-drinking water reuse a viable water supply option for public use? If Yes, please tick the appropriate boxes.
   [Fire fighting ☐ Street washing ☐ Landscape irrigation ☐ Water features (e.g. water fountains) ☐] [Sewer flushing ☐ Other (specify________________________) ☐]
5. Does a department exist in your organisation that specifically deals with non-drinking water reuse?
   ☐ Yes ☐ No
6. If Yes, this department's approximate staff strength: Technical personnel: __ Non-technical personnel: __
7. Does your organisation (or this department) inspect non-drinking water reuse facilities in your supply area?
   ☐ Yes ☐ No
8. Does your organisation (or this department) monitor the quality of non-drinking water produced for reuse?
   ☐ Yes ☐ No
9. If Yes, how often are monitoring exercises carried out on average?
   ☐ Daily ☐ Weekly ☐ Monthly ☐ Quarterly ☐ Bi-annually ☐ Annually
10. If Yes to number 9, are there adequate technical staff and equipment to carry out these water quality monitoring exercises? ☐ Yes ☐ No
11. Does your organisation provide/recommend any codes/documents for the installation/maintenance of non-drinking plumbing systems? ☐ Yes ☐ No

12. Are there consumers that your organisation supplies or that use from their own sources, non-drinking water for different purposes? ☐ Yes ☐ No (*If No, ignore questions 13-15)*

13. How often does your organization communicate with these non-drinking water reuse consumers?

    ☐ Not at all ☐ Daily ☐ Weekly ☐ Monthly ☐ Quarterly ☐ Bi-annually ☐ Annually

14. What is the main aim of your communication?

    ☐ General information ☐ Reporting on non-drinking water quality ☐ Other (Specify__________)

15. What is the mode of communication with these consumers?

    ☐ Post ☐ Radio ☐ TV ☐ News paper ☐ Internet ☐ Flyers/by hand ☐ Meetings/workshops

16. Does your organisation attend to customer complaints regarding non-drinking water reuse?

    ☐ Yes ☐ No

17. If Yes, what are the typical complaints received by this unit?

☐ Complaints relating to the physical characteristics (e.g. colour, smell, PH, etc.) of the water
☐ Complaints relating to the chemical characteristics (e.g. chemicals in larger than normal quantities) of the water
☐ Complaints relating to the biological characteristics (e.g. the presence of faecal coliforms) of the water
☐ All of the above
☐ Other
(specify____)

18. Have you encountered (or heard) of any negative incidents that have occurred from non-drinking water reuse in South Africa. Briefly list (if any).

Date (dd/mm/yyyy)	**Incident**	**Control solution(s)**

19. From your experience, please rank in the tables below, in order of priority from **1** (most important) to **7** (least important) the critical issues you would consider:

When <u>planning non-drinking water reuse</u>	**Rank**
Economics	
Technical/Engineering	
Public health and safety	
Legislation	
Organisational capacity	
Social/Cultural acceptance	
Public education	

When <u>planning a dual pipe water reticulation system</u> for drinking use and non-drinking reuse	**Rank**
Economics	
Technical/Engineering	
Public health and safety	
Legislation	
Organisational capacity	
Social/Cultural acceptance	
Public education	

20. Perceptions

Statement	**Strongly Opposed**	**Opposed**	**Neutral**	**Supportive**	**Strongly Supportive**
The use of non-drinking water reduces the amount of wastewater discharged to the environment					
Non-drinking water reuse reduces pollution to the environment					
Non-drinking water reuse reduces the depletion of groundwater and surface water resources					
The use of non-drinking water can save many South African communities from drought					
I am generally satisfied with the non-drinking water service provided by various Service providers					
Water is a valuable resource that should be recycled					
Fruits and vegetables irrigated with non-drinking water (e.g. treated effluent) should be labelled in the supermarket					
There is considerable savings of fertilizer on farms irrigated with treated effluent					
I would rather not recommend non-drinking water reuse					
I would never recommend non drinking water even in times of shortages					
I would only be prepared to recommend non-drinking water reuse in times of water shortages					
Every household should be free to choose their source of water supply (e.g. groundwater, surface water, treated effluent, etc.)					
Consumers have the right to know that the fruits and vegetables they are buying are irrigated with treated effluent					
Many organisations that I am affiliated with support the use of non-drinking water					

