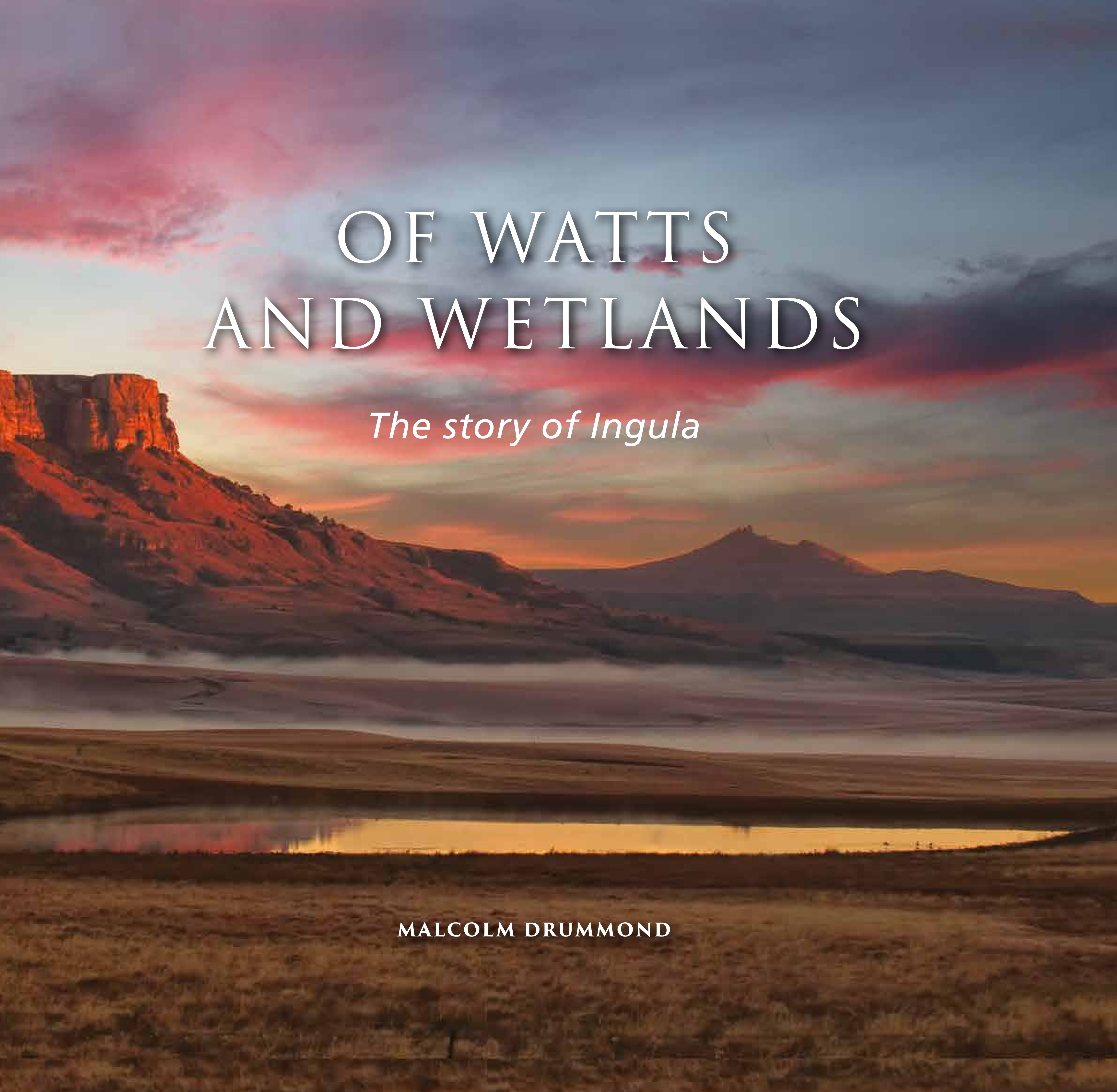
# OF WATTS AND WETLANDS

*The story of Ingula*

MALCOLM DRUMMOND



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The Ingula Partnership

Middelpunt Wetland Trust

Eskom

BirdLife South Africa
Giving Conservation Wings

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PREVIOUS PAGE: *Ephemeral pans on the upper site only hold water during the rainy season and then only to a maximum depth of a few centimetres. During that time they are host to beautiful flowers and Fairy Shrimps.* PHOTO BY DU TOIT MALHERBE



# FOREWORD

Close collaboration between non-governmental organisations (NGOs) and a major utility over an extended period of time is an unusual occurrence. Even more so when such a partnership can boast of extensive successes. This is the story of a major Eskom undertaking and its partnership with two environmental NGOs.

I was Minister of the Department of the Environment and Tourism at the time that Eskom lodged its environmental impact assessment for Ingula, requesting a favourable Record of Decision (RoD) to allow the project to begin. The Department had excellent wetland specialists and, upon their advice, I turned down the application. I was subsequently approached by Dr Reuel Khoza, then Chairman of Eskom. He made a convincing case for Ingula and suggested that I might wish to reconsider my decision.

Further discussions with experts identified conditions under which the project could be allowed to go ahead. However, a Minister is not allowed to retract a decision and, consequently, Eskom was obliged to appeal to the High Court, which resulted in Eskom being given the authority to proceed. The RoD was issued by the Department with specific conditions, including the purchase of 8 000 hectares of farmland around the Bedford Wetland that had to be managed as a protected area.

The fact that South Africa has had very advanced environmental protection laws for some years is a matter of great pride to me. It is important for citizens to be aware that the law is on the side of environmental protection and that they, and NGOs, must assert their rights. The Ingula Partnership is a classic example of a negotiated resolution to South Africa's need for additional peak electrical generation, balanced against broad environmental benefits. The 2018 declaration of the 8 000-hectare Ingula Nature Reserve is wonderful proof of the success of the Partnership.

To close the circle of my involvement, I served as Chairman of Eskom from 2005 to 2008.

It is with confidence that I state I am certain that Ingula and the Ingula Partnership will continue to serve as a shining example of what can be achieved for the environment when apparently disparate organisations work together to achieve agreed objectives.

Valli Moosa

OPPOSITE: *The snow-shrouded escarpment during a cold snap in July 2011*
PHOTO BY ALASTAIR CAMPBELL

# INTRODUCTION

This book is a portrayal, through text and images, of the story of Ingula, a story that involves an extraordinary, collaborative effort to meet both the human and environmental needs of South Africa today.

It could have been a one-sided account of a fascinating construction project: that of the Ingula Pumped Storage Scheme, a vital component of Eskom's ability to meet South Africa's electricity needs. However, because of the concerns raised by various conservation bodies and interested parties, a process ensued that resulted in the formation of the Ingula Partnership.

Hence, the journey described here is one of engineering and conservation. An unusual combination, but one that has resulted in a harmonious understanding and respect between those responsible for generating peak-period electricity and those responsible for the environmental management of some vital biomes: high-altitude grasslands, escarpment forest and wetlands. It has worked at Ingula!

The first part of the book deals with the principles of pumped storage and the selection of Braamhoek in KwaZulu-Natal as the most suitable site in South Africa for the project. It then goes on to describe the upgrading of provincial roads and the construction of an on-site road network to provide access to the various locations on the site. Details of the construction of the two dams then follow: one is a rockfill type and the other of compacted concrete.

The underground works are extensive and required special techniques to address numerous challenges, many of them geological. A pumped storage scheme is a complex engineering and construction undertaking and so the various components of the scheme are described.

The second part of the book goes into the reasons for the formation of the Ingula (initially Braamhoek) Partnership and the overall effects it has had on both the actual site and the broader region. Indeed, some of the Partnership's activities extend provincially, nationally and as far afield as Ethiopia. A major state-owned company, South Africa's leading ornithological NGO and a small, private conservation NGO may well seem to be unlikely partners, but, as one progresses through the book, it becomes apparent just how successful this Partnership has been. Not least of its achievements were the requirement that Eskom purchase eight thousand hectares of farmland on the upper dam site and the subsequent declaration of this area as the Ingula Nature Reserve in 2018. Its status was further enhanced by the 2021 designation of the Ingula Nature Reserve as a 'Wetland of International Importance' or Ramsar site.

OPPOSITE: A dramatic thunderstorm over the escarpment
PHOTO BY FIFI MEYER

# PUMPED STORAGE

# PUMPED STORAGE: THE PRINCIPLES

*Maintaining a constant and cost-effective supply of electricity for South Africa requires multiple solutions. One of the major challenges is the large fluctuation in demand for electricity over a 24-hour period. Most of South Africa's base-load generation is from thermal (coal-fired) stations and these are not designed to cope efficiently with variable demand.*

Peak consumption typically occurs from six until nine in the morning and from five until eight in the evening. An excellent way of addressing these peaks is through the use of pumped storage schemes, which are, in effect, large storage batteries. Energy is stored in the form of water during off-peak periods and released during peak demand.

Such schemes involve the construction of two reservoirs or dams, one at a significantly higher elevation than the other. During periods of low demand, normally during the night and over weekends, excess energy from the national grid is used to pump water from the lower reservoir to the higher reservoir. At times of peak demand, the process is reversed and water from the upper dam is allowed to flow back to the lower dam through hydraulic turbines, which drive generators and feed electricity into the national grid. Pumping and generating needs are provided by the same piece of equipment, a 'pump-turbine', the direction of rotation dictating the function.

PREVIOUS PAGE: *Nelson's Kop and wetlands at sunrise*
PHOTO BY FRIKKIE HITGE

OPPOSITE: *The specially-designed outlet (emulating natural water flow) into the wetland downstream of Bedford Dam with Skeurklip Mountain in the background*
PHOTO BY DU TOIT MALHERBE



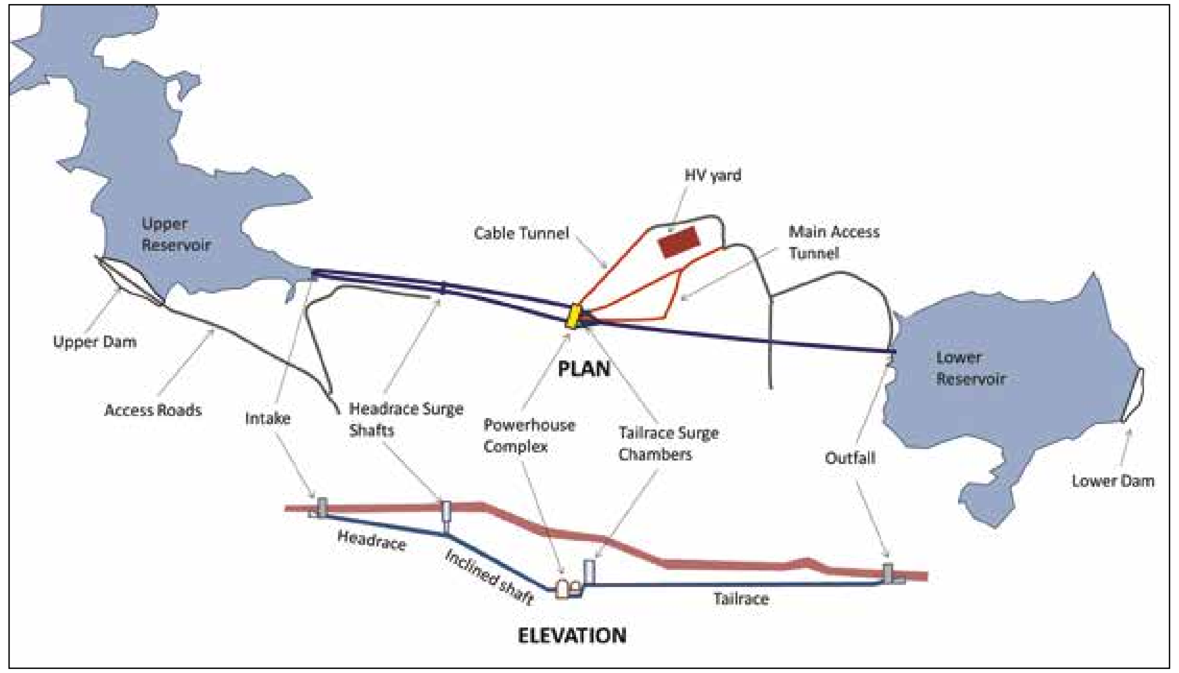
Oddly enough, a pumped storage plant is actually a net consumer of electricity, returning about four kilowatt-hours (kWh) of electricity into the grid for each five kWh required for pumping. However, there are a number of important benefits:

- The energy generated during peak periods has a higher monetary value than the energy required for pumping during off-peak periods
- The use of large quantities of off-peak power for the pumping process enables the base-load plant to operate under more stable loading conditions
- As it provides a rapid and flexible response to system load changes, it also has the ability to accommodate very large load swings
- Pumped storage schemes have very high pumping efficiency and can be effectively combined with a water transfer scheme by pumping more water than is required for the generation of electricity.

OPPOSITE TOP: *During construction of the 850m-long channel taking water from Bedford Dam to the intake structure*

OPPOSITE BOTTOM: *Bramhoek Dam at full capacity, holding 26-million cubic metres of water*

PHOTOS BY FIFI MEYER




*Graphic by Frans Louwinger*



# PUMPED STORAGE IN SOUTH AFRICA

### Steenbras

The first scheme in South Africa was constructed by Cape Town Municipality to meet increasing peak demand and to assist with the city's water supply. Steenbras is situated in the Hottentots-Holland mountains, above Gordons Bay. It came into operation in 1979, consisting of four 45MW units, with an operating head (that is, the vertical height difference between the two reservoirs) of 275m.

### Drakensberg

This scheme provided the ideal solution to two requirements: the need of the Department of Water Affairs to increase the water transfer capacity from the Tugela River to the Vaal Dam, across the Drakensberg escarpment, and Eskom requiring additional peak supply. The Drakensberg scheme consists of four 250MW units, with an operating head of 470m. It came into operation in 1982.

### Palmiet

Meeting Eskom's requirement for a back-up for the long transmission line to the Cape from Mpumalanga (where most of the base-load stations are situated) and the Department of Water Affairs' need to augment the water supply to the Cape Town area, Palmiet, consisting of two 200MW units, with an operating head of 260m, began operating in 1988.

The Palmiet scheme is regarded as a forerunner in environmental engineering, and is an excellent example of how industrialists, engineers and environmentalists can work together to achieve the best balance between technical performance and environmental conservation. The scheme received a number of accolades, as well as international recognition in 1998 when UNESCO registered the area as the Kogelberg Biosphere Reserve, the first such reserve in South Africa.

*Bedford Dam in November 2015, looking towards the escarpment*
PHOTO BY JACQUES DU PLESSIS

## Site selection programme

In the 1980s, Eskom initiated an extensive programme to identify other possible pumped storage scheme sites throughout South Africa. This resulted in the identification of 90 sites in total, with potential capacities varying from 400MW to 2 000MW and heads ranging from 220m to 610m and, in the case of several sites bordering Lesotho, as high as 1 050m.

From these, the seven most suitable sites were selected, using various criteria, including:

- The increasing need for pumped storage schemes, which indicated that each scheme should be at least 1 000MW
- The site chosen should be near the national grid, to prevent excessive transmission costs and losses
- The geology must be suitable for the construction of the two dams
- The water supply should be sufficient to fill one of the dams in two to three years
- The higher the head, the less flow would be required to generate the same power, resulting in smaller waterways and reservoir sizes
- Overall capital cost, which would include access, transmission integration, and operation and maintenance costs, was an important factor.

The seven sites proposed were *Impendle, Waayhoek* and *Ingula*[1] in KwaZulu-Natal, *Mutale* and *Steelpoort* in Limpopo, *Strijdom* in Mpumalanga and *Hogsback* in the Eastern Cape.

## Final selection

Pre-feasibility studies were successively conducted on these seven sites between 1987 and 1995, followed by a comparative study and ranking process. Eskom's Integrated Strategic Electricity Plan at the time identified the need for additional pumped storage supply of some 3 000MW over time. The search, therefore, had to be narrowed down to find the best three. This resulted in the selection of *Ingula*, *Steelpoort* and *Mutale*.

Feasibility studies continued for each of the sites in 1998 in order to complete the final ranking and to establish which of the sites should be developed first. These studies focused on environmental impact assessments, more detailed geotechnical investigations, supported by some 1 200m of drilling, updating of the preliminary designs and re-costing of the schemes.

The detailed geotechnical studies concluded that the *Mutale* scheme was unsuitable for further development. The storage capacity of the other two schemes was determined through an optimisation study, by comparing the incremental capital cost for increased storage volumes with the associated reduction in operating cost. This resulted in an optimum storage capacity of 21 000 Megawatt hours (MWh) for *Ingula* and 10 000MWh for *Steelpoort*. Ingula's larger capacity would allow higher operating flexibility and better back-up during emergencies, and so was selected as first choice.

Further optimisation of the Ingula scheme resulted in a final configuration of 1 332MW, a rated generating head of 441m, with a possible 16 hours of continuous generation. Environmental approval was obtained in 2002.

*Looking across Bedford Dam from the north bank towards the intake channel, which leads to the headrace intake. In the background are the two, circular surge shafts and the communications facility, right on the edge of the escarpment*

PHOTO: MALCOLM DRUMMOND

Footnote 1. The original names were the Braamhoek Pumped Storage Scheme and the Braamhoek Partnership, after one of the farms purchased for the project. However, it was felt that an isiZulu name would be more appropriate and so 'Ingula' (meaning the foam on top of milk in a calabash) was chosen. It should also be noted that the lower reservoir or dam is the Bramhoek Dam as it was named after the Bramhoek Spruit that feeds it, rather than the farm of almost the same name.

# DESIGN CHALLENGES

### Environmental sensitivity

As the upper reservoir is located in the upper reaches of a pristine wetland, the quality of water that would be released downstream was of utmost importance. Run-off was routed throughout the construction activities by a dedicated drainage channel and silt contamination settled out in a downstream pond. Further removal of small silt particles was achieved by a wide overflow strip covered by natural vegetation, which acted as a filter. The water quality released into the wetlands is still monitored regularly and has proven to be of similar quality to that before construction.

### Aesthetics

The design of the visible structures at the upper site took into account the environmental aesthetics of the area. The brick colour at the dam outlet and power intake was selected to blend in as far as was practically possible, and the height and diameter of the surge shafts near the edge of the escarpment were sized to minimise their visual impact.

### Underground cavern

The design at Ingula called for a machine hall with a span of 26m, which was seen as challenging because of the sedimentary rock conditions. Numerous in situ and laboratory rock testing, as well as careful computer modelling including 'what-if' scenarios, provided adequate confidence that such a large span could be constructed in these conditions. At the time, this was the largest span in the world ever constructed in these types of rocks.

TOP: *Initial excavations of the transformer hall ceiling*

BELOW: *Progressive downward excavation of the machine hall*

PHOTOS BY FIFI MEYER

# ROAD BUILDING
# AT AND AROUND INGULA

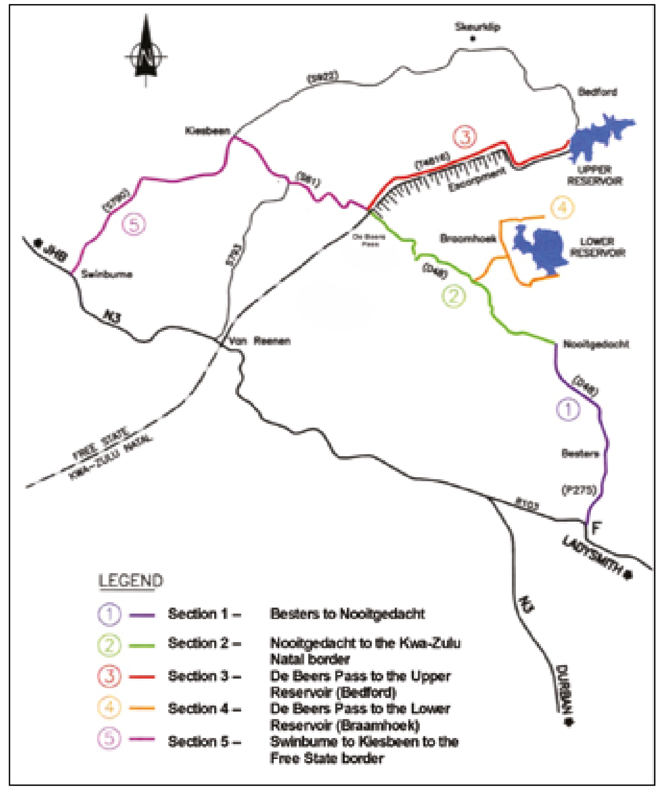
*Ingula is situated in a reasonably remote location, traversing the escarpment between the Free State and KwaZulu-Natal, and about 40km north-northwest of Ladysmith. Prior to construction, access was via poorly maintained gravel roads and farm tracks. The proposed upper and lower sites were linked by De Beers Pass, which was a gravel road in poor condition. It was essential to provide paved road access to the area for it to be possible to construct the Ingula Pumped Storage Scheme.*

OPPOSITE TOP: *The quarry in the Bramhoek Dam basin that produced three-million cubic metres of stone*

OPPOSITE BOTTOM: *The crusher plant adjacent to the dam where stone was milled into crushed stone, gravel and sand*
PHOTOS BY ANTON MYBURGH

The project requirement was to upgrade the main external access from the Ladysmith Road (R103) along the provincial Besters Road (P275) and then the provincial De Beers Pass (D48), which required some re-routing to remove excessively sharp bends and reduce the gradient in places. Access to the two dam sites and lower site construction area was only via little-used farm tracks. While the paved roads were being constructed, a journey from the lower to the upper site was both time-consuming and difficult, especially in wet weather.

The contract was for the upgrading and construction of 58km of existing and new roads and the maintenance of a further 28km of gravel roads in the area. Work on the roads began in October 2006 and was originally scheduled to be finished by October 2008. However, various complications extended the date of completion to June 2009.




The project was divided into five sections, the first four of which were to upgrade existing roads and build new paved roads, and the fifth was for the maintenance of an existing gravel road. The sections were as follows:

- Section 1: Besters (R103) to Nooitgedacht (D474) (13,6km)
- Section 2: Nooitgedacht (D474) to the KwaZulu-Natal border (16,2km)
- Section 3: De Beers Pass (D48) to the upper dam (Bedford) (15,2km)
- Section 4: De Beers Pass (D48) to the lower dam (Bramhoek) (12,5km)
- Section 5: Swinburne to Kiesbeen (S790) to the Free State border (S61) (28,3km)
- Sections 3 and 4 were started first to provide access to the upper and lower sites. These were followed by sections 1 and 2, with section 5 undertaken last.

A multiple-stage crusher and screening plant was established near the lower dam site, as well as an asphalt plant. The crushed stone source was quarried from an area that eventually became the lower dam and rock was removed below the low-water mark.

OPPOSITE: *Highlighting the crusher plant*
PHOTO BY ALASTAIR CAMPBELL

ABOVE: *Lower site construction footprint and Bramhoek Dam from the upper-site viewpoint*
BY JACQUES DU PLESSIS

FOUR PROGRESSIVE ROAD CONSTRUCTION IMAGES, FROM LEFT:
*Scouring the bare veld on the upper site in February 2007*
PHOTO BY PETER NELSON

*Preparing the base layers on the same road*

*Initial surfacing of the road*

*The near-complete access road on the lower site*
PHOTOS BY NIELESH MAISTRY

As it was located within the floodplain of the Bramhoek Spruit, flood protection berms were required to prevent flooding of the source. It was necessary to cross the Bramhoek Spruit to gain access to the quarry and a temporary bridge was constructed for this purpose. A location was identified that yielded good quality dolerite rock material, and this was used to obtain G2 granular crushed stone, which was then stockpiled for use on the roadworks.

