Balancing Power and Water at Braamhoek

It might be situated in the Little Drakensberg Escarpment, but the R8,9-billion Eskom Braamhoek Pumped Storage Scheme is certainly not a small project. In addition to economic and social considerations, the project faces tremendous environmental challenges. Lani van Vuuren visited to site to see how the needs of power generation and water are being balanced.

It has been almost 20 years since the construction of South Africa's last pumped storage scheme, Palmiet, near Grabouw in the Western Cape. Braamhoek will not only be the most modern pumped storage facility in South Africa but, with a capacity of 1 332 MW, also certainly the largest. Pumped storage schemes are said to be desirable, as they reportedly do not require much water, as the water is being continuously recycled. The main water losses stem from evaporation from the reservoirs.

The site straddles the Klein Drakensberg escarpment and spans over the farms Braamhoek and Zaaifontein, some 40 km north-west of Ladysmith in KwaZulu-Natal, and Bedford farm, located some 23 km east-north-east of Van Reenen, in the Free State. The pumped storage station itself will be located in KwaZulu-Natal.

MAIN FEATURES

Development of the Braamhoek Pumped Storage Scheme started in earnest following the Record of Decision in 2002. Main consultants, Braamhoek Consultants Joint Venture (BCJV), comprising Knight Piésold, Stewart Scott International and Arcus Gibb, started basic design in 2004. Various other local and international specialist sub-consultants are assisting in the project, especially with regards to implementing the latest pumped-storage technology.

BCJV Resident Engineer Michael Neumann explains that the scheme basically comprises two reservoirs situated about 6 km apart, with an elevation difference of 470 m between them. Unlike the Drakensberg Pumped Storage Scheme, Braamhoek is designed solely for the purpose of generating peak-time electricity, and will not be used for the inter-basin transfer of water. Therefore, the dams will be relatively small, with an active capacity of approximately 22 million cubic metres each. Water will only be drawn from the rivers to top up the reservoirs.

The reservoirs will be connected by underground waterway tunnels, an underground powerhouse complex, and access tunnels. Access roads and a new substation also form part of the project.

RESPECT FOR THE ENVIRONMENT

Conservation organisations initially opposed the construction of Eskom's latest pumped storage scheme at Braamhoek. Sparsely populated, the 8 500 ha site features mainly grasslands with wooded gulleys along the mountain streams. Yellowwood forest predominate in the ravines of the escarpment (none of which will be affected by this project). This is reported to be the third-largest complex of this forest type in KwaZulu-Natal.

However, closer inspection revealed that while the area offers huge conservation potential, overgrazing and historically poor land management have resulted in severe erosion and a loss of biodiversity in the surrounding veld. Invading alien plants, most notably black wattle, are widespread in the area.

The biggest bone of contention was the 240 ha peat wetland situated in the Bedford catchment. This wetland is home to a number of bird species that are either critically endangered, near endangered or at risk, including the elusive white-winged flufftail. About 5% of the total wetland area will be covered by the upper reservoir.

Following negotiations, leading to an amended Record of Decision, Eskom and various conservation organisations are now working together to improve biodiversity in the area. As BirdLife SA Executive Director Prof Gerhard Verdoorn points out, much of the land in the area of the marsh was degraded and in poor condition prior to the start of the project. The non-governmental organisation (NGO) first opposed the pumped storage scheme, but later withdrew its objection. "As a conservation organisation we could see that intervention was required to prevent it from degrading even further."

The Middelpunt Wetland Trust, which was created a few years ago with the sole aim of protecting the white-winged flufftail, confirms this.

"Without focused attention brought about through the Braamhoek project, the area would never have received the attention it requires," the NGO states on its website.

Three years ago, the Braamhoek Partnership was established between Eskom, Birdlife South Africa and the Middelpunt Wetland Trust. This is reportedly the first time in the power

All water from the tunnel is pumped to a holding dam before being treated and released back into the river system. Solid waste is also strictly controlled.

An aerial view of the present construction site. The entrance to the exploration tunnel is on the left. Unlike the Drakensberg Pumped Storage Scheme, no permanent construction village is planned for the site.

generator's history that conservation NGOs have been brought on board long before construction of a power plant is due to start.

Eskom is compelled by the Record of Decision to turn the entire site into a conservation area. This will increase the present extent of 'conserved grasslands' by about 81%. Eskom has committed itself to, among others, rehabilitating eroded areas, and halting alien plant encroachment. All areas affected by construction, including all quarries, will be fully rehabilitated.

