# Can SA afford to continue polluting its water resources? – With special reference to water pollution in two important catchment areas

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**Abstract**

The reuse potential of industrial, agricultural and domestic return flows in any region is directly dependent on the quality of treatment processes and the intended reuse applications. Although the direct recycling of polluted water for potable use does not occur in South Africa, water users downstream of polluted water resources are indirectly exposed to such reuse and suffer the consequences of poor pollution control measures in numerous catchments. It is often assumed that the cost of polluted return flows for environmental release and polluted water resource remediation for reuse is justified within a water scarcity context such as South Africa. However, a current CSIR investigation (funded by the Water Research Commission) indicates that South Africa cannot afford the increasing costs associated with such remediation strategies due to the sheer magnitude of ongoing water pollution.

Preliminary results in the Upper Crocodile-West Marico and Olifants River catchment areas indicate that primary pollution control measures, i.e. the waste water collection- and treatment infrastructure, directly affects the water quality and cost of purification for downstream use due to eutrophication and salinisation. The potential effect of salinisation on agricultural productivity in a section of the Olifants River catchment is provided to highlight the serious nature of this form of pollution on future food production activities. In addition, information regarding the general impact of microbial pollution of the available surface water resources on the South African economy and the national financial burden caused by sedimentation are provided and discussed. From the data presented in this document, both at a national level or where limited to the two specific case study areas, it is clear that the water quality directly affects its usability and therefore not only the value of the resource but also the cost associated with purification for industrial use and human consumption.

The results of this study indicate that the costs associated with the remediation of polluted return flows is largely in vain as, according to some of the results presented here, it does not appear to curb ongoing pollution of surface water resources. It seems as if the prevention of such pollution may represent the only sustainable approach to preserving the quality of the water available for the future economic growth of South Africa.

## 1. Introduction

The question "how much water pollution is too much" is a normative issue – it focuses on what should be rather than what is. Some are tempted to dismiss normative or ethical questions on opinionated grounds. However, in modern society, opinion matters because the underlying ethical viewpoints of politicians, bureaucrats and members of the public (voters) give direction to pollution policy in this country. South Africa already has a system of laws, regulatory frameworks and agencies responsible for controlling water

pollution and the White Paper on Integrated Pollution and Waste Management for South Africa (DEAT, 2000) identifies salinisation of fresh waters, nutrient enrichment of fresh water bodies, microbial degradation of water quality and sedimentation as key components of the total impact of water pollution in South Africa. This paper informs on a section of the investigation commissioned by the Water Research Commission (WRC) regarding the costs associated with these major components of pollution.

Although the deterioration in available water quality often occurs gradually and cannot always be linked to a single catastrophic event, environmental sustainability suffers in the long run. This investigation attempts to highlight the inadequacies inherent to the current pollution control systems, leading to the pollution of surface water resources as well as the cost impact of these increasing pollution loads. Two water management areas (WMAs), the Crocodile-West Marico WMA upstream of the Hartbeespoort Dam as well as the Olifants WMA, were selected, mainly due to the availability of the necessary data and the importance of these areas to the local and national economy. Data from these two water management areas, as well as data available on a national level, were used to investigate the cost impact of the different forms of pollution.

In 2006, about 50% of urban and industrial drainage was returned for re-use in areas such as Johannesburg and Pretoria (DEAT, 2006). The potential for return flow reuse depends largely on the quality of the return flow combined with user requirements. The availability and affordability of the treatment processes to meet these user requirements also play an important role in realising this potential. Increasing urbanisation, the necessity of meeting requirements for basic human needs and growing industrial activity, increases the pressure on available water supply, waste water collection and treatment infrastructure. An over-extension of the capacity of waste water control infrastructure inevitably leads to the discharge of poor quality effluent, impacting negatively on the environment and downstream water users. The current management approach is geared at extensive and expensive upgrades of existing infrastructure, the construction of new waste water treatment facilities and/or improvement of the technology available for downstream water purification. Little attention is given to pollution prevention measures, which may be more efficient and effective in the longer term.

The acceleration of the effects of eutrophication, salinisation, sedimentation and microbial contamination on water resources are symptoms of anthropogenic activities and require increasingly sophisticated treatment technologies to render the available water fit for downstream use. Currently, most industries in urban areas use water of potable quality, obtained from the distribution system of a water services provider (municipality or water utility) and discharge their wastewater into the municipal sewer system in accordance with the requirements of the Water Services Act, 1997, Section 7 (RSA 1997). As such, wastewater treatment facilities play a major role in pollution prevention of water resources and the downstream cost of treating water for reuse.

The economic impacts of polluted surface water resources include the cost of treatment for reuse, loss of agricultural yields, loss of water storage capacity, loss of human productivity and quality of life due to waterborne diseases and the loss of ecological services as a result of environmental impacts. The impacts and related costs are discussed in this paper, providing insight into the financial implications of current water pollution management strategies and the potential costs of future pollution remediation.

Direct and indirect costs associated with the different contributors to surface water pollution in the selected study areas and at a national level where applicable, were determined where possible and are also discussed.

