KSA 3: WATER USE AND WASTE MANAGEMENT

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SCOPE

This KSA focuses mainly on the domestic, commercial, industrial and mining water sectors. It aims to proactively and effectively lead and support the advancement of technology, science, management and policies relevant to water supply, waste and effluent management for these sectors. This KSA also supports studies on institutional and management issues, with special emphasis on the efficient functioning of water service institutions and their viability. Research on infrastructure for both water supply and sanitation is included.

A further focus is on water supply and treatment technology serving the domestic (urban, rural, large and small systems) as well as the industrial/ commercial and mining sectors of our economy. The KSA also focuses on waste and effluent as well as reuse technologies that can support the municipal, mining and industrial sectors and improve management in these sectors with the aim of improving productivity and supporting economic growth while minimising the negative effect on human and environmental health.

Water use by the sectors differs. The domestic sector generally requires high-quality potable water for drinking and commercial purposes, whereas the industrial and mining sectors require highly reliable and affordable water of adequate quality for their internal processes. Collectively the water usage activities of these sectors generate a large quantity of wastes and wastewater that are detrimental to the receiving environment, and these need to be managed. The supply of the water and the management of the wastes and wastewater are highly synergistic and the technologies and processes are applicable across the sectors.

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OBJECTIVES

The primary objective of this KSA is to provide knowledge that ensures reliable, affordable and efficient water use and waste management services to enhance the quality of life, and contribute to economic growth and improved public health.

The secondary objectives are to:

- Improve the management of water services in both rural and urban areas
- Develop appropriate technologies for improving the quality and quantity of our water supplies for both domestic use and industrial applications
- Develop new approaches to manage and enhance hygiene and sanitation practices
- Provide appropriate, innovative and integrated solutions to water and waste management in the industrial and mining sectors
- Develop applications for improved treatment of wastewater and effluent and improve processes for enabling increased reuse thereof
- Improve health, economic and environmental conditions, while supporting the development of appropriate technologies and socially-focused management practices related to water and effluent management

THRUSTS AND PROGRAMMES

The objectives of the KSA are orientated towards making a difference and impact in the areas of health, economy, environment and society. These are achieved through a portfolio of focused thrusts:

- Thrust 1:Water Services – Institutional and Management Issues
- Thrust 2: Water Supply and Treatment Technology
- Thrust 3: Sustainable Municipal Wastewater and Sanitation
- Thrust 4: Sustainable and Integrated Industrial Water Management
- Thrust 5: Mine Water Treatment and Management.
- Thrust 6: WaterSmart Fund

This KSA continues to build on and strengthen the strategic direction implemented over recent years, as well as with foresight orientating the portfolio to emerging and new issues. Emerging and novel research is channelled into Thrust 6. The scope of the strategic thrusts and programmes within KSA 3 is as follows:

THRUST 1: WATER SERVICES – INSTITUTIONAL AND MANAGEMENT ISSUES

Scope: The efficient functioning of water service institutions and their viability are key to sustaining water services in rural and urban areas. The focus of this thrust is to address strategic research aspects related to policy issues, institutional reform, regulation, infrastructure management, water-related competencies and capacity required for the strengthening of water institutions (water services providers, water services authorities, water boards, national departments) in providing sustainable water services.

Programme 1: Cost-recovery in water services	Scope: The issue of cost-recovery has been identified as a critical aspect affecting sustainable services. In an environment where genuine poverty affects cost-recovery, this programme intends to develop innovative strategies and processes to tackle the problem. The focus will be on generating in-depth knowledge of the problem and testing new approaches.
Programme 2: Institutional and management issues - Water services	Scope: Relationships and partnerships between service providers, both external and internal, are important prerequisites to sustainable water service delivery. This programme's objective is to generate knowledge and processes that would support this new form of service delivery. Innovative management techniques are a necessity for viable and sustainable water service provision. This programme intends to find innovative solutions to critical problems with the financing and management of essential services such as water supply and sanitation.
Programme 3: Innovative management arrangements - Rural water supply	Scope: The focus of research within this programme is to provide support to water service institutions with special reference to sustainable cost-recovery and implementation of the free basic water policy; key performance indicators for monitoring and evaluation of service delivery; guidelines for sound management of water service institutions and development of effective strategies for promoting an integrated approach to rural development.
Programme 4: Regulation of water services	Scope: Regulation of water services is important for the sector to achieve improved functioning and performance in the delivery of water and sanitation services, to the benefit of the population. Furthermore, it ensures greater efficiency and improved management of infrastructure and customers. This programme will support, through knowledge creation, the development of an effective water regulatory environment.

Programme 5: Water services education and awareness	Scope: A fully-informed community or individual plays a vital role in the sustainable use of water services, which contributes to water efficiency and improved environmental health. This programme will address education and awareness aspects which contribute to efficient water use, improved hygiene behaviour and sustainable services.

THRUST 2: WATER SUPPLY AND TREATMENT TECHNOLOGY

Scope: The provision and supply of affordable and reliable water of acceptable quality and quantity for drinking (domestic) and economic (industrial/commercial and mining) activities, remain continuous challenges. Research support for these activities is the focus of this thrust. The objective of this thrust is to develop innovative technologies and processes that address aspects related to bulk water supply, water treatment technology, distribution and water quality.

Programme 1: Drinking water treatment technology	Scope: The programme aims to acquire adequate understanding of potable water treatment processes and related activities and to be able to assist in treating our scarce water resources in the most efficient and cost-effective way to an acceptable quality for potable and industrial use. Expected outcomes include improved and more cost-efficient process technologies, increased operational efficiency of treatment plants and an improved manpower training level and knowledge base.
Programme 2: Water treatment for rural communities	Scope: This programme aims to produce innovative and appropriate water treatment and supply technologies and processes that will ensure an adequate supply of safe and clean drinking water for rural communities.
Programme 3: Drinking water quality	Scope: The programme aims to protect human health by ensuring that water supplies are of acceptable quality and standards. Outcomes include improved analytical methodologies, treatment technologies and hygiene practices.

Programme 4: Water distribution and distribution systems	Scope: The programme aims to optimise the quality, quantity and reliability of the distribution and supply of treated potable water to end-users. The programme has the following expected outcomes: to develop reliable processes in predicting and improving the operational efficiencies in distribution systems, with the purpose of reducing both capital and operational costs; to ensure that the quality and quantity of water is maintained in the distribution system – from the water treatment plant to the furthest end-user; and to develop innovative methods, tools and processes that will improve system integrity and reliability.

THRUST 3: SUSTAINABLE MUNICIPAL WASTEWATER AND SANITATION

Scope: This thrust focuses on the development of technologies and systems that optimise the full wastewater and sanitation services chain in the municipal (domestic) sector. This includes the reticulation, treatment and management of the residues. The challenge is to implement fitting solutions for a particular application that will remain functional throughout the intended lifespan of the installed infrastructure. This includes the responsible management of the wastewater sludge and faecal sludge that is generated. The need for innovative technologies and solutions is recognised as we prepare for the future – achieving more stringent effluent discharge standards, developing acceptable non-waterborne sewerage solutions, reliable treatment of ever-increasing high-strength domestic wastewater, informing future policy, etc.

Programme 1: Emerging treatment technologies – Preparing for the future	Scope: It is imperative to develop technologies which can achieve future policy objectives and stricter standards. It is also recognised that research generates information which could inform future policy. This programme encourages the development of technologies to address the future anticipated municipal waterborne sewage and sanitation needs as well as to support Government by informing future policy. It supports development of technological solutions addressing, amongst others: reuse, recovery, non-waterborne sewerage solutions, grey-water management, peri-urban sanitation solutions, high-strength effluent treatment, industrial and domestic effluent co-treatment, etc. It also supports research aimed at informing future policy through data interpretation, projections, risk assessments, addressing emerging pollutants, predictive models, etc.

Programme 2: Application of appropriate technologies and tools	Scope: This programme addresses the improvement and innovative application of existing 'fit for purpose' technology for waterborne sewage treatment and on-site sanitation. The objective is to optimise appropriate application to consistently achieve strict standards, with added benefits such as cost saving, ensuring ease of operation and maintenance, and improving reliability and energy efficiency. The integration of social and local economic development objectives is encouraged. The programme further focuses on the technical sustainability of wastewater treatment and sanitation services by critically appraising existing policy (including effluent discharge standards) and impacts.
Programme 3: Stormwater and sewerage systems	Scope: The programme supports the strategic and technical aspects of managing stormwater and sewerage and their impacts in urban, peri-urban and rural contexts. The development of generic stormwater and sewerage planning and technology selection, design and maintenance tools is encouraged to address current needs. In order to address anticipated needs, the programme supports research focusing on improved technology including water-sensitive urban design (WSUD) and stormwater reuse. It will cover technical design, operational, maintenance, refurbishment and management aspects of stormwater and sewerage reticulation systems, to provide sustainable infrastructure in the extended delivery of sanitation services as a national priority.
Programme 4: Wastewater sludge and faecal sludge management	Scope: All wastewater treatment and on-site sanitation facilities generate a solid/sludge that needs to be managed responsibly. This programme focuses on research dedicated to improve wastewater sludge and faecal sludge management practices. Research on characterisation, emerging technologies and solutions, anaerobic processes for stabilisation, minimisation, de-watering, disinfection and beneficiation is encouraged.
Programme 5: Sanitation technology and innovations	Scope: To develop innovative tools and technology which support appropriate sanitation that is socially, environmentally and financially sustainable.

THRUST 4: SUSTAINABLE AND INTEGRATED INDUSTRIAL WATER MANAGEMENT

Scope: Water is a strategic issue to the industrial sector. While water usage by the industrial sectors is not as great as, e.g., agriculture or domestic consumption, the impacts of the pollutants in industrial wastes and effluents on health and the environment can be significant, costly and long-lasting. The aim of this thrust is to quantify water use and waste production, predict impacts (risks) over the short-, medium- and long-term, and develop and apply methods of prevention, minimisation, reuse, recycle, recovery and beneficiation. This thrust also aims to provide appropriate, innovative and integrated solutions for water efficiency and waste management for industries. In addition, Thrust 4 establishes the governance, policy and regulatory environment that currently exists and the enabling environment that will be required to change behaviours to conserve water, grow the economy, protect society and the environment.

Programme 1: Emerging challenges and solutions for the 21st century	Scope: This programme seeks to look at major challenges that may face South Africa in future at a water quality, quantity, and security level. It will explore emerging fields in science and engineering, such as nanotechnology, to provide solutions to these challenges. In addition to seeking new solutions, this programme will also investigate new and emerging industries, their water needs and the associated threats to health and environment. The concept of sustainable future industrial complexes and their water management will allow for better planning and regulation of new industries, enabling improved adoption of integrated resource management systems, processes and tools.
Programme 2: Integrated management	Scope: This programme focuses on integrated and innovative management arrangements, e.g., public-private partnerships (PPP), to support industry and government programmes which may be site-, catchment- and/or region-specific. While the programme will focus on water, it aims to promote a more holistic approach to resource (water, energy and carbon) management by industries to bring about sustainable approaches to water and wastewater management ensuring that liabilities (waste) are turned into assets (resources) for the benefit of the environment, society and economy.
Programme 3: Quantification, prediction and minimisation of water use and waste production	Scope: In order to prioritise those facets of industrial water management that need the most urgent attention, it is important to quantify the water used and waste produced by different sectors. This programme will also look to develop new methodologies and models to aid in quantification, prediction and evaluation of data. The environmental consequences of waste products are almost always long-term in nature and these long-lasting (legacy) effects were often not fully appreciated in the past, and consequently not properly considered when waste was disposed of.

Programme 3: Quantification, prediction and minimisation of water use and waste production (continued)	Thus, this programme also aims to establish and improve pollution prediction capabilities appropriate to South African conditions and to develop cost-effective techniques and approaches to minimise or reduce the impact that legacy and new waste products have on the environment.
Programme 4: Governance, policy, regulatory, and economical instruments to improve industrial water management	Scope: The regulatory authorities are responsible for authorising and regulating the impact of industrial waste on the quality and quantity of our water resources. Traditionally the resource-intensive command-and-control approach was used almost exclusively to manage water quality. Internationally, use is increasingly made of indirect economic or other instruments to supplement or even replace the command-and-control approach to water quality management. These new approaches are believed to be more cost-effective and to improve equity. Both the established and new approaches are being investigated and refined in order to support improvements to the governance, policy, regulatory, self-regulatory, and financial mechanisms that could be used to control and reduce the negative environmental effects associated with industrial waste. This programme will largely look at these mechanisms from an industry perspective in order to improve, review and enable implementation.
Programme 5: Water efficiency, cleaner production, beneficiation and treatment of industrial effluents	Scope: This programme looks at water use efficiency and associated tools, methodologies and systems as a primary driver of reduced effluent generation. In spite of efforts to minimise waste production it is acknowledged that effluent production will for the foreseeable future remain an expected consequence of industrial activities, and thus this programme aims to support the development of a range of processes and techniques for effective beneficiation, recovery, reuse, recycle, disposal and ultimately treatment of industrial effluents. The international trend towards waste management is to minimise the production of waste by adopting cleaner production processes and green chemistry concepts for chemicals. Approaches such as life-cycle analysis are employed to ensure that the net effect is positive and does not merely represent the transfer of negative effects from one sector or environmental medium to another. In addition, the programme entails the exploration and exploitation of in-process recycling and reuse opportunities prior to end-of-pipe treatment solutions. Expected outcomes include the potential recovery of materials, water and energy for beneficial reuse, and fundamental scientific/engineering support for process development, and thus longer-term initiation of the secondary economy opportunities within South Africa.

THRUST 5: MINE WATER TREATMENT AND MANAGEMENT

Scope: The usage of water in mining and mineral processing/refining produces high volumes of solid wastes and liquid effluents. Some mining activities generate acid mine drainage (AMD) or other mining-impacted waters. This thrust aims to provide appropriate, innovative and integrated solutions to water use and waste management in the mining sector. Future operations will almost exclusively take place in water-scarce regions (e.g. Waterberg, Eastern Limb) and their development will require reallocation of already stretched resources through, e.g., improved water demand and water conservation management. Additional priorities will include brine handling, biological sulphur compound transformation and aversion of future impacts.

Programme 1: Water use and waste production	Scope: This programme focuses on investigations into quantification of water used and waste produced by the sector, currently, and predicting and quantifying the short-, medium- and especially long-term impacts the wastes generated will have. The environmental consequences of mining activity are almost always long-term in nature, with impacts that last for centuries. These long-lasting effects were often not fully understood in the past, and consequently not properly considered. In the present regulatory environment it is increasingly expected of waste producers to quantify the present and future environmental impacts of their past and present operations and to indicate how these will be remedied, as well as how such consequences can be avoided when planning future operations.
Programme 2: Regulatory, management and institutional arrangements	Scope: The creation of sustainable arrangements (e.g. public-private partnerships) that enable the mitigation and prevention of the environmental, social and economic legacies of the mining and minerals industries is complex. Priorities include addressing the treatment and supply of bulk water using acid mine drainage (AMD), a realistic estimate of non-point-source pollution relating to the waste discharge charge system and determining the price elasticity for water use of the sector (determine the potential to decrease water use through tariff increases). This programme interrogates such aspects from the perspective of the mining sector. (Note: Policy development falls under KSA1).

Programme 3: Minimising waste production	Scope: This programme focuses on investigations into developing technologies and methods to decrease/minimise the generation of waste products in the mining sector, either through cleaner production, by-product generation, life-cycle analysis or through applying other risk assessment methodologies. The programme incorporates novel mining methods and mining-impacted water prevention strategies. Waste minimisation at the national, regional, (catchment), complex or single-site scale is considered. Identification of opportunities to convert liabilities into assets and holistic, long-term research into the beneficial use and recovery of brines, their solutes, and other waste products, are also included.
Programme 4: Mining in the 21st century	Scope: The emerging challenges related to avoiding recreating the legacies of past operations call for emerging solutions. Programme 4 will investigate the prediction and avoidance of long-term water impacts and implications associated with establishing new operations within different geographical areas. It will also actively pursue beneficiation initiatives, re-mining of wastes, etc. (especially innovative ideas and piloting/scale-up).
Programme 5: Low-volume mined products	Scope: Much research attention has been paid to coal and gold mining; however, other quarried or mined products such as radio-nuclides and platinum group metals also require consideration and in some cases present unique challenges. Water use and demand management, water-conserving metallurgical and extraction processes and investigation of the impacts and amelioration of mine discards specific to these products will be addressed in this programme.

THRUST 6: WATERSMART FUND

Scope: Drinking water and commercial activities have a high cost and assurance attached to them, as well as growing competitive demands. The wise and efficient use of this water has a profound impact on our water environment, resources and investments. Thus, this fund will support research, demonstration and development of any innovative idea, technology or process which supports the efficient use, reuse and conservation of our precious water and related energy efficiency in the domestic, industrial and mining sectors.

BUDGET FOR 2012/13

The approved funding of the research portfolio for 2012/13 led to a committed funding budget of R39 526 385. The consolidated research project budget is presented below:

Research portfolio	Approved 2012/13 (R)
Current projects	30 626 385
New projects	8 900 000
Total	39 526 385*

** For the year 2012/13 the KSA over-budgeted by R936 000.00. This is due to an internal transfer of R 500 000.00 due from KSA 2 for a jointly funded project and an amount of R 436 000.00 received as new income from an already committed EU-supported project.*

CORE STRATEGY

Strategic context

Water is an essential ingredient for economic development, the maintenance of natural life support systems and basic human existence. Urbanisation and industrialisation rates in developing countries have escalated significantly and continue to grow. Economic growth and development result in a greater demand for water and annual consumption continues to rise in most countries. Ensuring a reliable source of clean water and adequate treatment of wastes and wastewater for large urban populations and rural communities poses great challenges for many developing countries. South Africa is no exception to this situation and this has led the Government to embark on major water-related infrastructure development projects and to introduce water conservation measures, the focus being on optimal utilisation of existing water resources, the upgrading of existing sources and the conservation and protection of catchment areas.

Although the water requirements for the domestic (rural 4% and urban 23%), industrial (3.5%), power generation (2%) and mining (2.5%) sectors are a fraction compared to total water availability and water consumed, it is the assurance (98%) and continuation of the supply that dictates the high capital and infrastructure costs. Industrial and mining processes, though a small user of water, together contribute to the bulk of the pollution affecting our water environment. The commercial use of water in the domestic urban areas accounts for 20% of the total urban water use. With the increase in population and the economy, it is projected that by 2025 water demand in the domestic sector will increase to between 30 and 35%. Any future peaks in water demand will affect the assurance levels, resulting in demand being exceeded and vulnerability increasing.

Whereas the provision of water for human needs plays a cardinal socio-economic role in the upliftment of people and in promoting a healthy population, it is the industrial and mining sectors which play a primary role in the development of the South African economy and, hence, in the development of the country in terms of wealth creation, employment creation and export earnings. Sanitation and wastewater treatment are essential elements of service delivery that contribute to maintaining a healthy environment for our population. Environmentally, the mining and industrial sectors have common features, such as an intensive demand

on material and energy resources, a major impact on the landscape, a relatively low demand on the national water use and a proportionately much higher pollutant profile. This includes effluents of high concentration, contaminants that are difficult or expensive to remove, and with these the potential to degrade large volumes of water, thereby rendering them less fit for other beneficial uses. Effluents from all of these sources arise either as point sources (e.g. piped effluents from factories or sewers) or as non-point sources (e.g. runoff from un-serviced high-density settlements and seepage from mine slimes dumps or mine workings).

A situation of growing dichotomy created by past practices, the current challenges for the water services sector are split into bridging the gap between the poor and unserved in terms of access to water and sanitation services, and supporting the growth of the economy through improving infrastructure and services to industry. The rate of urbanisation is fundamentally affecting the provision of water services and is beginning to result in regular failure of existing infrastructure. The increased migration from rural areas and influx to urban areas is continually putting demands on existing systems. In the rural areas, traditional settlements present significant challenges to service delivery. While many achievements have been made by the water sector over the years in addressing these issues, the greatest and most elusive challenge is the sustainability of these achievements. The lack of investment in infrastructure operation and maintenance over the years, coupled with a skills shortage and lack of investment in replacement of infrastructure, is resulting in many systems failing to meet the requirements of good service delivery. This situation is escalating and is evidenced by the increase in reports highlighting problems.

The situation is further compounded by climate change, shortages of high-quality water sources, growing mega-cities, growing informal settlements, capacity and financial constraints, energy shortages and higher expectations for water, which are challenging the sustainability of the water industry in the long term. Efficient use of water for domestic, industrial and mining purposes, as well as improved sanitation, would be critical for improving public health, eradicating poverty and contributing to global competitiveness.

Taking into account all of the achievements and developments to date, it is clear that South Africa has amassed a substantial knowledge base and the competencies required to face the future challenges. However, there is a need to develop more environmentally-sound technologies and processes that command greater integration in the solutions they provide. A more holistic and integrated approach is required towards providing sustainable solutions focusing on aspects related to the participation of society, the impact on the environment and resource base, institutional and management issues, minimisation of wastes and other emerging issues.

As water consumption continues to rise, Government will face the huge challenge of meeting increasing water supply and wastewater treatment demands. Only by developing long-term strategies to address these issues, including the introduction of water conservation measures and continued investment in water-related infrastructure, will access to clean water and treatment facilities be available to a greater proportion of the population in the future. It is clear that the cost of providing clean water to an expanding and growing population and growing economy will continue to increase.

To achieve the above, more innovative policies and improved implementation strategies for water use and waste management will be required, supported by a strong basis for appropriate technologies, changes

in infrastructure approaches and broader water management policies. It is inherent that institutional processes and capacity must be in place, supported by sound technologies and methodologies. The KSA's contribution to the national strategy for growth and development is through conducting research that can yield impacts on society, economy, health and environment as defined in the strategy and the WRC's impact areas:

In the impact area of **Water and Society**, the KSA contributions are made through understanding the effective demand for water services and the value society attaches to water. It is imperative that in dealing with challenges of water quality and availability, society is fully informed and participates in the management and use of water into the future. Initiatives delve into creating a good understanding of social scarcity and social vulnerability, people's usage of water and establishing a platform for involving society in the local regulation of water services. Some examples of projects which contribute to this impact area are: investigating the social vulnerability of people and their livelihoods and their response to water infrastructure; investigating operational and indigenous knowledge of water use and waste management, and establishing ways to integrate them into water services. In addition, eradicating all forms and types of water and sanitation-related disease, resulting in improvement in quality of life and an increase in productivity, is an ultimate desired impact. Good, clean, safe drinking water and safe sanitation technologies are key ingredients, together with strong institutional support to realise this objective. The KSA achieves this through the development of innovative technologies, improved testing protocols for measuring water quality, identifying emerging pollutants and their consequences on human health, developing sound educational materials and communication techniques and undertaking risk assessments. Some examples of projects which contribute are: the development of enhanced floating media separation for drinking water production and pre-treatment in rural water supply; the development of immersed membrane microfiltration systems for the treatment of rural waters and industrial waters; assessment of WatSan and hygiene in relation to home-/community-based care services for HIV/AIDS-infected individuals in rural and peri-urban areas; development of more user-friendly structures for home-based treatment in rural areas; development of more robust and lighter VIP structures.

The costs and the price of water and water services have a significant impact on the economic growth of the country, since water is considered to be both a social and economic good. Providing affordable water services allows the sector to effectively meet the basic water supply needs of society and stimulate economic growth. Impacts in the area of **Water and Economy** are achieved by undertaking projects which create an understanding of the role of water in economic development at all levels, development of economic instruments for the management of water and stimulating water efficiency. Some examples of projects which contribute are: investigating the mechanisms and processes used in setting water services tariffs; guidelines on pricing and debt management; value of water to the industry.

All activities related to the use of water have a direct and indirect impact on the water environment. The health of our ecosystems and quality of water are key requirements for sustainable water management, and thus the understanding of linkages between the natural environmental components and their interaction with the anthropogenic components within the water cycle are crucial. The KSA contributes to the area of **Water and the Environment**, by influencing the reuse of effluents through developing cutting-edge technologies, establishing monitoring techniques to

enable better regulation, introducing pollutant recovery and minimising processing techniques to minimise the impact on the environment. Some initiatives in this regard are: 'Health for Purpose' in wetlands treating waste streams; beneficiation of agri-industry effluents; development of a zero-effluent mathematical model for wastewater minimisation in a pharmaceutical facility; protocol for quantitative assessment of industrial effluents for discharge permitting; mass balance modelling for wastewater treatment plants; nanotechnology in water treatment; pilot application of a dual-stage membrane bioreactor for industrial effluent treatment.

