Implementation Plan for Direct and Indirect Water Re-use for Domestic Purposes – Sector Discussion Document

Report to the

WATER RESEARCH COMMISSION

by

AM van Niekerk and B Schneider

Golder Associates Africa

WRC Report No. KV 320/13

ISBN 978-1-4312-0484-7

November 2013

Obtainable from
Water Research Commission
Private Bag X03
Gezina, 0031

orders@wrc.org.za or download from www.wrc.org.za

The publication of this report emanates from a project entitled *Implementation Plan for Direct and Indirect Water Re-use for Domestic Purposes – Sector Discussion Document* (WRC Project No. K8/1029)

EXECUTIVE SUMMARY

The Department of Water Affairs (DWA) released the second version of the National Water Resource Strategy (NWRSII, 2013) in June 2013. The NWRSII defines water resources in a broad context. It recognises that the potential for development of additional conventional surface water resources is limited and that other reconciliation options need to be implemented such as water conservation and demand management, groundwater, desalination, rainwater harvesting and water reuse. The DWA also developed a National Strategy for Water Reuse, which provides a considered approach to the implementation of water reuse projects.

The National Strategy for Water Re-use has to date not been broadly communicated and consulted. The consultation process to date focussed on the core NWRSII document and not specifically on the enabling strategies which include the Desalination Strategy and the Water Re-use Strategy.

The WRC commissioned this Short Term Research Project, focused specifically on the direct and indirect reuse of water for domestic/potable purposes as a proactive step to generate a sector discussion document for the progressive implementation of the Water Re-use Strategy.

The aim of this short term project is to develop a plan to bridge the gap between the strategy and implementation of water re-use for domestic/potable water use in consultation with the Department of Water Affairs and the WRC.

The document was informed by a study of international best practices as well as a locally held workshop on water re-use.

The key strategic interventions recommended in the National Strategy for Water Reuse were unpacked and recommended actions developed based on the outcomes of the workshop. These actions can be summarised as follows:

1. Creating an enabling regulatory / legislative environment taking into account:
    - Lead agency / promoter for Water Re-use;
    - Interdepartmental agreement / understanding;
    - Licencing protocols / approaches;
    - Integration of other water themes / thrust (Water Use Efficiency / Waste Discharge Charges);
    - Enforcement / encouragement; and
    - Standards for Domestic / Potable Re-use of Water.
2. Empowering implementation and the implementing agencies through:
    - Development of guidelines:
        - For the planning, development and implementation of water reuse schemes;
        - To develop water re-use at catchment level as an unconventional water resource; and
        - To develop water re-use on City / Community / Municipal level.
    - Establishing or building competent implementation agencies though effective:
        - Capacity building programmes;
        - Institutional arrangements; and
        - Human resource development.
    - Skills development for Water – Re-use Practitioners considering:
        - Skills requirements / skills capacity assessment;
        - Training needs;
        - Water sector ability to expand; and
        - Training and educational institutions.
    - Building a sound business case for water re-use considering the:
        - Regulatory framework;
        - Funding;
        - Pricing policy; and
        - Tariffs.

3. Informing stakeholders, partners and participants including public awareness and education programmes; and

4. Developing appropriate technologies and undertaking baseline studies to determine the:

   - Status and extent of existing domestic / potable water re-use;
   - Level of public awareness / education;
   - Social, cultural, religious perspectives and values driving water re-use; and
   - Environmental / river aquatic life impacts of water re-use.

ACKNOWLEDGEMENTS

The authors would like to thank the following individuals for the assistance and the constructive discussions during the execution of the project:

- Chris Swartz (Chris Swartz Water Utilization Engineers);
- Danie van der Merwe (Ekurhuleni Metropolitan Municipality);
- Geert Grobler (DWA: Water Resource Planning Systems);
- Johan van Rooyen (DWA: National Water Resource Planning);
- Jones Mnisi (Johannesburg Water);
- Koot Snyman (City of Tshwane Metropolitan Municipality);
- Niel van Wyk (DWA: National Water Resource Planning);
- Paul Herbst (DWA: Water Use Efficiency); and
- Philip van der Walt (City of Tshwane Metropolitan Municipality).

TABLE OF CONTENTS

LIST OF FIGURES

1 INTRODUCTION

The National Development Plan (NPC, 2011) charts a new development path to stimulate growth, eliminate poverty and reduce inequality amongst South Africans by 2030. The plan contains a dedicated section on Water Resources and Services stating that "before 2030, all South Africans will have affordable access to sufficient safe water and hygienic sanitation to live healthy and dignified lives". This includes assuring water supply by investment in water infrastructure and reuse in particular. The Department of Water Affairs (DWA) recently released the second version of the National Water Resource Strategy (NWRSII, 2013). The NWRS2 adopts a holistic approach towards water management, its availability and its use. More importantly, it defines water resources in a much broader context. It recognises that the potential for the development of conventional surface water resources such as large storage dams are limited and that other water supply requirements reconciliation options need to be implemented such as water conservation and demand management, groundwater, desalination, rainwater harvesting and water reuse. The DWA developed a National Strategy for Water Reuse (Annexure A), which provides a considered approach to the implementation of water reuse projects.

1.1 National water re-use strategy

The NWRSII recognises water re-use as a key component of the basket of water resource development and use options.

The NWRSII (2013) defines water reuse as:

> "*Utilisation of treated or untreated wastewater for a process other than the one that generated it, i.e. it involves a change of user. For instance, the re-use of municipal wastewater for agricultural irrigation. Water re-use can be direct or indirect, intentional or unintentional, planned or unplanned, local, regional or national in terms of location, scale and significance. Water re-use may involve various kinds of treatment (or not) and the reclaimed water may be used for a variety of purposes*."

According to the NWRSII, re-use of water is becoming more acceptable and feasible because of increasing water shortages, improved purification technology and decreasing treatment costs. Improvements in membrane technologies and their affordability have made a significant contribution to the feasibility of water reuse in recent years. At present, it is estimated that up to 14% of water use in South Africa is reused, mostly through wastewater return flows to rivers from which it is abstracted further downstream for indirect re-use. Reuse of return flows could be significantly increased, particularly in coastal cities where treated wastewater ordinarily drains into the oceans.

Water re-use projects typically involve a range of activities that are subject to regulatory authorisation and control. The applicable laws and associates regulations include:

- National Water Act (Act 36 of 1998),
- Mineral and Petroleum Resources Development Act (Act 28 of 2002),
- National Environmental Management Act (Act 107 of 1998),
- National Environmental Management: Waste Act (Act 59 of 2008),
- Water Services Act (Act 108 of 1997),
- Coastal Management Act (Act 24 of 2008), and
- Municipal bylaws.

According to the NWRSII, the intention of the National Strategy for Water Re-use was developed to better inform decision-making surrounding this valuable resource through the development of guidelines for the implementation of water reuse projects. The guidelines will address the choice of wastewater treatment technology, water quality standards, project financing and tariff implications, project implementation, operations and maintenance.

The Department also iterates that particular attention must be given to public and stakeholder engagement, education and consultation. The Department plan to review water-related laws and regulations to assess the need for amendment to facilitate re-use and, in cooperation with the WRC, make water re-use technology development a key focus area for research. The Department also committed to explore the use of new technologies for reusing treated wastewater and treated mine water, and will encourage the development of centres of excellence in this regard at selected academic institutions (NWRSII, 2013).

DWA further plans to develop and implement a Water Re-use Communication Strategy to convey factual and reliable information on all aspects of water re-use to the public and shareholders (NWRSII, 2013).

The National Strategy for Water Re-use has to date not been broadly communicated and consulted. The consultation process to date focussed on the core NWRSII document and not specifically on the enabling strategies which include at this stage, the Desalination Strategy and the Water Re-use Strategy (Appendix A).

The direct re-use of treated wastewater for drinking purposes may pose a risk to public health and safety and must be managed carefully and must be subject to water quality management and control. Advanced treatment technologies, sufficient operating capacity and proper monitoring of all processes and quality of potable water produced is essential. Public perceptions and community acceptance of direct re-use of treated wastewater remain a challenge to direct re-use.

The WRC commissioned this Short Term Research Project, focused specifically on the direct and indirect reuse of treated wastewater as a proactive step to generate a sector discussion document for the progressive implementation of the water re-use strategy.

In order to move ahead incrementally in implementing direct and indirect water reuse for potable purposes, there needs to be a common understanding of the current knowledge gaps and the short, medium and long term interventions that are required to give momentum to the implementation of water re-use projects for domestic use. A well-structured plan is required for the sector as a whole as we have already experienced fast tracked re-use interventions in the absence of a clear regulatory framework, such as the Beaufort West Water Reclamation Plant (DWA, 2010). The plan will assist towards planned and progressive implementation of direct and indirect water re-use for domestic purposes written in the context of the other re-use initiatives taking place in the other sectors.

1.2 Drivers for water re-use

The drivers for the re-use of treated wastewater are mostly determined by water security which is threatened by limited available water resources, population growth, access to water and climatic conditions. In South Africa, the main driver is water security. South Africa has a limited supply of water with an uneven geographic distribution thereof, in regions which range from semi-desert to tropical. The rainfall is also highly variable, with frequent severe water shortages. Intensive industrial, mining and urban development aggravates this problem, creating a vital need for water reuse in the country. It is estimated that the population growth is 2.4% per year. This means that the water demand is likely to exceed available water resources in selected water management areas in the short to medium term. Water reuse and recycling is thus an undeniably necessary supplement to fresh water use.

2 PROJECT OBJECTIVE

The aim of this short term project is to develop a plan to bridge the gap between the strategy and implementation of water re-use for domestic use in consultation with the Department of Water Affairs and the WRC.

3 APPROACH

3.1 Review of international best practices

International practices related to water reuse were compared to the strategic intent detailed in the National Strategy for Water Re-use. China, India, Australia, Singapore, Israel, United States of America (USA) and Namibia were selected based on the following attributes:

- Developmental state – China and India were selected to represent developing countries with a gap between rich and poor and characterised by high economic growth forecasts;
- Leaders in water re-use and water use efficiency – Singapore, Israel and Namibia were selected based on the historic and published track records;
- Climatic similarities to South Africa – Australia, Israel, Namibia and the USA; and
- Advanced environmental and environmental policies and legislation – Australia and the USA.

The water re-use practices were assessed for the different countries to develop an understanding of:

- The drivers and incentives for re-use;
- What the reclaimed water is used for;
- What the international re-use trends are;
- The policy and legislative environments;
- Guidelines for decision making;
- Water quality standards for reuse;
- Public education and awareness programmes;
- Financing of reuse projects; and
- Research and development programmes.

The outcomes of the review of international best practices are documented in Appendix B.

3.2 Workshop

A consultation workshop was held involving:

- Officials responsible for implementing the re-use strategy in the Department of Water Affairs;
- WRC Research Managers who are involved in potable water, wastewater and mine water;
- Metropolitan water services representatives; and
- A representative of engineers involved in operating and monitoring of municipal water treatment plants.

The aim of this workshop was to review the international best practices document and to discuss a way forward in terms of water re-use for potable purposes in South Africa.

3.3 Final discussion document

The review of international best practices document, workshop outcomes, and the National Water Re-use Strategy were used to develop this sector discussion document. This document attempts to assist decision makers and key role-players in water re-use implementation to set water re-use in motion and to generate an enabling environment (political, regulatory, social, and economical) which encourages re-use.

4 WATER REUSE FOR DOMESTIC PURPOSES

4.1 A layman's description of domestic water reuse

Previously used water (wastewater and effluent) can be treated to a standard fit for domestic use (drinking purposes). Treated water can be supplied directly to households (direct re-use) or be discharged back to the (fresh) water resource where it is blended with other water and subsequently abstracted, treated and distributed for use (indirect re-use).

Planned direct water re-use

Direct water re-use is defined as the use of treated or untreated wastewater by directly transferring it from the site where it is produced to a different/separate facility for the next cycle or application use. In the case of direct water re-use for domestic purposes, the water is always treated and the quality is carefully monitored to ensure user safety. The direct re-use of treated domestic wastewater (sewage) is still not common in South Africa. A recent severe drought forced the Beaufort West Local Municipality to implement direct re-use of effluent from the wastewater treatment plant (WWTP) using an advanced treatment system (reverse osmosis) as an emergency measure (DWA, 2010).

Direct re-use of treated mine water for domestic purposes has increased over the last decade. Two examples are the:

- Emalahleni Water Reclamation Plant, owned and operated by Anglo American Thermal Coal which employs advanced treatment technology and disinfection to supply drinking water to the Emalahleni Local Municipality; and
- Optimum Water Reclamation Plant, owned and operated by Glencore Optimum Coal Holdings which employs advanced treatment technology and disinfection to supply drinking water to the Steve Tshwete Local Municipality.

Projects of this nature are subjected to a full environmental and social impact assessment (ESIA) including broad consultation with the affected communities and stakeholders. This process, supported by a rigorous regulatory approval, licensing and review of the technology used ensure that the public health and safety are guaranteed.

The implementation of these direct re-use of projects successfully overcame perceptions and risks related to public acceptance, trust in water services providers and sophisticated engineered treatment systems. In the case of the direct re-use of treated domestic wastewater, project implementers will need to overcome the “yuck” factor, perceived health risks, cultural and religious beliefs, trust in scientific knowledge and engineering systems, trust in water services authorities, social justice and fairness.

Unplanned/incidental re-use

In South Africa, raw water for domestic use is typically extracted from a water resource (dam, river or groundwater). Raw water is not fit for domestic use and needs to be treated at a Water Treatment Plant (WTP) before it is distributed to households for domestic use. The complexity of the treatment systems depends on the quality of the raw water. Households then use this treated water for cooking, cleaning, drinking and gardening. A portion of this water known as the grey water (water from baths, showers, hand basins and washing machines) and black water (sewage) reports to the sewer and eventually a central Wastewater Treatment Plant (WWTP) where it is treated before being discharged back into the water resource. There are strict water quality limits to which the treated wastewater must comply before release to the environment. This water is typically abstracted somewhere downstream from the discharge point and either treated for domestic use or used directly for irrigation, industrial use etc. This is called unplanned or *de facto* re-use.

Unfortunately, water resources in South Africa are being polluted due to indiscriminate releases of poorly treated wastewater/effluent and diffuse pollution. This obviously influences the downstream water uses as well as the treatment required to treat the water to a quality “fit-for-use”, whatever the use may be. The nature of such a system means that multiple downstream users are dependent on this water which may have been used by several upstream users, and thus become indirect water re-users. Unplanned or *de facto* re-use potentially holds a risk to water users because it is often not planned or monitored as a re-use system. This is explained in a hypothetical case study presented in Figure 1. It provides the typical scenario found in many of the South African catchments, and water management areas.

In this hypothetical case study the 1st water use is the abstraction of water from a river (water resource) for treatment in a water treatment plant (WTP) for domestic use in a community. The domestic wastewater is collected at the local WWTP and treated to a specified standard before releasing it back into the river. The conventional treatment technologies employed in South Africa (although sophisticated by global standards) do not remove all the pollutants or constituents of concern (CoC). The effluent may still contain small amounts of organic matter and pollutants, ammonia, nitrate, phosphate and in some cases parasites, viruses and bacteria. These CoCs (CoC 1 in Figure 1) blend and react with the river water. Downstream, water is abstracted again for agricultural and/or industrial use (direct re-use). In the case of agricultural use, diffuse runoff could add additional CoC (CoC 2 in Figure 1). The industry will use the water abstracted from the river with or without pre-treatment. The effluent from this industrial process is treated to meet the required licence conditions and discharged back into the river. This treated industrial effluent may contain low levels of additional CoC such as salts, metals and organic pollutants (CoC 3 in Figure 1). The catchment is also characterised by mining activities. The mining activity resulted in increased water recharge and generates acid mine drainage (AMD) which they neutralise and treat to the licenced discharge quality again adding small amounts of additional pollutants (CoC 4 in Figure 1). The mine could also be treating the water to potable water quality for direct domestic use. The domestic wastewater is collected at the local WWTP and treated to a licenced standard before releasing it back into the river, again adding small amounts of pollutants (CoC 5 in Figure 1). This process repeats itself downstream adding additional CoC (COC 6 in Figure 1) before ultimately reaching the marine environment. In this hypothetical case, there are 2 conventional domestic WTPs potentially treating completely different pollutants. The 1st upstream WTP will be treating the pollutants in the river as it enters this part of the catchment. On the other hand, the 2nd domestic WTP will need to successfully treat these pollutants as well as the CoC in the effluents released upstream of the abstraction point (CoC 1 + CoC 2 + CoC 3 + CoC 4 + CoC 5) which may require more sophisticated treatment technologies. The interaction of the different CoC should also be taken into consideration, in the progressive downstream re-use of water.

Many cities and towns may be situated downstream of mining, agricultural and industrial activities, and downstream of other towns and cities. Indirect water re-use for potable purposes is therefore prevalent in South Africa.

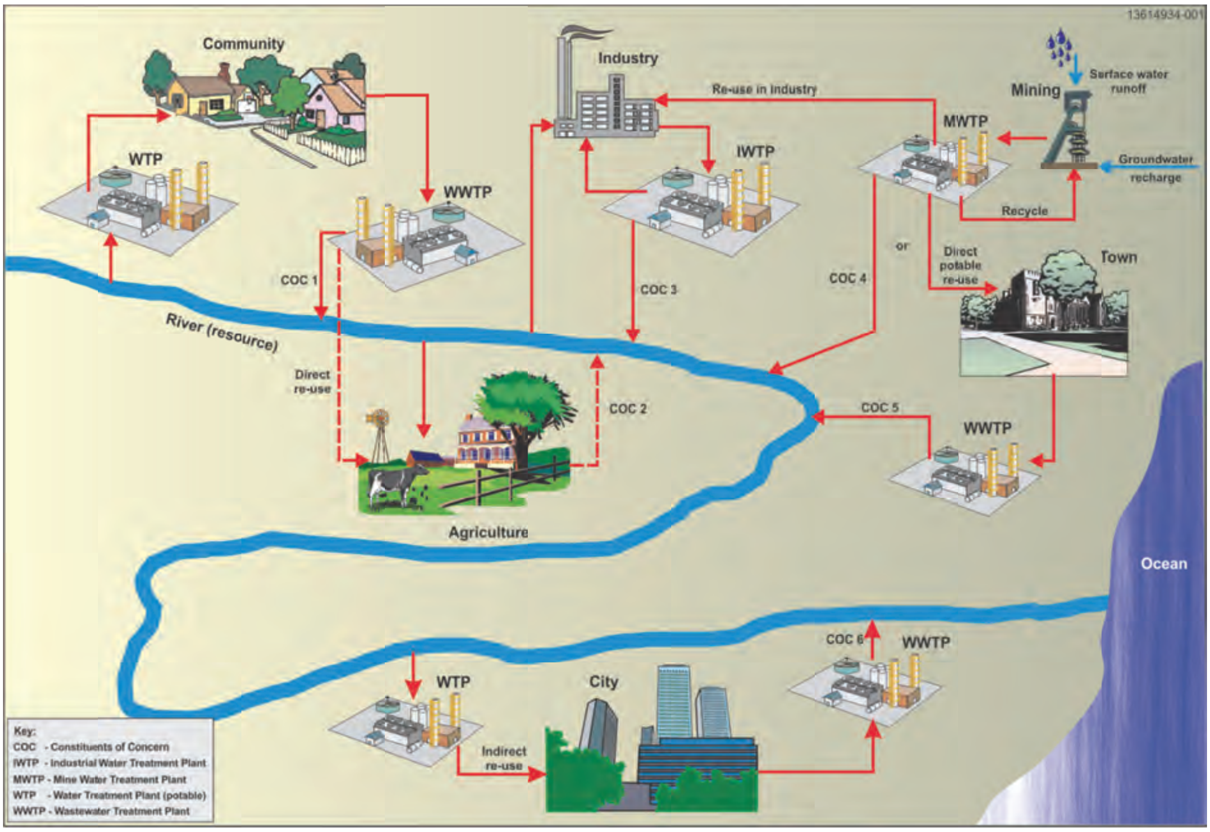


Figure 1: Typical catchment water use and re-use

5 RESEARCH AND DEVELOPMENT

The Water Research Commission commissioned several studies to address the concerns associated with the re-use of treated wastewater. The WRC recently published a document that details the perception of South Africans regarding drinking water quality and is currently funding several projects related to water re-use:

- K5/2121 – Investigation into the Cost and Water Quality Aspects of South African Desalination and Reuse Plants (SSI Engineers and Environmental Consultants);
- K5/1894 – Wastewater Reclamation for Potable Reuse (Umgeni Water);
- K5/2208 – An investigation into the social, institutional and economic implications of reusing reclaimed wastewater for domestic application in South Africa (Cape Peninsula University of Technology); and
- K5/2212 – Monitoring, management and communication of water quality and public acceptance in the direct reclamation of municipal wastewater for drinking purposes (Chris Swartz Water Utilisation Engineers).

6 KEY ELEMENTS OF THE NATIONAL STRATEGY FOR WATER RE-USE

A key step towards implementation of water re-use was the inclusion of the draft National Strategy for Water Re-use in the NWRS II, elevating its status to an official strategic document. The approved National Strategy for Water Re-use provides several strategic objectives unpacked in the context of water re-use in the domestic sector in the sections that follow.

6.1 Promoting sound decision making

The intent of the water re-use strategy is to encourage wise decisions relating to water re-use covering the full planning and implementation life cycle of a project. There are several important factors that can enable and support good decision making:

- A sound and clear policy and legislative framework, implying the project implementers and water users know rights and obligations, and what they can and cannot do;
- Water re-use benefits and challenges are clearly understood, and prices and costs accurately reflect the relative benefits among alternatives so that incentives are not distorted; and
- Decision makers have access to relevant information and support to make informed decisions to implement water re-use projects.

One of the key outcomes from the workshop was that water resource alternatives need to be considered when evaluating a direct domestic re-use scheme, especially the direct re-use of treated wastewater. Water conservations/water demand management (WC/WDM) and the reduction of non-revenue water must be implemented before considering water re-use as an option. Water offsetting could also be considered. For example, the treated wastewater could be re-used by a local industry which in turn reduces the fresh/potable water requirements. The group, however cautioned not to refer to water re-use for potable purposes as the last option in the water use hierarchy as it may create the wrong impression, further enhancing current negative public perceptions.

