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- SOUTH AFRICA -

"Making Knowledge work for us"

LESSON SERIES
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Achieve Green Drop status

Kruger National Park chooses green technology to achieve a Green Drop

WATER RESEARCH COMMISSION

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

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1 Introduction

Most people associate the Kruger National Park (KNP) with exciting game sightings and a pristine bush veld experience. When one enters the wastewater plant at Skukuza, this experience continues seamlessly. You smell earth and veld. A lone carmine bee-eater sits on the surrounding elephant fencing.

South African
NATIONAL PARKS

The ponds are a favourite gathering spot for marabou storks and Egyptian geese. The water that exits the reed bed is crystal clear. There is no smell or other evidence that this serene spot is actually treating between 240 000 and 320 000 litres of sewage per day.

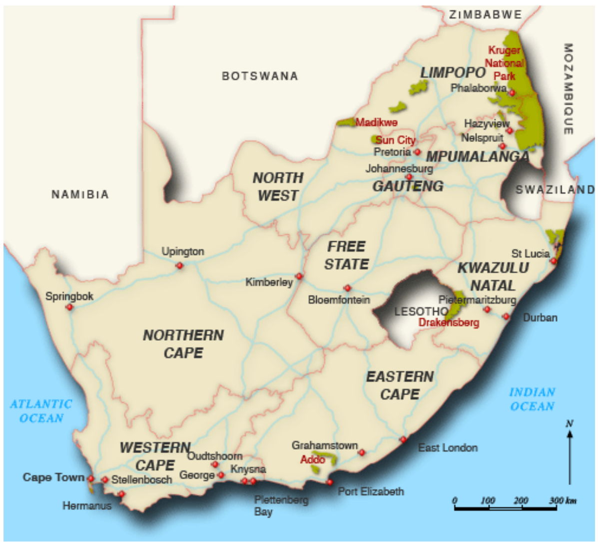
The Kruger National Park receives approximately 1.5 million tourists per year (plus-minus 4000 per day) and it has 2200 permanent staff. The Park owns and operates a total of 13 wastewater treatment plants with a design capacity of approximately 1000 kilolitres per day or 365 million litres per year.

The primary objective of wastewater treatment is to ensure that the treated effluent discharged to the environment does not pose unacceptable risks to human health and the ecosystem.

Oxidation pond systems are the technology of choice and preference. Over the years, the Park's engineers and operators have refined critical success factors in the design, operation and management of pond systems. This lesson will explore some of these success factors and the critical elements that convinced the Park that pond systems are more appropriate and sustainable for their specific needs than alternative treatment options.

2 The significance of a double Green for a national park

KNP is a national asset that South Africans can be proud of. It is an internationally renowned game park – one of the biggest in the world with an exclusive variety of African wildlife. This puts the Park in the international spotlight.



When SANParks, and KNP in particular, give presentations at international wildlife conferences, the SANParks' Board is expected to report that operations in the Park are green and ecologically sustainable. Tourists are also increasingly aware of green[1] technologies and demand green environmental management.

Oxidation pond systems offer such a green solution to wastewater management.

The Kruger National Park was established in 1898 to protect the wildlife of the South African Lowveld. This national park of nearly 2 million hectares is home to an impressive number of species: 336 trees, 49 fish, 34 amphibians, 114 reptiles, 507 birds and 147 mammals.

International tourists demand excellent service. The average tourist has a low tolerance furthermore for inefficiency or pollution of natural resources:

> *If a visitor gets ill in the Park, they always tend to blame the water. Nobody ever gets ill from bad roads. If a visitor is without water or electricity for more than 3 hours, he demands his money back. (Blake Schraader)*

Unlike a municipality, KNP must respond immediately when a pipe bursts or a blockage or spillage occurs. The average turnaround time for an incident is 2-4 hours. Power must be back up within 20 minutes.

Any ecological disaster in the Park would have international repercussions, not only for SANParks, but also for the image of South Africa. The Kruger National Park is therefore constantly searching for more efficient, sustainable and cost effective wastewater service delivery in the Park in their drive for excellence and recognition on national and international scale.

[1]"Green" technology does not disturb the environment, curbs the negative impact of human involvement and conserves natural resources.

It is for this reason that the Green Drop Certification programme and its focus on risk management appeals to the Park. To KNP management, Green Drop status translates to both a good reputation and good management practice:

> *We want to be the first national park with a Green Drop. If we are the first pond operator with a Green Drop Certificate in South Africa, we would indeed be very proud of such a special achievement!*

Abe Sibiya, Acting CEO of SANParks

3 The right people

Blake Schraader, General Manager Technical Services, heads the technical management team. His responsibilities include roads (all 4000 km!), civil and electrical infrastructure, water, wastewater and solid waste.

KNP has a relatively small staff contingent for the range of technical services that they have to cover. A corporate team of specialists is based in Skukuza. Derek Visagie manages civil and building infrastructure and projects. Ben du Plessis manages water, wastewater, mechanical services and waste management. Linford Molaba is in charge of the laboratory and tests all water and wastewater samples for compliance.

Blake Schraader, General Manager Technical Services of the Kruger National Park

The remainder of the team comprises the technical staff in charge of road maintenance and electrical distribution. Maintenance officers and electricians are responsible for the day-to-day maintenance of the infrastructure in the camps.

For Blake, good performance of the wastewater team supports the KNP goal to achieve a Green Drop for a green solution and a low residual footprint. Green and Blue Drops are part of the team's Key Performance Indicators (KPIs). The team is interviewed every three months and scored on their performance against KPIs and the compliance of the wastewater treatment systems with Departmental regulation and specification.

Derek Visagie manages civil and building infrastructure and projects

One is struck by Blake's obvious pride in the achievements of the team. He believes that:

> *If you appoint the right person for the right job, he will fly.*

Get the right people for the job

We have to work within the constraints of a budget, but there is no constraint on initiative. We have the space to experiment and we do.

KNP appoints staff with great care and diligence. *"Competency and proven experience"* are the key qualities that they search for. The following recruitment philosophy is followed when assessing candidates:

1. **Set high interview standards and questions.**
2. **Check the professional registration status of candidates.**
3. **Do thorough reference checks.**
4. **Ask appropriate technical questions to ensure that a candidate has the required understanding and knowledge.**
5. **Test practical skills to support assessment of theoretical knowledge.**
6. **If no suitable candidate is found, revert to headhunting.**
7. **Allow for a 6 month probation period.**
8. **Ensure that the relative 'isolation' of the Park environment is compatible with the candidate's personality and family structure.**

Not everyone will last in a national park. We need young people who love the bush. We have a saying: if someone has stayed in the Park for 5 years, they will stay for life. We have found that engineers who grew up in the surrounding areas are more likely to stay. We encourage young people with a passion for lifelong learning, because the Park gives them the space to grow and to develop.

9. **The Human Resources (HR) department is closely involved in the shortlisting process, but the technical manager takes the final decision.**
10. **Put a process in place to transfer institutional knowledge to new staff.**

Ben du Plessis - a unique career and knowledge path

Ben du Plessis was born and bred in Carletonville. After completing his high school education, he completed his trade test as a carpenter and started working in building and civil construction. He joined the Kruger National Park in February 1988 as a building foreman and was promoted to building inspector in 1989.

In 1991, when the Park decided to outsource building construction, Ben had already proved his value as employee, so the Park offered him a number of employment options. He accepted the position of officer in charge of the newly created Water and Waste section. In 1995, he was promoted to manager, water and waste management, and, from 2002, he also managed the mechanical section.

He is holding his Innovation Prize. The numerous accolades behind Ben's desk confirm the successes of a self-driven career .

I knew nothing about water, but it sounded interesting. So that is where I went.

But I very quickly said to myself: 'Ben, if you want to do this job properly, you will have to learn about water, and learn fast.'

He enrolled first for an N3 in water and wastewater treatment and then more and more courses followed as the years went by. He became deeply interested in microbiology and artificial wetlands and experimented with various improvements and their effect on effluent quality.

There is always something that you can do better. That's what we want to achieve.

Today, Ben is responsible for the Kruger National Park's water, wastewater, solid waste and mechanical services.

In 2013, he received a prize for Innovation for the extra mile that he was prepared to go in solid waste management. In partnership with Nampak, KNP put up a two stream waste bin system in the park. The one stream is for recyclable waste (paper, glass, metal) and the other for non-recyclables. Non-recyclable waste comprises 20% and is incinerated. In the next phase, KNP plans to design and construct a biogas plant for the use of methane to augment the increased energy demand.

Ben du Plessis is a lifelong learner and scientist, always inquisitive and indefatigable, always ready to innovate and to grow and develop from mistakes and lessons learnt. The energy of his commitment and his obvious pride in his work is tangible and a privilege to experience.

4 The right approach

The KNP Infrastructure Development Plan (IDP) makes provision for expenditure of R500 million over a 5 year planning horizon. A specific allocation is made to upgrade and replace wastewater systems as necessary.