Thank you for your time and information

APPENDIX C. AN ASSESSMENT FRAMEWORK FOR DUAL WATER RETICULATION SYSTEMS

A holistic evaluation exercise with sustainable results should ideally incorporate the Triple Bottom Lines (TBLs) of sustainability, i.e. technical and economic; social, institutional and regulatory; and environmental and public health and safety. The Department of Water Affairs and Forestry, DWAF (2004b) reinforces this assertion by setting a number of objectives against which strategies by water institutions or consumers (to influence the water demand and usage of water) should be measured vis-à-vis economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services, and political acceptability. Traditional methods of evaluation tend to focus on quantifiable factors (especially cost), leaving out equally important, yet mostly non-quantifiable factors that may have a significant influence on the project. Analysing quantifiable and non-quantifiable factors will help cast a wider net in identifying important issues during decision-making.

The objective of this chapter is to develop an assessment framework based on the different parameters that require consideration when planning the implementation of a dual water reticulation system. A framework refers to an essential planning support structure. The framework characterises the implemented dual systems highlighted in the previous chapters using similar criteria.

C.1. Sustainable Development

Sustainable Development discourse today presents an all-inclusive approach to infrastructure development than many predecessor approaches. A recent definition by Forum for the Future reads

"“A dynamic process which enables all people to realise their potential and to improve their quality of life in ways which simultaneously protect and enhance the earth’s life support systems”

Figure C1 contextualises the sustainable development definition within the water sector using the TBLs.

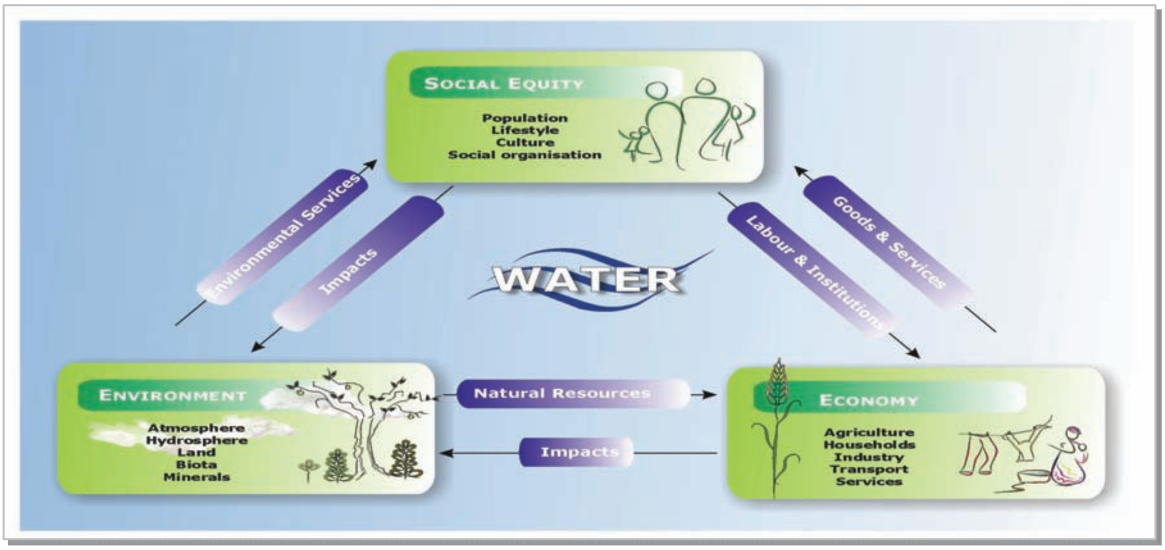


Figure C1. Sustainable development within the water cycle using the TBLs

(IUCN, 2005)

C.2. Assessment framework

Figure C2 encapsulates the framework proposed below for assessing the feasibility of implementing a dual water reticulation system