The crushing and screening plant provided:

- G2 granular crushed stone for the base layer works for all the road sections: 145 000m$^3$
- Fines for the gravel-wearing course: 20 000m$^3$
- Asphalt aggregate: 25 000m$^3$
- Concrete aggregate: 10 000m$^3$.

Borrow pits were scattered at various locations along the routes in the project area and were used for the provision of material for the sub-bases of the roads.

Some of the challenges faced by the contractor, which extended the time required to complete the project, included:

- The quantity and quality of the gravel that was estimated to be in the borrow pits by the consulting engineers was in reality found to be far less and of a lower quality. This necessitated sourcing material from alternative sources.
- Significant portions of section 3 of the road had very poor subsoil conditions. In the single worst case, about 200m x 9m x 2,5m of black cotton clay material had to be removed and the area treated with large dump rock and biddum (a finely woven material that holds back the fine sediments but allows water to pass through).
- Weather conditions, which always have an impact on construction activities. Given the geographical location of the project, the weather caused many delays. Summers were very hot, with significant amounts of rainfall, and the winters were extremely cold, with snowfalls.

Ingula is now accessible from an excellent tarred road network, and this benefits not only the pumped storage scheme, but also local farmers and other road users. The provincial section from the top of De Beers Pass to Besters has been handed back to KwaZulu-Natal for ongoing maintenance.

*A mundane crusher plant rendered surrealistic by a snowstorm*
PHOTO BY JANET DU PLOOY

# SCHEME COMPONENTS

### Upper dam

The upper reservoir is a concrete-faced, rock-fill dam, with a length of 810m and a maximum height of 49m. An outlet facility with a radial gate is provided to simulate floods of up to 1:10-year occurrence. An emergency spillway is provided with a 100m sill-crest length for spilling of excess water in the unlikely event of over-pumping in combination with high rainfall.

### Lower dam

The lower dam is a roller-compacted concrete structure, with a length of 310m and a maximum height of 39m. It has a 40m-long uncontrolled ogee (s-shaped curve) crest to allow spillage of the safe evaluation flood of 1 550m$^3$ per second.

### Powerhouse complex

The complex is constructed underground and consists of a machine hall, a transformer hall, a main access tunnel, a cable tunnel that routes the high-voltage cables to the surface, ventilation shafts and access tunnels that allow vehicle access to the various levels of the machine hall.

### Machine characteristics

- Station capacity: 1 332MW (4 units of 333MW)
- Rated head: 441m
- Rated generating flow: 340m$^3$ per second
- Pump-turbine synchronous speed: 428,6rpm
- Maximum transient pressure upstream of turbine: 726m

OPPOSITE: *A perfect reflection of Ingula's mountain on Bramhoek Dam*
PHOTO BY FIFI MEYER

### Waterways

*Headrace intake and approach channel*

The headrace intake structure is located at the reservoir's edge, at the end of an 850m-long, partially concrete-lined channel that connects it to the deeper parts of the reservoir. The single intake structure serves two headrace tunnels.

*Low-pressure headrace tunnels*

The scheme has two 6,6m diameter, 924m long, circular, reinforced, concrete-lined, low-pressure headrace tunnels. These change into two circular 5,1m diameter, 188m long, steel-lined sections. The rock is jointed in this section and steel lining was required to prevent leakage through the escarpment. The low-pressure headrace tunnel connects the intake with the headrace surge shafts.

*Headrace surge shafts*

There are two vertical, 16,5m diameter, post-tensioned, concrete-lined headrace surge shafts. The surge shafts are connected to the headrace tunnels by reinforced, concrete-lined riser shafts.

The main function of the headrace surge shafts and tailrace surge chambers is to reduce the distance between the free water surfaces. A shorter distance requires smaller machine inertias, which are needed to ensure hydraulically stable operations, and provides faster machine response times (that is, the time required for stopping and starting of the machine). A shorter distance also reduces the water hammer pressures during transient conditions.

*Headrace pressure shafts*

The two headrace pressure shafts are 5,1m-diameter, steel-lined tunnels, 974m long and, for most of this length, constructed at an inclination angle of approximately 24 degrees from the horizontal. The surrounding rock is unable to resist the high water pressures, hence the requirement for steel linings.

*Steel-lined penstocks*

There are two steel-lined penstocks, each dividing into two branches of 3,6m in diameter and feeding the four pump-turbine units.

LEFT: *Reinforcing the bifurcation (splitting into two) of the tailrace tunnel*
PHOTO BY DU FILMS

BOTTOM LEFT: *The steel linings (30mm at their thickest) provide a sense of scale to the project*
PHOTO BY DU FILMS

BOTTOM RIGHT: *Steel linings being installed*
PHOTO BY FIFI MEYER

### *Draft tubes and draft-tube extension tunnels*

The steel-lined, draft-tube tunnels carry the water from the pump-turbines to the two surge chambers.

### *Tailrace surge chambers*

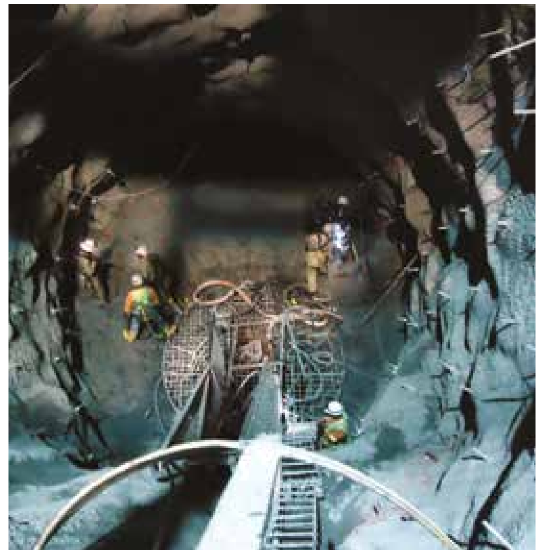
Each of the two tailrace surge chambers serves two draft tubes. The draft-tube gates, one for each draft tube, are accommodated in the surge chambers, with their lifting hoists located at the top of the surge chambers. The surge chambers are vertical, circular, 20m in diameter and lined with reinforced concrete.

### *Low-pressure tailrace tunnel*

The single tailrace tunnel collects the water from the two surge chambers and carries it to the lower reservoir (the flow is in the opposite direction during pumping). The 2 368m-long tailrace tunnel is circular, 9,4m in diameter and lined with reinforced concrete.

### *Tailrace outlet structure*

The reinforced concrete tailrace outlet structure is of the tower type and includes steel screens and stoplog gates. It has a top deck accessed via a concrete bridge.



OPPOSITE: *Ten-metre-diameter concrete lining in the tailrace tunnel*
PHOTO BY LOUW SWANEPOEL

FAR LEFT: *Completed access tunnel to the underground station*
PHOTO BY DU FILMS

LEFT: *Excavating a tailrace surge shaft*
PHOTO BY FIFI MEYER

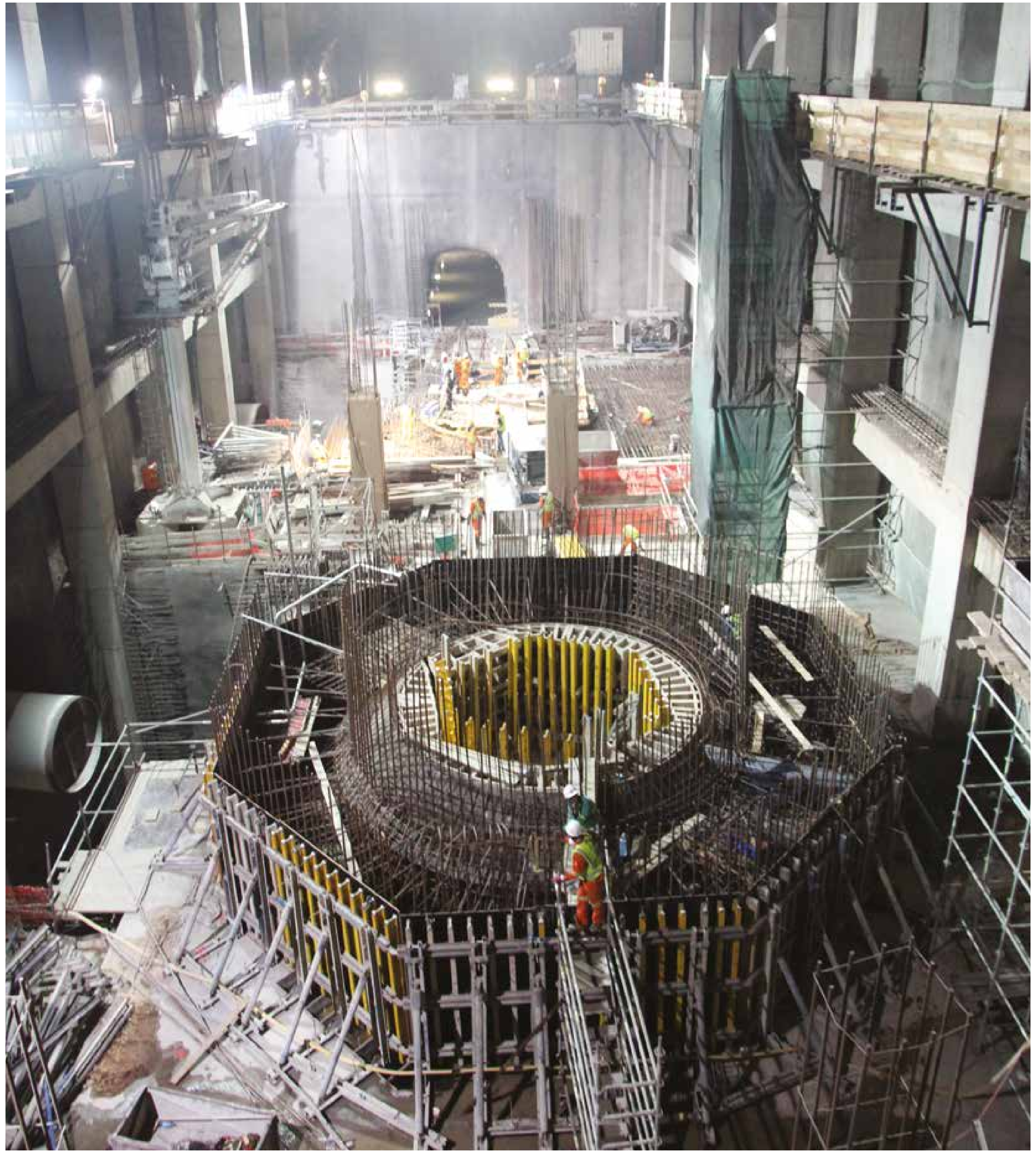
# EXCAVATION AND SUPPORT OF THE UNDERGROUND WORKS

*The underground works at Ingula consist of a complex of more than 10km of waterways and access tunnels, and over 2,5km of vertical and inclined shafts. One large cavern houses four units, each of which can operate as a turbine or a pump, together with their associated electro-mechanical works. The second cavern houses four transformers.*

The geology of the site is made up of near-horizontally bedded sedimentary rocks, with interbedded layers of dolerite. The sedimentary rocks comprise a series of silty mudstones and claystones, generally described as mudrocks, with occasional bands of sandstone. The mudrocks typically exhibit rapid disintegration on exposure to air. It is this characteristic that was the principal factor in determining the method of excavation and installation of support to the excavated cavern, which needed to take into account the size and geometry of the various excavation profiles.

The profiles of the excavation requirements at Ingula, varying from 5m- to 11m-diameter tunnels, and caverns up to 26m wide and 51m deep (equivalent to a 17-storey building), precluded the use of mechanised excavation with tunnel-boring machines. The selected means of excavation was thus by drill and blast, which is very flexible in terms of handling varying sizes and geometry of excavations, as well as variable geology. This entails drilling the face of the excavation, filling the drilled holes with explosives and blasting away the rock.

OPPOSITE: *Constructing the entrance to the machine hall*
PHOTO BY FIFI MEYER



The number and length of the drill holes and the amount of explosive determine the amount of rock that is removed at a time, allowing adjustment to accommodate the geology in which the excavation is being carried out. In the softer, less stable mudrock formations, the length of the drill holes and the amount of explosive used are reduced, with the opposite being the case for the stronger, more stable formations comprising dolerite or sandstone.

The propensity of mudrock to deteriorate on exposure to air also determined that the sooner the excavated rock profile was sealed, the better. The sealing method used was a layer of shotcrete, otherwise known as pneumatically applied concrete (PAC), which is applied by a compressed-air gun that sprays a layer of concrete onto the surface of the rock. This not only seals the rock surface, but also provides a measure of support, which is enhanced by the inclusion of steel fibres or mesh in the PAC.

The application of the PAC is immediately followed by the installation of bolts, comprising steel rods (rock bolts) or cable anchors drilled directly into the rock. The amount of support can be varied by the number, spacing and length of bolts or anchors installed, and the subsequent application of further layers of fibre- or mesh-reinforced shotcrete. In the extreme circumstances at Ingula, the support was supplemented by the installation of steel sections that formed support arches and were fabricated to the profile of the excavation.

The method of excavation adopted at Ingula is commonly referred to as the sequential excavation method (SEM), whereby the whole sequence of excavation and installation of support is prescribed, dependent on the geometric profile of the excavation and the structural integrity of the rock. The most impressive use of this method at Ingula was the excavation and support of the machine-hall cavern, which accommodates the four turbine-generators and a host of other items of electrical and mechanical plant. If you take into account the inherent instability of the mudrocks in which this massive cavern is constructed, some 350m below the surface, it transpires that the cavern has the largest span ever constructed in mudrocks anywhere in the world. Measuring 184m in length, it has a span of 26m and a depth of 51m at its deepest point.

This cavern was excavated working downwards from the crown, starting with the excavation of a 10m-wide by 10m-high central tunnel or heading in the crown of the cavern, which extended its entire length. As the excavation proceeded, rock bolts and fibre-reinforced

OPPOSITE: *Installing concrete reinforcing for the footing of pump/turbine unit 2*

ABOVE: *A 'road train' transporting a 285-ton transformer to Ingula in December 2013*

PHOTOS BY FIFI MEYER

PAC were installed in the roof and sidewalls. The next stage was to extend the excavation to eight metres either side of the central tunnel to open up the finished width of the cavern to 26m. Prior to doing these side-headings, it was necessary to go back the length of the central tunnel to install longer and higher capacity support in the form of cable anchors, with a 20-ton capacity, to accommodate the larger excavation span that the construction of the side-headings would create.

The side-headings were excavated one at a time to reduce the rate of increase of the span and to prevent the occurrence of an excessively large unsupported span at any one time. During this delicate stage of the excavation, the rock profile was carefully monitored and, where necessary, the support was augmented by the installation of 15m-long cable anchors with a 60-ton capacity.

The application of this method continued downwards with the construction of five-metre deep benches in sequence, excavating initially a six-metre wide, ten-metre long central bench, followed by a ten-metre wide, ten-metre long side-bench on the one side. This in turn was followed by the side-bench on the opposite side.

In the machine hall, 6 000 rock bolts, varying in length from three to six metres, and some 7 000 cable anchors were installed, varying in length from nine to fifteen metres and with capacities of 30 and 60 tons. In the more critical roof section of the machine hall alone, 6 000 rock bolts and cable anchors were installed.

The 176m long, 19m wide and 24m deep transformer hall cavern, which houses the four large generator transformers and four station transformers, was excavated and supported in a similar fashion. Altogether, including the access and waterway tunnels, the shafts and the caverns, the total excavated volume of the underground works amounted to an impressive 1,1 million cubic metres (equivalent to 440 Olympic-sized swimming pools), of which the machine hall had an excavated volume of rock of 168 000m$^3$.

All the tunnels and shafts that convey water to and from the turbines were lined. The type and thickness of the lining depended on the pressure of the water, bearing in mind that, upstream of the turbines, the static water head or pressure of the water is 441m or 44 bars. However, surges in this water head, or pressure, during operation of the turbines are taken into account to accommodate a surge head of 700m (three times the height of the tallest building in South Africa), or 70 bars. In such conditions the tunnels are lined with steel, encased in concrete. Over three kilometres of steel lining were fabricated and installed at Ingula with a total mass of 15 000 tons. In the tunnels and shafts, which are not subject to such high heads, the lining comprises only reinforced concrete.

Including the concrete encasement and support structures for the electro-mechanical plant in the machine and transformer halls, and that used for the waterway tunnels and shafts, the total volume of concrete in the underground works amounts to some 390 000m$^3$. With the exception of the concrete encasement of the steel lining, all the concrete was reinforced with more than 22 000 tons of steel bars. It has been estimated that if the steel reinforcing bars were laid end-to-end, they would stretch over a distance of 7,6 million kilometres: enough to circumnavigate the world 189 times!


*The 'Dante's Inferno' that was the extraordinary excavation of the machine hall*

PHOTO BY FIFI MEYER

# INGULA DAMS

*The two dams at Ingula form the reservoirs, or 'water-battery', components of the pumped storage system. The scheme straddles the continental watershed, with Bedford Dam on the upper site in the Wilge River catchment, which flows into the Vaal River, the Orange River and ultimately empties into the Atlantic Ocean. The Bramhoek Dam, on the lower site, lies on the Bramhoek Spruit, which flows into the Klip River, the Thukela River and then the Indian Ocean.*

Design of the dams started in September 2007, initially with a dam-type selection study, followed by more detailed designs. The most economical dam type selected at Bedford was a concrete-faced rockfill (CFR) dam, with a roller-compacted concrete (RCC) dam at Bramhoek.

**Bedford Dam**

Bedford Dam has a small catchment area and is situated close to the Little Drakensberg escarpment, at an altitude of 1 710m above sea-level. A design consideration was that flood volumes occurring at the dam site would be smaller than the water volume pumped from the lower reservoir, via the power station. The spillway, which would release the water flow from the dam into the wetland below it, was therefore designed to accommodate the higher pumped-water volume.

The dam layout incorporates a 49m-high embankment with a crest length of 810m, encompassing over one million cubic metres of sandstone rockfill and storing 23 million cubic metres of water. When full, the dam covers 255 hectares. A landscape architect was tasked with

OPPOSITE: *Bedford Dam from across the wetland*
PHOTO BY FRANCIS SERETLO

FROM LEFT: *Progress on the Bedford sandstone rock-fill dam, with only an up-stream concrete lining*
PHOTO BY BRAAMHOEK CONSULTANTS JOINT VENTURE

*Quarrying of one-million cubic metres of sandstone took place in what was to become the dam basin*
PHOTO BY MALCOLM DRUMMOND

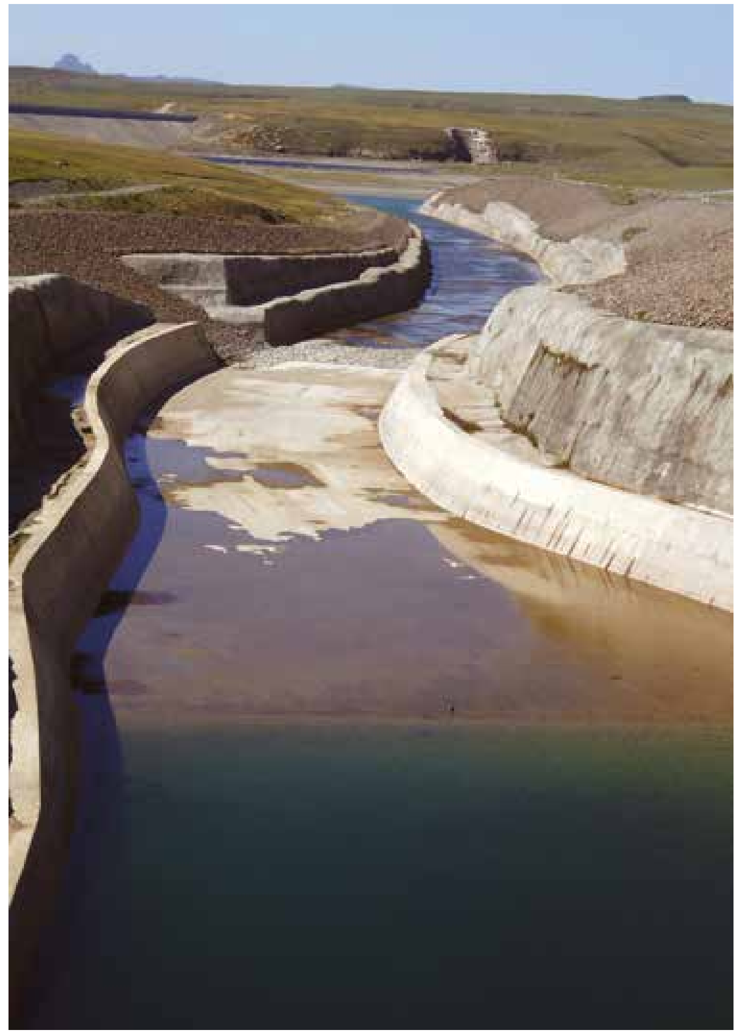
*The dam nearly complete, its basin is being levelled with waste rock excavated from the underground works*
PHOTO BY BRAAMHOEK CONSULTANTS JOINT VENTURE

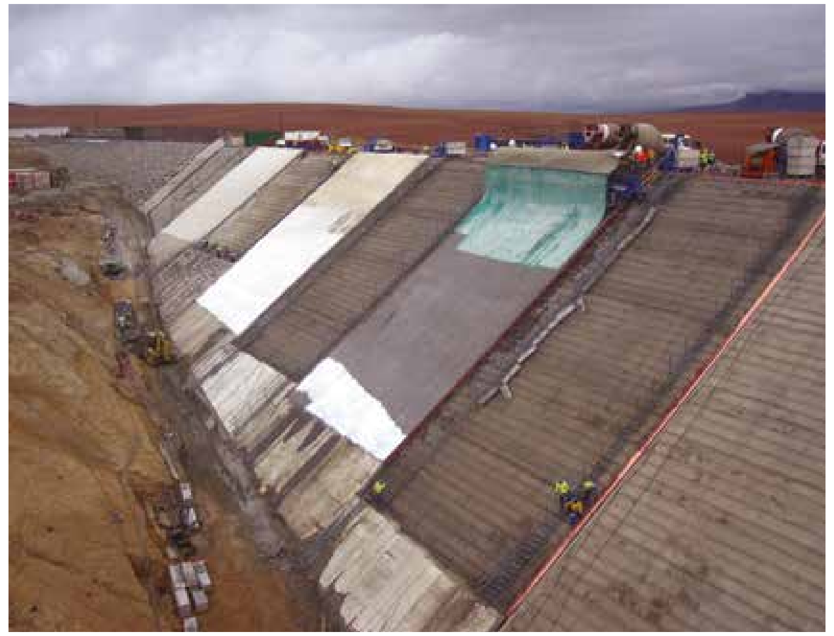
ensuring that the dam embankment would have a 'sense of place' and blend into the environment. Consequently, the dam embankment was curved to follow the rolling hills of the area.

Sandstone rockfill for the embankment was quarried on site, approximately a kilometre upstream of the dam, and below the eventual water level. The distance of the quarry from the embankment was ideal: far enough away to carry out blasting at the quarry without evacuating the entire site, but also close enough to ensure a short turnaround time to get material onto the embankment.

Bedford Dam is located in a very sensitive wetland, home to a *Critically Endangered* bird species, the White-winged Flufftail (of which, more later). The dam outlet system was designed to release flows that would cater for the one-in-ten-year floods, on average inundating the downstream wetland once every ten years. There was a concern that the wetland could be eroded by a concentrated flood entering it, and so an outlet stilling basin and pond were designed and modelled to ensure that water flows into the wetland evenly and at a velocity of less than one metre per second.