The KNP values the Wastewater Risk Abatement Plan (W_2RAP) process and finds it invaluable when planning and prioritising infrastructure projects and doing proactive maintenance.

W_2RAP helps us to prioritise, motivate for funding and implement against milestones. We can motivate in terms of the risk that a particular situation poses. Also, KNP's long term capital development programme is based on risk. W_2RAP fits in well with this philosophy.

W_2RAP allows the Park to determine risk, allocate resources and implement and report reduced risk.

We plan and operate on a 5 year infrastructure development plan. The plan is based on risk and a proactive approach... we remain flexible to change priorities, as and if, a risk profile changes. For example, we identified a risk at Mopani and allocated sufficient budget to replace the bulk sewer lines.

If you are reactive, you are running after trouble; if you are proactive, you can identify your risks in time, prioritise, allocate the necessary budget and resolve the issue before the trouble hits you. (Derek Visagie)

The Selati River

Infrastructure in the Park is insured for R1,6 billion, which covers seasonal flood damage as experienced in 2011 and 2012, as well as elephants destroying oxidation ponds or reed beds. Many of the rest camps are situated on the banks of the major rivers and although they build above the 100 year flood line, flash floods can still cause major damage.

A major incident tends to highlight new risks and new priorities. For example, the incident of December 2013 (Bosveld Phosphate's spillage into the Selati) highlighted the critical risk of insufficient alternative water sources. The Park subsequently developed plans to sink more boreholes to ensure sufficient potable water in the event of a water crisis and emergencies.

The W_2RAP has determined the Critical Control Points (CCPs), for which they have a monthly check list. For example, it is essential to ensure that all main camps and pump stations have electrical supply 24/7. All camps and pump stations have generators as a back-up. Maintenance on the backup system includes 3 hour full load checks on all generators each month. Plus, all generators have batteries with trickle chargers that keep them charged. All batteries run on a service programme and are replaced after a specific time.

Response time for incidents at Critical Control Points is 2-3 hours. Various measures help to speed up turnaround time for repairs and maintenance:

a. KNP standardises equipment as far as possible, both in technical specification policy and in practice, trying not to use more than two manufacturers.

b. They keep spares in stock of the electrical-mechanical parts most likely to break to ensure short turnaround repair time.

c. Technical services have practical and clear procurement guidelines for parts that they do not have in stock. Effort is taken to support and empower local suppliers with a good track record, who are willing to assist outside office hours, over weekends and on public holidays.

d. Minor repairs are done in-house; major repairs are outsourced. KNP also outsources specialist engineering services for the design of a new wastewater treatment plant or the construction of new ponds and reed beds.

Ben du Plessis with spare pumps in the workshop

The cost to treat wastewater in the Park is R1.25/kl. Costs associated with wastewater treatment include:

- Labour
- Pumps: maintenance and replacement
- Power usage
- Pipe network maintenance
- Maintenance on fences
- De-sludging of ponds and septic tank systems
- Maintenance of reed beds (artificial wetlands)
- Office equipment
- Laboratory equipment and chemical reagents
- Transport
- Capital depreciation

Below is the Park's incident control protocol from their W_2RAP for health-related incidents that involve wastewater treatment plants and operations:

Alert Level 1: Pump failure, sewerage spillages and blockages	
Health implication or risk	• No significant risk to health • Odour • Water source pollution
Incident management	**Internal:** Supervisor, Manager, General Manager Technical Services and Operational Health and Safety (OHS) Manager **External:** None
Required response time	Within 2 hours after receiving the complaint
Action	• Communicate the incident to relevant staff; • Assess associated information and implement corrective action to rectify the incident; • If implementation of the corrective action fails, proceed to Alert Level 2.

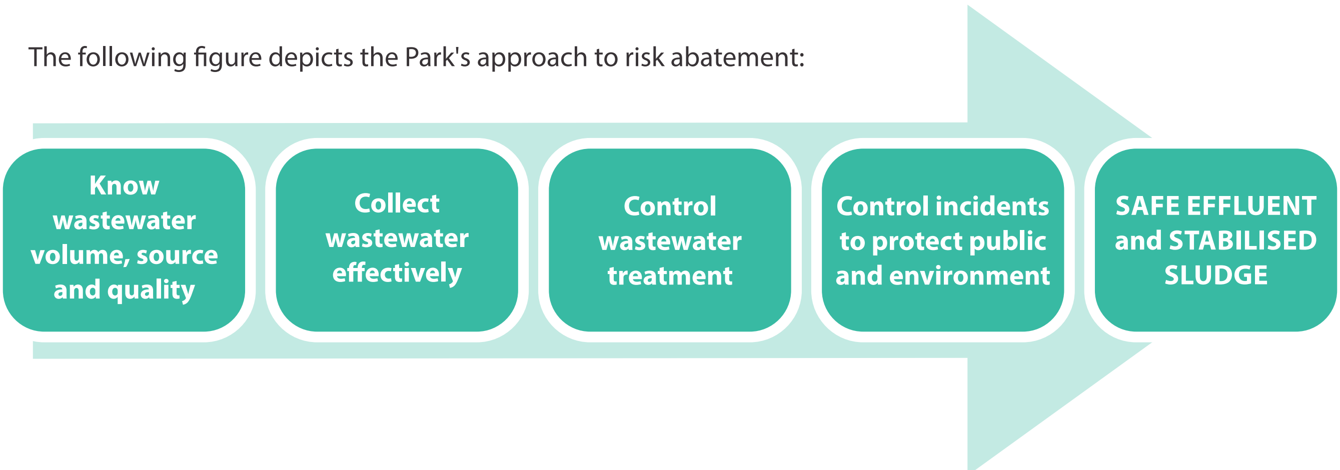
Alert Level 2: Effluent quality failure	
Health implication or risk	• Potential risk to health • Indirect associated impacts on health through the shielding of bacteria from disinfection.
Incident management	**Internal:** Supervisor, Manager, General Manager Technical Services and OHS Manager **External:** Regional offices of the Departments of Water Affairs (DWA) and Environmental Affairs (DEA)
Required response time	Same day as the results are released
Action	• Request additional monitoring as required (both spatially and increased frequency) to establish the source of the contamination and the risk to public health; • Assess treatment process efficiency and implement corrective action to optimize the treatment process; • Communicate the effluent failure and health risk to the relevant staff, DWA and DEA; • If any additional sample results exceed concentrations specified in Alert Level 2, proceed to Alert Level 3.

Alert Level 3: Raw sewerage enters a water source	
Health implication or risk	• Clinical infections common, even with once-off consumption. • Significant and increasing risk of infectious disease transmission. • Significant risk of protozoan parasite infection.
Incident management	**Internal:** Supervisor, Manager, General Manager Technical Services, OHS Manager and KNP Risk Manager **External:** Regional DWA and DEA
Required response time	Same day as the results are released
Action	• Engage Emergency Management Team; • Communicate drinking water emergency and health risk to relevant staff, DG of DWA, head of provincial DEA; • Continue additional monitoring and extend to the distribution system and point-of-use to establish the source and extent of the incident and the risk to public health; • Assess the users at risk and the need for an alternate water supply; • Communicate drinking water emergency to end users; • Implement specialist process assessment and optimisation of the drinking water supply system from catchment to consumer; • Phase out additional monitoring once the source of the incident has been identified and rectified and two consecutive results have been within specification; • Prepare notifications advising of the end of the emergency; • Assess required preventative action to reduce the likelihood of the incident recurring; • Prepare a report to document and close the incident; • Review and update Incident Management Protocol; • Retrain staff on revised Incident Management Protocol.

Incidents do happen. The Park's team does not let red tape prevent them from sorting out the issue:

> *If you have to go through all the red tape to get permission before you act, a small incident has already evolved into a major one. The tourists ask for their money back. The Department of Health closes your camp. We cannot afford this kind of situation. The damage and the negative publicity are just too big. We have to be able to act and act fast.*

The following figure depicts the Park's approach to risk abatement:



5 The right technology

KNP has wastewater collector and treatment plants of various sizes and configurations, ranging from a simple septic tank to an extensive system comprising cutter pumps, anaerobic digesters, primary, secondary and tertiary oxidation ponds, and two or more artificial wetlands. In total, there are 75 septic tanks that soak-away; 16 septic tanks that discharge into a reed bed system; 11 oxidation ponds with reed beds and 2 oxidation pond systems with anaerobic digesters and reed beds.

Each component of the system makes use of natural decomposition and stabilisation processes.

Skukuza has the biggest wastewater treatment plant; it discharges 238 000 litres of treated effluent per day into the Sabie River.