Linkages to Government Outcomes

The portfolio for 2012/13 was aligned and responsive to Government's Outcomes as highlighted below: Specific activities within each thrust and their contributions are described below:

- The portfolio of programmes and projects in Thrust 1 contribute towards Government outcomes of improving the effectiveness and functioning of local government to provide water services, as well as, importantly, to strengthen regulation and reduce the existing water services backlog while stimulating livelihoods at a local level. With the biggest challenges being in rural municipalities, to date we have investigated institutional options for effective local-level management and delivery of water services. The research outputs on franchising have been realised in an experimental pilot, which is proving to be a successful model and offers one option for municipal arrangements. Supporting this option we have completed a study on people-centred approaches to management of water services. At an urban level, studies have looked at how local people can participate in supporting municipalities, by unlocking procurement and operational hurdles. New initiatives address the concepts of adapted CLTS with the intention of stimulating local ownership, investment and livelihoods in the delivery and maintenance of sanitation facilities, resulting in accelerating sanitation delivery and moving towards Government's outputs on improving access to sanitation for the poor. Ongoing projects are investigating further opportunities or modalities to enhance local levels of service provision and looking at institutional models for both centralisation and decentralisation. Effective municipal institutions are supported by a healthy and robust financial situation, which is one of the key outputs of Government. Three new projects have been initiated which aim to support the strengthening of municipal finances. These look at understanding proper tariff setting, establishing capital investment requirements for regional water management and establishing the funding requirements to completely meet Green Drop requirements. Future research will put greater emphasis on municipal finances and funding of new infrastructure. These initiatives further contribute to and support Government's output towards establishing a robust water economic regulator. In support thereof we have completed studies on the standardising of municipal accounts, since these form an importance base for water services revenue and consumer awareness. New initiatives are looking at how customers value their water services and the resources; this forms an integral part of regulation since user behaviour will influence water use, tariffs and affordability and form the basis for regulation.

- Thrust 2 contributes directly to Outcome 6: 'An efficient, competitive and responsive economic infrastructure network', for example, through the development of an internet-based electronic Water Quality Management System, which provides a tool which will enable the water service authorities and DWA to work together to attain Output 6: 'Develop a set of operational indicators for each segment'. Programme 2 (Water Treatment for Rural Communities) in particular speaks to Outcome 7: 'Vibrant, equitable and sustainable rural communities and food security for all', Output 3: 'Rural services and sustainable livelihoods' and Output 4: 'Rural job creation linked to skills training and promoting economic livelihoods'. The WRC has supported projects to develop appropriate water treatment units based on membrane technology, gravity and wave power, which will not only enable rural households to access clean, safe drinking water but will also foster local economic activity for the servicing and repair of the treatment units themselves. One example is the immersed membrane microfiltration system for the treatment of rural and industrial waters.
- The programmes and projects in Thrust 3 largely contribute directly towards Government outcomes of the protection of environmental assets and natural resources from domestic and industrial waste that is currently treated within treatment plants. This thrust has projects that deal with the development of technologies such as the anaerobic baffle reactor system being piloted in eThekwini Municipality as a decentralised wastewater treatment option for communities. Linked to this is the concept of sustainability, which sees the addition of previously developed WRC-funded flat-sheet membranes and constructed wetlands as technologies for polishing the final effluent to a quality which can be used for small-scale agricultural crops by the community. The WRC has embarked on several constructed-wetlands projects which will feed knowledge, capacity building and know-how into these pilot innovations by municipalities, which can then be replicated elsewhere in the country. The WRC has sought to stimulate new ideas for future wastewater treatment technologies by funding a project on innovative designs (i.e. biomimicry) for constructed wetlands of the future. It has provided solutions for the incremental improvement of nitrogen standards by demonstrating the ability of using South African clinoptilolite as a polishing step at wastewater treatment works. Additionally, projects on sewerage in South Africa, especially for dense informal settlements, will lead to guidelines on technology options and implementation for municipalities. A project looked at management of stormwater using water-sensitive urban drainage principles to lessen pollution loads to rivers and prepare for more frequent rainfall events which may be due to climate change. Indirectly, this thrust touches on providing solutions to Government for supporting rural services, such as 'sewer planning made simple', a set of tools for small rural municipalities, as well as knowledge generation which leads to more effective local government decision-making by repackaging existing knowledge on technology choices and decision support tools in user-friendly poster formats. In partnership with SALGA, WIN-SA, DBSA, DWA and municipalities, this thrust has

also seen the need to capture operational case studies on the infrastructure refurbishment costs, and operation and maintenance and infrastructure asset management efforts, in municipalities.

- The programmes and projects in Thrust 4 were revised in 2010 and largely contribute directly towards Government outcomes of the protection of environmental assets and natural resources from industrial waste. A series of projects relating to membrane bioreactors and membrane technologies have been funded for the pulp and paper, textile, olive oil and chemical industries, which will assist in industries meeting the standards for discharge standards to either the natural environment or municipal sewers. One of the key gaps with the use, and thus the sustainability and cost-effectiveness, of membranes is fouling, and a project under Thrust 3 at the University of the Western Cape has investigated the possibility of designing membranes that foul less. The knowledge derived can be used for both industrial and domestic wastewater treatment. Over 10 years of WRC research on co-digestion of various industrial effluents has led to eThekwini municipality piloting a full-scale implementation at one of its works, for the eventual capture of biogas and the reuse of the final effluent. This builds on a more holistic and sustainable approach to waste management, as set out in Programme 2 of this thrust. The completion of projects such as sustainability factors in industrial complexes has highlighted an emerging concern around brine (salt) disposal and liability. The initiation of projects such as forward osmosis and industrial brine minimisation deals with the emerging issues faced by Government around energy use by different technologies and brine-waste accumulation in South Africa. This thrust also supports local government effectiveness by developing protocols for the evaluation of industrial wastewaters for discharge permitting and technical guidelines for the determination of municipal effluent charges, as a means to encourage industries to switch to cleaner production approaches rather than end-of-pipe approaches.
- The programmes and projects in Thrust 5 were revised in 2010 and contribute directly towards Government outcomes of the protection of environmental assets and natural resources from industrial waste. This thrust also supports local government effectiveness by developing methods for the evaluation of the long-term impacts of mining activities, to encourage industries to switch to cleaner production rather than waste generation followed by treatment. The WRC has been conducting mine-water related research for over ten years. The research is conducted with specific end-user groups in mind. These range from the general public to mine engineering staff, practitioners and specialists. The earlier research projects dating back to the year 1989 were based on gold and uranium mines. The focus areas of these studies were the water requirements and pollution potential of these mines. Subsequent research projects focused on issues such as the impact of mining on the surface water environment, treatment options for mine effluents and the rehabilitation of mine soils. A significant amount of research is conducted on modelling techniques and predictive tools. The studies tackled issues such as industry-

wide water balance, development of low-cost passive water treatment systems and water modelling systems for the mining industry. From the year 2005 the WRC extended its scope to coal mines and acid mine drainage, where it focused on predictive tools for long-term water quality management in underground collieries, as well as the quantification of the potential and magnitude of acid mine drainage under South African open-cast conditions. Support to Government Outcomes is exemplified by the Regional Mine Closure Strategy. In 2005 the Department of Minerals and Energy developed and subsequently implemented a regional mine closure strategy for hydraulically linked mines following a significant array of research conducted by the WRC on mine-water and dating back to the year 1989. Specifically, the WRC published a report on mine closure strategy entitled 'The development of appropriate procedures towards closure of underground gold mines from a water management perspective', which made an important contribution to the DME closure strategy. The premise of the mine closure strategy was that most mines are hydraulically interconnected with adjacent mines. As such the closure of one mine within the region will often have impacts on the remaining mines. The last mine to cease operations in the region also ran the risk of bearing the cumulative burden imposed by all the other mines that ceased operations before it. The mine closure strategy thus assisted in providing an equitable basis to share responsibility between neighbouring mines in the same region. It also contributed to long-term plans to deal with the legacy of poor quality water from mines, thus assisting to address Outputs 1, 3 and 4 within Outcome 10: 'Environmental assets and natural resources that are well protected and continually enhanced'.

- Thrust 5 is directly linked to support Government's output on 'Reduction of water loss from distribution networks from current levels of approximately 30% to 18% by 2014 coupled with encouraging users to save water'. As highlighted above, the objective of Thrust 3 is to stimulate innovation and application of novel water-saving and efficiency devices which can, overall, reduce the consumption of water and the generation of wastewater.

Needs analysis

The KSA, in its endeavour towards identifying research needs, as well as developing and improving research strategies at the thrust level, has continuously engaged at a strategic level both nationally and internationally, to identify any gaps and to strengthen the portfolio of priority research topics and areas requiring attention. We believe that the continuous process of analysing and reviewing our strategy ensures that the KSA remains on a strategic path, as well as responding to challenges of the sector. The new DWA framework, Water for Growth and Development, has set priority imperatives for the water sector and the KSA portfolio is aligned to respond to the challenges posed.

In previous years, interaction with the Minister of Water Affairs highlighted the following areas of priority of relevance to the KSA's activities:

- **Climate change:** need for interventions at provincial and local levels

- **Water conservation and demand management:** more emphasis at a domestic and industrial level
- **Water pollution:** development of technology-based solutions and changing public attitude, as well compliance and enforcement
- **Rainwater harvesting:** Raising its profile, with the need for new technologies and awareness

Similarly, ongoing strategic sessions with a broad representative group of stakeholders, highlighted the following areas of concern:

- Better understanding and management of the water crisis
- Skills development
- Non-compliance issues
- Water security and availability
- Carbon footprint vs. water footprint debate
- Water pollution
- Cost of water to industry
- Improved dissemination and knowledge transfer
- Water quality
- Asset management
- Dealing with acid mine drainage
- Performance of wastewater systems
- Financing of water services infrastructure
- Energy efficiency

In reviewing the wealth of information generated through the various processes, including consultation with DWA and other stakeholders, it was clear that the key challenges facing the water sector in South Africa, as identified in previous years, remained unchanged and warrant greater emphasis and support. The KSA's strategy and focus are in line with supporting Government's long- and short-term objectives, and especially those of ASGISA (Accelerated Shared Growth Initiative for South Africa) and the DWA framework strategy, Water for Growth and Development. These objectives are:

- In a changing and dynamic legislative and strategic environment many solutions are required for sustainable and affordable water services provision. A key focus over the next few years will be on strengthening the capacity of local government to function in this challenging environment, the introduction of successful models of service delivery which enjoy the support of all stakeholders, addressing the issue of poverty and service provision (including affordability and cost-recovery), development of appropriate strategies, tools and policies to regulate water services and give effect to the water services and related legislation. The aspects of community participation and local economic development are central to these objectives.
- The realisation of the challenges of meeting the MDG targets, and, in the case of South Africa, eliminating the water and sanitation backlogs.
- The water services environment is in a continuous process of dynamic change. The newly-published related legislation, besides setting a new set of challenges and goals for the sector, has reached a point of review. It will be imperative that the success of these frameworks and legislation will realise the ultimate goal of

national water policy and local government legislation.

- The provision of sanitation is more complex and provides greater challenges as the responsibility is spread across many government departments. The short-, medium- and long-term goals are to find effective and efficient mechanisms to accelerate sanitation delivery and hygiene education coverage. These two components are essential ingredients for sustainability and for achieving public health objectives. Focus areas over the short term are to develop appropriate technical solutions, finding cost-effective ways to provide high-impact hygiene education, finding acceptable and affordable service arrangements, models for sanitation delivery and O&M, and improving the legislation and policies that contribute to an enabling environment. The sustainability of low-cost and onsite sanitation systems is already beginning to surface. Short design life, pit emptying, relocation and access to pits are some of the key technical challenges which may jeopardise achievements made to date and the provision of sustainable sanitation.
- It is evident that new issues in water supply (water treatment, distribution, etc.) will continue to emerge as new contaminants are introduced into the water sources. Great challenges also exist in providing sustainable and affordable technical solutions for the poor and indigent sections of the population.
- The energy crisis in the previous years has raised the need for more efficient use of electricity and the need for alternative energy sources. As part of the KSA's objective of efficient and affordable water services, three key variables have been the focus for many years; these being energy, chemicals and materials, which together make up an estimated 70% of the operational cost of providing water services. More emphasis is now being placed on energy issues and proactively we have initiated and promoted many approaches to support this important cause. The research on efficient water use has also been stepped up, and this has a direct bearing on the energy requirements of supplying water services. These areas will continue to grow in an endeavour to meet the needs.
- Gearing the sector towards the impetus created towards water for growth and development.
- In water supply and treatment technology, the needs over the next few years revolve around the supply of more affordable water of improved quality, especially to those people who do not yet have a reliable drinking water supply. Specific issues and research needs include the reduction in cost of water treatment and supply; the removal of organic contaminants; the removal of *Cryptosporidium*, *Giardia* and other pathogens; the identification and removal of emerging contaminants posing negative health effects; safe and efficient water fluoridation; improvement in the cost efficiency and sustainability of small- to medium- sized water treatment plants; dependable and efficient distribution systems; cost-effective distribution systems for rural water supply and sustainable and low-cost small water treatment systems. Medium- and long-term goals are to focus on infrastructure and asset management.

- Most of the country's industrial and mining activities are concentrated in areas where there is a lack of water resources. These sectors generate large amounts of wastes (toxic and non-toxic), which have a profound impact on the ecology of the receiving water environments. As urbanisation and industrialisation increase, increasingly complex wastewater streams are introduced. It is imperative that solutions are generated to manage these negative impacts. Furthermore, there is growing recognition for more innovative approaches such as water footprint, cleaner production and waste minimisation. These areas require greater research support for knowledge generation and application.
- The mining industry presents additional needs that emanate from its legacy of water quality-degrading waste that has been accumulating for more than a century, and which could potentially affect water quality for future generations. In the case of gold mines these needs have to be addressed with urgency, as many mines are about to close down, which may represent lost opportunities to introduce pollution-prevention measures. Key areas to be addressed include the process of acceleration of cleaner production and waste minimisation technology, and the development of innovative solutions to deal with the legacy of waste and acid mine drainage potential that has accumulated as a result of mining activities.
- There is a need for improving institutional capacity in the management of water and wastewater problems, as it has become increasingly clear that these problems cannot (in the South African context) be solved by technical solutions alone. Institutional reform and strategic management issues (such as regulation, capacity, competencies, partnerships, tariffs, community participation, etc.) all play an equivalent role in achieving an integrated solution. Great strides in information gathering and knowledge generation and application are required in this area over a short period.
- Over the past few years great strides have been made in covering water and sanitation backlogs resulting in significant achievements. This has also resulted in the expansion and growth in infrastructure in urban and rural areas. More small schemes have come into existence and, from international and local experience, pose greater challenges in their sustainable management.
- Furthermore, the infrastructure and associated resources are the assets of our country and contribute to improving the quality of life, and these assets need to be managed effectively. Lack of attention over the past few years to O&M, together with the lack of training and capacity, is beginning to show its weaknesses in the state of our water infrastructure. This valuable investment, if not given due attention, could prove costly for the country.
- Industry and mining is facing increasing pressure with the rising cost of water, but also increased scrutiny on the sustainable use of the resource. The concept of a 'water footprint' is an emerging and effective tool being developed to assist industry to scrutinise their activities and continuously strive to reduce their footprint on the environment.

Overview of technological trends

At an international level key pressures which drive research and solutions are:

- Economic development and population growth
- Increasing demand for food, energy and water
- Global and regional changes to the climate
- Degradation of water quality
- Risks associated with infrastructure deterioration

Thus there is a continuous move towards new approaches to the provision of water services and adaptation of new approaches to improve domestic water quality and availability of water through alternative advanced technologies. Within these objectives climate change and energy efficiency are now becoming key drivers and influences. In the quest to achieve efficient and sustainable water service delivery, it is becoming more and more important to include these two variables or factors, which have a significant impact on the continuous provision of services. Against the background of South Africa's current electricity challenges, energy efficiency and wise water use are priorities.

A trend in developing countries is to decentralise or devolve the management of services to a local level or to a local government level, with the national authorities moving into a stronger regulatory role. This shift provides a number of challenges of capacity and competency in the delivery of water services, especially in developing countries where there is the need to address the plight of the poor and indigent who make up a large portion of the customer base. Thus, innovative institutional arrangements and partnership models between public/private/community are being investigated to provide optimum solutions. Specifically in Africa, the issue of capacity and competency requirements, technology choices, institutional arrangements and costs and affordability are key areas of activity.

Internationally, there is a new drive to accelerate sanitation and hygiene education delivery and radical new policies and strategies are being investigated to achieve the millennium goals. It is essential that these concepts and ideas be translated at a local level, thus requiring the need for developing improved strategies, policies and mechanisms that create a sustainable and enabling environment.

In water supply, the emphasis is on efficient use of water and managing demand, as well as looking at the contributory elements such as energy, pipe components and materials, water supply components and behavioural aspects. In terms of treatment technology, the current international trends are toward the increased removal of more specific contaminants in the water. In addition, it is aimed at adding fewer chemicals to the treated water product (improved source quality). The removal of pesticides, heavy metals, endocrine disruptors, disinfection by-products and other harmful organics is receiving attention. The removal of *Cryptosporidium* and *Giardia* and the use of membrane filtration in this regard are receiving much attention – especially in the USA. There is a strong trend towards improving determination techniques for these emerging contaminants. An area receiving considerable attention is in the use of molecular biology and genetic engineering techniques. In developing countries the emphasis continues to be on breaking the transmission cycle of faecal-oral and water-related diseases through understanding the practices and

behaviours which contribute to their spread. Improved education and knowledge are central strategies to tackle these problems.

In the quest for improving the water quality delivered to consumers, there are growing needs for improved analytical methods to analyse for undesirable and emerging contaminants. In this regard new improved methods are continuously being investigated, keeping up with the international trends.

In the developed world, there is greater attention and focus being placed on managing source quality for improved potable water quality. Secondly, as desalination technologies become cheaper, we see more use of these technologies (Singapore/Middle East are examples). This source of water is also being seriously considered by some South African coastal cities. Further to the concerns of the diminishing levels of fossil fuels, water and waste are being looked at amongst the renewable resources for energy creation. Greater attention is also being given to new promising technologies such as nanotechnologies, membranes, etc., as they may greatly benefit water treatment technology.

In both the municipal and industrial sectors, the most significant trend internationally, nationally and at local authority level has been the growing realisation of recognising effluent wastewater and wastes as a resource. The treatment of wastewaters and wastes that have been generated without the application of cleaner production and waste minimisation principles is a losing game, ultimately costing all the parties material and energy resources, i.e., money. The consequences are profound: co-regulation becomes a meaningful negotiation; value as co-product is extracted from 'wastes' before discharge, thereby further reducing the waste load requiring treatment; technologies for treatment aim at being 'cleaner', are more focused towards specific waste fractions or even constituents and include recovery and reuse where technically and economically justifiable; resource-efficient technologies are not only favoured, but even their optimum deployment ('where' in the process stream) is critically examined, etc. These trends are predicted to not only continue, but, in fact, accelerate in the future.

The mining industry has yet to embrace these new realities, and wastewater and waste treatment in this sector presently continues to be material- (e.g. chemicals) and energy-intensive, although more environmentally-friendly solutions are increasingly favoured; for example, biotechnological treatment of acid mine drainage associated with potential recovery and reuse of the renovated water for a variety of purposes. The cost-effectiveness of cleaner production technology is increasingly recognised and will in itself be a strong driving force for the accelerated introduction of the technology. Another driving force is the international trade sanctions that are increasingly being applied against manufacturers that do not apply responsible environmental practices. Increased activity in the field of mine-water has resulted in the creation of a dedicated thrust with two entirely new programmes to cater for it. In South Africa, it is foreseen that the introduction of waste-discharge charges will be a further powerful driver towards internalising pollution costs and implementation of cleaner technology.

The contribution of mining-related non-point sources to water quality degradation is increasingly appreciated and has given rise to a need for improved techniques with which to quantify their contribution and improved technologies to minimise their effect.

Key stakeholders

The Minister of Water and Environmental Affairs is the shareholder of the WRC, and DWA and DST are its key

stakeholders. In addition, the following stakeholders also continue to be of key importance to the WRC in general and to this KSA in particular. They comprise both internal and external stakeholders. Over the years, our international partners and business partners have also proven valuable to us.

The internal stakeholders are the WRC personnel, Executive Management and the Board, with the shareholder being the Minister of Water and Environmental Affairs.

The external stakeholders include:

- Government ministries and departments (Water and Environmental Affairs, Cooperative Governance and Traditional Authorities, Health, Mineral Resources, Science and Technology, Education, Human Settlements, etc.)
- Beneficiaries (i.e., the users or potential users of research, development and knowledge products produced through WRC funding)
- SALGA, local government, provincial government units; including one-to-one interactions at the local and district municipality level
- Development Bank of Southern Africa
- Water boards, water services providers, catchment management agencies, water user associations
- Industrial sectors and industry-representative bodies (mining, forestry, water services, etc.)
- NGOs, CBOs and international aid agencies
- Private consultants
- Tertiary institutions, primary and secondary education institutions, science councils, professional bodies (Water Institute of Southern Africa (WISA), South African Institute of Civil Engineering (SAICE), Institute of Municipal Engineering of Southern Africa (IMESA), etc.), media agencies
- The public
- International coalitions such as Global Water Research Coalition (GWRC), Water Supply and Sanitation Collaborative Council (WSSCC), Water Utility Partnership (WUP), Emerging Technologies (ET), United Nations Environment Programme (UNEP), International Resource Centre (IRC), Water Research Fund of Southern Africa (WARFSA)
- The business sector

Providers

Providers are solicited or unsolicited individuals and organisations who generate research, development and knowledge products with WRC funding. The key providers are tertiary institutions, science councils, consultants, NGOs, water boards, research units within government departments and local government, private companies and individuals.

RESEARCH PORTFOLIO FOR 2012/13

The results of the strategic needs analysis and its review, needs expressed by the Minister of Water and Environmental Affairs through the variety of workshops and seminars, and engagement with DWA and other stakeholders with regard to its objectives and thrusts, have been well supported. Reviews highlight that the

relative weight of this KSA's thrusts seems to be well-balanced regarding the needs of urban-industrial-mining and rural research needs. Feedback from these exercises has ratified the KSA direction and the many valuable inputs assisted in strengthening the portfolio.

During 2012/13 the portfolio continued to build on the strategic changes from previous years, as well as strengthen the portfolio towards making greater impacts on the social and health aspects, environment and economy of the country. In summary, we do not foresee any major changes to the KSA strategy and portfolio of thrusts over the next few years.

The primary objective of this KSA is to continue to provide knowledge that ensures reliable, affordable and efficient services to enhance the quality of life, and contribute to economic growth. These objectives are in line with the Department of Water Affairs strategic goals in meeting the objectives set in the Water Services Act and the National Water Resource Strategy, as well as the new DWA framework strategy, Water for Growth and Development (Version 6). The strategic context of the KSA and its activities respond to the WRC five-year strategy. Within this context the KSA will put greater emphasis over the next few years on the following concepts:

- One Water – this is based on a vision that there is no wastewater in the system and that all qualities of water are a resource for use.
- Resource recovery – this promotes the view that there are and will be no pollutants in the sources of water, only resources which can be recovered for beneficiation offering opportunities for direct reuse.
- Energy resource – the role of water resources in the efficient use of energy, as well a net contributor of green energy.

The new portfolio of projects for 2012/13 continues to provide solutions that support these directions in the following ways:

- Developing tools, guidelines and appropriate institutional models for accelerating sustainable delivery of water and sanitation services
- Providing information that supports the development and application of water services legislation
- Improving understanding and knowledge on sanitation and hygiene education
- Management of brines
- Management of acid mine drainage
- Extending the implementation of water footprints, waste minimisation, cleaner production, cleaner consumption and clean technologies
- Climate change adaptation and mitigation
- Investigating the potential and technologies required for recovery and reuse of water from industrial, mining and domestic wastewaters (including grey-water and stormwater)
- Furthering the knowledge and technologies for recovery and reuse of material and energy resources in water and wastewater management
- Enhancing ways to predict pollutants and their impacts
- Addressing infrastructure security and sustainability
- Optimisation of water and wastewater treatment processes

- Developing innovative and cutting-edge technologies and solutions
- Producing cutting-edge science and technology
- Investing in emerging contaminants affecting water quality, especially trace organics
- Energy efficiency and generation, as well as the energy water nexus
- Institutional strengthening – financing, regulation, etc.