Considering some international case studies, Singapore Public Utilities Board controls the discharge qualities and quantities of a large number of CoC. It also makes installation of water metering and water saving devices mandatory. By doing this, large volumes of water can be saved and pollution of water resources can be minimised. Furthermore, recycled water (NEWater) does not attract a Water Conservation Tax, which makes it preferable to use this water, instead of fresh water sources. The tariff for domestic water use above 40 m^3 per household/establishment per month is also higher than any other water use tariff in the country. Tax is also exempted from income where money was spent to reduce consumption of potable water.

In Australia, the National Water Commission implemented the National Water Initiative (NWI) and the Australian Government Water Fund. Both of these agencies are inter-governmental and are aimed at improving the efficiency of water use. Looking at the State of Victoria specifically, there are certain requirements to start a re-use project as well as providing / using reclaimed water. The Environmental Protection Agency then audits these water re-use projects regularly. Where operations and maintenance are not up to scratch, funding may be provided by the National Water Fund to rectify this. As a result, water users trust the quality of reclaimed water, although no direct potable water re-use project has been implemented in Australia.

The group agreed that the following key steps need to be followed in order to take water re-use projects forward:

- Assess the best technical scheme for domestic/potable water supply (in a specific catchment or region), taking factors such as input water quality, technology, health and safety, cost effectiveness, impacts on downstream users, etc. into account; and
- Incorporate the plan into the next water reconciliation plan (for that particular catchment or region), cost and budget for it.

Fundamentally, a water resource decision needs to be taken, based on a comparison of alternative potential water resources. Sea water desalination may prove to be the most viable option for water supply at coastal cities; however, pumping this water to inland cities may be too costly. Re-use of domestic wastewater may therefore be an attractive water supply option for inland cities.

Recommendations:

Develop clear regulatory guidance and incentives to support water re-use projects where appropriate.

Develop, document and disseminate decision making methodologies in cases where water re-use is one of several water resources development/water supply project options.

6.2 Creating a clear policy and legislative environment

Water re-use projects typically involve a range of activities that are subject to regulatory authorization and control. These controls exist in a range of legislation that includes, but is not limited to the National Water Act, Act 36 of 1998, the Mineral and Petroleum Resources Development Act, Act 28 of 2002, the National Environmental Management Act, Act 107 of 1998, the National Environmental Management: Waste Act, Act 59 of 2008, the Water Services Act, 108 of 1997, the National Environmental Management: Integrated Coastal Management Act, Act 24 of 2008, and municipal by-laws.

The fact that these regulatory controls exist in so many different acts, and that regulatory mandates and approaches may differ between the acts, makes it difficult to implement water re-use projects confidently, speedily and cost-effectively. This makes water re-use projects less favourable compared to other alternatives even where it is practical and cost-effective to re-use wastewater.

Successful implementation of water re-use across the country will not be possible without a competent lead agency to promote re-use. A lead agency should thus be identified and a mandate should be given to this agency to drive implementation, to unblock bottlenecks and to instil trust in the regulatory support for such projects.

This agency will be actively involved in public education and awareness programs. However, public awareness alone is not enough to encourage water re-use. The lead agency must have a minimum threshold of capacity and competency, being able to prove that it has sufficient technical expertise, planning ability, project management capability, financial strength and rating. It must demonstrate its capability in supporting and promoting water re-use projects. This will ensure that the public has surety and trust in the re-use projects supported by this agency.

In order to encourage the re-use of water for potable or non-potable use, there must be an interdepartmental agreement or understanding. Australia is a good example of a country which has an inter-governmental initiative (the National Water Initiative) which is aimed at improving the efficiency of water use. The Water Fund is also a national entity which provides financial support to water projects that meet the objectives of the National Water Initiative. In this type of regulatory environment, it becomes beneficial for companies and organisations to implement water re-use as a method of water use efficiency.

Singapore also has one Ministry with full responsibility for any water and wastewater related affairs, and this Ministry established the Public Utilities Board, which manages water, waste water and flood control. This allows policy formation, regulatory support, and implementation of water re-use to be efficient and effective.

DWA, in the National Water Re-use Strategy undertook to champion water re-use by:

- Developing clear and practical guidelines for water re-use projects on what regulatory approvals are needed, the status of reclaimed water in terms of right to use and how these can be obtained cost and time effectively (see ‘Guidelines’ below);
- Working with other national departments to align legislation, reduce the regulatory burden wherever practical, and unblock regulatory approval obstacles to water re-use;
- Act as the lead regulatory authority to assist in working with other Departments in getting approval for viable water re-use projects,

- Working with municipalities to ensure that municipal by-laws support the appropriate re-use of water;
- Ensuring that water quality standards implemented are appropriate in a context where water re-use is a strategic imperative; and
- Use the water licensing process as a key tool to promote water use efficiency; and
- Implement the waste discharge charge system.

Recommendations:

Document the current regulatory compliance map for different types of water re-use schemes and identify gaps as well as aspects that hinder implementation of water re-use.

Facilitate discussions between the relevant departments including DWA, Department of Environmental Affairs, Department of Mineral Resources, Department of Health and local government to develop an enabling legislative framework.

Create and enabling regulatory / legislative environment through:

- A strategic statement on the imperative and support for Water Re-Use;
- Announcing DWA as the lead agency and champion for Water Re-use;
- Finalising and implementing the interdepartmental agreement / understanding;
- Developing and communicating the water re-use licencing protocols / approaches;
- Integrating water re-use as one of the water reconciliation options to be considered when developing water resources solutions; and
- Create a balance between enforcement / encouragement.

6.3 Review water quality standards

Water quality standards for discharges into water resource and water quality standards and regulations for different types of water use (for example, standards for potable water use, irrigation use for food and non-food crops) play a large role in influencing water re-use decisions. It is important that these standards are realistic and achievable making re-use projects viable while not compromising public safety and the environment. This is a complex area of regulation and a lot of attention has already been paid to this in South Africa. The following standards exist:

- South African Water Quality Guidelines for a number of different water user sectors (DWAF, 1996);
- Drinking water quality standards (SANS 241); and the
- General and Special Standards pertaining to the discharge of treated wastewater to the water resource.

These standards and guidelines were not specifically developed to address the issues associated with water re-use. Worldwide research into water re-use is producing new information, which needs to be considered in guiding and regulating water re-use projects. DWA undertook in the National Water Re-use Strategy to review and/or develop standards and guidelines specifically aimed at water re-use.

Water re-use projects may be implemented for a large spectrum of potential water users. The different categories / types of water re-use will require quantitative standards to define and manage the fitness for use. The standards must be developed to address the following aspects:

- Water quality variables of concern in a specific water re-use application;
- Quantification of risk and acceptable risk levels; and
- Monitoring requirements in terms of water quality variables, frequency and location of sampling / analysis.

The WRC already commenced with a project (K5/2208) to investigate the social, institutional and economic implications of wastewater re-use for potable / household purposes. This project focusses on water quality aspects and public perception, looking at examples of other projects in the world in terms of institutional set-up, reviewing existing monitoring data, etc.

Recommendations:

Expand WRC research programme related to water re-use to:

- Identify water quality variables of concern in a specific water re-use application;
- Quantification of risk and acceptable risk levels;
- Formulating a risk-based methodology to develop water re-use standard for different domestic/potable applications; and
- Monitoring requirements in terms of water quality variables, frequency and location of sampling / analysis.

6.4 Clear incentives

Water re-use projects are much more likely to be implemented where it is more cost-effective compared to other water resource development and supply alternatives. Households and business have limited budgets and will generally choose least cost options to meet their water use needs. Similarly, municipalities are resource constrained and typically opt for least cost choices related to securing water supplies for their residents, businesses and industries in order to limit water price and municipal rates increases.

Sound water re-use outcomes will arise where the relative costs and benefits of alternatives are not distorted. Where fresh water supplies are subsidized, water users are less likely to choose water re-use options even if these options are cost-competitive with the cost of securing additional fresh water supplies. Conversely, subsidizing the re-use of water is unlikely to lead to least-cost outcomes and the efficient allocation of resources.

DWA undertook in the National Water Re-use Strategy to consider the importance of price signals and incentives in water re-use decisions into account when reviewing the raw water pricing strategy.

Recommendations:

DWA to consider the importance of price signals and incentives in water re-use decisions when reviewing the water pricing strategy.

In the USA, the water rights framework means that the person who treats water has the first right to re-use this water, before discharge or selling the water. However, the government cannot place any penalties on those who do not re-use water, since the water use rights themselves neutralise these penalties.

In China, incentives are given for companies to re-use water, as follows:

- Tax reduction awarded to companies on the “Comprehensive Resource Utilization List”;

- Exemption from taxes for a period for products created through comprehensive resource utilization processes;
- Wastes that could not be re-used or recycled must be offered free of charge to other enterprises for beneficiation or recycling; and
- Enterprises which implement reuse projects that have no economic benefit to them are also given favourable treatment through loans from banks with extended payment terms.

6.5 Information and capacity to support sound decision making and implementation

DWA recognizes the important role that good information plays in supporting sound decisions. There are three aspects of information to consider:

- Educating users with respect to the benefits and acceptance of water re-use
- Sound methodology in the evaluation of water resource options to balance water requirements and supply; and
- Providing people who are considering water re-use with clear guidelines on how to implement water re-use projects.

Recommendations:

- Skills development for Water – Re-use Practitioners:
  - Skills requirements / skills capacity in sector
  - Training needs
  - Water sector ability to expand
  - Training and educational institutions

6.5.1 Methodologies for evaluating water resource development options

Water resource reconciliation studies undertaken for specific catchments and water management areas in South Africa routinely consider conventional water supply augmentation options alongside water re-use, desalination and water conservation and demand management options.

DWA undertook in the National Water Re-use Strategy to continue to develop and refine the methodologies used to assess water resource development options. This is to ensure that options are evaluated on a comparable basis and that the methodologies employed support sound decision making.

6.5.2 Guidelines for implementing water re-use projects

DWA undertook in the National Water Re-use Strategy to develop guidelines for the implementation of water re-use projects. These guidelines will support sound decision making and implementation. The guidelines will address the choice of technology, project implementation, operations and maintenance, project financing, development and implementation of tariffs, public and stakeholder education, engagement and consultation. Separate guidelines will be developed for different types of water re-use projects.

Recommendation:

Develop guidelines / best practices:

- For the planning, development and implementation of water reuse schemes (direct and indirect potable use)
- To develop water re-use on catchment level as an unconventional water resource
- To develop water re-use on City / Community / Municipal level to support use of water
- Business case for Re-Use:
  - Regulatory framework
  - Funding
  - Pricing policy
  - Tariffs

The EPA produced document in 2012 “Guidelines for Water Reuse” provides guidelines for different categories of water reuse, thus giving clear direction for water reuse projects could be a useful start.

6.5.3 Technology selection

The selection and implementation of the appropriate treatment technology are key to the successful implementation of water re-use projects. It is strategically important to achieve this objective by:

- Selecting capable agencies/organisations with knowledgeable and competent staff to implement re-use projects;
- Planning and procuring of technology with the appropriate emphasis on functionality and proven performance;
- Ensuring that local knowledge of and support for the technology are available; and
- Providing technology guidance and training to re-use project implementing agencies/organisations.

Recommendation:

Expand WRC research programme to:

- Ensure that local knowledge on available appropriate water reclamation and water re-use technologies are available captured and disseminated; and
- Develop technology guidance and training material to re-use project implementing agencies/organisations.

6.6 Public education and awareness

The concept and implementation of domestic/potable water re-use will require a focused and sustained public education program to develop and entrench awareness of the different facets of water use and specifically water re-use.

Multiple awareness creation and information campaigns related to a spectrum of water related matters are launched by the Department of Water Affairs, public institutions and private companies each year.

It is important to develop and incorporate communication material related to water re-use into these campaigns.

Public perceptions and opinions vary on the topic of water re-use, specifically as it relates to indirect or direct water re-use for domestic/potable applications. A structured communication strategy must be developed and implemented based on:

- An understanding of the diversity of perceptions and opinions;
- Appropriate material to inform the public and stakeholders;
- Active communication and debate on the topic; and
- Targeted media coverage.

The overall objective of public awareness creation and information dissemination programs is to enhance the understanding and promote informed decision making related to water re-use.

The current public perceptions and awareness of the poor operation, maintenance and performance of municipal wastewater treatment plants pose a specific challenge. It will be difficult to gather support for water re-use within the current situation. The national efforts to address the poor performance of municipal wastewater and effluent treatment plants may have to show results on a consistent basis, before placing water re-use onto the national water agenda.

Recommendation:

Develop and implement a structured communication strategy based on:

- An understanding of the diversity of perceptions and opinions;
- Appropriate material to inform the public and stakeholders;
- Active communication and debate on the topic; and
- Targeted media coverage.

The Israeli Ministry of Agriculture hosts annual meetings which farmers, academics and decision makers attend. In these meetings, water re-use experiences are shared in an attempt to develop more efficient water practices. The Technion University is also involved at these meetings, and young engineers, economists, hydrologists and politicians collaborate to debate and develop the best water management solutions.

In Namibia, the entire country is aware of the shortage of water, and all industries and municipalities work together to provide and use water sustainably and efficiently. Residential wastewater/sewage is collected and treated separately. This treated wastewater is the source water for the Goreangab Water Reclamation Plant which augments the drinking water supply to Windhoek. Industrial effluents and wastewater are treated separately. All people living in the city are aware of this, and support it.

Looking at Singapore, whenever a new law or regulation concerning the environment or water is to be passed, a campaign is launched to inform the public and to invite debate and discussions. The campaign is soon followed by regulatory promulgation of the laws/regulations. In this way, the public is always aware of the laws in the country, and are aware of what is required.

6.7 Technology innovation and development

A range of water re-use projects have been implemented in South Africa (see Appendix A). South Africa has the potential to be a leading innovator in water re-use technology, particularly in the area of the treatment and reclamation of acid mine drainage.

DWA undertook in the National Water Re-use Strategy to encourage the WRC to make water re-use technology development a key focus area, and encourage the development of centres of excellence at selected academic institutions.

Recommendation:

Expand WRC research programme and funding to ensure the focused development of water re-use technology.

Encourage the Department of Science and Technology to identify and provide support to centres of excellence at selected academic institutions focusing on technology development / selection (including waste handling)

6.8 Capacity to implement

6.8.1 Competent implementing agencies

Water re-use projects have many sophisticated technical, engineering, financial, operational and maintenance aspects. A key consideration to any such project is the fact that the water typically has to be treated to improve/upgrade its quality, before it is fit for re-use by a downstream user. The downstream user must be guaranteed an appropriate quality of water to protect designated use of the water. Re-use projects therefore require a high level of confidence in the implementation and operating agencies.

A public sector agency, such as a municipality or water board must have a minimum threshold of capacity and competency, before it can be considered as capable of implementing a water re-use project. This threshold can be evaluated in terms of technical expertise, planning ability, project management capability, financial strength and rating, trusted water services delivery and accepted by the community and stakeholders as a reliable organisation.

An agency/organisation must be able to demonstrate the capability to implement water re-use projects. It is likely that the agencies and organisations with an acceptable capability and capacity profile to implement water re-use projects would be limited to metropolitan municipalities, water boards, some larger local municipalities, private companies specialised in the water services sector and public private partnerships.

Private sector management, engineering and financing capacity, as demonstrated by several successful water re-use projects in mining and industry is well established in South Africa. International interest in local water re-use projects has been expressed. The substantial private sector capacity must be leveraged in the implementation of water re-use projects.

Recommendations:

Create empowered implementation/implementation agencies through:

- Competent implementation agencies
    - Capacity building
    - Institutional arrangements
    - Human resource development

6.8.2 Developing the necessary skills for operating and maintaining water re-use systems

Water re-use projects will typically incorporate more sophisticated treatment technology and systems compared to conventional fresh water and groundwater treatment. Such projects will fail unless trained, knowledgeable and motivated operations and maintenance staff is available. It is strategically important to implement the following actions:

- Prepare an assessment of the current and future skilled and trained people needed to operate water reclamation, water recycling and water re-use projects;
- Encourage water services authorities and water services providers to consider and plan for the staffing and training needs to support water re-use projects; and
- Alert training and educational institutions in the water sector of growing needs for trained and skilled operations and maintenance staff.

The planning and implementation of water re-use projects must also include a comprehensive assessment of operations and maintenance aspects, including staffing, resources and system requirements.

Recommendation:

Engage with the SETAs and DWA on a specific skills development programme for Water Re-use Practitioners.

Identify the:

- Skills requirements and establish the current skills capacity in sector;
- Training needs, and
- Training and educational institutions to develop and provide such training programmes.

6.9 Financing water re-use projects

Water re-use projects may be financed through the Municipal Infrastructure Grant, Regional Bulk Infrastructure Grant, loans from development and commercial banks, project financing linked to public-private partnerships and through bonds issued by agencies such as the Trans Caledon Transfer Authority (TCTA). The waste discharge charge can also provide a source of funding for water re-use projects. This may specifically apply to indirect water re-use projects, where an upstream wastewater discharge containing residual waste is re-used by a downstream water user. The downstream user may have to implement relatively sophisticated and expensive water treatment technology and systems to produce water fit for use. The income generated by the waste discharge charge system may be applied to offset the incremental treatment cost associated with a re-use project.

Financing considerations are similar to those for other water resource development projects, except that the risk profile of the project may be different.

Tariffs can be applied specifically for different water re-use applications. Tariff setting may be subject to the National Water Act (Act No. 36 of 1998), the Water Services Act (Act No 108 of 1997), the Municipal Systems Act (Act No. 32 of 2000) and the Public and Municipal Financial Management Acts (Act No. 1 of 1999), depending on the specific application.

Recommendation:

Develop a business case for water re-use projects based on taking into consideration the:

- Regulatory framework;
- Funding models;
- Pricing policy; and
- Tariffs.

In the USA, the Drinking Water State Revolving Fund provides money as an incentive to those wishing to start projects which conserve water. This includes water reuse projects.

Singapore supports public-private partnerships, even though its government has a financial surplus. The government also provides contracts to water treatment plants. Tariffs are a big incentive to use reclaimed water in Singapore. The lowest tariff is for industrial water, which is non-potable reused water. The next lowest tariff is that of NEWater, which is reused water of a potable standard. Water tax is also not applied to NEWater or to industrial re-use water.

In Australia, the price of reclaimed water is set below that of potable water. Since the actual cost of reclaimed water is higher than the cost of fresh water or of collected storm water, this requires a subsidy, which is provided by the Australian Government Water Fund.

In Israel, water is priced according to the cost of treatment and reticulation.

In Namibia, the water pricing was changed on a sliding scale to reduce the burden on poorer communities and increase revenue from richer communities. There is a minimum water charge, with an included small volume of water, and thereafter the unit cost of water escalates as unit consumption increases.

6.10 Enforcement

The performance of existing wastewater treatment plants in terms of meeting discharge standards and reliability is critical to the successful application of water re-use in South Africa. These facilities discharge water that impacts on the safety, economy and fitness for use by downstream users. Strict enforcement of discharge standards, and addressing the management and performance failures of municipal wastewater treatment plans is therefore critical to the future of water re-use in South Africa.

6.11 Baseline work required

In addition to the strategies listed in the National Water Re-use strategies (Section 6.1 to 6.10), the following baseline work will also be required:

- Establishing the current status and extent of domestic / potable water re-use in all key water management areas as well as the impacts;
- Research the social, cultural, religious perspectives and values driving water re-use;
- Quantify the environmental / river aquatic life impacts of water re-use.

Recommendation:

WRC funding to commission the additional baseline work, to support further focused research of domestic/potable re-use.

7 CONCLUSIONS

The publication of the second version of the National Water Resource Strategy (NWRSII, 2013) containing the National Strategy for Water Reuse accelerates of discussion related to implementing water re-use. This document focused specifically on the direct and indirect reuse of water for domestic/potable purposes as a proactive step to the progressive implementation of the National Water Re-use Strategy. This document is intended to be the input material to broad sector consultation to develop the detailed implementation plan for domestic/potable re-use water.

8 REFERENCES

NWRSII, 2013. National Water Resource Strategy. Water for an Equitable and Sustainable Future. 2nd Ed. Department of Water Affairs.

DWA, 2010. Reconciliation Strategy for Beaufort West (accessed www.dwa.gov.za on 31 October 2013).

Appendix A

Annexure D of the NWRS II: National Strategy for Water Re-use

Annexure D
National Strategy for Water re-use

June
2011

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

Table of Contents

INTRODUCTION

South Africa has limited fresh water resources and has been defined as water stressed by International standards[1].

The re-use of water in South Africa accounts for approximately 14% of total water use, and return flows account for a large part of water available for use from some of the important river systems[2]. The National Water Resources Strategy (First Edition) identifies water re-use as one of a number of important strategies to balance water availability with water requirements in future and the extent of water re-use in South Africa is very likely to increase substantially over time. There is an associated risk that water re-use is unplanned, unregulated and/or results in unintended or undesirable consequences.

The re-use of water is widely practiced in the world, both in developed and emerging economies. Many countries have developed water re-use policies and associated laws and regulations. Water re-use internationally contributes to reconcile the gap between water availability and water needs in such countries as the United States of America, Spain, Australia, Israel and China.

Within the above context, this document provides a strategy for a considered approach to implementation of water re-use projects that is consistent with the National Water Resource Strategy[3] and national water policy and legislation.