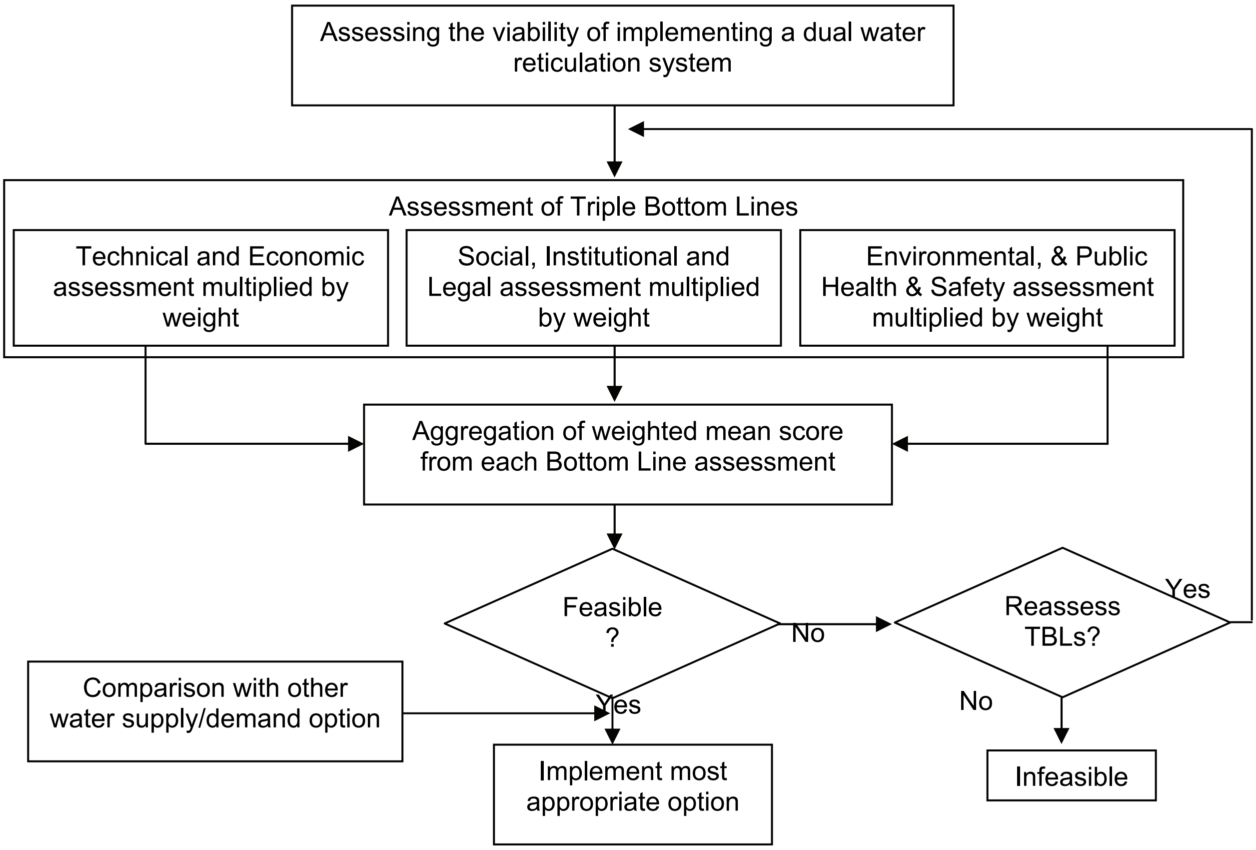


Figure C2. Framework for assessing the feasibility of implementing a dual water reticulation system

C.3. The Triple Bottom Line approach

The TBL approach provides a robust structure for evaluating alternatives. It is designed to provide decision-makers with a framework to understand the costs, benefits, impacts, etc. of alternatives across a spectrum of social, economic and environmental attributes. In this way, a more balanced view of alternatives is created rather than one that relies on only quantifiable factors. It also allows decision makers to vary or weigh criteria to discover those criteria that have the greatest influence on differentiating alternatives (CRD, 2007).

The TBL approach involves the following:

- *goals* to be achieved.
- *criteria* which determine whether the goals are achieved,
- evaluation *questions/statement* by which each criteria is measured, and
- A range of *scores* for measuring each criterion.

Any number of goals and criteria can be selected. In developing goals and criteria, a number of important rules must be followed, i.e. (i) independent; (ii) non-duplicative; (iii) measurable; and (iv) exhaustive or comprehensive. These rules facilitate an objective approach to achieving the goals for each system. Documenting, using these rules, why a particular system achieves certain goals better than another system is critical to the decision-making process.