5.1 Why Ponds?

In response to the question: "**Why ponds?**" the senior engineer said the following:

> *Kruger must use green technology. Oxidation ponds offer a green solution for wastewater treatment.*
>
> *The life cycle costs and the large carbon footprint of activated sludge plants render this technology unsuitable and inappropriate for the Kruger National Park.*
>
> *Although the Park still uses diesel pumps, their medium term planning is to convert all diesel power to solar power and thereby reduce the residual carbon footprint even further.*
>
> *KNP generates relative small quantities of uncomplicated, low strength wastewater. The oxidation pond systems offer the most cost effective solution to treat this type of wastewater. The warm climate of the Park is also conducive to the effective functioning of oxidation pond systems.*
>
> *The Park covers 19,485 km^2, which is a huge area. Each small wastewater treatment plant at each rest camp or picnic spot must function independently and efficiently to meet tourists' expectations and the national regulator's compliance requirements. Oxidation pond systems are ideal for this kind of scenario, where high quality standards must be sustained with a small staff contingent over a large geographic area.*
>
> *Why oxidation ponds and not evaporation ponds? Again the greening of operations was the key consideration. Since we use water from the rivers flowing through the Park, we have to put water back into the system.*
>
> *Oxidation ponds and reed beds offer added value to our tourists. For example, at the Tamboti camp there is a bird hide at the reed bed.*

However, Blake and Ben emphasise that, although oxidation ponds are ideal for their particular circumstances, one principle applies without exception:

> *Every system is as good as it is managed.*

5.2 Wastewater composition

We do not have difficult wastewater to treat. Our volumes are relatively small and predictable; it is mostly domestic wastewater and there is little variation in the influent quality. We do not have industrial wastewater or heavy metals to deal with. Plus, we can control the pesticides and cleaning materials that are used in the Park. We regulate the restaurants and shops.

Although the wastewater composition is normally not complex, KNP operated a full scale abattoir during the years when the Park culled elephants on a regular basis. The resultant abattoir effluent was also treated in a pond system and the method that was used holds a valuable lesson for municipalities that have to deal with abattoir waste.

Pre-treatment of the abattoir effluent was extensive: the animal intestines were removed and re-used as animal feed. Skins were treated with salt on-site in a lined evaporation salt pan. Wastewater was screened using fat traps with sieves. Abattoir wastewater was diluted with clean water in a 1:4 ratio before entering the ponds. Since the CITES ban 11 years ago, the abattoir operation was scaled down drastically. Today it is only used when problem animals have to be disposed of, or for research purposes.

Most grey water is re-used. Individual camps wash their own towels, but all linen is centrally washed in Skukuza's laundry. The laundry's grey water is pumped to a reservoir next to the Sabie River, where it is mixed with river water and pumped back to irrigate the gardens in the Skukuza camp.

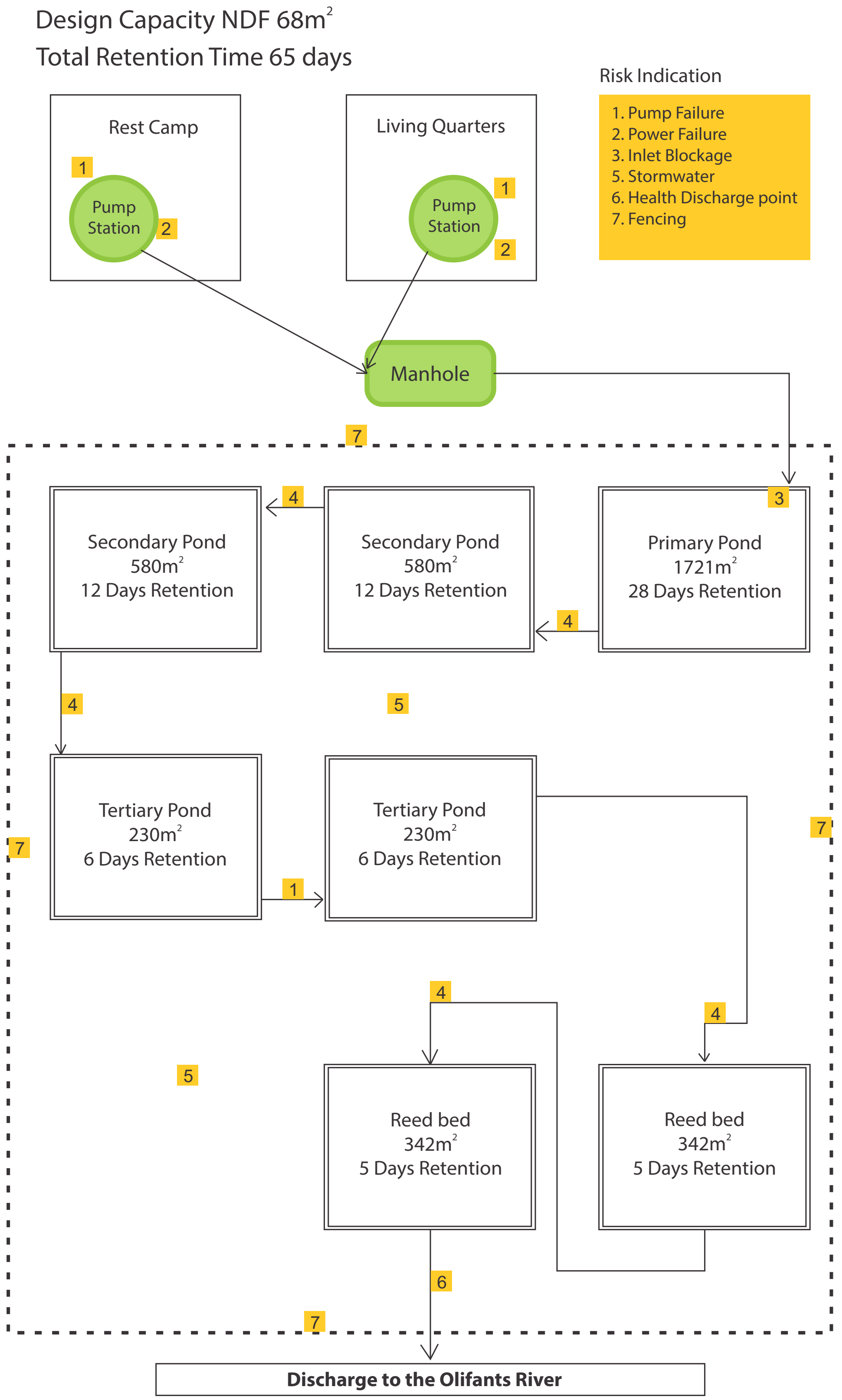
Grey water is used to irrigate the gardens in Skukuza

5.3 Design

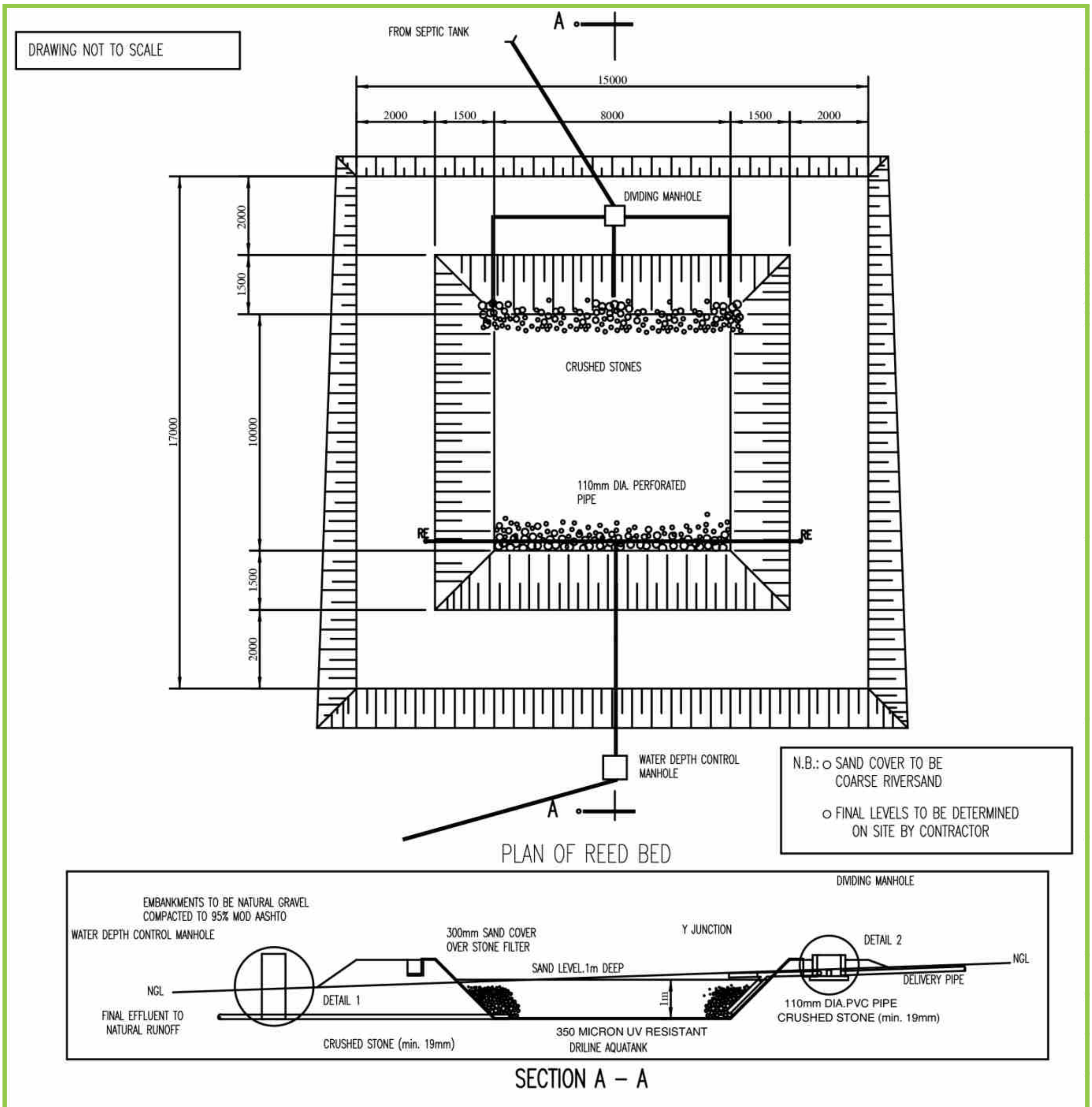
Kruger has a standard design for their pond systems, which is used as blue print when assessing new plants for development. The preliminary design and design specification are done in-house, whilst the final drawings, schedule of quantities and construction are outsourced to specialist consultants and service providers. A typical Process Flow Diagram is in place for each treatment system and forms part of the W_2RAP.