The original plan had been to design a downstream weir across the wetland, but, after engineers had studied the topography, it was agreed to position the spreader weir next to the catchment stream. This had the distinct advantage of being able to construct the outlet works from day one, without having to first divert the stream. Once the outlet had been completed, the stream was diverted through the outlet works, allowing the required excavation activities in the main stream section. Most importantly, the construction process had minimal impact on the wetland.





The way in which water is released into the Bedford Wetland was the overriding design factor of meeting the unique habitat conservation requirements of the wetland. The system consists of a 42m-high intake tower, a 3m-diameter conduit running below the dam wall, a sunken stilling basin and a pond, with an extended discharge sill at riverbed level. It is able to release 50m³ per second when the reservoir level is at its lowest in the pumped storage cycle. State-of-the-art hydraulic modelling software was used to ensure optimal functioning of the stilling basin and pond. Eleven different layouts were modelled and compared in order to arrive at the most proficient design. Testing of the system after construction confirmed the effectiveness of the design.

ABOVE LEFT: *Looking from the intake channel towards Bedford Dam wall and the artificial ibis nesting site in January 2016*
PHOTO BY JACQUES DU PLESSIS

ABOVE RIGHT: *Preparing the dam's up-stream face for its concrete lining*
PHOTO BY FIFI MEYER

A fascinating discovery throughout excavations for the dam foundations was that of finding more than 60 plant and animal fossils, dating back some 250 million years. Removal of fossils during construction was managed in such a way that the construction process was not disrupted. Among the fossils discovered are gorgonopsian, dicynodont and lystrosaurus, and a large number of fossilised trees and tree ferns, some up to one metre in diameter. This treasure trove provided an on-site palaeontologist with a wealth of material for identification and further investigation. Much of the recovered material was sent to the National Museum in Bloemfontein and, once curated and catalogued, will add to our knowledge of the Permian Extinction.

There is the possibility that a new species will be identified from the material recovered at the Bedford excavations. Once cleaned, identified and classified, some of the material will be returned for display at the Ingula Visitors Centre.

A major challenge at the Bedford Dam was the removal of a seven-metre layer of peat, which was spread across the entire dam footprint upon which the rockfill was to be located. Excavation was complicated by saturated soil conditions that necessitated the installation of drains and dewatering around the area to be excavated. The problem was innovatively resolved by placing 'soil traps' in the dump-truck buckets to prevent the peat material from washing out while in transit from the site.

Construction was undertaken in adverse conditions, affected by the altitude, winter temperatures falling well below zero, snow and an extremely rigorous schedule. This resulted in the concreting of the upstream face of the dam wall being undertaken in a 24-hours-a-day process. To cope with the conditions, the concrete mix was enhanced by adding an agent to enable placement in sub-zero temperatures. After placement, it was immediately covered by tarpaulins to trap hydration heat and prevent rapid water loss, enhancing the curing process. Fly-ash, a by-product from coal-fired power stations, was added to the concrete mix to ensure that the development of the concrete strength was gradual, resulting in a high-strength concrete that is less prone to cracking. The best-quality dolerite aggregate in the area for the concrete was mined and crushed within the lower Bramhoek Dam basin.

This process required an enormous concerted effort, so that about 700 people were involved in the construction of Bedford Dam.

*Bedford Dam seen from the south bank* PHOTO BY MALCOLM DRUMMOND

OPPOSITE: *Bramhoek Dam wall with the up-stream quarry that will eventually be under water*
PHOTO BY BRAAMHOEK CONSULTANTS JOINT VENTURE

BELOW: *Early days of dam wall construction*
PHOTO BY JACQUES DU PLESSIS

## Bramhoek Dam

The Bramhoek Dam is 337m long, 37m high and has a capacity of 26 million cubic metres, with a surface area of 240 hectares when full. The main dam wall consists of 77 000m$^3$ of roller-compacted concrete.

Foundation excavations were a particular construction challenge. The upstream section of the dam was founded on dolerite rock, while the downstream section was on mudstone. Dolerite foundations were discovered to consist of large, loose, blocky boulders standing on top of each other. Drill cores through these boulders appeared to indicate competent rock, and, after being opened up, engineers agreed to remove the dolerite boulders.


Another challenge was keeping concrete placement temperatures below the specified 23˚C. This was successfully completed by placing concrete at night and by cooling the aggregates with the use of two chiller plants that reduced the water temperature to 4˚C. This cooled water was then sprayed onto the aggregates, and also used as batching water.

The intake tower is 32m high and the outlet works consist of 12 000m$^3$ of conventional structural and mass concrete. The dam has two flood-release outlet pipes, each with a diameter of 2,8m, as well as a one-metre-diameter outlet pipe for environmental releases. The hydro-mechanical items, especially the large outlet pipes, were challenging to install and keep in position while casting concrete around them because of the uplift forces of the concrete. This problem was overcome by securing the components in place, using a combination of nylon and steel straps to ensure that no movement would take place during the concrete placement.

The lifting and rigging of the two 2,8m-diameter butterfly valves, each weighing about 16 tons, required the use of a 100-ton mobile crane, used in combination with a specialised rigging team. These valves are installed in the flood-release pipes in the lower section of the intake tower, and are the largest such valves ever manufactured in South Africa. For consistency, the outlet works were designed with the same outlet capacity as at Bedford Dam, i.e. 50m$^3$ per second.

The grout-enriched, roller-compacted concrete (GE-RCC) method was used on both the upstream and downstream faces of the dam to increase the impermeability of the dam wall. GE-RCC was used in preference to normal skin concrete as it offered a number of advantages. Productivity on site was increased because only one batch plant was used, as opposed to the two required for a normal skin-concrete face. The overall construction period was shortened and the bond strength between layers increased because the delay between placing subsequent layers was reduced. This increased the shear and tensile strength of the dam wall. GE-RCC has a higher bearing capacity when wet, compared to high-slump conventional concrete, and this enables far more effective use of the compaction plant.

TOP LEFT: *Layers of roller-compacted concrete being placed on Bramhoek Dam's wall* PHOTO BY JACQUES DU PLESSIS

BOTTOM LEFT: *Construction of the intake/outlet structure that interfaces between the dam and the tunnel to the power station* PHOTO BY FIFI MEYER

BELOW: *Bramhoek Dam nearing completion* PHOTO BY BRAAMHOEK CONSULTANTS JOINT VENTURE



Production of conventional concrete was minimised and the size of the construction crew was thus reduced.

The dam spillway is a 40m-wide ogee spillway, designed to release 750m$^3$ of water per second. There is a concrete stilling basin at the bottom of the spillway to dissipate energy in the event of a flood and prevent downstream scouring of the river bed.

Bramhoek Dam was scheduled early in the overall project construction programme for two reasons. First, the dolerite quarry supplying the entire project with good-quality concrete aggregate was situated within the dam basin and aggregate had to be extracted before filling of the dam started. Secondly, Bramhoek Dam had to be the major source of water for the project, as environmental restrictions were placed on storing water in the upper reservoir. The dam hydrology study indicated that filling of the lower reservoir by the Bramhoek Spruit could take between three months and three years. As it turned out, after heavy rains during November and December 2010 and January 2011, the dam filled to capacity within three months! It was required for the lower reservoir to be filled by the end of the powerhouse construction period to ensure that full-capacity power generation was possible immediately after construction.

Construction of both dams started in April 2008 and was completed by May 2011.

*Looking across Bramhoek Dam towards the Ingula escarpment* PHOTO BY BRAAMHOEK CONSULTANTS JOINT VENTURE

*No wonder that Ingula has enraptured so many people* PHOTO BY DU TOIT MALHERBE

# THE INGULA PARTNERSHIP

The Ingula Partnership

# BACKGROUND TO THE INGULA PARTNERSHIP

*The environmental impact assessment for the Ingula Pumped Storage Scheme was finalised and submitted in 1999. However, the presence of the Critically Endangered White-winged Flufftail in the Bedford Chatsworth Wetland and other important species, including the Wattled Crane, led to a host of objections from NGOs and various provincial and national government bodies.*

Eskom then entered into dialogue with BirdLife South Africa and Middelpunt Wetland Trust with the aim of forming the Braamhoek Partnership. BirdLife South Africa (BLSA) is a national body and the leading ornithological NGO in South Africa. At that stage, Middelpunt Wetland Trust (MWT) was a small, privately run NGO. It was initiated in 1992 for the specific purpose of conserving the White-winged Flufftail and its habitat. In 1998 the Trust discovered that Bedford Wetland was visited by the flufftail, becoming only the ninth such-known site in South Africa. It was realised that the environment as a whole would stand to gain more if Eskom and the NGOs were to work together on the environmental aspects of the project. To secure a positive Record of Decision (RoD) for the project, Eskom was obliged to obtain a High Court judgment and the authorisation was granted in 2004.

PREVIOUS PAGE AND OPPOSITE PHOTOS BY FRIKKIE HITGE

Discussions between the three parties began in 2000 and, over time, the structure, modus operandi and scope of a potential partnership were developed. It was only in March 2004, after the Department of Environmental Affairs had issued the Record of Decision, that a formal Memorandum of Understanding between Eskom, BirdLife South Africa and Middelpunt Wetland Trust could be signed. Since then, the Partnership has evolved and successfully executed three, formal, five-year contracts between the three organisations. A fourth contract is currently in place.

A steering committee, with representatives from the three organisations, was established to ensure that the objectives of the Partnership were achieved. These objectives included the improvement of the long-term integrity of the conservation area through appropriate decisions and management practices. Initially, the Partnership met every two months, but for the past few years this has been reduced to four times a year.

Relevant staff from Eskom's environmental management department, stakeholder management, communications and construction representatives (during the construction phase of the project) attend Partnership meetings, as well as other participants as may be required for particular aspects of the project.

The Steering Committee also established the Ingula Advisory Committee: Conservation (IACC) in order to be more closely involved with some of the day-to-day activities on the site. The IACC consists of Eskom and BirdLife staff, representation from the Steering Committee, various local, provincial and national government departments, and from conservation NGOs. Local farmers' associations also participate.

The RoD led to the required purchase by Eskom of a number of farms in the area surrounding the two storage dams, and these were initially managed by Eskom as a conservation area and now as a formally declared nature reserve. The project's upper dam is built near several important high-altitude wetlands and most of the conserved area occurs in the vicinity of these. The Ingula property consists of 9 585 hectares of former agricultural land, scarps, rocky outcrops and wetlands. The declared conservation area covers approximately 8 000 hectares. The primary aim of the property's management was to ensure that construction on a small portion of this area took place with due consideration of conservation issues and, in addition, that the integrity of the larger area should be enhanced and protected.

Eskom's responsible management of the greater wetland area, together with mitigation measures to compensate for any environmental damage, has resulted in improved protection of the Bedford Chatsworth Wetland, which is designated as a BirdLife International's globally

OPPOSITE: *A snow-blanketed Skeurklip Mountain*
PHOTO BY FIFI MEYER

recognised 'Important Bird and Biodiversity Area', and will also soon be designated as a global 'Key Biodiversity Area'.

However, prior to the initiation of the Ingula project, much of the land in the area of the undertaking was degraded as a result of decades of poor farming practices. There is still a significant amount of work to be done on erosion rehabilitation and wetland restoration in the Ingula conservation area.

The Partnership has been involved in many aspects of the changing face of Ingula. These have seen a network of roads built across the upper and lower sites to enable access, the building of two dams, the underground works and then a process of rehabilitation to remove the scars of construction. Some of the Partnership's areas of interest and involvement are described below.

OPPOSITE: *The majestic Martial Eagle has bred in the escarpment forest at Ingula for many years*
PHOTO BY ROBIN COLYN

RIGHT: *Oxbows and meanders on the upper site's Wilge River*
PHOTO BY PETER NELSON

# PALAEONTOLOGY

*Discoveries during construction encouraged the Partnership to initiate investigations into the palaeontology and archaeology of the site.*

Excavations for the footing of the Bedford Dam crossed the Permian Extinction line, a cataclysmic event some 250 million years ago that eradicated about 90 per cent of all species on the planet. However, the excavations uncovered a treasure trove of fossils from this event and a geologist/ palaeontologist was brought in to recover as much fossil material as possible. This included a large amount of plant material, mostly from the abundant *Glossopteris* family (large seed ferns, known as 'tongue-ferns', that contributed significantly to coal deposits), and several tree trunks.

The site was interesting enough for Professor Bruce Rubidge, Director of the Bernard Price Institute, and Professor Marion Bamford, a palaeobotanist from the University of the Witwatersrand, to pay a visit to Ingula.

About 150 fossils were recovered and taken to the National Museum in Bloemfontein, which was tasked with their preparation and analysis. Work will continue for many years, after which some of the fossils will be returned for exhibition at the Ingula Visitors Centre. The presence of gorgonopsians (mammal-like reptiles) has been confirmed, as well as several species of dicynodonts, that is, herbivorous animals with two tusks.

The possibility exists that the first-ever, post-cranial material from a dicynodont *Dinanomodon* (from the late Permian Period of the Karoo Supergroup) was among the finds. It is hoped that the analysis undertaken at the National Museum will confirm this discovery.

CLOCKWISE FROM TOP LEFT: *Probable dicynodon tusk being revealed*

*A section of a fossilised Glossopteris tree fern. These grew up to 30 metres high and formed a major component of South Africa's coal deposits*

*A stunning example of two, possibly three, dicynodon skeletons recovered from the excavations of the Bedford Dam wall footing*

*A fossil from Ingula being curated/prepared at the National Museum in Bloemfontein*

PHOTOS BY FIFI MEYER

# ARCHAEOLOGY

*The area in which Ingula lies is rich in heritage, going back millennia. A small section of rock containing San rock art was removed from Klipgat Cave and is displayed in the Visitors Centre.*

The cave itself, and the nearby Southern Bald Ibis nesting site, are now under the surface level of Bedford Dam. (Provision of an artificial nesting site for the ibises is described later.) Much of the art had sadly been disfigured by graffiti, dating back as far as the late 1800s. The images consisted of a possible lion or leopard and three eland.

Archaeological excavations were undertaken at Klipgat Cave and among the findings were pieces of thin-walled pottery dating from the Late Iron Age, but they could not be attributed to a specific group of people. The pottery indicates, however, that the cave was inhabited until about 300 years ago.

Among the finds were stone tools consisting of adzes, scrapers, blades and a drill made from cryptocrystalline silicates or dolerite. Associated with the tools were wood shavings that would have been produced when digging sticks and arrow shafts were made. Several bovid long-bones were found and also one piece of worked bone in the form of a spatula.

Well-preserved hearths were uncovered, together with charcoal, indicating that occupation of the cave almost certainly goes back more than 1 000 years. A number of small (less than 2mm in diameter), coloured (blue, black, pink, white and green) glass beads were recovered and these date back to approximately 300 years ago.

While the site itself has in effect disappeared, a good understanding of the archaeological history of it has been recorded.

TOP: *San rock art, representing an Eland, recovered from Klipgat Cave in what is now the inundated Bedford Dam basin*

BOTTOM: *Archaeological excavations outside the same cave*

PHOTOS BY GAVIN ANDERSON

# LAND MANAGEMENT

*A number of projects have been initiated that are associated with the conservation and sustainable development of the Ingula properties. These have been implemented as a direct result of the research undertaken at Ingula by the Partnership and the on-going management of the area.*

The key projects are designed either to fulfil the requirements of the Record of Decision, or to contribute to the environmental protection and sustainability of the Ingula Nature Reserve.

### Fire management

The fire management programme has seen the implementation of a fire strategy to:

- Eliminate risk at the site for individuals, equipment and infrastructure
- Reduce risk to and from neighbours
- Manage biodiversity to ensure a sample of grassland remains unburnt each year and that refuge areas for animals are developed
- Enhance conservation management principles to maximise biodiversity at the Ingula site.

RIGHT: *Fire is a major hazard in high-altitude grasslands*

FAR RIGHT: *Managed burning of fire breaks reduces the risk of indiscriminate burning, sadly often the result of deliberate fire-setting*
PHOTOS BY FIFI MEYER

*Effective burning of fire breaks demands experienced management under carefully-selected wind and weather conditions. About 150km of breaks are burned every year* PHOTO BY ALASTAIR CAMPBELL

ABOVE: *Mozambique Spitting Cobras and other reptiles have adapted to survive runaway fires and floods*
PHOTO BY JANET DU PLOOY

OPPOSITE: *A dramatic image of a managed block burn to remove massed, moribund material*
PHOTO BY ALASTAIR CAMPBELL

Approximately 150km of firebreaks are burnt annually to assist in meeting these objectives. They are burnt in conjunction with local farmers as part of a strategic network of breaks in the district.

Fire management is possibly the most important influence on biodiversity in the area. As the frequency of fires is being reduced, so biodiversity in the area is responding. There are still historical burning practices that threaten the area, however, and a significant amount of time is spent on educating local communities and landowners in ecologically sensitive burning practices.

This involves working with landowners in the region and dwellers on the property, with the objective of changing burning practices traditionally used in the area for many years. Historically, the area was burnt annually in late winter to encourage early spring growth, which was intended for feeding livestock after the long, dry winter. This resulted in major utilisation of the land early in the season and a loss of biomass later in summer. These practices are being changed to introduce a more sustainable utilisation pattern that will benefit local biodiversity.

ABOVE: *Large sections of treated wattle can be seen to the left of untreated areas*
PHOTO BY PETER NELSON

RIGHT: *Before the treatment of wattle, dry stream beds scattered the lower slopes of the escarpment. Today, they are running with water for the first time in many years*
PHOTO BY MALCOLM DRUMMOND



## Alien vegetation eradication

Before Eskom purchased the farms now comprising Ingula, approximately 500 hectares were heavily infested with black wattle, seriously depleting the water supply to the beautiful mountain streams running down from the escarpment. The Partnership has taken a keen interest in advising and monitoring the ongoing alien eradication programme.

More than 98 per cent of alien trees on the Eskom property have been treated and, of these, 90 per cent have been effectively controlled. A detailed management plan has been developed to eradicate these plants, which if not controlled would significantly reduce water flow into Bramhoek Dam. The control of these trees has resulted in a number of streams now flowing throughout the year, and these supply water to the local environment, as well as to the pumped storage scheme. It is estimated that approximately ten per cent of the water in the catchment area was previously consumed by alien vegetation.

Control mechanisms include physical removal, as well as chemical control by contractors, and these are monitored continually by the conservation team. This ensures that appropriate standards are maintained and that there is no negative environmental impact.

The involvement of the community in this process remains a significant element, as it not only creates direct employment opportunities through local contractors, but also allows for independent harvesters to utilise the wood.

Follow-up of regrowth is a critical part of the management programme, so that areas are monitored regularly to identify its occurrence. This is complemented by a concerted effort to prevent the growth of seedlings and to reduce alien biomass. Construction areas that have been rehabilitated are particularly susceptible to alien infestations and monitoring has been increased until all these areas have been stabilised and returned to natural grassland.

A detailed plan has been established following the promulgation of the latest list of alien invasive species, as specified in the National Environmental Management Act. Twenty-five of these terrestrial alien species have been included in the latest management plan, and a full monitoring programme is in place to prevent aquatic alien vegetation establishing itself at Ingula.

BELOW: *Clearing of treated wattle at Ingula provided lucrative business opportunities for people living on the lower site*

BOTTOM: *Apart from water depletion, wattle infestations results in reduced grazing opportunities*
PHOTOS BY MALCOLM DRUMMOND

## Erosion control

Historically, the properties at Ingula were livestock farms, which meant that, with persistent overgrazing over many decades, multiple erosion gullies resulted, scarring the landscape. It is a condition of the RoD that these erosion features be rehabilitated.

A number of programmes have been implemented to control erosion, largely guided by the erosion control strategy document developed in conjunction with the IACC and approved by the Partnership Steering Committee. The impact of historic erosion caused by years of overgrazing and unsustainable stock management is steadily being reduced, largely assisted by means of the reduction of livestock on the property and minimising activities that could create new, or exacerbate existing, erosion.

A three-phase erosion programme was initiated at the beginning of the project. This involves the following processes:

- Monitoring and managing of construction processes to prevent erosion occurring
- Reduction of the causes of existing erosion on the property to allow natural stabilising of erosion events
- Physical rehabilitation of active points.

TOP: *Much of the less severe erosion has been naturally redressed through a huge reduction in the number of cattle on site*

ABOVE: *More severe erosion, as a result of poor grazing regimes over more than a century, is being addressed through a long-term, labour-intensive programme*
PHOTOS BY PETER NELSON

Through Eskom-related erosion projects and environmental awareness programmes, which ensure that people are aware of the impacts caused by off-road driving and inappropriate veld management, the likelihood of further erosion occurring on site has been minimised.

Now that the construction phase has been completed, the final long-term phase of erosion rehabilitation has also been implemented, providing job creation for some of the unemployed people in the area.

Large areas of erosion have already been rehabilitated in the vicinity of the Bramhoek Dam and in the catchment of the Bedford Dam. A study has established that the effectiveness of the reduction of stock numbers on the site has resulted in significantly fewer active erosion points.

*Some erosion gullies almost beggar belief* PHOTO BY MALCOLM DRUMMOND

# COMMUNITY DEVELOPMENT

*When Eskom purchased the properties to develop the Nature Reserve, as required by the RoD, there were a number of communities living on the land as subsistence farmers. In many cases these families were living in areas where there would be a direct conflict with construction activities in the proposed dam basin or in ecologically sensitive areas.*

Additional properties were therefore purchased on the boundary of Ingula Nature Reserve in order to offer families the chance to farm sustainably and to gain title of their own property. This social reform project was closely aligned to the development of the Nature Reserve, and an extensive consultation process was followed. People are an integral part of the landscape, and no environmental programme is complete, or can be effective, without including the management of social impacts.

Houses were built for families that opted to move, and farms were subdivided into sustainable units to allow the development of sustainable communities. Six families moved to the adjoining Zaaifontein farm on the lower site, and five families moved to farms adjoining the upper site, in the Free State. A number of families, however, chose to stay on the Ingula property and not have title to the parcel of land on which they live and farm. This has resulted in the development of a sustainable village in a less sensitive part of the reserve and near the Wilge River. Communities have easier access to roads in case of emergency, and water and sanitation services are also available. Electricity is supplied through solar panels, with the long-term possibility of joining the national grid.

*A traditional homestead that was situated in an ecologically sensitive area near Bedford Dam* PHOTO BY ANTON MYBURGH

Communities still have controlled access to Eskom property, and cattle are used to manage vegetation on the reserve. Access to graves is provided, and communities harvest a number of natural resources on the property. These include firewood and thatching grass, and some sustainable harvesting of medicinal plant parts.

The Nature Reserve and local communities are managed as an integrated unit, and it is planned to utilise the resources of the reserve, including its eco-tourism opportunities, in order to develop them so that they can serve as a hub for economic upliftment of this very isolated area. The communities already have employment opportunities in conservation-related jobs, including erosion rehabilitation and, in addition, have the potential to develop accommodation and farming opportunities.