1.1 Defining water re-use

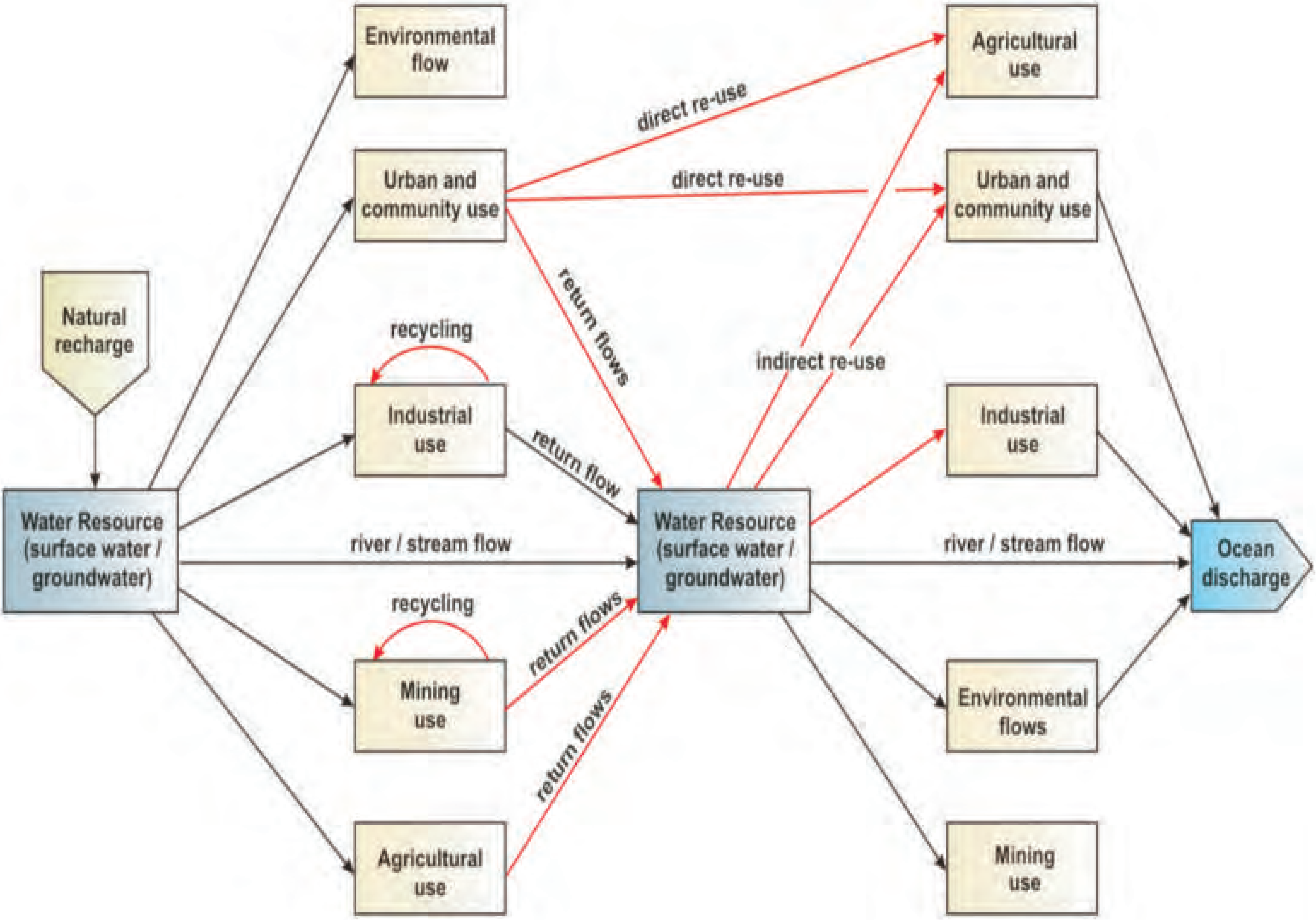
Water re-use can be direct or indirect, intentional or unintentional, planned or unplanned, local, regional or national in terms of location, scale and significance. Water re-use may involve various kinds of treatment (or not) and the reclaimed water may be used for a variety of purposes. These different kinds of water re-use have different implications for a re-use strategy. It is therefore important to be precise in the use of terminology. Definitions of commonly used terms are given in **Table 1.**

Figure 1 illustrates how water can be re-used and recycled. This illustration does not cover all possible methods of water re-use, but is only intended to demonstrate the concepts involved in water re-use and water recycling.

Table 1: Water re-use terminology

[1]Water Re-use, An International Survey of Current Practice, Issues and Needs. Editors Blanca Jimenez and Takashi Asano. IWA Publishing. 2008.
[2]Integrated Water Resource Planning for South Africa. A Situation Analysis 2010. Department of Water Affairs. Report No RSA 000/00/12910.
[3]National Water Resources Strategy, Department of Water Affairs and Forestry, First Edition, September 2004.

Term	Definition
Water re-use	Utilization of treated or untreated wastewater for a process other than the one that generated it, i.e. it involves a change of user. For instance, the re-use of municipal wastewater for agricultural irrigation.
Water recycling	Utilization of treated or untreated wastewater for the same process that generated it, i.e. it does not involve a change of user. For instance, recycling the effluents in a pulp and paper mill.
Direct re-use	Re-use of treated or untreated wastewater by directly transferring it from the site where it is produced to a different/separate facility for the next use.
First water use	Water coming from a fresh water source receiving no identifiable upstream wastewater discharges.
Indirect re-use	Re-use of treated or untreated wastewater after it has been discharged into a natural surface water or groundwater body, from which water is taken for further use.
Intentional or planned re-use	Use of treated or untreated wastewater as part of a planned project. It is always performed intentionally, consciously and using reclaimed water for a specific user.
Unplanned or incidental re-use	Subsequent use of treated or untreated wastewater after it has been discharged into a surface water or groundwater body from which water is taken for drinking purposes or another use. Initially, it always occurs as a subconscious activity; with time it might occur consciously but not as part of a planned project in which wastewater is properly treated and water quality monitored for the specific water use purpose.
Reclaimed water	Wastewater that has been treated to a level that is suitable for sustainable and safe re-use.
Return flows	Treated and/or untreated wastewater that is discharged to a natural surface water or groundwater body after use.
Wastewater	Water derived from any of a number of uses of water and typically containing residual pollutants associated with the use of the water.
Grey water	Wastewater derived from the domestic and household use of water for washing, laundry, cleaning, food preparation etc. Grey water does not contain faecal matter.
Black water	Wastewater containing faecal matter and urine associated with water use in toilets and urinals.



Note: This figure does not show all possible water use, re-use and recycle, but demonstrates the concepts

Figure 1: Illustration of different ways that water can be re-used and re-cycled

2

UNDERSTANDING RE-USE IN THE CONTEXT OF WATER SUPPLY

There are essentially three generic sources of 'used' water associated with different scales of water re-use:

- At a micro-level, the water that has been used by a household, a business, an institution or industrial facility, a power station, a farm or a mine. The key feature is that this used water is available at a specific and local geographic location. The quantity and quality of water available for re-use will depend on how it has been used and if there is any local (on-site) treatment or not.
- At a community or facility level, where wastewater has been collected from a group of users (typically within a natural drainage basin), and typically through a sewer network. In this case, the used water is available at the discharge point of the treatment facility at a quality that is dependent on both the characteristics of the inflow to the treatment facility as well as the treatment technology used and its effectiveness (both in terms of design and operational performance).

- At a river system level, where used water (treated and untreated) has been discharged (or found its way) back into the river system. In this case, the used water is blended with the 'fresh' water in the river system. The quality of the river water will depend on the quality and quantity of the return flows, the state of the receiving water body and its assimilative capacity, and the ratio of fresh water flows to return flows (the dilution effect).

At a river system level, it is estimated that approximately 1 800 million m3 per annum of water flowing in our rivers is return flow, that is used water, accounting for 14% of the total available water in South Africa. At the treatment facility level, South Africa has in excess of 1 000 municipal wastewater treatment works, discharging approximately 2 100 million m3 per annum of treated effluent, back to the river systems[4]. At the "micro level", the availability of South Africa's water for re-use may be broadly categorized and aggregated into different industrial, mining, power generation and agricultural sources[5]:

Mines, in addition to using fresh and re-using water, may also 'generate' water. This occurs through the filling of mine cavities and the need to pump this water, or the natural decanting of this water where pumping does not take place. This water is referred to as mine decant or mine drainage. This water may be acidic, saline and may contain heavy metals. The mine water typically needs to be treated before it can be re-used

3

UNDERSTANDING THE NEED FOR WATER RE-USE

3.1 Key drivers affecting water re-use choices

There are five key considerations that affect choices related to water re-use as an option for water supply and augmentation:

- Water quality and security of supply
- Water treatment technology
- Cost relative to other water supply alternatives
- Social and cultural perceptions
- Environmental considerations

Although these are likely to be inter-related in practice, it is useful to discuss each in turn.

3.1.1 Water quality and security of supply

The cost of water is strongly related to the source of water, the required water quality and the associated treatment requirements (for both supply and discharge). Where water quality requirements are relatively low or where wastewater discharge costs are high, the re-use of water is likely to be more attractive.

Water quality as it relates to public health is important in considering water re-use as a water supply option. Any real or even perceived threat to public health would be considered a fatal flaw.

The re-use of water may increase the security of supply for specific users and may therefore be attractive in these cases, even where the cost exceeds alternative supplies. Note that it is not necessarily the case that increased water re-use increases the security of supply for an overall water supply system.

3.1.2 Water treatment technologies

The choice of treatment technology is a function of both the nature of the pollutants in the water and the required quality of the re-use water. An overview of applicable treatment technologies is given in **Table 2.**

The best practice in water re-use projects applies the multiple barrier approach to the control and removal of pollutants. This implies that in the sourcing, treatment and distribution of reclaimed water several control, technological and management barriers are set up to achieve a high level of assurance with respect to pollutants removal and producing a reclaimed water fit for use and safe for human consumption.

[4]Wastewater Treatment in South Africa: From Crisis to Compliance. Water Research Commission. Report No. 8001/8295/3/P, August 2006.
[5]A First Order Inventory of Water Use and Effluent Production by South African Industrial, Mining and Energy Generation Sectors. Water Research Commission.
Report No. 1547/1/10, April 2010.

Table 2: Applicable water treatment technologies for water re-use

Category of Pollutants	Applicable Technologies
Macro-organics, COD and BOD5	• Biological treatment (activated sludge, trickling filtration, fixed film reactors, membrane bioreactors) • Chemical coagulation/flocculation and clarification
Particulate and suspended solids	• Chemical coagulation/flocculation and clarification • Granular media filtration • Membrane filtration
Nutrients – Nitrogen	• Biological nitrogen removal (nitrification/denitrification) • Air stripping (ammonia) • Chemical coagulation/flocculation and solids separation
Nutrients – Phosphorus	• Biological phosphorous removal (enhanced biological phosphorus uptake) • Chemical precipitation (typically metal salt addition) • Chemical precipitation (packed bed reactors)
Microbiological Agents: •Bacteria •Viruses •Parasites	• Membrane filtration • Chemical disinfection (chlorine, bromine compounds etc.) • Ultra Violet (UV) radiation
Salinity, inorganic salts	• Precipitation • Ion exchange • Membrane desalination (nanofiltration /reverse osmosis)
Metals	• Precipitation • Chemical adsorption • Membrane separation
Micro-organics: •Volatile Organics •Pesticides •Pharmaceuticals •Endocrine Disruptors	• Advanced oxidation (H2O2/UV) • Adsorption by activated carbon (granular/powder) • Membrane separation (nanofiltration /reverse osmosis) • Biologically enhanced adsorption (BAC)
Disinfection byproducts	• Modify disinfection agent in upstream processes • Advanced oxidation • Adsorption by activated carbon (PAC/GAC) • Membrane separation (nanofiltration /reverse osmosis)
Radionuclides	• Precipitation • Chemically enhanced adsorption • Membrane separation (nanofiltration /reverse osmosis)

The wastewater and effluent treatment technologies for re-use applications are generally proven for South African conditions. A local knowledge base exists to plan, design, construct, operate and maintain a wide range of treatment technologies. However, some of the more sophisticated technologies such as advanced oxidation, membrane desalination etc. have been applied to a limited number of local projects. The South African water industry will need to grow capacity to confidently implement some of the more advanced water re-use technologies.

3.1.3 Cost considerations

Where water re-use is more cost-effective compared to other alternatives (such as reducing water requirements, securing a fresh water supply or desalinating sea water), then water re-use becomes an attractive choice provided that the quality of water can meet the necessary requirements and there are not any important cultural or social objections to the use of this water.

Costs are affected primarily by water quality requirements (related to both supply and discharge and the associated treatment requirements) and the relative geographical locations of water supply and needs. As supply costs increase and with the introduction of waste discharge charges, the cost of re-using water is becoming increasingly competitive with the traditional supply alternatives and this will be a key driver for increasing re-use of water in future[6].

The typical increasing cost of different water sources is reflected conceptually on **Figure 2.** Water re-use must be considered as one of several options to augment water supply to a city, industry or mine, once the conventional fresh water resources are fully developed or the cost of water re-use becomes comparable to development of conventional water sources.

The economic value/cost of water must also be seen in the broader context of affordability, reliability and responsible use of a limited resource.

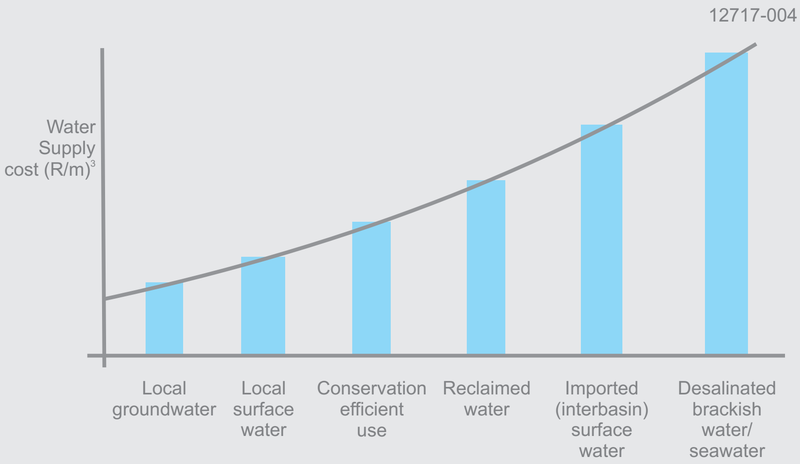


Figure 2: Comparative cost of different water sources

3.1.4 Social and cultural perceptions

Public perceptions and cultural taboos may create obstacles to certain water re-use applications. The two most important of these relate to the re-use of suitably treated municipal wastewater (comprising domestic sewage) for irrigation of food crops and for potable water supply. People attach religious, cultural and aesthetic values to water and any water re-use project must remain sensitive to these values[7].

3.1.5 Environmental considerations

Receiving water quality objectives (related to the actual and desired environmental status of a water resource) may affect abstraction rights and volumes, discharge standards, waste discharge charges and associated rights and obligations to return used water to a water system. These will ultimately affect the relative costs and benefits of re-use compared to other alternatives.

Re-use of water will typically have positive environmental benefits, specifically on the water environment through protection of aquatic ecosystems by not having to abstract more water from a natural source, and avoiding degradation of natural waters by not discharging wastewater, but rather using reclaimed water. Water re-use projects may, however, still have an environmental footprint and energy usage depending on the water reclamation technologies used. Water re-use must therefore be evaluated in the context of other water supply and water augmentation options with consideration of environmental impacts, carbon footprint, ecological footprint and energy usage.

Wastewater treatment to produce reclaimed water fit for re-use typically produces a waste stream. The handling and disposal of waste (such as brine from a mine water reclamation plant) will typically have environmental impacts. The potential exists and should be actively researched and developed to extract useful products and energy from such waste.

3.2 The need for water re-use by sector

3.2.1 Agricultural sector

Even though the agricultural sector uses about 7 680 million m^3 per annum (accounting for about 60% of total water use in South Africa), only a small proportion of irrigated agriculture directly uses treated wastewater. In contrast to this, Israel has a strategic objective to collect and treat all of its domestic wastewater for re-use in agriculture.

[6]Assessment of Ultimate Potential and Future Marginal Cost of Water Resources in South Africa. Department of Water Affairs. Report No. PRSA 000/00/12610, September 2010.
[7]Religious, Philosophical and Environmentalist Perspectives on Potable Wastewater Re-use in Durban, South Africa. Wilson Z and Pfaff B. Pollution Research Group, School of Development Studies. University of KwaZulu-Natal.

Therefore considerable potential exists to substantially expand the use of treated wastewater for irrigation purposes in South Africa. This will bring many benefits. Irrigation is often labour intensive and expanding the area under irrigation may create jobs. Wastewater return flows are typically available close to urban areas and thus close to urban markets for agricultural produce, provided suitable land is available for irrigation. Treated wastewater can substitute for freshwater, thus making more freshwater available for other uses[8].

Any such re-use of water by agriculture will have to be balanced by the competing other requirements and historical allocations of water in the specific water management area.

3.2.2 Municipal sector - non-potable water

The main source of water for re-use in municipal (urban) areas is wastewater from municipal treatment works. This typically comprises a mix of domestic sewage and other wastewater. Other sources of water for re-use include grey water (usually available at the household/water user level only) and industrial effluents.

The main potential uses of treated wastewater from municipal wastewater treatment works is for the irrigation of public open spaces (parks etc.) sports fields (municipal, schools and clubs), golf courses and cooling (related to industry and power generation). The return flows from wastewater treatment works can also be important for urban water systems (rivers, lakes, dams and wetlands). Treated wastewater and/or grey water can also be used for fire fighting, toilet flushing, cooling systems, street cleaning, dust control and a variety of applications that do not require potable water.

Of the total volume of municipal wastewater treated, it is estimated that only a small fraction is re-used, most of it is for the irrigation of public open spaces, sports fields, golf courses and cooling systems. In the past, the urban/municipal re-use of treated wastewater was not actively promoted due to the cost of such systems and the potential public health risks. Some re-use of water, for example in the irrigation of recreational areas and golf courses may be in competition with other essential water uses.

3.2.3 Municipal sector - potable water

Used water can be treated to a standard fit for domestic use (drinking purposes). Treated water can be supplied directly to households (direct re-use) or be discharged back to the (fresh) water resource where it is blended with other water and subsequently abstracted, treated and distributed for use (indirect re-use).

There are many potable water re-use schemes in operation in the world. The majority of these schemes are based on an indirect re-use approach. Indirect water re-use for potable purposes is well established in South Africa. It is common for a treated wastewater effluent to be discharged to a river system and for water to be abstracted downstream of this discharge point and to be treated and used for drinking water. The direct re-use of used water for potable purposes has not been implemented in South Africa, but has been successfully implemented in Windhoek, Namibia, since the 1970's[9].

The main concerns related to both the direct and indirect re-use of water for potable purposes include the following: the presence of pollutants such as pharmaceuticals, health care products, pesticides, industrial chemicals, heavy metals etc. in municipal wastewater and industrial effluents that may be difficult or costly to treat adequately, the associated risks in terms of the ability to design and manage treatment processes with a suitable level of confidence and to predict the public health impacts of re-using water for drinking purposes. Public perceptions and acceptance of direct and indirect re-use of water for drinking purposes are also challenges and in this case sophisticated and reliable technical and management systems will be required.

3.2.4 Industrial sector

The re-use of water is already widely implemented by water intensive industries (through process water recycling and cascading water uses). The extent of re-use and the specific details as to how water is re-used is industry and process specific. Nevertheless, industrial water use is typically organized according to the quality of water required, as follows:

- Processes requiring high quality water such as steam generation, wash-water in clean environments, foods processing, final product rinsing, product make-up etc;
- Processes requiring moderate water quality such as for cooling, refrigeration, general washing and rinsing, etc; and
- Processes requiring low water quality such as for raw material hydraulic transport, ore washing and milling, dust control, minerals processing etc.

Many industries do not require high quality water for process applications and can therefore use treated wastewater from municipalities and treated effluents from other industries. The wastewater from the upstream user must, however still be adequately treated and prepared for subsequent industrial use.

Industries can be operated as zero effluent discharge (ZED) facilities by adopting the principle of water recycling and re-use. This may require the treatment of industrial effluent to a high standard to allow re-use of water even by sensitive water users, such as for human consumption. **Figure 3** shows an example of potential water re-use applications in a soft drink bottling industry.

[8]The Wealth of Waste: The Economics of Wastewater Use in Agriculture. Winpenny J et al. Food and Agriculture Organisation of the United Nations. Rome. 2010.
[9]Direct Potable Re-use – A Path Forward. Tchobanoglous G. et al. Water Re-use Research. California. 2011.