The example right is of the Olifants wastewater treatment plant. The numbers in yellow indicate Critical Risk Control Points (CRRs).

Olifants wastewater treatment plant flow diagram

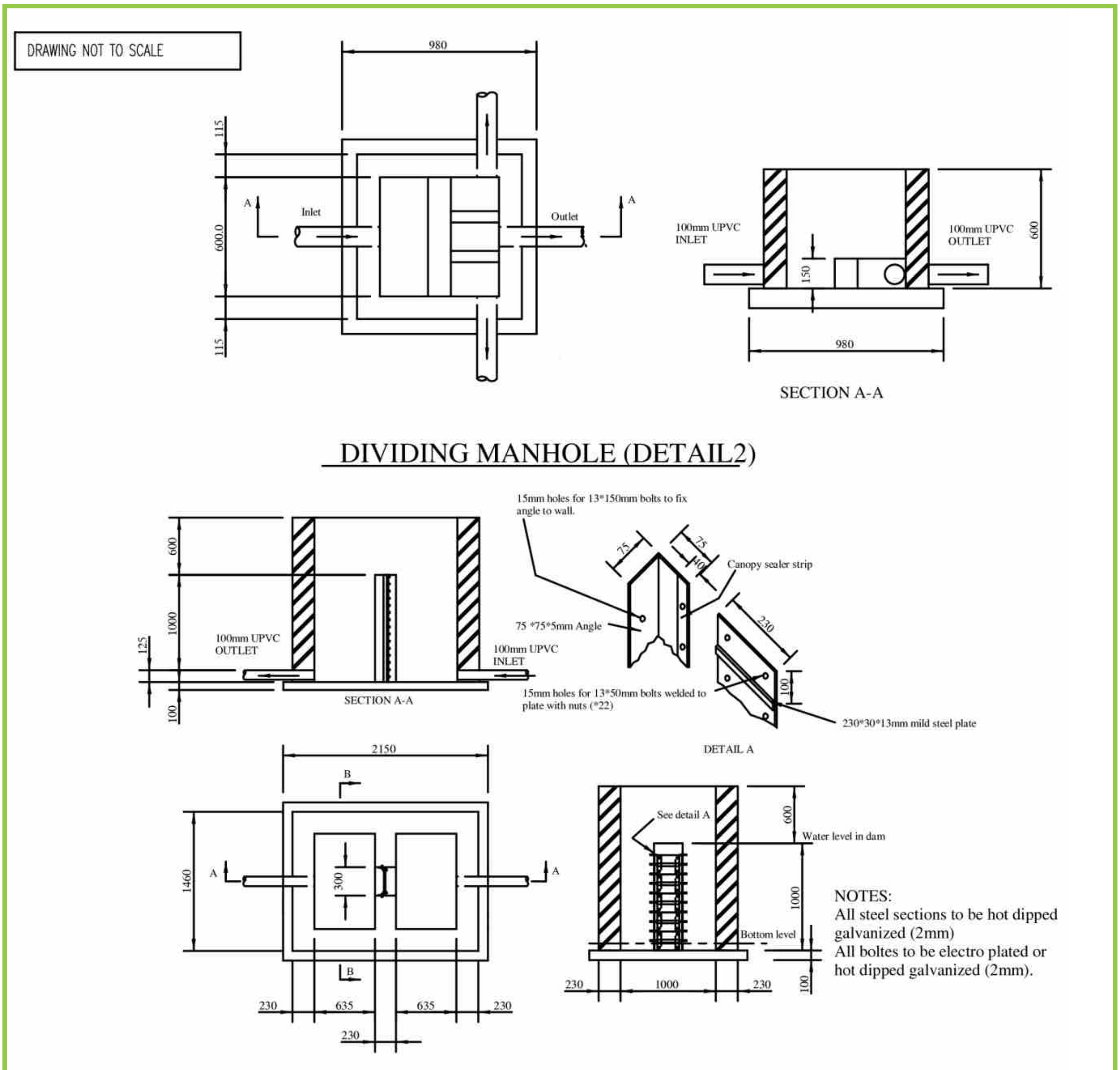


The standard design for a reed bed looks as follows:



Technical Services Department
KRUGER NATIONAL PARK

Project: Typical detail REED BED ARTIFICIAL WETLAND
Drawing: Plan of a reed bed
Designed by Blake Schraader
Date: 03-01-31



Technical Services Department
KRUGER NATIONAL PARK

South African
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Project: Nerina Lodge Details 1 & 2
Drawing: Dividing Manhole / WATER DEPTH CONTROL MANHOLE
Designed by Blake Schraader
Date: 03-01-31

The reader will notice that the design makes provision for three inlets and three compartments. This is done to prevent short circuiting, to make sure that the water spreads evenly through the reed bed and to avoid 'dead spots'. Larger reed beds could have four inlets.

> *For Skukuza, we use an inlet channel that runs across the full length of the reed bed.*

5.4 Design parameters

The following general design plan is followed to cater for different facilities and different volume brackets (volume is expressed as equivalent persons):

Facility	Equivalent persons (1 person is equivalent to 75l/day)	Treatment plant configuration
Single housing units, rangers posts, trails camps and picnic sites	1-20 persons	Septic tank with soak away. Soil conditions will determine the soak away design.
Multiple housing units, entrance gates, bush and private camps	10-200 persons	Septic tank with artificial wetland
Staff housing units, rest camps	More than 200 persons	Septic tank, oxidation ponds and artificial wetlands
Large rest camps such as Skukuza		Septic tanks, cutter pumps on the network and a series of anaerobic digesters and oxidations ponds, which are polished via two reed beds systems before discharge into the river

The following design parameters are used for septic tanks, oxidation ponds, artificial wetlands and anaerobic tanks:

Septic tank design criteria: Septic tank with soak away or artificial wetland		
Facility	**Equivalent persons**	**Treatment plant configuration**
	75l/per day (p/d) and 4-5 days retention	**Length*breadth*depth**
Three chamber septic tank	1-6 persons	2000*1000*1200mm
Three chamber septic tank	7-10 persons	2600*1100*1200mm
Three chamber septic tank	11-15 persons	3000*1400*1400mm
Three chamber septic tank	16-40 persons	3500*1500*1500mm
Three chamber septic tank	41-80 persons	4500*2000*1500mm
Three chamber septic tank	81-120 persons	5500*2200*1600mm
Three chamber septic tank	121-200 persons	6400*2500*1800mm

The configuration was changed after 1999 when anaerobic tanks were added, as the two tables below illustrate:

Oxidation ponds and artificial wetland: Designs before 1999		
Oxidation ponds: No recycling		
Facility		**Treatment plant configuration**
Primary ponds:	Depth 1.5m	Retention period minimum 25 days
	135kg BOD/ha/day or 270-300mg COD/ha/day	
Secondary ponds:	Depth 1.2 -1.5m	Total retention period minimum 25 days
		First secondary pond minimum 10 days
		Other ponds minimum 5 days
Ageing ponds:	Depth 1.2 -1.5m	Total retention period minimum 10 days. Ideally - 4,2,2,2 days for 4 ageing ponds
Total retention:	Minimum 60 days	
	Artificial wetland design	
Horizontal flow reed bed system:	Surface area: 200l/m^2/day	Minimum 5 depth retention Depth: 1000-1500mm