## 2. Methodology

A literature review of available information relating to the cost of pollution was done. In the two catchment areas identified earlier in this document, available analytical data on water quality was sourced from the Department of Water Affairs and supplemented with data from municipalities and operators of water treatment facilities. This analytical information was used to investigate the ongoing nutrient pollution and

salinisation of the surface water in these two areas. As the most quantifiable measures regarding the costs of nutrient pollution are found by investigating the costs incurred by municipal and private entities responsible for waste water treatment and potable water purification, the operators of water and wastewater treatment plants were interviewed to understand the drivers for upgrades in technologies, as well as the effect thereof on treated water quality. Figures on capital and operational expenditure associated with upgrades in technologies over the past number of years were also obtained. This information is presented as an indication of the direct costs of nutrient pollution.

Indirect costs of increased pollution include the potential reduction in agricultural yields, the deterioration of human health due to microbial pollution and the loss of surface water storage capacity due to sedimentation. The impact of these last three forms of pollution was obtained through the use of existing literature and recent studies on these subjects.

## 3. Results and discussion

*Where reference is made to monetary values, the internationally accepted symbol for the South African rand ZAR is used. On 05/08/2010 ZAR 1 was the equivalent of US$ 7.24.*

### 3.1 Eutrophication

#### 3.1.1    Analytical data showing increasing pollution loads in the two study areas

The available analytical data show increasing pollution loads entering the Hartbeespoort Dam (Figure 4) and the Olifants River downstream of the Loskop Dam (Figure 5) (Roux and Oelofse, 2010). An increasing trend over time in salinity in the Olifants River down-stream of Loskop Dam was reported in literature in 1997 (Aihoon *et al.*, 1997). The results further show that the Hartbeespoort Dam acts as pollution sink (Figure 2) for nutrients and salts. The same situation can also be expected for the Loskop - and Rietvlei Dams in this study area.
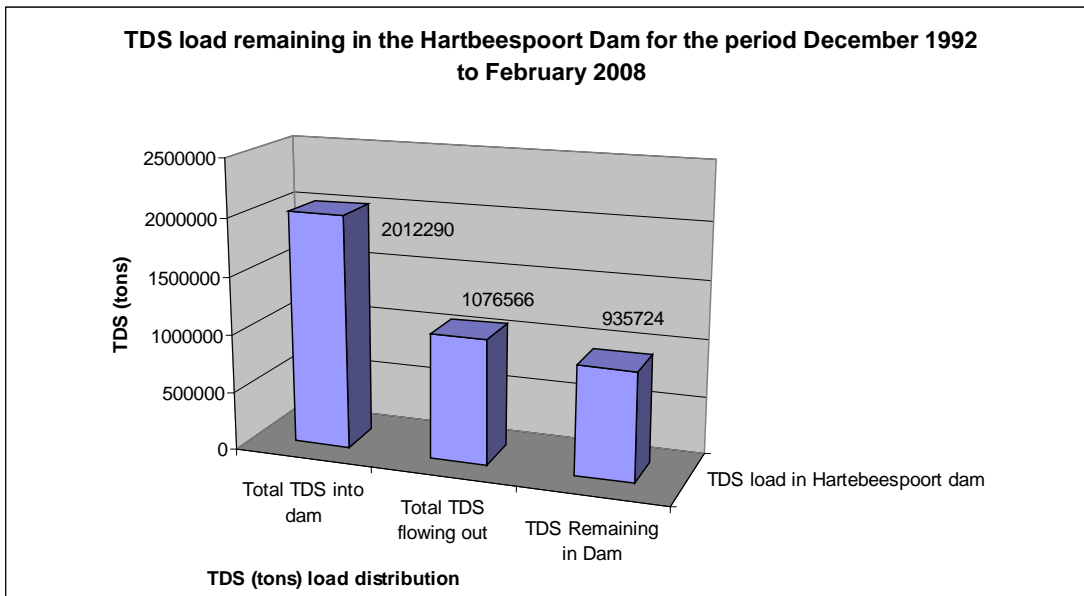