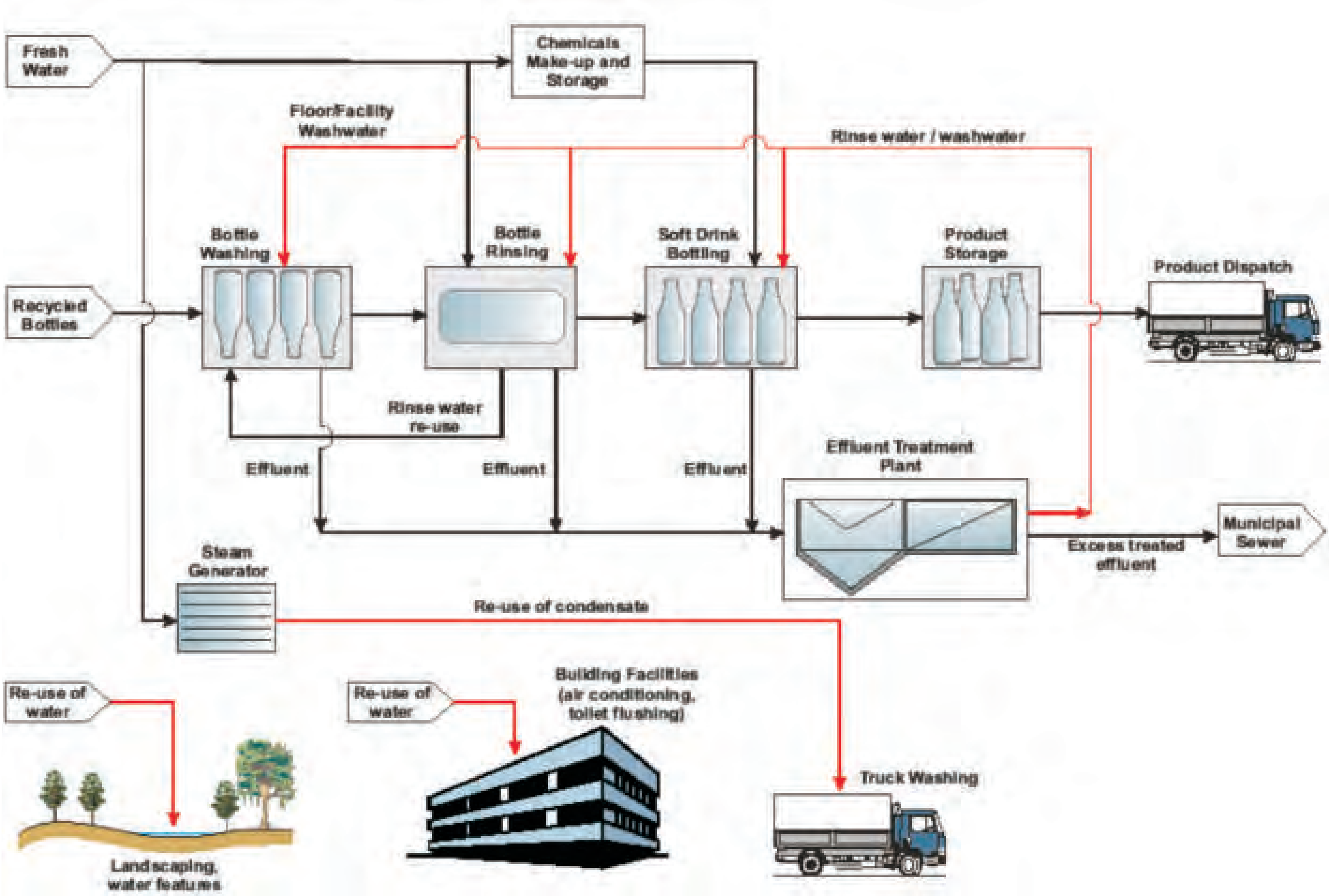


Figure 3: Water re-use applications for a soft drink bottling facility

3.2.5 Mining sector

Mining and minerals processing facilities use large volumes of water and recycling and re-use is widely implemented to reduce costs and to meet environmental requirements. Typical water re-use applications include:

- Cascading use of fresh intake water to different processes which require different water qualities, for example, blowdown from cooling towers can be used to mill the ore
- Capture and use of mining impacted water to replace fresh intake water
- Return and re-use of water from mining waste facilities, such as tailings deposition facilities

Water re-use opportunities in the mining and minerals processing industry are illustrated in **Figure 4.** The issue of acid mine drainage (AMD) is pertinent to the mining sector. AMD can potentially have very negative impacts on the natural aquatic environment and downstream users if left to decant and flow untreated into the fresh water resources. The collection, treatment and re-use of AMD turns the negative impacts into a positive beneficial water use.

3.2.6 Power generation sector

The power generation sector has in the past used and continues to use large quantities of fresh water, requiring in many cases inter-basin transfer of water. As the available fresh water resources become fully utilized, the sector has implemented dry cooling technologies. The need for improved air emission control has, however increased the water requirements. Coal-fired power stations in South Africa are typically operated as zero effluent discharge facilities. The sector is continuously improving the efficient use of water, specifically in the handling and management of ash and waste.

The water requirements and water re-use opportunities in nuclear power generation and renewable energy facilities will have to be understood as South Africa progressively moves to energy diversification.

3.2.7 Environmental requirements

Water supports and sustains natural and man-made aquatic ecosystems by, for example, maintaining minimum flows and appropriate flow regimes in streams, rivers and estuaries, recharging wetlands and maintaining the water levels of man-made water features such as urban lakes and dams.

Re-used water can play an important role in the above, supplementing or even partially substituting for freshwater. However, care must be taken to clearly define receiving water quality objectives and to manage the impact of water re-use on water quality. More advanced treatment may be required to further encourage this form of water re-use and to meet strict receiving water quality requirements.

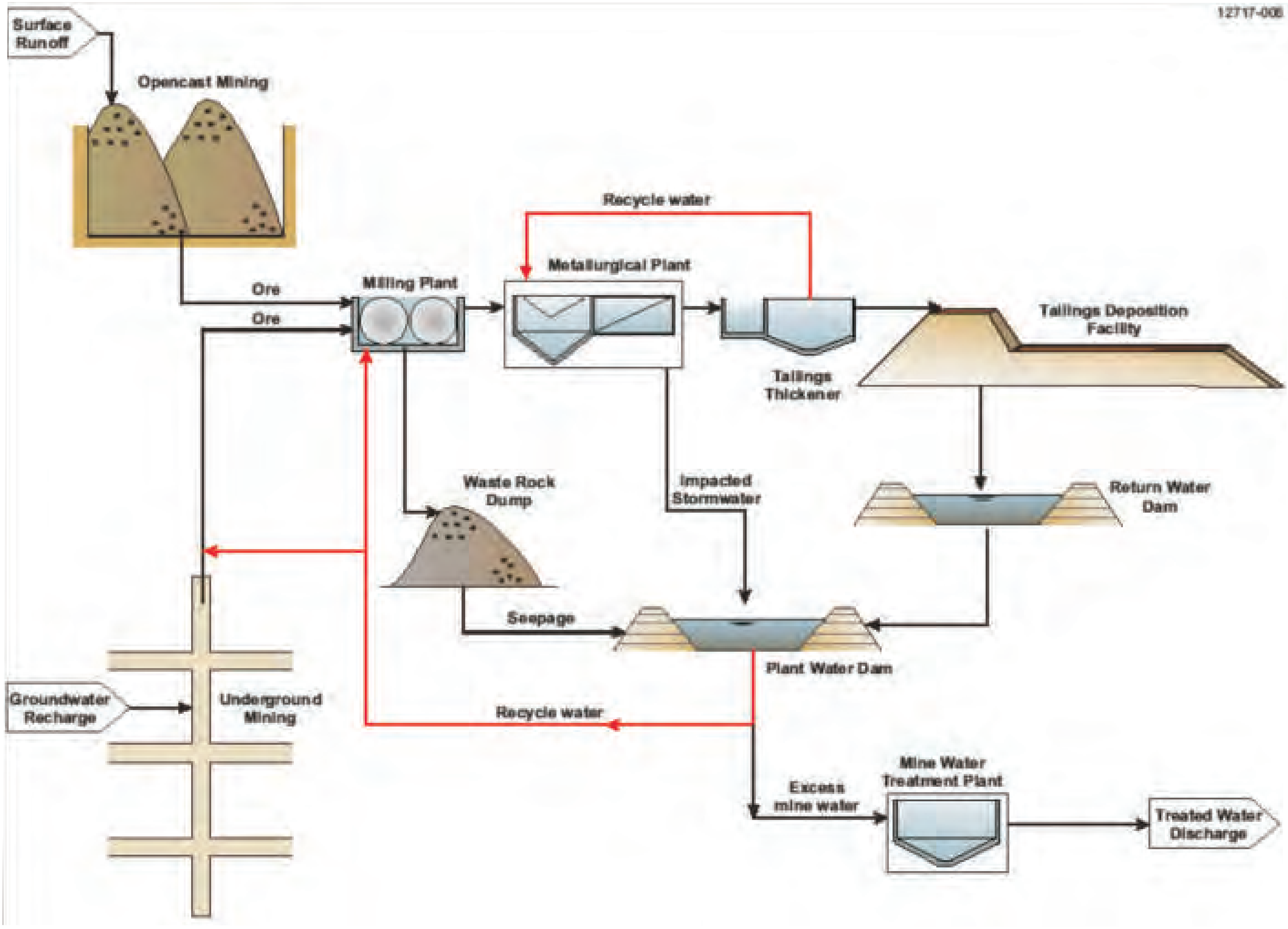


Figure 4: Water re-use applications in the mining and minerals processing industry

4

WATER RE-USE CASE STUDIES

The cost of re-using water relative to other alternatives is one of the most important factors that will determine water re-use decisions. It is therefore important to understand the key factors that will affect costs and how these vary between different applications of re-use and are likely to change over time, relative to other water supply alternatives. It is also important to understand how these costs might be reduced so as to make water re-use more economically attractive. The key determinants of cost are location, water quality, treatment technology and volume (scale).

Because the possible applications of water re-use (and hence the appropriate treatment technologies to be used) are very extensive, it is not feasible to discuss these exhaustively or in any detail here. Instead, five main applications of water re-use are discussed in the form of 'case studies' with the understanding that the approaches and principles emerging from these cases can be applied to other similar water re-use applications. The six 'case studies' are:

- The use of treated municipal wastewater for urban uses
- The use of treated municipal wastewater for industrial use
- Zero discharge mining/industrial facilities
- Rethinking household sanitation and grey water
- The direct re-use of treated municipal wastewater for potable use purposes
- The treatment of acid mine drainage

Appendix A contains a list of selected South African case studies to demonstrate some existing local water re-use projects.

4.1 Using treated municipal wastewater for urban uses

The re-use of treated wastewater for urban applications such as public parks, sports fields, golf courses etc. could replace the use of freshwater. The construction and operation of a separate recycled water reticulation system is relatively expensive and has been an impediment to implementation. Water re-use systems ("purple pipes") have, however been successfully implemented in many countries with appropriate controls and safeguards. The concept of small scavenging wastewater treatment plants, taking wastewater from the sewers and producing a water fit for re-use at the local point of the water requirement may be more cost effective. Municipal bylaws would have to be adapted to encourage but also better regulate such re-use of water.

4.2 The use of treated municipal wastewater for industrial uses

Several successful projects to re-use treated municipal wastewater for industrial processes are in operation in South Africa – refer to Appendix A. These projects typically involve a large wet industry such as a steel mill or pulp/paper mill linked to a source of treated wastewater. The concept is well established and the project drivers are a combination of the factors listed in Section 3.1 of this document. Some innovative implementation models involving private sector financing, operation and maintenance are available. Since an industry is involved, private sector resources can be readily deployed to implement such water re-use projects.

4.3 Zero discharge for mining/industrial facilities

Industries discharging effluents to municipal sewers may require pretreatment to achieve trade effluent standards set in bylaws. Industries discharging effluents back to streams/rivers implement treatment systems to achieve licensed discharge standards. Many wet industries now implement water recycling and re-use projects based on considerations of water availability and cost. Stream/river discharge standards may be strict and the quality of a treated effluent may be adequate for re-use, thus saving the cost of purchasing fresh water. The re-use of a treated industrial effluent may also be a strategic decision to improve the availability of water and diversify on sources of water.

4.4 Rethinking household sanitation and grey water

Conventional waterborne sanitation uses potable standard water to wash away human faeces, in the process combining good quality water with potentially valuable resources (faeces and urine) to create polluted water that needs to be treated. This is not an efficient system in a context where fresh water is scarce and precious and where fertilizer inputs for agriculture productivity are limiting. As resource scarcity and prices change over time, it may make increasing sense to rethink our conventional sanitation solutions and to invest in more environmentally friendly and sustainable alternatives.

Similarly, the implications of current practices of adding phosphates to detergents and soaps used in washing processes, and then combining this water (grey water) with domestic sewage will need to be carefully considered. These practices are likely to need to change in future as fresh water becomes more valuable and the cost of treating polluted water resources becomes higher.

A limited number of countries in the world have implemented urine separation and collection systems, with the aim of nutrient (nitrogen, phosphorous and potassium) recycle to agriculture. Changing household practices at this fundamental level may have significant implications for water use and the availability of wastewater for re-use in the long term. A water re-use strategy that is forward thinking over ten to twenty years needs to take these possible changes into account. The economic tipping point for the implementation of alternative household sanitation approaches will dictate the speed of change.

4.5 Direct re-use of treated municipal wastewater for potable purposes

The direct re-use of treated municipal wastewater for potable purposes is practised at a limited number of locations in the world. The knowledge of municipal wastewater composition and sophisticated treatment technologies has advanced to the point where this can be considered as an option in the spectrum of water supply alternatives. Specific opportunities exist in the coastal communities and cities where treated municipal wastewaters are discharged to the ocean, effectively losing an opportunity for water re-use.

The implementation of such direct re-use projects will, however, have to overcome perceptions and risks related to public acceptance, trust in scientific knowledge and engineered systems, trust in water supply authorities, social justice and fairness.

Direct re-use of treated municipal wastewater for potable purposes would only be practical where sophisticated technology, competent operational and management systems and safeguards are in place to protect the public health.

4.6 Treatment of acid mine drainage

Acid mine decant or drainage is a potentially important source of water for re-use. This water must be treated to limit current and future environmental damage to water resources, and can be treated for re-use for industrial and even potable water use purposes.

Several AMD treatment and re-use projects have now been implemented in South Africa demonstrating the technical feasibility, financial viability and stakeholder acceptance of such projects. Challenges remain to address the issues of appropriate and long term (post mine closure) operation and maintenance of such AMD re-use schemes.

AMD treatment and re-use projects could utilize the large storage available in mining workings, do not have to contend with evaporation loss of water and can deliver reclaimed water in proximity to several large urban areas, such as the Witwatersrand and Mpumalanga Highveld. .

5

NATIONAL STRATEGY FOR WATER RE-USE

5.1 Promoting sound decision making

The implementation of water re-use can take place at different scales or levels: at a very local level involving a single facility such as a building or a factory, for a group or cluster of facilities, at a treatment facility level (for example, such as a municipal treatment works) or at a river system level (natural drainage areas/catchments). Decision-making will vary across these applications and could involve individual or groups of households or businesses, municipalities and national government (including entities owned by government).

The intent of the water re-use strategy is to encourage wise decisions relating to water re-use for all of these different decision makers. There are three important factors that can enable and support good decision making:

- A sound and clear policy and legislative framework, that is, decision-makers and water users know what their rights and obligations are, and what they can and cannot do.
- The benefits, risks and costs are clearly understood, and prices and costs accurately reflect the relative benefits and costs between alternatives so that incentives are not distorted.
- Decision makers have access to relevant information and support to make informed decisions, with the necessary support and backup to implement water re-use projects.

Each of these aspects are addressed in further detail below.

5.2 Creating a clear policy and legislative environment

Water re-use projects typically involve a range of activities that are subject to regulatory authorization and control. These controls exist in a range of legislation that includes, but is not limited to the National Water Act, (Act 36 of 1998), the Mineral and Petroleum Resources Development Act, (Act 28 of 2002), the National Environmental Management Act, (Act 107 of 1998), the National Environmental Management: Waste Act, (Act 59 of 2008), the Water Services Act, (Act 108 of 1997), the National Environmental Management: Integrated Coastal Management Act, (Act 24 of 2008), and municipal by-laws.

The fact that these controls exist in so many different acts, and that regulatory approaches may differ between the acts, makes it difficult to implement water re-use projects confidently, speedily and cost-effectively. This makes water re-use projects less favourable compared to other alternatives, even where it is practical and cost-effective to re-use wastewater.

The Department of Water Affairs will address this issue by:

- Developing clear and practical guidelines for typical water re-use projects on what regulatory approvals are needed, the status of reclaimed water in terms of right to use and how these can be obtained cost and time effectively (see 'guidelines' below)
- Working with other national departments to align legislation, reduce the regulatory burden wherever practical, and unblock regulatory obstacles to water re-use
- Act as the lead regulatory authority to assist in working with other Departments in getting approval for justifiable water re-use projects
- Working with municipalities to ensure that municipal by-laws support the appropriate re-use of water
- Ensuring the water quality standards implemented are appropriate in a context where water re-use is a strategic imperative (see 'reviewing water quality standards' below)

- Use the water licensing process as a key tool to promote water use efficiency
- Implement the waste discharge charge system

The Department will also review water related laws and regulations to assess the need for revision driven by water re-use. Legislation may then be revised to accommodate the need to facilitate, streamline, encourage and control water re-use projects.

5.2.1 Reviewing water quality standards

Water quality standards for discharges into the water resource and water quality standards and regulations for different types of water use (for example, minimum standards for potable water use, irrigation use for food and non-food crops) play a large role in influencing water re-use decisions. It is important that these standards are not so onerous that they make treatment for re-use prohibitively expensive and not so lax that they compromise public safety and the environment.

This is a complex area of regulation and considerable attention has already been paid to this in South Africa. The following standards exist:

- South African Water Quality Guidelines for a number of different water user sectors (DWAF, 1996)
- Drinking water quality standards (SANS 241, 2005, Edition 6), and the
- General and Special Standards pertaining to the discharge of treated wastewater to the water resource.

These standards and guidelines were not specifically developed to address the issues associated with water re-use. Worldwide research into water re-use is producing new information, which needs to be considered in guiding and regulating water re-use projects. The Department will review and/or develop standards and guidelines for water re-use.

Water re-use projects may be implemented for a large spectrum of potential water users. The different categories / types of water re-use will require quantitative standards to define and manage the fitness for use. The standards must be developed to address the following aspects:

- Water quality variables of concern in a specific water re-use application
- Quantification of risk and acceptable risk levels, and
- Monitoring requirements in terms of water quality variables, frequency and location of sampling / analysis.

5.3 Clear incentives

Water re-use projects are much more likely to be implemented where it is more cost-effective compared to other water supply alternatives. Households and business have limited budgets and will generally choose least cost options to meet their water use needs. Similarly, municipalities are resource constrained and typically opt for least cost choices related to securing water supplies for their residents in order to limit water price and municipal rates increases.

Sound water re-use outcomes will arise where the relative costs and benefits of alternatives are not distorted. Where fresh water supplies are heavily subsidized, water users are much less likely to choose water re-use options even if these options are cost-competitive with the cost of securing additional fresh water supplies. Conversely, subsidizing the re-use of water is unlikely to lead to least-cost outcomes and the efficient allocation of resources.

The Department will take the importance of price signals and incentives in water re-use decisions into account when reviewing the raw water pricing strategy.

5.4 Information to support sound decision making and implementation

The Department recognizes the important role that good information plays in supporting sound decisions. There are three aspects of information to consider: educating users with respect to the benefits and acceptance of water re-use; providing people who are considering water re-use with clear guidelines on how to implement water re-use projects, and sound methodology in the evaluation of options to balance water requirements and supply.

5.4.1 Methodologies for evaluating water resource development options

Water resource reconciliation studies undertaken for specific catchments and water systems in South Africa routinely consider conventional water supply augmentation options alongside water re-use, desalination and water conservation and demand management options.

The Department will continue to develop and refine the methodologies used to assess options to ensure that options are evaluated on a comparable basis and that the methodologies employed support sound decision making.

5.4.2 Guidelines for implementing water re-use projects

The Department will develop guidelines for the implementation of water re-use projects. These guidelines will support sound decision making and implementation. The guidelines will address the management and control, project implementation, choice of technology, operations and maintenance, project financing, development and implementation of tariffs and public and stakeholder education, engagement and consultation. Separate guidelines will be developed for different types of water re-use projects.

5.4.2.1 Technology selection

The selection and implementation of the appropriate treatment technology are key to the successful implementation of water re-use projects. It is strategically important to achieve this objective by:

- Selecting capable agencies/organisations with knowledgeable and competent staff to implement and operate re-use projects;
- Planning and executing the procurement of technology with the appropriate emphasis on functionality and proven performance;
- Ensuring that local knowledge of and support for the technology are available; and
- Providing technology guidance and training to re-use project implementing agencies/organisations.

5.4.3 Public education and awareness

The concept and implementation of water re-use will require a focused and sustained public education program to develop and entrench awareness of the different facets of water use and specifically water re-use.

Multiple awareness creation and information campaigns related to a spectrum of water related matters are launched by the Department, public institutions and private companies each year. It is important to develop and incorporate communication material related to water re-use into these campaigns.

Public perceptions and opinions vary on the topic of water re-use, specifically as it relates to indirect or direct water re-use. A structured communication strategy must be developed and implemented based on:

- An understanding of the diversity of perceptions and opinions
- Appropriate material to inform the public and stakeholders
- Active communication and debate on the topic
- Targeted media coverage

The overall objective of public awareness creation and information dissemination programs is to enhance the understanding and promote informed decision making related to water re-use. The current public perceptions and awareness of the poor operation, maintenance and performance of municipal wastewater treatment plants pose a specific challenge. It will be difficult to gather support for municipal water re-use within the current situation. The national efforts to address the poor performance of municipal wastewater and effluent treatment plants may have to show results on a consistent basis, before placing municipal water re-use onto the national water agenda.

5.5 Technology innovation and development

A range of water re-use projects have been implemented in South Africa (see Appendix A). South Africa has the potential to be a leading innovator in water re-use technology, particularly in the area of the treatment of acid mine drainage.

The Department will encourage the Water Research Commission (WRC) to make water re-use technology development a key focus area, and encourage the development of centers of excellence at selected universities.

5.6 Capacity to implement

5.6.1 Competent implementing agencies

Water re-use projects have many sophisticated technical, engineering, financial, operational and maintenance aspects. A key consideration to any such project is the fact that the water typically has to be treated to improve/upgrade its quality, before it is fit for re-use by a downstream user. The downstream user must be guaranteed an appropriate quality of water to protect designated use of the water. Re-use projects therefore require a high level of confidence in the implementation and operating agencies.

A public sector agency, such as a municipality or water board must have a minimum threshold of capacity and competency, (in terms of technical expertise, planning ability, project management capability, financial strength and rating), be a trusted water services deliverer and be accepted by the community and stakeholders as a reliable organization, before it can be considered as capable of implementing a water re-use project.

An agency/organisation must be able to demonstrate the capability to implement water re-use projects. It is therefore likely that the agencies and organisations with an acceptable capability and capacity profile to implement water re-use projects would be limited to metropolitan municipalities, water boards, some larger local municipalities, private companies specialised in the water sector and public private partnerships.

Private sector management, engineering and financing capacity related to water re-use, as demonstrated by several successful water re-use projects in mining and industry, is well established in South Africa. International interest in local water re-use projects has been expressed. The substantial private sector capacity must be leveraged in the implementation of water re-use projects.

The Department will investigate, together with established professional bodies in the water sector; the merits of establishing an industry-agreed evaluation/accreditation system for agencies/organisations implementing water re-use projects.