Anaerobic tanks, oxidation ponds and artificial wetland - Designs after 1999		
Anaerobic tank / septic tank is added to reduce COD between 40-50%		
Retention time in oxidation ponds is reduced to between 43-47 days		
Anaerobic tank and oxidation pond design		
Facility	**Equivalent persons**	**Treatment plant configuration**
Three chamber septic tank	1 person equivalent to 75l/d	24 hour retention
Primary pond		22 days retention
Secondary pond nr1		11-14 days retention
Secondary pond nr 2	(Or two Secondary ponds with 5,5 days retention)	10-11 days retention
Total retention	All ponds	43-47 days retention
	Artificial wetland design	
Horizontal flow reed bed system	Surface area: 200l/m^2/d	Minimum 5 days retention Depth: 1000—1500mm

A typical construction process is illustrated as follows:

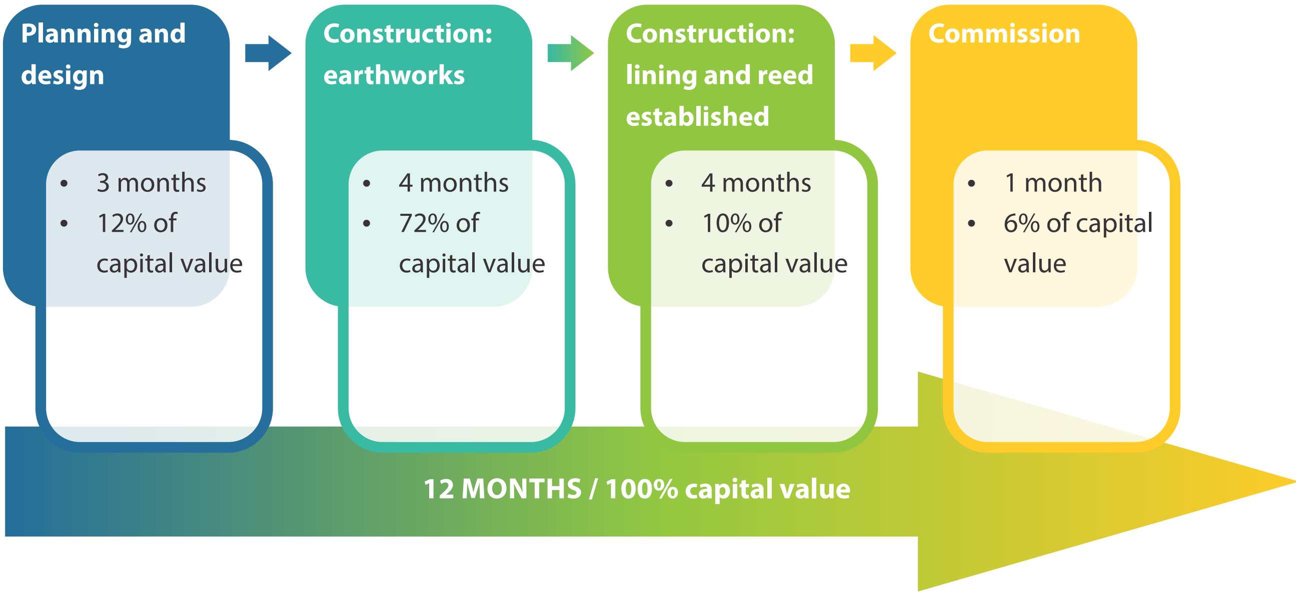
A reed bed under construction: PVC lining and sand

A reed bed under construction - new reeds are planted

The Punda Maria plant

A pond system is relatively fast to build: The Satara pond system took 3 months to plan and design; and 9 months to build from the day the contractor arrived on site to the day the first wastewater entered the system.

The figure below depicts the typical construction cycle of a pond system:



5.5 Guidelines for an oxidation pond system

The KNP has a long history of building and operating ponds systems. The lessons learnt over this period have enabled them to improve the technology continuously and incrementally.

The team shares the following lessons that they have learnt through practical experience:

5.5.1 Preliminary treatment

- Wastewater is screened before it enters the pump stations. Screenings are removed and incinerated.
- The use of cutter pumps in the pump stations reduces the amount of screenings to be removed; it ensures liquefied sewage to ponds, but it adds COD to the anaerobic preliminary treatment.
- KNP has 91 septic tanks. Many of the smaller plants do not discharge, but the Park is moving away from the soak away system, which conventionally follows the septic tanks. Soak-aways are not regarded as best practice for a wilderness area, especially where groundwater is an important water resource. As alternatives, the wastewater from the septic tanks is gravitated or pumped to the plant's reed bed. Currently, 21% of wastewater from the septic tanks systems is pumped into the reed beds. Y-pieces and P-traps are inserted to trap gasses and to control odour from wastewater flowing from a septic tank into the reed bed.
- Whilst the earlier versions of design allowed for ponds only, anaerobic digesters have been added at the larger camps to reduce the COD before the wastewater enters the oxidation ponds. These reactors comprise horizontally placed (prefabricated) PVC tanks. The digesters accomplish an actual COD reduction of 30%, which is satisfactory compared to industry benchmarks of 40-50% COD removal. The hydraulic retention time, i.e. the time which wastewater spends to move through the entire treatment system, is 24 hours.

The Skukuza ponds are designed to handle 460m^3 per day, with an anaerobic digester before the water enters the ponds, one could increase volume to 600m^3 per day.

- Maintenance on these anaerobic digesters is minimal. The first chamber of an anaerobic digester tank will have to be de-sludged after 20 to 30 years as it builds up a layer of grit, which reduces the treatment capacity.

5.5.2 Oxidation ponds

Critical factors that have an impact on successful wastewater treatment in a pond system are:

- **Volume and strength of wastewater**
- **Control of stormwater ingress**
- **The climate (biological treatment is less effective in low temperatures) and evaporation rate**
- **The incline of the terrain and the ponds themselves**
- **The number of ponds, their size and their depth**
- **The hydraulic retention rate**
- **The maintenance of the pond embankment**
- **Proper fencing to keep out humans and animals**

5.5.2.1 Volume and strength of wastewater

Although flow meters are preferable, one can use pump hours to measure inflow quite accurately.

5.5.2.2 Control of stormwater ingress

Ponds are built at least 500mm above the 100 year stormwater line. Flood records of KNP date back to 1937. In Kruger, they have no stormwater ingress into their wastewater treatment systems, except for water that rains into the ponds – no ingress is found from the sewage collector system or from the surrounding area. (See Challenges below.)

A release valve at the last pond can be used to control the release of effluent under flood conditions.

5.5.2.3 The incline of the terrain and the ponds themselves

The terrain must have a slope so that the water can gravitate from one pond to the next.

The incline of the terrain is a design parameter to determine the size and the slope of ponds, as well as the number of ponds that can be built. A gradient of 2-3% for each pond is ideal.

5.5.2.4 Lining and walls

The use of local material, such as local clay and local stone, cuts down cost significantly. Local material is also more likely to suit local conditions.

All the oxidation ponds are lined with clay as the elephants destroy PVC lining. The plasticity index (PI) of the clay is critical.

> *We compact the clay in layers of 300 mm at a time, using the same principles as for building roads.*

5.5.2.5 Climate and evaporation rate

It is important to know your evaporation rate. Evaporation rates of 5-10mm per day are typical for the warm climate of the KNP.

5.5.2.6 The number of ponds, their size and their depth

The number of ponds and pond size are a function of the volume and strength of the wastewater that enters the system.

The ideal depth for oxidation ponds is 1.2 m.

5.5.2.7 The hydraulic retention rate

If the effluent leaving the ponds does not meet quality standards, internal recycling can be added to remove ammonia and to increase the hydraulic retention time of microbial biomass and nutrients in the ponds.

5.5.2.8 The maintenance of the ponds

Pond walls need to be covered next to the water edge with local rock or bricks to prevent damage from wind and wave action and to avoid grass cuttings getting into the water. Wind direction also needs to be taken into consideration.

It is essential to keep grass around ponds short, to avoid breeding of insects due to rotting plant material. Vegetation on embankments has to be cleaned monthly.

> *Because the sewage that enters our plants has been through cutter pumps and anaerobic digesters, which further break down any remaining solids, we do not have to de-sludge often.*

Initially, oxidation ponds require de-sludging after 15-20 years of operation, then more frequently - every 5 years.

In my time we only had to de-sludge three ponds. When a pond needs to be de-sludged, we take two or three of the ponds out of the system and divert the water to bypass the ponds that are to be de-sludged.

The removed sludge is used to rehabilitate old burrow pits. De-sludging involves the following process:

- The pond is drained by pumping the water to another pond, and then isolated from active flow. The sludge is left as slurry; it is not required for the sludge to be fully dry.
- Gravel from road construction projects has been stored in burrow pits. This gravel is transported to the pond that has been earmarked for de-sludging, where it is then mixed with the sludge in a 1:1 ratio and then transported back to the burrow pit.
- The burrow pits are filled with the gravel-and-sludge mixture, and then covered with top soil from the environment and planted with grass.
- Note: Burrow pits are registered with DWA.

5.5.2.9 Proper fencing to keep out people and animals

Electrified fences are useful if you have to keep out intruders such as elephant and buffalo.

5.5.3 Constructed reed beds or artificial wetlands

Constructed reed beds or artificial wetlands are used to polish effluent before it is released into rivers.