C.4. The Technical and Economic Bottom Line

Table C1 presents a framework of goals, criteria, evaluation questions and scores for assessing technical and economic criteria. The framework was developed primarily from the surveys administered, case study results and other source material (i.e. CRD, 2007; Dimitriadis, 2005; Mukheibir and Sparks, 2005; and DWAF, 2006)

Table C1. Framework for assessing technical and economic bottom line criteria

GOAL	CRITERIA	EVALUATION QUESTION / STATEMENT	SCORE			WEIGHT	REAL SCORE
			1	2	3		
Technical feasibility	Increase in total supply	Percentage increase in total supply due to non-potable water use (*Sections C.4.1 and C.4.2*)	Significant (> 50%)	Moderate (20-50%)	Insignificant (<20%)	x 2.09 =	
	Potential supply to current demand	Ratio of potential non-potable supply to current demand for non-potable water supply	Significant (>2)	Moderate (1-2)	Insignificant (<1)	x 2.09 =	
	Distance	Average distance between potential supply and demand	Insignificant < 0.5 km	Moderate 0.5-1.0 km	Significant > 1.0 km	x 2.09 =	
	Non-potable water use/reuse	Potential for human contact with the non-potable water	Insignificant	Moderate	Significant	x 2.09 =	
	Treatment technology	Treatment technology readily available?	Locally available	Nationally available	Must be imported	x 2.09 =	
	Retro-fit system	Ease to retro-fit a dual system?	Significant	Moderate	Insignificant	x 2.09 =	
	Supply reliability	Reliability of non-potable water supply (51 weeks a year / 98% of the time)?	Significant	Moderate	Insignificant	x 2.09 =	
	Treatment quality reliability	Treatment technology meets effluent quality requirements under expected operating conditions?	Significant	Moderate	Insignificant	x 2.09 =	
	Operation & Maintenance	Level of skill required to operate and maintain the dual system	Low	Moderate	High	x 2.09 =	
	Utilise existing infrastructure	Potential to utilise existing infrastructure (e.g. WWTW)?	Significant	Moderate	Insignificant	x 2.09 =	
	Upgradeability	Extent dual system can be readily expanded to supply future flows?	Significant	Moderate	Insignificant	x 2.09 =	
Technical sustainability	Long-term applicability	Period of impact of the system? (short to long term)	Significant > 10 yrs	Moderate 3-10 yrs	Insignificant < 3 years	x 2.09 =	
	Flexibility	Technology can be adapted to meet more stringent effluent standards in the future?	Significant	Moderate	Insignificant	x 2.09 =	
	Future supply to current demand	Ratio of future non-potable supply to future demand for non-potable water supply	Significant (>2)	Moderate (1-2)	Insignificant (<1)	x 2.09 =	
Economical feasibility	Cost difference	Difference in the overall cost of supplying potable and non-potable water	Significant	Moderate	Insignificant	x 1.16 =	
	Savings	Extent of cost savings for non-potable use	Significant	Moderate	Insignificant	x 1.16 =	

GOAL	CRITERIA	EVALUATION QUESTION / STATEMENT	SCORE			WEIGHT	REAL SCORE
			1	2	3		
	Financial help	Financial assistance/incentives for non-potable use	Significant	Moderate	Insignificant	x 1.16 =	
	Job creation	Potential for job creation	Significant	Moderate	Insignificant	x 1.16 =	
Weighted mean of Real Scores (ΣReal Score/ΣNumber of items) (Range: 1.9-5.7)							

C.4.1. Increase in total supply due to recycling return flows

Grobicki and Cohen (1999) proposed an urban water demand model for water reuse potential in South Africa. A revised model (Figure C3) shows an urban water demand and supply system incorporating reuse.

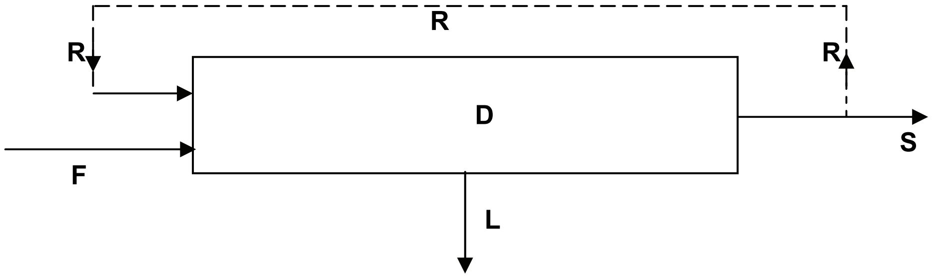


Figure C3. A schematic mass balance of an urban water system incorporating reuse

where F = Potable water supply
R = Recycled water supply
D = Non-potable and potable water demand
L = Losses (e.g. leakage and evaporation)
S = Effluent discharge

A water balance equation of the system above is:

F + R = D + L + S + R 1

Assuming total demand plus losses (D + L) = 50% of total supply (F + R) and all return flows are recycled, i.e. S = 0, equation 1 becomes

R = F 2

By substituting (2) into the left hand side of equation 1, equation 1 becomes

2F = D + L + S + R 3

This implies that if all return flows are recycled (and assuming D+L equals to 50% of total supply), total available supply into the system would become double the potable water supply (i.e. an increase of 100%). It is assumed that the recycled water is suitable for potable and non-potable water requirements.