COMPLETED PROJECTS

THRUST 1: WATER SERVICES – INSTITUTIONAL AND MANAGEMENT ISSUES

Programme 1: Cost-recovery in water services

Assessing the impact of expansion of bulk infrastructure on capital requirements of Water Boards
Palmer Development Group
No. 2086

Water Boards were established under the Water Services Act of 1997 to provide bulk water to other water services institutions and to serve as water services providers when contracted by municipalities. A number of recent initiatives have been aimed at expanding the operations of Water Boards. Expanding the areas of activity of Water Boards will have an impact on their financial viability, most notably on capital expenditure requirements. As a result, the WRC supported this study to conduct research on the impact of expansion of bulk infrastructure on the capital requirements of Water Boards. The study involved two main streams of work. The first stream focussed on modelling the impact of expanding areas of activity on the financial viability of Water Boards; the second on identifying indicators for assessing the ability of Water Boards to access capital finance, particularly under expansion. The results from this study highlight the fact that the expansions to Water Boards' footprints and activities proposed under the IRR process pose considerable challenges. Expansion will require the Water Boards taking on significant new assets and incurring considerable capital expenditure over the next 20 years. This will place strain on operating accounts, and on the ability to raise capital. When considering the implications of expansion, an assessment of the performance and structure of the municipal areas into which the Water Boards are being asked to expand is vital.

Cost: R767 845
Term: 2011 - 2012

Programme 2: Institutional and management issues - Water services

Guidelines on condition assessment of water services infrastructure
University of Pretoria
No. 1950

The management of physical assets involves a wide scope and range of processes including acquisition, control, use and disposal of the assets in a manner that satisfies the constraints imposed by business performance, environment, ergonomics, and sustainability requirements. The focus of this research is on condition assessment of the water services infrastructure components and the development of guidelines for the condition assessment of these components. The objective was to focus on what should be done and therefore the research did not address

any detail of a prescribed protocol of how condition assessment for the different system components should be conducted. The methodology included the review of existing operational information to gain insight into the procedures followed to conduct asset management and to relate the operational experience to the remaining useful life by formulating a relationship between the status and remaining life. The outputs emanating from the study include:

- Data requirements to define the water infrastructure components
- Conceptual model between performance and life expectancy
- Applicable non-destructive techniques for condition assessment of water transfer
- infrastructure
- Description of the economic evaluation techniques to compare replacement or refurbishment
- Development of software (spread sheet) to determine the remaining useful economic life

Cost: R338 657
Term: 2009 - 2012

Development of protocols and guidelines for municipalities to undertake studies to determine the impact or influence of climate change on water service delivery
University of the Witwatersrand; Gondwana Environmental Solutions (Pty) Ltd; University of Pretoria; Rand Water; CSIR
No. 1953

Water services management is likely to be one of the most complex problems facing South African municipalities in the future. There is a strong link between water services and climate variability around the country. Trends towards greater urbanisation and densification, coupled with environmental changes such as climate change, are likely to exert pressure on water resources. It is necessary for strategic planning at a local government level to avoid water supply challenges in the future. The risk that climate change poses to water supply and demand is growing both globally and locally. Incorporating climate change projections and their implications into municipal management is gaining support in cities around the world (e.g. London, New York). Projected climate change is important for various planning horizons, particularly those that aim to address climate and development issues in the short and longer term. Improving the understanding of current storm risks is not purely for the benefit of the science-policy dialogue, but for that of affected communities. Efforts also need to be made to understand how flood risk is framed and perceived by those most affected by such storms. The purpose of this study was to evaluate the impact that climate change is likely to have on water services management for a local authority in South Africa by modelling future climate scenarios for South and Southern Africa, identifying the risks associated with the expected consequences of the predicted changes in climate and evaluating the impact on water management using a hydrological model. The key findings emanating from this study indicate that municipalities will have to deal with more frequent high-intensity short-duration storms. This is going to put huge pressure on existing drainage infrastructure such as stormwater and sewerage systems, but will also have an impact on associated infrastructure such as road, buildings etc. Low-lying low-income settlements were identified to be the most vulnerable and proper planning and intervention is required now to avert any future crisis.

Cost: R700 000
Term: 2009 - 2012

Programme 3: Innovative management arrangements - Rural water supply

Franchising partnerships for operation and maintenance of water services
CSIR
No. 1952

Year after year, the operation and maintenance of too much of South Africa's water services infrastructure has been found to not comply with the required standards. Breakdown of service delivery is too often the outcome. The primary objectives of the Butterworth schools sanitation and water servicing pilot project was the demonstration of the suitability of social franchising partnerships under these circumstances, and the development of a model which can be used for rolling out similar services to the rest of the more than 4 000 rural schools across the Eastern Cape. These objectives were successfully achieved. The pilot was extended to the pit-emptying of 400 household toilets for the Amathole District Municipality. This was also completed successfully. In short, the franchising partnerships concept, as it has been applied in the Eastern Cape pilot, has been an unqualified success in terms of the quality and reliability of service delivered.

Cost: R4 800 000
Term: 2009 - 2012

Bridging the policy divide: Women in rural villages and the Water for Growth and Development Framework
Mvula Trust
No. 1988

The study investigated the implementation of water legislation and policies at the grassroots level, evaluating whether the intentions of specifically the Water for Growth and Development framework to bring water services and water resources together in support of women as strategic users of water, and in particular rural women's use of water for their emerging productive activities, were being met in reality. The study also examined the extent to which local authorities meet their developmental mandate to promote local economic development by supporting rural women's multiple uses of water. Women in rural areas use water for domestic use but also for emergent productive use to sustain their livelihoods and develop incomes for themselves and their households. This means women are local economic actors as envisaged in the Water for Growth and Development policy. Water policy, in particular water resource management policy such as the National Water Resource Strategy and Water Allocation Reform Strategy; recognises that equity in access and use of water should be secured for emergent productive users of water, such as women in Strydkraal and Apel. The lack of formation of water resource management structures has seriously impeded women's development as emergent users of water for productive purposes. While both policy and legislation recognise the need for equity in post-1994 water management and supply, policy goes further to identify emergent productive water users such as women as a sectoral group that requires servicing and assistance for its water needs. The National Water Act gives these policies legal force through water resource management structures and processes- such as WUAs, CMAs, Catchment Management Strategies and Allocation Plans, which were envisaged to be in the forefront of supporting emergent productive water users to sustainably pursue their livelihoods and economic activities.

Cost: R596 000
Term: 2010 - 2012

Strategy for large scale roll-out of community-based service provision
Palmer Development Group; Mvula Trust; North-West University (Potchefstroom); University of Pretoria
No. 2090

The central tenet of this research study was to identify the key factors of success for the large-scale implementation of community-based service provision; and to draft a strategy on integration of community-based water services provision. The study has developed a Strategy for the Upscaling of Community Based Service Provision. The vision of the Strategy is for every household and enterprise requiring potable water in rural areas to have access to a safe and reliable water supply, for poor households to have access to a basic water supply free of charge, for those that are not poor or who consume water in amounts above the free basic water limit to pay for water, and for water to be conserved with an emphasis on avoiding losses in distribution systems. The Strategy provides a definition of what a Community-Based Partner is and outlines a range of options and arrangements for involving the community in water supply. The research presents an approach by which local and national government can respond to water service provision in largely rural areas using community-based operators. The findings from this research can also be used to target the support strategy for the 21 presidential districts.

Cost: R645 500
Term: 2011 - 2012

THRUST 2: WATER SUPPLY AND TREATMENT TECHNOLOGY

Programme 1: Drinking water treatment technology

Development of a durable and reliable Wave-Energy Reverse Osmosis Pump (WEROP) desalination system
The Impact-Free Water Group; University of the Western Cape; Confluence Associates; African Centre for Water Research; AH Associates; Environmental Monitoring Group; Institute for Maritime Technology; University of Stellenbosch; UNISA; University of Cape Town
No. 1716

In recent decades South Africa has witnessed a rapid shift from scattered inland populations to concentrated coastal development. In 20 years some estimate that more than half the population will live within 10 km of the shore. This zone is already the most water-stressed and ecologically fragile strip in the country, pushing groundwater pumping and surface storage to costly and dangerous limits. This project developed a prototype of an alternative water supply technology that works with nature rather than against it. We call it a Wave Energy Reverse Osmosis Pump, or WEROP. Primary research was carried out on site around the Cape Peninsula, using constructive feedback and lessons learned to improve operation and design of the WEROP. Despite difficult working conditions, the model unit proved to be relatively straightforward to assemble, deploy, and operate. Over several months it remained very durable, with little corrosion despite the lack of paint, with little maintenance required other than replacing the sacrificial anodes. The unit has been tested to 90 bars, which is far higher than the 62 bars required for reverse osmosis. It was shown that, in theory, this could be pushed to an average of 2 500 L/day in an average sea with a

wave height of 0.5 m and a period of 8 s. This is rather conservative, as the average period of wind chop is around 4 s, thus doubling production. A wave height of 0.5 m is also very modest, as the waves found in the target area are on average over 1 m in height.

Cost: R1 400 450
Term: 2007 - 2013

Assessment of the prevalence of organic compounds in raw and treated water for potable purposes, their fate in current treatment plants, and compilation of a guideline on best available technology for the removal thereof
University of Johannesburg; Chris Swartz Water Utilisation Engineers; Technical University of Delft
No. 1883

This project investigated the nature of natural organic matter (NOM) appearing in source water in the relevant parts of the country, and presents an assessment of the efficiency of selected drinking water treatment plants. The plants reflect typical unit processes used throughout the country. The report classifies the NOM categories according to their removal efficiency. Work on actual plants was supplemented by suitable bench-scale process simulation investigations, since the treatment performance of full-scale treatment plants did not provide sufficient detail, and extensive bench-scale work was required to provide a large enough database. Three advanced methods were sufficiently developed to apply in the project, namely BDOC, FEEM and modified PRAM. Suitable existing and novel techniques and processes which could be employed to remove the problematic NOM fractions were identified, and included enhanced coagulation, activated carbon and nanoporous polymers. Enhanced coagulation and carbon adsorption were thoroughly covered. Ion exchange (both weak and strong resin) was covered in less detail. Ozonation was addressed through a limited number of samples from full-scale treatment plants. Some exploratory work on nanomaterials was included towards the end of the project. A guideline on the efficient removal of NOM from South African source waters was compiled and is included in the final report.

Cost: R1 800 000
Term: 2009 - 2012

Development of a costing model to determine the cost-efficiency and energy-efficiency of water treatment technologies and supply options
Chris Swartz Water Utilisation Engineers; Cape Peninsula University of Technology; Development Bank of Southern Africa; GO Water Management; Umgeni Water
No. 1992

This project developed a user-friendly costing model, WATCOST, for estimating costs of drinking water supply systems. This allows economic comparison between different water treatment and supply options being considered for a water supply scheme. It also allows costing reports to be done for existing water treatment systems, which assists with budgeting and asset management processes. The aim of WATCOST is two-fold: firstly, the manual can be used as a reference document for information on costing data for water supply projects, with actual costing figures that can be obtained from the tables and graphs in the document. Secondly, the manual is also an aid when using the WATCOST model to obtain costing data for water supply projects, either in total or for specific components in the drinking water supply cycle. The WATCOST Costing Model is available electronically, downloadable from the WRC website. The model will also be available on

a CD inside the manual. The electronic copy of the model on CD contains the following: user instructions, input component (where the user will enter required information), software that will do the cost calculations – the model component, output component (that will provide the tables and graphic costing results), and a database of costing information (not accessible to the user, only for doing cost calculations). The WATCOST model is aligned with the DWA costing model, so that it can be integrated with this model as required.

Cost: R776 800
Term: 2010 - 2012

An independent investigation into the purification capacity of small-scale water purification units manufactured and supplied in South Africa
National Institute of Occupational Health; University of Pretoria; University of Johannesburg
No. 1994

Recent failures in potable water delivery as well as outbreaks of waterborne diseases in South Africa have led to members of the public investigating the use of home water treatment devices (HWTDs) to ensure that their tap water is safe for human consumption. Very few independent studies have been published on the capacity of HWTDs to effectively treat water. The majority of publications refer to projects which only tested for a single organism or compound and/or a single product. To date, only two studies have been published where HWTDs were tested for more than one compound. A need therefore existed for an independent study to evaluate a representative number of units sold in South Africa against the claims that are made in sales brochures. The study evaluated the performance capacity of tap mounted and jug-type HWTDs available in South Africa for domestic use, with regard to their ability to remove microorganisms under a variety of running conditions as prescribed by the National Standards Foundation, and to compare the findings to the SANS241 requirements for potable water quality and with the claims made by the manufacturers of the products. Most of the HWTDs tested within this study could potentially improve the water quality in terms of its aesthetic attributes (such as reducing scale), but in terms of taste, odour, heavy metal and microbiological reduction claims, the HWTDs tested performed poorly compared to the manufacturers' claims. Devices which used ultrafiltration and sediment filtration mechanisms were most successful at reducing bacteria and cysts, however none of the HWTDs tested removed viruses. Most of the devices tested decreased or removed chlorine. In terms of turbidity, mechanical reduction and dissolved solids assays, ultrafiltration and sediment water treatment technologies were the most successful at excluding particles in water. None of the HWTDs tested reported any success of reducing fluoride in water. Some of the HWTDs removed copper, aluminium or zinc from water but none was effective at removing iron, manganese and lead. Most of the HWTDs failed to remove carbon; conversely, some of them added to the total organic carbon in the water. This is a concern as carbon is a substrate for microbes which could lead to fouling of HWTDs. Lastly, most of the HWTD's failed to comply with NSF P231, 42 or 53 and SANS 241:2006 water treatment device standards and most of them did not meet the claims made by their manufacturers.

Cost: R809 000
Term: 2010 - 2013

Energy efficiency in the South African water industry: a compendium of best practices and case studies

Chris Swartz Water Utilisation Engineers; The Water Group; Waterscience cc; Amatola Water

No. 2092

Energy will in future become a high-cost item for municipalities and utilities which operate and maintain water and wastewater processes. Energy consumption will continue to increase as more people are provided with water and sanitation and new technologies are implemented to meet stricter effluent and potable water quality requirements. To position the water sector globally with regard to energy consumption, the Global Water Research Coalition (GWRC) embarked on a project entitled Energy Efficiency in the Water Industry: A Compendium of Best Practices and Case Studies, which looks at these best practices worldwide. The project is supported by the GWRC partners world-wide as represented by the four Continental Coordinators in Australasia (Australia and Singapore), Europe, South Africa and the USA. Each continental group created a report of best examples submitted by utilities in their region. The four continental reports, when available, will be compiled into the global compendium. The report by the UK Water Industry Research Ltd. (UKWIR, 2010) on energy efficiency in the UK water and wastewater sector concluded that overall energy efficiency gains of between 5 and 15% may be achieved, with up to 25% energy efficiency improvement in wastewater treatment processes (mainly activated sludge processes).The report further indicated that renewable energy, mainly in the form of combined heat and power (CHP) from sludge gas, could contribute significantly to the net energy demand of the water industry. A similar report was compiled by the Water Environment Research Foundation (WERF, 2010) in the USA, and provides best practices for the energy-efficient operation of wastewater industry assets in North America. The WRC, as partner of the GWRC, has funded the current project to develop a Compendium for the South African water industry. The scope of work covered the principal activities of water and wastewater businesses and focused on the identification of current best practice, tools and technologies. The study evaluated both incremental improvements in energy efficiency through optimisation of existing assets and operations, and substantial improvements in energy efficiency from the adoption of new technologies. It also highlighted new processes, plant types and systems which realise more substantial energy gains. Water and wastewater treatment plant surveys were conducted to document case studies and examples of best practice.

Cost: R1 000 000
Term: 2011 - 2013

Programme 3: Drinking water quality

β-*N*-methylamino-L-alanine bioaccumulation and bio-magnification: Health risks and water treatment possibilities

Nelson Mandela Metropolitan University; Cripsis Environment; IGB- Leibnitz Institute of Freshwater Ecology and Inland Fisheries

No. 1885

β-*N*-methylamino-L-alanine (BMAA) is a neurotoxic amino acid produced by cyanobacteria. BMAA is implicated in neurodegenerative disease as it causes motor neuron damage at fairly low concentrations. Potentially harmful BMAA within cyanobacterial cells may be released on cell senescence. Collapse of a substantial cyanobacterial bloom may result in release of large amounts of the toxin into water. The aims of this project were to evaluate potential risk to consumers, the fate of the toxin in the environment, the environmental

consequences of BMAA in the water, and the potential for contamination of drinking water. Data suggested that BMAA is rapidly taken up by a wide range of organisms and becomes freely available in food webs. Furthermore, data showed that bioaccumulation occurs in certain species while biotransformation can occur in some species. Standard methods including sand filtration, chlorination and the use of activated carbon were all successful at removing BMAA at laboratory scale. The absence of BMAA in any treated water tested, including treated water from bloom-containing raw water, confirms that standard water treatment practices adequately protect consumers from BMAA at known concentrations in raw water.

Cost: R1 800 000
Term: 2009 - 2013

Nanotechnology solutions for drinking water
Rhodes University
No. 1991

The work focused on nanotechnology-based solutions for drinking water in which electrospun nanofibres were used for removal/detection of contaminants in water. The aim was to develop electrospun nanofibre-based devices for water purification as well as monitoring of water quality. Nanofibres were fabricated by electrospinning. The experimental approach consisted of evaluating the recognition principle (compounds or metallic nanoparticles) responsible for selectivity in solution phase, then incorporating it in or on a nanofibre platform. The objectives of the project were to: (1) develop sorbents for uptake of metals in water; (2) develop nanofibres with antimicrobial properties for control of pathogens in water; (3) develop optical probes for the detection of heavy metals and organic contaminants in water; and (4) develop enzyme/substrate immobilised electrospun nanofibres for removal and monitoring of contaminants in water. All four objectives were achieved. Sorbents were developed for uptake of metals, and were demonstrated to be selective for arsenate species. The uptake of arsenate was not affected by competing anions. The interaction between arsenate and the electrospun nanofibres is suspected to be via hydrogen bonding of the anion with the hydroxyl groups on the primidine ring. Nanofibres incorporated with 2-substituted N-alkylimidazoles showed excellent antimicrobial activity against Gram-positive bacteria. Electrospun nanofibres incorporated with silver(I) complexes showed a broader spectrum antimicrobial activity, attributed wholly or partially to the silver(I) ions, depending on the type of microorganism. Optical detection probes were developed which discoloured in the presence of Ni(II) but not when exposed to other metals. Another probe, for the colorimetric detection of 17β-estradiol, was developed using gold nanoparticles in electrospun nylon 6 and polystyrene polymer nanofibres. This probe was also highly selective for and sensitive to the target compound. The research detailed in this report has enhanced the understanding of the use of electrospun nanofibres as a platform for water purification and contaminant detection strategies. The new probes invented during this project are protected by patents 2012/08972, 2012/08973 and 2012/08971.

Cost: R1 800 000
Term: 2010 - 2013

Scoping study and research strategy development on currently known and emerging contaminants influencing drinking water quality
University of the Free State;
University of Pretoria; Dames
No. 2093

The aims of this project were to review literature on emerging contaminants (ECs) in drinking water and identify three critical ECs for which (a) analytical methods would be reviewed, (b) a national reconnaissance survey performed, and (c) a risk matrix developed. Critical EC-related issues would be also identified and a future research strategy developed. Three contaminants were chosen for the national survey: atrazine (herbicide), carbamazepine (analgesic and anticonvulsant) and terbuthylazine (herbicide). Samples were taken of treated drinking water in Bloemfontein, Cape Town, Durban, Johannesburg, Pietermaritzburg, Port Elizabeth, and Pretoria. Samples were taken in February, May, August and November of 2012. All samples were quantitatively analysed using HPLC-MS for the three selected contaminants. All samples were also qualitatively screened for the presence of over 600 possible contaminants using liquid chromatography tandem mass spectrometry (LC-MS-MS). The LC-MS-MS screening analysis revealed the presence of a total of 38 pesticides or pharmaceuticals. The HPLC-MS analysis showed that even the maximum concentrations of atrazine, carbamazepine and terbuthylazine were more than 10 times less than maximum contaminant levels set by the US EPA. A national programme should be considered in which drinking water is seasonally or bi-annually qualitatively screened, and frequently-observed ECs are quantitatively analysed. It is also recommended that a similar qualitative screen and quantitation of the level of selected ECs be undertaken in one or more rural communities that routinely use raw water directly from rivers and dams. A study is also recommended on the presence of pharmaceuticals in borehole water due to leaching from medical waste dumping grounds.

Cost: 598 900
Term: 2011 - 2014

Verification and validation of analytical methods for testing the levels of PPHCP (pharmaceutical and personal health care products) in treated drinking water and sewage
UNISA
No. 2094

The main aim of this work was to develop, verify and validate appropriate analytical methods for hormones and other pharmaceuticals and personal health care products (PPHCPs). The focus was on using charged aerosol detector–high pressure liquid chromatography (CAD-HPLC). PPHCPs and their metabolites have been recognised as a group of the emerging contaminants in aquatic environments. Effluent from wastewater treatment works (WWTWs) is one of the major routes by which these compounds enter the environment. The large number of potential compounds and their diversity creates specific analytical challenges. A separation method was developed for the 12 non-hormonal PPHCPs which showed good linearity and accuracy. Relatively high limits of detection and quantification were obtained making them likely to be applicable to the higher concentrations one might expect in wastewater treatment plants but not in drinking water. Some PPHCPs were detected in WWTWs influents and fewer in effluents.

Cost: 500 000
Term: 2011 - 2013

Programme 4: Water distribution and distribution systems

Determining the change in hydraulic capacity of pipelines
University of Pretoria; Cripsis Environment; Rand Water; TCTA
Rand Water
No. 1820

It is generally accepted that the operational life of pipelines could well be longer than the 30 years which are used in the economic analyses of pipeline systems. Networks of Rand Water and other water utilities prove this, although there are a number of reported cases in which pipelines failed short of the expected operational lifespan. Funding of new water projects in the near future will have to compete with the capital that is required for the renovation, replacement and upgrade of existing infrastructure. An informed status assessment of a pipeline can only be made if the operational performance history of the pipeline is known. Optimal capital expenditure and operational cost is based on the performance and expected hydraulic performance decay rate of pipeline systems. Long-term performance data is essential for this assessment and an effort should now be made to gather information on a regular basis for a number of different pipelines in South Africa. This project highlighted the general lack of hydraulic performance history; hence little information is available to be considered for the hydraulic assessment and future planning of extensions or improvements to system components. Monitoring the performance of infrastructure provides knowledge to make informed decisions on the limitations and decay of the system and to optimally determine the required upgrade and extensions to the system. The expected high-energy cost in South Africa highlighted the importance of re-assessing the energy efficiency of pumping systems. In this regard a decision diagram has been developed to guide the decision whether to upgrade, replace or rebuild sections of the pipeline system. The influence of biofilms on hydraulic capacity and the energy losses occurring at field joints of pipelines needs to be researched in further detail.

Cost: R785 000
Term: 2008 - 2011

Full-scale trial to investigate the correlation between modelled and measured residential water demand and wastewater flow based on end-use modelling
University of Stellenbosch; Overstrand Municipality; AVDM Consulting Engineers
No. 1995

The objective of this study was to correlate measured and modelled water use at a high spatial resolution and time scale, in order to assess diurnal patterns and peak flows for individual properties. An 'end-use' of water has numerous definitions and meanings in the literature depending on the scale of the investigation. An end-use may be either an indoor end-use or an outdoor end-use. Typical outdoor end-uses include garden watering and a swimming pool, while indoor end-uses include toilet, bath, shower, (clothes) washing machine, dishwasher, etc. The focus of this work was on indoor end-use. The water use in both study areas was compared to the theoretical peak flows and derived peak factors, based on the end-use model. The theoretical 15-minute peak factor was found to be 62 for a single house, that is in the range of the recorded peaks. However, it was unexpected to find such a large variation in actual peak factors from one home to the next.