**Figure 1:    Analytical data show increasing salinisation of the Hartbeespoort Dam (Roux and Oelofse, 2010).**
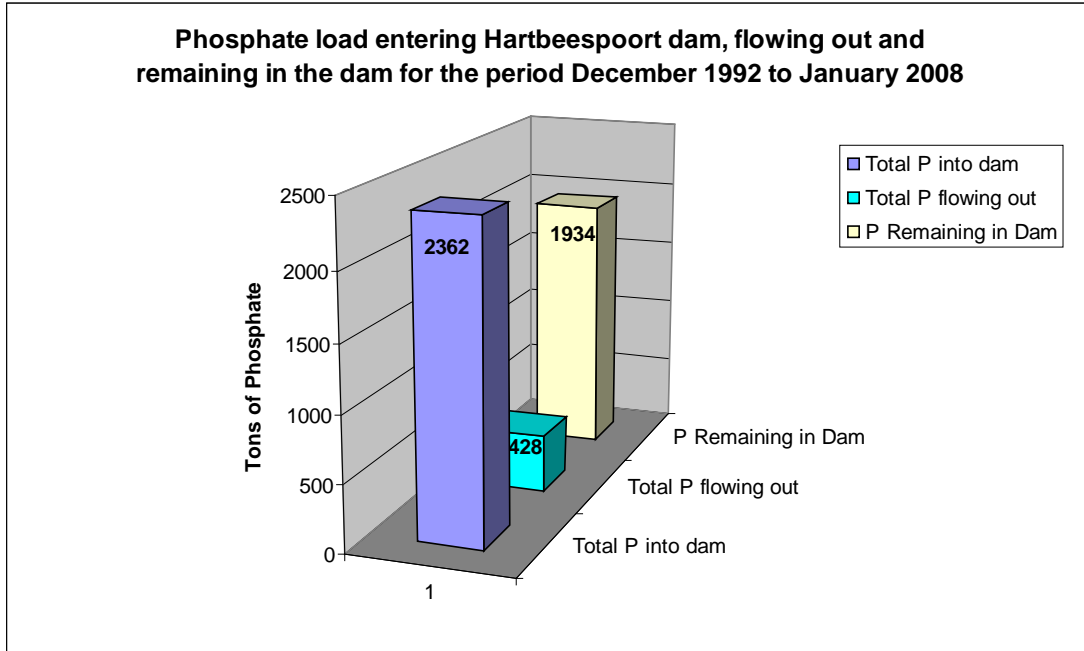
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**Figure 2: Only a small percentage of the phosphate that discharges into the Hartbeespoort Dam flows out via the Crocodile River (Roux and Oelofse, 2010).**
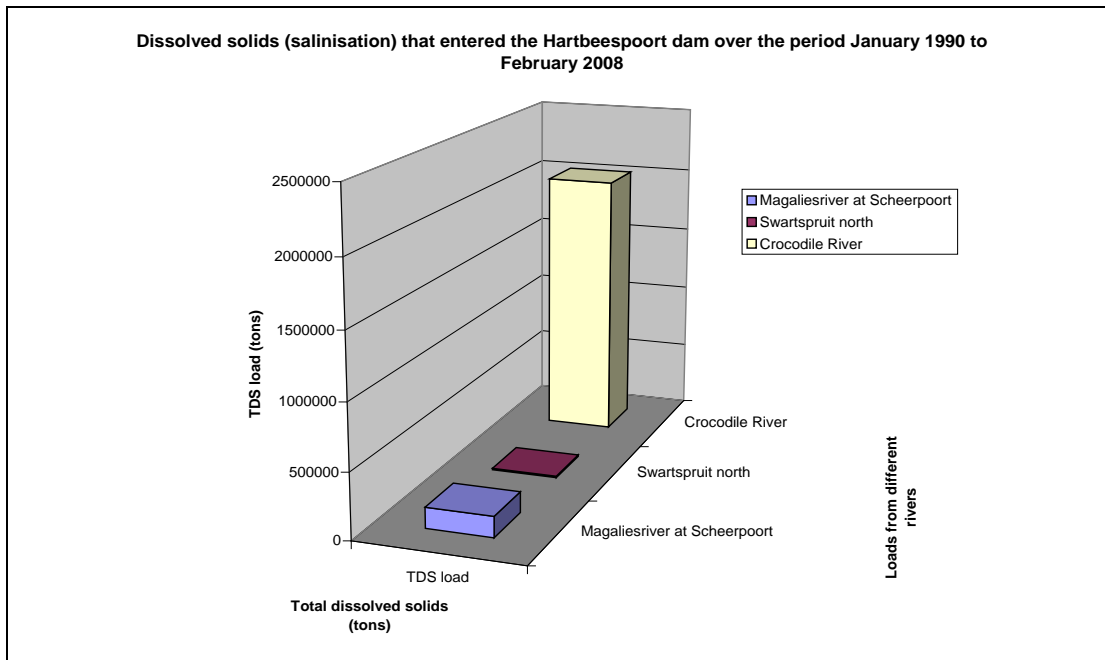


**Figure 3: Most of the pollution loads of dissolved solids (including nutrients) flows into the Hartbeespoort Dam via the Crocodile River, carrying pollutants from human activities including treated domestic waste water and mining effluent (Roux and Oelofse, 2010).**

**TDS load (monthly averages) entering the Hartebeespoort dam *via* the Crocodile river from January 1990 to May 2008**

TDS (tonnes)

◆ TDS load
— Linear (TDS load)

Dates

**N load for the Crocodile (south) at Kalkheuwel for the period January 1990 to May 2008**

N load (tons)

◆ N load
— Linear (N load)

Date

**Phosphate load (monthly averages) measured at for the Crocodile (south) at Kalkheuwel for the period January 1990 to May 2008**

Phosphate load (tons)

◆ Crocodile at Kalkheuwel  — Linear (Crocodile at Kalkheuwel)