5.6.2 Developing the necessary skills for operating and maintaining water re-use systems

Water re-use projects will typically incorporate more sophisticated treatment technology and systems compared to conventional surface water and groundwater treatment. Such projects will fail unless trained, knowledgeable and motivated operations and maintenance staff is available. It is strategically important to implement the following actions:

- Prepare an assessment of the current and future skilled and trained people needed to operate water reclamation, water recycling and water re-use projects
- Encourage water services authorities and water services providers to consider and plan for the staffing and training needs to support water re-use projects, and
- Alert training and educational institutions in the water sector of growing needs for trained and skilled operations and maintenance staff.

The planning and implementation of water re-use projects must also include a comprehensive assessment of operations and maintenance aspects, including staffing, resources and system requirements.

5.7 Financing water re-use projects

Water re-use projects can be financed through the Municipal Infrastructure Grant, loans from development and commercial banks, project financing linked to public-private partnerships and through bonds issued by agencies such as the Trans Caledon Transfer Authority (TCTA). The waste discharge charges can also provide a source of funding for water re-use projects. This may specifically apply to indirect water re-use projects, where an upstream wastewater discharge containing residual waste is re-used by a downstream water user. The downstream user may have to implement relatively sophisticated and expensive water treatment technology and systems to produce water fit for use. The income generated by the waste discharge charge system may be applied to offset the incremental treatment cost associated with a re-use project.

Financing considerations are similar to those for other water resource development projects, except that the risk profile of the project may be different.

Tariffs can be applied specifically for different water re-use applications. Tariff setting may be subject to the National Water Act (Act No. 36 of 1998), the Water Services Act (Act No 108 of 1997), the Municipal Systems Act (Act No. 32 of 2000) and the Public and Municipal Financial Management Acts (Act No. 1 of 1999), depending on the specific application.

5.8 Enforcement

The performance of existing wastewater treatment plants in terms of meeting discharge standards and reliability is critical to the successful application of water re-use in South Africa. These facilities discharge water that impacts on the safety, economy and fitness for use by downstream users. Strict enforcement of discharge standards, and addressing the management and performance failures of municipal wastewater treatment plans is therefore critical to the future of indirect water re-use.

5.9 Recognition of success

South Africa has implemented a number of successful water reclamation and re-use projects in diverse sectors of the economy. It is also necessary to recognize water re-use as an important aspect of the efficient and responsible provision of water services. Consideration may in future be given to a "purple drop" recognition of safe and successful water re-use projects and operations, similar to the blue drop and green drop awards.

6 REFERENCES

1. Department of Water Affairs. Assessment of Ultimate Potential and Future Marginal Cost of Water Resources in South Africa. Report No. P RSA 000/00/12610, September 2010.
2. Department of Water Affairs. Integrated Water Resource Planning for South Africa. A Situation Analysis 2010. Report No RSA 000/00/12910.
3. Department of Water Affairs and Forestry. National Water Resources Strategy. First edition. September 2004.
4. Jimenez B & Takashi A (Editors). Water Re-use. An International Survey of Current Practise, Issues and Needs. IWA Publishing. 2008.
5. Tchobanoglous G. et al. Direct Potable Re-use – A Path Forward. Water Re-use Research. California. 2011.
6. Water Research Commission. A First Order Inventory of Water Use and Effluent Production by South African Industrial, Mining and Energy Generation Sectors. Report No. 1547/1/10, April 2010.
7. Water Research Commission. Wastewater Treatment in South Africa: From Crisis to Compliance. Report No. 8001/8295/3/P, August 2006.
8. Water Re-use Association. How to Develop a Water Re-use Program. Manual of Practice. 2009.
9. Wilson Z & Pfaff B. Religious, Philosophical and Environmentalist Perspectives on Potable Wastewater Re-use in Durban, South Africa.
10. Winpenny J, Heinz I, Koo-Oshima S, Salgot M, Collado J, Hernandez F & R Torricelli. The Wealth of Waste: The Economics of Wastewater Use in Agriculture. Food and Agriculture Organisation of the United Nations. Rome. 2010

APPENDIX A
Selected Water Re-use Projects in South Africa

Source of Reclaimed Water			Reclaimed Water User		Type or Re-use	
Water Services Authority	**Facility**	**Level of treatment**	**Institution/**	**Category of use**	**Planned / unplanned**	**Direct/Indirect**
City of Cape Town (Metropolitan Municipality)	Potsdam WWTP	Secondary, tertiary	Organization	Industrial, process water	Planned	Direct
Saldanha Bay Local Municipality	Urban Stormwater	Storage, infiltration	Chevron Refinery	Recharge of aquifer	Planned	Direct
City of Johannesburg (Metropolitan Municipality)	-	Secondary, disinfection	Kelvin Power Station	Industrial, cooling water	Planned	Direct
Rustenburg Local Municipality	Rustenburg WWTP	Secondary, disinfection	Platinum Mines	Metallurgical process and mining process water	Planned	Direct
City of Tshwane Metropolitan Municipality	Rooiwal WWT	Secondary, disinfection	Rooiwal Power station	Industrial, cooling water	Planned	Direct
eThekwini Municipality (Metropolitan)	Southern WWTP	Secondary, tertiary	Mondi Paper Company	Industrial, cooling water	Planned	Direct
Metsimaholo Local Municipality	Sasol 1 WWTP	Secondary trickling filtration	Sasol, Sasolburg	Industrial Process water	Planned	Direct
Emalahleni Local Municipality	Emalahleni Water Reclamation Plant	Advanced, disinfection	Emalahleni Municipality	Drinking and municipal water	Planned	Direct
Steve Tshwete Local Municipality	Optimum Water Reclamation Plant	Advanced, disinfection	Steve Tshwete Municipality	Drinking and municipal water	Planned	Direct
Steve Tshwete Local Municipality	Boskrans Wastewater Treatment Plant	Secondary, disinfection	Kanhym Feed Lots	Agro industry use	Planned	Direct
Lephalale Local Municipality Polokwane Local Municipality	Lethabo Water reclamation Plant	Advanced membrane treatment	Lethabo Power Station	Industrial, cooling water	Planned	Direct
Polokwane Local Municipality	Pietersburg Wastewater Treatment Plant	Secondary, disinfection	Platinum Mines	Mining and metallurgical process water	Planned	Direct
City of Johannesburg (Metropolitan Municipality)	Southern Wastewater Treatment Works	Secondary, disinfection	Water users along Middle Vaal River	Full Spectrum	Planned	Indirect
City of Johannesburg (Metropolitan Municipality)	Northern Wastewater Treatment Works	Secondary, disinfection	Water users along Crocodile West River	Full spectrum	Planned	Indirect
City of Tshwane Metropolitan Municipality	Zeekoegat Wastewater Treatment Works	Tertiary, disinfection	City of Tshwane via Wallmansthal Plant	Potable	Planned	Indirect
Msunduzi Local Municipality	Darvill Wastewater Plant	Secondary, disinfection	Umgeni Water	Potable from Inanda Dam	Planned	Indirect
Emalahleni Local Municipality	Wastewater Treatment Works	Secondary, disinfection	Loskop Dam water users	Mainly irrigation, but full spectrum	Planned	Indirect

Appendix B

Discussion Document: Constraints and opportunities related to direct and indirect re-use of water for domestic use

1 INTRODUCTION

The National Development Plan (NPC, 2011) charts a new development path to eliminate poverty and reduce inequality amongst South Africans by 2030. The plan contains a dedicated section on Water Resources and Services stating that "before 2030, all South Africans will have affordable access to sufficient safe water and hygienic sanitation to live healthy and dignified lives". This includes assuring water supply by investment and reuse in particular. The Department of Water Affairs (DWA) recently released the second version of the National Water Resource Strategy (NWRS 2, 2012) for comment. The NWRS2 adopts a more holistic approach towards water management, its availability and its use. More importantly, it defines water resources in a much broader context. It recognises that the possibilities for the development of additional large storage dams are limited and that other reconciliation options need to be implemented such as water conservation and demand management, groundwater, desalination, rainwater harvesting and water reuse. The NWRS2 contains a number of implementation and support strategies which includes Water Re-Use. The Draft National Strategy for Water Re-use (DWA, 2011) addresses the water re-use needs in the agricultural, municipal, industrial, mining and energy sector. The drivers are not the same for all sectors. However, the sectors can be clustered into 3 categories based on drivers: (1) industrial, mining and energy sectors; (2) agricultural; and, (3) domestic. Investment in the treatment and reuse of acid mine drainage water, industrial water and water used in the energy sector has already proven to be successful and is receiving dedicated attention through the Effluent and Wastewater Management Working Group (EWWM) of the Strategic Water Partnership Network (SWPN) announced by the Minister of Water Affairs in April 2011. Water re-use in the agricultural sector receives dedicated attention through the Department of Water Affairs and the research steered through the WRC's KSA 4: Water Utilization in Agriculture.

This Short Term Research Project focuses on the direct and indirect reuse of domestic treated wastewater. Used water can be treated to a standard fit for domestic use (drinking purposes). Treated water can be supplied directly to households (direct re-use) or be discharged back to the (fresh) water resource where it is blended with other water and subsequently abstracted, treated and distributed for use (indirect re-use). The intent of the National Strategy for Water Re-use is to encourage wise decisions relating to water re-use for all of these different decision makers. There are three important factors that can enable and support good decision making:

- A sound and clear policy and legislative framework, that is, decision-makers and water users know what their roles and responsibilities are, and what they can and cannot do.
- The benefits and costs are clearly understood, and prices and costs accurately reflect the relative benefits and costs between alternatives so that incentives are not distorted.
- Decision makers have access to relevant information and support to make informed decisions, with the necessary support and backup to implement water re-use projects.

With regard to the reuse of domestic wastewater for potable purposes, a focused and sustained public education program will need to be developed and entrenched. The overall objective of public awareness creation and information dissemination programs is to enhance the understanding and promote informed decision making related to water re-use.

The WRC recently published a document that details the perception of South Africans regarding drinking water quality and is currently funding several projects related to water re-use:

- K5/2121 – Investigation into the Cost and Water Quality Aspects of South African Desalination and Reuse Plants (SSI Engineers and Environmental Consultants)
- K5/1894 – Wastewater Reclamation for Potable Reuse (Umgeni Water)
- K5/2208 – An investigation into the social, institutional and economic implications of reusing reclaimed wastewater for domestic application in South Africa (Cape Peninsula University of Technology)
- K5/2212 – Monitoring, management and communication of water quality and public acceptance in the direct reclamation of municipal wastewater for drinking purposes (Chris Swartz Water Utilisation Engineers)

In order to move ahead incrementally in implementing direct and indirect water reuse for potable purposes, there needs to be a common understanding of the current knowledge gaps and the short, medium and long term interventions that are required to give momentum to the implementation of water re-use projects for domestic use. This draft discussion document provides some background which feeds into the final deliverable titled: "Implementation plan for direct and indirect water re-use for domestic use – Sector Discussion Document". A well-structured plan is required for the sector as a whole as we have already experienced fast tracked re-use interventions in the absence of a clear regulatory framework such as the Beaufort West Direct Water Reclamation Plant. The plan will assist towards planned and progressive implementation of direct and indicted water re-use for domestic use written in the context of the other re-use initiatives taking place in the other sectors.

The aim of this short term project is to develop a plan to bridge the gap between the strategy and implementation of water re-use for domestic water use in consultation with the Department of Water Affairs and the WRC.

2 APPROACH

International practices were compared to the strategic intent detailed in the Draft National Strategy for Water Re-use (DWA, 2011). China, India, Australia, Singapore, Israel, United States of America (USA) and Namibia were selected based on the following attributes:

- Developmental state – China and India selected to represent developing countries with a large gap between rich and poor and characterised by high economic growth forecasts;
- Leaders in water re-use and water use efficiency – Singapore, Israel and Namibia were selected based on the historic and published track record;
- Climatic similarities to South Africa – Australia, Israel, Namibia and the USA;
- Advanced environmental policies – Australia and the USA;

The re-use guidelines and current practices were assessed to unpack, for the different countries:

- The drivers and incentives for re-use;
- What the reclaimed water is used for;
- What the international re-use trends are;
- The policy and legislative environments;
- Guidelines for decision making tools developed;
- Water quality standards for reuse;
- Public education and awareness programmes;
- Financing reuse projects; and,
- Research and development programmes.

3 REVIEW OF INTERNATIONAL PRACTICES

3.1 Drivers for re-use

The drivers for the re-use of treated wastewater are mostly driven by water security which is threatened by available water resources, population growth, access to water and climatic conditions. In South Africa, the main driver is water security. South Africa has a limited supply of water with an uneven distribution thereof countrywide, in regions which range from semi-desert to tropical. The rainfall is also highly variable, with frequent severe water shortages. Intensive industrial and urban development aggravates this problem, creating a vital need for water reuse in the country. It is estimated that the population growth is 2.4% per year. This means that the water demand is likely to exceed available water resources soon after 2020. Water reuse and recycling is thus an undeniably necessary alternative to fresh water use. Research of 2004 revealed that over 1000 water treatment plants exist throughout the country, and it was estimated that only 3% of this water was reused. There is thus large capacity for reuse in the country (EPA, 2004).

3.1.1 China

The main driver for water reuse in China is due to the water crisis in the North East of China. According to a report completed in 2005, an estimated additional 52 million m^3/d will be required from non-traditional sources by 2015. The only way to fulfil this requirement is to transfer water from the south to the north, with an essential alleviation of this massive task by water reuse and recycle in the water scarce regions.

Another important driver for water re-use and a general water strategy in China is for National Security. Water scarcity in China is a huge threat to its farmers, impacting food stability and social stability, especially in Northern China. Continued water scarcity and instability will threaten the investment of foreign and domestic companies into the country, further reducing development of treatment facilities. The water problem in China also affects the public health, as an estimated 300 million people lacked access to drinking water in 2004 (Shalizi, 2006). The damage already done to the biodiversity and ecology in the country is another major driving force to reduce pollution and promote water reuse. An increase in sustained water treatment infrastructure and operation and maintenance will provide strength to China's social and economic security (Hu, 2010).

3.1.2 India

Only about 72% of the 17 million m^3 of wastewater generated annually in India is collected. However, less than 25% of the collected sewage is treated. Sewage farms irrigating salad crops with low quality wastewater are prevalent even though this is forbidden. As a result, the number of waterborne disease cases in the country is very high. Industrial wastewater is treated, sometimes even by reverse osmosis, but tertiary treatment of municipal wastewater is rare (Crook, et al., 2005).

India lacks any policy on water reuse or recycling. A large portion of the freshwater used in the country is used directly for non-potable purposes. In some cases, 75% of the domestic supply is used for toilet fixtures alone, according to the Centre for Environment and Development (CED, 2011). At present, wastewater management is focused on wastewater disposal instead of reuse or recycle. There is an ever-increasing population in urban areas (Delhi's population increased from 9.4 million in 1991 to 16.3 million in 2011 – (IWA, 2012)), with an increase in pressure on the existing water resources. The water scarcity is made worse by the geographical and economic constraints in some cities. As a result, reuse would be a highly desirable addition to water management in the country.

3.1.3 Australia

Australia carries out recycling and reuse of water extensively across the continent. The main driver for water reuse and recycling is population growth and its associated effects, coupled with a decreasing reliability from traditional rainfall-dependant water supply sources. A report written in 2006 stated that Australia had a drought lasting 10 years, affecting nearly the whole country, and the drought had intensified in the last two years (DTI, 2006). Both floods and droughts take place in Australia, and due to this, most urban water supply planners now incorporate alternative water supplies into future plans. Policies and jurisdictions aim to promote water recycling, and the feasibility of a target of recycling 30% of national wastewater by 2015 is currently being explored (Whiteoak, et al., 2008).

3.1.4 Singapore

Singapore's water reuse driver is political. Singapore consists of a small land mass which is highly populated. In the 1960s, Malaysia committed to sell water to Singapore, accounting for all of the country's demand. However, the agreements run to 2011 and 2061, respectively, with the problem of forming a new agreement for a new price for future water supply, which the respective governments cannot agree to. As a result, Singapore has decided to become self-sufficient, reusing and recycling all of its water, with an additional supply of water by a desalination plant (DTI, 2006).

3.1.5 Israel

Israel is one of a number of countries facing high risks in water scarcity. This means that the major portion of the renewable water resource is withdrawn annually. Israel also faced a number of droughts between 1996 and 2002. As a result of this, a large number of water reuse projects were started in order to use urban waste water from major cities and towns to irrigate crops. Now Israel is able to support its population, industry and irrigation demand with a water supply less than a quarter of the benchmark value for water stress (EPA, 2004).

3.1.6 USA

Water scarcity is a growing issue in the southern and south-western parts of the U.S. Water reuse is presenting itself as an increasingly popular solution to this problem, despite related costs. It is also a solution which supports many of the stringent environmental regulations in the country, which are currently preventing the use of other options such as desalination in California. However, certain regulations still rend the use of non-traditional water sources very limited (GWI, 2005).Growing populations in urbanised regions are also driving city planners towards water reuse and recycling solutions in order to support existing water supplies.

3.1.7 Namibia

A large portion of Namibia is desert, including the area around its largest city, Windhoek. In 1960, the already low rainfall lowered to below 300mm/year, forcing the country to take necessary steps in order to supply enough water to fulfil the city's demand. The solution to this problem included transporting water from the eastern parts of the country, building a large local surface reservoir, and the construction of a large water reclamation plant, which treats all sewage and industrial water from the city. Windhoek remains the only example of direct potable water reuse globally (EPA, 2004).

3.2 Current application of water reuse

Many countries group their water re-use in terms of municipal, industrial, planned potable, unplanned potable, and other such categories, and have limited data on rural water reuse. **Table 1** provides an indication of the re-use applications for the selected countries (Friedler, et al., 2006). Namibia seems to be the only country in the world which practices direct planned potable reuse of municipal wastewater. Most of the other countries practice indirect water reuse, but in the majority of these cases, this indirect reuse is unplanned, or occurs due to groundwater recharge and then reuse. Singapore is the only country which practices large-scale planned indirect reuse of wastewater.

Table 1: Reuse sectors by country

Country	Irrigation	Urban		Rural		Industrial	Mining	Power Generation
		Potable	Non-potable	Potable	Non-potable			
Australia	x	Indirect	x	Indirect	x	x	x	x
China	x	Indirect	x	Indirect	x	x		x
India	x	Indirect	x	Indirect	x	x		
Israel	x		x		x			
Namibia		Direct	x		x	x	x	
Singapore	x	Indirect	x			x		x
South Africa	x	Indirect	x	Indirect	x	x	x	x
USA	x	Indirect	x		x	x	*	x

* No data available

Israel reuses 75% of its municipal waste water (Friedler, et al., 2006). However, all of this waste water is used for irrigation and some other minor non-potable applications. All potable water emanates either from freshwater or desalinated water. It must be noted, however, that internal recycling has not been accounted for. This table only considers the nature of water sources.

3.3 Reuse trends per sector

3.3.1 Irrigation

In many areas of the world – China and India included – the use of treated and untreated sewage and wastewater is a common practice. In some poor areas, even when other water sources are available, farmers prefer to use wastewater due to its nutrient content, which reduces or even eliminates the need for expensive fertilizers. Developed countries, such as the USA and Australia, view irrigation with untreated wastewater as unsafe. However, treatment may be too expensive for countries such as India, and reuse for agriculture in this situation is preferable to uncontrolled discharge of waste into water courses.

A pioneer for water reuse for agricultural purposes is Israel, which currently treats and reuses 75% of its municipal wastewater for irrigation. This, despite a massive population growth due to immigration, is a great achievement, and offsets the huge agricultural demand for water. The long-term effects of irrigation with wastewater is also being investigated and monitored in Israel. There are fears that possible increases in concentrations of salts, such as bromide, may occur, and efforts are thus in place to treat the wastewater to ensure this does not happen (Vigneswaran & Sundaravadivel, 2004).

Public opinion of usage of treated wastewater for irrigation is generally positive, and this form of water reuse is thus highly abundant in developed countries, especially due to the enormous water demand of the agricultural sector.

3.3.2 Urban

Collection and disposal of wastewater in the urban environment has always been a large financial and management burden to cities. The collection systems (sewers) need to be installed and maintained. Added to this, is the treatment costs of the waste water. Many poorer countries are still at the stage of trying to collect their sewage, and are a long way away from the point of reclaimed water use for toilet flushing, for example.

However, reclaimed water reuse is used extensively in more developed countries. For example, in Tokyo, reclaimed water is used for toilet flushing, offsetting the potable water requirement by about 970 000 m^3/year (Nolde, 1999). Reclaimed water use for city park, golf course and sports ground irrigation is commonly practiced in cities in the United States, Europe, Australia, and in South African cities such as Cape Town. In Australia, the use of reclaimed and recycled water is highly developed, with entire estates and complexes functioning on dual reticulation systems, using reclaimed water for toilet flushing, garden watering, and other non-potable applications.

Another example of urban water reuse is for wetland conservation and development of recreational water courses. In Kolkata, India, a wetland system is used to treat and polish waste water while also preserving the ecosystem and supporting wildlife. The wetlands on the eastern periphery of Kolkata take up an area of 2 500 ha, which treats a combined flow of sewage and drainage. These wetlands are made up of fisheries with inlet and outlet sluice boxes for periodical wastewater sewage feed exchange from the city's drainage canal system (Ghosh, 2013).

Windhoek, Namibia, is a unique city in terms of urban water reuse. It is the only city which incorporates direct waste water reuse into the city reticulation system. This water is supplied to the city at a ratio of 1:3.5 to the fresh water taken from the nearby Goreangab Dam and from boreholes (Van der Merwe, 1998). This water is then used for all purposes, including potable and industrial use.

3.3.3 Rural

The extent for water reuse in rural households is generally greater than in urban households, since waste water from these households must be treated on-site, and adding or adapting an existing treatment system to allow reuse may not be very expensive. Greywater reuse is also a method of reducing the overall potable water expenditure, especially where there is a large garden or areas of land which need irrigation.

Australia is a good example of how individual households contribute to the general management of water resources. Many houses have separate water reticulation systems for potable and non-potable use, and incorporate recycling systems, in order to use as much reclaimed water as possible. In the dryer regions it is common to find every house with its own rainwater collection dam to be used as an additional water source.