Cost: R842 000
Term: 2010 - 2013

Compendium of case studies relating to water loss and water demand interventions at the municipal level in South Africa
Resolve Consulting
No. 1997

The need for demand-side interventions that effectively reduce physical losses in water networks, artificial demand at the end-user level created through leakage, as well as apparent losses due to metering and billing deficiencies, is abundantly clear. In response to this need, municipalities across the country have initiated interventions, programmes and projects to reduce the demand for water, with varying levels of success. Aimed at identifying, documenting and disseminating the experiences of municipalities in water demand management, the WRC directed the development of a compendium of case studies relating to water demand management at the municipal level in South Africa, presenting 40 case studies in an anecdotal easy-to-read format. The presented case studies highlight not only best practice in the industry, but also less effective approaches that can potentially achieve greater effectiveness through improved management and implementation. It is hoped that technical, financial and managerial officials of municipalities, as well as councillors, community leaders and communities themselves, will use this compendium as a tool to identify, conceptualize, formulate and implement initiatives based on the case studies presented that effectively address water demand and reduce water wastage.

Cost: R545 195
Term: 2010 - 2012

Apparent losses in selected areas in South Africa
University of Cape Town
No. 1998

While apparent losses look like real losses to a municipality, this is not actually the case. The main components of apparent losses are water meter under-registration and unauthorized consumption, but meter reading and data errors are also contributing factors. Thus the objective of this study was to estimate the extent of apparent losses due to meter under-registration in South Africa. The occurrence and flow rate distributions of on-site leakage were measured in Cape Town and Mangaung using the same methodology as an earlier Johannesburg study. The study found that, based on on-site leakage investigations in Cape Town, Mangaung and Johannesburg, it is estimated that the meter under-registration error for on-site leakage will be 15% of the registered leakage rate. This is equal to roughly 2.2% of demand. The total meter under-registration error in middle- to high-income areas is thus estimated to be 5% of consumption. In low-income areas, on-site leakage occurs with much higher incidence and thus meter under-registration can be expected to be higher. A review of meter audits done on bulk consumers showed that a lot more needs to be done to ensure that these meters are correctly sized and installed and in good condition. Based on the increase in revenue investigations after the meter audits performed in Tshwane and Ekurhuleni, it seems that the apparent losses of bulk consumers are potentially around 20%.

Cost: 400 000
Term: 2010 - 2012

THRUST 3: SUSTAINABLE MUNICIPAL WASTEWATER AND SANITATION

Programme 1: Emerging treatment technologies– Preparing for the future

The development and commercial exploitation of a suite of technologies to supplement the Biosure process
ERWAT; Phatamanzi Minerals (Pty) Ltd; CSIR (NRE); Keyplan
No. 1780

The development of the BioSURE Process commenced at Rhodes University in the early 1990s. Following bench-scale studies, the process was scaled-up to a pilot plant (Corbett, 2001) with a treatment capacity of 40 m^3/day located on-site at Grootvlei Mine in Springs, Gauteng Province. This plant operated for 18 months treating an AMD stream with a sulphate load of approximately 2 000 mg/L. Kinetics and engineering studies were then conducted at the Water Research Group, Department of Civil Engineering, University of Cape Town (Ristow, 1999, Ristow et al. 2002; 2005), resulting in the design and successful operation of another pilot-scale operation at the ERWAT Ancor WCP, Springs, with a treatment capacity of up to 2 ML/day. A 2.4 km pipeline has been constructed to feed mine water from Grootvlei Shaft No 3 to the Ancor WWTP. This investigation showed that using the correct reactor configuration, with strict control over the mine water flow rate and the primary sludge dosing rate, the biological process could reliably remove sulphate to concentrations below 100 mg/L at hydraulic retention times as low as 12 h. Based on these positive results, and with a degree of safety in the design, a full-scale plant was designed to treat 10 ML/d of mine water from Grootvlei Shaft No 3 in Gauteng, South Africa (Neba et al. 2006; Neba, 2007). The successful construction, commissioning and operation of the full-scale 10 ML/day BioSURE Process provided useful information on the following aspects:

- Demonstrated that the plant can operate well and meet strict effluent standards
- Confirmed the accuracy of the kinetic model and process design criteria, but also gave a clear idea of the operating limits of the plant
- Highlighted the importance of meeting the minimum COD/SO_4 requirements
- Emphasized the need to improve the process to remove hydrogen sulphide from the effluent
- Further pilot studies indicated that the biological sulphate-reducing process (BSRP) is able to convert permanent hardness into temporary hardness that allows the use of cold-lime softening processes to desalinate the water
- Offered the opportunity to consider the option to utilize waste organic material other than PSS (primary sewage sludge), such as abattoir and dairy waste as carbon and energy source; this scenario allows the possibility to reduce the load on the existing landfill-sites and limit the leachate production potential and offers an opportunity for revenue generation.

Cost: R1 350 000
Term: 2007 - 2012

The optimisation of waste stabilisation ponds by combining duckweed-based and algal-based systems, together with aerated rock filters
Africa Remediation Technology; Tshwane University of Technology
No. 2005

Wastewater stabilization pond (WSP) technology is one of the most important natural methods for wastewater treatment, especially in rural areas. It was found that while there was a wealth of information available on the design considerations for algal pond systems, there was a lack of information on duckweed-based systems, particularly with respect to the optimal growth conditions, expected nutrient uptake rates and recommended harvesting rates for removal of nutrients from the system. This study therefore focused on duckweed-based treatment at a pilot scale. The following conclusions and observations were made from the studies undertaken:

- The surface density of duckweed in the duckweed ponds is important. If too high, the plants will have limited access to nutrients in the upper layers, and limited light, gas exchange and space to grow, reducing the potential for nutrient uptake.
- The harvesting rate is important for the maintenance of the correct surface density and to allow for the growth of the duckweed to reach its full potential. If the frequency of harvesting is too high, young plants will continually be removed from the system.
- At the concentrations of nutrients tested under the artificial light conditions with low light intensity, higher concentrations resulted in lower growth rates and wash out of the cultures at the harvesting rates tested, especially at the lower temperatures of 13 and 18°C. Thus at lower temperatures for full-scale duckweed systems it may be necessary to dilute the influent with either final effluent of the treatment system or of the duckweed ponds themselves through a recycle.
- At lower nutrient concentrations, where duckweed were expected to be nutrient limited, it was observed under all temperatures and light intensities that the roots and fronds of the *Lemna* spp. increased in length and size.
- Duckweed preferentially take up ammonia nitrogen as a nitrogen source, rather than nitrate. Duckweed ponds must therefore precede algal ponds, rather than vice versa, as ammonia nitrogen will be converted to nitrate nitrogen through nitrification in the aerobic environment of algal ponds. It is also important that an anaerobic process precede the duckweed stage, where organic material can be mineralized and ammonia-nitrogen and ortho-phosphorus released in the bulk liquid.
- The light intensity and temperature applied to a mixed duckweed culture affected the species composition, with *Lemna turionifera* being the dominant species under high light intensity in the sun, and *Wolffia* spp. dominating under medium light intensity in the shade.
- It is important that the duckweed layer not become mass transfer limited, as this will result in low nutrient uptake. Introduction of turbulence in the duckweed treatment system is therefore a requirement, either by gentle mechanical mixing or through the use of baffles.

The results of the laboratory study were applied to develop potential conceptual designs for a pilot-scale trial proposing several configurations for an integrated WSP system.

Cost: 1 000 000
Term: 2010 - 2012

Programme 3: Stormwater and sewerage systems

Alternative technology for stormwater management
University of Cape Town; City of Cape Town; eThekwini Municipality; IDS (Information Decision Systems); Johannesburg Municipality; SRK Consulting (SA) (Pty) Ltd; Tshwane Metropolitan Municipality
No. 1826

Stormwater management in the urban areas of South Africa has been, and continues to be, predominantly focused on collecting runoff and channelling it to the nearest watercourse. This means that stormwater drainage currently prioritises quantity (flow) management with little or no emphasis on the preservation of the environment. The result has been a significant impact on the environment through the resulting erosion, siltation and pollution. An alternative approach is to consider stormwater as part of the urban water cycle, a strategy which is being increasingly known as Water Sensitive Urban Design (WSUD) with the stormwater management component being known as Sustainable Drainage Systems (SuDS). SuDS attempts to manage surface water drainage systems holistically, in line with the ideals of sustainable development. It aims to design for water quantity management, water quality treatment, enhanced amenity, and the maintenance of biodiversity. In so doing many of the negative environmental impacts of stormwater are mitigated and some benefits may in fact be realised. This study set out to identify and develop new and appropriate guidelines for the use of alternative stormwater technology in South Africa. The project resulted in the development of the following knowledge products:

- Sustainable Drainage Systems – South African case studies.
- The South African Guidelines for Sustainable Drainage Systems (The South African SuDS Guidelines)
- The 'SuDS Economic Model (SEM)'
- The 'SuDS Conceptual Design' poster
- The'Working Sustainable Drainage Systems into the City' poster
- The 'Water Sensitive Urban Design: South Africa' website (www.wsud.co.za)

There is unfortunately limited experience and data available locally; therefore the parameters quoted in this guideline have all been collected from international literature. These parameters are dependent on a variety of factors including, inter alia, climate, pollution composition and concentration, technical design, and maintenance. Local conditions should thus be carefully considered before the use of these values.

Cost: R1 800 000
Term: 2008 - 2012

Improving sewerage for South Africa
University of Cape Town; City of Cape Town; eThekwini Municipality
No. 1827

Informal dwellings tend to be laid out in a manner that is not conducive for retrofitting drainage according to conventional engineering standards. Coupled with unfavourable ground conditions (ranging from settlements in flood-prone areas to discontinued landfills), retrofitting and/or installing conventional sewerage in such conditions is inherently problematic, particularly in situations where residents refuse to relocate (even temporarily) for fear of further

marginalisation. Alternative approaches to providing sewerage to informal settlements were investigated in order to determine whether there are other means of providing these areas with low-cost wastewater collection systems. This report builds on South African research into alternative sewerage systems (Du Pisani, 1998a, b; Eslick and Harrison, 2004; Van Vuuren and Van Dijk, 2011a, b) by presenting the outcome of their utilisation and management in three Western Province applications: simplified sewers and vacuum sewers in two Cape Town informal settlements and settled sewers in the formal areas of Hermanus. The progress in planning a pilot settled sewer project for the Cape Town informal settlement of Barcelona is also presented. The four case studies reported upon in the document endeavour to illustrate a variety of socio-political and risk factors that cause sanitation facilities and projects to succeed or fail, especially in informal settlements. A significant amount of 'best practice' literature and discourse was also reviewed on how best to develop alternative sewerage schemes and participatory approaches as a means to possibly improve urban sanitation conditions in South Africa's high-density informal settlements. More cost-effective and flexible sewerage than conventional systems are needed to sewer South African informal settlements, and this need can potentially be met through alternative technologies such as simplified, settled or vacuum sewerage. These technologies are technically proven to work elsewhere in the world; however, the South African research to date has reached the conclusion that the ability of sewers to function as designed is closely related to how sanitation technologies are planned, managed and used. In other words, the social processes that underlie the planning, provision and management of sewerage systems are just as significant as technology choice.

Cost: R1 500 000
Term: 2008 - 2012

Programme 5: Sanitation technology and innovations

Evaluation of the bucket eradication programme
Hlathi Development Services; Tshwane University of Technology
No. 2016

In February 2005, the bucket sanitation backlog in formal townships was estimated at 252 254 buckets (DWAF, 2006). According to the Department of Water Affairs' closing out verification report of the bucket eradication programme (BEP), between February 2005 and December 2007, the national Government allocated a total of R1.8 billion for the BEP (DWA, 2009). The majority of municipalities used the conventional waterborne sanitation system to replace buckets in urban formal settlements. This presented a challenge for municipalities servicing areas without bulk sewers and inadequate wastewater treatment capacity, and in some cases the available water supply could not support the new waterborne sanitation systems. This study was initiated to assess what worked and what did not work, to evaluate the extent of compliance of the bucket eradication programme (BEP) with sanitation policy principles and the impact of the BEP on quality of life for the beneficiary communities. The BEP case study municipalities failed to comply with most of the sanitation policy principles. The found that the supply-driven approach adopted in the implementation of the BEP failed to plan for sustainable sanitation service delivery because it focused on toilet construction. This led to poor performance of wastewater treatment works which were assessed as part of the study because no resources were allocated to the proper operation and maintenance of new or upgraded WWTWs. The BEP put limited emphasis on hygiene awareness, community involvement and user education.

Cost: R920 000
Term: 2010 - 2012

Evaluation of the user acceptance and functioning of mobile communal sanitation facilities – a case study of Cape Town
Cape Peninsula University of Technology
No. 2017

Technical innovations often lack sustainability due to a lack of attention to or provision of operational requirements and community involvement. The application of sanitation technologies in informal settlements lacks a framework for introducing and assessing the performance and functioning as well as an understanding of the perspectives of end-users of the new technology, despite the existence of the national Strategic Framework for Water Services. This general framework does not clearly define 'basic sanitation' in terms of technology. This research was initiated to deal with this problem by investigating the current approaches to the implementation of a new sanitation technology, and the acceptance and functioning of the technology in the natural setting of informal settlements. The study concludes that the MCSF can adequately function in the context of informal settlements (IS), provided strict observance of each phase of the framework's criteria and associated indicators. The functioning of MCSF is context based and depends on user's demand for sanitation, compliance with operational requirements and the extent of O&M (with regard to the way reported issues are responded to). The high level of user's acceptance of the facilities registered through the application of the framework and the adequate functioning of the facilities are aligned with the research hypothesis, except for the planning phase of the functioning. For this phase of the framework, the research has shown that adequate functioning of the facility is influenced by the demand for sanitation and appropriate design is only a secondary issue.

Cost: R716 750
Term: 2010 - 2012

THRUST 4: SUSTAINABLE AND INTEGRATED INDUSTRIAL WATER MANAGEMENT

Programme 2: Integrated management

An assessment of the key factors that influence the environmental sustainability of a large inland industrial complex
CSIR, University of Stellenbosch; Eco Innovation, University of Cape Town; University of KwaZulu-Natal (Durban), University of Stellenbosch, No. 1833

This project looked at the key factors that influence the environmental sustainability of a large inland industrial complex, the Secunda Industrial Complex. The main finding for this study is that the long-term increasing trend for unaccounted salt flows to the surface water systems indicates control of salt storage and disposal is the key factor for environmental sustainability. The economics of desalination and waste storage are driven by the cost of water and the management of post-closure liabilities. These two parameters are controlled in the governance system for clean water conservation and mine-water production, which is the main source of salts. A key weakness in the governance component appears to be the absence of public data on relative techno-economic and environmental performance for alternatives identified by stakeholders in the complex. Research is currently system-specific, proprietary and therefore uncoordinated. Findings on capacities and leakage are not reported in the public domain.

Lessons from this project indicate that the problems of technology selection and economic viability are less complex when there is a sustainable economic plan to eliminate uncertainty on post-closure liabilities, and a set of technologies that can be made to work using a purchase contract for the recovered water. The main environmental uncertainty appears to be around the long-term stability of the salt storage systems. The systems were established under a different regulatory framework which had a much lower concern for water shortages, long-term salination and decanting of acid mine water. Definitive guidelines on salt storage and post-closure management of the salt stockpiles have not been developed and subjected to the scrutiny of public review. This appears to be a key barrier to the quantification of environmental and economic sustainability. The key sustainability problem is how to reverse the trends of positive feedback on the salt storage problem. Another concern is the increasing trend in salination and risk of AMD pH-dependent river flows.

Cost: R3 000 000
Term: 2008 - 2011

Programme 4: Governance, policy, regulatory, and economical instruments to improve industrial water management

Protocol for quantitative assessment of industrial effluents for discharge permitting
University of KwaZulu-Natal (Pietermaritzburg); University of the Cape Town; Durban University of Technology; eThekwini Water and Sanitation; Sasol; University of Ghent
No. 1734

The major elements that the local authority has for managing industrial wastewater are its wastewater treatment plants for remediation, discharge permits for placing limits on what may be discharged, and a discharge tariff for financing the treatment and for providing a set of incentives and penalties to influence users of the system. An effluent discharge permit consequently is a crucial interface between the local authority and an industry, and the permit system has to carefully balance protection of the general public and the environment against the rights of those working in industry and the promotion of economic activity. The activated sludge process is the most common form of treatment for municipal wastewater in South Africa. In many of South Africa's WWTP's, an industrial wastewater fraction is accepted for treatment with domestic sewage. However, no biological or modelling approach is currently used to estimate impacts and, therefore, set limits on discharge. Hence, the conceptual basis of this project was to develop a protocol, involving a combination of laboratory testing and process modelling, which would be able to predict the effect of a range of loads of factory effluent on the operation of the treatment plant receiving its effluent, to inform the process of granting a discharge permit. Due to the sustained high impact of textile effluents on several WWTPs in eThekwini, textile effluents were chosen as the subject of all of the investigations. Baseline models were developed for two WWTPs in the eThekwini Municipality: Mariannridge and Verulam. Both were selected because they received a significant proportion (approximately 30% by volume) of industrial effluent, and because they experienced significant problems associated with textile effluent, primarily high colour and conductivity. Several series of tests were carried out to establish a methodology for assessing the biodegradability of surfactants using the OUR apparatus. However, the project faced several challenges: Characterisation of the incoming wastewater proved to be the major difficulty in both investigations.

Attempts to transfer the OUR measurement techniques to municipal staff met with very little success. This was partly due to the problems with the reliability of the technique, but also the unavailability of technical staff with the required level of skill, patience and time to devote to such a time-consuming measurement. Thus, although the project was motivated by a perceived need of the municipality to develop a more scientifically defensible basis for setting permit limits, there seems little chance that they would be able to implement such a complex protocol in-house for the foreseeable future. The obvious alternative would be to set up a specialist consultant service, with integrated laboratory and computational capabilities.

Cost: R1 600 000
Term: 2007 - 2013

Evaluation of partitioning coefficients for South African soils to inform the new National Framework for the Management of Contaminated Land with emphasis on the protection of water resources
Golder Associates Africa (Pty) Ltd;
University of Pretoria
No. 2102

Appropriate screening is imperative to the registration of contaminated land and has significant implications for industry, government and the environment. Inappropriate screening during initial investigations will result in some constituents and sites being screened for further detailed assessment and registered as contaminated land on the basis of naturally-occurring soil concentrations. On the other hand, some constituents and sites that pose a potential risk may appear uncontaminated while further investigation is actually warranted. A high degree of uncertainty therefore exists in screening soils for further assessment and registration as contaminated land. The aim of this study was to address a number of uncertainties and to assist in refining the norms and standards for the assessment of contaminated land. Following the results obtained from this investigation, the following is recommended: The 1:2.5 soil:solution ratio extract should be used to estimate the pore water quality of soil. This is also the standard method used for the determination of soil pH(H_2O) and therefore considered as an acceptable method and easily implementable by commercial laboratories. Based on the Kds determined in this study for 10 different diagnostic South African soil horizons, preliminary additional soil screening values could be calculated which are specific for certain soil types. However, the SA baseline concentrations for natural soils were also considered. Based on these calculations, soil types were grouped together and preliminary risk-based soil screening values (RBSSV) were established which can be used during Phase 1 contaminated land assessments. During Phase 2 contaminated land assessments, where more information will be available on soil type and properties, the Kds can be used to further refine the soil screening values for specific soil types/horizons. Vertic soils, red oxidic soils with high clay content, melanic soils and gley soils can have higher soil screening values for Cu and Pb, since these soils have a strong sorption capacity and the risk for groundwater contamination will be less. The Kds determined during this investigation showed a strong correlation with soil pH and therefore soil pH can be used to refine the Phase 2 soil screening values. Preliminary recommended pH-specific SSV (pH-SSV) for Cu, Pb and V were calculated which can be used during Phase 2 contaminated land assessments.

The potential risk that a contaminant may pose to groundwater can be assessed by determining the soluble fraction of the contaminant in the soil. A 1:2.5 deionised

water extract can be conducted on soil samples during the Phase 1 screening level assessment and the results can be compared to the Water Quality Guidelines for the specific contaminant to indicate potential risk for groundwater contamination.

Cost: R480 000
Term: 2011 - 2013

Programme 5: Water efficiency, cleaner production, beneficiation and treatment of industrial effluents

Pilot application of a dual stage membrane bioreactor for industrial effluent treatment
Alt Hydro cc; Dekker Envirotech; Cape Peninsula University of Technology; North-West University (Potchefstroom)
No. 1900

This project investigated the application of the dual-stage operations strategy in a pilot plant evaluation of a membrane bioreactor (MBR) for the on-site treatment and recovery (reuse) of industrial trade effluent. The goal of the study was to use the MBR system as a pre-treatment for the reduction of the wastewater pollution load so that a downstream reverse osmosis (RO) system can be incorporated to facilitate a zero-liquid discharge strategy as well as effluent reuse potential for the industrial partner. A textile manufacturer located in the Western Cape was chosen as one of the industrial partners for the on-site evaluation of the pilot plant. A 5 to 10 m^3/day MBR pilot plant incorporating sidestream Airlift™ membrane modules was designed and was operated on-site from March to December 2010. The design of the dual-stage MBR process was geared towards optimal microbial community enrichment and was based on a pre-denitrification configuration coupled with enhanced biological phosphate removal (EBPR) (anaerobic-anoxic-aerobic with recycle loops). The anaerobic-anoxic-aerobic process was designed to incorporate two primary functionalities: influent azo dye cleavage in a reducing environment followed by oxidation of the resultant aromatic amines; and biological nutrient removal through enrichment of associated microbial consortia using nitrification, denitrification, and phosphate removal processes. To achieve this, the preliminary data analysis was used to identify critical scale-up criteria. In terms of overall results, COD removal fluctuated considerably during the 3-month start-up stage (~100 days); thereafter, an average of 90–95% removal was achieved under optimised conditions. When compared to the South African Government discharge standard for COD (≤ 5 000 mg/L), the COD value for the treated textile effluent (20 mg/L) was well within this standard. A paper and pulp industry located in the Western Cape was also chosen as an industrial partner for the evaluation of a pilot-scale MBR plant for the treatment of paper mill effluent. A 45–65 L/day MBR pilot plant incorporating ceramic membranes in an external modular configuration (similar to the sidestream Airlift™ membrane modules) was designed and was operated in a laboratory from June to December 2010. The design of the dual-stage membrane bioreactor was based on a pre-treatment high-rate anaerobic system (EGSB) coupled with a post-treatment denitrification/nitrification configuration (anaerobic-anoxic-aerobic with recycle loops). The high-rate anaerobic process was designed to reduce influent COD in an attempt to reduce the need for high volume dosing. The anoxic-aerobic processes were designed to incorporate two primary functionalities: further reduction of COD concentration; and biological nutrient removal through enrichment of associated microbial consortia using nitrification and denitrification processes. In terms of effluent COD reduction efficiency,

the anaerobic pre-treatment stage gave an average of 70% COD removal while the MLE-MBR stage increased the total COD removal to 97%.

Cost: R950 000
Term: 2009 - 2011

Recovery and beneficiation of nutrients, water and energy from brewery effluent by means of algal assimilation, hydroponics and aquaculture
Rhodes University; Department of Water Affairs; Dames
No. 2008

The HRAP/wetland system is an environmentally sustainable method of treating brewery effluent that allows for the recovery of water and nutrients from the wastewater. It is a low-energy, low-maintenance system (both biologically and physically), driven mainly by gravity and the sun's energy. The only external energy inputs for the HRAP system were two small (0.45 kW) motors that drove the paddlewheels. As such, the cost to build and operate the system could be recovered quickly and the potential exists to recover these costs even faster if the water and nutrients that are recovered are reused or sold. The HRAP and wetland system consistently brought most water quality parameters tested here to within or close to the DWA general limits for the discharge of industrial effluent into a natural water resource. A model was developed that made it possible to predict the success of this system under various conditions that might be applied to other industries. Furthermore, the treatment/recovery process involved the production of downstream products such as algae, fish feed, fresh vegetables and healthy fish. This programme also saw the first attempt at optimising the use of industrial effluent as an inorganic source of fertiliser for hydroponic vegetable production. Fish and vegetable production can take place using post-HRAP water, or water that has been subject to both HRAP and CW treatment. The CW did not require pre-treatment in the HRAP and operated more efficiently when HRAP was not included in the treatment chain; however, it was not possible to exclude the primary facultative pond (PFP) prior to treatment in the CW. The advantage of the wetland is that it is entirely self-sustaining but is difficult to clean/recharge, may clog up over time and takes more time to commission, whereas the HRAP can be inoculated and fully functional within days. The downside of the HRAP/CW system is that it takes up considerably more space than conventional methods of water treatment, such as activated sludge systems, for example. The estimated area required to treat 1 000 m^3/day of post-AD brewery effluent is probably around 1.4 to 2.0 ha. However, with improved efficiency and optimisation this footprint might be further reduced. The programme has successfully demonstrated that industrial effluent, which is currently considered a costly liability by most industries, can be turned into a job-creating, income-generating stream, using simple technologies that have been available for years.