Dates

**Chlorphyll a as indication of algae present in Rietvlei dam**

Chlorophyl a (ug/L)
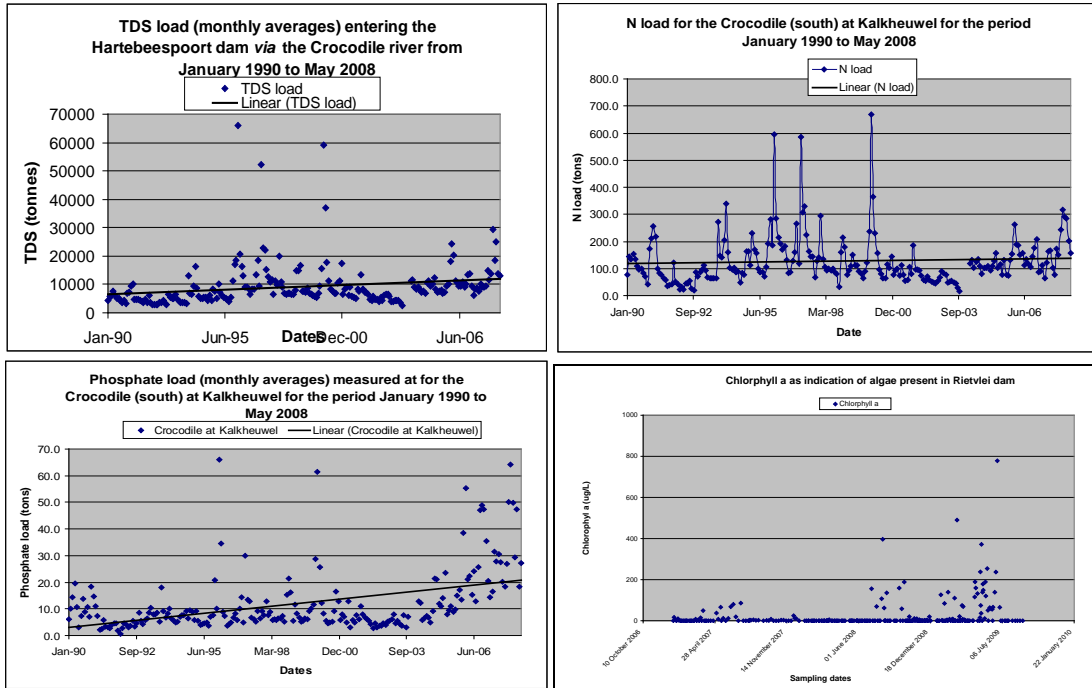
◆ Chlorphyll a

Sampling dates

**Figure 4: These graphs indicate the increasing pollution load discharging into the Hartbeespoort Dam and the increasing algal load (eutrophication) in the water used for the production of potable water at the Rietvlei water purification facility (lower right graph) (Roux and Oelofse, 2010).**

The water from both the Hartbeespoort and Loskop Dams is used for irrigation and human consumption. It is therefore of concern that higher than normal amounts of dissolved aluminum and the nutrients phosphate and nitrate have been detected in the inflow water of the Loskop Dam (Oberholster *et al.*, 2010). The potential impact of the deteriorating water quality of the Olifants River is discussed in the section on salinisation.
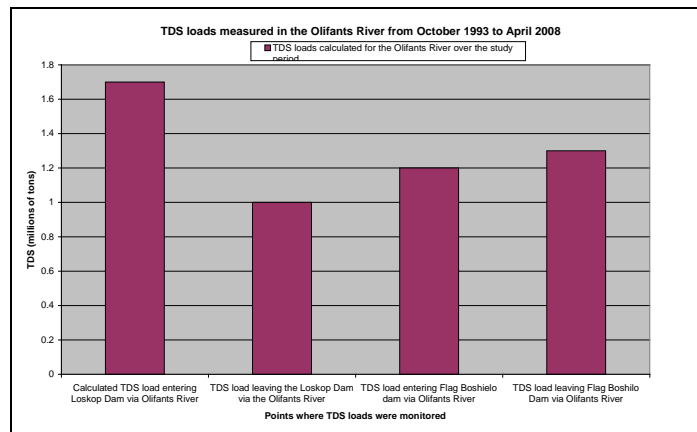
**TDS loads measured in the Olifants River from October 1993 to April 2008**

TDS (millions of tons)

■ TDS loads calculated for the Olifants River over the study period

Points where TDS loads were monitored

Calculated TDS load entering Loskop Dam via Olifants River / TDS load leaving the Loskop Dam via the Olifants River / TDS load entering Flag Boshielo dam via Olifants River / TDS load leaving Flag Boshilo Dam via Olifants River

**Figure 5: Increasing salinisation of the Olifants River down-stream of Loskop Dam.**

### 3.1.2    Direct cost of waste water treatment

The hypertrophic status of the Hartbeespoort Dam is an indication of the severity of the pollution problem associated with industrialization and urbanization in the upper reaches of the Crocodile-West Marico WMA. This is a clear indication that the pollution prevention measures, including the waste water

treatment works (WWTWs) in this WMA, are ineffective. Based on the large amount of upgrading of these WWTWs currently underway (see Table 1), to be completed by 2025 at a total cost of approximately ZAR 1.364 billion, the treatment capacity of these WWTWs appear to be the main problem (Roux and Oelofse, 2010). It remains to be seen whether the ongoing expansion of the waste water treatment infrastructure in this WMA will be able to reduce the pollution load flowing into the Hartbeespoort Dam in the long run. If the economic growth and population increase in this area continues at the current rate, the planned increase in waste water treatment capacity will only temporarily alleviate the situation. The question must be asked whether the expansion of WWTWs presents a sustainable solution to the problem of pollution associated with the production of large quantities of waste water in this region.