In other countries, rural water reuse examples are very specific to small communities, such as rural schools (Tare, 2011), lodges (Van der Merwe, 1998) or to individual farm irrigation systems. Developed countries with a reasonable supply of freshwater resources have limited rural water reuse. This is the case with North America and Europe. However, other countries with more limited water resources try to reuse water to a far greater degree. For example, Tunisia sends treated wastewater from urban areas to the arid rural areas to be used for non-potable applications and for irrigation. Egypt is expected to follow suit, as it is unable to expand its renewable water sources (WB, 2011).

South Africa applies indirect water reuse throughout its rural areas due to the way in which the water system is managed. All water treatment plants and water users are expected to treat their waste water (or send their waste water to be treated), before disposal into river systems. Rural areas downstream then reuse this water, often as their primary water source.

3.3.4 Industrial

In developed countries, industry accounts for 50-80% of the total water demand, and still has a substantial effect in agriculture-dominated countries, where it makes up 10-30% of the total water demand, and this also is certain to increase (Visvanathan & Asano, 1999). Reusing and recycling wastewater is an attractive alternative and helps to conserve freshwater resources for future generations. It also reduces the amount of effluent to be treated, and thus reduces treatment costs. Many industries are also currently concentrating on methods to reduce the use of potable water as this is becoming an expensive resource.

Wastewater reuse began in the United States in the 1940s when chlorinated domestic wastewater was used for steel processing. Since then, reuse and recycling of water in industry escalated throughout the USA and Europe, and lately also in Asia and other parts of the world. In 1989, the average rate of industrial water reuse in China was 56% (Asano & Visvanathan, 2001).

The reuse and recycling of water in industries is very common. Although reused water may cause problems such as scaling, corrosion, slime formation and foaming, all of these problems have known solutions. Problematic characteristics are also easier to resolve if streams are treated at the exit of the process. In other words segregated stream treatment, instead of combined stream treatment, is easier and cheaper to treat since specific wastes can be removed and possibly recovered while avoiding possible solutions of species which are difficult to separate. In general, the main industrial water reuse applications are for cooling and boiler feed. Cooling water recycling is easy to achieve by simple engineering modifications, and the effluent water does not require extensive treatment. Other major areas where water may be saved by reuse and recycling, is in industries where large volumes of diluted process streams are used. This is the case for the steel industry and paper and pulp industry. Sappi Pulp and Paper Group's Enstra mill and Mondi Paper Mill at Piet Retief are two instances in South Africa where major water savings have been achieved by recycling and using reclaimed water (Jimenez & Asano, 2008).

3.3.5 Mining

In most countries, mining is a relatively small water user compared to agriculture and other industries. However, it may well be the largest water user in a specific watershed (for underground water users) or any other specific water source. In addition to this, mines may produce highly contaminated effluent. Future mining operations are also located in many regions with growing water challenges, such as Australia, Chile and South Africa (Miranda & Sauer, 2010). In some countries, water shortages are becoming severe enough to result in major effects on the mining companies. For example, in Chile, Xstrata's Collahuasi mine operation was asked to reduce its water usage to approximately a third of its original usage during 2010 (Boccaletti, et al., 2010), forcing it to consider desalination, shipping in of water and/or methods of water reuse and recycling. Another problem with mining is that any accidental spillage can have major effects, and this produces a general distrust of mines in the general public opinion. As a result, mines are going the extra mile to ensure safe mining and to incorporate measures such as reuse and recycling of water and other resources to improve public opinion and to reduce their effect on the surrounding environment.

Acid mine drainage is a major problem in mining, as it comes hand in hand with the mining of pyrite and sulphide ores, which is the most prevalent ore in gold, coal, copper, zinc and lead mines (Miranda & Sauer, 2010). It is the responsibility of mines to prevent and treat acid mine drainage. With the growing water shortages worldwide, it will become common practice to use treated acid mine drainage as a source of water in the mines, along with water reuse and recycling.

3.3.6 Power generation

There are two major types of power generation plants: steam power and nuclear power. Steam power plants require large amounts of water as cooling water, boiler water and coal drainage. Nuclear power plants require water in the processing of ores, research lab wastes, processing fuel and power plant cooling water. In both cases, cooling requires a large amount of water. But this water can easily be recycled with some treatment, and reclaimed water can be used for any additional make-up, since the water quality required is not high. Many plants around the world use reclaimed water such as treated sewage for boiler feed water or power plant cooling, and thus save on costs. For example, in 1995, 20.74 billion litres of water was conserved in Ponhandle and the South Plains of Texas, by reusing wastewater in this way and treating it with lime softening to prevent scaling (Visvanathan & Asano, 1999).

3.4 Policy and legislative environment

3.4.1 China

There is no separate law regarding reuse/recycling of water. Reuse has been mentioned in a number of environmental, resource, and economic laws and regulations. However, the absence of a well-established framework leads to an overlap of responsibilities and limited supervision, and implementation of reuse projects is difficult in such a situation, according to the Water Partnership Program (WPP, 2011).

At present, direct regulation through command and control measures play the most important role. However, incentive-based and market oriented measures such as taxes and levies are gradually being introduced to a larger extent. An example of current laws and regulations include tax reduction awarded to companies in the "Comprehensive Resource Utilization List"; products created through comprehensive utilization processes are exempt from taxes for a period; and wastes that could not be reused or recycled by enterprises must be offered free to other enterprises for reuse or recycling. Enterprises which execute waste reuse projects that have no economic benefit to the enterprise are also to be given favourable treatment through loans from business banks, with postponed deadlines for payment (Wang, 1995).

Article 11 of the amended Water Pollution Prevention and Control Law stipulates that relevant people at all levels should make a rational plan for conduct rectification and technical transformation of enterprises that have caused water pollution, and to adopt measures for prevention and control, raising water recycle rate, integrated resource use, and reduction of discharge and pollution. However, no incentives or levies have been set by this Law (Wang, 1995).

In the rural sector, when it comes to actual planning, development, construction and running of water treatment plants and reuse schemes, the burden lies on the shoulders of municipal and village government institutions, and non-government organisations (NGOs), to implement (WPP, 2011).

3.4.2 India

India does not provide any guidelines or policies to address wastewater reuse (Panchal, 2012). However, there is a National Urban Sanitation Policy (NUSP) and a National Water Policy (NWP), which affect potential wastewater reuse. The NUSP mentions the reuse of wastewater as an important factor in environmental protection in urban areas, and also recommends a minimum reuse of 20% per city. The NWP mentions it in terms of a method of meeting water requirements, but it gives no clear guidelines for wastewater reuse except by the indirect promotion of alternative water sources by its strict control over any further deterioration of already exploited groundwater sources.

Another problem with India is that it does not have any separate laws dealing with all water sources and related aspects regarding use of water sources. Neither does it have any legal framework with regards to water rights. All legalities regarding water are spread out among other legal frameworks and policies (Panchal, 2012).

3.4.3 Australia

The National Water Commission implements the National Water Initiative (NWI) and the Australian Government Water Fund. The National Water Initiative is an inter-governmental agreement aimed to increase the efficiency of Australia's water use. The Water Fund provides financial support to water projects that meet the objectives of the NWI (DTI, 2006).

Documented rules and regulations, given by the government, based on water pricing, institutions, irrigation systems, water allocation and entitlement are implemented at the state and federal level. The National Water Quality Management Strategy includes a series of guidelines, such as the Guidelines for Sewerage Systems and Effluent Management. The National Water Policy includes targets with time frames for effluent use, storm water retention and pollution removal. A Cabinet White Paper was released in 2004 by the Victorian government with the aim of securing the State's water assets over the next 50 years. This includes reuse and recycle of water (Mekala, et al., 2008).

Individual States also provide guidance on water reuse and recycling. For example, there are three main organisations or groups in Victoria, one of the front-running States in Australia, that are responsible for wastewater recycling: Environmental Protection Agency (EPA), Department of Human Services (DHS) and the council or local government (Mekala, et al., 2008). The EPA is responsible for developing and applying best practice guidelines for reclaimed water use. The guidelines are written in detail, looking at the topics of reclaimed water, environmental, social and economic factors, with desired results, risks, practices and monitoring required for each of these factors. Every wastewater reuse project requires the approval of both the Department of Human Services and the EPA, and the EPA must be able to show that appropriate measures are in place to make sure the guidelines are being adhered to, before commissioning takes place. The EPA also undertakes audits and reviews for continuous improvement of the guidelines.

The DHS is responsible to make sure Class A water is indeed Class A water. It makes sure that reuse schemes do not pose a risk to public health. All treatment plants must refer to the DHS for validation before their treated water can be used. Council and local government controls land use and size of infrastructures. Any developments which will use recycled water require consent from the council.

3.4.4 Singapore

Singapore has a strong government, whose support of the Four National Taps Strategy has enabled the water reuse scheme to go ahead. The first tap is the supply of water from local catchments, the second tap is imported water, the third tap is NEWater – drinking water-quality water produced by wastewater purification – and the fourth tap is desalinated water. The strategy is to increase the portions of the first, third and fourth taps.

Previously, there was a Public Utilities Board (PUB) and a Ministry of Environment, which managed water and sewage separately. The new Ministry of Environment and Water Resources (MEOWR) now has full responsibility for any water and wastewater related affairs, including policy formation and planning. The PUB is now under the new MEOWR and includes management of sewage and flood control. This causes implementation to be effective and efficient, according to the World Bank AAA Program (WB, 2006).

Singapore has a complete and clear environmental legislative system and strict implementation. Regulations include the following:

- Environmental Pollution Control Act, with effluent discharge limits of a very large number of chemicals and water properties
- Environmental Public Health Regulations, with legislated controls specified for different toxic industrial wastes
- Sewerage and Drainage Act, which gives PUB full responsibility for all sewer and drainage related matters
- Public Utilities Act, which specifies the PUB's responsibilities
- Public Utilities Regulations, which among other things makes water metering and water saving devices mandatory.

3.4.5 Israel

There are a number of legislations, standards, and guidelines which deal with water and wastewater reuse. The following list is taken from Jimenez & Asano (2008).

- Drainage and Flood Protection Law (1957) states that water projects have priority over other projects
- The Water Law (1957) states that wastewater is a water resource, and water resources are public property controlled by the state
- Public Health Law (1973) states that the Minister of Health will control treatment of wastewater to be used for irrigation
- Public Health Law (1981) restricts the list of allowed crops to be irrigated by wastewater, and states that all reuse projects require a permit
- Public Health Law (1995) dictates that all towns with population >10 000 must treat its effluents to BOD < 20 mg/L and TSS < 30 mg/L
- The Halperin Commission (1999) sets the public health requirements for wastewater irrigation according to the Californian standard
- Several rules and standards are added to reduce the salts concentrations in waste water.

A problem with the Israeli legal framework is that there are many institutions involved in wastewater reuse, which results in overlapping of responsibilities, both between Ministries and between central (Ministries) and local (municipalities) agencies. Some inter-ministerial commissions have been created to overcome these problems.

3.4.6 USA

The Environmental Protection Agency (EPA) produced a document in 2012 titled "Guidelines for Water Reuse", updating the previous version of this document, written in 2004. Prior to the first production of this document in 1992, there were no federal regulations governing water reuse. Separate states also have their own sets of rules and regulations for water reuse to best suit individual state requirements. In several states, water reuse is included in the law, and is thus enforceable, however in other states there only exist guidelines, which are not enforceable but provide the certainty that if a project meets requirements set out in the guidelines, it will be permitted (EPA, 2012).

The new EPA water reuse guidelines stipulate that all water reuse regulatory programs must work within the prevailing water rights. In the United States, there are two types of water rights: appropriative rights in water-scarce areas, and riparian rights in water-abundant areas. Appropriative rights are based on the precedence of which users first laid claim to specific water. Riparian rights are based on the water user's proximity to water sources and are obtained by land purchase. What this means is that water reclamation facilities generally have first rights to the use of the reclaimed water, with some exceptions given by the reuse Guidelines.

Each separate state may set its own standards and conditions for water supply. These may include supply or water use restrictions or credits associated with reclaimed water use. Each state may set its own method of enforcement, including fines, disconnect of service, or jail time. However, the National water use rights may neutralise these penalties, which means that although rules and regulations are set out, there is a large chance that they are not adhered to at all.

The 1972 Clean Water Act encourages water reuse, although it is not specifically stated. The Clean Water Act sets out minimum requirements with the goal of making all surface waters "fishable and swimmable". It controls the concentration as well as total mass of pollution discharged into surface waters, thus indirectly supporting water reuse.

The Safe Drinking Water Act sets out drinking water source standards, as well as setting requirements for source water protection. This Act also requires each state to assess all of its drinking water sources, making it easy to identify contamination and thus become a method of enforcing entities to discharge at the required quality standard. Some states have also set laws that require new developments to have sustainable water management plans, which encourage water reuse.

The Reuse Guideline document itself provides guidelines for different categories of water reuse, thus giving a clear direction for water reuse projects.

3.4.7 Namibia

The Ministry of Agriculture, Water and Forestry is responsible for all management and regulation of the water cycle and water resources in the country. Under this Ministry, the Directorate of Rural Water Supply (DRWS) was established to be in charge of rural water supply and management, while the bulk water supply was positioned under the control of the state owned Namibian Water Corporation Limited (NamWater). The Ministry of Agriculture, Water and Forestry's Water Supply and Sanitation Policy (MAWF, 2008) suggested that sanitation be transferred from the Ministry of Health and Social Services to the Ministry of Agriculture, Water and Forestry, and that the DRWS be put in charge of this, with a name change to 'Directorate of Water Supply and Sanitation Coordination'. This institution would then not only be responsible for the supply of water, but also for ensuring that sanitation meets the requirements for health and hygiene countrywide.

There are many poor and marginalised people living in Namibia, who have limited or no sanitation, and where water supply is limited. Provision of water and sanitation is thus under the control and supervision of government, with the responsibility of outsourcing services where necessary and appropriate. The Water Supply and Sanitation Policy also states that the cost of services increases as the standards of living increases. The government is also responsible to provide information and education on environmentally sustainable development and efficient utilisation of resources (MAWF, 2008). This type of education will likely also result in the increase of water reuse applications, as this is a method of sustainable and efficient resource use. In addition to this the Policy states that the water tariff structure should encourage “dry sanitation or systems that conserve water and reduce wastage or that reuse or recycle waste water.”

According to Neumann (Neumann, 2013), Integrated Water Resource Management is being used in Namibia, resulting in sustainable and efficient use of water by all, with little conflict.

3.4.8 South Africa

In South Africa, there is no objection to the reuse of grey water or treated effluent provided it is permitted and monitored by the relevant authority. The following documents provide guidelines and regulations regarding water reuse.

- Government Gazette No. 9225, Regulation 991: Requirements for the purification of wastewater or effluent
- Latest revision of the Water Services Act of 1997 concerning grey-water and treated effluent
- National Water Act of 1998, concerning irrigation of land using wastewater
- The South African Guide for the Permissible Utilisation and Disposal of Treated Effluent (1978)
- The South African Water Quality Guidelines (1996)
- Department of Water Affairs Guidelines for permissible use of wastewater sludge (2006)
- Guidance for use of greywater in gardens and small-scale agriculture (2010)

The 1978 Guide for the Permissible Utilisation and Disposal of Treated Effluent is more than 30 years old and, according to (Ilemobade, et al., 2009), promotes “no potential risk”, which requires extensive treatment, which may be too expensive for lower-income households.

The water quality standards and policy regarding water use, treatment and reuse are extensive and often more stringent than international standards. As a result, it is often too costly to develop water reuse projects. Other problems with the system include fragmentation of responsibilities for sanitation at national, provincial and local levels, low revenue collection, inadequate capacity of the Department of Water Affairs and other water institutions to drive programs, and resistance towards using the private sector in water management and service delivery (Viljoen, 2012).

On the other hand, high water quality standards also encourage industries to reuse and recycle water internally to lower the rate of water discharge, and thus reducing costs in procuring and treating water.

3.5 Tools for decision making

3.5.1 China

Quality requirements have been established to regulate the use of reclaimed water. The government decree, Urban Wastewater Reuse Category (GB/T 189198-2002), divided wastewater reuse into five categories, and provides national standards for each. These are as follows, taken from Yi, et al (Yi, et al., 2011):

1. Urban Wastewater Reuse Water Quality Standard for Urban Miscellaneous Water (GB/T 18920-2002), which specifies water quality, sampling and analysis methods involving urban miscellaneous water.
2. Urban Wastewater Reuse Water Quality Standard for Scenic Environment Water (GB/T 18921-2002), which specifies water quality and use for landscapes.
3. Urban Wastewater Reuse Water Quality Standard for Industrial Water (GB/T 19923-2005).
4. Urban Wastewater Reuse Water Quality Standard for Groundwater Recharge (GB/T 19772-2005).
5. Urban Wastewater Reuse Water Quality Standard for Farmland Irrigation water (GB 20922-2007).

Standards were further established to assist enterprises and systems to implement the urban wastewater reuse plan. These standards are as follows (taken from Yi, et al., 2011):

1. Municipal Wastewater Treatment Plant Construction Quality Acceptance (GB 50334-2002)

2. Code for Design of Wastewater Reclamation and Reuse (GB 50335-2002)
3. Architecture Design for Reclaimed Water Systems (GB 50336-2002)

These standards were created in order to normalise technical data in order to develop functioning wastewater treatment and reclaimed water systems nationwide with improved reliability and performance.

Further, an integrated reclaimed water reuse plan and a comprehensive regulatory framework are still needed regarding licencing and/or authorisation of reuse projects. No clear regulations are available to provide clear guidelines in implementing and managing reclaimed water reuse projects, and neither do clear rules about distribution and uses of reclaimed water exist.

3.5.2 India

Although water reuse is encouraged, there are no specific guidelines aiding those who desire to incorporate water reuse and/or recycling. The way in which the legal frameworks are set out, it is preferable and more profitable for companies to use freshwater instead of recycled water. It is also preferable to use untreated sewage for irrigation regardless of its detrimental health effects. Policies must be changed before safe wastewater reuse can be properly implemented.

3.5.3 Australia

In Australia, the largest resistance to wastewater reuse is the cost of infrastructure, and the lack of financial incentives (Mekala, et al., 2008). The presence of guidelines is not lacking and access to technical knowledge is abundant. There are clear codes and guidelines to follow for those who wish to embark on wastewater reuse schemes. In order to obtain licencing or authorisation of reuse projects, the council or local government must be approached for consent. Hereafter, the rules and regulations of the particular state must be followed. However, the national laws and regulations given by the National Water Policy and the National Water Quality Management Strategy will provide a guideline on how the reuse project should be undertaken, since these guidelines are agreed to by the different states.

3.5.4 Singapore

Water reuse is strictly controlled in Singapore. In fact, reuse is applied in all parts of Singapore through its NEWater tap. Contrary to requiring authorisation for reuse projects, authorisation is required for using any water from any reservoirs and streams (WB, 2006). The Department of Technology and Water Quality is in charge of the planning, evaluation, testing and budget management for new projects (WB, 2006), and is likely the go-to for those wishing to start a large water reuse project. It is however to be expected that the strict effluent discharge regulations and cost of freshwater would encourage industries and individual users to invest in water reuse and recycle as much as possible.

3.5.5 Israel

Israel has a very tight system operating between farmers, technical people and decision-makers. Farmers are commonly found in Kibbutzim, which are small groups of people who work together. These farmers commonly use the same main source of both potable and recycled water, and work together to distribute these resources to best suit the Kibbutz. Farmers, people with technical expertise, and decision-makers meet together annually to determine problems, share knowledge, and find solutions (Mehrel, 2009). In this way, any new reuse projects can be encouraged or discouraged based on the support of the surrounding community and countrymen.

In terms of legislation, wastewater is seen as a resource, and wastewater reuse is widely applied in the country. In terms of wastewater reuse for agriculture, the Ministry of Health is responsible for all reuse applications, and would have to be applied to for a permit. Wastewater reuse for potable purposes is not widely accepted in Israel. Desalinated water is preferred for this application (EPA, 2004).

When it comes to water quality required for reuse projects, the water quality standards in Israel are not only guidelines, they are law, and are strictly regulated. There is thus no discrepancy or confusion about these requirements.

3.5.6 USA

The USEPA has provided a clear national level water reuse guideline document which stipulates how reuse projects must be undertaken. This document states the water quality requirements for all reuse categories, additional requirements such as monitoring and storage, and also gives the general background of water reuse in America and in each of the individual states. This guideline also gives information on treatment technologies and project funding.

The National Environmental Policy Act requires an environmental impact assessment for all projects receiving federal funds. Some states have such a requirement, but for all projects prior to construction. Some of these requirements include public review (EPA, 2012). Depending on the project, it may require permitting by multiple agencies. It is thus dependent on each state to consolidate regulatory requirements for integrated water management systems and water reuse projects in order to make them possible or easier to achieve.

3.5.7 Namibia

Within the City of Windhoek, reclaimed water is already added to the potable water supply system. However, the high tariffs and public awareness encourages water reuse and recycle within industry and other entities around the city. However, when it comes to water reuse projects, there is greater scope outside of the city limits. In these areas there is little government control, especially on farms and plots which make up most of Namibia. In these areas, farmers are able to design and construct their own water reuse and recycle systems as they desire, with limited supervision. Due to their knowledge of water scarcity, and the enormous cost of trucking in water from cities, farmers will do all within their power, knowledge and funds to make sure water supply is as reliable as possible on their farms. Case studies of mines and lodges exist, which incorporate water reuse and recycling in order to reduce their freshwater use without limiting production (in the case of the mines) (Van der Merwe, 1998). Absolute guidelines aiding those that are willing to incorporate reuse and recycling are however lacking in Namibia.

3.5.8 South Africa

South Africa has extensive laws and guidelines regarding water use and reuse applications, and quality required for the use of water. The list of these rules and guidelines can be found in section 5.1.8. Water reuse and recycling is highly encouraged within all operations. For example, in waste permits, it is required that opportunities for waste minimisation, recycling or reuse be identified. These wastes also include wastewater (Oosthuizen & Armstrong, 2009). Only use and discharge of water and wastewater is regulated, thus allowing freedom within a process to reuse and recycle waste water.