Peter Nelson was appointed Reserve Environmental Manager a few months ago, and he will inherit any development that takes place on site. "There is no reason why this project cannot be a world-class example of responsible infrastructure development. Crucial to this, however, is a respect for the land on which the development is taking place, a respect that has to be instilled in every single employee from the lowest worker to the project manager."

Rivers and streams in the area have been found to be in a good to excellent condition. Nelson explains the importance of finding a balance between power generation and water. "Eskom realises the importance of infrastructure development that is sustainable, from an economic, social and environmental point of view. South Africa needs more power but, at the same time, we are a water-scarce country, thus we must protect the water resources that we have. We cannot ignore the fact that this project is being constructed in the headwaters of two strategically important river systems."

UPPER RESERVOIR

Situated in the top catchment, the Bedford Dam will be located in the headwater tributary of the Wilge River, which flows into the Vaal River system. The concrete-faced rockfill dam will have a length of 810 m and a height of 40,9 m, with a 100 m-long emergency spillway. The dam crest elevation will be 1 740,6 m while the crest width will be 8 m. All the rockfill material will be sourced on site, and the main quarry will be located within the reservoir basin.

It is reported that the outlets works will be capable of a range of discharges at all impounded water levels to meet the strict release requirements to accommodate the conditions set out in the Record of Decision. The outlet works will comprise a tower in the reservoir with radial gate and maintenance stoplogs. The tower will be accessed by a bridge from the dam. This high-flow bottom outlet system will have a maximum discharge capacity of 70 m^3/s at fully supply level, and 52 m^3/s at minimum operating level.

A flow distributing weir will also be constructed downstream of the dam to distribute reservoir outflows across the wetland. This is crucial, as a disregard for the instream flow requirements would have a significant impact on the wetlands downstream of the dam.

It is interesting to note that the presence of an isolated population of an unidentified *Barbus* species has been found in a stream draining the eastern section of the Bedford catchment. To prevent hybridisation of fish species in the different river systems, fish barriers will be constructed at the headrace and tailrace tunnels.

Important plant species that will be inundated by the two reservoirs, such as the Red Data *Kniphofia flammula*, will be identified and relocated. A nursery will be established to house endemic and rare plants.

LOWER RESERVOIR

In turn, 38,6 m-high roller-compacted concrete Braamhoek Dam will be located in a very distinct poort in the headwater of the Klip River (Braamhoek Spruit), which flows south-eastwards into the Thukela River.

Design selection is based mainly on the presence of underlying dolerite. The spillway will be a stepped chute on the downstream face of the dam, with a 40 m-long crest featuring a stilling basin with baffles. The

Many of the soils found in the area are highly leached and strongly acidic. The presence of light textured, silty subsoils underlain by slaking mudrock renders many of these soils susceptible to erosion.

Entrance to the 5 m x 5 m exploration tunnel. The 6 m³ dump trucks used at present will later make way for articulated dump trucks once construction of the main machine hall starts. Passing bays are being excavated every 100 m along the tunnel to permit empty trucks give way to fully laden trucks hauling uphill.

Braamhoek Dam will have a length of 331 m and a crest width of 5 m.

The dam will have a high-flow outlet with a maximum discharge capacity of 74 m³/s and a low-flow outlet capacity of about 2,3 m³/s. Neumann notes that the dam wall height has been selected to provide a 0,5 m freeboard to accommodate flood inflows, such that a 1:200-year flood will not cause the dam to spill.

Nonetheless, flood inflows will normally be released downstream through the outlet works to mimic the natural flow of the stream. The dam therefore attenuates the effects of natural floods.

POWER GENERATION

Similar to the Drakensberg Pumped Storage Scheme, power generation will be conducted entirely underground. The machine hall, housing four 333 MW single-stage reversible Francis pump-turbine units, will have a length of 172 m, a height of 40 m, and an average width of 23 m. The adjoining transformer hall will be of similar length or longer (depending on the equipment needed), with a span of 18 m and a height of 17 m.

The waterways will include an intake structure for twin 6,6 m-diameter concrete-lined headrace tunnels, each with a length of 1 030 m, to the surge shafts (the main headrace surge shaft will have a diameter of 15 m). Twin inclined steel-lined pressure shafts of 5,1 m-diameter will lead into steel-lined penstocks of varying diameter. In turn, these bifurcate to two smaller penstocks leading to the inlet valves and the machine hall. They will have an overall length of just over 1 200 m to the main inlet valves, which are housed in the machine hall.