The loss of the once profitable tobacco industry in the Brits area due to the high chloride content of the water from the Hartbeespoort Dam, an example of the damaging effects of salinisation, shows how poor water quality from one area can impact on the economic sustainability of the next down-stream area. Another, equally serious problem that will impact on communities relying on polluted water sources for the production of potable water, is the eventual costs of potable water. Continued discharge of nutrient-rich effluent into surface water resources leads to eutrophication, as has occurred in both the Hartbeespoort Dam and Rietvlei Dam. Both dams are situated downstream of industrial and urban areas where conventional waste water treatment systems have failed to protect surface water resources from salinisation and eutrophication. Both dams are classified as hypertrophic (DWAF, 2003). The impact of dam water quality degradation is especially evident at the municipal potable water production facility at Rietvlei Dam. The production of potable water at this treatment facility has been maintained only through the introduction of continual, increasingly expensive technology upgrades. These technologies are introduced to combat the effects of eutrophication, including increased turbidity and the prevalence of blue-green algae (Roux and Oelofse, 2010) with its potential to secrete toxic substances into the water. These toxins and their impact on human health are summarized well by Messineo et al., (Messineo et al., 2008). Problems regarding the supply of potable water from increasingly polluted water resources are already reported at Hartbeespoort Dam and Brits.

In this WMA, the capital value for the construction of WWTWs is estimated at ZAR 6.5m /ML.day, not too dissimilar from the costs of ZAR 4.6m/ML.day for the Rietvlei water purification facility. The production costs for these facilities are also similar at ZAR 1 030/ML for water purification and between ZAR 794.1/ML and ZAR1 500/ML for waste water treatment (Roux and Oelofse, 2010). However, these costs by themselves do not provide a clear picture of the full extent of the problems caused by the increasing pollution of surface water in this WMA.

The expected economic- and population growth in both study areas predict a further increase in the quantities of waste water produced, therefore perpetuating the never-ending increase in - and cost associated with the treatment of this increasing volume of waste water. The waste water collection and treatment infrastructure have to expand at a rate comparable to that of the increase in waste water production in order to prevent further pollution and ensure sustainable human activities in these areas. The example of the increasing technological upgrading of the Rietvlei water purification works includes a dissolved air flotation (DAF) system installed in 1980, followed by activated carbon treatment in 1999. More recently, ozonation equipment was introduced and as Cyanobacteria, the dominating algal population in Rietvlei Dam in recent years, complicate treatment and increase associated costs, the "Solarbee" algae management system was recently introduced as well (Roux and Oelofse, 2010). Further problems regarding water treatment for potable use that may impact on treatment costs in the near future include emerging pollutants and increased levels of salinity. This may impact so drastically on the technology required to treat this water for reuse that the constitutional human right of having access to high quality water may become a moot point. Treatment costs will become so excessive that water may well become available only to those who can afford it.

**Table 1: WWTWs in the selected study area**

| No | WWTW | Discharge River | Capacity (ML/day) | Average flow (ML/day) | Operating costs ZAR/ML | Planned expansion of facilities | Replacement value/ Capital value in ZAR |
|---|---|---|---|---|---|---|---|
| 1 | Hartbees-fontein (6) | Swartspruit | 45 | 50 | 1 500 (an average price for all ERWAT WWTWs) | New 120 ML/day WWTW on the Swartspruit. Phase one (50 ML/day to be completed in 2013 @ R260m) | 315m at R7m/ML.day |
| 2 | Esther Park (6) | Swartspruit | 0.4 | 0.4 | See Hartbeesfontein | | |
| 3 | Olifants-fontein (6) | Kaalspruit | 105 | 70 | See Hartbeesfontein | | 735m at R7m/ML.day |
| 4 | Sunderland Ridge (7) | Hennops River | 65 | 58 | 794.1 | Increase capacity to 95 ML/day by 2010 – 2013 @ R300m; New 50 ML/day WWTW near Skurweberg on Hennops River to be completed in 2016 @ R260m | 585m at R8m/ML.day |
| 5 | Northern Works (8) | Jukskei River | 450 | 380 | | Phase two to be completed in 2013 with phase 3, (an additional 50 ML/day) planned for 2025 | 2 700m at R6m/ML.day |
| 6 | Driefontein (8) | Crocodile River | 35 | 35 | | Expansion of additional 25 ML/day @ R150m | 210m at R6m/ML.day |
| 7 | Percy Stewart (9) | Blougatspruit | 15 | 18 | | Increasing the capacity to total 25ML/day by 2012 at a cost of R94.3m | 139.5m at R9.3m/ML.day |
| 8 | Magalies | n/a | n/a | n/a | n/a | | |

*Note: The capital (current replacement) value is supplied according to the information supplied by the owner/operators of the different WWTWs. Various factors including location, specific design and size determine that the different WWTWs are valued at different capital amounts/ML.day (Roux and Oelofse, 2010).*

In order to break this vicious cycle of increasing volumes of polluted water threatening to overrun treatment systems, future research into water management strategies should focus on the minimisation of water use by both industrial and domestic users.

### 3.2 Sedimentation

Soil erosion is a common sight in South Africa as a result of poor land-use practices combined with erodible soils. Water has been identified as the main cause of soil erosion and silt rich run-off leads to the sedimentation of water resources (Le Roux *et al.*, 2007). The observed average sediment yield per unit area in South Africa varies between 10 to more than 1 000 t/km$^2$/year (Braune and Looser, 1989). The main physical impacts of sediment entering surface water resources are a decline in the storage capacity of dams and blocking of irrigation systems. Sedimentation damage to agricultural land resources include the overwash of infertile material, impairment of natural drainage and swamping due to channel aggregation, associated floodplain scour and bank erosion (Braune and Looser, 1989). In addition, suspended inorganic material carries an electrical charge that could result in a number of dissolved substances, including nutrients, trace metal ions and organic biocides to become adsorbed onto the surfaces of these particles. Substances adsorbed to particles are not biologically available, which may be advantageous in the case of toxic trace metal ions and biocides, but disadvantageous in the case of nutrients (DWAF, 1996a). Suspended organic solids on the other hand, may decrease the concentration

of dissolved oxygen in the water body due to the oxidation of the solids by micro-organisms (DWAF, 1996b).