There are extensive guidelines on water use and waste management licensing. For example, any extraction of water requires a licence from the Department of Water Affairs and Forestry (a Generic Water Use Authorisation Application Process guideline is available); non-hazardous waste management requires a basic assessment process before a license is considered, while hazardous waste requires a scoping process, and an environmental impact report. Also, The Water Conservation and Water Demand Management Guideline (WC/WDM) provides detailed information, aid and regulations on how water should be managed (Wimberley, 2011). These guidelines reflect a shift in focus from water supply management to water demand management.

3.6 Water quality standards for reuse

3.6.1 China

There are four categories of water: surface water, ground water, irrigation water and water used for fisheries. Each of these categories has their own Water Quality Standards document. There is also a wastewater discharge standard. These documents are only available in Chinese.

3.6.2 India

There are no set water quality standards for reuse in India.

3.6.3 Australia

Water quality in Australia is divided into classes A, B, C and D. Class A is the highest rating for recycled water use for non-potable purposes, and exceeds the limits provided by the World Health Organisation, and can be used for irrigation of crops eaten raw. Class D water can only be used for woodlands and flowers irrigation. Although this class of water is not dangerous for use in primary industries, the salinity and mineral content may cause a build-up of concentrations of unwanted substances over time, thus reducing the available applications of this class of water.

The water quality classes are summarised in the **Table 2**, as shown by (EPA, 2003)

Table 2: Water quality classes in Australia

Water Class	**Water quality objectives**	**Range of uses (higher class includes all lower class uses)**
Class A	<10 *E. Coli* org/100 mL Turbidity <2 NTU <10/5 mg/L BOD/SS pH 6-9 1 mg/L Cl2 residual	Urban non-potable with uncontrolled public access Agricultural e.g. human food crops consumed raw Industrial open systems with potential worker exposure
Class B	<100 *E. Coli* org/100 mL pH 6-9 <20/30 mg/L BOD/SS	Agricultural e.g. dairy cattle grazing Industrial e.g. wash-down water
Class C	<1000 *E. Coli* org/100 mL pH 6-9 <20/30 mg/L BOD/SS	Urban non-potable with controlled public access Agricultural e.g. human food crops cooked/processed, grazing/fodder for livestock Industrial systems with no worker exposure
Class D	<10000 *E. Coli* org/100 mL pH 6-9 <20/30 mg/L BOD/SS	Agricultural non-food crops such as turf, woodlots and flowers

In Queensland, reclaimed water is divided into yet another class, defined as Class A+, which has similar quality objectives as Class A with the addition of 0 mg/L TSS. This class can be used in applications with high human contact and medium risk of ingestion (Jimenez & Asano, 2008).

3.6.4 Singapore

The water quality in the reservoirs is tightly monitored and controlled. The water quality requirements in the city are based on those stipulated for drinking water by USEPA and WHO drinking water standards. However, the PUB ensures that the NEWater finished water quality is higher than these standards (DTI, 2006). The water qualities of NEWater and Industrial Water are not publicised.

3.6.5 Israel

Israel has separate water quality standards for irrigation (separated into unrestricted irrigation, Class A, Class B and Class C irrigation), and for discharge into rivers. Class A water can be used for the irrigation of cooked vegetables, parks, playgrounds, and road sides within city limits. Class B is for fruit trees, road sides outside city limits, and landscapes. Class C is for irrigation of field crops, industrial crops and forest trees.

Some selected parameters have been summarised in the **Table 3**, adapted from Medaware (MEDAWARE, 2005).

Table 3: Allowable limits for wastewater reuse or disposable

Parameter	**Unit**	**Discharge to rivers**	**Unrestricted irrigation**	**Class A**	**Class B**	**Class C**
BOD	mg/L	10	10	30	200	300
COD	mg/L	70	100	100	500	500
DO	mg/L	<3	<0.5	<2	-	-
TSS	mg/L	10	10	50	150	150
pH	mg/L	7-8.5	6.5-8.5	6-9	6-9	6-9
Turbidity	NTU			10	-	-
Nitrate	mg/L			30	45	45
Total Nitrogen	mg/L	10	20	45	70	70
E. Coli	Number/ 100mL	200	10	100	1000	-
Helminthes Eggs	Egg/L	< or = 1	< or = 1	< or = 1	< or = 1	< or = 1

There are further quality standards for metals and other residuals.

3.6.6 USA

Table 4 summarises the water quality guidelines are given by the Guidelines for Water Reuse given by the USEPA (EPA, 2012).

Table 4: National guidelines for water reuse

Reuse Category	**Water Quality**	**Setback Distances**
Urban Reuse		
Unrestricted: non-potable application with unrestricted access	pH = 6-9 ≤ 10 mg/L BOD ≤ 2 NTU ND(1) faecal coliform/100 mL ≥ 1 mg/L Cl2 residual	15m to potable water supply wells; 30m in porous media
Restricted: non-potable application restricted by barrier such as a fence or advisory signs	pH = 6-9 ≤ 30 mg/L BOD ≤ 30 mg/L TSS ≤ 200 faecal coliform/100 mL ≥ 1 mg/L Cl2 residual	90m to potable water supply wells; 30m to areas accessible to the public (for spray irrigation)

Reuse Category	Water Quality	Setback Distances
Agricultural Reuse		
Food crops: Food which may be eaten raw	pH = 6-9 ≤ 10 mg/L BOD ≤ 2 NTU ND faecal coliform/100 mL ≥ 1 mg/L Cl2 residual	15m to potable water supply wells; 30m in porous media
Processed food crops: Food consumed by humans, processed Non-food crops: crops not consumed by humans and any pasture, nurseries, and non-crop lands	pH = 6-9 ≤ 30 mg/L BOD ≤ 30 mg/L TSS ≤ 200 faecal coliform/100 mL ≥ 1 mg/L Cl2 residual	90m to potable water supply wells; 30m to areas accessible to the public (for spray irrigation)
Environmental Reuse		
Use of water to create wetlands, enhance wetlands, or sustain stream flows	Depending on stream/wetland, but not to exceed: ≤ 30 mg/L BOD ≤ 30 mg/L TSS ≤ 200 faecal coliform/100 mL ≥ 1 mg/L Cl2 residual	
Industrial Reuse		
Cooling	Depending on recirculation ratio: pH = 6-9 ≤ 30 mg/L BOD ≤ 30 mg/L TSS ≤ 200 faecal coliform/100 mL ≥ 1 mg/L Cl2 residual	90m from areas accessible to the public. May be reduced if higher disinfection is provided.
Other industrial uses are dependent on site specific end use		
Groundwater Recharge – non-potable reuse		
Aquifer recharge not used as potable water source	Site specific and use dependent	Site specific
Indirect Potable Reuse		
Groundwater recharge into potable aquifers (by spreading or injection)	Includes, but not limited to: pH = 6.5-8.5 ≤ 2 NTU ≤ 2 mg/L TOC of wastewater origin ND total coliform/100 mL ≥ 1 mg/L Cl2 residual	Distance to nearest extraction well provides minimum 2 months retention time in underground
Surface water reservoir augmentation	Includes, but not limited to: pH = 6.5-8.5 ≤ 2 NTU ≤ 2 mg/L TOC of wastewater origin ND total coliform/100 mL ≥ 1 mg/L Cl2 residual Meet drinking water standards	Provide minimum 2 months retention time between introduction of reclaimed water and intake to potable water treatment plant.

(1) Not Detected

3.6.7 Namibia

Compared to the USA and Australia, the water quality requirements for Namibia are not very stringent. Namibian water is divided into four categories:

- Group A: Water with an excellent quality
- Group B: Water with acceptable quality
- Group C: Water with low health risk
- Group D: Water with a high health risk, or water unsuitable for human consumption

According to the Water Act, 1956, water "should ideally be of excellent quality (Group A) or acceptable quality (Group B), however in practice many of the determinants may fall outside the limits for these groups. If water is classified as having a low health risk (Group C), attention should be given to this problem. If water is classified as having a higher health risk (Group D), urgent and immediate attention should be given to this matter."

Table 5 summarises some of the water quality requirements for the different water groups (Water Act, 1956).

Table 5: Water quality requirements for Namibian drinking water

Determinant	**Units**	**Limits for groups**			
		A	B	C	D*
Turbidity	NTU	1	5	10	10
Free chlorine	mg/l Cl	0.1-5	0.1-5	0.1-5	5
Nitrate	mg/l N	10	20	40	40
pH		6-9	5.5-9.5	4-11	4-11
Ammonia	mg/l N	1	2	4	4
Total coliform	Counts/ 100mL	0	10	100	100
Faecal coliform	Counts/ 100mL	0	5	50	50
E. Coli	Counts/ 100mL	0	0	10	10

*All values greater than indicated

3.6.8 South Africa

South Africa has water quality guidelines for a large variety of water types and applications. Looking at fresh water, there are guidelines for domestic, recreational and industrial use, irrigation, livestock watering, and aquaculture. When it comes to marine water, there are guidelines for the natural environment, recreational use, industrial use and mariculture. The quality for freshwater use is shown in Table 6.

It must be noted that only the water drinking standards are Law, while the other values are all guidelines. The guidelines also mention variables applicable to the use of the water. For example, irrigation includes concentrations of metals and salinity, while recreational use includes nuisance plants and floating matter.

Table 6: Water quality guidelines for South Africa

Application of water	Constituent	Target Range
Fresh water		
Drinking water	*E. Coli* or faecal coliforms Protozoan parasites (*Cryptosporidium* and *Giardia* species) Total coliforms Free chlorine TDS Turbidity pH	Not detected Not detected ≤ 10 counts/100 mL ≤ 5 mg/L ≤1200 mg/L ≤ 1 NTU 5 to 9.7
Domestic Use	Ammonia Total Coliforms Faecal Coliforms Nitrate pH TDS Turbidity TOC	0-1 mg/L 0-5 counts/100 mL 0 counts/100 mL 0-6 mg/L 6-9 0-450 0-1 NTU 0-5 mg C/L
Recreational Use	Faecal Coliforms pH	0-130 counts/100 mL 6.5-8.5
Industrial Use*	COD pH TSS TDS	0-75 mg O2/L 5-10 0-25 mg/L 0-1600 mg/L
Irrigation	Faecal Coliforms pH TSS	0-1 counts/100 mL 6.5-8.4 0-50 mg/L
Livestock watering	Nitrate Total coliform	0-100 NO_3 0-200 counts/100 mL
Aquaculture	Ammonia DO Nitrate pH	≤ 0.025 mg NH_3/L (cold water fish) ≤ 0.3 mg NH_3/L (warm water fish) 6-9 mg/L (cold water fish) 5-8 mg/L (intermediate and warm water fish) < 300 mg NO_3-N/L 6.5-9

* There are four categories of industrial use. The values for the lowest class are shown in this table.

3.7 Incentives for reuse

3.71 China

As has been mentioned in the policy and legislative environment section of this report, China has made some attempt to provide incentives for reuse, with water reuse embedded in the wider frame of resource utilization. Incentives include tax reduction awarded to companies in the "Comprehensive Resource Utilization List"; exemption from taxes for a period for products created through comprehensive utilization processes; and wastes that could not be reused or recycled by enterprises must be offered free to other enterprises for reuse or recycling. Enterprises which execute waste reuse projects that have no economic benefit to the enterprise are also to be given favourable treatment through loans from business banks, with postponed deadlines for payment (Wang, 1995).

When it comes to actual large-scale water reuse, there is no general incentive given. Money is provided to install large water treatment plants. However, in many cases the treatment plants are left un-operated. Also, there is not enough effort put into the collection of wastes to be taken to treatment plants. So although treatment plants are sized for the waste found in a city or town, the waste does not get sent to the treatment plants. In some cases, wastes are secretly disposed of to avoid waste treatment fees and waste discharge fees (Cao & Liu, n.d.).

However, ever since the 2008 Olympic Games in Beijing, efforts have been made to improve things. In Beijing, it is required that newly developed residential buildings with a construction area of over 30 000m^2 must build on-site wastewater reuse facilities (Yang, 2007).

3.7.2 India

The NUSP and NWP mention wastewater reuse as a positive aspect. However, these policies are not supported by the Acts and Regulations, thus creating no proper guidelines to follow. Service Level Benchmarks recommends a minimum of 20% wastewater reuse per city. However, this Service Level Benchmark is not enforced. The Central Pollution Control Board describes untreated sewage discharge into water courses as the most important water pollution source in India (Panchal, 2012). However, this only encourages unsafe reuse of untreated sewage in applications such as irrigation, since finances for sewage treatment are mostly unavailable. As such, there are no distinct incentives set to bring about safe wastewater reuse.

3.7.3 Australia

Although a review by Mekala, et al (2008) shows that the greatest resistance to wastewater reuse is its cost, Australia does provide the incentive for reuse by the reclaimed water price, which is set below that of drinking water. Since the actual cost of reclaimed water is up to 15 times as much as potable water and that of storm water is up to 6 times as much, this requires a large subsidy. However, the Australian Government Water Fund exists for this purpose, and for further incentives in creating new wastewater reuse projects through its three programmes: Community Water Grants, Water Smart Australia and Raising National Water Standards. Australia also has awareness-raising programmes to bring about a desire to use recycled water, seeing as the drought severities in Australia are considerable.

3.7.4 Singapore

To encourage water reuse, Water Conservation Tax is not applied to NEWater or to Industrial Water, which is non-potable reused water. Furthermore, the tariff for NEWater and Industrial Water is much lower than potable water. The following table, taken from the (WB, 2006), shows the tariffs used in 2006.

Table 7: Water Tariffs in Singapore

Category	Consumption (m^3 per month)	Tariff (cents/m^3)	Water Conservation Tax (% of tariff)
Domestic	1 to 40	117	30
	Above 40	140	45
Non-domestic	All units	117	30
NEWater	All units	115	0
Industrial Water	All units	43	0

Furthermore, tax exemption is granted on a portion of income, based on expenditure on projects or activities that reduce consumption of potable water (WB, 2006).

Singapore government policy also encourages private participation in urban sanitation, and has awarded a contract for two NEWater factories in 2003 and 2005.

3.7.5 Israel

According to Voss (Voss, 2013), the water price in Israel is relatively high, and is priced according to the cost of treatment or procurement. There is thus no incentive for wastewater use by addition of subsidies in recycled water prices. However, it is likely that recycled water is cheaper than potable water, since, according to Voss, 60% of urban potable water is provided through desalination, which is an expensive process.

Israeli reclaimed water users, however, do not require incentives, since reclaimed water is used only for irrigation, and this is strictly regulated. According to Voss (Voss, 2013), the government water policy restricts freshwater use even for irrigation, which gives the farmers no choice but to use reclaimed water.

3.7.6 USA

Reclaimed water is priced at 50 to 100% of potable water prices, with an average of 80% across the different states. This reduced pricing aims to promote reclaimed water use. Water use regulations may also provide incentives as part mandatory or voluntary water efficiency goals. Such incentives may include fulfilling water reuse goals as a prerequisite for grants, loans or other benefits, or penalties may be placed on those using water above the water use restrictions. The Drinking Water State Revolving Fund also provides money as an incentive to those wishing to start projects which conserve water (EPA, 2012). This includes water reuse projects.

3.7.7 Namibia

In order to change the culture of water use, the water tariff structure for water was changed to a minimum water charge, with a small volume of water included, and a much larger unit cost per volume hereafter. In this way, poorer communities' water expenditure was reduced, and the expenditure of large water users was vastly increased. However, this had no effect on the overall water use in the country. Successful results were only obtained through discussions and commitments by some industries to save water (Van der Merwe, 1998).

3.7.8 South Africa

Possibly due to previous cases of wastewater treatment plant failures, many South Africans do not like the idea of reusing water due to the 'Yuck' factor. A major influence in this issue against reusing water is their distrust of the service provider, even if the quality is assured by a local authority (Ilemobade, et al., 2009). An effort is thus necessary to first build trust by assuring the public of technologies and other structures in place which will ensure that the water is safe, before any wastewater reuse project can become a success.

One of the major incentives for reuse in South Africa is the strict discharge regulations, which require extensive treatment. This water could be reused or recycled to reduce the amount that needs to be treated, or to make more efficient use of the water. Mines also have the problem of acid mine drainage, which must in anyway be treated, which they can then use as process water instead of paying for the transport of fresh water to the mines.

In some places, agreements have been made between treatment plants, municipalities and industries, to make most beneficial use of available water sources. This is the case at Witbank and also between the Durban municipality and Mondi paper mill (Jimenez & Asano, 2008).

3.8 Public education and awareness programmes

3.8.1 China

Water reclamation as a way of supplementing water resources has not been broadly recognised across the country. When experiencing water shortages, cities tend to aim at developing new freshwater sources instead of using reclaimed water. With the new policies, governments and cities have started using reclaimed water. However, this was done with little promotion and public awareness measures, as the water reuse was set by governmental decrees. As a result, there is little knowledge or trust in the benefit and safety of reclaimed water use, which has limited the drive for water reuse (Yi, et al., 2011).

In Hong Kong, pilot scale schemes are being conducted, which use reclaimed water for toilet flushing and gardening (OECD, 2009). These pilot plants are used as an example to improve public awareness and acceptance of using reclaimed water, and will be used as a blueprint for future reclaimed water use schemes.

3.8.2 India

Groundwater use in India is very low-cost, and thus makes it undesirable for industries to use treated water instead. As a result, the only way to bring about wastewater reuse is to enforce at least a percentage of treated water reuse. Panchal (Panchal, 2012) also mentions previous public resistance and legal action, suggesting that people in India do not prefer the use of reclaimed water. There are currently no known large public awareness or education programmes in India.

3.8.3 Australia

Reuse projects in Australia have often been carried out on a small scale basis. However, these examples can be found in every state in Australia. Looking at the Rouse Hill residential area, which has a dual reticulation system, most residents were aware of the scheme, regarded it with a sense of pride, and had few concerns, although they were unsure where the recycled water came from (e.g.: human waste) and what was involved in the treatment. In contrast, residents using the dual reticulation system at New Haven had a good knowledge of the source of the water and indicated no concerns over the water system. At Hervey Bay, reusing wastewater for irrigation was rejected in 1991 due to concerns. However, a farmer took the initiative and started using this recycled water. After years of success, the wastewater reuse project was spread to other farms in the area (Juliane, et al., 2003).

Although no large educational programs have been mentioned, it is clear that Australians are well-aware of the idea of wastewater reuse and recycling, and there is general support, although the support does not extend to potable reuse.

3.8.4 Singapore

Public awareness is highly supported in Singapore. Specialised campaigns are conducted, the education system at schools includes the environment and water issue, and there are the added “Clean and Green Week” campaigns. Each “Clean and Green Week” is held with a different theme in the schools, in order to bring across environmental information to the youth (Leitmann, 2000).

3.8.5 Israel

A national survey of public opinion has never been done in Israel (Friedler, et al., 2006), despite the widespread use of recycled water. However, the water shortage problem in Israel is well known and highly publicised.

The Israeli Ministry of Agriculture hosts annual meetings that farmers, academics and decision makers attend. These meetings are intended for sharing of water experiences and to strive for more efficient water practices. The Technion University is highly involved in these meetings and solutions, and consists of economists, engineers, hydrologists and politicians who work together in water management. As a result of the collaboration between different water users at the different levels, there is high public awareness and support of strict water control measures and methods of efficient water use (Voss, 2013).

3.8.6 USA

A large number of water reuse applications have been done in the United States. California is a pioneer in water reuse, with over 230 reuse projects operating by 2003 (Juliane, et al., 2003). The sheer number of reuse projects indicates that at least a large number of Americans are aware of and support water reuse and recycle. A study conducted by San Diego County Water Authority shows a notable shift in perceptions between the year 2004 and 2011. The following graph is redrawn from the results of this study, and proves to show that the public awareness regarding water in America is improving.

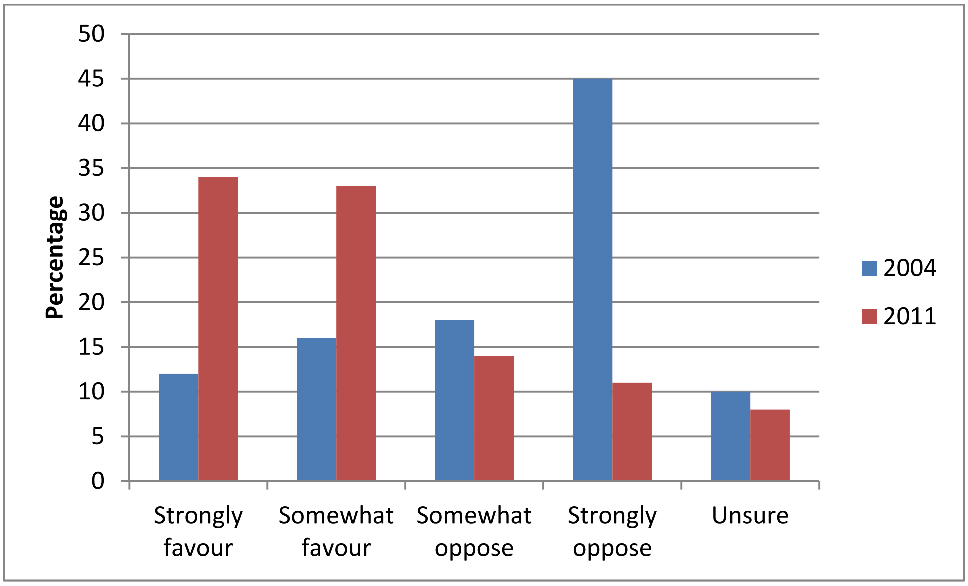


Figure 1: Survey results: Opinion about using advanced treated recycled water as an addition to drinking water (SDCWA, 2012)

The Water Environment Federation is a non-profit association made up of a group of water quality professionals who strive to protect water worldwide. They do this by providing bold leadership, innovation, and knowledge to support clean and safe water. They also run campaigns aimed at raising public awareness of water-related issues (WEF, n.d.).