OPPOSITE: *Newly-built housing, replacing original housing, square-metre for square-metre, on owner-titled land, provides modern facilities for Ingula residents*
PHOTO BY PIKKIE FISCHER

TOP LEFT: *Life at Ingula was about to change dramatically*
PHOTO BY MALCOLM DRUMMOND

TOP RIGHT: *Hamilberg School, completely renovated and extended by Eskom, is now managed by the Free State Education Department*
PHOTO BY MALCOLM DRUMMOND

BOTTOM: *However visually attractive, the residents of these buildings were more than happy to move to modern, well-built housing*
PHOTO BY MALCOLM DRUMMOND

# BIRDLIFE SOUTH AFRICA AT INGULA

*An integral responsibility of the Ingula Partnership has been the support of an on-site BirdLife project manager since 2006. The first manager was David Maphisa, whose initial work at Ingula included baseline monitoring of bird distribution through regular recording along transects.*

David grew up as a cattle herder in Lesotho, but went on to earn an MSc on the biology of Rudd's and Botha's Larks. He collected sufficient relevant data to be able to undertake analysis and develop an adaptive management plan for Ingula, which would use burning and grazing regimes as the main management tools. In 2015 David successfully completed a PhD on adaptive management. This tool has applicability for all South Africa's high-altitude grasslands and so will benefit habitat far beyond Ingula. With his extensive natural-history knowledge and experience, David has contributed significantly to the identification of butterflies, reptiles and plants at Ingula.

Sakhile Mthalane, a local resident of the Kleinfontein community adjacent to Ingula, joined the Ingula BirdLife staff in 2010 as a survey assistant. Under David's mentorship, Sakhile gained exceptional knowledge of local bird species and their behaviour. Subsequently, Sakhile has taken up the role of a bird guide for groups visiting Ingula, while additionally providing invaluable assistance in breeding assessments of priority bird species and other ecological monitoring projects.

Robin Colyn joined as the BirdLife Project Manager at Ingula in August 2014, with a specific focus on providing scientific input and coordinating ecological activities at Ingula. His background in landscape ecology and the evaluation of species richness and distributions has been applied across Ingula in a number of ecological research and monitoring projects. Robin developed ground-breaking habitat-modelling techniques that have proved invaluable at Ingula and have also been used to establish potentially suitable habitat for the White-winged Flufftail all the way from South Africa to Ethiopia. These techniques have a wide applicability for any bird or mammal species and have been employed in identifying areas of suitable habitat for a number of threatened bird species. Robin, together with Alastair Campbell (at the time an environmental officer at Ingula), developed a method for successful camera trapping in wetlands: a world first.

*A graceful Three-banded Plover captured in flight* PHOTO BY FRIKKIE HITGE

ABOVE: *The White-winged Flufftail displays unmistakable white in its flight feathers when flying away from an observer. Once seen, never forgotten*
PHOTO BY DR WARWICK TARBOTON (A FOUNDER TRUSTEE OF MIDDELPUNT WETLAND TRUST)

Carina Coetzer (now Pienaar) took up the position of project manager at Ingula in October 2017. She has continued with BirdLife activities and responsibilities at Ingula, and beyond, and has played a lead role in the Upper Wilge Stewardship programme. Carina is also leading the national Southern Bald Ibis monitoring programme.

### White-winged Flufftail

The White-winged Flufftail was one of the major reasons for the formation of the Ingula Partnership, hand-in-hand with which was the purchase of more than 8 000 hectares of farmland for the creation of a protected area. The core of this area is the Bedford Chatsworth



Wetland and, as one of the few sites in South Africa where the flufftail is known to visit, its conservation is critical for the bird's survival.

There is still much to learn about the elusive White-winged Flufftail. It breeds in Ethiopia and, as recently discovered, in South Africa, and is classified as globally *Critically Endangered* in the IUCN Red List, just one step from extinction in the wild. It is also regionally listed as *Critically Endangered* in the *Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland* (2015).

Recent preliminary research results have established that the birds found in Ethiopia and South Africa are the same species, confirming that there is genetic mixing of the two populations, i.e. these two populations come into contact and are not isolated. This strengthens the likelihood that the flufftail migrates between the two countries, but only further research will prove or disprove this.

As a wetland species, the flufftail's habitat is severely threatened by continued habitat destruction, especially from afforestation, dam construction, mining, draining and poor agricultural practices. It has been found that the flufftail prefers a wetland underlain by peat and with a mixture of grasses and sedges. The depth of surface water in a wetland plays a critical role in the flufftail's presence or absence, and it is believed that the bird moves from wetland to wetland in an area, dependent on water depth. There is currently limited knowledge of the flufftail's diet, but it is known that crustaceans, insects and vegetation are eaten.

The Ingula Partnership has enabled Middelpunt Wetland Trust to undertake two workshops, one in South Africa and one in Ethiopia, to prepare Species Action Plans for the White-winged Flufftail. More recently, the Partnership has contributed towards fieldwork in Ethiopia. Furthermore, Eskom has been the BirdLife 'Species Champion' for the White-winged Flufftail. The declaration of the Ingula property as a Nature Reserve under the Protected Areas Act has ensured the long-term protection and management of this vital wetland and its source of water.

ABOVE: *A bird in the hand: a classic photograph of the White-winged Flufftail taken in Ethiopia in the late 1990s. Believe it or not, these images are the first ever taken of the flufftail*
PHOTO BY DR WARWICK TARBOTON

Historically, it had always been believed that the White-winged Flufftail bred in Ethiopia and was only a summer visitor to South Africa. However, the innovative wetland camera-trapping techniques developed at Ingula (see below) were also deployed at Middelpunt Wetland in Mpumalanga. Middelpunt Wetland is a 60-hectare marsh at the very head of the extensive Lakenvlei wetland system, lying between Belfast and Dullstroom in Mpumalanga Province. It was the degraded state of this wetland that prompted the initiation of Middelpunt Wetland Trust in 1992. Following the Trust's rehabilitation of the marsh, it has become the most reliable site in the country for establishing the flufftail's presence (between November and March) and, as yet, the only site in South Africa where positive proof of breeding has been established.

In both the summer seasons of 2017/18 and 2018/19, images were captured of female flufftails with chicks! This turned previously held beliefs upside down, creating a whole new set of intriguing conundrums. It has also led to the planned surveying, both with camera traps and audio equipment, of other suitable breeding habitat in South Africa (identified through habitat modelling) to establish the presence of the flufftail. This will enable suitable conservation and habitat management regimes to be implemented at any additional sites where it is found to occur.

### *Audio call detection*

The White-winged Flufftail is such a small, secretive bird that lives in difficult-to-study wetland habitat that, despite many efforts, until recently there had been no verified recording of its calls. Because of the difficulties involved in studying the White-winged Flufftail, verifying and correctly characterising the species' call would directly benefit conservation efforts under way, as well as fill a critical data deficiency.



The intriguing challenge of gathering data about this enigmatic flufftail led Robin Colyn and Alastair Campbell (an environmental practitioner working at Ingula) to work together to extend research opportunities from their joint and innovative wetland camera-trapping techniques in an attempt to record and verify the bird's calls.

In 2017, for the first time, Robin and Alastair succeeded in recording the White-winged Flufftail's calls at Middelpunt Wetland, which was verified by the recorder's proximity to camera trap images of the bird. It was decided to combine camera traps and acoustic recorders in Ethiopia to confirm the vocal repertoire of the flufftail. Playbacks of vocalisations recorded in South Africa were used at the wetland in Berga and the technique was completely successful, establishing that the calls in South Africa and Ethiopia are near-identical.

This technique has proved to be extremely valuable in detecting the presence of White-winged Flufftails in wetlands in South Africa. Placing audio recorders in wetlands is both non-intrusive and cost-effective. It is also quicker and less complicated than deploying a grid of camera traps.

### *Genetics*

For many years, it was believed that the White-winged Flufftail bred in Ethiopia and migrated to South Africa as a summer visitor. Consequently, DNA testing was conducted in 2015 on material from ten birds from Ethiopia and three from South Africa.

The migratory connection, if any, has been poorly understood between the Ethiopian and South African White-winged Flufftail populations. Analyses of mitochondrial and nuclear gene regions of White-winged Flufftail samples from South African and Ethiopian birds confirm that the populations are not different species or subspecies. The genetic results could support the hypothesis of one migrating population with two seasonally occupied ranges and does not exclude the possibility of additional breeding and non-breeding sites.

The sequencing of nine toll-like receptor (TLR) genes described a low genetic variation in the innate immune regions of the White-winged Flufftail, similar to that observed in other bird species that have undergone population bottlenecks. The low TLR diversity indicates that the White-winged Flufftail is likely to be negatively influenced by changes in the environment. Any stochastic events, such as potential exposure to new diseases, could have hazardous impacts on the species' survival and thus it is of critical importance to protect pristine habitat for the species.

OPPOSITE TOP: *The nest and eggs of a White-winged Flufftail at Berga Wetland in Ethiopia in the 90s. At that time, it was believed that the flufftail bred only in Ethiopia* PHOTO BY DR WARWICK TARBOTON

OPPOSITE MIDDLE: *An adult female displaying the characteristic white secondary feathers in the wings* CAMERA TRAP IN MIDDELPUNT WETLAND, MPUMALANGA

OPPOSITE BOTTOM: *The famous image proving that the White-winged Flufftail, contrary to previous beliefs, does breed in South Africa. The head of a female with two chicks captured in Middelpunt Wetland in November 2017. Unfortunately, camera-trap images (especially in wetlands) are often not sharp and clear* CAMERA TRAP IN MIDDELPUNT WETLAND MPUMALANGA

*The African-Eurasian Migratory Waterbird Agreement (AEWA)*

This agreement is an intergovernmental treaty dedicated to the conservation of migratory waterbirds and their habitats across Africa, Europe, the Middle East, Central Asia, Greenland and the Canadian Archipelago. AEWA brings together countries and the wider international conservation community in an effort to establish coordinated conservation and management of migratory waterbirds throughout their entire migratory range.

The role of AEWA is to coordinate and catalyse the implementation of an action programme. The International White-winged Flufftail Single Species Action Plan was developed in 2008 at a workshop held in Addis Ababa and is managed by an international working group. This workshop was funded by the Ingula Partnership, which continues to play an active role in the international working group. The working group comprises designated representatives of national state authorities (Ethiopia and South Africa), representatives of conservation organisations and scientists.

The second meeting of the AEWA White-winged Flufftail International Working Group took place in August 2015 in Addis Ababa, Ethiopia. One of the outputs from the workshop was an updated species action plan, based on input from fieldwork that had taken place since 2008. The third meeting of the Working Group was held in November 2019 at Verlorenkloof Estate, near Dullstroom, Mpumalanga, in November 2019. This meeting was chaired and funded by the South African Department of Environment, Forestry and Fisheries. As well as further updates to the species action plan, the workshop provided the ideal opportunity for attendees from the represented organisations to get a better idea of the progress that had been made in conservation activities and to contribute to planning for the future.

*When you are lucky enough to see a White-winged Flufftail in flight you will see the distinctive body positioning, and white in the wings*
PHOTO BY DR WARWICK TARBOTON

## Southern Bald Ibis

There has been a small breeding colony of Southern Bald Ibis at Ingula for many years and an unfortunate effect of the water level in Bedford Dam is that it covers their historical nesting ledges. Prior to filling the dam, it was therefore decided to create an artificial nesting site nearby, in the hope that the birds would make use of it. The original plan was to incorporate the nesting ledges into the main dam embankment. However, this would not have been situated above water, where nesting ledges are most commonly positioned.

A site close to the dam wall was identified, investigated and selected. Rockfill cliffs were blasted vertically to ensure that the nesting sites would be above water and nesting ledges created just above the maximum water level. This also had the benefit for the contractor of generating rockfill close to the dam.

The colony has indeed moved to the new site, and four chicks fledged successfully from six nests in the 2017/18 breeding season. In the process, invaluable lessons have been learned for any future development of artificial breeding ledges. Factors influencing the hatching and fledging rates include the aspect and size of the ledges, which have a direct bearing on the vulnerability of the nests to weather and predation. Another significant threat is the illegal harvesting of eggs and young chicks for consumption, or for use in traditional medicine and ceremonial purposes.

*Cooperation. Dam construction engineers making it easy to ring Southern Bald Ibis fledglings at Klipgat Cave (now under water) on the upper site*
PHOTOS BY MALCOLM DRUMMOND

The Ingula Partnership supports BirdLife South Africa's national programme to study the Southern Bald Ibis. As the Species Champion of the Southern Bald Ibis under BirdLife International's Preventing Extinctions Programme, Eskom has supported conservation work on Southern Bald Ibis through a satellite-tracking project, which is designed to determine the movement patterns of these birds across seasons.

## Avifaunal surveys

A wide range of avifaunal surveys is currently conducted on a routine basis at Ingula, including monthly species counts, walked transects and seasonal breeding assessments. Monthly counts have been conducted since June 2013 and aim to evaluate any changes in species richness at Ingula, expressed over time. Results thus far have revealed a total of more than 335 bird species across the Nature Reserve (see Appendix C). These results not only provide insight

OPPOSITE: *A Southern Bald Ibis on its nest at Ingula*
PHOTO BY DU FILMS

ABOVE: *The artificial nesting site near the dam wall at Bedford Dam. Southern Bald Ibis now nest in the 'alcoves' situated very near the top of the structure*
PHOTO BY FIFI MEYER

into the species-richness dynamics at Ingula, but additionally supply vital information on the presence and status of threatened species, as well as the condition and availability of their required habitats. Twenty-three species have been recorded with varying degrees of threat status, including *Critically Endangered, Endangered, Vulnerable* and *Near Threatened*.

### Camera-trap studies

An innovative camera-trap survey method was applied across wetland habitat at Ingula to determine the effectiveness of camera traps at surveying and compiling inventories of elusive and rare wetland avian species. The results were very promising in that they documented a range of highly secretive species. These included four species of rallid, African Grass Owl, Wattled Crane, Grey Crowned Crane and African Marsh Harrier.

A range of mammalian species was also recorded, including Oribi (*Endangered*), Common Reedbuck, Water Mongoose, Spotted-necked Otter (*Near Threatened*), Cape Clawless Otter and Serval (*Vulnerable*).

This original work, first developed and conducted at Ingula in 2015, has been further refined and applied at Middelpunt Wetland in Mpumalanga. It has become the first reliable, non-invasive and effective method of surveying rare and elusive bird species in wetland habitats. Over a period of two years following the development of this technique, surveys have been conducted across various sites in an attempt to assess the status of, arguably, Africa's most threatened wetland avian species, the *Critically Endangered* White-winged Flufftail.

In addition to the wetland camera-trap studies conducted at Ingula, two further projects were initiated in 2015. The first was an assessment of the medium-to-large vertebrate species richness across Ingula's grassland and riparian habitats. The study took place over six months and yielded 18 mammalian, five avian and one reptilian species.

The second study, built on the foundation laid by the first, incorporated 20 camera traps across escarpment forest habitat located from Van Reenen through to Ingula. The aim was once again to assess species richness, but additionally to understand how these habitats were connected across this area of rugged escarpment and if this habitat acted as a crucial conservation corridor for certain species. Significantly, the study resulted in the identification of 37 mammalian species, including Aardvark, African Porcupine, Black-backed Jackal, Serval (*Vulnerable*), Leopard, Brown Hyena, Spotted Hyena, Aardwolf, Small-spotted Genet, Water Mongoose, Egyptian (Large Grey) Mongoose, Yellow Mongoose, Common Duiker, Mountain



TOP: *Camera traps have broadened our knowledge of Ingula considerably and provided some wonderful images. Here, an adult caracal clearly shows its feline qualities* CAMERA TRAP

TOP: *A caracal and kitten* CAMERA TRAP

*A graphic example of hibernation: ladybirds clustered together in a rock cavity during very cold conditions*
PHOTO BY ALASTAIR CAMPBELL

Reedbuck, Common Reedbuck, Bushbuck, Steenbok, Oribi (*Endangered*), Cape Clawless Otter, Chacma Baboon and Vervet Monkey (see Appendix D for a complete list).

The study also yielded insights into interesting symbiotic associations between avian and mammalian species, such as that between the Chorister Robin-Chat and Bushbuck. Camera trap footage recorded numerous sightings of the robin perched on the indigenous forest specialist, the Bushbuck. Sightings not only recorded birds perched on antelope, but included many records of birds flying off to forage around leaves and undergrowth disturbed along the antelope's trail.

### Modelling core habitats for threatened species

Under the auspices of the BirdLife South Africa Conservation Modelling project, Robin Colyn developed numerous fine-scale habitat models for highly threatened species such as the White-winged Flufftail (*Critically Endangered*), Rudd's Lark (*Endangered*) and Yellow-breasted Pipit (*Vulnerable*) during his time at Ingula. The modelling includes novel spatial, climatic and satellite data to assess the critical habitat requirements needed for a species to persist and thrive in a given area. This method allows for the regional and national assessment of our most threatened

*Although previously observed, this is the first photographic record of the symbiotic relationship between the Chorister Robin-Chat and Bushbuck*
CAMERA TRAP

species and thus supports the direction of conservation initiatives aimed at promoting species recovery plans. Some examples of how this has been implemented include conservation projects for the Southern Bald Ibis, the White-winged Flufftail and that for Mesic Grasslands.

Robin transferred to Cape Town in September 2017, where he ran BirdLife's Conservation Modelling and Arid Species projects in the Northern Cape. In recognition of his successes and innovations with camera trapping, Robin was invited by Professor Peter Ryan, Director of the Percy FitzPatrick Institute of African Ornithology, to undertake a PhD. It is aimed at assessing the population size, distribution and habitat connectivity of threatened and range-restricted lark species across an aridity gradient in southern Africa. Robin and his family have subsequently relocated to Canada.

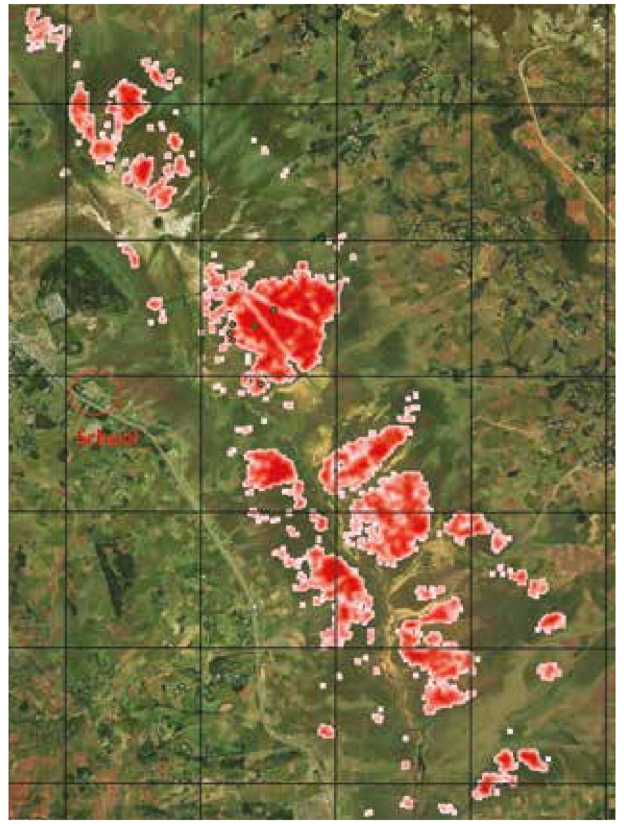
### Threatened bird species monitoring

Breeding assessments within the greater Ingula area were initiated in 2014, and four years of breeding frequency and success data were collected for 13 priority threatened species.

Species monitored are Wattled Crane, Martial Eagle, African Marsh-Harrier, Grey Crowned Crane, Yellow-breasted Pipit, Secretarybird, Southern Bald Ibis, Lanner Falcon, Blue Crane, Crowned Eagle, White-bellied Korhaan, Bearded Vulture and Half-collared Kingfisher. The results obtained provide valuable information for avian conservation in the broader landscape, and the knowledge that has been gained will contribute significantly to the protection of these threatened species.

### Species Action Plans

Species Action Plans have been developed and implemented at Ingula for the Wattled Crane *(Critically Endangered)* and the Yellow-breasted Pipit *(Vulnerable)*. Implementation began in 2015 and 2016 and the plans are subject to ongoing revisions. A national Species Action Plan has been prepared and implemented for the Southern Bald Ibis *(Vulnerable)*.



LEFT: *A vivid example of core habitat modelling that has proved to be an invaluable tool for conservation. Covering the Berga Wetland in Ethiopia, this model identifies, to the metre, the most suitable habitat for the White-winged Flufftail. The denser the red, the better the habitat* IMAGE BY ROBIN COLYN



ABOVE: The Endangered *(threat status) Secretarybird on its nest in the Ingula escarpment forest* CAMERA TRAP

LEFT: A face-off in the escarpment forest: the porcupine won CAMERA TRAP

*The* Vulnerable *Yellow-breasted Pipit is a scarce resident of the upper site's grasslands* PHOTO BY DR DAVID MAPHISA

These plans highlight the ecological requirements of each respective species, while providing the necessary actions required to manage specific threats. Additionally, included in the plan are any monitoring requirements needed to further understand the dynamics of the species, and thereby more effectively conserve it.

**Small Mammal Study**

A survey was begun in May 2015 to determine small mammal diversity and abundance across habitats that have been exposed to varied management practices, particularly fire frequency. It incorporated 60 traps placed across 10 transects over a five-day trapping period. Eight species were recorded across more than 50 captures within three variations of grassland habitat. The species recorded were Striped Mouse, Multimammate Mouse, Water Rat, Greater Red Musk Shrew, Reddish-grey Musk Shrew, Lesser Dwarf Shrew, Swamp Shrew and Tiny Musk Shrew (see Appendix D for more detail). Other flora and fauna that have been recorded at Ingula over the years are also included in Appendix D.

**Power-line surveys**

Power lines continue to be a major risk to birds across the country through either electrocution or collision. Eskom, supported by the Endangered Wildlife Trust (EWT), is assessing the lines at Ingula. A national management plan that would allow Eskom to follow best practice principles to prevent collisions and electrocutions has already been implemented.

BirdLife South Africa currently undertakes quarterly surveys across all power-line infrastructure at Ingula in order to ensure that the associated impact is monitored and mitigated where necessary. All data collected are collated within an Ingula database and also sent through to the greater EWT power-line database. Mitigation measures have been installed at Ingula at points considered to be hazardous for birds. High-voltage transmission lines have had 'spiral bird diverters' installed and 'flappers' on lower voltage lines. These interventions appear to have provided an effective means of reducing the impact of power infrastructure on birds at Ingula.

**Stewardship programme**

Buffers around a protected area that contains untransformed habitat play a valuable role in minimising outside threats to that area. For this reason, in 2016 the Ingula Partnership Steering Committee identified the need to establish a conservation area bordering the Ingula

Nature Reserve. A proposal was therefore submitted to the Free State Provincial Government to establish a Protected Environment and was immediately accepted.

Some important reasons why this area was eligible to be declared a Protected Environment include that the Wilge River catchment is not only an important ecological unit but is also vital for the sustainability of the Eskom Ingula Pumped Storage Scheme. The conservation area includes the upper catchment of the Wilge River and a short section of the river downstream from Ingula. It also overlaps with priority conservation areas, as identified in various conservation plans, and is extremely significant from a biodiversity perspective: the area hosts most of the bird species of conservation concern found at Ingula, as well as the Giant Girdled (Sungazer) Lizard and four threatened ecosystems.

The area is also of great importance as a water catchment area, as it falls within the Strategic Water Source Areas. These cover only eight per cent of the land area in South Africa, Lesotho and Swaziland, but provide 50 per cent of the water in these countries.

Formal protection of this area aims to ensure that threatened biodiversity is protected, and that the Ingula Pumped Storage Scheme is sustainable by means of conserving the greatest part of the upper catchment of the Wilge River. Also in line with Eskom's Biodiversity Conservation Plan, one of the responsibilities of which is to promote conservation and enhance ecosystem services, which can only be achieved through conservation at a landscape level.