5.5.3.1 Size and type

KNP uses horizontal subsurface-flow artificial wetlands (reed beds). Subsurface-flow wetlands move effluent parallel to the surface through a medium of river sand, on which plants are rooted. All water is kept below the sand medium to prevent rotting of plant material. As a result, the system doesn't attract mosquitoes, is less odorous and less sensitive to winter conditions. Bacteria, attached to the reeds' roots and rhizomes, and the surface area of the sand grains, are the main elements responsible for the degradation of organic compounds in the wastewater.

The size of the reed bed is a design function of influent volume. The reed beds have an incline of 1%.

5.5.3.2 Lining and sand bed

The latest reed beds are lined with plastic (12 micron); previously they were lined with clay. Unfortunately, when elephants break through the fence, they destroy the plastic lining; therefore clay lining is still regarded as the better lining material.

The reeds are planted in a medium of 1000 mm graded river sand. The inlet pipes are covered with 20-30 mm stone. The wastewater goes through the stone to remove grit and to prevent surface water on the ponds. The outlet pipe is perforated and covered with 500 mm stone to prevent blockages. The depth of the sand is increased to 1900mm at this point to keep the depth of the sand consistent at 1000mm. If you don't do this, you get short circuiting.

5.5.3.3 Reeds

The wetlands are planted with Common Reed (*Phragmites Australis*). Nine reeds are planted per square meter.

For the plant to survive, its roots have to be submerged in water. The water table is then gradually lowered in the sand bed, thereby forcing the roots to expand in the sand substrate. To achieve this, the operator removes the top of a multi-level series of sluice plates every 4-5 months, to drop the water level by 100 mm, until the water level reaches the bottom of the sand bed. As a result, the root system expands into the full volume of the sand, increasing the contact area between roots and the nutrients contained in the effluent.

More recently, an innovative approach to control water levels in the reed bed was introduced. Instead of using expensive stainless steel plates, the operator inserts a normal sewer pipe in a vertical position, and, every three months, simply cuts off 100 mm from the top of the sewer pipe until the water level reaches the bottom of the sand bed.

5.5.3.4 Retention time

The retention time in the reed bed is a function of the design of the reed bed. Based on the volume of wastewater and the desired retention time of 5 days, one can design the size of the reed bed. In KNP, the team bases the size of a reed bed on equivalent persons: $0.38m^2$ per person. If the wastewater system must make provision for 10 000 people, a reed bed of $3800m^2$ is required. This figure, in turn, is based on the quality of the influent, the amount generated per person and the type of wastewater that is generated. A municipality will have to find a formula that fits its own particular climate, influent quality and volumes.

5.5.3.5 Maintenance

It should not be necessary to replace a reed bed from scratch. In the 26 years that Ben has been at KNP, it has never been necessary to replace a reed bed – that is if the elephants don't destroy it.

In terms of maintenance, the reeds need to be cut every few years and the river sand has to be replaced every 8 to 10 years, because fine particles remain in the sand and eventually clog it up.

The team avoids channelling or short circuiting, which takes place when part of the water follows a fast, preferential path through the wetland, by cutting down the plant material often and removing reeds when they become too dense. The wastewater team burns or cuts reed beds every 3 to 4 years. Reeds need cutting when a reed stem is about 25-30mm thick.

When cutting reeds, make sure that you cut to above root level. This will allow the plants to regrow from the roots. It is important to remove the leaves from the sand bed. We usually rake the leaves away and then use a fork to loosen the sand. The reeds make new growth from the root system; it is not necessary to bring in new plants.

In terms of DWA requirements, no weeds are allowed to grow among the reeds and no pool forming is allowed in a reed bed. It is also important to prevent the discharge of solids to a reed bed, because it will cause septic conditions.

5.5.3.6 Performance

The results that follow depict improvements of 15-60% that were achieved by adding a reed bed system as a secondary treatment process after a conventional oxidation pond and septic tank system.

The tables below illustrate the impact of a reed bed on effluent quality in an oxidation pond system and a septic tank system in the Kruger National Park.

Raw sewerage: Typical domestic quality

Criteria	Raw Sewarage
COD mg/l	350-500
Sus. Solids mg/l	150-200
E coli Cnt 100ml	>100
Amm/n as Nh_4^+mg/l	36-40
Nitrate as NO_3 mg/l	20-25
Phosphorus as PO_4 mg/l	25-30

Oxidation pond system:

Criteria	Raw Sewarage	Before Reedbed	After Reedbed	Improvement of Reedbed	Permit limit
COD mg/l	350-500	80-130	45-55	50-60%	75mg/l
Sus. Solids mg/l	150-200	70-120	20-26	60-80%	25mg/l
E coli Cnt 100ml	>100	>100	>100	0.00%	100counts/ml
Amm/n as Nh_4^+mg/l	36-40	10-20	9-15	15-25%	6mg/l
Nitrate as NO_3 mg/l	20-25	3-8	1-3	30-40%	15mg/l
Phosphorus as PO_4 mg/l	25-30	25-30	18-20	0-15%	10mg/l

Septic tank system:

Criteria	Raw Sewarage	Before Reedbed	After Reedbed	Improvement of Reedbed	Permit limit
COD mg/l	350-500	120-260	45-60	50-60%	75mg/l
Sus. Solids mg/l	150-200	70-130	15-25	60-80%	25mg/l
E coli Cnt 100ml	>100	>100	>100	0.00%	100counts/ml
Amm/n as Nh_4^+mg/l	36-40	30-36	10-12	15-25%	6mg/l
Nitrate as NO_3 mg/l	20-25	5-12	2-3	30-40%	15mg/l
Phosphorus as PO_4 mg/l	25-30	20-25	22-25	0-15%	10mg/l

5.6 Adaptive management and options to improve

Although Blake feels that adaptive management does not come naturally to an engineer, he has adopted this approach from the scientists as the best way to work:

> *We put systems in place that we believe are the best. If something does not work, we learn from the mistake, adapt, improve and go forward.*
>
> *To give an example, when the Letaba pond system was built, it comprised only 3 oxidation ponds. As volumes increased, it became necessary to expand the plant with another two ponds. The single reed bed proved to be insufficient and we had to make a plan. Initially, we increased the retention time by pumping the water back to the first pump, but that was not a green solution. So it was decided to add another reed bed.*

In Shingwedzi, wastewater moved from a septic tank to two reed beds. The wastewater volume to the beds proved to be too high, resulting in an unsatisfactory final effluent quality. The team then replaced the one reed bed with an oxidation pond, which allowed for a higher hydraulic loading and resulted in good effluent quality.

What options do you have with an oxidation pond system if you need to improve effluent quality?

- Add anaerobic digesters, if there is a need to remove more COD and reduce organic loading to the plant.
- Add an extra pond, if additional hydraulic retention time is required to meet effluent quality standards.
- Add a reed bed, if additional nutrient uptake is required to remove nitrate and phosphate.
- Recycle part of the effluent stream, if nutrients (e.g. ammonia) remain in the final ponds which can be removed if returned to previous ponds.
- Improve housekeeping, to avoid rotting of plant material or septic conditions by accumulated sludge and grit.

5.7 Sampling and monitoring

As the larger wastewater plants discharge into the rivers from which KNP extracts its drinking water, effluent quality is a critical element in the water supply value chain.

KNP samples the rivers in which they discharge once a month, upstream only. Reed beds that discharge are also monitored once a month. The full process of a plant (all ponds and reed beds) is monitored once every 6 months.

The Park runs a full scale laboratory to test all water and wastewater samples. The turnaround time for analysis in the laboratory is 48 hours for microbiological results and 7 days for chemical results.

Linford Mulaba tests water and wastewater samples

The Park is crucially aware of their effluent quality standards and the Department of Water Affairs' requirements and permit conditions, as set out in the table below:

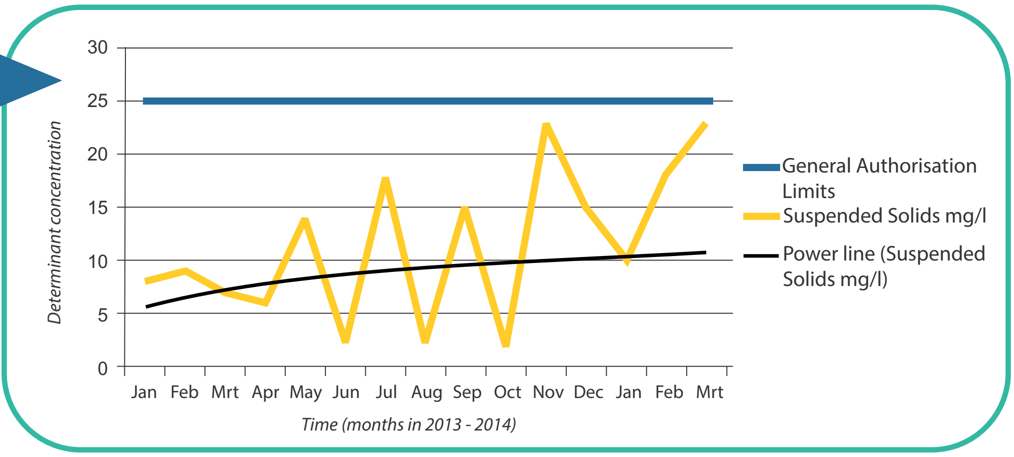
General and special limits as set by the Department of Water Affairs