Cost: R1 798 000
Term: 2010 - 2013

Development of hybrid membrane-chromatography system for simultaneous recovery of valuable products and water purification for recycle in the olive Industry, with a view towards commercial application thereof
University of Cape Town; African Biological Extracts (Pty) Ltd; Cape Olive Trust (Pty) Ltd; Ikusasa Water (Pty) Ltd; Moss Group cc
No. 2010

Olives are exceedingly bitter and need to be cured to make them palatable before consumption. The curing process involves placing the olives in a brine solution whereupon a spontaneous lactic acid and/or yeast fermentation takes place. The brining process takes from 3 to 12 months, and is associated with various washing and rinsing steps. This results in noxious darkly-coloured and acidic wastewaters with a high organic load (COD < 70 g/L, high phenolic content (< 5 g/L), and high salinity (~10% NaCl, three times more than seawater). It is a water-intensive process; up to 10 kL of water is consumed per ton of olives processed. The wastewaters generated present an environmental disposal problem, as they are not amenable to biological treatment, and cannot be disposed of in municipal sewage systems or the environment for toxicity reasons. They are generally disposed of in evaporation ponds. A modular treatment system was successfully designed, constructed and operated in order to process wastewater brines from the table olive industry. The system was comprised of two main unit operations: membrane separation and chromatographic adsorption. These two sequential unit operations were able to simultaneously produce purified brine for recycling back into the table olive process, and recover high-value antioxidants which would otherwise have been discarded. In addition, the volume of wastewater for final disposal was significantly reduced. The process can be considered to be green, as no environmentally harmful or toxic chemicals were used or produced. Despite lower than anticipated yields and productivity in terms of antioxidant recovery, the project was considered overall to be a success. The membrane system operated adequately in terms of separating the darkly-coloured high molecular weight phenolic components from the brine, which was then treated by the chromatography system to produce purified brine for recycle. The purified brine was good quality and was deemed to be suitable for re-use. Overall process performance and economic feasibility of the system was evaluated. While not optimal, based on market analysis there is a strong case to be made for continued and improved operation of the system, and for subsequent increase to full-scale operation. In this regard a spin-out company is to be created in order to exploit the technology developed during the course of the project.

Cost: R892 000
Term: 2010 - 2012

THRUST 5: MINE WATER TREATMENT AND MANAGEMENT

Programme 3: Minimising waste production

Preparation of magnetic nano-composite beads and their application to remediation of mine wastewaters

University of the Witwatersrand
No. 2014

In this study, magnetic ion- imprinted polymers with high recognition for uranyl (UO_2^{2+}) and chromium Cr(VI) ions were prepared for the first time. The prepared magnetic ion-imprinted polymers were characterised and optimised in the laboratory. They were then applied to wastewaters from acid mine drainage and influent from a wastewater treatment plant. The optimum extraction parameters in batch format for magnetic ion-imprinted polymers for uranyl ions were found to be: sample pH of 4, and 50 mg of magnetic ion-imprinted polymers for a 25 mL sample volume. The optimum contact time was found to be 45 min at a stirring speed of 1 500 r/min. The lower maximum extraction time implies that the magnetic ion-imprinted polymers have fast binding kinetics. Under these

optimum conditions, the recovery of uranyl ions was found to be above 80%. The binding of uranyl ions on the magnetic ion-imprinted polymers was found to follow pseudo second order kinetics with rate constant (k_2) and correlation coefficient (R^2) ranging from 0.273 to 0.678 and 0.9811 to 0.9992, respectively. This implied a chemisorption interaction of the uranyl ions with the magnetic polymers. The adsorption of uranyl ions onto the polymers fitted both Freundlich and Langmuir models. The maximum adsorption capacity was found to be around 1.2 mg/g which is in the same range as other magnetic ion-imprinted polymers but lower than other ordinary polymers or imprinted polymers without magnetic ions. Despite low binding capacity, the prepared magnetic ion-imprinted polymers, when tested for selectivity, were found to have superior selectivity for uranyl ions compared to major competitors of Fe^{3+}, Pb^{2+}, Ni^{2+} and Mg^{2+}, ions that have similar ionic radius. The selectivity order observed was as follows: $UO_2^{2+} > Fe^{3+} > Pb^{2+} > Ni^{2+} > Mg^{2+}$. The same selectivity and recovery was observed when the magnetic ion-imprinted polymers were applied to wastewaters from acid mine drainage and influent from wastewater treatment plants. The optimum extraction conditions for the prepared magnetic ion- imprinted polymers for Cr (VI) were found to be as follows; sample pH of 4, adsorbent amount of 20 mg for a 25 mL sample volume. The extraction time was 40 min at stirring speed of 1 500 r/min. The low extraction time indicates fast binding kinetics of Cr(VI) to the prepared polymers. At optimum conditions, the recovery of Cr(VI) was above 80%. The maximum adsorption capacity for the magnetic polymers was found to be 6.20 mg/g. The optimum time for the adsorption of the Cr (VI) analyte was determined as 40 min at stirring speed of 600 r/min. The binding of Cr(VI) on the magnetic ion-imprinted polymers was found to follow pseudo second order kinetics. This implied a chemisorption interaction of the Cr(VI) ions with the magnetic polymers. The adsorption of Cr(VI) onto the polymers fitted neither Freundlich nor Langmuir models. The prepared magnetic ion-imprinted polymers were found to very selective towards Cr(VI) compared to SO_4^{2-}, F^- and NO_3^-. The order of selectivity of anions followed the trend: $Cr_2O_7^{2-} > SO_4^{2-} > F^- > NO_3^-$. The prepared magnetic materials may not be suited for remediation of polluted wastewater for uranyl and Cr(VI) ions on a large scale because of high cost of preparing them but are very good as sample extraction materials before final quantification. This is very important because direct analysis of these metal ions from wastewaters is a huge challenge because of other interfering ions. Since the materials can be reused more than six times, this makes them inexpensive for sample extraction purposes.

Cost: R378 500
Term: 2010 - 2013

Evaluating approaches to and benefits of minimising the formation of acid mine drainage through management of the disposal of sulphidic waste rock and tailings

University of Cape Town; Imperial College London
No. 2015

The ideal approach to handling of sulphidic waste rock is to prevent the potential for generation of acid rock drainage (ARD) through the removal of the sulphide phase before its disposal, thus avoiding the need for long-term mitigation strategies. In the best case, this processing of waste rock prior to disposal should result in an increase in the recovery of values from the starting material and the re-allocation of waste materials as feedstocks for other uses. This report focused on the goal of establishing feasible approaches for the prevention of the formation of ARD from mining wastes by the removal of the risk rather than its delay.

Current ARD prevention strategies focus on covers and coatings. While these are effective, the life span of their effectiveness remains in question. The potential for the removal of sulphides from tailings was demonstrated in WRC Report No.1831/1/11, using tailings and waste rock from a base metal operation as a model system. The removal of sulphide by both separation and by reaction was demonstrated for the tailings and waste rock respectively, with the former showing the most promise. In this report, the general application of sulphide removal by separation to reduce the risk of ARD generation is presented across tailings and finely-divided mineral wastes from various sources, including a variety of coal fines and tailings from the gold industry. Demonstration of the removal of sulphide is presented with the associated reduction in potential for ARD generation. Further, the cost implications and disposal routes for the sulphide and benign fractions removed are considered. With respect to removal by reaction, accelerated bioleaching has, to date, shown limited value; however new approaches, using a broader spectrum of reaction systems, have been highlighted for further study. To extend this work, it is necessary to recognise the need for both acceleration of the reaction of sulphide under controlled conditions as well as deceleration or closing off of these reactions by restricting the supply of reactants through restricting access of water, oxygen, leach agents as well as microbial colonisation. The closing off of these reactions may be a treatment in itself or may follow the accelerated reaction to remove readily reactive sulphur. The role in waste rock dump characteristics, including permeability, as a means to manipulate this is addressed. An experimental study was conducted to establish methodology and provide proof of concept of the 'mingling' approach through analysis of flow. The impact of flow rate on colonisation and leaching was also studied experimentally. Recent studies on the removal of sulphide from tailings by separation were reviewed. This demonstrated that significant strides forward, independent of this study, have not been reported in the open literature since the publication of WRC Report No. 1831/1/11. In this study, we have extended the sulphide removal studies to a range of finely divided materials, including the tailings from the preparation of pyritic gold ore concentrate, the BIOX® tailings, and coal fines. In addition to demonstrating the preparation of the bulk of the material for disposal such that the ARD generation potential is small, potential uses for the residues are considered, as is the process costing. Using a series of five samples of coal fines, the proof of concept was demonstrated of sulphide removal from the bulk of the waste tailings by separation, in this case flotation, in order to eliminate or decrease ARD generation potential. Further, it was demonstrated that biodegradable oleic acid was an excellent collector, yielding improved performance over dodecane. A similar study on tailings from the gold industry has illustrated mixed results. Using flotation to upgrade the tailings from the laboratory, bioleaching of pyritic gold concentrates has been successful with decreased sulphide grades reporting to the bulk tailings. Here ARD generation potential was reduced but not eliminated as with other mineral systems. On treatment of the tailings (collected from the tailings dam) from the concentrator circuit by further flotation, no significant upgrading was achieved; however the sulphide associated with the solid tailings was already low. The study of gold tailings samples was limited by those samples attainable. It is recommended that further representative samples be sourced for study to further assess the generalised nature of the findings. Potential uses for both the sulphide-rich and sulphide lean tailings samples have been identified and illustrate a range of potential applications. In order to establish a framework for the economic costing of the sulphide removal from tailings and fine waste materials, a flotation desulphurisation flowsheet has been proposed to follow

the traditional coal processing flowsheet. This has been used as the basis for an order of magnitude estimate of a new fine coal desulphurisation plant using flotation and performance estimates. Based on assumptions specified, this preliminary costing has suggested potential for economic viability. A sensitivity analysis is presented which targets, among others, value of the resource recovered, yield and reagent costs as key considerations for optimisation of the approach.

Cost: R1 435 250
Term: 2010 - 2013

Programme 4: Mining in the 21st century

Nanotechnology in water treatment
University of the Western Cape; Wroclaw University of Technology; University of Stellenbosch; Cape Peninsula University of Technology
No. 1897

Zero valent nano-iron, zeolites, ordered mesoporous carbons, electro-deionization, an electrohydraulic discharge reactor, and chemical vapour deposition were investigated and each was found to show great potential as an effective means to treat industrial wastes such as acid mine drainage (AMD) and brine. The full project report details experimental work ascertaining the effectiveness of integrating selected nanomaterials into six different remediation strategies for the treatment of model and real contaminated water samples. The waters included AMD from Gauteng and Mpumalanga, industrial brine effluents, dyes, and bacteria-laden water. Clays and zeolites underwent mild activation steps and were then shown to be effective in removal of ammonia and salinity from solutions. Zero-valent nano-iron successfully treated mine water, and a one step process (where the mine water is the source of iron) was the most effective option. Ordered mesoporous carbons were very effective as mercury sorbents after being modified with suitable functional groups. An electro-deionization cell was implemented as an effective system for removal of up to 1 500 ppm of the major cations from industrial brine. Model solutions and industrial brines were used to explore the exchange capacity of new membranes for their applicability in brine purification. An electrohydraulic discharge reactor incorporating supported titanium dioxide nanofibres was shown to demineralise dyes, and disinfect *Escherichia coli* spiked waters. The work has been patented. Lastly, a chemical vapour deposition method was used to synthesize titanium dioxide nanoparticles supported on carbon nanotubes (CNTs). The silver nanoparticles deposited on the titanium dioxide acted as electron acceptors, enhancing the charge separation of the electrons and holes, and that led to a transfer of the trapped electrons to the adsorbed oxygen during UV radiation.

Cost: R1 565 590
Term: 2009 - 2012

Extended investigations into recovery of water and salts from multi-component hypersaline brines using eutectic freeze crystallisation
University of Cape Town; University of the Western Cape; TU Delft; Cape Peninsula University of Technology
No. 2012

Hypersaline inorganic brines are generated by a number of industries, including mining operations, power generation and petrochemical refining. In addition, because of pressures on water resources, and thus further water recycling and reuse, these brines present an increasingly significant global problem. Brine management consists mainly of disposal to

lined evaporation ponds, which is both a costly and unsustainable solution. Viable brine treatment solutions do not currently exist, and thus there is an urgent need to both develop and implement such treatment options. Eutectic freeze crystallization (EFC) has been identified as a possible novel brine treatment method, but to date it has not been applied to multi-component streams such as brines. Therefore, the overall aim of this project was to investigate the applicability of EFC to the multi-component hypersaline brines produced by major South African industries. The first objective was to establish the thermodynamic and kinetic factors governing the operation of a sequential eutectic freeze crystallization process. The second objective was to summarise the effect of real brines compared to synthetic brines on the operation and control of a eutectic freeze crystallization process. For the third objective, the effect of impurities and contaminants on the ice product formed during a eutectic freeze crystallization process was investigated. For the fourth objective, the effect of impurities and contaminants on the ice product produced in an EFC process was investigated. The fifth and last objective was to investigate how operating temperatures affect the yield and purity of the final products formed in an EFC process. Four brines were studied overall: two from the coal mining industry (Brine 1 and Brine 2), and two different brines from the platinum mining industry in South Africa. The thermodynamic modelling software was able to predict and simulate the phase equilibria of a multicomponent aqueous system over a wide temperature range by estimating the standard state terms and the excess terms with the use of various thermodynamic models. This was an important step because the identities of the potential salts, the temperatures at which they would crystallize and the potential yields of the various products could be predicted before any experiments were conducted. However, the thermodynamics only offered an equilibrium prediction. It was only by investigating the kinetic aspects of the system that the identity, crystallization temperatures and yield of products under real operating conditions could be confirmed.

Cost: R1 571 490
Term: 2010 - 2013

Programme 5: Low-volume mined products

Development of an analytical sensor for the identification, quantification and detection of heavy metal pollution associated with precious metal refinery wastewater
CSIR; University of the Western Cape; Cape Peninsula University of Technology; Anglo Platinum Research Laboratories; Dublin City University
No. 2013

The use of fast, reliable and continuous monitoring techniques for water quality analysis has become essential. This project assessed the aquatic environment around platinum group metal mining, determining to what extent the aquatic environment has been polluted by these mining activities, and determined whether the current analytical tools and techniques used to analyse metals are adequate. Environmental water samples displayed low metal concentrations. Seasonal influences affected the diversity of taxa for the biota samples collected and the metal concentrations within these samples. High Ni, Pb and Zn concentrations were recorded and it is possible that these metals are released from the sediment-water interface. The concentrations in the biota and algae were low, indicating that mining activities had a low impact at the sampling sites. The August biota samples showed higher concentrations of Al, Fe, Ni, Zn and Pt than in November. This may be due to higher water flow during November 2010, since sampling was done during the rainy season. The

main focus of this project was the development of an electrochemical sensor for the identification and quantification of metals in environmental samples. The results showed that modifying the surface of a glassy carbon electrode with a bismuth film assisted in the stripping analysis of the $M(HDMG)_2$ complexes, with M as the PGM (Pd, Pt and Rh) and dimethylglyoxime (DMG) as the chelating agent. The results obtained for the evaluation of the sensor showed varying results. The pH, DMG concentration, deposition potential, deposition time and PGM concentration were optimised. The effect of interfering ions was investigated and Ni(II) and Co(II) were the main interferences. The limit of detection (LOD) was found to be 0.12 $\pm$ 0.06 µg/L for Pd, 0.04 $\pm$ 0.007 µg/L for Pt and 0.23 $\pm$ 0.04 µg/L for Rh. The ranges to which the sensor can be applied were 0.1 to 3.5 µg/L for Pd, 0.5 to 4.0 µg/L for Pt and 0.1 to 4.0 µg/L for Rh. The sensor was successfully applied in the determination of Pd, Pt and Rh in freshwater and sediment samples.

Cost: R716 000
Term: 2010 - 2012

THRUST 6: WATERSMART FUND

Programme 1: Watersmart fund

In-field demonstration of a remote, real-time water quality monitoring system
CSIR; Prime Africa Consultants
No. 2196

The aim of the project was to supply data in real time to municipalities so that they could better manage their wastewater quality. Initially pitched as a field trial at one remote rural WWTW, the interest and opportunities provided by eThekwini Municipality prompted the change to the selection of four WWTWs in that municipality, and the project was implemented at the Kingsburgh, Verulam, Mpumalanga and Amanzamtoti WWTWs. The WQMS stations were installed in August and September 2012 and six months of data was collected by the stations. Despite some challenges in installation and station operation, the sampling and data communication is now stable and reliable. The team was able to develop a comprehensive maintenance manual and identify the appropriate channels and methods of knowledge transfer. The study showed that the accuracy of the data collected and transmitted is unreliable, as evidenced by the variation from laboratory results (both CSIR and eThekwini) and the variation of probe readings between calibrations. For this reason, beyond an introduction to the online reporting system and an illustration of use, it was not shared as a functioning system for the four eThekwini WWTWs.

Cost: 250 000
Term: 2012 - 2013

CURRENT PROJECTS

THRUST 1: WATER SERVICES – INSTITUTIONAL AND MANAGEMENT ISSUES

Programme 1: Cost-recovery in water services

Strengthening the sustainability and effectiveness of Free Basic Water
Counterpoint Development
No. 1989

There is growing recognition across South Africa of the pivotal importance of sustainability in water services provision: sustainable funding and revenue to support ongoing service delivery, sustainable water resources

management to meet current and future demand, and sound operation and maintenance of all associated infrastructure to sustain continuous provision of potable water to citizens and key sectors of the economy. But does provision of Free Basic Water support or undermine sustainable provision of water services? The need to provide support to households living in poverty to enable them to access at least basic water services affordably is not in question. But how sustainable is the provision of Free Basic Water, as currently implemented, if it sends out mixed messages about the real value of water in a context of growing scarcity, and if it is contributing to operating shortfalls in municipal revenue arising from unbilled water? What are the trade-offs in the current approach? Are there more effective ways of achieving the desired outcome of ensuring that even the poorest citizens can afford at least basic services? There is growing evidence that the administrative and financial requirements for providing Free Basic Water and Sanitation sustainably to those who need it have been underestimated. Free Basic Water is at risk of becoming increasingly anti-poor, because many municipalities lack the capacity to implement it effectively or sustainably, are not able to manage their available funds optimally, and are funding service provision through under-spending on operation and maintenance. Inevitably these weaknesses compromise the quality of service provision, and it is the most impoverished households who are impacted most. In a context of chronic poverty, limited administrative capacity in many municipalities, and growing water scarcity, is the provision of Free Basic Water the most effective and sustainable way of giving force to the Constitutional right of access to adequate water? This study aims to review international good practice around financing water services and designing water tariffs for sustainable water servicing and to review approaches and funding mechanisms adopted by relevant middle-income developing countries with substantial poor populations to providing affordable water services to needy and vulnerable citizens.

Estimated cost: R1 400 000
Expected term: 2010 - 2012

Mechanism for pricing and financing the implementation of the Green Drop Report to guide the strategic decrease of the risk factor of wastewater treatment works
Asset Research
No. 2085

During 2010 the Department of Water Affairs published its 2009 Green Drop Report. Only 32 of the 852 wastewater treatment plants obtained a Green Drop award, i.e., were considered to have performed and achieved a delivery of service at acceptable risk levels. It was found that most facilities in the rural areas and smaller towns are not adequately equipped with staff of appropriate skills and this constrained the performance of these systems in their overall Green Drop assessment. While the report wishes to promote incentive-based regulation and acknowledge excellence in wastewater quality management, it neither reflects on the financial cost and resources required for achieving this nor on the economic costs and implications of not achieving the desired turn-around in waste management and improvement in performance of the wastewater treatment works. This study wishes to address these issues

Estimated cost: R597 500
Expected term: 2011 - 2013

Providing water services at tariff levels that cover cost and that are sensitive to demand
Nelson Mandela Metropolitan University
No. 2087

The benchmarks for municipal water service provision in South Africa have been set nationally and with reference to the level of income of the community – with a better service being provided to the well-off sections than to the poor. Historically, those users who were required to pay for the cost of providing the service were concentrated in relatively small urban areas. The tariff structure they faced was flat and determined with reference to a diverse range of accounting principles and practices. The burden of covering the cost of provision was averaged for the well-off users, proportional to use. More recently there have been several important changes – an increase in the level of high-standard service provided to the poor (towards a uniform service for all) and a movement away from a flat tariff structure to an increasing block tariff. This project proposes to contribute insights on the latter issue. There are many relevant questions in this regard. Does existing pricing policy incorporate the full financial costs of managing water? Are economic costs taken into account in the pricing of water services?

Estimated cost: R1 250 000
Expected term: 2011 - 2014

Programme 2: Institutional and management issues – Water services

Adapting and piloting the new concepts of Community-Led Total Sanitation (CTLS) in the South African municipal environment
Cape Peninsula University of Technology
No. 2088

Community Led Total Sanitation (CLTS) focuses on behaviour change rather than toilet construction. CLTS mobilises a cooperative approach based on people deciding together how to create a hygienic environment that benefits everyone. Total sanitation ensures that everyone uses a hygienic toilet and safely disposes of their domestic waste, creating a safe and clean environment. The CLTS approach encourages responsibility by the community, taking its own action. Cooperation among households is a key element, as is spontaneous emergence from within communities of 'natural leaders' (NLs) as facilitators. The objective of this study is to adapt and test the concepts of CLTS in the South African environment and context.

Expected cost: R2 500 000
Expected term: 2011 - 2014

A comparative analysis of water management devices in Cape Town and prepayment meters in Johannesburg
University of the Western Cape
No. 2089

South Africa has made great strides in improving access to water supply. Many poor people previously supplied with water, and those with new connections, face the grim reality of water un-affordability, exacerbated by the installation of prepaid meters and water management devices. Yet it has also been argued that the unwillingness of water users to pay is a remnant of anti-apartheid rent boycotts. This study aims takes the debate on water metering technology and cost recovery methods further. It seeks to expose the differing experiences of two major technologies used in South Africa – prepayment meters and water management devices which are ostensibly different. While these technologies may operate differently on the surface, it is likely that their effects are the same.

Estimated cost: R500 000
Expected term: 2011 - 2013

Programme 5: Water services education and awareness

Social norms and moderation of water consumption in a major South African city
EPRU
No. 2091

South Africa has a fairly limited supply of water. This supply of water is coming under increasing strain as democracy and economic growth have seen the water consumption of a growing number of South Africans increase, as their livelihoods improve and basic services are extended ever further. Much of this increased consumption is occurring in South Africa's large cities, Johannesburg, Durban and Cape Town, where the greatest share of South Africa's growing businesses are located and which are consequently the epicentres of growth and magnets for people migrating within the country. This study proposes testing a demand-side management strategy, based on reporting comparative social norms for water consumption, within one of South Africa's major cities' households and businesses. The strategy is to test the process of people making decisions based upon information that is reported in a particular fashion, rather than upon contexts such as price increases or slow roll-out of basic services.