However, although there are groups of people who work towards efficient water use and reuse, there is still a lack of collaboration between water users, technically skilled people and policy-makers in the USA, according to Voss (Voss, 2013). Although the level of expertise and technology is far above the world average, and water saving technology as well as reuse and recycling is used extensively around the country, there are still a large number of individuals who cling to their water rights with the mentality of “use it or lose it”. This makes it difficult to bring about the kind of change that is evident in Israel, where all water users are informed and work together to reduce freshwater use and to use water as efficiently as possible.

3.8.7 Namibia

In Namibia, with the exception of the major city, Windhoek, there is little need for public awareness programs, as water scarcity is well known and experienced in the country. However, an increase in public knowledge of simple and/or cheap methods of water reuse and recycle is highly lacking, and would be vastly beneficial to resourceful individuals or groups in the country.

3.8.8 South Africa

A large portion of the public is aware of water shortages. However, the preferred solution is generally reduction in use rather than reusing water. There are several examples of water reuse in South Africa. However, there are no highly publicised projects to educate the public or to raise awareness about water reuse.

3.9 Mechanisms to ensure sound operation and maintenance

3.9.1 China

The National and Provincial government agencies in China are only involved in creating policies and providing finances. It thus falls to the shoulders of Municipal, County and Village government agencies to develop water treatment and reuse schemes, and to make sure of sustainable operation and maintenance. China encourages the involvement of NGOs, both domestic and international, as these organisations have had a major influence in the management and sustainable operation of water treatment and reclaimed water reuse systems (WPP, 2011). However, where these organisations are not involved, operation and maintenance of water treatment plants, collection systems, and reuse and recycle schemes is generally lacking (Cao & Liu, n.d.).

In rural areas, particularly, Municipalities and Counties have adopted a policy encouraging contractors in charge of wastewater treatment and reuse systems to hire local labour to work on the construction of the project. Hereafter, the contractor will be required to operate and maintain the project for an 18-month period, during which training will be conducted among designated local operators. After the 18-month period the local group such as a village committee will become fully responsible for the project, and the project will be transferred to the local group (WPP, 2011).

3.9.2 India

Wastewater treatment is not a high priority in India in terms of laws and regulations, and as such there are no mechanisms to ensure any operation and maintenance of any existing or future treatment plants or water reuse systems.

3.9.3 Australia

Management of wastewater treatment works and reuse schemes is highly dependent on the state. Each individual state provides their own guidelines on how these schemes should be run, although there is an overarching, inter-governmental guideline document supported by all states. The example of the state of Victoria has previously been given. The state provides consent to reuse projects, after which the Department of Human Services makes sure that the reuse project provides and/or uses reclaimed water that is up to standard. Hereafter, the Environmental Protection Agency regulates the project with audits to makes sure that guidelines are adhered to. The National Water Fund may also apply finances if it is found that operation and maintenance is not up to scratch.

In order to ensure sound operation and maintenance, there must be clear guidelines as to what the treatment requirements and outcomes must be, so that plants know what to aim for, and there must be trust among the public in order to make the reuse scheme worthwhile since it ensures that the reclaimed water will be used. Due to the clear policy documents, and the number of widespread reuse projects found in Australia, both guidelines and trust are not an issue in this country.

3.9.4 Singapore

Before the passing of a new law or regulation concerning the environment or water, a campaign is held in order to enlighten the public. This is then soon followed by strict enforcement. With this type of structure, the public is well aware of all issues happening in the country, and there is no second thought about how or whether the law should be carried out. The Department of Technology and Water Quality is in charge of planning, evaluating, testing and budget management of new projects, which ensures that there is sound operation and planning of these treatment and reuse systems. The Department of Water Reclamation has also ensured that treatment plants are updated for production of reused water (WB, 2006).

Currently, there are three NEWater factories in Singapore, all of which are functioning correctly, and local enterprises are involved in these schemes. As a result, the technology is well known and well understood, and has been used successfully, so that the water users are able to trust the source. Singapore has also advertised NEWater worldwide, gaining trust worldwide for the reused water and its quality.

3.9.5 Israel

It has been mentioned that the Israeli Ministry of Agriculture hosts annual meetings which farmers, academics and decision makers attend. These meetings are intended for sharing of water experiences and to strive for more efficient water practices. The Technion University is highly involved in these meetings and solutions, and consists of economists, engineers, hydrologists and politicians who work together in water management (Voss, 2013).

As a result of this collaboration, there is a high surety of optimal operation and maintenance of all reuse projects. There is complete trust between farmers and the government. The farmers are well-aware of the situation and completely support government decisions.

3.9.6 USA

The Guidelines for Water Reuse (EPA, 2012) provide information on technology selection, and details of how each type of equipment used in water treatment functions. The 2012 guidelines also mention that detailed operation and maintenance procedures and advice can be found in the 2004 Guidelines for Water Reuse. This provides a standard which can be followed by treatment plants nationwide, which is a method of building trust for those who use the treated water. The fact that all water potable water sources are monitored in all of the states as a requirement set out in the Law, any contamination will quickly be found and dealt with. This makes sure that all treatment plants produce water of the correct quality.

3.9.7 Namibia

One of the main factors assuring sound operation and maintenance, and trust between water users and water suppliers, is the factor of time. The water reclamation plant in Windhoek has been running for more than 30 years, with no known major problems. As a result, Namibians have no problem drinking the water, and paying the tariff required to obtain this water. However, there is little available support for water treatment solutions in rural areas, also due to the lack of technical expertise in these areas. In rural areas, dry or minimum-water-using solutions are preferred for the treatment of wastes.

3.9.8 South Africa

South Africans are generally distrustful of local utility providers and also in political transparency (Ilemobade, et al., 2009). Trust is built out of longstanding experience, and in knowledge. South Africa needs to educate its people on water treatment and the possibilities in water reuse.

3.10 Financing reuse projects

3.10.1 China

In the 11th 5-year plan approved in 2005, China adopted a water treatment tariff system, which enterprises need to pay in order for their wastewater to be treated. This was done so that centralised wastewater management programs may become self-funded enterprises, to cover operations and maintenance costs. The tariff guidelines are based on actual costs incurred for each customer, with the “polluter pays” and “beneficiary contributes” backbone.

According to (Yi, et al., 2011), there is general uncertainty of how the water reuse operations should be financed. Users of reclaimed water often do not pay the reclaimed water supplier, or were unable to once they became insolvent, and in turn, companies providing reclaimed water were unable to operate. Compared with other services, water reclamation is very scarcely funded. Funding is mainly provided by the government, with little investment from the private sector. Financing is also difficult to secure due to the lack of potential reclaimed water users.

3.10.2 India

There are no dedicated schemes for treatment, disposal or reuse of wastewater. Wastewater treatment and disposal falls under the Urban Local Body, as one of its specific functions. Treatment of wastewater is thus left to the ULB to decide depending on the availability of funds. As a result, little or no treatment is done.

3.10.3 Australia

Australia has a national Government Water Fund, which exists solely for the purpose of funding water systems, which includes wastewater reuse and recycling. This fund consists of three sub-sections: Community Water Grants, Water Smart Australia and Raising National Water Standards. Water Smart Australia funds projects that contribute to improving water efficiency and positive environmental outcomes. This includes reuse and recycling of reclaimed water, improvement of water systems, desalination, sewerage management, and new smart technologies and practices. This fund was worth A$1.6 billion in 2006 (DTI, 2006). The Raising National Water Standards programme is more involved with improving the management of water resources, which also includes measuring and monitoring of the water resources. This responsibility is given to the individual states.

3.10.4 Singapore

According to the World Bank AAA Program (WB, 2006), Singapore supports private-public partnership in water infrastructure. This is done in order to make investment more efficient, although the government has a financial surplus. The government also provided contracts to the NEWater plants. This indicates that there is an unlikelihood of a short-fall of financial assistance for those wishing to start reuse projects in the country.

3.10.5 Israel

According to Voss (2013), water prices reflect the costs of treatment and transportation. However, these prices are affordable for all. This indicates that the farmers are not extremely poor, and are well able to reuse water without incurring unsustainable costs. Also, since farmers work together in groups or small communities, they also put money together in order to afford water reuse projects, which then support all of the farmers.

3.10.6 USA

Previously, it was the custom for wastewater treatment plants to form contracts or agreements with gold courses or other reclaimed water users to deliver water at low or no cost. However, reclaimed water is now recognised as a valuable product. Reclaimed water should come at a cost, which is specified in the following documents (EPA, 2012):

Principles of Water Rates, Fees and Charges, 5th Edition

Water Rates, Fees and the Legal Environment, 2nd Edition

Financing and Charges for Wastewater Systems

Water Reuse Rates and Charges, Survey Results

Pricing the reclaimed allows the reclaimed water system to fund itself, in order to cater for all of its operation and maintenance costs, as well as a reserve for other possible expenses. It is also suggested in the 2012 Guidelines that reclaimed water cost accounting should be separated from other costs so that funds will not be diverted to other unrelated water services (EPA, 2012).

However, it is still found that reclaimed water prices are lower than potable water prices, in order to provide the incentive for people to use the reclaimed water. The price of reclaimed water thus lies with the reclaimed water producer to plan in order to cover costs as well as allow a market of buyers.

There are funding schemes and grants which may be given to projects which reuse water. However, according to the Clear Water Act, projects are only eligible for funding if they have fully studied and evaluated techniques for reclaiming and reusing water. Also, the project must be able to run itself in the long run (the grant or fund only provides money to offset initial capital costs). The Clear Water Act also stipulates that facilities using or treating water will utilize recycle and reuse techniques if the estimated life-cycle costs are within 15% of the most cost-effective alternative.

According to the 2012 Guidelines (EPA, 2012), there are a number of sources of funding for water reuse projects, each with its set requirements for eligibility. Some funding may also be provided by the state.

New developments in some states are also required to have dual reticulation systems installed, although reclaimed water is not yet available in the region. This is done since retrofitting is much more expensive than building the dual system as part of the initial construction, and it is assumed that most developments will be using reclaimed water in the near future.

3.10.7 Namibia

The major water treatment plant and reclamation plant were largely funded by the Kreditanstalt für Wiederaufbau (40%) and the European Investment Bank (55%) (Lahnsteiner & Lempert, 2007). Regional sectors of government agencies are in charge of managing water supply and treatment in towns and cities, while companies such as mines are responsible for water reuse and recycling costs within their own processes.

3.10.8 South Africa

The municipal sector is responsible for water treatment systems, as well as providing water to the municipality. This includes any water reuse systems within the municipality. However, the government is responsible for funds, which it gives to the municipal sector. According to David Winter (Frost&Sullivan, n.d.), funding is not made available on time, which results in wastewater plants going for long periods of time without maintenance, which reduces plant life. Other water reuse projects are funded by the organisation which is implementing the project. In most situations, companies providing treated water form contracts with municipalities or industries to buy their water.

3.11 Research and development

There are a large number of research foundations and funds which support water reuse. The Water Environment Research Foundation (WERF) is currently involved in a large number of research projects related to water reuse. These projects look at membranes, salinity, pathogen detection/disinfection, trace organics, resource recovery, and more (WERF, 2012). An example of a WERF project, is one in which they are working together with the Soap and Detergent Association (SDA) on a research program into long-term greywater reuse and its effect on human health and the environment.

Another major research foundation is the WateReuse Association. This foundation is a non-profit organisation dedicated to conduct and promote research on reclamation, recycling, reuse and desalination of water. WateReuse is funded by its subscribers, and partners such as the Bureau of Reclamation, the California State Water Resources Control Board, and the California Energy Commission (WateReuse, n.d.).

In all countries around the world, there are examples of research and development done with regards to water reuse. In Israel, water is reused extensively across the country, and this is constantly monitored to determine if there are any long-term effects (Vigneswaran & Sundaravadivel, 2004).

The South African Water Research Commission (WRC) has published an extensive body of work applicable to the reuse of wastewater:

- A pilot study was made on the opportunities for greywater reuse for toilet flushing in high-density urban buildings (Report No. 1821/1/11) (Ilemobade, et al., 2012). This report also includes a structure for a national guideline for greywater reuse for toilet flushing.
- Report No. TT418/09 is based on water management in Namaqualand, which does not have much surface water (Pietersen, et al., 2009).
- Report No. TT 219/03 discusses the concept of artificial groundwater recharge (Murray, 2003).
- Report No. TT 419/09 provides a planning framework to position rural water treatment in South Africa in the future, including water management and reuse (Swartz, 2009).
- Ilemobade, et al ((Ilemobade, et al., 2008) researched the viability of implementing dual reticulation systems in South Africa. This research report explores examples of greywater reuse and dual water reticulation systems found in South Africa; and provides a framework to be used in determining the viability of dual-reticulation of water in settlements.

4 LIST OF REFERENCES

Asano, T. & Visvanathan, C., 2001. *Industries and Water Recycling and Reuse.* Stockholm, Asian Institute of Technology.

Boccaletti, G., Grobbel, M. & Stuchtey, M. R., 2010. The business opportunity in water conservation. *McKinsey Quarterly,* Volume 1, pp. 66-74.

Cao, M. & Liu, M., n.d. *Analysis of urban wastewater management in China: from law and policy dimension,* s.l.: China University.

CED, 2011. *Urban Wastewater Management.* [Online] Available at: http://www.indiawastemanagementportal.org/index.php?option=com_content&view=article&id=49&Itemid=148 [Accessed 19 April 2013].

Crook, J., Mosher, J. J. & Casetline, J. M., 2005. *Status and Role of Water Reuse,* London: Global Water Research Coalition.

DTI, 2006. *Water recycling and reuse in Singapore and Australia,* s.l.: s.n.

EPA, 2003. *Guidelines for Environmental Management: Use of Reclaimed Water,* Victoria: Publication 464.4 ISBN 0 7306 7622 6.

EPA, 2004. Water Reuse Outside the U.S.. In: *Guidelines for Water Reuse.* Washington, DC: U.S. Environmetnal Protection Agency, pp. 241-286.

EPA, 2012. *Guidelines for Water Reuse,* Washington, DC: CDM Smith Inc..

Friedler, E., Lahav, O., Jizhaki, H. & Lahav, T., 2006. Study of urban population attitudes towards various wastewater reuse options: Israel as a case study. *Journal of Environmental Management,* pp. 360-370.

Frost&Sullivan, n.d. *South Africa's Water Markets Will Show a Mixed Reaction to the Global Economic Downturn.* [Online]
Available at:
http://www.bwa.co.za/Articles/South%20Africa%E2%80%99s%20Water%20Markets%20Will%20Show%20a%20Mixed%20Reaction%20to%20the%20Global%20Economic%20Downturn,%20Says%20Frost%20&%20Sullivan.pdf [Accessed 23 April 2013].

Ghosh, S., 2013. *Future options for urban wastewater reuse.* [Online]
Available at: http://www.waterworld.com/articles/wwi/print/volume-20/issue-6/features/shyfuture-options-for-urban-wastewater-reuse.html
[Accessed 17 April 2013].

GWI, 2005. *Reuse goes for global growth, Vol 6, Issue 6.* [Online] Available at:
http://www.globalwaterintel.com/archive/6/6/market-insight/reuse-goes-for-global-growth.html
[Accessed 19 April 2013].

Hu, Y., 2010. Foregin Investment in China's Water Infrastructure: A Strategy for National Security. *China Security, Vol. 6,* 6(2), pp. 39-48.

Ilemobade, A. A., Adewumi, J. R. & van Zyl, J. E., 2008. *Framework for assessing the viability of implementing dual water reticulation systems in South Africa,* s.l.: Water Institute of Southern Africa.

Ilemobade, A. A., Adewumi, J. R. & van Zyl, J. E., 2009. *Framework for assessing the viability of implementing dual water reticulation systems in South Africa.* [Online]
Available at: http://www.scielo.org.za/scielo.php?pid=S1816-79502009000200012&script=sci_arttext
[Accessed 23 April 2013].

Ilemobade, A. A., Olanrewaju, O. O. & Griffioen, M. L., 2012. *Greywater reuse for toilet flushing in high-density urban buildings in South Africa: a pilot study,* s.l.: Water Research Commission.

IWA, 2012. *CH2M HILL partnership to increase India wastewater resue and boost potable supplies.* [Online] Available at: http://www.iwapublishing.com/template.cfm?name=w21prodnews030712c
[Accessed 19 April 2013].

Jimenez, B. & Asano, T., 2008. Water reuse in Australia and New Zealand. In: *Water Reuse: An International Survey of Current Practice, Issues and Needs.* London: IWA Publishing, pp. 105-121.

Jimenez, D. & Asano, T., 2008. *Water Reuse: An International Survey of current practice, issues and needs.* London: IWA Publishing.

Juliane, M. P., Kaercher, D. & Nancarrow, B. E., 2003. *Literature Review of Factors Influencing Public Perceptions of Water Reuse,* s.l.: CSIRO Land and Water.

Lahnsteiner, J. & Lempert, G., 2007. *Water management in Windhoek, Namibia,* Windhoek: Aqua Services and Engineering (Pty) Ltd.

Leitmann, J., 2000. *Integrating the Environment in Urban Development: Singapore as a Model of Good Practice,* Washington DC: The World Bank.

MAWF, 2008. *Water Supply and Sanitation Policy,* Windhoek: Ministry of Agriculture, Water and Forestry.

MEDAWARE, 2005. *Development of tools and guidelines for the promotion of the sustainable Urban Wastewater and Treatment and Reuse in the Agricultural production in the Mediterranean Countries, Task 5,* s.l.: s.n.

Mehrel, L. T., 2009. *Green Shalom: The New Kibbutz Movement.* [Online] Available at: http://www.kibbutzlotan.com/creativeEcology/articles/greenShalom.html#.UXTygLEaJjo [Accessed 22 April 2013].

Mekala, G. D., Davidson, B., Samad, M. & Boland, A., 2008. *Wastewater Reuse and Recycling Systems: A Perspective into India and Australia,* Colombo, Sri Lanka: International Water Management Institute.

Miranda, M. & Sauer, A., 2010. *Mine the Gap: Connecting Water Risks and Discolsure in the Mining Sector,* Washington, DC: WRA Working Paper.

Murray, R., 2003. *Artificial Groundwater Recharge: Wise water management for towns and cities,* s.l.: Water Research Commission.

Neumann, M., 2013. *Namibian Water Resources Management.* [Online] Available at: http://www.giz.de/themen/en/8368.htm [Accessed 22 April 2013].

Nolde, E., 1999. Greywater reuse systems for toilet flushing in multi-storey buildings – over ten years experience in Berlin. *Urban Water,* pp. 275-284.

OECD, 2009. *Alternative Ways of Providing Water,* s.l.: s.n.

Oosthuizen, N. & Armstrong, A., 2009. *A review of a Selection of Local Waste Bylaws Against the Framework of the National Environmental Management: Waste Bill, 2007,* s.l.: Water Research Commission.

Panchal, K., 2012. *Policy Incentives & Disincentives for Wastewater Reuse,* India: s.n.

Pietersen, K., Titus, R. & Cobbing, J., 2009. *Effective Groundwater Management in Namaqualand: Sustaining Supplies,* s.l.: Water Research Commission.

SDCWA, 2012. *Public Opinion Research Website.* [Online] Available at: http://sdcwa.org/public-opinion-research [Accessed 22 April 2013].

Shalizi, Z., 2006. *Addressing China's Growing Water Shortages and Associated Social and Environmental Consequences,* Washington DC: Develpment Research Group, World Bank.

Swartz, C. D., 2009. *A Planning Framework to Position Rural Water Treatment in South Africa for the Future,* s.l.: Water Research Commission.

Tare, V., 2011. *Review of Wastewater Reuse Projects Worldwide,* s.l.: s.n.

Van der Merwe, B., 1998. *Water Demand Management Country Study – Namibia,* s.l.: IUCN.

Vigneswaran, S. & Sundaravadivel, M., 2004. *Recycle and Reuse of Domestic Wastewater,* Oxford: Eolss Publishers.

Viljoen, P., 2012. *International Conference Water Reuse for Drinking purposes: Environmental Impacts Asspcoated with Water Reclamation and Reuse Projects in South Africa.* [Online] Available at: http://www.ewisa.co.za/misc/CONFERENCESWISA/RE%20USE%20DRINKING%20WATER/Pieter%20Viljoen%202.pdf [Accessed 23 April 2013].

Visvanathan, C. & Asano, T., 1999. *The Potential for Industrial Wastewater Reuse,* Pathumthani, Thailand: Asian Institute of Technology.

Voss, K., 2013. *National Geographic.* [Online] Available at: http://newswatch.nationalgeographic.com/2013/02/27/parallel-worlds-water-management-in-israel-and-california/ [Accessed 19 April 2013].

Wang, X. J., 1995. *Waste reuse: legilsation and enforcement in China,* Beijing: Peking University.

WateReuse, n.d. *WateReuse Research: Advancing the Science of Water Reuse and Desalination through Research.* [Online] Available at: http://www.watereuse.org/foundation/about [Accessed 23 April 2013].

WB, 2006. *Dealing with Water Scarcity in Singapore: Institutions, Strategies, and Enforcement,* Washington, DC: The World Bank.

WB, 2011. *Water Reuse in the Arab World: From Principle to Practice.* Dubai-UAE, The World Bank.

WEF, n.d. *Water Environment Federation: the water quality people.* [Online] Available at: http://www.wef.org/publicinformation/ [Accessed 22 April 2013].

WERF, 2012. *Water resue related reserach projects,* s.l.: s.n.

Whiteoak, K., Boyle, R. & Wiedemann, N., 2008. *National Snapshot of Current and Planned Water Recycling and Reuse Rates,* s.l.: Marsden Jacob Associates.

Wimberley, F., 2011. *Water Conservation and Water Demand Management Guideline for the Mining Sector in South Africa,* s.l.: Department of Water Affairs.

WPP, 2011. *Guide for Wastewater Management in RUral Villages in China,* Washington DC: World Bank.

Yang, H., 2007. Analysis of wastewater reuse potential in Beijing. *Desalination,* Volume 212, pp. 238-250.

Yi, L., Jiao, W., Chen, X. & Chen, W., 2011. An overview of reclaimed water reuse in China. *Journal of Environmental Sciences,* 23(10), pp. 1585-1593.