BirdLife South Africa and the Endangered Wildlife Trust have performed the groundwork for the project on behalf of the Ingula Partnership and mediated the negotiations between the province and the landowners. The first phase of the project has seen 19 landowners, owning more than 30 000 hectares, participating in the programme. Once declared, this area will make it one of the largest Protected Environments in South Africa and will contribute significantly to the conservation of high-altitude grasslands.

OPPOSITE: *Our ideal: coexistence* PHOTO BY ALASTAIR CAMPBELL

# INTER-BASIN FISH TRANSFER

*Biodiversity in South Africa continues to face a number of significant threats, including the transfer of endemic species to areas outside their natural range. Southern Africa's freshwater ecosystem faces the risk of biological invasion through inter-basin transfers, largely as a result of poor historic environmental practices and a lack of knowledge on the management of fish stocks in river systems.*

The Ingula scheme is situated on the continental watershed, so that the transfer of water from one catchment to another could cause an inter-basin transfer of historically isolated Chubbyhead Barb (*Barbus anoplus)* populations, which could potentially result in interbreeding and genetic biodiversity loss. One population exists in the Wilge catchment in the Free State, while the other is in the Klip River catchment in KwaZulu-Natal.

The effects of the operational pressures of the pumped storage system on the fish were examined through a modelled pressure chamber to assess whether the barb would survive them and whether interbreeding could be prevented. The study showed that the species is indeed likely to survive the pressure exposure created through an inter-basin transfer. The opportunity for the different populations to interbreed, compromising genetic and ecological integrity, would therefore be a real possibility. Consequently, pressure alone has been found not to be a suitable measure to prevent the potential hybridisation of *Barbus anoplus* populations.

Eskom then engaged with the provincial conservation authorities and the Department of Environmental Affairs and, owing to the near impossibility of preventing inter-basin transfer of the fish, a resolution was obtained to allow for the possibility of the historically separated *Barbus anoplus* populations to mix.

OPPOSITE: *A fish that caused much consternation: the Chubbyhead Barb*
PHOTO BY MALCOLM DRUMMOND

# INVERTEBRATES

*An invertebrate study, aimed at gaining an understanding of the terrestrial invertebrate diversity of the Ingula grasslands and forests, was conducted in 2012 and 2013. Fifteen sampling points, between 1 271 and 1 775m above sea level, in the regional vegetation communities of Eastern Free State Sandy Grassland, Northern KwaZulu-Natal Moist Grassland and Northern Afrotemperate Forest, were sampled in July 2012 and February 2013.*

During the two sampling periods, 184 invertebrate species were collected, including the endemic butterfly *Paralethe dendrophilus indosa* (Eastern Bush Beauty or Forest Beauty) and the endemic forest specialist dung beetle *Xinidium dewitzi*.

Almost half of the species were collected from the Northern KwaZulu-Natal Moist Grassland macro-habitat type, and the sampling points of this habitat were the most species rich and species diverse, with the species identified distributed evenly across sampling points.

*The humble Milkweed locust: a wonder of creation* PHOTO BY FRIKKIE HITGE

# VELD CONDITION

*An outcome of the environmental impact assessment for the pumped storage scheme was the need to complete a veld condition assessment, particularly as there were large numbers of cattle on the various farms at the time of purchase.*

*The different biomes at Ingula provide suitable conditions for a wide variety of plants*
PHOTO BY FIFI MEYER

The creation and maintenance of clean, silt-free water supplies for the two dams are essential requirements for the long-term success of the scheme. Soils of the Ingula properties are highly sensitive to erosion and there is ample evidence of extreme gully development and terracing of the hillsides.

Erosion has occurred primarily because the land has a long history of being grazed beyond its capacity. Under these conditions, valuable topsoil resources are rapidly lost and the infiltration capacity of the soil is drastically reduced. This has resulted in increased floodwater carrying heavy silt loads, as well as reduced perennial flows of clean water from the streams in the area. These outcomes are counterproductive to the fundamental objectives for which the scheme was established.

Historical farming practices have tended to install fences in straight lines, often directly up and down slopes. Cattle usually follow these fence lines, thereby creating paths that rapidly lead to the development of erosion gullies.

Over the past ten or so years, livestock numbers have been greatly reduced on the property, so that there has been a considerable improvement in the veld quality. While erosion has also been reduced, a programme of erosion rehabilitation will continue for some years to come.



*The Watsonia – a harbinger of Spring*
PHOTO BY MALCOLM DRUMMOND

Both uncontrolled fire and overgrazing have resulted in decreased veld potential, so that it has become necessary to have a burn and grazing programme. The veld condition is also critical in assessing how many different species, populations and individuals of wild, medium-to-large herbivores can be maintained on the property.

Satellite imagery is being used to monitor veld condition and provide input for the burning programme and managed grazing.

# ECOSYSTEM SERVICES

*Eskom's purchase of more than 8 000 hectares of farmland surrounding the Ingula operations has meant that this land could be set aside purely for conservation purposes.*

The area supports a range of ecosystems, including wetlands, grasslands and escarpment forest. These represent the ecological infrastructure and refer to functioning systems that deliver valuable services to people, such as fresh water, climate regulation, storm protection and soil formation, and are therefore known as ecosystem services. They are defined as the set of ecological (or environmental) goods and services that provide both intermediate and final benefits to humans, and these can include food, fuel, pollution control, erosion control, recreation and spiritual value.

Ingula has a significant ecological infrastructure value by virtue of its location in a high water-production area straddling the Upper Vaal and Thukela water management areas. Key ecosystem services identified at Ingula include water purification, regulation and provisioning, waste absorption, genetic resources, eco-tourism and a sense of place. The property is also important to a range of downstream beneficiaries that rely on the effective, continual and sound management of this ecological infrastructure.

The ecological infrastructure and ecosystem services at Ingula were evaluated through the methodology proposed by the World Business Council for Sustainable Development. The total value of ecosystem services, based on this methodology, is approximately R6 650 per hectare, per annum, which is equivalent to a total value of about R55 million per annum for the Ingula property. This is more than ten times the purchase price of the same land, based on agricultural value. The results of this study have provided Eskom with valuable information that can be used for the management of the property.

OPPOSITE: *The waterfall, Klipgat Cave (home of the San painting) and Southern Bald Ibis nesting ledges (both to the right of the waterfall) upstream from Bedford Dam, now all under water*
PHOTO BY FIFI MEYER

# GEOHYDROLOGY

*The Bedford Dam is located within the Bedford Chatsworth Wetland, which is largely in its natural condition and is of significant importance because of its high ecological diversity, high stream-flow regulation and water-purification capabilities.*

The ecological significance of the wetland was of particular concern, given that the construction of the dam and the operation of the scheme might have an impact on the hydrological conditions in the area and affect the functioning of the wetland.

To address this concern, a study was conducted to establish a realistic model for the water storage in the wetland in order to quantify the sources and fluxes contributing to its long-term water balance. An in-depth monitoring assessment was undertaken in which data were captured on the functioning and the formation of the wetland. In this process a simulation of the wetland water balance was generated and the water quality of the wetland was determined.

The investigation found that the baseflow within the wetland is being predominantly maintained by perennial groundwater. The movement of groundwater into the wetland is not, however, that simplistic, owing to the complex dyke systems present in the area. Also, a significant amount of transient groundwater is lost through evapotranspiration.

Based on an improved understanding of the wetland, recommendations were made to monitor the water quality in both dams and in the wetland itself. In addition, groundwater levels are constantly monitored to assess dam leakage, and water levels in the wetland are maintained through direct dam releases.

OPPOSITE: *Tandjiesberg from the upper site* PHOTO BY FRIKKIE HITGE

# NATURE RESERVE AND RAMSAR DECLARATIONS

*The Ingula Partnership Steering Committee was instrumental in generating a proposal to consider the declaration of Ingula as a nature reserve to ensure the long-term conservation of this sensitive habitat.*

In terms of the Record of Decision for the Ingula Pumped Storage Scheme, Eskom was obliged to buy various farms surrounding the Bedford Wetland and create a protected area, in close co-operation with the relevant provincial departments. Eskom is currently managing the land in compliance with the specific environmental conditions in the Record of Decision and through the guidance and oversight of the Ingula Partnership. This includes alien plant eradication, fire management and erosion control.

Ingula is in South Africa's severely threatened high-altitude grassland biome, with less than two per cent of this ecosystem enjoying any formal protection. The Department of Environment, Forestry and Fisheries welcomes any increase in areas under formal conservation management and has been highly supportive in assisting Eskom with the declaration process. This was concluded in conjunction with KwaZulu-Natal and Free State provinces for the declaration of the Ingula property as a Nature Reserve in 2018. This is considered a major step forward, fulfilling both the requirements of the RoD and the long-term conservation aspirations of the Ingula Partnership. Interestingly, Ingula is the largest privately-owned nature reserve in South Africa and the only one that crosses a provincial boundary.

Declaration of Ingula as a Nature Reserve has come with various benefits, including provincial support for management activities, stewardship programme advantages and tax benefits.



As an added bonus, the declaration has brought international recognition of the success achieved by the partnership between a major state-owned company and two environmental NGOs. It has also seen the implementation of the Ingula Partnership's objective of encouraging the expansion of the protected area through adjacent landowners adopting sound environmental land-management practices.

A valued accolade was awarded when The Ingula Partnership won the *Stewardship* category of the 2019 South African Wetland Awards.

The Ramsar Convention is an international treaty for the conservation and sustainable use of wetlands, and was established in 1971 by the United Nations. To qualify, a wetland has to meet a series of ecological criteria and Ingula fulfils these requirements. The Department of Environment, Forestry and Fisheries nominated the Ingula Nature Reserve and it was designated as a Wetland of International Importance in 2021. Ingula thus became South Africa's twenty-seventh Ramsar site. Global recognition of the importance of the Ingula Nature Reserve is a major achievement and adds considerably to its status.


Ramsar
CONVENTION ON WETLANDS
CONVENTION SUR LES ZONES HUMIDES
CONVENCIÓN SOBRE LOS HUMEDALES
This is to certify that
*Ingula Nature Reserve*
has been designated as a
Wetland of International Importance
and has been included in the
List of Wetlands of International Importance
established by Article 2.1 of the Convention.
This is site No: 2446
Date of designation: *01 March 2021*
Martha Rojas Urrego
Secretary General
Convention on Wetlands

*Ramsar certificate*

# ROD AND ENVIRONMENTAL MANAGEMENT PLANS COMPLIANCE MONITORING

*Audits are conducted regularly by a contracted external auditor on the Ingula project, focusing on the RoD (Record of Decision), the Water Use Licence, the Operational Environmental Management Plan and the Reserve Management Plan. Results are shared with the Department of Environment, Forestry and Fisheries, Peaking Division management, funders, and other interested and affected parties.*

The establishment of a certified ISO 14001 management system, covering the construction and conservation elements of the project, contributes significantly to the management of environmental issues at Ingula. The system facilitates the proactive identification of environmental impacts and ensures that all issues are addressed. It is a system that has received national acclaim.

*The Oribi is a welcome sight at Ingula, especially because it is an* Endangered *(threat status) antelope* PHOTO BY ANTON MYBURGH

# BIOMONITORING

*Biomonitoring gives an indication of whether or not pollution has entered a river or stream. It is a useful tool in determining whether the construction of the dams and operation of the station have had any impact on the surrounding water systems.*

To provide thorough coverage of the site, a methodology, developed by the South African Bureau of Standards, was employed. Consequently, there is one sampling point above the Bedford Dam and two in the wetland below it, as well as one point above the Bramhoek Dam and one below it. Sampling began before construction started and will continue indefinitely.

Some minor concerns have been raised during the monitoring period, but there have been no significant impacts to date on the system as a result of construction or system operation. Biomonitoring continues to be assessed on site and the results have aided Eskom in carrying out corrective environmental management.

The value of the biomonitoring further reaffirms that the objectives of the Partnership Steering Committee are met and that overall environmental management and monitoring are aligned. Eskom continues to be compliant to all conditions of the RoD and EMP.

LEFT: *Undergoing SASS5 aquatic biomonitoring (aquatic macro invertebrates). (How healthy are the bugs/nunus in this system?)* PHOTO BY MALCOLM DRUMMOND



TOP: *'Electrofishing' on the Bramhoek Spruit to establish the fish species present, their health and abundance*

ABOVE LEFT: *Checking the on-site water chemistry: pH, dissolved oxygen, temperature, etc.*

ABOVE RIGHT: *Measuring turbidity/water clarity (all three images taken on the Bramhoek Spruit)*
PHOTOS BY MALCOLM DRUMMOND

# COMMUNICATIONS

*The Ingula Visitors Centre opened its doors in May 2009 and has been hosting approximately 5 000 visitors a year. The face-to-face interaction with visitors provides a hands-on experience of power generation and of all the nature conservation efforts at Ingula. Most noticeable has been the interest shown by local schools and universities that have attended site visits.*

The *Ingula Update* newsletter has continued to get positive responses from its readers. The publication contains articles covering construction, and social and environmental issues that inform all interested parties of the current status of the project (about 60 issues have so far been published).

The first World Wetlands Day event was held in February 2010 and has since become an annual event, growing in popularity every year. It includes a choice of guided hikes through the wetlands, as well as on- and off-site presentations designed to raise awareness of the importance of wetlands and their conservation.

A photographic competition was launched in 2011 and invited entries from anyone working at Ingula or associated with it to submit images taken on the site or in the vicinity. It ran for a number of years during the construction phase of the project, becoming an annual institution, with high-quality submissions and photographs that were used to produce an annual calendar.

A number of fact sheets have been generated and these are available at the Visitors Centre. Many of the topics are relevant to the Ingula Partnership and cover such subjects as the Ingula Partnership, BirdLife South Africa, Middelpunt Wetland Trust, the White-winged Flufftail, fossil finds and wetlands. In addition, the Communications team has produced a range of posters, many with environmental themes, such as snakes, reptiles, mammals, invasive plants and birds found on the Ingula property.

OPPOSITE TOP: *The Visitors Centre at Ingula*
PHOTO BY FIFI MEYER

OPPOSITE BOTTOM: *The centre has hosted and enlightened many thousands of visitors, a high percentage of whom have been schoolchildren*
PHOTO BY NONHLANHLA SHEZI



The Ingula project and its many facets have also been captured in a series of videos that are shared at the Visitors Centre and are also available on the Eskom website. Topics include construction of the scheme and its operation, conservation, the Ingula Partnership and the notable fossil finds made on site.

A broad range of communication initiatives has raised awareness of the Ingula Partnership and its objectives. These have included television inserts, radio interviews, print media articles and a stand at the annual African Bird Fair in Johannesburg. A presentation about Ingula and the Partnership was made at the African Hydro Symposium, held in 2011 at the Champagne Sports Resort in KwaZulu-Natal. Further international awareness of Ingula was created when the same symposium was held at Ingula in 2016.

# CONCLUSION

*It may have been easy in 2000 to say that this was a convenient way for Eskom and two NGOs to circumvent the EIA process with a 'greenwash', as was suggested by many passionate opponents of the pumped storage scheme when it was initially proposed.*

Although it took another four years for the Partnership to be formally proclaimed, an unambiguous understanding and statement of its objectives had already been formulated. The clearest of these was Eskom's commitment to purchase about 8 000 hectares of farmland around the Bedford Chatsworth Wetland that would form the nucleus of a protected area and its long-term management. In addition, adjacent properties were purchased for the resettlement of families whose historical positioning would jeopardise the operation of the pumped storage scheme, or continue to pose an ecological threat to the effective management of critical wetlands. Furthermore, the importance of improving people's lives through progressing from a subsistence existence to one of sustainable farming needed to be the core of social development into the future.

Measuring up to an ideal that was generally met with scepticism by opposing factions, ranging from NGOs and academics to provincial and national departments, was never going to prove easy. However, the Partnership's long-established vision that 'The Ingula Nature Reserve is a sustainable and internationally acclaimed conservation area' has always been one of its prime goals.

The Ingula Partnership has no illusions about the Nature Reserve and Ramsar declarations being the final goals of its objectives and responsibilities. While both are visible and positive indicators of success, they are just a stepping-stone in a long path to ultimate success, which may possibly be considered as the preservation of sustainable catchments that can supply



*A golden, late-afternoon view of the Ingula escarpment*
PHOTO BY PIKKIE FISCHER

ecological services to both Eskom and society. Much has been achieved in terms of an unusually comprehensive understanding of the ecological values of a specific geographic area, especially as the core nature reserve area falls within South Africa's severely threatened high-altitude grassland biome.

The Ingula properties must be one of the most extensively studied areas in the country. As an extension from the original and comprehensive EIA studies, the Partnership has commissioned multiple additional investigations to collate a comprehensive baseline for the measurement of future changes.

A long-term belief of the Partnership has been that Ingula should be considered as a 'laboratory' for the furtherance of the understanding of the environment and its human interaction. There are no limitations to its participants: school interest groups, social (bird clubs and other natural history groups, for instance) and the entire spectrum of opportunities for further postgraduate studies.

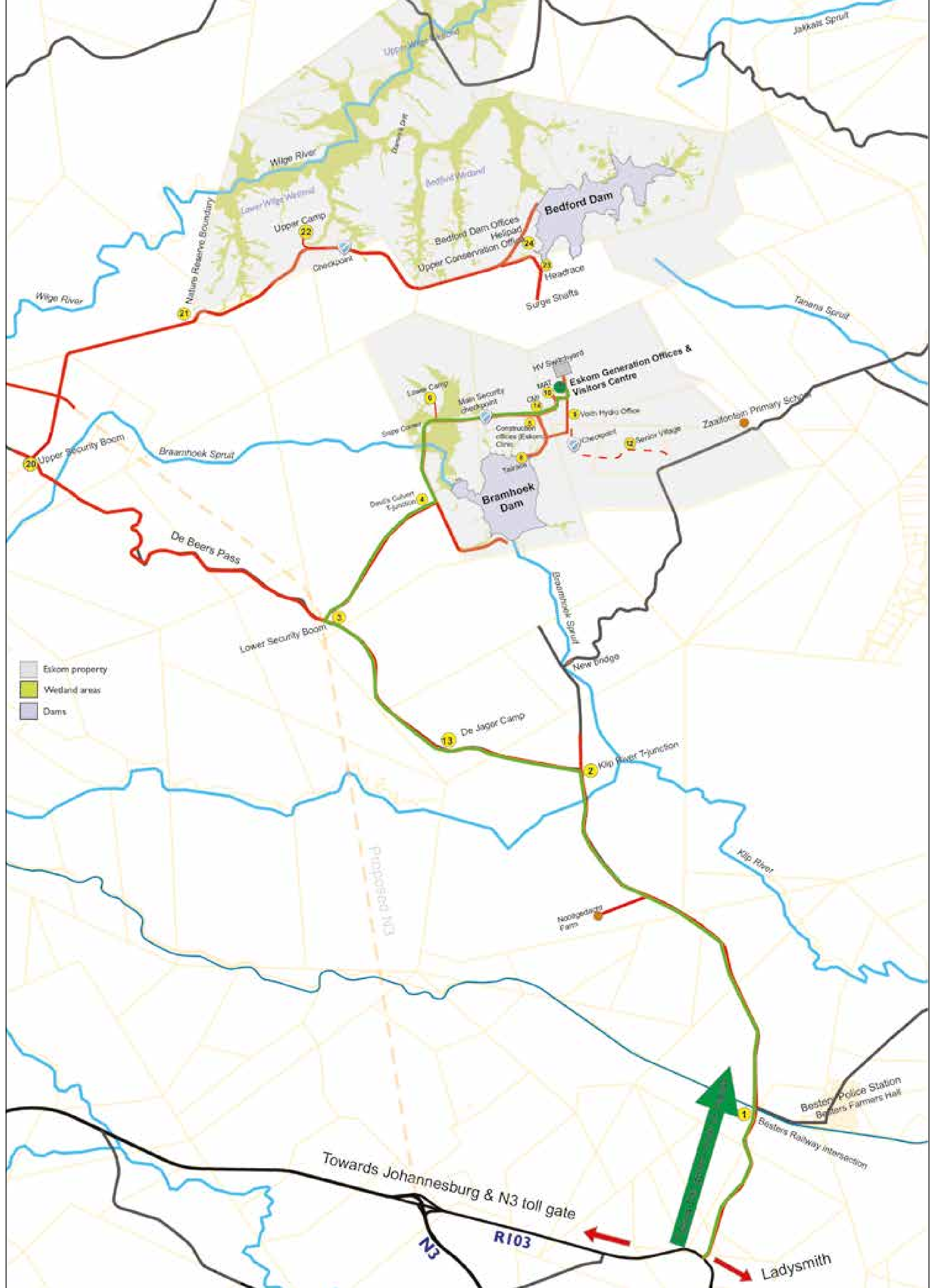
The Partnership's vision must always be balanced against the reality of its mission: 'To enable an environment in which a pumped storage scheme can operate sustainably and equitably in a conserved area supported through partnerships'. Ingula is generating 'peaking' power and is a flagship example of the melding of developmental necessity with environmental responsibility.

Limited eco-tourism, in the form of wetland walks and birdwatching, has already started at Ingula. Formalisation of the Nature Reserve and completion of construction now allow for the expansion of tourism activities, clearly demonstrating the value of the Partnership for the environment and for creating employment opportunities for local communities.

The Ingula Partnership has evolved through an invaluable learning process of respect, trust, understanding, collaboration and friendship. A determination to meet its objectives has become a hallmark of the Partnership and will surely characterise future successes. It has already proved that a major industrial development and NGOs can effectively work together for the benefit of the environment, the local communities and the economy as a whole. It is hoped that the Ingula Partnership will serve as a model for other developments in South Africa and elsewhere in the world.

*A mystical sunrise over Bramhoek Dam*
PHOTO BY FRIKKIE HITGE

*One Wattled Crane accompanying a host of Blue Cranes. All three crane species breed at Ingula*
PHOTO BY FIFI MEYER






# APPENDIX A

## Map of Ingula

### *Ingula map descriptions*

| NO | DESCRIPTION | STATUS |
|---|---|---|
| 1 | Besters railway intersection | Permanent feature |
| 2 | Klip River T-junction | Permanent feature |
| 3 | Lower security boom | Permanent feature |
| 4 | Devil's Culvert T-junction | Permanent feature |
| 5 | Clinic, helipad and offices | Some to remain, most removed and rehabilitated |
| 6 | Lower labour camp | Removed and rehabilitated |
| 7 | Eskom offices and Visitors Centre | Permanent feature |
| 8 | Tailrace | Permanent feature |
| 9 | Contractors' offices | Removed and rehabilitated |
| 10 | Main access tunnel | Permanent feature |
| 12 | Senior staff village | Removed and rehabilitated |
| 13 | Road contractor's camp | Removed and rehabilitated |
| 14 | Main contractor's offices | Removed and rehabilitated |
| 20 | Upper security boom | Removed and rehabilitated |
| 21 | Nature reserve boundary | Permanent feature |
| 22 | Upper labour camp | Removed and rehabilitated |
| 23 | Headrace | Permanent feature |
| 24 | Upper environmental and contractors' offices and helipad | Environmental offices to remain |

This map was produced during the construction phase of the project. Most of the buildings have been removed. Rehabilitation across the site has been meticulously undertaken and, in most cases, no visible sign of construction-phase disturbances (buildings, storage yards, temporary roads, etc.) remains.

*The photographic 'golden hour' of late-afternoon light: a view across Bramhoek Dam to the escarpment*
PHOTO BY FRIKKIE HITGE

OPPOSITE: *Map created during the construction phase at Ingula*

# APPENDIX B

## Interesting Facts

The construction of Ingula was a major undertaking, comparable in size and complexity to any in South Africa. Its extent is certainly not apparent to any passing observer. Yes, there are two dams, each with its associated waterways, and impressive enough in themselves. However, the major extent of the project is out of sight, underground.