It is difficult to accurately determine the cost of sedimentation, but a study by Braune and Looser (1989) estimated the cost of sedimentation based on the total storage and mean loss of storage capacity for 170 reservoirs. At an average storage loss rate of 0.35% per annum, the total storage loss per annum was calculated at 105 $Mm^3$ at an estimated cost of ZAR 53 million per annum (Braune and Looser, 1989). A more recent study by Sawadogo (2008) estimated the storage loss rate at 0.28% per annum (109 $Mm^3$). Both calculations excluded the thousands of private farm dams. Replacement of lost storage can be achieved by the construction of new storage through increasing the dam wall height, construction of a new dam at a different site or by removal of the sediments. Construction costs of new storage can be calculated per cubic meter of storage volume (Braune and Looser, 1989). At an estimated construction cost of ZAR $12/m^3$, the annual loss of capacity is ZAR 1.3 billion, excluding indirect costs (Sawadogo, 2008). The raising of the Flag Boshielo Dam in the Olifants WMA by 5 meter was done to increase the storage capacity from 100 million $m^3$ to 188 million $m^3$. The project was complete in 2006 at a cost of ZAR 200 million (ZAR $2.27/m^3$) (RSA, 2003). Construction of the new De Hoop Dam in the Steelpoort valley started in July 2007 and will create 347 million $m^3$ of storage capacity at an estimated cost of ZAR 2.5 **billion (ZAR $7.21/m^3$)** (DWA, 2010). The construction of new dams is, however, limited due to a lack of suitable sites for new dam construction. Sediment removal, on the other hand, may be possible, but its economic viability is likely to depend on physical, hydrological and financial parameters (Palmieri *et al.*, 2001).

Water with high turbidity increases the requirement for capacity at the treatment works and requires special design such as pre-sedimentation tanks and other special sediment removal equipment. It also increases the demand for flocculent and disinfection resulting in an increase in operational costs of ZAR 6 million per year (Braune and Looser, 1989). Disposal of sediments adds another cost and operational challenge. The annual increment on capital outlay for the treatment of water with higher than normal turbidity was estimated at 2% of the total capital cost (Braune and Looser, 1989).

The total off-site cost impact of sediments in South Africa in 1989, excluding the environmental damage, was estimated at ZAR 90 million/year (Braune and Looser, 1989).

### 3.3 Salinisation

The study presented the monetary impact of water pollution in terms of the income being lost when crops are irrigated with polluted water, *viz.* the production costs associated with clean versus high salinity irrigation water. A key step to achieve this was to assess how the quality of irrigation water changed "with" and "without" salinisation prevention measures. The results of the assessments provided estimates for the baseline (without policy) water quality, and the subsequent (with policy) water quality. Estimates of the baseline and the subsequent groundwater conditions were used to define the change in the irrigation water quality.

The marginal value product (MVP) of irrigation water represents the "true" economic value of an additional unit of irrigation water to a farmer. It represents the "economic value in use" to the farmer. Generally speaking, this additional unit of water would produce additional agricultural output. The value of the additional output is dependent upon the type of crop grown and the producer price that is specific to the region (Jabeen *et al.*, 2006). The MVP gradient of irrigation water represents how economically sensitive a crop is to increased salinity (Figure 1). Citrus, being the most sensitive, has an MVP gradient of -0.81, which implies that for every 100 mg/ℓ increase in total dissolved solids (TDS), citrus production suffers a ZAR $0.81/m^3$ loss in the MVP of irrigation water. Maize follows with an MVP gradient of -0.33, which implies that for every 100 mg/ℓ increase in TDS, maize production suffers a ZAR $0.33/m^3$ loss in the MVP of irrigation water. Potato follows with an MVP gradient of -0.29 and this implies that for every 100 mg/ℓ increase in TDS, potato production suffers a ZAR $0.33/m^3$ loss in the MVP of irrigation water. Wheat,