C.4.2. The case for water reclamation: The City of Cape Town

In the City of Cape Town,

Current freshwater usage, F = 1180 Ml/day

Current return flow, S = 643.57 Ml/day (i.e. 54% of freshwater usage, F)

Hence, total demand plus losses (D + L) = 46% of total supply (F + R). Assuming all return flows are recycled, i.e. S = 0, equation 1 becomes

R = 1.18F 4

By substituting (4) into the left hand side of equation 1, equation 1 becomes

2.18F = D + L + S + R 5

This implies that if all return flows are recycled (and assuming D+L equals to 46% of total supply), total available supply into the system would be 2.18 times the potable water supply (i.e. an increase of 118%).

C.5. The Social, Institutional and Regulatory Bottom Line

Table C2 presents a framework of goals, criteria, evaluation questions and measurement scales for assessing social, institutional and regulatory criteria. The framework was developed primarily from the surveys administered, case study results and other source material (i.e. CRD, 2007; Dimitriadis, 2005; Mukheibir and Sparks, 2005; and DWAF, 2006)

Table C2. Framework for assessing social, institutional and regulatory bottom line criteria

GOAL	CRITERIA	EVALUATION QUESTION / STATEMENT	SCORE			WEIGHT	REAL SCORE
			1	2	3		
Social feasibility	Disgust	Extent of ‘disgust’ to non-potable water use	Insignificant	Moderate	Significant	x 2.84 =	
	Acceptance[**]	Acceptance of the dual system by the community	Significant	Moderate	Insignificant	x 2.84 =	
	Aesthetics	Unpleasant sight, noise and/or odour emissions from the system	Insignificant	Moderate	Significant	x 2.84 =	
	Trust/confidence in service provider	Consumers’ level of trust and confidence in the potable water service provider	High	Moderate	Low	x 2.84 =	
Institutional feasibility	Local capacity	Availability of Institutional capacity to operate the system	Significant	Moderate	Insignificant	x 2.44 =	
	Acceptance[**]	Acceptance of the dual system by decision makers	Significant	Moderate	Insignificant	x 2.44 =	
Legislative availability	Legislation / Regulation	Municipal Regulations/by-laws available to guide system planning and operation	Significant	Moderate	Insignificant	x 2.28 =	
Weighted mean of Real Scores (ΣReal Score/ΣNumber of items) (Range: 2.7-7.9)							

[**] *A score of 1 for this evaluation statement may likely render the project infeasible*

C.6. The Environmental, and Public Health and Safety Bottom Line

Table C3 presents a framework of goals, criteria, evaluation questions and measurement scales for assessing environmental and public health and safety criteria. The framework was developed primarily from the surveys administered, case study results and other source material (i.e. CRD, 2007; Dimitriadis, 2005; Mukheibir and Sparks, 2005; and DWAF, 2006)

Table C3. Framework for assessing environmental and public health and safety criteria

GOAL	CRITERIA	EVALUATION QUESTION / STATEMENT	SCORE			WEIGHT	REAL SCORE
			1	2	3		
Environmental feasibility	Erosion and scouring	Anticipated increase in erosion and scouring in the receiving water course?	Insignificant	Acceptable	Significant	x 1.00 =	
	Flow regimes	Anticipated unnatural alterations to the flow regime in the receiving water course?	Insignificant	Acceptable	Significant	x 1.00 =	
	Water quality	Anticipated negative changes in water quality in the receiving water course?	Insignificant	Acceptable	Significant	x 1.00 =	
	Wetlands	Extent wetlands will be negatively affected and/or wetland value diminished?	Insignificant	Acceptable	Significant	x 1.00 =	
	Habitats	Extent to which habitats in the downstream water course will be disrupted?	Insignificant	Acceptable	Significant	x 1.00 =	
	Downstream availability	Anticipated decrease in downstream water availability for users due to upstream reuse?	Insignificant	Acceptable	Unacceptable	x 1.00 =	
	Energy efficiency	Application of the technology results in greenhouse gas emissions?	Insignificant	Acceptable	Significant	x 1.00 =	
Public health and safety	Monitoring and control	Monitoring and control systems in place to minimise public health hazards?	Significant	Acceptable	Insignificant	x 1.00 =	
	Risks	Health risks to O&M staff or consumers?	Low	Acceptable	High	x 1.00 =	
	Liability	Insurance cover in case of system failure?	Significant	Acceptable	Insignificant	x 1.00 =	
Public education	Education / Awareness	Current level of education/awareness about non-potable water use	High	Moderate	Low	x 2.85 =	
	Public education	System implementation enables public education opportunities to be maximised	Significant	Acceptable	Insignificant	x 2.85 =	
Weighted mean of Real Scores (ΣReal Score/ΣNumber of items) (Range: 1.3-3.9)							
AGGREGATION OF THE WEIGHTED MEAN OF REAL SCORES FOR THE TRIPLE BOTTOM LINES (RANGE: 5.9-17.5)							