Estimated cost: R462 000
Expected term: 2011 - 2013

THRUST 2: WATER SUPPLY AND TREATMENT TECHNOLOGY

Programme 1: Drinking water treatment technology

Application and performance of slow sand filtration
Cape Peninsula University of Technology
No. 1836

Slow sand filtration is generally highly recommended in small and rural community water treatment because of its simplicity in design, operation and maintenance. However, little awareness of the application of slow sand filters exists in South Africa. Very little is further known about the slow sand filters in operation in South Africa and how they are performing. The project, therefore, aims to investigate the extent of slow sand filtration applications in the country and practical performance of these filters, covering both successful and failed examples. It will also investigate and document the types, application and performance of the various pre-treatment processes prior to slow sand filtration. A database of all sand filtration plants in the country will further be compiled.

Estimated cost: R760 000
Expected term: 2008 - 2011

Wastewater reclamation for potable reuse
Umgeni Water
No. 1894

Water is a scarce resource, especially in South Africa where runoff exceeds rainfall and is unevenly distributed. South Africa has been classified as water stressed and water should therefore be conserved. The pressure exerted on surface and groundwater supplies should be reduced or at best maintained, rather than increased

as the country's human population and industrial development increase. Wastewater reuse offers such a possibility, and reclaiming domestic wastewater from Darvill Wastewater Works for potable reuse using membrane bioreactor technology is therefore being investigated. This project is intended to pave the way for technology enabling South African water suppliers to produce consistent, acceptable drinking water quality through used-water reclamation. Initial feasibility work will be followed by a demonstration plant designed and operated over a long-term trial to establish operating guidelines that ensure reliable product water will be generated at all times.

Estimated cost: R650 000
Expected term: 2009 - 20112

Development of design and operating guidelines for high-rate clarifiers in the South African water treatment industry
Umgeni Water
No. 1942

High-rate clarification is a relatively unexplored technology in South Africa, even though this technology is being used extensively abroad. There is only one known water treatment plant using high rate clarification in South Africa, i.e., the Bethlehem Water Works (a review of the performance of this plant is included as part of this project). This technology is not as widely used in South Africa as it is abroad due to poor marketing and a poor fund of knowledge on this technology. In conventional clarifiers, clarification rates of 1.0 m/h to 4 m/h are generally used, whereas in high-rate clarification processes clarification rates as high as 10-30 m/h can be achieved. With the increased cost of construction and especially the doubling of the price of steel over the last year, it is critical that structures with smaller footprints, using 10-20 times less steel and concrete be critically considered in future designs. As a typical example, a 4 m diameter clarifier operating at an upflow rate of 10 m/h would produce 3 ML/d of treated water. In contrast a similar diameter clarifier operating at conventional upflow rates of 1.0 m/h would only produce 0.3 ML/d.

Estimated cost: R1 800 000
Expected term: 2009 - 20112

Programme 2: Water treatment for rural communities

Compilation of guidelines for the selection and use of home water treatment systems and devices
Tshwane University of Technology
No. 1884

At least 5.7 million people in South Africa still have no access to treated, potable water within reasonable distances from their dwellings and many thousands more take water from water sources and use it untreated because of problems experienced with adequate and reliable potable water supply. Surface waters have steadily become more polluted – especially with regard to microbiological quality, which exacerbates the situation of the immuno-compromised when drinking inadequately treated or poor-quality water. A number of home treatment systems and devices are being used internationally by small, rural communities without potable water services (decentralised systems). These units vary from the most simple – such as using material as filter – to the most sophisticated systems treating grey-water to potable standards. Although various systems and devices have been extensively reported on in the literature, and some exploratory work has been performed in South Africa, little is known locally about the existing options – and little has been done

to assist local communities or their advisers in making informed choices on whether such a system or unit will be appropriate to their situation, or which unit should be selected. This project will meet the need to source and investigate appropriate units, to determine their efficiencies of contaminant removal under local conditions as well as their sustainability potential, and to provide guidance on the selection and use of these units under local conditions.

Estimated cost: R1 200 000
Expected term: 2009 - 2012

Programme 4: Water distribution and distribution systems

Energy generation from distribution systems
University of Pretoria
No. 2095

In South Africa we are facing an energy crisis which places additional importance on the harvesting of all available feasible renewable energies. The initial scoping investigation highlighted the potential hydropower generation at the inlets to storage reservoirs, i.e., the bulk water distribution systems. In South Africa there are 284 municipalities and several of the water supply utilities all own and operate gravity water supply distribution systems which should be considered for small-scale hydropower installations. Most of these water supply/distribution systems may be equipped with the pumps as turbines, replacing the pressure throttling valves allowing for the hydroelectricity generation. The hydro-energy may be used in the own plant, supplied to the national electricity grid or used to feed an isolated electricity demand cluster. This study aims to prove that it is feasible and technically possible to generate energy from distribution systems.

Estimated cost: R2 500 000
Expected term: 2011 - 2013

THRUST 3: SUSTAINABLE MUNICIPAL WASTEWATER AND SANITATION

Programme 1: Emerging treatment technologies– Preparing for the future

Mass balance modelling over wastewater treatment plants III
University of Cape Town; University of KwaZulu-Natal
No. 1822

The series of projects aims to develop a plant-wide wastewater treatment plant (WWTP) model used to accurately predict the outcome of the various biological, physical and chemical processes taking place in a WWTP. These tools can result in more economical wastewater plant design and operation and improved effluent quality. Significant advances have been made towards developing steady state mass balance-based integrated WWTP models which link primary sedimentation, nitrification-denitrification activated sludge and aerobic or anaerobic digestion of primary and waste activated sludges (K5/1338 and K5/1620). This project aims to determine the kinetics of P release from biological P-removal systems and determine the extent to which mineral precipitation takes place. The P release in anaerobic digestion will be compared to that observed in aerobic digestion. Certain aspects such as the mineral precipitation in aerobic digestion, the un-biodegradable fraction of primary sludge and the un-biodegradable fraction of the waste activated sludge from nitrification-denitrification systems will be confirmed. The research will determine whether the presence of primary sludge will assist in the hydrolysis of waste activated in anaerobic digestion.

Estimated cost: R998 950
Expected term: 2008 - 2010

Effects of urine separation and treatment on wastewater effluent quality
CSIR (Stellenbosch); AFRICON;
University of Stellenbosch
No. 1824

The project deals with alternative sewage collection and treatment for both low and high income communities in urban settings. The concept includes the separate treatment of urine and the rest of the black/grey sewage to achieve better effluent quality. This project aims to demonstrate at pilot scale that the DWA Special Standards can be achieved through (partial) separate collection of urine. In addition, this increases the capacity of the receiving wastewater treatment plant which could delay extensions. The research will be reconfiguring toilets and urinals to allow (partial) urine separation on pilot scale. It will determine the composition of urine and demonstrate the effectiveness of treating wastewater with less urine than normal in varying quantities to achieve very low nutrient effluent concentrations (DWA special authorisation), as well as relatively low salt effluent concentrations. The study will assess the operational issues, such as struvite and other forms of scaling in urine drains, odours, etc. This project will assist in creating awareness for the potential positive impacts of urine separation and the feasibility thereof.

Estimated cost: R1 200 000
Expected term: 2008 - 2011

Biotech in sanitation: biopolymer production with *Natronococcus occultus*, a haloalkaliphile using municipal wastewater and other waste resources
University of Cape Town
No. 2000

Natronococcus occultus is a haloalkaliphile isolated from East African soda lakes, which are characterised by low Ca and Mg levels, with high Na, Cl and CO3 concentrations and a pH of 10-11. *Natronococcus occultus*, produces a glutamic acid-rich polymer, poly-glutamic acid (PGA). This polymer has a wide range of uses including hydrogels, flocculants and soil conditioners and may be used for medical applications. Preliminary work in CeBER (UCT) laboratories has shown more consistent growth in the high salt environment under non-sterile conditions. This project aims to study this organism using wastewater as a feed substrate to produce a biopolymer or environmentally friendly flocculants. It can also be cross-linked and blended with the treated sludge for a high-value soil conditioner. This project investigates the potential of municipal wastewater treatment plants to produce materials required by the plant for operation, from its own waste resources.

Estimated cost: R356 000
Expected term: 2010 - 2012

Co-digestion of sewage sludge and industrial concentrates
University of KwaZulu-Natal
No. 2001

The WRC has supported several laboratory-scale and feasibility projects on co-digestion of industrial effluent as a treatment strategy for toxic industrial wastes. eThekwini municipality has agreed to pilot full-scale

anaerobic co-digesters at Amanzimtoti WWTW. The digesters are expected to be refurbished in 2010. As a support to this initiative, this project will look at using WEST software to assist in building and transferring knowledge on operation and training needs. The investigation will be undertaken in six phases that will overlap with one another. The project will look to develop an in-line model of the laboratory-scale AD which will be followed by the development of an unsteady state model for the anaerobic digesters at Amanzimtoti WWTW. This will be used to predict performance of the full-scale digester. The WEST model will also be developed to analyse tests undertaken with selected industrial effluents in order to determine the parameters necessary for describing the kinetic effects of co-digestion of different feeding rates of the effluent. The model will be assessed for its ability to predict and test the performance of several industrial concentrates at once. The project will also investigate scenarios to maximise methane production or toxic effluent treatment and to demonstrate recovery from process upsets. Finally, the West model will be used to train the operational staff on how to react to different hypothetical upset conditions. If during the period of the project, upset conditions occur, data will be recorded so that a portfolio of case studies can be developed and procedures will be developed to determine the root cause of the upsets. Overall, this project will assist in developing a model to assist in the process control and training of support staff for the implementation of co-digestion at a full-scale AD.

Estimated cost: R1 050 000
Expected term: 2010 - 2012

Urban effluent treatment in a rhizofiltration system
Durban University of Technology; University of Stellenbosch; University of Cape Town
No. 2004

Urban effluent includes stormwater, drainage from informal settlements and townships, sewer overflows, illegal industrial effluent connections to stormwater systems, and so on. Stormwater should ideally be treated at the source and this is the rationale behind permeable asphalt roads, swales and buffers. Whereas in the past the objective of urban drainage was to remove rainwater from settlements as quickly as possible, the philosophy has changed towards retention and drainage as slowly as possible. Where stormwater transport is inevitable, the aim is also to remove and contain pollutants where the flow originates, at source, through vegetated and sand filters. This project proposes that passive treatment systems would be able to remove (or trap) pathogens from urban effluent, together with other pollutants such as nutrients, hydrocarbons, dissolved metals and toxic substances. The objective of this research is removal of dissolved substances and pathogens from stormwater outlets, and is complementary to initiatives such as litter traps, or source control measures. Natural wetlands remove pollutants and improve surface water quality greatly while constructed wetlands have long been used as polishing processes downstream of municipal wastewater treatment. Three generations of constructed wetlands consist of the surface flow wetland, subsurface flow wetland, and vertically integrated wetland that shares characteristics with trickling filters and slow sand filtration. An important difference between the constructed wetlands as used downstream of wastewater treatment works and downstream of urban effluent discharges is the variability of flow: treated effluent runs at a steady flow rate with recurring daily peaks, while an urban effluent discharge would see

highly variable flow rates and composition, followed by periods of low or no flow. This study will include design of an experimental rhizofiltration system, where the wetland plant root zone provides oxygen and a biofilm habitat for treatment, where the filter material are selected to accommodate high flow rates, and which is hydraulically flexible to operate as different kinds of wetlands according to the above classification. The research work would be the performance evaluation of such a system under different conditions.

Estimated cost: R2 400 000
Expected term: 2010 - 2012

The development of nanocomposite polysulphone membrane with reduced fouling properties for use in wastewater treatment
University of the Western Cape
No. 2006

Polysulphone (PSF) membranes are the most common membranes used in ultrafiltration of wastewater due to their mechanical robustness and structural- and chemical stability. Unfortunately PSF is a hydrophobic material, making its surface prone to fouling due to adsorptive mechanisms. Fouling can either be caused by cake formation on the surface of the membrane, or by adsorption of the foulants both on the surface and in the membrane pores. Cake fouling is generally reversible and can be removed by backwashing or water flushing. Foulant adsorption however is irreversible and can only be remedied by very harsh chemical cleaning. Many studies have been conducted to increase the hydrophilic properties of the polysulphone membrane surface. These studies can be divided into three categories: 1) blending PSF with hydrophilic nanoparticles such as SiO_2, ZrO_2 and TiO_2; 2) grafting with hydrophilic polymers, monomers or functional groups; and 3) coating with hydrophilic polymers. Despite these efforts to minimise fouling of PSF membranes during wastewater treatment, there are still many unanswered questions regarding the mechanisms involved. This study will attempt to develop a novel PSF nanocomposite membrane with minimised fouling properties and will address the electrochemical characterisation of fouling onto the unmodified and modified membrane surface.

Estimated cost: R900 000
Expected term: 2010 - 2012

Exploring knowledge on natural processes for novel approaches to constructed wetland design and performance for wastewater using biomimicry
Golder Associates
No. 2096

This study will look to exploit knowledge on natural wetlands, their processes and biodiversity to better engineer/design constructed wetlands to meet the challenges of current and emerging pollutants and pathogens. The study should also look to explore the potential of using constructed wetlands to support sustainable livelihoods. The first phase of this project is innovation-focused and will explore, through the process of biomimicry, novel approaches that can be used to improve constructed wetland design and implementation. The potential exists for this process to deliver innovative solutions for wastewater (both industrial, domestic) treatment, transformation and filtration.

Estimated cost: R3 000 000
Expected term: 2011 - 2016

Programme 2: Application of appropriate technologies and tools

Denitrification in trickling filters
CSIR (Stellenbosch); Virtual Buro;
Tshwane University of Technology
No. 1825

Many wastewater treatment plants in South Africa are equipped with trickling filters which could be obsolete if they cannot achieve denitrification. The researchers aim to demonstrate (at full scale) that trickling filters can denitrify by changing the effluent recycle over trickling filters and/or limiting the rotation speed of distribution arms. They will then model the processes of aerobic COD removal, nitrification and denitrification in a biofilm system and calibrate the model with results from 2 trickling filters in order to gain a better mechanistic understanding of the combined processes. This will result in a set of practical operating guidelines to achieve denitrification in trickling filters.

Estimated cost: R930 500
Expected term: 2008 - 2010

Ultra-sensitive electrochemical nanobiosensors array devices for real-time determination of oestrogenic endocrine disruptors in municipal wastewater (ENDOTEK)
University of the Western Cape
No. 1999

There is a current concern in South Africa that water resources are heavily contaminated with pollutants generally classified as endocrine disruptors or endocrine disrupting chemicals (EDCs). This study will focus on endocrine disruptors that are natural and synthetic estrogenic hormones such as estriol, 17-estradiol and 17-ethinylestradiol and estrone. Estrogenic hormones are the most endocrine-disrupting chemicals because the disrupting potency can be several thousand times higher than other chemicals such as nonylphenol. This implies that natural and synthetic oestrogens can be biologically reactive even at low nanogram per litre levels. Consequently, the detection of these trace contaminants in municipal water resources and their elimination are very important areas of current research interest. The level of contamination of municipal wastewater in South Africa by individual synthetic and natural oestrogens is not fully known and there is no available technology for their real-time determination. The main methods for the determination of estrogenic EDCs have been through vitellogen (a biomarker for EDCs) enzyme-linked immunosorbent assay (ELISA) on fish samples or by chromatographic (HPLC) analysis of wastewater. They are very technical methods requiring extensive sample pre-treatment and high-level qualified personnel. Thus the development of rapid, simple and low-cost procedures for detection of estrogenic activity in wastewater samples is of utmost importance. The proposed research is on the development of a nanostructured electrochemical DNA aptamer array biosensor for detecting and quantifying estrogenic endocrine disruptors in wastewater samples down to the femto- or atto-molar range. The idea is to determine individual oestrogen compounds simultaneously in one measurement using multichannel microchip array signal transduction approach.

Estimated cost: R1 665 000
Expected term: 2010 - 2012

Evaluation of the DEWATS process for decentralised wastewater treatment
University of KwaZulu-Natal
No. 2002

Several WRC projects have looked at the anaerobic baffle reactor (ABR) as a decentralised technology option for wastewater treatment. The DEWATS system aims to provide a treatment train consisting of the ABR connected to a wetland or membranes to study final effluent quality. The aim is to reuse the effluent for agricultural trials and thus link the technology to agriculture and food security. This projected will be piloted in KwaMashu, KZN and aims to: (1) understand the capabilities of the DEWATS system for municipal waterborne sanitation, (2) re-assess the provision of sanitation to poor households and its opportunities, (3) gain experience in using different wastewater streams in agriculture, and (4) gain knowledge in disinfecting treated wastewater using gravity membranes at a larger scale. The data from the performance of the ABR will be compared to that of the earlier laboratory and pilot-scale systems and the previously developed model will be assessed and improved where necessary. The performance of the anaerobic filter compartments will be assessed in a similar way to the ABR compartments. While failure is not expected to occur, the performance under different loading rates will be assessed and a model of this part of the system will be developed. Effluent from different stages of the ABR through the process will be supplied for specific agricultural trials to assess suitability for agriculture. The suitability of the soil at the Permaculture Centre will be assessed for different qualities of irrigation water and a selection of appropriate crops made. Water and nutrient balances will be undertaken across different agricultural plots and the two planted gravel filters to assess the impact of using treated effluent. The removal of pathogens at different points through the system will be assessed and quantitative microbial risk assessments are to be undertaken for agricultural workers and for the use of different crops irrigated in different ways.

Estimated cost: R900 000
Expected term: 2010 - 2012

Microbial database-tool for evaluating the BNR processes in KZN
Durban University of Technology
No. 2003

Biological nutrient removal treatment processes are highly organised systems that depend on a synergy between microbial populations and plant configuration and operating parameters. These microbial populations comprise primarily of functional groups of organisms such as ordinary heterotrophs that facilitate COD removal and denitrification, nitrifiers that facilitate nitrification, phosphate-accumulating organisms that are responsible for biological phosphate removal and filamentous bacteria that are responsible for the formation of the core of the floc in activated sludge processes. There is a fine balance between these different groups that has to be maintained in order for optimal functioning of these processes. Selection of these populations is generally based on influent characteristics, operating parameters and process configuration and therefore the microbial population dynamics in full scale treatment processes are closely linked to the former operational conditions. In South Africa, previous studies on these correlations were conducted a long time ago (Ekama et al., 1999), focusing primarily on engineering paradigms. The microbial population investigations were based on conventional microbiological techniques. With the advent of novel molecular techniques, there has been a paradigm shift in microbial population dynamic studies allowing a high degree of accuracy. An IWA specialist group on activated sludge separation problems stated the general situation in conventional and BNR plants in South Africa (Pitman, 2006), but most of the referenced publications

were over two decades old. Therefore there is need for more updated knowledge in population dynamics. The proposed research will focus on using these novel molecular techniques to accurately profile functional groups of microorganisms and correlate to plant operating parameters and influent characteristics with the aim of understanding microbial contributions. It is hoped that this will aid in optimising plant performance and prevent problems such as bulking and foaming. The approach will be unique in South Africa and findings will be relevant to the South African wastewater treatment systems

Estimated cost: R900 000
Expected term: 2010 - 2012

Programme 3: Stormwater and sewerage systems

Investigation into pumps and pressurised flow in separate sewer systems
University of Stellenbosch
No. 2007

In a former WRC study a first-order national audit of sewerage reticulation issues was presented which highlighted amongst others various urgent future research aspects pertaining to sewer infrastructure. The proposal sets out to address a number of pertinent issues with regard to pumps, pump stations, rising mains, and other elements in the sewer system where pressurised flow occurs in separate sewer systems by means of applied research. It is hoped that the research will provide solutions to reducing the high energy input for pump stations. Energy consumption at pumping installations is an ever-increasing concern. From a strategic point of view sewer pump stations form only another component of the entire sewer system. Rising mains are another, and are often separately assessed. However, these two components are integrated hydraulically and should be optimised in combination, not separately. It is hoped this study will link theory to practice when it comes to pumping sewerage. Hydraulics and theory have their place, but a lot of experience has over the years been gained based on practical considerations, particularly as it pertains to local conditions. For example, work on the design and construction of sand/silt/rag traps as well as pump stations by members of the project team has underlined the urgent need to handle insoluble matter of all sorts arriving at sewer pump stations with the flow. This study intends to capture as much of the local knowledge in this field, test and verify it, and present a solution in the form of a tool and guide for use by both academics (e.g. published research to disseminate knowledge among peers; lecture notes) and those in the engineering fraternity (e.g. acting as a design guideline).

Estimated cost: R1 000 000
Expected term: 2010 - 2012

Programme 4: Wastewater sludge and faecal sludge management

Investigation into the long-term risks associated with deep row entrenchment of pit latrine and wastewater treatment sludges for forestry and land rehabilitation purposes
Partners in Development (Pty) Ltd
No. 2097

While South Africa struggles to provide basic sanitation for all, a substantial amount of existing basic sanitation infrastructure (conventional pit latrines and VIPs) has reached or is reaching the end of its design life. Urgent interventions are required to deal with the accumulation of sludge in these units. The low-cost options for the disposal of these sludges are limited. This project aims to establish whether deep row entrenchment of faecal

sludges with agroforestry is a safe, cost-effective and beneficial sludge disposal option. It will add significantly to the understanding of how buried sludge changes in nature over time, in terms of its physical and biological structure. It will also improve understanding of how buried sludge affects groundwater.

Estimated cost: R1 000 000
Expected term: 2011 - 2014

Programme 5: Sanitation technology and innovations

Piloting and testing the pour-flush latrine technology for its applicability in South Africa
Partners in Development
No. 1887

Recent research studies concluded by the WRC have raised many concerns about the long-term sustainability of dry sanitation technologies. The studies have found that the technology has led to unintended consequences due to misuse by users, as well as the lack of understanding of the science of dry sanitation systems. A combination of these factors and the stringent design requirements are proving it difficult to access pits for pit emptying. This is further compounded by user behaviour which is resulting in the intrusion of solid waste, plastics and other undesirables into the pits, resulting in difficulties around pit emptying and the rapid filling of pits. This coupled with the fact that there is no easy mechanical or physical *modus operandi* for servicing full pits. All of these issues are raising many new challenges which jeopardise the sustainability and the target set by government for coverage of sanitation. Amongst the suite of technologies, pour-flush latrines, which are used widely as a basic sanitation norm in South East Asian countries, have the potential to resolve many of these issues. However, very little promotion and application has been done in South Africa. This research study aims to create an understanding of the technical, social and environmental challenges associated with its application.

Estimated cost: R1 000 000
Expected term: 2009 - 2011

An investigation into technical sanitation solutions for informal areas
Cape Peninsula University of Technology
No. 2098

Urbanisation, in fact, is a health hazard for certain vulnerable populations, and this demographic shift threatens to create a humanitarian disaster. The threat comes both in the form of rising rates of endemic disease and a greater potential for epidemics and even pandemics. The poor are especially affected by inadequate and substandard sanitation services and these effects are not only limited to the health impact resulting from daily exposure to polluted habitats. It is recognised that problems caused by informal settlements are multiple. The most difficult is the provision of adequate sanitation services that can sustain livelihoods and protect the general environment from pollution and health risks to humans. Technology is one element in the overall solution to sustainable sanitation for informal areas, but it is an important barrier to the spread of diseases, and also important for the provision of a clean environment. The chaotic settlement patterns and densities, as well as other factors, make many solutions inappropriate and ineffective, and this is further compounded by the lack of institutional support. To date many solutions have been experimented with, with limited success, and we are yet to find the most appropriate solution for informal

areas. This study aims to develop and establish new sanitation solutions for informal areas.

Estimated cost: R500 000
Expected term: 2011 - 2013

THRUST 4: SUSTAINABLE AND INTEGRATED INDUSTRIAL WATER MANAGEMENT

Programme 1: Emerging challenges and solutions for the 21st century

A tunable immobilised lignocellulosic enzyme (TILE) system for treatment of industrial wastewaters
Cape Peninsula University of Technology
No. 2009

This project will look at biosolubilising lignocellulosics, using a 'Tunable Immobilised Lignocellulosic Enzyme (TILE)' system. This involves rationally selected key enzymes, focusing on integration of their synergistic action to depolymerise lignocellulosic residues. Isolated enzymes are preferred to whole cell organisms because they have greater specificity, are easier to handle and store, and the enzyme concentration used in the process is not dependent on microbial growth. The primary objective is to liberate carbon in a form suitable for uptake as nutrient by biomass, thus removing the carbon and generating clean reclaimable water. This proposal addresses three major global problems: 1) the increasing scarcity of clean water, leading to the need for effective treatment of industrial effluents and reuse of water, 2) agri-industrial effluents which are produced in significant volumes but are problematic to treat cost-effectively, with few successful processes available, and 3) agri-industrial wastes which contain lignocellulosics presenting particular challenges. This work aims to develop a continuous process using immobilised enzymes in a membrane bioreactor incorporating a selected group of enzymes which are immobilised together to effect depolymerisation of the lignocellulosic content of the waste and will include in- situ generation of peroxide and hence prevention of inhibitor build-up.