A wealth of facts is contained in this appendix, many of them of really surprising proportions. As this book will be read by people with diverse interests, much of the following information will be of more interest to those with construction and engineering involvement. A list of generally interesting facts features at the end of the appendix.

*Underground*

During construction of the underground power station complex, 1 150 000m³ of rock was excavated and 390 000m³ of concrete was used. Approximately 17 500 tons of reinforcing steel were used in the concrete, and 75 000 rock bolts inserted. If all the reinforcing bars were laid out end-to-end, they would stretch for 7,6 million km - enough to circumnavigate the earth at the equator 189 times.

*Bedford Dam and Intake Canal*

The dam wall is 810 metres long, 39 metres high, and is a concrete-faced rock-fill type embankment. The total rock-fill comprises 1 050 000m³ of sandstone, quarried from inside the dam basin. The capacity of the dam is 23 million m³ at full supply, with a surface area of 255 hectares.

Water is channelled to the intake structure via an 840m canal with a trapezoidal profile. The canal varies in depth from 5 to 15,45m. Two control towers are situated at the end of the canal and contain the intake gates and stop-logs. The canal is concrete lined and the slopes are protected by placed rip-rap.

*Bramhoek Dam*

The dam wall is a roller-compacted concrete (RCC) embankment. During construction, 67 000m³ of RCC was used and a further 81 800m³ of concrete. The dam wall is 335m long and 31,1m high. The surface area is 240 hectares and it holds 26,26 million m³ of water, of which 19 million m³ is the live volume used for generation. The Bramhoek Spruit was impounded on 10 April 2010.

*Quarry*

Aggregate required for concrete was mined from within the basin of Bramhoek Dam. A total of 2 600 000 tons of dolerite was blasted and crushed from May 2007 to September 2010.

The crushing plant supplied an average of 5 400 tons of aggregate a day. The plant produced all the required sizes of aggregate for the construction of Ingula, from 900mm rip-rap to sand. The crushing machines used were Osborne and Metso crushers, which crushed up to 350 tons of rock per hour.

To mine these huge quantities of rock, around 700 000 tons of explosives were used to fracture the rock into suitable sizes for its intended purpose. A water-based, gel-emulsion explosive was used.

*Mechanical Aspects*

The four reversible Francis-type turbine sets are designed to generate a rated output of 333MW each at 428rpm, and to pump against a maximum head of 441m.

*Operational efficiency*

Losses during pumping and generation mean that the scheme requires about 1,36 units of pumping energy for each unit generated. As the same plant is used for pumping and generation, the maximum theoretical load factor for generation is approximately 72%.



## Technical data

| | | |
|---|---|---|
| **1. Bedford Dam (upper reservoir)** | | |
| *Structural and reservoir information* | | |
| 1.1 | Full supply level (FSL) | 1 738,6masl |
| 1.2 | Spillway crest level | 1 740,6masl |
| 1.3 | River bed level | 1 701,0masl |
| 1.4 | Length of spillway | 80m |
| 1.5 | Max water depth at full supply level | 37,6m |
| 1.6 | Maximum storage volume | 22,43 million m³ |
| 1.7 | Minimum storage volume (dead volume) | 3,28 million m³ |
| 1.8 | Total wall length | 773m |
| 1.9 | Type of dam wall | Concrete-faced rock fill |
| 1.10 | Rock fill volume | 982 000m³ |
| 1.11 | Concrete volume | 73 000m³ |
| 1.12 | Surface area at FSL | 255ha |
| 1.13 | Capacity at lowest drawdown level (LDL) | 3,230 million m³ |
| 1.14 | Reservoir volume at non-overspill crest | 28,0 million m³ |
| *Emergency spillway and outlets* | | |
| 1.15 | Design capacity | 240m³/s |
| 1.16 | Outlet capacity at FSL | 71,2m³/s |
| 1.17 | Outlet capacity at LDL | 52,2m³/s |
| 1.18 | Peak pumping inflow | 348m³/s |
| 1.19 | Peak generating outflow | 240,9m³/s |
| **2. Bramhoek Dam (lower reservoir)** | | |
| 2.1 | Full supply level | 1 270masl |
| 2.2 | Non-overspill crest level | 1 274,60masl |
| 2.3 | River-bed level | 1 243,50masl |
| 2.4 | Lowest foundation level | 1 236masl |
| 2.5 | Max height above lowest foundation | 38,6m |
| 2.6 | Max height above river bed | 31,1m |
| 2.7 | Max water depth at FSL | 26,0m |
| 2.8 | Total concrete volume | 81 800m³ |
| 2.9 | Roller-compacted concrete (RCC) volume | 67 000m³ |
| 2.10 | Gross capacity at FSL | 26 262 000m³ |
| 2.11 | Surface area at FSL | 240ha |
| 2.12 | Reservoir volume at safety evaluation flood | 38 470 000m³ |
| 2.13 | Maximum storage volume | 26,26 million m³ |
| 2.14 | Minimum storage volume (dead volume) | 4,34 million m³ |
| 2.15 | Total wall length | 335m |
| 2.16 | Spillway length | 40m |
| 2.17 | Spillway crest level | 1 270,5m |
| *Flood hydrology: Catchment data* | | |
| 2.18 | Catchment area of dam | 60,11km² |
| 2.19 | Mean annual precipitation | 1 053mm |
| **3. Intake channel & tower** | | |
| 3.1 | Channel profile | Trapezoidal |
| 3.2 | Base width | 25m to 49,27m |
| 3.3 | Depth | From 5m to 15,45m |
| 3.4 | Length | 840m |
| 3.5 | Tower height | 49m (16 storeys) |
| 3.6 | Intake gates and stoplogs | 6,6m high x 5,5m wide (2 tunnels) |
| **4. Headrace tunnels** | | |
| 4.1 | Number | 2 |
| 4.2 | Internal diameter | 6,6m concrete-lined and 5,1m steel-lined |
| 4.3 | Length up to surge shaft | 1 061m for tunnels 1 & 2 and 1 058m for tunnels 3 & 4 |
| 4.4 | Type of construction | Concrete-lined for 873m for the 4 tunnels, thereafter steel lined |
| 4.5 | Maximum flow velocity in concrete-lined section | 5m/s at rated generating flow<br>7,3m/s at generating start-up (transient) |
| 4.6 | Maximum flow velocity in steel-lined section | 8,3m/s at rated generating flow<br>12,3m/s at generating start-up (transient) |

### 5. Headrace surge shafts

| | | |
|---|---|---|
| 5.1 | Number | 2 |
| 5.2 | Type | Cylindrical |
| 5.3 | Internal diameter | 16,5m |
| 5.4. | Height | 191m |

### 6. Pressure inclined shafts and tunnels

| | | |
|---|---|---|
| 6.1 | Number | 2 |
| 6.2 | Internal diameter | 5,1m to bifurcation, then 3,6m to reducer, thereafter 2,5m to spiral |
| 6.3 | Length (from surge shaft up to spiral inlet) | 1 081m |
| 6.4 | Type of construction | Steel lined |
| 6.5 | Maximum flow velocity | Rated generating flow from 8,3m/s to 17,3m/s |

### 7. Underground power station

| | | |
|---|---|---|
| 7.1 | Number of machines | 4 |
| 7.2 | Continuous rating of each machine for generation | 333MW |
| 7.3 | Maximum power for pumping per machine | 360MW |
| 7.4 | Range of net head for generation | 433,6m to 465,8m |
| 7.5 | Head range for pumping | 462m to 489,7m |
| 7.6 | Rated generating flow per machine | 84,9m³/s |
| 7.7 | Maximum permissible pressure in penstocks | 7,22MPa |
| 7.8 | Type of pump-turbine | Single-stage, reversible Francis |
| 7.9 | Rated speed for both directions of rotation | 428,6rpm |
| 7.10 | Method of pump starting | Static frequency converter |
| 7.11 | Type of control | Local and remote |
| 7.12 | Machine Hall Cavern | 183m x 26m x 48,75m high to machine pit, 55,5m to drainage gallery |
| Distance from inlet to outlet | | 4,7km |
| Distance from dam wall to dam wall | | 8km |

### 8. Tailrace surge chambers

| | | |
|---|---|---|
| 8.1 | Number | 2 |
| 8.2 | Type | Cylindrical |
| 8.3 | Internal diameter | 20m |
| 8.4 | Height | 109,3m |

### 9. Tailrace tunnel

| | | |
|---|---|---|
| 9.1 | Number | 1 |
| 9.2 | Internal diameter | 9,4m |
| 9.3 | Length | 2 340m |
| 9.4 | Type of construction | Concrete lined |
| 9.5 | Maximum flow velocity | 4,9m/s at rated generating flow<br>7,7m/s at generating start up (transient) |

### 10. Outlet channel & tower

| | | |
|---|---|---|
| 10.1 | Channel Profile | Trapezoidal |
| 10.2 | Base width | 50m |
| 10.3 | Depth | From 5m to 21m |
| 10.4 | Length | 500m |
| 10.5 | Tower height | 43m |
| 10.6 | Outlet stoplogs | 10m high x 4,5m wide (2 openings) |

### 11. Operating data

| | | |
|---|---|---|
| 11.1 | Maximum energy storage capacity | 21GWh |
| 11.2 | Time required to pump live volume from lower to upper reservoir | 20 hours |
| 11.3 | Type of cycle for operation | Weekly |
| 11.4 | Cycle efficiency | 78 per cent |

### 12. Electrical Aspects

| | | |
|---|---|---|
| 12.1 | Rated voltage | 420kV |
| 12.2 | Rated frequency | 50Hz |
| 12.3 | Lightning surge voltage, 1,2/50s | 1 425kV |
| 12.4 | Switching surge voltage, 25/2 250s | 1 050kV |
| 12.5 | AC voltage, 50Hz/min | 630kV |
| 12.6 | Rated current | 2 500A |

### 13. Short-circuit current

| | | |
|---|---|---|
| 13.1 | Symmetrical | 31,5kA |
| 13.2 | Asymmetrical | 38,6kA |
| 13.3 | Single-phase-to-earth-fault | 36,2kA |
| 13.4 | Making current, peak value | 92,4kA |

### 14. Construction

| | | |
|---|---|---|
| 14.1 | Construction commenced | 2006 |
| 14.2 | Construction completed | 2016 |

### 15. Commissioning (synchronised to the grid)

| | | |
|---|---|---|
| 15.1 | Unit 1 | 30 October 2016 |
| 15.2 | Unit 2 | 21 May 2016 |
| 15.3 | Unit 3 | 6 March 2016 |
| 15.4 | Unit 4 | 24 March 2016 |

### ADDITIONAL INFORMATION

| | |
|---|---|
| Total weight of a unit | Rotating mass ± 530t |
| Turbine shaft diameter | 410mm |
| Turbine shaft length | 5 000mm |
| Turbine shaft weight | ± 44t |
| Diameter of a runner | 170mm |
| Weight of a runner | ± 28t |
| Guide vanes statistics | 19 wicket gates/guide vanes: ± 1t each |
| Pump rate during pump mode | ± 63,8 - 68,1m³/s, high head to low head |
| Flow rate during gen mode | ±85m³/s per unit |
| Rotor weight | 406t |
| Rotor poles | 14 poles at ±12t each |
| Stator | ±180 000 plates per rotor |
| Time to stack | 6 weeks |
| Stator weight | ±380t |
| Stator & Rotor Lifting Beam weight | ±34t |
| Cabling | 400kV |
| Capacity of cranes on the turbine operating floor | 2 x 265t, 1 x 12t and 2 x 8t |
| Main inlet valves (4) | 135t each, inlet diameter of |
| | 2,5m inlet diameter |
| | 4,5m wide |
| | 3,5m long |

### Brief, interesting facts

- Total generating capacity: 1 332MW (4 x 333MW units)
- Energy storage capacity: 16 hours (21 000MWh)
- The main access tunnel is 1,4km in length with a 1:10 gradient
- The underground power station is 115m below the entrance to the main access tunnel and 350m below the top of the mountain
- At peak flow, the equivalent volume of eight Olympic-sized swimming pools will pass through the turbines every minute
- Fossils uncovered during construction are around 255 million years old: much older than the dinosaurs
- Four of South Africa's *Critically Endangered* bird species occur in the conservation area (White-winged Flufftail, Wattled Crane, White-backed Vulture and Bearded Vulture)
- Ingula is the largest privately-owned nature reserve in South Africa and the only one that crosses a provincial boundary
- The Ingula Partnership won the Stewardship category of the 2019 South African Wetland Awards
- More than 2,5 million tons of rock were excavated from the underground works
- The quarry produced 2,6 million tons of aggregate
- The concrete works were reinforced by 3 600 tons of steel
- Almost 17 kilometres of tunnels were constructed, of which eight are waterways
- 450 000m³ of concrete was used
- Over three kilometres of steel lining was manufactured on site, weighing 15 000 tons
- Over 18 kilometres of welds were done on the steel linings, weighing 96 tons
- Time spent on welding the steel linings was 94 000 man hours
- 700 000 welding rods were used for the steel linings
- A total of 22 700 tons of reinforcing was installed
- If all of the reinforcing bars were laid out end-to-end, it would stretch for 7,6 million km - enough to circumnavigate the earth, at the equator, 189 times
- The difference in altitude between the upper and lower dam is 441 metres.

### Key abbreviations

| | | |
|---|---|---|
| masl | = | metres above sea level |
| MW | = | Megawatt |
| GWh | = | Gigawatt hours (1GW=1000MW) |
| MPa | = | Megapascals |
| m3 | = | cubic metres |
| rpm | = | revolutions per minute |

# INTRODUCTION TO APPENDICES C AND D

## The Birds of Ingula and Ingula's Biodiversity

The Ingula Nature Reserve, of approximately 8 000ha, has been extensively researched, studied and observed over a period of 15 years. During this time, many people have taken part in formally recording a broad range of species, especially the three BirdLife South Africa project managers (David Maphisa, Robin Colyn and Carina Pienaar), as well as Eskom environmental officers and interested contractor staff. The bird list of more than 340 species is one of which any property would be proud and is sure to grow over the years. The threat status of birds is taken from *The 2015 Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland*.

Most of the species in the Biodiversity List have also been recorded by field observation. Because of having been recorded by various methods, field observations were not included in the 'Method of record' column of this table to avoid confusion. If this column is blank for a particular species, this indicates that the species was only recorded by field observation and not during a specific study.

Threat statuses for biodiversity have been obtained from:

- Mammals: *2016 Mammal Red List of South Africa, Lesotho and Swaziland* (Endangered Wildlife Trust)
- Butterflies: *South African Red Data Book: butterflies* (South African National Biodiversity Institute [SANBI], 2009)
- Plants: *Red List of South African Plants* (SANBI, 2020)
- Reptiles: *Atlas and Red List of the Reptiles of South Africa, Lesotho and Swaziland* (SANBI, 2014).

It has been a long-held belief of the Partnership that Ingula should be considered as a 'laboratory' for the furtherance of the understanding of the environment and its human interaction. There are no limitations to its participants: school interest groups, social (bird clubs and other natural history groups, for instance) and the entire spectrum of opportunities for further postgraduate studies.



# APPENDIX C

## The Birds of Ingula

| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Apalis, Bar-throated | Apalis thoracica | LC | | | |
| Babbler, Arrow-marked | Turdoides jardineii | LC | | | |
| Barbet Black-collared | Lybius torquatus | LC | | | |
| Barbet, Acacia Pied | Tricholaema leucomelas | LC | | | |
| Barbet, Crested | Trachyphonus vaillantii | LC | | | |
| Batis, Cape | Batis capensis | LC | | | Yes |
| Batis, Chinspot | Batis molitor | LC | | | |
| Bee-eater, Blue-cheeked | Merops persicus | LC | | | |
| Bee-eater, Little | Merops pusillus | LC | | | |
| Bishop, Southern Red | Euplectes orix | LC | | | |
| Bishop, Yellow | Euplectes capensis | LC | | | |
| Bishop, Yellow-crowned | Euplectes afer | LC | | | |
| Bittern, Eurasian | Botaurus stellaris | LC | | | Yes |
| Bittern, Little | Ixobrychus minutus | LC | | | |
| Blackcap, Bush | Lioptilus nigricapillus | VU | SLS | Yes | |
| Bokmakierie | Telophorus zeylonus | LC | | | |
| Boubou, Southern | Laniarius ferrugineus | LC | | | Yes |
| Brownbul, Terrestrial | Phyllastrephus terrestris | LC | | | Yes |
| Brubru | Nilaus afer | LC | | | |
| Bulbul, Dark-capped | Pycnonotus tricolor | LC | | | Yes |
| Bunting, Cape | Emberiza capensis | LC | | | |
| Bunting, Cinnamon-breasted | Emberiza tahapisi | LC | | | |
| Bunting, Golden-breasted | Emberiza flaviventris | LC | | | Yes |
| Bunting, Lark-like | Emberiza impetuani | LC | | | |
| Bush-shrike, Grey-headed | Malaconotus blanchoti | LC | | | |
| Bush-shrike, Olive | Chlorophoneus olivaceus | LC | | | |
| Bush-shrike, Orange-breasted | Chlorophoneus sulfureopectus | LC | | | |
| Bustard, Black-bellied | Lissotis melanogaster | LC | | | |
| Bustard, Denham's | Neotis denhami | VU | | Yes | |
| Buttonquail, Black-rumped | Turnix nanus | EN | | | |
| Buttonquail, Kurrichane | Turnix sylvaticus | LC | | | |
| Buzzard, Common (Steppe) | Buteo buteo | LC | | | |

| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Buzzard, European Honey | Pernis apivorus | LC | | | |
| Buzzard, Forest | Buteo trizonatus | LC | SLS | | |
| Buzzard, Jackal | Buteo rufofuscus | LC | NE | | |
| Camaroptera, Green-backed | Camaroptera brachyura | LC | | | |
| Canary, Black-throated | Crithagra atrogularis | LC | | | |
| Canary, Brimstone | Crithagra sulphurata | LC | | | |
| Canary, Cape | Serinus canicollis | LC | NE | | |
| Canary, Forest | Crithagra scotops | LC | SLS | | Yes |
| Canary, Yellow-fronted | Crithagra mozambica | LC | | | |
| Chat, Anteating | Myrmecocichla formicivora | LC | | | |
| Chat, Buff-streaked | Campicoloides bifasciatus | LC | SLS | | |
| Chat, Familiar | Oenathe familiaris | LC | | | |
| Chat, Mocking Cliff | Thamnolaea cinnamomeiventris | LC | | | |
| Chat, Sickle-winged | Emarginata sinuata | LC | NE | | |
| Cisticola Wing-snapping | Cisticola ayresii | LC | | | |
| Cisticola, Cloud | Cisticola textrix | LC | | | |
| Cisticola, Croaking | Cisticola natalensis | LC | | | |
| Cisticola, Lazy | Cisticola aberrans | LC | | | |
| Cisticola, Levaillant's | Cisticola tinniens | LC | | | |
| Cisticola, Pale-crowned | Cisticola cinnamomeus | LC | | | |
| Cisticola, Rattling | Cisticola chiniana | LC | | | |
| Cisticola, Wailing | Cisticola lais | LC | | | |
| Cisticola, Zitting | Cisticola juncidis | LC | | | |
| Coot, Red-knobbed | Fulica cristata | LC | | | |
| Cormorant, Reed | Microcarbo africanus | LC | | | Yes |
| Cormorant, White-breasted | Phalacrocorax lucidus | LC | | | |
| Courser, Bronze-winged | Rhinoptilus chalcopterus | LC | | | |
| Courser, Temminck's | Cursorius temminckii | LC | | | |
| Crake, African | Crex egregia | LC | | | |
| Crake, Baillon's | Porzana pusilla | LC | | | |
| Crake, Black | Amaurornis flavirostra | LC | | | Yes |
| Crake, Corn (Corncrake) | Crex crex | LC | | | Yes |

**Appendix C The Birds of Ingula continued**

| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Crake, Spotted | Porzana porzana | LC | | | Yes |
| Crane, Blue | Grus paradisea | NT | NE | Yes | |
| Crane, Grey Crowned | Balearica regulorum | EN | | Yes | Yes |
| Crane, Wattled | Grus carunculata | CR | | Yes | Yes |
| Crombec, Long-billed | Sylvietta rufescens | LC | | | |
| Crow, Cape | Corvus capensis | LC | | | |
| Crow, Pied | Corvus albus | LC | | | |
| Cuckoo, African | Cuculus gularis | LC | | | |
| Cuckoo, Black | Cuculus clamosus | LC | | | |
| Cuckoo, Diederik | Chrysococcyx caprius | LC | | | |
| Cuckoo, Klaas's | Chrysococcyx klaas | LC | | | |
| Cuckoo, Red-chested | Cuculus solitarius | LC | | | |
| Cuckooshrike, Black | Campephaga flava | LC | | | Yes |
| Cuckooshrike, Grey | Ceblepyris caesius | LC | | | |
| Darter, African | Anhinga rufa | LC | | | |
| Dove, Cape Turtle- | Streptopelia capicola | LC | | | Yes |
| Dove, Laughing | Spilopelia senegalensis | LC | | | |
| Dove, Lemon | Columba larvata | LC | | | Yes |
| Dove, Namaqua | Oena capensis | LC | | | |
| Dove, Red-eyed | Streptopelia semitorquata | LC | | | |
| Drongo, Fork-tailed | Dicrurus adsimilis | LC | | | |
| Drongo, Square-tailed | Dicrurus ludwigii | LC | | | |
| Duck, African Black | Anas sparsa | LC | | | |
| Duck, Maccoa | Oxyura maccoa | NT | | | |
| Duck, White-backed | Thalassornis leuconotus | LC | | | |
| Duck, White-faced | Dendrocygna viduata | LC | | | |
| Duck, Yellow-billed | Anas undulata | LC | | | Yes |
| Eagle, African Fish | Haliaeetus vocifer | LC | | | |
| Eagle, Black-chested Snake | Circaetus pectoralis | LC | | | |
| Eagle, Booted | Hieraaetus pennatus | LC | | | |
| Eagle, Long-crested | Lophaetus occipitalis | LC | | | |
| Eagle, Martial | Polemaetus bellicosus | EN | | Yes | |
| Eagle, Tawny | Aquila rapax | EN | | | |
| Eagle, Verreaux's | Aquila verreauxii | VU | | | |
| Eagle, Wahlberg's | Hieraaetus wahlbergi | LC | | | |
| Egret, Great | Ardea alba | LC | | | |

| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Egret, Little | Egretta garzetta | LC | | | |
| Egret, Western Cattle | Bubulcus ibis | LC | | | |
| Egret, Yellow-billed (intermediate) | Ardea intermedia | LC | | | |
| Falcon, Amur | Falco amurensis | LC | | | |
| Falcon, Lanner | Falco biarmicus | VU | | Yes | |
| Falcon, Peregrine | Falco peregrinus | LC | | | |
| Falcon, Red-footed | Falco vespertinus | NT | | | |
| Finch, Cuckoo | Anomalospiza imberbis | LC | | | |
| Finch, Cut-throat | Amadina fasciata | LC | | | |
| Firefinch, African | Lagonosticta rubricata | LC | | | |
| Firefinch, Red-billed | Lagonosticta senegala | LC | | | |
| Fiscal, Common | Lanius collaris | LC | | | |
| Flamingo, Greater | Phoenicopterus roseus | NT | | | |
| Flufftail, Red-chested | Sarothrura rufa | LC | | | Yes |
| Flufftail, White-winged | Sarothrura ayresi | CR | | | |
| Flycatcher, African Dusky | Muscicapa adusta | LC | | | |
| Flycatcher African Paradise | Terpsiphone viridis | LC | | | |
| Flycatcher, Blue-mantled Crested | Trochocercus cyanomelas | LC | | | |
| Flycatcher, Fairy | Stenostira scita | LC | NE | | |
| Flycatcher, Fiscal | Melaenornis silens | LC | NE | | |
| Flycatcher, Pale | Melaenornis pallidus | LC | | | |
| Flycatcher, Southern Black | Melaenornis pammelaina | LC | | | |
| Flycatcher, Spotted | Muscicapa striata | LC | | | |
| Francolin, Grey-winged | Scleroptila afra | LC | SLS | | |
| Francolin, Red-winged | Scleroptila levaillantii | LC | | | |
| Francolin, Shelley's | Scleroptila shelleyi | LC | | | |
| Goose, Egyptian | Alopochen aegyptiaca | LC | | | |
| Goose, Spur-winged | Plectropterus gambensis | LC | | | Yes |
| Goshawk, African | Accipiter tachiro | LC | | | Yes |
| Goshawk, Gabar | Micronisus gabar | LC | | | |
| Grassbird, Cape | Sphenoeacus afer | LC | NE | | |
| Grebe, Little | Tachybaptus ruficollis | LC | | | |
| Greenbul, Sombre | Andropadus importunus | LC | | | |
| Greenshank, Common | Tringa nebularia | LC | | | |
| Guineafowl, Helmeted | Numida meleagris | LC | | | |
| Gull, Grey-headed | Chroicocephalus cirrocephalus | LC | | | |



| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Hamerkop | Scopus umbretta | LC | | | |
| Harrier, African Marsh- | Circus ranivorus | EN | | Yes | Yes |
| Harrier, Black | Circus maurus | EN | NE | | |
| Harrier, Montagu's | Circus pygargus | LC | | | |
| Harrier, Pallid | Circus macrourus | NT | | | |
| Harrier-Hawk, African | Polyboroides typus | LC | | | |
| Hawk, African Cuckoo | Aviceda cuculoides | LC | | | |
| Heron, Black-crowned Night- | Nycticorax nycticorax | LC | | | |
| Heron, Black-headed | Ardea melanocephala | LC | | | |
| Heron, Goliath | Ardea goliath | LC | | | |
| Heron, Grey | Ardea cinerea | LC | | | Yes |
| Heron, Purple | Ardea purpurea | LC | | | |
| Heron, Squacco | Ardeola ralloides | LC | | | |
| Honeybird, Brown-backed | Prodotiscus regulus | LC | | | |
| Honeyguide, Greater | Indicator indicator | LC | | | |
| Honeyguide, Lesser | Indicator minor | LC | | | Yes |
| Hoopoe, African | Upupa africana | LC | | | |
| Hornbill, Trumpeter | Bycanistes bucinator | LC | | | |
| Ibis, African Sacred | Threskiornis aethiopicus | LC | | | |
| Ibis, Glossy | Plegadis falcinellus | LC | | | |
| Ibis, Hadeda | Bostrychia hagedash | LC | | | Yes |
| Ibis, Southern Bald | Geronticus calvus | VU | SLS | Yes | |
| Indigobird, Dusky | Vidua funerea | LC | | | |
| Kestrel, Greater | Falco rupicoloides | LC | | | |
| Kestrel, Lesser | Falco naumanni | LC | | | |
| Kestrel, Rock (Common) | Falco rupicolus | LC | | | |
| Kingfisher, Brown-hooded | Halcyon albiventris | LC | | | |
| Kingfisher, Giant | Megaceryle maxima | LC | | | |
| Kingfisher, Half-collared | Alcedo semitorquata | NT | | Yes | |
| Kingfisher, Malachite | Corythornis cristatus | LC | | | Yes |
| Kingfisher, Pied | Ceryle rudis | LC | | | |
| Kite, Black | Milvus migrans | LC | | | |
| Kite, Black-shouldered | Elanus caeruleus | LC | | | |
| Kite, Yellow-billed | Milvus aegyptius | LC | | | |
| Korhaan, Blue | Eupodotis caerulescens | LC | SLS | | |
| Korhaan, Northern Black | Afrotis afraoides | LC | | | |

| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Korhaan, White-bellied | Eupodotis senegalensis | VU | | Yes | |
| Lapwing, African Wattled | Vanellus senegallus | LC | | | |
| Lapwing, Blacksmith | Vanellus armatus | LC | | | |
| Lapwing, Black-winged | Vanellus melanopterus | LC | | Yes | |
| Lapwing, Crowned | Vanellus coronatus | LC | | | |
| Lark, Red-capped | Calandrella cinerea | LC | | | |
| Lark, Chestnut-backed Sparrow- | Eremopterix leucotis | LC | | | |
| Lark, Eastern Long-billed | Certhilauda semitorquata | LC | SLS | | |
| Lark, Pink-billed | Spizocorys conirostris | LC | | | |
| Lark, Rudd's | Heteromirafra ruddi | EN | E | | |
| Lark, Rufous-naped | Mirafra africana | LC | | | |
| Lark, Sabota | Calendulauda sabota | LC | | | |
| Lark, Spike-heeled | Chersomanes albofasciata | LC | | | |
| Longclaw, Cape | Macronyx capensis | LC | | | |
| Mannikin, Bronze | Lonchura cucullata | LC | | | |
| Martin, Banded | Riparia cincta | LC | | | |
| Martin, Brown-throated | Riparia paludicola | LC | | | |
| Martin, Common House | Delichon urbicum | LC | | | |
| Martin, Rock | Ptyonoprogne fuligula | LC | | | |
| Martin, Sand | Riparia riparia | LC | | | |
| Moorhen, Common | Gallinula chloropus | LC | | | |
| Mousebird, Red-faced | Urocolius indicus | LC | | | |
| Mousebird, Speckled | Colius striatus | LC | | | |
| Myna, Common | Acridotheres tristis | LC | | | |
| Neddicky | Cisticola fulvicapilla | LC | | | |
| Nightjar, Fiery-necked | Nycticorax nycticorax | LC | | | Yes |
| Oriole, Black-headed | Oriolus larvatus | LC | | | |
| Osprey | Pandion haliaetus | LC | | | |
| Owl, African Grass | Tyto capensis | VU | | | Yes |
| Owl, African Wood | Strix woodfordii | LC | | | |
| Owl, Cape Eagle- | Bubo capensis | LC | | | |
| Owl, Marsh | Asio capensis | LC | | | |
| Owl, Spotted Eagle- | Bubo africanus | LC | | | |
| Owl, Westen Barn | Tyto alba | LC | | | |
| Oxpecker, Red-billed | Buphagus erythrorynchus | LC | | | |
| Petronia, Yellow-throated | Gymnoris superciliaris | LC | | | Yes |

**Appendix C The Birds of Ingula continued**

| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Pigeon, African Olive | Columba arquatrix | LC | | | |
| Pigeon, Speckled | Columba guinea | LC | | | |
| Pipit, African | Anthus cinnamomeus | LC | | | |
| Pipit, African Rock | Anthus crenatus | NT | SLS | | |
| Pipit, Buffy | Anthus vaalensis | LC | | | |
| Pipit, Nicholson's (Long-billed) | Anthus similis | LC | | | |
| Pipit, Plain-backed | Anthus leucophrys | LC | | | |
| Pipit, Striped | Anthus lineiventris | LC | | | |
| Pipit, Yellow-breasted | Anthus chloris | VU | E | Yes | |
| Plover, Common Ringed | Charadrius hiaticula | LC | | | |
| Plover, Kittlitz's | Charadrius pecuarius | LC | | | |
| Plover, Three-banded | Charadrius tricollaris | LC | | | |
| Pochard, Southern | Netta erythrophthalma | LC | | | |
| Prinia, Drakensberg | Prinia hypoxantha | LC | SLS | | |
| Prinia, Tawny-flanked | Prinia subflava | LC | | | |
| Puffback, Black-backed | Dryoscopus cubla | LC | | | |
| Quail, Common | Coturnix coturnix | LC | | | |
| Quail-finch, African | Ortygospiza atricollis | LC | | | |
| Quelea, Red-billed | Quelea quelea | LC | | | |
| Rail, African | Rallus caerulescens | LC | | | Yes |
| Raven, White-necked | Corvus albicollis | LC | | | |
| Robin, White-browed Scrub | Cercotrichas leucophrys | LC | | | |
| Robin-Chat, Cape | Cossypha caffra | LC | | | Yes |
| Robin-Chat, Chorister | Cossypha dichroa | LC | SLS | | Yes |
| Roller, European | Coracias garrulus | NT | | | |
| Ruff | Calidris pugnax | LC | | | |
| Sandpiper, Common | Actitis hypoleucos | LC | | | |
| Sandpiper, Marsh | Tringa stagnatilis | LC | | | |
| Sandpiper, Wood | Tringa glareola | LC | | | |
| Saw-wing, Black | Psalidoprocne pristoptera | LC | | | |
| Scimitarbill, Common | Rhinopomastus cyanomelas | LC | | | |
| Secretarybird | Sagittarius serpentarius | EN | | Yes | |
| Seedeater, Streaky-headed | Crithagra gularis | LC | | | |
| Shelduck, South African | Tadorna cana | LC | | | |
| Shoveler, Cape | Spatula smithii | LC | | | |
| Shrike, Lesser Grey | Lanius minor | LC | | | |

| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Shrike, Red-backed | Lanius collurio | LC | | | |
| Snipe, African | Gallinago nigripennis | LC | | | Yes |
| Sparrow, Cape | Passer melanurus | LC | | | |
| Sparrow, House | Passer domesticus | LC | | | |
| Sparrow, Southern Grey-headed | Passer diffusus | LC | | | |
| Sparrowhawk, Black | Accipiter melanoleucus | LC | | | |
| Sparrowhawk, Rufous-breasted | Accipiter rufiventris | LC | | | |
| Spoonbill, African | Platalea alba | LC | | | |
| Spurfowl, Natal | Pternistis natalensis | LC | | | Yes |
| Spurfowl, Swainson's | Pternistis swainsonii | LC | | | |
| Starling, Cape Glossy | Lamprotornis nitens | LC | | | |
| Starling, Pied | Lamprotornis bicolor | LC | SLS | | |
| Starling, Red-winged | Onychognathus morio | LC | | | |
| Starling, Violet-backed | Cinnyricinclus leucogaster | LC | | | Yes |
| Stilt, Blackwinged | Himantopus himantopus | LC | | | |
| Stint, Little | Calidris minuta | LC | | | |
| Stonechat, African | Saxicola torquatus | LC | | | Yes |
| Stork, Black | Ciconia nigra | VU | | | |
| Stork, Marabou | Leptoptilos crumenifer | NT | | | |
| Stork, Saddle-billed | Ephippiorhynchus senegalensis | EN | | | |
| Stork, White | Ciconia ciconia | LC | | | |
| Sunbird, Amethyst | Chalcomitra amethystina | LC | | | |
| Sunbird, Greater Double-collared | Cinnyris afer | LC | SLS | | |
| Sunbird, Malachite | Nectarinia famosa | LC | | | |
| Sunbird, Purple-banded | Cinnyris bifasciatus | LC | | | |
| Sunbird, Scarlet-chested | Chalcomitra senegalensis | LC | | | |
| Sunbird, Southern Double-collared | Cinnyris chalybeus | LC | NE | | |
| Sunbird, White-bellied | Cinnyris talatala | LC | | | |
| Swallow, Barn | Hirundo rustica | LC | | | |
| Swallow, Greater Striped | Cecropis cucullata | LC | | | |
| Swallow, Lesser Striped | Cecropis abyssinica | LC | | | |
| Swallow, South African Cliff- | Petrochelidon spilodera | LC | BSLS | | |
| Swallow, White-throated | Hirundo albigularis | LC | | | |
| Swamphen, African | Porphyrio madagascariensis | LC | | | |
| Swift, African Black | Apus barbatus | LC | | | |
| Swift, African Palm | Cypsiurus parvus | LC | | | |

TOP: *A Pin-tailed Whydah captured in mid-hover* PHOTO BY FRIKKIE HITGE
ABOVE: *Tundra in Bedford* PHOTO BY ALASTAIR CAMPBELL

| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Swift, Alpine | Tachymarptis melba | LC | | | |
| Swift, Common | Apus apus | LC | | | |
| Swift, Horus | Apus horus | LC | | | |
| Swift, Little | Apus affinis | LC | | | |
| Swift, White-rumped | Apus caffer | LC | | | |
| Tchagra, Black-crowned | Tchagra senegalus | LC | | | |
| Teal, Cape | Anas capensis | LC | | | |
| Teal, Hottentot | Spatula hottentota | LC | | | |
| Teal, Red-billed | Anas erythrorhyncha | LC | | | |
| Tern, Caspian | Hydropogne caspia | VU | | | |
| Tern, Whiskered | Chlidonias hybrida | LC | | | |
| Tern, White-winged | Chlidonias leucopterus | LC | | | |
| Thick-knee, Spotted | Burhinus capensis | LC | | | |
| Thrush, Cape Rock | Monticola rupestris | LC | SLS | | |
| Thrush, Groundscraper | Turdus litsitsirupa | LC | | | |
| Thrush, Karoo | Turdus smithi | LC | NE | | |
| Thrush, Kurrichane | Turdus libonyana | LC | | | |
| Thrush, Olive | Turdus olivaceus | LC | | | Yes |
| Thrush, Sentinel Rock | Monticola explorator | LC | SLS | | |
| Tinkerbird, Red-fronted | Pogoniulus pusillus | LC | | | |
| Tit, Southern Black | Melaniparus niger | LC | | | |
| Tit-Babbler, Layard's | Sylvia layardi | LC | NE | | |
| Vulture, Bearded | Gypaetus barbatus | CR | | Yes | |
| Vulture, Cape | Gyps coprotheres | EN | | | |
| Vulture, White-backed | Gyps africanus | CR | | | |
| Wagtail, African Pied | Motacilla aguimp | LC | | | |
| Wagtail, Cape | Motacilla capensis | LC | | | |
| Wagtail, Mountain | Motacilla clara | LC | | | |
| Warbler, African Reed | Acrocephalus baeticatus | LC | | | |
| Warbler, Barratt's | Bradypterus barratti | LC | NE | | |
| Warbler, Dark-capped Yellow | Iduna natalensis | LC | | | |
| Warbler, Great Reed | Acrocephalus arundinaceus | LC | | | |
| Warbler, Lesser Swamp | Acrocephalus gracilirostris | LC | | | |
| Warbler, Little Rush | Bradypterus baboecala | LC | | | |
| Warbler, Sedge | Acrocephalus schoenobaenus | LC | | | |
| Warbler, Willow | Phylloscopus trochilus | LC | | | |

| Common name | Scientific name | Threat Status | Endemism | Breeding monitoring undertaken | Recorded on camera traps |
|---|---|---|---|---|---|
| Warbler, Yellow-throated Woodland | Phylloscopus ruficapilla | LC | | | Yes |
| Waxbill, Blue | Uraeginthus angolensis | LC | | | |
| Waxbill, Common | Estrilda astrild | LC | | | Yes |
| Waxbill, Orange-breasted | Amandava subflava | LC | | | |
| Waxbill, Swee | Coccopygia melanotis | LC | NE | | |
| Weaver, Cape | Ploceus capensis | LC | NE | | |
| Weaver, Southern Masked- | Ploceus velatus | LC | | | |
| Weaver, Spectacled | Ploceus ocularis | LC | | | |
| Weaver, Thick-billed | Amblyospiza albifrons | LC | | | |
| Weaver, Village | Ploceus cucullatus | LC | | | |
| Wheatear, Mountain | Myrmecocichla monticola | LC | | | |
| White-eye, Cape | Zosterops virens | LC | NE | | Yes |
| Whydah, Pin-tailed | Vidua macroura | LC | | | |
| Widowbird, Fan-tailed | Euplectes axillaris | LC | | | |
| Widowbird, Long-tailed | Euplectes progne | LC | | | |
| Widowbird, Red-collared | Euplectes ardens | LC | | | |
| Widowbird, White-winged | Euplectes albonotatus | LC | | | |
| Wood-Hoopoe, Green | Phoeniculus purpureus | LC | | | |
| Woodpecker, Bearded | Chloropicus namaquus | LC | | | |
| Woodpecker, Cardinal | Dendropicos fuscescens | LC | | | |
| Woodpecker, Goldentailed | Campethera abingoni | LC | | | |
| Woodpecker, Ground | Geocolaptes olivaceus | LC | SLS | | |
| Woodpecker, Olive | Dendropicos griseocephalus | LC | | | |
| Wryneck, Red-throated | Jynx ruficollis | LC | | | |

**THREAT STATUS**
CR = *Critically Endangered*
EN = *Endangered*
VU = *Vulnerable*
NT = *Near Threatened*
LC = *Least Concern*

**ENDEMISM IN SOUTH AFRICA**
(not southern Africa as in field guides)
E = endemic
SLS = endemic to South Africa, Lesotho and Swaziland
NE = near endemic (i.e. ~70% or more of population in RSA)
BSLS = breeding South Africa, Lesotho and Swaziland endemic

# APPENDIX D

## Ingula's Biodiversity

| Common name | Scientific name | Threat status | Endemism | Method of record | Camera trap study |
|---|---|---|---|---|---|
| **ANTELOPES** | | | | | |
| Blesbok | Damaliscus pygargus phillipsi | LC | E | | |
| Bushbuck | Tragelaphus sylvaticus | LC | | CT | Grassland; Forest |
| Duiker, Common | Sylvicapra grimmia | LC | | CT | Grassland; Forest |
| Eland | Tragelaphus oryx | LC | | CT | Forest |
| Kudu | Tragelaphus strepsiceros | LC | | | |
| Oribi | Ourebia ourebi ourebi | EN | NE | CT | Grassland |
| Reedbuck, Common | Redunca arundinum | LC | | CT | Grassland |
| Reedbuck, Mountain | Redunca fulvorufula fulvorufula | EN | NE | CT | Grassland; Forest |
| Rhebuck, Grey | Pelea capreolus | NT | E | CT | Grassland |
| Steenbok | Raphicerus campestris | LC | | CT | Grassland |
| **CRUSTACEANS** | | | | | |
| Crab, Forest (unidentified) | | | | CT | Forest |
| **PREDATORS** | | | | | |
| Aardvark | Orycteropus afer | LC | | CT | Grassland |
| Aardwolf | Proteles cristata | LC | | CT | Forest |
| Badger, Honey | Mellivora capensis | LC | | CT | Grassland; Forest |
| Caracal | Caracal caracal | LC | | CT | Grassland; Forest |
| Genet, Large Spotted (Cape) | Genetta tigrina | LC | E | CT | Grassland; Forest |
| Leopard | Panthera pardus | VU | | CT | Grassland; Forest |
| Mongoose, Large Grey | Herpestes ichneumon | LC | | CT | Grassland; Forest |
| Mongoose, Slender | Herpestes sanguineus | LC | | CT | Grassland; Forest |
| Mongoose, Small Grey | Herpestes pulverulentus | LC | NE | CT | Grassland; Forest |
| Mongoose, Water | Atilax paludinosus | LC | | CT | Grassland; Forest |
| Mongoose, Yellow | Cynictis penicillata | LC | | CT | Grassland |
| Otter, Cape Clawless | Aonyx capensis | NT | | CT | Grassland |
| Otter, Spotted-necked | Hydrictis maculicollis | VU | | CT | Grassland |
| Polecat, Striped | Ictonyx striatus | LC | | CT | Grassland |
| Serval | Leptailurus serval | NT | | CT | Grassland; Forest |
| Weasel, African Striped | Poecilogale albinucha | NT | | CT | Grassland |
| **PRIMATES** | | | | | |
| Baboon, Chacma | Papio ursinus | LC | | CT | Grassland; Forest |
| Monkey, Vervet | Chlorocebus pygerythrus | LC | | CT | Grassland; Forest |

| Common name | Scientific name | Threat status | Endemism | Method of record | Camera trap study |
|---|---|---|---|---|---|
| **HARES** | | | | | |
| Hare, Scrub | Lepus saxatilis | LC | NE | CT | Grassland |
| **RODENTS** | | | | | |
| Gerbil, Highveld | Gerbilliscus brantsii | LC | | SMS | |
| Hyrax, Rock | Procavia capensis | LC | | CT | Grassland; Forest |
| Mole, Hottentot's Golden | Amblysomus hottentotus | LC | E | FO | |
| Mouse, Grey African Climbing | Dendromus melanotis | LC | | CT | Forest |
| Mouse, Multimammate | Mastomys spp. | LC | | SMS | |
| Mouse, Striped Field | Rhabdomys dilectus | LC | | CT, SMS | Forest |
| Porcupine | Hystrix africaeaustralis | LC | | CT | Grassland; Forest |
| Rat, African Water | | | | SMS | |
| Shrew, Forest | Myosorex varius | LC | E | SMS | |
| Shrew, Greater Red Musk | Crocidura flavescens | LC | NE | SMS | |
| Shrew, Lesser Dwarf | Suncus varilla | LC | | SMS | |
| Shrew, Reddish-grey Musk | Crocidura cyanea | LC | | SMS | |
| Shrew, Tiny Musk | Crocidura fuscomurina | LC | | SMS | |
| Shrew, unidentified | | | | CT | Forest; Wetland |
| Springhare | Pedetes capensis | LC | | CT | Grassland |
| **SCAVENGERS** | | | | | |
| Bushpig | Potamochoerus larvatus | LC | | CT | Grassland; Forest |
| Hyena, Brown | Parahyaena brunnea | NT | | CT | Grassland |
| Hyena, Spotted | Crocuta crocuta | NT | | CT | Grassland |
| Jackal, Black-backed | Canis mesomelas | LC | | CT | Grassland; Forest |
| Warthog | Phacochoerus africanus | LC | | CT | Forest |
| **AMPHIBIANS** | | | | CT | Forest |
| Frog, Clicking Stream | Strongylopus grayii | LC | | | |
| Frog, Common River | Amietia quecketti | LC | | | |
| Frog, Painted Reed | Hyperolius marmoratus | LC | | | |
| Frog, Rattling | Semnodactylus wealil | LC | | | |
| Frog, Snoring Puddle | Phrynobatrachus natalensis | LC | | | |
| Kassina, Bubbling | Kassina senegalensis | LC | | | |
| Toad, Guttural | Amietophrynus gutturalis | LC | | | |