ASSESSMENT RESULT BASED ON THE AGGREGATED WEIGHTED MEAN OF REAL SCORES FOR THE TBLs

5.9	**-**	**8.6**	**:**	**Very high potential to be viable**
8.6	**-**	**11.4**	**:**	**High potential to be viable**
11.4	**-**	**14.2**	**:**	**Middle to low potential to be viable**
14.2	**-**	**17.5**	**:**	**Unlikely to be viable**

APPENDIX D: PROJECTS AND PUBLICATIONS FROM THIS STUDY

Investigational Project

M. Mohapi and V. Molefe. A pre-feasibility study of using a dual water reticulation system conveying different water qualities in South Africa. University of the Witwatersrand, Johannesburg. 2006.

Journal articles

i. A.A. Ilemobade, J.R. Adewumi and J.E. van Zyl. Framework for assessing the viability of implementing dual water reticulation systems in South Africa. Water SA. In press.

ii. J. R. Adewumi, A.A. Ilemobade and J.E. van Zyl. Wastewater reuse in South Africa: overview, potential and challenges. Under review as at 26th January 2009.

Conferences articles

i. J. R. Adewumi, A.A. Ilemobade and J.E. van Zyl. (2008). Model matching treated effluent quality to non-potable water reuses in South Africa. Proceedings. 9th Waternet/WARFSA/GWP-SA Symposium in association with the International Commission on Water Resources Systems (ICWRS). Water and Sustainable Development for Improved Livelihoods. Johannesburg. Oct 29-31.

ii. J. R. Adewumi, A.A. Ilemobade and J.E. van Zyl. (2008). Planning model for wastewater reuse systems in South Africa. Proceedings. Water Distribution Systems Analysis conference (WDSA2008). Eds. JE van Zyl, AA Ilemobade and H Jacobs. Skukuza, Kruger National Park. Aug 18-20.

iii. A.A. Ilemobade, J. R. Adewumi and J.E. van Zyl. (2008). Non-potable water use/reuse in South Africa: review and strategic issues. Proceedings. Water Distribution Systems Analysis conference (WDSA2008). Eds. JE van Zyl, AA Ilemobade and H Jacobs. Skukuza, Kruger National Park. Aug 18-20.

iv. J. R. Adewumi, A.A. Ilemobade and J.E. van Zyl. (2008). Public perceptions towards the use of dual water reticulation systems in South Africa. Proceedings. Water Institute of Southern Africa Biennial Conference and Exhibition (WISA 2008). Sun City. May 18-21.

v. AA Ilemobade, JE van Zyl, and JR Adewumi (2007). A preliminary framework for assessing the viability of implementing dual water reticulation systems in South Africa. Water Management Challenges in Global Change. B Ulanicki, K Vairavamoorthy, D Butler, P L M Bounds, and FA Memon (editors). Taylor and Francis Group, London, ISBN 978-0-415-45415-5. Pp615-621. From Proceedings, Water Management Challenges in Global Change (CCWI2007_SUWM2007). De Montfort University, Leicester, UK. September 3-5 2007.

vi. M. Mohapi, V. Molefe, and A. Ilemobade. The feasibility of implementing different water quality use and dual reticulation systems in South Africa. Proceedings, 2nd Water Research Showcase (Poster presentation). University of Pretoria, Pretoria. 6 October 2006.

News articles

i. T. Carnie (2007). SA mulls new water recycling. The Mercury. 10 December.

ii. T. Carnie (2007). SA may turn to other water sources to flush loos. Cape Times. 10 December.