being the most salt-tolerant, did not display any loss in the MVP of irrigation water within the TDS investigation range of this study (900-1 800mg/ℓ TDS).
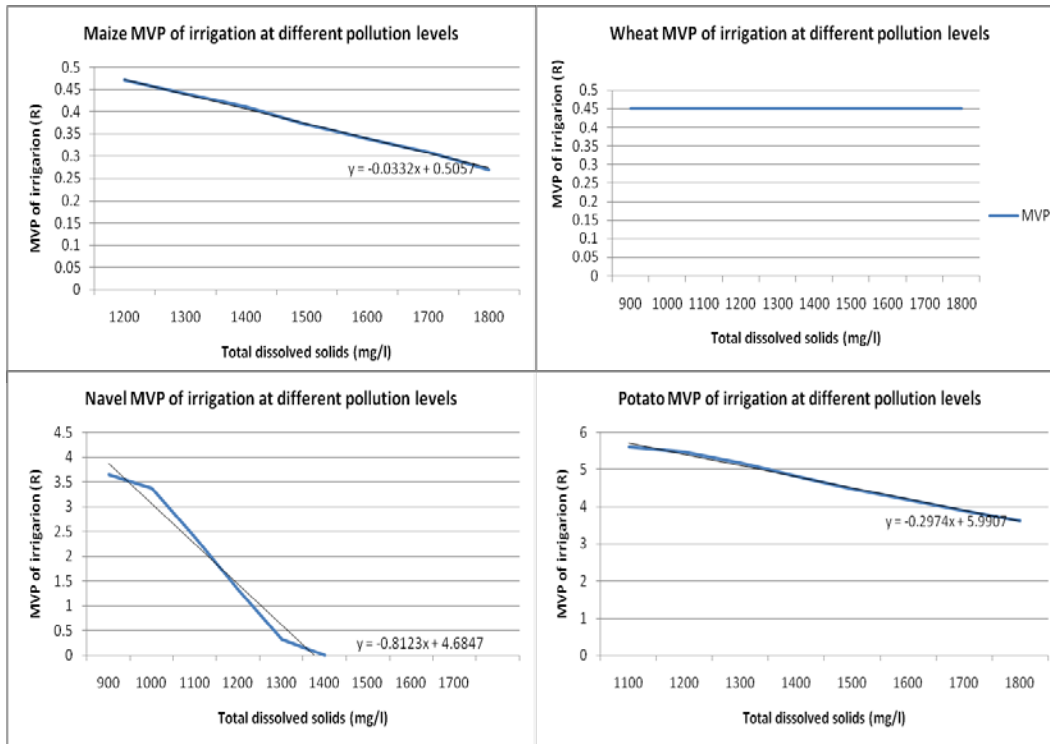


**Figure 1: MVP of selected crops at different pollution levels.**

Apart from being the most sensitive to salinity in economic terms, citrus production was also observed to suffer the highest decrease in terms of the MVP per m$^3$ of irrigation water with increased salinity. The MVP of citrus decreased from ZAR 3.65/m$^3$ at 900 mg/ℓ TDS to ZAR 0.00/m$^3$ at 1 400 mg/ℓ TDS, amounting to a ZAR 3.65/m$^3$ MVP loss for irrigation water. ZAR 3.65/m$^3$ represents the costs associated with a change in irrigation water quality "with" and "without" salt prevention strategies and policies at play. It is a comparison between the MVP of clean irrigation water and the MVP of more saline irrigation water within the salinity investigation range of this study. The difference is the loss in the economic value of irrigation water in a situation where salinisation is prevalent, in contrast with a situation of clean irrigation water.

The linear model applied an irrigation water availability constraint of 7 700 m$^3$/ha for all crops. Citrus required 10 510 m$^3$/ha of irrigation water, which was in excess of the water constraint and dictated that only 18.32 ha of the typical farm unit could be irrigated. The high sensitivity of citrus to salinity resulted in the MVP/m$^3$ of irrigation water reaching zero at 1 400 mg/ℓ TDS. At this level, it was not economically viable to produce any citrus. A typical citrus producing farm in the Loskop water user association (WUA) area was observed to reap a total gross margin above specified cost (TGMASC), ranging from ZAR 678 248 to ZAR -25 247, as salinity increased; this translated to a loss in TGMASC of ZAR 703 495 per typical farm in the Loskop WUA area as a result of salinisation. A typical maize producing farm in the Loskop WUA area was observed to reap a TGMASC ranging from ZAR 69 015 to ZAR 38 908 as salinity increased; this translated to a loss in TGMASC of ZAR 30 107 per typical farm in the Loskop WUA area as a result of increased salinity. The MVP of maize decreased from ZAR 0.47/m$^3$ to ZAR 0.27/m$^3$, which is a ZAR 0.20/m$^3$ MVP loss for irrigation water. ZAR 0.20/m$^3$ represents the costs associated with a change in irrigation water quality "with" and "without" a salinity prevention policy in place. A typical potato producing farm in the Loskop WUA area was observed to reap a TGMASC ranging from ZAR 775 994 to ZAR 495 857 as salinity increased, which translated to a loss in TGMASC of ZAR 200 137 per typical farm in

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the Loskop WUA area as a result of salinisation. The MVP of potato decreased from ZAR 5.60/m$^3$ to ZAR 3.62/m$^3$, translating to a ZAR 1.98/m$^3$ MVP loss for irrigation water. ZAR 1.98/m$^3$ represents the costs associated with a change in irrigation water quality "with" and "without" a salinity prevention policy in place. A typical wheat producing farm in the Loskop WUA area was observed to reap a constant TGMASC of ZAR 83 179 as salinity increased. Wheat is tolerant to salinity and as such did not show any economic losses due to salinisation within the salinity range of this study. The MVP of wheat remained constant at ZAR 0.45/m$^3$, with a resultant ZAR 0.00/m$^3$ MVP loss for irrigation water. Only for wheat was there no cost associated with a change in irrigation water quality "with" and "without" a salinity prevention policy in place in the Loskop WUA area.

For the purpose of the MVP estimates, it was assumed that the salinity of irrigation water is directly proportional to the salinity of the saturated soil (which is not always the case). The average maximum allowable salinity in the Loskop area is 1 700 mg/ℓ TDS, while the recommended operational salinity limit is a maximum of 1 000 mg/ℓ TDS (Ferreira, 2009). These specifications determined the salinity range that was used to investigate economic impacts of salinisation in this study. A salinity range from 900 mg/ℓ TDS (100 mg/ℓ TDS below the recommended salinity limit) up to 1 800 mg/ℓ TDS (100 mg/ℓ TDS above the maximum allowable water salinity) was considered appropriate, given the reality in the Loskop WUA area.