In addition, there will be four 4,7 m-diameter draft tube tunnels with a length of 135 m each, to reach the twin 20 m-diameter tailrace surge chambers. Two short 6,6-m diameter tailrace tunnels will lead to a single 9,4 m-diameter tailrace tunnel, in turn, leading to an outlet structure. This will be situated 2 530 m downstream of the surge chambers.

The main access tunnel will be 9 m x 9 m with a gradient of 1:10 and a length of 1 250 m. Tenders for this tunnel closed in November. Construction on the tunnel is scheduled to start in March, with completion expected by December 2009.

Spoil and waste rock material resulting from the tunnelling process is being stockpiled temporarily for use as fill to the access roads, to create temporary terraced working platforms for the power station contractor, and for rehabilitation of erosion features within the project boundaries. All excess waste rock will be disposed of below the minimum operating levels of the two reservoirs.

EXPLORATION TUNNEL

The first construction contract was awarded to Concor-Ukhozi Joint Venture in August 2005 for the construction of the 873 m-long exploration tunnel. The 5 m x 5 m

The Braamhoek Spruit will be dammed by a roller-compacted concrete wall. Compensation flows will, however, ensure uninterruoted flow to downstream users.

horseshoe-shaped tunnel has a gradient of 1:8 and leads to the underground powrhouse complex. As the name implies, the exploratory tunnel was initially planned for investigating different types of support materials, exploratory drilling and for the installation and monitoring of instrumentation (incorporating convergence stations, extensometers, instrumented rockbolts, and rock anchors) to provide geotechnical data for design purposes.

Since construction of the machine hall will start prior to the completion of the main access tunnel, the exploration tunnel will initially form the only access for the excavation of the underground works. It will later house the 400 kV transmission cables leading to the surface switchyard, and provide a second means of egress from the underground power station. In addition, it will be used as a ventilation tunnel.

Construction of the exploration tunnel is taking place in three shifts working 24 hours, six days a week. Neumann reports that more than 600 m of tunnelling has been completed to date. The projected completion of the tunnel is June.

The geology of the area has proven quite challenging. The area is underlain by sedimentary rocks (mostly sandstone and mudrock) of the Ecca and Beaufort Groups of the Karoo Supergroup, intruded by dolerite dykes and sills, with some faulting occurring. Approximately 137 boreholes have been drilled around the site to explore the underlying rock formations in the dam foundations, along the various tunnel alignments, potential quarry sites and cuttings of the access roads.

“By studying this core material, we believe we have gained important insight into what lies where,” BCJV geologist John Reid tells *the Water Wheel.* This knowledge is crucial as the dolerite will require less support than mudrock, which typically of many Karoo mudrocks, experience rapid disintegration when exposed. For this reason, Neumann emphasises the importance the immediate installation of support following blasting, comprising roof bolting and shotcrete.

The present minimal water ingress into the tunnel is being pumped out to a holding dam outside the portal. While the water was mainly used for dust suppression in winter, it is now being treated at a 44 m^3/day water treatment plant on site before being released back into the river system. Water samples are tested weekly by an independent laboratory in Winterton.

SOCIAL ASPECTS

About 30 families remain in the upper and lower catchments of the Braamhoek Pumped Storage Scheme. It is understood that all the homesteads in the area will be relocated, and alternate tracts of land has been purchased for this process.

Nelson reports that the power generator does not want to merely move these communities, but wants to equip them with sustainable land management practices for the long term.

ENVIRONMENTAL RESEARCH AND DEVELOPMENT

Prof Verdoorn is happy to report that Eskom is diligently following the stipulations of the Record of Decision. BirdLife South Africa has performed extensive surveys on birds and plants on the Braamhoek site, and a monitoring programme on habitats and birds has been established.

In addition, the NGO participates actively in monitoring the construction work, advising on environmental management and mitigating impacts. Field officer David Maphisa was appointed to conduct all the biological work. A formal conservation project on the southern bald ibis, which has been found nesting in the area, has also been launched.

Middelpunt Wetland Trust has established links with the Ethiopian Natural History Society (Ethiopia being the only other country where the white-winged flufftail has been recorded). With funding from Eskom, the NGO established an education centre at the main breeding site of Berga, in Ethiopia.

Eskom is also a trustee of the Ekangala Grassland Trust, which is driving a pilot study to conserve high-altitude grassland in South Africa at present.

A number of neighbouring farms have expressed interest in joining the conservation area, and it is hoped that more will follow as the project progresses. “This is going to be the best example of how industry and NGOs can collaborate to improve environmental conditions for a natural area” concludes Prof Verdoorn.