SUBSTANCE/PARAMETER	GENERAL LIMIT	SPECIAL LIMIT
Faecal coliforms (per 100ml)	1000	0
Chemical Oxygen Demand (mg/l)	75(i)	30(i)
pH	5,5-9,5	5,5-7,5
Ammonia (ionised and un-ionised as Nitrogen (mg/l)	6	2
Nitrate/Nitrite as Nitrogen (mg/l)	15	1,5
Chlorine as Free Chlorine (mg/l)	0.25	0
Suspended Solids (mg/l)	25	10
Electrical Conductivity (mS/m)	70 mS/m above intake to a maximum of 150 mS/m	50 mS/m above the background receiving water, to a maximum of 100mS/m
Ortho-Phosphate as phosphorous (mg/l	10	1 (median) and 2,5 (maximum)

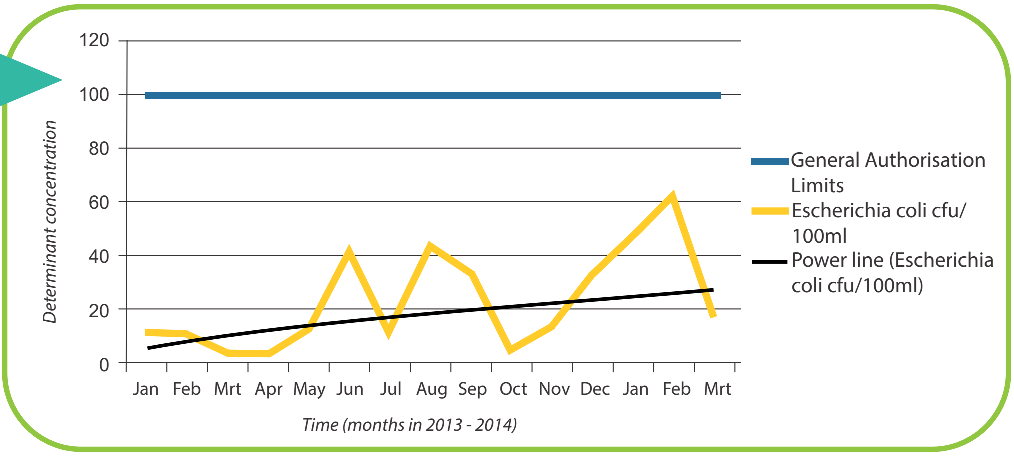
Compliance monitoring is done on an annual basis and performance by staff is reported against compliance.

The following graphs depict the compliance of the Skukuza plant against the DWA's General Limits over a 2 year period:

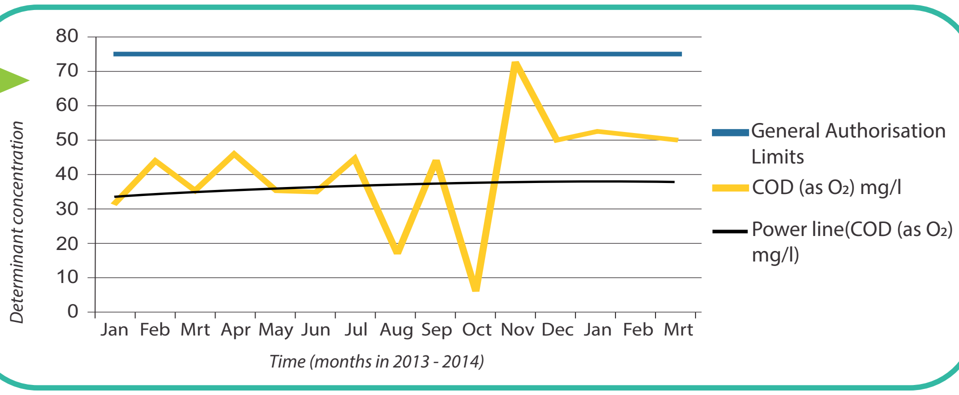
Suspended Solids



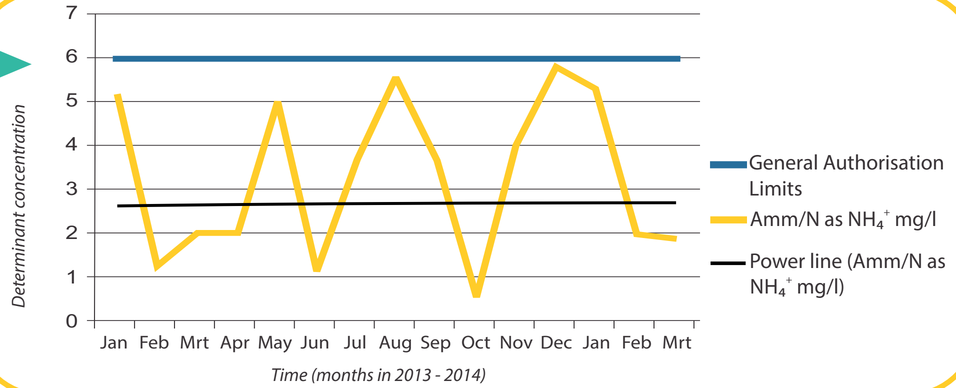
Escherichia coli



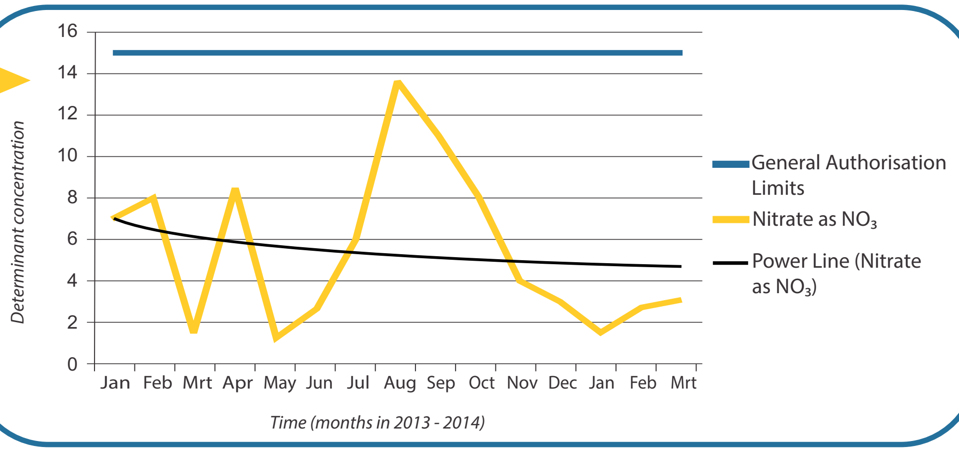
COD



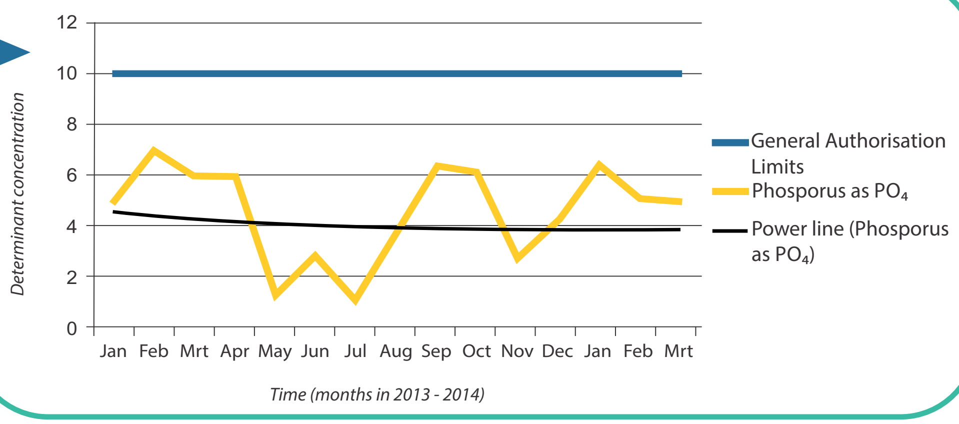
Ammonia-N as NH_4^+



Nitrate-N as NO_3



Phosphate-P as PO_4



Standard operating procedures in terms of the Permit from the Department of Water Affairs include the following:

1. The operator must be equipped with the necessary safety equipment (gum boots, gloves, safety glasses and respirator).
2. The operator must work a 9 hour shift daily (no work on public holidays and weekends).
3. Equipment needed on site: rakes, spades, slashers, hose-pipe and wheelbarrow.
4. Electric fence must be checked daily.
5. Circulation pump, where it is installed, must be checked daily and serviced when necessary.
6. Recall hour meter readings of sewerage pumps at the end of each month.