**3.4 Microbial contamination and its cost impacts on society**

Microbial (bacteriological, viral, protozoan or other biological) contamination can result in serous health concerns of the people who need to consume river water when no other drinking water is available. High concentrations of faecal bacteria are associated with untreated or poorly treated sewage effluents (point sources) and urban run-off (non-point sources). In addition, uncontrolled effluent discharges from the dairy, fish processing, poultry and red meat industries can contribute to the deterioration of the microbial quality of river water. It has become apparent that nationally, a large number of waste water treatment plants are not operated optimally (Snyman *et al.*, 2006). In an assessment of 449 municipal waste water systems (53% of the total 852 municipal waste water systems) only 7.4% of the waste water treatment systems achieved green drop certification (DWA, 2010). The risk of microbial pollution in South African water resources are therefore of concern, especially in areas with high population densities and low levels of basic services.

Healthcare expenditure by a household experiencing illness in rural South Africa incurred a direct cost burden of 4.5% of total household expenditure in 2009 (Goudge *et al.*, 2009). In addition, a visit to a public clinic generated a mean burden of 1.3%; 20% of households incurred a burden of over 10% for complex treatments, while transport costs accounted for 42% of this burden (Goudge *et al.*, 2009). An outpatient visit generated a burden of 8.2%, while an inpatient stay incurred a burden of 45%. About 38% of individuals who reported illness did not take any treatment action (Goudge *et al.*, 2009). This is not surprising, when considering the high levels of unemployment and poverty in rural settings.

A study conducted by the then Department of Water Affairs and Forestry in 2000 (DWAF, 2001) estimated the potential cost of poor water quality in densely populated areas nationally at **ZAR** 2.9 billion per annum. This figure is based on the cost of treating diarrhoea, as it was the only disease for which reasonably verifiable statistics could be obtained (DWAF, 2001). The cost estimate can be broken down into direct and indirect health costs, as well as the cost of water treatment. "The total direct health costs of Low Service Levels in Dense areas is ZAR 2.07 billion and this is the product of an estimated 1.1 million cases treated in SA at an average of ZAR 1 904 per treatment" (DWAF, 2001). The bulk of this cost is incurred in densely populated areas with low levels of services. It is reported that in 2000, 35% of the South African population was living under these circumstances (DWAF, 2001).

## 4. Conclusions

In these study areas pollution loads are increasing over time at a rate and cost that have serious economic implications for the country. It is clear from this study that poor water quality originates from inadequate pollution prevention practices in large industrial and densely populated areas. The measurable impact of pollution includes the deterioration of available water for downstream use. Although salinisation, sedimentation and eutrophication are natural phenomena, anthropogenic activities cause drastic increases in the rate at which these impact on - and affect down-stream communities and human activities. The microbial contamination of surface waters can be attributed to poorly functioning waste water management infrastructure, in combination with a lack of sanitation in certain areas and storm water run-off. The rapid increase in pollution loads in the rivers of the study areas indicates that pollution management systems are ineffective and insufficient. The negative impacts on the economy are also significant.

The South African waste water treatment capacity has an estimated capital replacement value of > ZAR 23 billion, operating at an estimated expenditure of > R 3.5 billion per annum (DWA, 2009). It can be argued that the > R 3.5 billion operational expenditure equates to wasteful expenditure in light of the pollution potential of poor effluent quality being discharged. It is further clear that pollution of surface water sources has serious impacts on the economy of South Africa. The cost of poor water quality on densely populated areas is estimated at ZAR 2.9 billion and the loss of storage capacity adds a further ZAR 1.3 billion. The loss of economic value for irrigated agriculture is also shown to be significant for most crops.

One way of dealing with the problem involves the use of more modern technology for treatment and/or the costly expansion of waste water treatment works. This approach is capital intensive and has, to date, failed to provide an adequate, sustainable solution to the water pollution problem. The alternative is to treat polluted effluent streams at source, therefore taking advantage of cost savings associated with the use of specific technology for the treatment of concentrated but low volume streams. This strategy, if enforced rigorously, will place the responsibility and costs for pollution prevention onto the polluters in line with the "polluter pays principle". This strategy will allow traditional WWTWs to deal with what they were designed for, organic material and nutrient removal. In addition, modification of waste water management infrastructure and the implementation of strategies to minimise the volumes of waste water produced by both industry and domestic users, should be investigated through research activities as a matter of urgency. By reducing the volumes of waste water produced through recycling/reuse and water limited- or waterless sewage systems, the demand for capital intensive upgrading of WWTWs can be reduced.

South Africa cannot afford to continue polluting its water resources. Water pollution is costing the country billions of Rand annually, but even more importantly, it is affecting the quality of human life. To find a sustainable solution for the reduction of the volumes of valuable, potable water that is being polluted and then simply passed on to downstream users, current waste water management systems will have to be developed, maintained and where necessary upgraded to enforce treatment-at-source principles. Furthermore, serious attention is required to rectify general non-compliance regarding the operation and management of WWTWs. The continuation of the pollution of South Africa's surface water resources must lead to the increase in the price of potable water. If the social costs of water pollution are internalised in the price of water, this cost increase could be of significant proportions.

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