Estimated cost: R2 200 000
Expected term: 2010 - 2012

Industrial brine minimization: determining the physical chemical parameters that affect evaporation rates on multi-component hypersaline effluents
University of the Western Cape
No. 2100

Brines are a major waste by-product from industrial activities. This study aims to understand and provide solutions for the efficient minimisation of industrial brines. The study will evaluate evaporation rates and design and assemble climate-controlled enclosures for the study of evaporation processes of brines. The data will result in the development of protocols for the measurement of evaporation rates from brines which will lead to the development of empirical models for determining evaporation processes of industrial brines under controlled laboratory conditions and the development of theoretical models for determining evaporation rates of brines. Finally, it is envisaged that this understanding will result in the development of novel textured surfaces and absorbents for enhanced evaporation of industrial brines.

Estimated cost: R1 500 000
Expected term: 2011 - 2014

Evaluation of forward osmosis technology for the treatment of concentrated brines
University of KwaZulu-Natal (Durban)
No. 2101

Forward osmosis is a new technology for industry in South Africa and this scoping project is to assess the applicability for further application of concentrated inorganic brines. The study will aim to evaluate whether forward osmosis can be used as a lower energy consuming technology compared to reverse osmosis. It will evaluate the advantages, limitations and feasibility of using forward osmosis technology to concentrate various high ionic strength wastewaters and to assess the fouling characteristics of forward osmosis on various high ionic strength industrial streams which are known to be badly fouling.

Estimated cost: R354 000
Expected term: 2011 – 2014

Programme 2: Integrated management

Adapting water footprints for South Africa and exploring the value of integrating water, carbon and energy (environmental) footprints for the South African industrial sector
Pegasys Strategy and Development (Pty) Ltd
No. 2099

This study aims to review global and national practices in assessing water, energy and carbon footprints and the trade-offs that industries have to make to meet the goals set. It will investigate tools and methodologies that can be applied to determine water, energy and carbon footprints with the aim to provide a consolidated environmental footprint and a decision support tool. It is hoped that the understanding will be developed through the use of industry case studies.

Estimated cost: R2 000 000
Expected term: 2011 - 2013

Programme 4: Governance, policy, regulatory, and economic instruments to improve industrial water management

Valuing water for South African industries: A production function approach
CSIR
No. 2103

The project aims to ensure more efficient use of water by industry, based on an improved understanding of the marginal value of industrial water, and of the responsiveness of industry to water pricing strategies. This is in keeping with the National Water Act's objective to price water correctly, and will look to feed in to the current DWA pricing strategy.

Estimated cost: R780 000
Expected term: 2011 - 2013

Programme 5: Water efficiency, cleaner production, beneficiation and treatment of industrial effluents

Adapting constructed wetlands for real-world applications
Cape Peninsula University of Technology
No. 2104

This project builds on previous research and will use the new fingerprinting techniques that have been developed and customised to define the parameters which will allow the effective use of constructed wetlands to treat wastewaters using natural processes. It will also investigate the reproducibility of constructed wetlands adapted for specific waste-containing

waters in varied environments by characterising the microbial communities in these environments, and to understand the extent to which microbial communities in constructed wetlands can accommodate changes in waste impacts and the rates at which they can adapt. Finally it will develop a matrix of parameters and thus guidelines to use to adapt wetlands.

Estimated cost: R1 100 000
Expected term: 2011 - 2015

Integrated photo-catalytic and anaerobic treatment of industrial wastewater for biogas production
Vaal University of Technology
No. 2105

This project aims to test, at a laboratory scale, the use of zeolite as a support material to improve biogas production and anaerobic reactor stability. In addition, the study will concentrate on synthetic industrial effluents and use a photocatalyst (titanium dioxide) to break down these complex chemicals to simpler ones and evaluate the anaerobic reactor efficiency. Knowledge from these tests can be used in future to improve anaerobic digestion efficiencies by allowing microorganisms to come into contact with simpler compounds and prevent washout of the sensitive methanogenic bacteria.

Estimated cost: R500 000
Expected term: 2011 - 2013

THRUST 5: MINE WATER TREATMENT AND MANAGEMENT

Programme 1: Water use and waste production

Toxicity evaluation of metals and metal oxides nanoparticles to aquatic invertebrates and algal species
CSIR
No. 2107

Since the beginning of the 1990s, nanotechnology has matured from a laboratory-based research and development phase into full commercialisation of nanoproducts. For example, there are numerous novel consumer products and industrial applications of nanotechnology including: nanoelectronics, molecular assemblies, tissue engineering, biomedicine, nanocomposites, cosmetics, paints, pesticides and water purification modules. Among the nanomaterials, used in the nanoproducts reported above, with high potential of release in large quantities into aquatic environments are metals and metal oxides. In view of the rapidly increasing quantities of nanomaterials released into different environmental compartments – especially water and sediments – it is imperative that the potential risks that may be associated with nanomaterials attract attention, to ensure long-term safe, responsible, and sustainable development of this novel technology for optimal benefit of society. Due to the limited data, on potential risks of nanomaterials to aquatic organisms, which could support practical risk assessment and risk management after entry into the environment, this project will investigate the effects of nanomaterials on organisms at different trophic levels. Secondly, the mechanism by which nanomaterials cause toxic effects to the receptor organisms will be explored through use of DNA, reactive oxygen species (ROS) generation techniques.

Estimated cost: R495 000
Expected term: 2011 - 2014

Programme 3: Minimising waste production

Removal of metal ions from industrial effluents and acid mine drainage by metal sulphide precipitation
University of Cape Town
No. 2108

The main aim of this research is to further the understanding of the precipitation of metal sulphides in the treatment of acid mine drainage via sulphate reduction and metal precipitation. The project will characterise the effect of operating conditions on the physical characteristics of the formed metal sulphide precipitate by investigating the effect of metal to sulphide ratio on precipitation behaviour, the effect of the operating pH on the precipitation process and using a technique based on moment transformations of the number density function n(L) to make inferences about the mechanisms involved in the particle formation processes. The project will also investigate the factors affecting the solid-liquid separation characteristics of the formed particles. The effects of the processing conditions on solid-liquid separation characteristics of the formed precipitates will be quantified using particle size distribution measurements, settling characteristics and zeta potential measurements for surface charge determination. These studies will be carried out on a number of model metal systems. Finally, the project will investigate factors that potentially influence the solid-liquid separation characteristics of the formed particles. As a result of the investigations carried out, it should be possible to identify a number of factors, possibly different additives, which would influence the separation characteristics of the formed precipitates. Thus the effect of these ions (as well as other additives) on the coagulation and aggregation phenomenon will be quantified by measuring their effect on particle size distribution, surface charge and settling characteristics of the precipitate.

Estimated cost: R884 820
Expected term: 2011 - 2013

Development of a toolkit to enable quantitative microbial ecology studies of sulphate-reducing and sulphide-oxidising systems
University of Cape Town
No. 2109

The catastrophic effects of untreated mine-water discharges are well known and several high profile events have been documented. Mine-water has traditionally been treated using oxidation-neutralisation-precipitation which effectively removes metal, but the treated stream still contains sulphate. Biological treatment systems, based on the activity of sulphate-reducing bacteria have received considerable attention. Their widespread application has been constrained by the provision of a carbon source/electron donor and the management of the sulphide-containing effluent. Both these issues are addressed in the Integrated Passive Treatment System (IMPI) technology which makes use of a mixture of complex, lignocellulosic carbon sources and incorporates a sulphide oxidation step. Both the sulphide oxidation and sulphate reduction processes are catalysed by a consortium of different microorganisms. Different components of the consortium have different tolerances to sulphate, sulphide and heavy metals. As a consequence, changes in feedstock can lead to major changes in the microbial community. This may have catastrophic effects on system performance. Until recently these changes were poorly understood and system management was based on empirical rules of

thumb. The advent of molecular biology techniques has facilitated qualitative microbial ecology studies. While these have been useful in confirming the presence or absence of species or groups of species they provide limited information on dynamic changes in population structure, which could be extremely useful in predicting the response of a system to specific perturbations. This project will develop a molecular toolkit for performing quantitative microbial ecology work in sulphate-reducing and sulphide-oxidising systems. The toolkit will initially be used to characterise the microbial populations in the IMPI demonstration plant at Middleburg Mine. This technology has the potential to treat mine-water effectively and economically over a sustained period of time.

Estimated cost: R487 500
Expected term: 2011 - 2013

Addressing the challenges facing biological sulphate reduction as a strategy for AMD treatment through analysis of the reactor stage: raw materials, products and process kinetics
University of Cape Town
No. 2110

Mine-waters generated during active mining or resulting from groundwater rebound at abandoned sites have major environmental and economic implications. Active chemical treatment of the waters is the most widely employed technology. Recently there has been increasing interest in active and passive biological treatment processes. These systems rely on naturally-occurring biological and geochemical processes to improve water quality with minimal operational and maintenance requirements. Biological sulphate reduction is a well understood and efficient process that has been frequently demonstrated at laboratory and pilot scale. However, its full-scale implementation has been limited. The challenges facing sulphate reduction systems have been identified as: provision of a cost-effective carbon source; enhancing reaction kinetics when complex carbon sources are used; and management of the resulting sulphide. This study will undertake a critical review of existing technologies, from a technological and economic perspective. Furthermore the feasibility of using microalgal biomass as a carbon source/electron donor will be investigated. The study will also evaluate the requirements for algal cultivation at the scale required to sustain the SRB process. To address the issue of enhanced reaction kinetics the effect of decoupling the hydrolysis and acidogenesis reactions from the sulphate reduction will be investigated. The study will include a review of available technologies and investigate the application of cross-flow microfiltration membranes to recover and recycle biomass to both the hydrolysis/acidogensis and sulphate reduction reactors.

Estimated cost: R1 050 000
Expected term: 2011 - 2014

Programme 5: Low-volume mined products

Application of emulsion liquid membranes in the recovery of platinum group metals from precious metal refinery wastewaters and mining effluents
Rhodes University
No. 2011

Growing attention has been paid to the environmental implications of liquid effluents from mines and metal refineries. At the same time, water demand of the mining/metal refinery operations and values of precious metals have been increasing while the known reserves have decreased. This led to intense research into the recovery of precious metals from wastewaters. Methods studied include solvent extraction, biosorption,

precipitation, ion exchange, electrochemical techniques, cementation, and membrane-based separations. Applicability of a particular method will depend on the speciation and the concentration of the metal in question, as well as on the chemical composition of the effluent in question. These factors can limit the efficacy of individual processes. Solvent extraction with emulsion liquid membranes (ELMs) reduces energy and financial costs, the kinetics of extraction is generally faster, and the extraction yields are higher in comparison with diluent-extractant mixtures. The disadvantages of ELMs include the instability of emulsion globules against shear fluid stress, and the resulting decreases in the rates of mass transfer. These drawbacks can be eliminated by increasing the stability of the ELM through the application of non-Newtonian ELMs, and the application of the Taylor-vortex column instead of the continuously stirred tank. After the design of an efficient extraction system at laboratory scale, the scale-up can be achieved by a simple constancy of the Taylor number, thus reducing the process development costs. The application of this process to precious and platinum group metals (PGMs) has not been investigated. The aim of this project is to fill this knowledge gap, and to examine the chemical changes and toxicological implications of the proposed process.

Estimated cost: R337 450
Expected term: 2010 - 2012

NEW PROJECTS

THRUST 1: WATER SERVICES - INSTITUTIONAL AND MANAGEMENT ISSUES

Programme 1: Cost recovery in water services

Identifying efficiency and inefficiency in municipal water service provision
Nelson Mandela Metropolitan University
No. 2118

A very important, but perhaps neglected type of efficiency analysis of water service provision is that of the efficiency in mix of water service output. It has the aim of getting the right product mix. An analysis of efficiency in the mix of water service output relates the service produced to demand. It is not efficient to produce a mix of outputs that the recipients cannot afford. Nor is it efficient to produce less output than the recipients are willing to pay for. There are many very important issues related to this type of efficiency assessment. The main methodological aspect which this proposal concerns itself with is efficiency in the production of water service outputs – cost efficiency, including the choice of least-cost production technology. The aim of doing so is to enable regulation by an independent body of this aspect of municipal water service provision.

Estimated cost: R970 000
Expected term: 2012 - 2015

Programme 2: Institutional and management issues – Water services

Constraints on providing sewerage in South African informal settlements: A study of social and institutional management concerns
University of Cape Town
No. 2120

Full-flush toilets are generally preferred by residents and deemed by the National Government as being the most appropriate technology for dense urban settlements. Yet standard conventional (gravity) systems are costly to implement and sometimes impractical in flat terrains where residents, fearing increased marginalisation, have resisted relocation. Further challenges arise because informal settlements are often regarded by planners as temporary, with the result that sanitation services installed are not always of high quality. Municipal officials countrywide report a pattern of shared (communal) facilities in densely-populated informal areas deteriorating rapidly, allegedly a result of mismanagement and apparently senseless destruction. All of these situations are likely a consequence of residents' desire, and increasingly their demand, for security of tenure and a national policy for service delivery that is supply-side driven. While present policy is indeed supply-side driven, it makes no provision for sanitation management costs despite this being an expectation of residents who claim a right to free operation and maintenance of communal sanitation services (O&M). This study intends to analyse the social and municipal concerns with, and attempts to address, current sanitation planning and management processes. Many municipal officials question how to achieve this economically and rapidly, and on a large enough scale that it results in services which residents are satisfied with and will develop a sense of propriety over and therefore protect. The research hopes to assist municipal officials, and, by extension, residents, by first detailing the criteria whereby and reasons that officials and residents consider some sanitation projects 'successes' and others 'failures'.

Estimated cost: R1 000 000
Expected term: 2012 - 2014

Social protest and water service delivery in South Africa
University of the Western Cape
No. 2133

From a planning perspective, lack of simple correlations in the occurrence of water services related protests raises an important methodological question about whether or not such unrest can be predicted and/or pre-empted. Although useful quantitative and qualitative insights on social protests are provided by Municipal IQ and by the Dialogue Unit of the Institute for Democracy in South Africa (IDASA), a major problem is that much of the evidence on social protests is based on media reports and anecdotal evidence, with a limited range of in-depth scientific analyses. Post-apartheid reforms have not only partially resolved these inequalities, but have also spawned unprecedented social challenges associated with societies in transition. For example, formal institutional responses to the mushrooming of urban informal settlements have often failed to keep pace with urban social change and many such settlements remain with insecure access to water. Similarly, formal institutional responses in rural areas have often fallen short of meeting newer social consumption patterns, livelihood aspirations and expectations for service delivery. A key question for further research is why water-related protests have largely been confined to urban areas, irrespective of socio-economic status. The study will provide for an in-

depth scientific understanding of this development and a broadened focus to include both the lived realities of historically disadvantaged individuals (HDIs) in informal rural and urban economies as well as those of other socio-economic groups within South Africa.

Estimated cost: R1 500 000
Expected term: 2012 - 2015

Programme 3: Innovative management arrangements – Rural water supply

Capacity building for climate change adaptation and disaster risk reduction in rural South African Communities: Tsengiwe, Eastern Cape
Umvoto Africa
No. 2126

The study follows on recommendations made in WRC K5/1888//3 (Investigating the Social Vulnerability of People and their Livelihoods and their Response to Water Infrastructure) to refine the proposed methodology for risk assessment. Improving understanding of community-level risk was partly achieved by adapting the HFA (which provides a framework for risk reduction at the national level) to develop community level indicators for social vulnerability and coping capacity. Several recommendations for improving risk assessment at the community level arose from the WRC study, in particular, the inclusion of community-based climate change planning and adaptation.

Estimated cost: R800 000
Expected term: 2012 - 2015

Sanitation subsidies in perspective: how to increase the effectiveness of sanitation subsidies in South Africa
Sustento Development Services
No. 2136

There is a growing perception amongst sanitation practitioners in South Africa that the increase in the capital cost for construction of a basic sanitation facility has escalated beyond inflation-related increases in the past 10 years. The perception is that the cost of providing a subsidised flush or VIP toilet is currently significantly and unreasonably higher than what is was 10 years ago. However, it is unclear whether this perception is correct, and, if so, what the drivers are of these escalating costs. With regulation of provision of basic sanitation being assigned to the new Department of Human Settlements, the department responsible for administering the housing subsidy, there is a lack of clarity as to how the MIG sanitation subsidy processes and procedures integrate or conflict with the low-cost housing subsidy processes. There are perceptions in the sector that some households have benefited from both subsidies and thus there are cases where households received two subsidised toilets through the MIG and through the housing grants. The study will investigate the historic and present economic and social cost of subsidised sanitation facilities constructed from MIG and housing grants and determine the overlaps between, and gaps in, sanitation-related subsidy policies and processes.

Estimated cost: R488 765
Expected term: 2012 - 2014

Programme 4: Regulation in the water services sector

Municipal guidelines for implementing WDM
WRP Consulting Engineers (PTY) LTD
No. 2130

Water demand management (WDM) is becoming a key issue throughout South Africa. Many books and publications have been produced to assist water supply managers to develop strategies to address the various WDM issues and many software packages have also been developed to assist in this regard. The emphasis is now moving from the development of WDM strategies to the actual implementation of WDM interventions. The proposed guidelines are therefore aimed at providing useful information and advice on a wide variety of WDM interventions as they should be applied in a South African context. When completed, the guide will provide a useful reference to all water supply managers in South Africa who are intending to implement WDM interventions in their supply areas. The guidelines will concentrate on the practical implementation of WDM measures rather than the theory or background to such measures.

Estimated cost: R500 000
Expected term: 2012 - 2014

THRUST 2: WATER SUPPLY AND TREATMENT TECHNOLOGY

Programme 1: Drinking water treatment technology

Investigation into the cost and water quality aspects of South African desalination and reuse plants
SSI Engineers and Environmental Consultants (Pty) Ltd
No. 2121

Desalination and wastewater reuse by various membrane processes ranging from micro-, ultra-, and nanofiltration to reverse osmosis, in combination with other advanced technologies, can be used in different configurations to augment water supplies. With known feed-water and target product-water qualities the basic plants are relatively standard and consistent in price. However, the infrastructures in front of (intakes, pre-treatment, etc.) and following (waste discharge, product water pumping systems) the basic plant building block (membrane system) are major variables in determining the capital and operating costs of the selected solutions. Each location and situation has different advantages and challenges to be evaluated in making the best decisions for implementation. This project will compare and document actual cost and water quality data from various South African projects to establish a first-order knowledge base for desalination and reuse for the augmentation of water supply in a South African context.

Estimated cost: R1 000 000
Expected term: 2012 - 2015

Advanced oxidative treatment process for water disinfection using an electrohydraulic discharge reactor and TiO_2 immobilised on nanofibres
University of the Western Cape
No. 2132

In this project, the design and methods for applying electrical energy to multiple electrodes will be explored and described. An assembly having at least more than two electrodes may be configured such that the high voltage electrodes are submerged in the inner tubes, positioned at parallel relative to one another, and the grounded electrode is directly submerged into the wastewater setup, resulting in production of a cocktail of chemical species, such as OH radicals, ozone and hydrogen peroxide, which can target and

attack the pollutants in the water without the addition of chemicals. Electrohydraulic discharges have been studied for several years; however, the integration of innovations in nano-science and nano-photocatalytis has been incorporated into this area of research on a very limited scale. The new system will be designed so as to generate plasma directly in water, which will produce radicals from water ionisation. Furthermore, in this multifunctional reactor multiple electrodes across the water flow path, in combination with TiO_2 electrospun nano-fibre consolidated photocatalysts, are applied that can promote and enhance the formation of oxidants.

Estimated cost: R1 392 800
Expected term: 2012 - 2015

Decision-support model for the selection, costing and application of drinking water treatment and supply options to address water shortages and improve water services delivery (with focus on upgrading options, water reclamation and desalination)
Chris Swartz Water Utilisation Engineers
No. 2119

Water supply authorities (WSAs) in South Africa are currently facing two major challenges with sustainable supply of sufficient quantities of high quality drinking water to the population. On the one hand is the highly variable availability of raw water sources due to changing weather patterns (resulting in prolonged drought periods (spatially and temporally) and intermittent flooding periods), while at the same time poorly-capacitated municipalities are experiencing major problems with water service delivery. Various options are available when WSAs, the Department of Water Affairs (DWA), planners and funders (such as DBSA) want to improve the water source surety (and sustainability) or make provision for drought periods. Sufficient information on the options is most often not readily available for the planners/authorities to make informed selection of the best options for a specific situation. The information that is lacking includes technical, costing, energy and environmental data. Even if the data and information are obtained, comparison of the best possible options is not feasible or effective, because of the differences in priorities assigned to the multitude of factors making up the main components of the selection criteria. This project will therefore create a decision-support system that can be used by municipalities and water boards to identify, evaluate, compare and select appropriate options that can be used to produce sufficient quantities of safe drinking water from available water sources.

Estimated cost: R450 000
Expected term: 2012 - 2014

Programme 2: Water treatment technology for rural communities

Point-of-use disinfections systems designed for domestic rainwater harvesting (DRWH) tanks for improved water quality in rural communities
University of Stellenbosch
No. 2124

Domestic rainwater harvesting (DRWH) has the potential to improve water availability in rural communities in Southern Africa. In the Eastern Cape and KwaZulu-Natal DRWH is already an important source of drinking water. The quality of water collected by DRWH remains disputed with reports of microbial contamination above acceptable drinking water standards. Water collected by RWH therefore needs to be further treated in many cases to adhere to drinking water standards. Chlorine, slow sand filtration and pasteurization by solar technology have been proposed for treating rainwater

in tanks. The objectives of this study are to determine the microbiological and chemical quality of rainwater collected in existing DRWH tanks; and to install tanks at a university for investigation of cost-effectiveness, material analysis and filter systems. Lastly the social perception and feasibility of the tanks in the community will be explored.

Estimated cost: R746 000
Expected term: 2012 - 2014

Programme 3: Drinking water quality

An investigation into the presence and impact of free-living amoebae and amoeba-resistant bacteria on drinking water production, storage and distribution to health care institutions in greater Johannesburg, South Africa
National Institute of Occupational Health
No. 2138

Free-living amoebae (FLA) are ubiquitous in groundwater and surface waters used for drinking water production. They feed on smaller micro-organisms like bacteria, fungi and algae. Although mostly non-pathogenic, some FLA, particularly *Acanthamoeba* and *Balamuthia* species and *Naegleria fowlerii* are known human pathogens which may cause life-threatening disease in both healthy and immunocompromised individuals. They can survive in this dormant stage for long periods of time, only to excyst and become active again when conditions return to normal. International studies continue to highlight the potential of FLA containing amoeba-resistant bacteria (ARB) to survive routine drinking water production and treatment processes. The overall aim of the study is to establish whether the occurrence of FLA and ARB in drinking water production plants has an impact on the quality of the water supplied to health care institutions in greater Johannesburg, to use this information to assist the drinking water production industry to improve the quality of water supplied to these institutions and to assist the institutions to establish appropriate water management programmes in areas where the patients and personnel are most at risk of infection.

Estimated cost: R423 500
Expected term: 2012 - 2015

Programme 4: Water distribution and distribution systems

Practical guidelines for operation and maintenance of water distribution systems in South Africa
University of Cape Town
No. 2135

Proper operation and maintenance procedures are key to ensuring that the investments in new infrastructure provide a continuous and sustainable high level of service. Components of water distribution systems do not last forever, and need to be operated within their design parameters and inspected, repaired and replaced at appropriate times to ensure that the integrity of the infrastructure is maintained. Lack of proper operation and maintenance invariably leads to faster degradation of the infrastructure, with an associated decrease in service levels of both quantity and quality of water supplied. If this process is not checked, it eventually leads to complete breakdown of the system integrity, which requires the infrastructure to be replaced at huge cost. This project will provide clear and practical guidance on the operation and maintenance of water distribution systems. The focus of the project will be on applying current knowledge on water distribution management to South African conditions, and to make this information accessible to South African engineers and managers.