6 Challenges

6.1 From inside Kruger

6.1.1 Elephants

The Park changed their policy for water provision to animals. Instead of artificial water holes, they reverted back to natural water resources in an attempt to reinstate migration patterns. Unfortunately, the elephants did not settle easily back into previous migration patterns; they broke through the fences around the water and wastewater plants to get to water, causing damage of millions of Rand. And with them, crocodiles and hippos followed. In Punda Maria, the elephants broke through the fence and fed on the final water and reeds, completely destroying the reed bed. Elephants also damaged and removed plastic lining.

6.1.2 Duck weed

Duck weed that grows on the surface of ponds depletes oxygen and reduces the effectiveness of the oxidation process to remove nitrogen and phosphate. Duck weed also keeps sunlight out of the oxidation ponds and reduces the evaporation rate. The KNP operators make use of the wind to drive the weed to one end or corner of a pond and then drag two drums with shade-net through the accumulated duck weed and remove it manually.

6.1.3 Seasonal floods

A number of rest camps are situated on the banks of the major rivers running through the park. When a river overflows its banks, there is always the danger that it could flood the camp and its wastewater and water treatment plants. The Park mitigates the risk by building their plants above the storm water line, and by taking out insurance against flood damage; yet flash floods could still cause a disaster. In such a situation, there is no other option but to close the camp until the affected plants are up and running again. When Shingwedzi flooded in 2013, Ben and his team of three worked day and night to get the water and wastewater treatment plants up and running within a week.

6.2 From outside Kruger

From time to time, surrounding municipalities and industries illegally discharge sewage or industrial effluent into the rivers that run through the Park. These activities impact on the quality of the raw water that is treated to drinking water standard for human consumption in the Park.

Landfill leachate into side streams, as well as seepage into groundwater is another source of pollution to these rivers. The pollution endangers animal and plant life, but importantly, also contaminates the source of drinking water for the Park.

It remains problematic for KNP to control or prevent pollution from external sources, as this is not part of their mandate. The plan is to put a permanent spokesperson in the various river catchment forums to exert pressure on guilty parties. According to the team, "the result will only be as good as cooperation within the structure."

The plan is also to monitor and test river water as it enters the Park and to sink additional boreholes as proactive measures if an incident, such as the December 2013 industrial spillage into the Selati River, which forced the Park to use an alternative water source for some of their camps, should happen again.

7 Pond systems as appropriate technology for municipalities

Many people say it is impossible to clean wastewater with oxidation ponds to the required legal standard. We say it is a piece of cake. A technology is as good as the people who operate it. (Blake Schraader)

Pond systems are cheaper than activated sludge systems and easier to maintain. Ponds require staff of a lower technical skills level than activated sludge systems, and no operators are required full time on site to operate the plants.

But can you treat complex wastewater in an oxidation pond system?

Most constructed wetlands around the world are still mainly used to treat municipal wastewater, but in the past few years, it has become more common to treat industrial and agricultural wastewater, stormwater runoff and landfill leachate in pond systems and artificial wetlands.

Despite the mistrust of many civil engineers and water authorities, constructed wetlands have been widely accepted around the world and have become a suitable and appropriate solution for wastewater treatment.[2]

Unfortunately, knowledge of ponds is limited in South Africa. Many municipal wastewater managers do not understand the technology and hence feel uncomfortable to take decisions in this regard.

[2](Vymazal, J. 2008. Constructed Wetlands for Wastewater Treatment: A Review. In Proceedings of Taal 2007, edited by Sengupta, M. and Dalwani, R.)

DWA's enforcement of strict special standards in areas where they are not necessary may exacerbate the problem. For example, ponds and reed bed systems alone will not be a suitable technology when phosphate and nitrogen standards of less than 1.0mg/l are required.

Yet, if a pond system fails for some reason, then it still produces a fairly stable effluent, compared to an advanced technology that collapses.

The Park would like to accommodate students to conduct research where critical gaps and questions have been identified over years of operation. Key research areas proposed include the following:

- The impact of reed density on reed bed performance.
- Monitoring of sand quality as indicator of when to replace sand.
- The impact of sand diameter and quality on reed bed performance.
- Monitoring of root systems to determine the performance on nutrient removal at various wastewater strengths, specifically the removal of carbon, nitrogen and phosphorus.
- Optimisation of water level control to encourage dispersed root growth through the reed bed.
- The use of different reed species, or combinations of reed species, to optimise nutrient removal.
- The incline of reed beds to get the optimal result.
- The effect of a stone bed or wall in the middle of a reed bed.

8 Kruger Park on the Green Drop process

Kruger Park approached the Department of Water Affairs three years ago with the specific request to be included in the Green Drop audit process. The rationale for this was as follows:

- Green Drop criteria contain the key KPIs that any wastewater system needs to comply with to prove best management practice and legal compliance.
- Green Drop is a credible and scientific verification and certification vehicle which holds up the highest standards in the industry. This is attractive to the Park in the light of its international reputation and green vision.
- A Green Drop will allow the Park's results to be benchmarked and peer reviewed against the best in South Africa.
- Shortcomings and gaps are clearly identified during the audit process, which allows the Park to pursue its philosophy of continuous improvement.

Having been part of the Green Drop process, Kruger National Park would like to see the programme progressing by considering the following:

- Review Regulation 17. It is not cost effective to have Class 2 process controllers on a pond treatment site full time with technology that requires minimum operational control. However, one could rotate Class 2 operators through the plants so that there is a qualified operator on each plant every week.
- Instead of a building on-site, allow the required signage to be put on a board or on the entrance gate to plant sites. In a natural environment you want to have as few buildings as possible.
- Waive the requirement for flow meters on small plants, and allow pump-hours (or alternative measures) to calculate flow.
- Allow a differentiated approach with less strict requirements for pond systems, such as less, and simpler Standard Operating Procedures (SoPs).
- The splitting of the budget is problematic and artificial, as the Park manages all infrastructure in a consolidated budget, but the requirement for a ring-fenced budget is understandable.
- More emphasis must be placed on, and incentives given to, proactive planning and maintenance.
- Include assessors with expertise in oxidation ponds and artificial wetlands.
- Add appropriate technology as a criterion going forward with Green Drop requirements in 2014/15.

9 Future objectives

The team is clear on their objectives for the future. They want to:

- Be the first National Park in SA to obtain Green Drop Certification.
- Provide for increased volumes of wastewater per day. In the next 10 years, the number of visitors to KNP may double. Plans to increase the number of tourists that the Park can accommodate per day are underway. Two hotels in the form of safari lodges are planned for the Park; one in Malelane and one in Skukuza. There is no intention to increase the entry gate quotas for self-drives, however park-and-ride facilities at the gates will take tourists into the park in open vehicles when the quotas are reached.
- Replace aging infrastructure, specifically water and sewer lines, which are 30 years + (Olifants Camp and Lower Sabie).
- Take in interns and work with education institutions to research pond systems and alternative technologies that cater for green options, re-use and value adding.
- Expand monitoring to the boundaries of the Park to ensure that spillages or pollution to the Park's water resources are detected and addressed as early as possible.
- Increase cooperation with catchment forums and environmental pressure groups to detect problems earlier and to ensure that preventative measures are taken.
- Continue to reach out and share knowledge and experience with private game reserves, municipalities and mines.

Green Drop

South African NATIONAL PARKS

Aiming for Green Drop Certification in 2015

10 Further reading

Kröpfelová, L. 2008. *Wastewater Treatment in Constructed Wetlands with Horizontal Sub-Surface Flow*. Springer.

Vymazal, J. 2008. Constructed Wetlands for Wastewater Treatment: A Review. In Sengupta, M and Dalwani, R (editors). Proceedings of Taal 2007: the 12th World Lake Conference: 965-980.: http://moef.nic.in/sites/default/files/nlcp/H-%20Constructed%20Wetlands/H-1.pdf

Kadlec, R.H. and Wallace, S., D. 2009. *Treatment Wetlands*. New York: CRC Press (Faylor & Francis Group LLC) Extensive references and flow models in the Appendix. http://www.firelandstributaries.net/pdfs/Local%20workgroup/Treatment_Wetlands.pdf

Wikipedia. 2014. Constructed wetlands. http://en.wikipedia.org/wiki/Constructed_wetland

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The WIN-SA lesson series aims to capture the innovative work of people tackling real service delivery challenges. It also aims to stimulate learning and sharing around these challenges to support creative solutions. To achieve this, the lessons series is supported by ancillary learning opportunities facilitated by WIN-SA to strengthen people-to-people learning.

This document hopes to encourage ongoing discussion, debate and lesson sharing. To comment, make additions or give further input, please email to julietm@win-sa.org.za.

The Water Research Commission (WRC) and Water Information Network of South Africa (WIN-SA) have been actively involved in showcasing municipalities' good practices in wastewater management on the road to Green Drop status. WIN-SA and the WRC identify 'sparks' of excellence in South Africa, write it up and create forums where these good practices can be shared and discussed

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