*A Brown-veined White butterfly*
PHOTO BY ALASTAIR CAMPBELL





| Common name | Scientific name | Threat status | Endemism | Method of record | Camera trap study |
|---|---|---|---|---|---|
| **LIZARDS** | | | | | |
| Agama, Eastern Ground | Agama aculeata distanti | LC | E | | |
| Agama, Southern Rock | Agama atra | LC | NE | | |
| Chameleon, Common Flap-necked | Chamaeleo dilepis | LC | | | |
| Lizard, Cape Grass | Chamaesaura anguina | LC | E | | |
| Lizard, Delalande's Sandveld | Nucras lalandii | LC | E | | |
| Lizard, Drakensberg Crag | Pseudocordylus melanotus melanontus | LC | E | | |
| Lizard, Yellow-throated Plated | Gerrhosaurus flavigularis | LC | | CT | Forest |
| Seps, Breyer's Long-tailed | Trachydactulus breyeri | VU | E | | |
| Skink, Cape | Trachylepis capensis | LC | | | |
| Skink, Striped or Speckled Rock | Trachylepis punctatissima | LC | | | |
| **MONITORS** | | | | | |
| Monitor, Nile or Water | Varanus niloticus | LC | | CT | Forest |
| **SNAKES** | | | | | |
| Adder, Puff | Bitis arientans arientas | LC | | | |
| Adder, Rhombic Night | Causus rhombeatus | LC | | | |
| Cobra, Mozambique Spitting | Naja nivea | LC | | | |
| Rinkhals | Hemachatus haemachatus | LC | NE | | |
| Skaapsteker, Spotted (Striped morph) | Psammophylax rhombeatus rhombeatus | LC | | CT | Wetland |
| Snake, Aurora House | Lamprophis aurora | LC | E | | |
| Snake, Bibron's Blind | Typhlops bibronii | LC | NE | | |
| Snake, Brown House | Boaedon capensis | LC | | | |
| Snake, Common Brown Water | Lycodonomorphus rufulus | LC | | | |
| Snake, Cross-marked Grass | Psammophis crucifer | LC | NE | | |
| Snake, Dusky-bellied Water | Lycodonomorphus laevissimus | LC | E | | |
| Snake, Many-spotted (Green Morph) | Amplorhinus multimaculatus | LC | NE | | |
| Snake, Mole | Pseudapsis cana | LC | | | |
| Snake, Natal Green | Philothamnus natalensis occidentalis | LC | E | | |
| Snake, Olive Whip | Psammophis mossambicus | LC | | | |
| Snake, Rhombic Egg-eating | Dysypeltis scabra | LC | | | |
| Snake, Spotted Bush | Phylothamnus semivariegatus | LC | | | |
| Snake, Sundevall's Garter | Elapsoidea sudevalli | LC | | | |

| Common name | Scientific name | Threat status | Endemism | Method of record | Camera trap study |
|---|---|---|---|---|---|
| **BUTTERFLIES** | | | | | |
| Acraea, Dusky | Acraea eserbria | LC | | | |
| Acraea, Garden | Acraea horta | LC | | | |
| Acraea, Marsh | Telchinia rahira rahira | LC | | | |
| Acraea, Natal | Acraea natalica | LC | | | |
| Acraea, Orange | Telchinia anacreon anacreon | LC | NE | | |
| Acraea, Speckled Red | Acraea violarum | LC | | | |
| Acraea, Wandering Donkey | Acraea neobule neobule | LC | | | |
| Bar, Mozambique | Cigaritis mozambica | LC | | | |
| Beauty, Table Mountain | Aeropetes tulbaghia | LC | | | |
| Blue, Common Meadow | Cupidopsis cissus cissus | LC | | | |
| Blue, Cupreous | Eicochrysops messapus mahallakoaena | LC | NE | | |
| Blue, Dotted | Tarucus sybaris sybaris | LC | | | |
| Blue, Galka | Zizula hylax | LC | | | |
| Blue, Long-tailed | Lampedes boeticus | LC | | | |
| Blue, Natal Spotted | Azanus natalensis | LC | | | |
| Blue, Patrician | Lepidochrysops patricia | LC | | | |
| Blue, Sooty | Zizeeria knysna | LC | | | |
| Blue, Variable | Lepidochrysops varabilis | LC | | | |
| Border, Common Dotted | Mylothris agathina agathina | LC | | | |
| Bronze, Common Geranium | Cacyreus marshalli | LC | | | |
| Brown, False Silver-bottom | Pseudonympha magoides | LC | NE | | |
| Brown, Rainforest | Cassionympha cassius | LC | NE | | |
| Charaxes, Forest King | Charaxes xiphares xiphares | LC | E | | |
| Charaxes, Foxy | Charaxes jasius saturnus | LC | | | |
| Charaxes, Green-veined | Charaxes candiope candiope | LC | | | |
| Commodore, Garden | Junonia archesia | LC | | | |
| Commodore, Gaudy | Precis Octavia sesamus | LC | | | |
| Commodore, Marsh | Precis ceryne ceryne | LC | | | |
| Copper, Eastern Sorrel | Lycaena clarki | LC | NE | | |
| Copper, Giant Mountain | Aloeides pallida pallida | LC | E | | |
| Copper, Karoo Daisy | Chrysoritis chrysantas | LC | | | |
| Copper, Roodepoort | Aloides dentatis maseruna | LC | NE | | |

| Common name | Scientific name | Threat status | Endemism | Method of record | Camera trap study |
|---|---|---|---|---|---|
| Diadem, Common | Hypolimnas misippus | LC | | | |
| Eye, Common Black | Gonatomyrina gorgias gorgias | LC | | | |
| Flat, Western Large | Celaenorrhinus mokeezi mokeezi | LC | E | | |
| Hairtail, Black Striped | Anthene amarah amarah | LC | | | |
| Hottentot, Common | Gegenes niso niso | LC | | | |
| Joker, Common | Byblia antavara | LC | | | |
| Joker, Spotted | Byblia ilithyia | LC | | | |
| Lady, Painted | Vanessa cardui | LC | | | |
| Migrant, African | Catopsilia florella | LC | | | |
| Monarch, African | Danaus Chrysippus | LC | | | |
| Opal, Burnished | Chrysoritis chrysaor | LC | E | | |
| Pansy, Blue | Junonia oenone oenone | LC | | | |
| Pansy, Eyed | Junonia orithya madagascariensis | LC | | | |
| Pansy, Soldier | Junonia terea elgiva | LC | | | |
| Pansy, Yellow | Junonia hierta cebrene | LC | | | |
| Pie, Black | Tuxentius melaena melaena | LC | | | |
| Pirate | Catacroptera cloanthe cloanthe | LC | | | |
| Policeman, Striped | Coeliades forestan forestan | LC | | | |
| Protea, Orange-banded | Capys alphaenus extentus | LC | E | | |
| Protea, Russet | Capys disjuctus disjuntus | LC | | | |
| Ranger, Fulvous | Kedestes mohozutza | LC | | | |
| Ranger, Pale | Kedestes callicles | LC | | | |
| Ranger, Wallengren's | Kedestes wallengrenii wallengrenii | LC | | | |
| Rocksitter, Amakoza | Durbania amakosa amakosa | LC | E | | |
| Rocksitter, Natal | Durbania amakosa | LC | E | | |
| Sandman, Mountain | Spiacia spio | LC | | | |
| Scarlet, Common | Axiocerses tjoane | LC | | | |
| Swallowtail, Citrus | Princeps demodocus demodocus | LC | | | |
| Swallowtail, Emperor | Princeps ophidicephalus | LC | E | | |
| Swallowtail, Forest | Papilio euphranor | LC | E | | |
| Swallowtail, Green-banded | Papilio nireus nireus | LC | | | |
| Sylph, Gold-spotted | Metisella metis paris | LC | | | |
| Tip, Queen Purple | Colotis Regina | LC | | | |
| White, African Common | Belenois creona severina | LC | | | |
| White, Brown-veined | Belenois aurota aurota | LC | | | |
| White, Cabbage | Pieris brassicae | LC | | | |
| Yellow, Broad-bordered Grass | Eurema brigitta brigitta | LC | | | |

| Common name | Scientific name | Threat status | Endemism | Method of record | Camera trap study |
|---|---|---|---|---|---|
| **ORCHIDS AND PROTEAS** | | | | | |
| | Disa cooperi | LC | | | |
| Orchid, Golden | Disa cornuta | LC | | | |
| | Disa crassicornis | LC | | | |
| | Disa nervosa | LC | | | |
| | Disa oreophila | LC | | | |
| | Disa patula | LC | | | |
| | Disa polygonoides | LC | | | |
| | Disa stachyoides | LC | | | |
| | Disa tysonii | Rare | | | |
| Orchid, Pride of Table Mountain | Disa uniflora | LC | E | | |
| Orchid, Apple Blossom | Disa versicolor | LC | | | |
| Orchid, Hutton | Orthochilus aculeatus huttonii | LC | | | |
| Protea, Sugarbush (Common) | Protea caffra | LC | | | |
| Protea, Drakensberg Dwarf | Protea dracomontana | LC | | | |

**THREAT STATUS**
LC - *Least Concern*
NT - *Near Threatened*
VU - *Vulnerable*
EN - *Endangered*
CR - *Critically Endangered*

**ENDEMISM**
E - Endemic to South Africa
NE - Near-endemic

**METHOD OF RECORD**
CT - Camera Trap Study
SMS - Small Mammal Study



# APPENDIX E

## Acknowledgements

Creating *Of Watts and Wetlands, The story of Ingula*, has been an odyssey over a number of years. For the first time I will be writing in my personal capacity, as Ingula has been an important part of my life since 1998. Deon Coetzee (a co-founder of Middelpunt Wetland Trust) and I first visited Bedford Chatsworth Wetland, which had been identified as a White-winged Flufftail site, in that year. It was only two years later that we learnt of Eskom's intention to build a pumped storage scheme at the then Braamhoek. As recounted in this book, the rest is history.

Visits to Ingula over the years have been many and it has been a fascinating journey to watch its transformation from fairly remote farmland, only accessible by poor dirt roads, to what it is today. During this time, I have met many people and am privileged to have been given an insider's insight into every aspect of Ingula. The construction and technical components of Ingula are massive, complex and fascinating. The environmental importance of what has been achieved at Ingula is outstanding.

There are so many people who have provided input and information for this book that it is impossible to mention them all. However, I must single out a few who were kind and diligent enough to have provided me with the material I needed.

The underground excavations at Ingula were extremely challenging. Indeed, the machine hall was the largest underground excavation ever undertaken in basically unstable mud rock. Jim Richards was Contracts Manager of the Underground Works during the construction phase of the project. He provided me with an impeccably written account of the excavation and support of the underground works and it makes both fascinating and informative reading. Jim is now partially retired and living on the North Coast of KwaZulu-Natal.

Jacques du Plessis, an engineer, was involved in the construction of both Bedford and Bramhoek dams and provided a wealth of both information and images. Jacques became fascinated with the creation of the Southern Bald Ibis artificial nesting site and was instrumental in both its positioning and construction. He is now involved with the Highlands Water Scheme in Lesotho and, in cooperation with the Lesotho Highlands Development Authority, made sure that a proposed part of the construction was repositioned as it was too close to a Bald Ibis nesting site: a wonderful example of the Ingula effect!

In the early days of construction at Ingula, travelling from the offices on the bottom site to the dam at the top site could take hours, especially when the weather was wet. Nielesh Maistry was initially Eskom's Roads Project Manager during their construction and kindly prepared that section for me. Nielesh is currently Project Manager at Majuba Power Station and is working on several refurbishment projects.

I would like to thank Carina Pienaar, current BirdLife South Africa Project Manager at Ingula, for the time and trouble she took to collate data from many different sources to create the two meaningful and information-rich appendices: The Birds of Ingula and Biodiversity at Ingula.

Ingula has a unique, unfathomable quality that seems to have an effect on everyone who has been involved with the project, both from the construction and operational side, as well as from the environmental aspects. I have yet to speak to anyone who has not fallen in love with Ingula.

I am using my prerogative as author to single out a few people who have not only become friends over the years but have also contributed significantly to the success that is Ingula today.

### DEIDRE HERBST

Discussions between Eskom, BirdLife South Africa and Middelpunt Wetland Trust began in 2000 and Deidre was one of two Eskom staff members involved in that process. At the time, she was a senior manager in the Generation Division of Eskom. I have sat through countless meetings at which Deidre was unfailingly impartial and knowledgeable. One of the most hard-working people I know, she has always found time for the Ingula Partnership, which is now in its fourth contract with Eskom. Were it not for Deidre's understanding of Eskom's internal workings, and her determination that the value of the partnership justified its continuation, it is unlikely that it would still exist. Deidre is one of only three people who have been involved with the Partnership from conception, right through until today. She currently heads up Generation Division's Environmental section.

### PETER NELSON

I first met Peter in 1997 when he was an environmental officer, based at Megawatt Park. He and I were responsible for the Eskom funding of *The Eskom Red Data Book of Birds of South Africa, Lesotho and Swaziland, 2000*. If I remember correctly, the funding was for R40 000. Peter has also been involved at Ingula since its inception and was transferred to Ingula as Environmental Manager in 2006. He was responsible for the ISO 14001 certification of Ingula and for managing all aspects of audits and reporting. Peter provided considerable input for this book and has always been available for discussion and advice. We both have a passion for birdwatching and have shared many sightings of Ingula's rich bird diversity. Peter is now responsible for the environmental management of all Peaking Division's sites, of which Ingula is one.

**TONY STOTT**

As the second Eskom staff member at the initial Braamhoek discussions, Tony, in his position as a Senior Manager in the Generation Division, brought an astute mind (he has two MScs: one in Nuclear Physics and the other in Nuclear Reactor Science and Engineering) to the formation and initial stages of setting the objectives and direction of the Partnership. His contributions were always well considered and respected. Tony left Eskom in 2014 and took up a position as Operational Lead in the Nuclear Infrastructure Development Section of the International Atomic Energy Agency in Vienna, Austria. I had dinner with Tony in that beautiful city some few years ago.

**FRANS LOUWINGER**

As Corporate Specialist (Hydro) at Ingula, Frans's presentations at Partnership meetings, delivered with his dry sense of humour, were always eagerly awaited. His skilful PowerPoint presentations, including animation, kept us up-to-date with construction and enginering progress at Ingula. His graphics made us all realise just how complex is the network of tunnels and excavations. Frans showed sensitive consideration to the design aesthetics and its visual impact on the environment. I was lucky enough to have shared several day trips to Ingula with Frans and I learnt so much from him. His contribution to the book was invaluable and encompassed the introduction to pumped storage and its history in South Africa, Ingula site identification and selection, design challenges and scheme components. Frans retired in 2013 and lives near Mossel Bay with his wife.

**VANESSA CARPEL**

It was clearly understood from the early days of the Partnership that Ingula was a most unusual project in many ways and that its progress and achievements should be widely communicated. Vanessa became involved with the Partnership in 2008 through her role as Generation Division's Communications Manager. Communications is comparable to an octopus, with tentacles in every direction. The Ingula Visitors Centre (with all its material), television, radio, the print media and informative videos have all played their part in broadcasting the Ingula story. Vanessa is a participant in Steering Committee meetings and has always promoted Ingula, internally and externally. Her colleague, Karen Lingerfelder, is a great supporter and has played an important behind-the-scenes role in the execution of these key activities. She has also been the driver behind the Ingula Visitors Centre and its engagements with stakeholders, far and wide.

**KISHAYLIN (KISH) CHETTY**

Joining Eskom in 2009 as a Graduate in Training, Kish soon became involved with Ingula and has become one of its greatest protagonists. He has so often been Eskom's 'man on the ground' and played an important role in interactions with provincial and national departments, especially with the nature reserve and Ramsar declarations. These took years of perseverance and patience, to the extent that he was trained to submit copious data directly into the Ramsar system. Another agonisingly convoluted project that Kish managed was the inter-basin fish transfer, resulting in the eventual authorisation for a condition within the Record of Decision. He provided input to the book for the above-mentioned projects and for ecosystem services. He is currently a Senior Environmental Advisor in Eskom's Biodiversity Centre of Excellence, where he represents Eskom as the project manager of the Ingula Partnership.

**FIFI MEYER**

Joining Eskom in 2009 as Communications Manager at Ingula's Visitors Centre, Fifi is the essence of a communicator and innovator. As well as managing the Visitors Centre, Fifi produced the *Ingula Update*, a regular, illustrated newsletter about construction progress, environmental matters and other articles of interest. Apart from printed copies, there was an electronic distribution of about 1 500, internal to Eskom and also external, far and wide. These issues were of great value in providing information for this book. Fifi also started and ran an annual photographic competition, bearing in mind that, at the peak of construction, there were about 5 000 people on site, including some very keen photographers. A number of these images have really enhanced *Of Watts and Wetlands*. Nothing is ever too much trouble for Fifi, and gathering all the information and images for the book would have been far more difficult without her. The number of Fifi's images in this book give a clear indication of her involvement and passion for Ingula. She relocated in 2017 to manage the Visitors Centre at Koeberg Nuclear Power Station in the Western Cape.



**DR HANNELINE SMIT-ROBINSON**

The Ingula Partnership requires that BirdLife South Africa nominates two primary members and Hanneline has held that role since she joined the organisation in 2009 as Manager of the Terrestrial Bird Conservation Programme. She soon became involved with work on the White-winged Flufftail and it was a huge relief to me when, over time, she became as passionate about the bird as I am. There will be a champion for the flufftail for years to come! Hanneline has been a pillar of BirdLife's work at Ingula, supporting succeeding project managers. She has worked closely with Eskom's Kishaylin Chetty and their close cooperation has played an important part in the successes of the Partnership. Hanneline and I have enjoyed several trips to Ethiopia together, working with local communities for the conservation of the flufftail. I have learnt to have great respect for her abilities and these have been endorsed by her promotion to Head of Conservation at BirdLife South Africa.

**IAN RUSHWORTH**

Many aspects of progress at Ingula required government involvement, mostly at provincial level. Representing KwaZulu-Natal Province through Ezemvelo KZN Wildlife, Ian Rushworth, its Manager, Ecological Services, West, became involved at Ingula during the environmental impact assessment process as far back as 2000. He has been involved ever since, including his membership of the Ingula Advisory Committee: Conservation and the current, ongoing Ingula Nature Reserve Advisory Committee. Ian has attended many meetings, both on and off site, and has consistently provided measured, knowledgeable and valuable input. Ian's contribution to Ingula's success has been considerable.

**ELEANOR-MARY CADELL**

I first met Eleanor-Mary in 1986 when, as publisher-owner and editor of Acorn Books, she published the magnificent book, *Ducks of Sub-Saharan Africa*. Although I consider myself a reasonably competent editor and proofreader, I was determined that *Of Watts and Wetlands* should be of the highest possible standard. Although semi-retired, Eleanor-Mary agreed to be my editor and I could not have made a better request. She has been patient with me. She has also given me some excellent suggestions and has always been open-minded. In one or two instances, she even came round to my way of thinking! I still like to learn and Eleanor-Mary has helped me to refine my skills. Especially because of her involvement, I hope that *Of Watts and Wetlands* will give her great satisfaction. As an aside, Eleanor-Mary has been a volunteer librarian at BirdLife South Africa and has contributed to its excellent condition and appearance.

**RENÉ DE WET**

When I asked Eleanor-Mary Cadell if she could recommend a designer for the book she suggested, without hesitation, that I get in touch with René. After supplying some text and images, René generated a mock-up to match the requirements and specifications that I had provided. It was immediately accepted. It is a pleasure to work with such a professional and the results speak for themselves. René is the ultimate professional, working with single-minded commitment to the job at hand and with insight and flair. A collection of photographs and text must tell a story, the story of Ingula, and unless the composition has great visual appeal, much of the story will never be read. If you got this far, René has done the job!

**PHOTOGRAPHS AND PHOTOGRAPHERS**

The story of Ingula is so broad-based and fascinating that it deserves to be widely read and enjoyed. The Partnership has always hoped that it would be used as a model of the results of cooperation for the common good, both in South Africa and abroad. A dry, written paper would never achieve this. We have been fortunate to have had so many excellent photographers involved at Ingula. The photographic competitions generated some outstanding images and you will see many of these in *Of Watts and Wetlands*. They contribute enormously to the readability, visual impact and appeal of the book and, wherever possible, they have been attributed to their photographer. It has not, however, always been possible to do so and we apologise for these omissions.

**FRIKKIE HITGE**

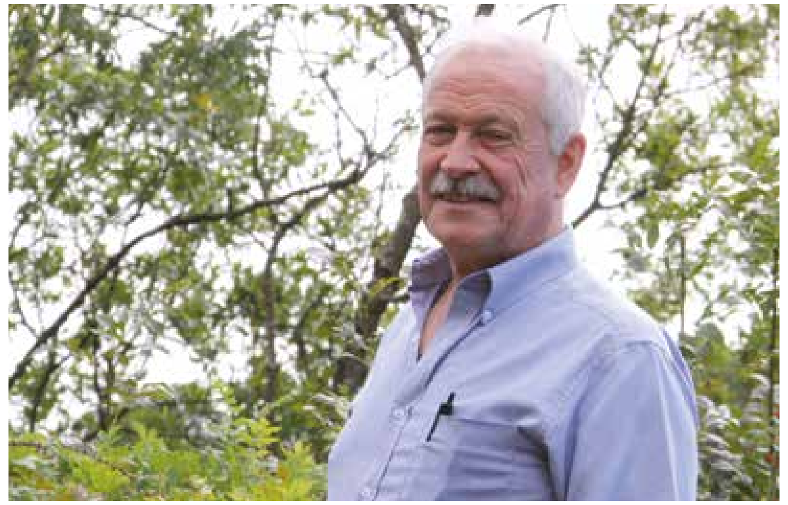
Having completed the book, it would be remiss of me not to specifically mention one photographer: Frikkie Hitge. He worked at Ingula as Chief Safety Officer for the underground mechanical works from 2009 to 2013. Frikkie has been in Rwanda for the past six months, working on the construction of a methane-fuelled power plant. You will see his images throughout the book and they show great perception and sensitivity for the subject. He has an uncanny ability to capture extraordinary light effects. Frikkie has been fascinated by photography for the past thirty-five years.

# BIOGRAPHY

Malcolm grew up on a farm in England where his life-long love of nature was born. He emigrated to South Africa in 1968 and after visiting the Kruger Park was immediately hooked on the country's amazing biodiversity. This led to him becoming a part-time Wilderness Leadership School trails officer and then an avid birdwatcher in the mid-1980s. Malcolm was a founder member of Middelpunt Wetland Trust in 1992 and this led, with no hesitation, to his involvement at Ingula from 2000.

Malcolm spent 35 years in the computer industry until, at the age of 58, he threw away his white shirts and dark suits and started writing for a living. His first venture was to co-author a book to celebrate Gold Fields' 120th anniversary, which provided a fascinating insight into the gold-mining industry. Malcolm spent five years as Chairman of BirdLife South Africa and realised the organisation's need for a resource to assist in fund-raising. This resulted in his creating *A Feathership of Partners* in 2008, which proved to be a great help with marketing the NGO.

The combination of Malcolm's passion for the White-winged Flufftail and his love of the English language made it almost inevitable that he would offer to document the story of Ingula.



## ABOUT THE AUTHOR

As one of Eskom's senior managers, involved with the Ingula Partnership from its inception, it is fitting that I share a few words on the author.

Malcolm, one of the founding members of the Partnership, brought a healthy scepticism, tempered with pragmatism, to the discussions that led to its establishment. His passion for the natural environment and its conservation, combined with his willingness to listen, and then strongly push for a desired objective to be achieved in a more environmentally friendly manner, have been the hallmarks of his involvement. He can be truly proud of the superb contribution that he has made over many years to this amazing, successful partnership that has at its very heart the protection of the rich ecosystem of Ingula.

*Deidre Herbst, Generation Division's Environmental Manager*

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Published privately in 2021 by The Ingula Partnership
The Ingula Partnership is sponsored by Eskom Holdings SOC Ltd



Conceptualised and created by: Malcolm Drummond – malcolm.drummond46@gmail.com
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Editor: Eleanor-Mary Cadell
Printer: ABC Press
Printed in Cape Town on FSC certified paper

COVER: *Early morning light on the iconic Nelson's Kop* PHOTO BY FRIKKIE HITGE

HALF-TITLE PAGE: *Looking towards Tandjiesberg* PHOTO BY FRIKKIE HITGE

TITLE PAGE: *An ephemeral pan, only shallowly filled with water for two or three months in the rainy season becomes home to beautiful flowers and the Fairy Shrimp* PHOTO BY DU TOIT MALHERBE