Estimated cost: R757 000
Expected term: 2012 - 2013

Determination of the change in hydraulic capacity in pipelines
University of Pretoria
No. 2140

Optimal capital expenditure and operational cost is based on the performance and the expected hydraulic performance decay rate of pipeline systems. Long-term performance data is essential for this assessment and an effort should now be made to gather information on a regular basis for a number of different pipelines in South Africa. This research, which builds on previously-completed work, will broaden the database, maintain the current momentum of the original research and will provide improved understanding of the hydraulic behaviour of pipelines to be able to improve the design philosophy. The preliminary finding was that the presence of biofilm significantly reduces the hydraulic capacity. In this study emphasis will be placed on the review of newly-installed pipelines (sewage, raw and clear water), but existing pipelines will also be included in the field work. A roughness database reflecting the hydraulic capacity time history will provide a sound basis for the design of new pipelines as well as assist in the operation and refurbishment of existing pipelines.

Estimated cost: R1 125 000
Expected term: 2012 - 2015

THRUST 3: SUSTAINABLE MUNICIPAL WASTEWATER MANAGEMENT AND SANITATION

Programme 1: Emerging technologies and solutions

Characterization of indigenous anaerobic ammonium oxidizing (anammox) bacteria grown in microaerobic environments
University of Pretoria
No. 2117

The project builds on the lessons learned in an earlier WRC-funded project conducted by Stellenbosch University entitled 'Fishing for indigenous anammox bacteria'. The main goal of the study was to find out if anammox bacteria exist in some South African anaerobic environments. The study has shown some impressive results with regards to the existence of these bacteria from various habitats. However, the researchers had difficulty in obtaining sufficient biomass to sustain the anammox process using the gas-lift reactors. In addition, the study also showed that oxygen is very inhibitory to the growth of anammox. Furthermore the constant feeding and mixing of the reactor contents resulted in biomass washout thereby hampering the progress of the enrichment process. Based on the abovementioned findings, the principal objective of this proposed study will be to develop an anammox enrichment system that will be designed to endure microaerobic conditions

Estimated cost: R460 400
Expected term: 2012 - 2014

Fate and behaviour of engineered nanomaterials (ENMs) in wastewater treatment systems
CSIR
No. 2122

In contributing towards our collective understanding on the fate, behaviour and transportation of engineered nanomaterials, ENMs, in WWTP processes. This study will be to establish possible mechanisms of ENM accumulation and/or degradation in wastewater sludge, as well as the potential effects of ENMs on the microbial population which could be useful in current wastewater treatment processes. To understand the fate, behaviour and transportation of ENMs in the environment, the following processes, viz: aggregation, adsorption, complexation, entrapment, degradation, reactivity, mobility or degree of stability, given the size of ENMs which is within the colloidal region, will be carefully investigated. The derived knowledge will provide sound evidence to allow for the search for technologies that can remove ENMs from wastewater efficiently.

Estimated cost: R680 000
Expected term: 2012 - 2014

Performance and efficacy of integrated algae ponding systems in wastewater treatment for water reuse and cost recovery through biomass valorization

Rhodes University
No. 2123

A rapid implementation of robust, easy to deploy and operate, sustainable wastewater treatment technology is urgently required. Furthermore, climate change, together with reduced water availability, has major food security implications for South Africa, its neighbours, and other arid, water-poor countries. These two factors alone have profound management implications for both government and business. Correct implementation and management of integrated algae pond systems (IAPS) developed for South African conditions can produce clean water for recycling and reuse, provide energy, and generate a biomass suitable as a broadcast or liquid fertilizer in organic row crop agriculture and high-value horticulture. Even so, and as with any near market-ready technology, there is an element of risk and/or failure to comply. Performance of the IAPS needs to be closely monitored and its efficacy in routinely producing a final effluent that meets the standard (i.e. <75 mg/L COD and <25 mg/L SS) thoroughly elaborated. Futhermore, an evaluation of all factors contributing to final COD and SS must be carried out and included: design and re-design of the algae settling tanks, introduction of more robust separation/filtration technologies for removal of biomass and/or water, and full characterisation of the residual COD and SS in the final effluent. Armed with this information a document emphasising the merits of IAPS and addressing questions and concerns about its implementation will be available to facilitate informed decision making.

Estimated cost: R1 500 000
Expected term: 2012 - 2015

Integration of aquatic chemistry with bio-process models

University of KwaZulu-Natal
No. 2125

The IWA has has set up a task group to develop a 'physico-chemical framework' for modelling of water and wastewater treatment processes. The inaugural meeting of the task group took place at the Watermatex 2011 conference in San Sebastian, 20–22 June 2011. Two South African researchers are members of this task group, because models which they have developed over a series of WRC projects already exhibit many of the characteristics which are consistent with the aims of the group. A substantial part of the proposed project will involve transferring the technology represented by

models which have already been developed, and which incorporate the principles set out in the IWA task group motivation. However, in keeping with the systematic approach of the task group, the underlying theory needs to be set out in a comprehensive reference document, together with training material for use in post-graduate courses. Furthermore, the application of the models needs to be demonstrated in practical case studies.

Estimated cost: R480 000
Expected term: 2012 - 2013

Development and demonstration of a woven fabric immersed membrane bioreactor package plant for decentralised sanitation
University of Stellenbosch
No. 2287

South Africa faces a challenge in providing sanitation for all of its people. Decentralised, small-scale 'package' sanitation plants have great potential to overcome some of the logistical challenges and could make a significant contribution to the roll-out of sanitation in peri-urban and rural areas. Internationally, there has been a major swing towards immersed membrane bioreactor (IMBR) technology for wastewater treatment due to the advantages that IMBRs offer over conventional biological wastewater treatment. IMBR package sanitation plants could have a significant impact on addressing the sanitation backlog. However a major barrier to the application of IMBRs is the cost and lack of robustness of current IMBR membranes. Generally, current commercial IMBR membranes are expensive and cannot withstand rough handling. Further, there is a perception that IMBR technology is 'first-world', complicated, and requires highly skilled operators, and hence cannot be applied for decentralized sanitation in developing regions. To enable South Africa to benefit from IMBR technology this project will demonstrate to wastewater practitioners, vendors of package plants, etc., that IMBR technology can be simple, robust, easy to operate and cost effective.

Estimated cost: R793 875
Expected term: 2013 - 2015

Programme 2: Application of appropriate technologies and tools

Self-regulation of the package plants/small wastewater treatment industry: Development of a framework of standards, a conceptual model for a test facility and an accreditation system for each technology provided by suppliers
Royal Haskoning DHV
No. 2193

The SWWTW industry in South Africa has grown rapidly from a small base and is currently unregulated in terms of process design, construction materials, etc. Most of the suppliers are not process experts but rather entrepreneurs who have funded the development of their product using limited resources. Furthermore, SWWTW's are often purchased on the basis of purchase cost which means that at present product costs have to be minimized. This is achieved by omitting any form of redundancy in the plant such as aerators and pumps, overloading media, and using optimistic upflow rates in settlers. Lack of regulation of the SWWTW sector has led to a number of problems in terms of performance, durability and reliability. This project aims to use the experience gained locally, together with international standards and practices to develop:

- A framework of appropriate standards for the SWWTW industry

- Implementation of the standards in a simple manner without duplication
- A conceptual model with key criteria for an independent testing facility for the different technologies
- An accreditation system for the various technologies which will encompass technical and managerial aspects. This would be based along the lines of the Green Drop system, but taking into consideration the fragmented roles of the sector stakeholders. The study will also evaluate who should manage and audit the accreditation process, the cost of the process and who bears the cost.

Estimated cost: R800 000
Expected term: 2012 - 2014

A gap analysis of technologies, techniques and capacity for the water and wastewater (domestic and industrial) sector in South Africa
University of Cape Town
No. 2258

The rationale for the study is to address the concern that multiple research nodes in water-based research in South Africa are largely organic in nature, without significant design, and are not necessarily aligned with national initiatives such as the National Planning Commission, the National Strategy for Sustainable Development and Action Plan, and the 10-Year Innovation Plan of the Department of Science and Technology. The principle aim of the study is to provide an overview and analysis of the gaps involved in water and wastewater research including development, demonstration and commercialisation of products and technologies. The study will also critically evaluate the technology needs of the sector and provide recommendations on how best to synergize areas of expertise in water and wastewater research along the value chain, linking applied research to technology or product development, with the final outcomes being a more robust product development, efficient technology transfer and the building of capacity and competence in the sector to service the technology, products and services. The study will contribute to new insights in the social, environmental and economic fields of knowledge to support the national effort to identify and safeguard human resource capacity, technologies and techniques in the water sector. The response to the gap analysis study must demonstrate a clear understanding about what needs to be done to assure the sustainable supply of water and wastewater treatment in continuing to meet the social and environmental needs of South Africa.

Estimated cost: R450 000
Expected term: 2012 - 2013

Programme 4: Wastewater sludge and faecal sludge management

Quantifying the fertilizer value of wastewater sludges for agriculture
University of Pretoria
No. 2131

This study follows on from a previous WRC project (K5/1724/3) on the sustainable agricultural use of sludge. The previous project included a local field-scale study, conducted across a range of cropping systems using anaerobically-digested air-dried sludge and incubation trials for model N and P parameterization. This study highlighted that sludge application rates that attempt to match nutrient supply to crop demand depend on cropping intensity, availability of water,

management practices, and sludge N and P content. In order to accommodate such complex interactions between sludges, soils, climate, and cropping systems, a mechanistic nutrient (N and P) balance cropping-systems model (SWBSci) was developed for use as a reasoning support tool to guide decision makers with the responsible use of municipal sludges in agriculture. The model was calibrated and validated under various cropping systems, proving its potential as such a reasoning support tool. This model is a fairly complex scientific research tool, and requires detailed weather, soil, crop, and sludge parameters in order to be deployed. Interest in using the model to assist with the development of sludge management strategies for different wastewater care works has been expressed on several occasions by industry partners. However, in its current form, routine use of this reasoning support tool by industry partners or extension officers is highly unlikely, as parameterization is not completely trivial, and there is a definite need to simplify the procedure to follow in running simulations. In order to render this tool more usable, the model needs to be populated with soils, crops, and long-term weather data parameters around the perimeter of wastewater care works, as well as sludge parameters. Sludge parameterization for the various N and P pools relies on a long-term incubation trial which is tedious, time consuming and impractical in real life. Therefore, practical and affordable methods are required to identify the various N and P pools for model parameterization. It is also vital to add a simple heavy metal module into the model to estimate the accumulation of heavy metals in the soil profile across time. The long-term trial could be continued for another three years to validate and calibrate the heavy metal model. This is because beneficial agricultural use of sludge is prohibited if the concentration of heavy metals in the soil profile exceeds a certain threshold value. The model can then be run for various scenarios for several local cropping systems to generate a database of options.

Estimated cost: R2 100 000
Expected term: 2012 - 2015

Programme 5: Sanitation technology and innovations

Investigation into risks of exposure of workers and households to pathogens through current desludging practices and development of guidelines to minimise risks
Partners in Development
No. 2134

There is strong growing evidence that the methods used to empty the pits of on-site sanitation systems result in transmission of disease from sludge to workers or householders This undermines the impact of basic sanitation and health objectives of breaking the cycle of faecal-oral disease transmission. This study aims to investigate the risks of transmission of pathogens to workers or householders through current emptying methods and to develop guidelines for institutional support to minimise these risks.

Estimated cost: R1 200 000
Expected term: 2012 - 2015

Pour-flush and Portapotty sanitation systems
University of KwaZulu-Natal (Durban)
No. 2137

The nature of the waste material from a pour-flush system is different to that of a pit latrine (in that it has a higher moisture content and contains all the urine) and that of a septic tank (in that it is much more concentrated and does not contain any grey-water).It is believed that

moisture content and ammonia concentration affect the rate of biological degradation of any waste stream, but these effects have not been clearly established for pit toilet, pour-flush toilet and septic tank contents. This study will investigate the nature of the feed (specific loading and composition), the extent and kinetics of biodegradation, which need to be determined in order that a rational design procedure can be proposed.

Estimated cost: R1 281 500
Expected term: 2012 - 2015

Demonstration and scaled-up implementation of pour-flush sanitation in South Africa
Partners in Development
No. 2203

While many South Africans aspire to full waterborne sanitation, this is not an achievable goal given the many demands on limited resources. The alternative has been limited to VIP's. However, these are not without their shortcomings including health and safety, environmental and operational issues. In 2009 the WRC commissioned a project to develop and test a prototype for pour-flush sanitation in South Africa. This was done successfully and 20 units have now been in operation for between 7 and 22 months. Funding was received from Irish Aid to demonstrate, on the strength of lessons learned, a large scale pour-flush sanitation pilot and to share the experiences from this pilot with appropriate audiences. Thus the objective of this study is to implement 275 pour-flush units in a rural community.

Estimated cost: R1 475 175
Expected term: 2012 - 2013

THRUST 4: SUSTAINABLE AND INTEGRATED INDUSTRIAL WATER MANAGEMENT

Programme 1 : Emerging challenges and solutions for the 21st century

Application of mineral carbonation processes for brine remediation
University of the Western Cape
No. 2128

Currently the typical method of brine disposal is the use of evaporation ponds, which is aimed at reducing the volume of the brine and providing a manageable solid product. Unfortunately, this approach does not stabilize the brine and the cost of long-term storage is still very expensive. Fly ash is another waste material that is being produced in huge amounts by coal-fired power plants. Eskom for instance produces 36.7 Mt of fly ash per annum. The majority of this ash is disposed of in ash dumps while only 5% is applied in the making of building and construction materials. This fly ash presents a major resource that can be utilized in the carbonation of brine, thereby leading to the formation of carbonates which are benign and can be applied as mine backfill. This project proposes to utilize fly ash through mineral carbonation to remediate the effluent brine, which would lead to potable water that can be reused in the power generation process as well as domestic and agricultural purposes. Moreover, this will also lead to reduction of the carbon emissions from power plants.

Estimated cost: R1 362 750
Expected term: 2012 - 2015

Programme 3: Quantification, prediction and minimisation of water use and waste production

Water management efficiency: The development and testing of an optimisation model at selected Eskom sites for an integrated water solution
University of Pretoria
No. 2289

Pinch analysis is a process integration tool, which was first developed for the design of heat recovery systems during the late 1970s. This work formed the basis for the design of water-using systems, with a design objective of minimising water consumption by maximising the reuse of water, using a graphical technique which was termed Water Pinch Analysis. Water Pinch Analysis thus involves a set of systematic formal techniques to handle the complex problem of hierarchical water allocation to a system consisting of a number of processes, and choosing the best combination of strategies. The WRC has funded several projects (1241/1/06; 1158/1/05; 851/1/01) in the past to test the applicability of the technique for water management in both the industrial and water resource fields. The industry-based studies investigated the applicability for three large water users to varying degrees of success and were valuable in gaining insights into its application, limitations and theory. Water Pinch Analysis exposed the water sector to a new technique and developed new capacity in the research domain. These studies also showed that pinch analysis could be used as a neutral tool to set targets and to indicate their environmental performance to the public and authorities. Thus, this study aims to build on the knowledge gained and to develop, test and apply an optimization model for cooling water systems at selected Eskom sites. This project also aims to build capacity for optimization models for water management efficiency.

Estimated cost: R1 500 000
Expected term: 2013 - 2016

THRUST 5: MINE WATER TREATMENT AND MANAGEMENT

Programme 2: Regulatory, management and institutional arrangements

Development of risk criteria for water management aspects of mine closure
Golder Associates Africa
No. 2127

The DWA recently produced a series of Best Practice Guidelines that give specific guidance on procedures to be adopted in the development of mine closure plans (BPG G5) and in the prediction of future impacts that are associated with mine closure (BPG G4). While the BPGs provide clear methodologies for undertaking the assessments required to support a mine closure application, they do not provide any practical guidance on how issues such as: agreement on the acceptable levels of confidence for the prediction that will limit the State's liability to acceptable levels; statistical representivity of the datasets used in the prediction and their suitability for addressing the issues that pertain to the particular closure application; the definition and descriptions of uncertainty inherent in the predictions and acceptance that the defined uncertainty meets the requirements of the regulator; and the suitability and adequacy of financial provisions to cater for uncertainties and risks for post-closure water management and treatment. This project will address the above issues through review of international best practice on these topics and engagement with all stakeholders (DWA, DEA, DMR, mining industry and consultants) in order to provide guidance on how

to address these issues when considering impact predictions and mine closure applications.

Estimated cost: R535 000
Expected term: 2012 - 2014

Programme 3: Minimising waste production

Treatment of mine water using a combination of coal fly ash and flocculants in a jetloop reactor system
University of the Western Cape
No. 2129

The generation of contaminated high-sulphate mine-water and waste coal fly ash are undesired by-products in coal mining and coal-fired power stations, respectively. Mine-water is contaminated by contact with oxygen and pyrite-bearing rock, or leaches from mine tailings due to infiltrating rain. Mine-water produced in coal mines could be acidic, neutral or alkaline depending on the geology of the mines. Acidic mine-water, often termed acid mine drainage (AMD) is produced when rock that contains more acid-producing minerals than acid-neutralizing minerals was disturbed during mining. Prior work has been done on the fly ash neutralization process and stability of solid residues formed during neutralization, as is recorded under the 'general information' section. This study will optimize the jetloop reactor system which will make this system using fly ash for remediation viable in an industrial environment, and thus a serious contender for low cost mine-water treatment and recovery.

Estimated cost: R1 033 000
Expected term: 2012 - 2015

Investigation of carbon flux and sulphide oxidation kinetics during passive biotreatment of mine water
University of Cape Town
No. 2139

Mine wastewaters generated during active operations or resulting from groundwater rebound at abandoned sites will have major environmental and economic implications for South Africa in the medium and longer term, particularly as active dewatering of some underground basins ceases. Active treatment of the wastewaters, involving oxidation, neutralisation and sedimentation, is the most widely employed technology. However, active systems are not appropriate for all scenarios, particularly lower-volume discharges in remote areas. For these waters there has been increasing interest in biological treatment processes, particularly passive or semi-passive systems. These rely on naturally-occurring biological and geochemical processes to improve water quality with minimal operational and maintenance requirements. In order to understand and therefore apply such systems, this project will (1) characterise the packing of lignocellulosic material in the degrading packed bed reactor (DPBR) to facilitate estimation of void volume, flow patterns and hydraulic retention time, (2) investigate carbon flux through the DPBR and linear flow channel reactor (LFCR), where sulphide oxidation takes place, to determine whether additional supplementation with readily accessible carbon (e.g. molasses) is required and, if so, at what rate, (3) determine the rate of release of phenolic compounds from lignocellulosic material in the DPBR and evaluate potential inhibition of sulphate-reducing bacteria (SRB) (4) develop a one-dimensional unsteady-state mass transport model to describe the upward diffusion of sulphide and downward diffusion of oxygen through the

biofilm, and (5) refine the existing oxygen requirement model to account for impeded diffusion as a result of the biofilm.

Estimated cost: R279 450
Expected term: 2012 - 2013

A detailed acid-base accounting study of the Karoo formations in the Waterberg coalfield
University of the Free State (Institute for Groundwater Studies)
No. 2142

Coal mining has a pronounced impact on surface and groundwater quality and quantity. Local experience indicates that the influx of water may be as low as 1% of rainfall for deep bord and pillar mines with no subsidence, to as much as 20% for some opencast mines. Such differences have significant impacts on the quantity and quality of surface and groundwater resources in a local area and further afield. The Waterberg is the only remaining large area with proven coal reserves in South Africa and they are being targeted for large-scale mining in the foreseeable future. Most of this will be opencast mining, resulting in large volumes of spoils and also discards (due to the fact that a number of coal seams will be mined with approximately 50 m of interburden between the coal layers) being handled on surface. This project will provide detailed in-depth acid-base potential studies in the area in order to determine how spoils should be handled in future by the mining companies, due to the complexity and volume of the spoils and discards. If handled correctly, acid generation can be minimized. This study will consolidate the existing information, and obtain new information regarding the possibility of acid generation of the overburden, interburden and discards.

Estimated cost: R1 775 000
Expected term: 2012 - 2014

THRUST 6: WATERSMART FUND

Programme 1: Watersmart fund

Development and testing of a water treatment bottle for use during emergency diarrhoeal outbreak conditions
University of Johannesburg
No. 2194

Although there are various commercial water treatment options available for the treatment of water under severe circumstances, most of these are dependent on a consumable(s) and equipment that needs to be delivered to the people. When the consumables run out the water treatment also comes to a standstill leaving the people without treated potable water. The ideal would be to provide a water treatment device that can be used with commercially available options, home-based chemicals or, in extreme situations, things we find in the environment. In an attempt to come up with a design that could provide an option to deal with all these situations, members of the Water and Health Research Centre designed a water bottle that can be used for the treatment of smaller volumes of water (less than 1 L) in all of the above contexts. A prototype of the design has been produced to ensure that everything, in terms of the design itself, is in order before the water bottles go to the production and testing stage. Initial tests, such as testing of the flow rates, effectiveness of filtration materials, etc., have been done in the laboratory to ensure that the design is as close to manufacturing standard as possible. The novelty of the water bottle lies in the fact that the design allows for various applications and adaptations without any structural changes needed.

This literally means that the user can adapt the use to suit what they have available at that stage. The design now gives the user the freedom to transport treated drinking water while having the facility available to treat more water. It can be used by people living in areas without treated potable water, hikers or in emergency situations where treated water might not be available.

The combined aim of this study is to produce the water bottle using injection moulding and to test the effectiveness of the water bottle using a variety of commercially available treatment options, household-derived treatment options and worst case scenario water treatment options.

Estimated cost: R320 000
Expected term: 2012 - 2014

New housing unit designed for ceramic water filters to be more applicable in rural and peri-urban communities in South Africa
University of Venda
No. 2195

In a recently completed WRC-funded study (Project No. 1653) by the University of Venda and the University of Johannesburg ceramic water filters sourced from Ghana were implemented in rural households in the Vhembe District of the Limpopo Province (South Africa). Part of the study involved investigating the extent to which rural communities accepted the filters and what possible changes could be made to increase the efficiency of the filters. It was found that if certain design aspects could be addressed the water filter would be better accepted. This study will test a newly-designed housing unit for the Potters-for-Peace ceramic filter as a point-of-use treatment system in rural and peri-urban communities of South Africa

Estimated cost: R500 000
Expected term: 2012 - 2014

In-field demonstration of a remote, real-time water quality monitoring system
CSIR; Prime Africa Consultants
No. 2196

The aim of the project is to supply data in real time to municipalities so that they can better manage their wastewater quality.

Estimated cost: 250 000
Expected term: 2012 - 2013

Filter for the removal of suspended solids naturally found in harvested water
Durban University of Technology
No. 2197

Rainwater/stormwater has been used as drinking water for at least 6 000 years without harm to the user. However in recent times, with the debatable exception of Australia, authorities worldwide have not been inclined to fully approve private rainwater harvesting as an alternative to piped municipal water, due to skills shortage, and reliance on the self-discipline required for adequate maintenance and water quality. What is plainly evident is that none of the research done thus far has sought alternatives to conventional first-flush methods, relying instead on using either diverter or secondary settlement tanks or in the case of industrial application pressure or sand filtration. This study will be the first research into alternative self-maintaining methods of filtering rain water. The motivation for this research is based on the shortcomings of rainwater harvesting practices internationally. In short the reluctance to

approve the use of rain water domestically is based on research covering all aspects of harvesting water, such as biological, atmospheric, and maintenance problems, and reported dangers to the health of the user. The novel filter is an alternative method of rain water filtration which has been designed to overcome most if not all of these problems. Access to good quality potable water is becoming a universal challenge. Water is a limited resource and being a water-scarce country, South Africa is no exception to this trend.

Estimated cost: R426 400
Expected term: 2012 - 2013

Developing a low-flush latrine for application in public schools
Partners in Development
No. 2198

In May 2011 eThekwini Metropolitan Municipality asked Partners in Development to consider developing a low-flush latrine which could be used in public schools. This study will design and test a robust low-flush system to contribute to the development of a range of on-site sanitation options which take into consideration the full life cycle of a system, including user behaviour, pit emptying and beneficial disposal of sludge.

Estimated cost: R250 000
Expected term: 2012 - 2013

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