Environmental Observations of Hydropower Plants in Africa and Norway

Report by Claire Chapman

October 2011

Overview

I was awarded a Winston Churchill Memorial Trust Scholarship in April 2011, to visit hydropower plants in Norway, South Africa, Lesotho, Zambia and Tanzania, to learn about their operational activities, and any environmental sensitivities the sites have had to deal with.

This document details my findings and any recommendations, both for the operating companies and for the UK, in terms of implementing environmental good practices.

Full details of the site specifications and all information from the site visits was recorded on my daily travel blog, and can be found at http://clairemchapman.wordpress.com.

Findings and recommendations are found at the end of each section, with a final conclusion summing up the report findings.

Acknowledgements

I would like to thank the Winston Churchill Memorial Trust for this opportunity to travel and learn. I am grateful to Scottish Water, for supporting my travels, and my husband Rufus and my family for their enthusiasm and moral support.

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1 Aims and Objectives

A century ago, Britain had a thriving hydropower industry. With the advent of the National Grid in the 1950s, turbines were allowed to fall into neglect, and there were no incentives for individuals to maintain their own turbines. Turbines were abandoned in-situ in rotting power houses, with old mill lades becoming overgrown and collapsing.

How things have changed! In the last decade the hydro industry in Britain is once again in a fever-pitch, as awareness grows of the need to change from carbon-based thermal energy production, such as coal-fired power stations, to Renewables. Hydropower is ranked as the lowest producer of greenhouses gases, lower even than wind or photovoltaic energy, however it requires high amounts of capital and long lead in times, so is not always suitable for urgent energy demands. Furthermore, there are environmental downsides to hydro as well; the hydro plants can be disruptive to surrounding ecosystems both upstream and downstream of the plant site.

Pumped storage is a method of producing electricity to supply high peak demands by moving water between reservoirs at different elevations, and it often involves mixing water from different catchments. There are a currently only a handful of pumped storage sites in Britain, including Cruachan on Loch Awe in Scotland, although there are more in planning. South Africa has a natural escarpment in the Drakensberg Mountains, and consequently provides an ideal platform for developing pumped storage hydro sites. Pumped storage is being considered as a mechanism for storing excess power produced from wind in hilly Scotland, where there may be opportunity for implementing more pumped storage.

The introduction of the Feed-In-Tariffs in April 2010 has stimulated the development of green energy schemes including hydro. Whilst I visited hydropower sites in other countries, I was keen to see if any similar schemes existed, and whether they have helped boost the hydro industry.

Key aims of this hydropower study tour included:

1) **Assessing and learning about environmental impacts – both good and bad**
2) **Understanding environmental licence requirements for hydro, and their impacts**
3) **Researching environmental issues pertaining to pumped storage**
4) **Understanding the impact of financing schemes to help develop hydro sites.**

I recently cycled through a small village in Perthshire, Scotland, called Comrie, and stopped at a weir, originally built to power a saw mill in the area. In 1911, a small hydropower plant was built on the mill lade, and produced a tiny 2 amps – which gave Comrie House the first electrically powered lamps in the village! And here we are 100 years later, trying to reinvent the wheel, and put a hydroturbine back in again…I hope to be a part of that change back to green power in Scotland and the UK.

2 Norway

2.1 Introduction

I visited Norway from 12-22 June 2011. During this period I visited people and organisations as listed below:

- Rune Skjevdal of Norsk Gronnkraft AS (Oslo)
- Section for Hydropower licencing - Norwegian Water Resources and Energy Directorate (NVE) (Oslo)
- Norwegian University of Science and Technology (NTNU) (Trondheim)
- Centre for Environmental design of renewable energy (CEDREN, SINTEF Energy Research) (Trondheim)
- Lyse Produksjon AS (Stavanger)

2.2 Norsk Gronnkraft

I started my Norwegian leg in Oslo, where I spoke to Rune Skjevdal, the CEO of Norsk Gronnkraft. He explained to me that there are 3 down times for hydro in Norway: the ice in winter, when everything is frozen, the flooding in spring when the snow waters melt and the volumes get out of control, and the leaves in autumn when all the leaves clog the infrastructure and stops operation. This downtime gives Norsk Gronnkraft a typical operational performance of 40 % at full peak, which was lower than I'd expected.

Rune Skjevdal of Norsk Gronnkraft.

2.3 Norwegian Water and Energy Regulator (NVE)

2.3.1 Licencing

I met up with Eirik Thorsen, who works for NVE, which is the Norwegian water and energy regulator (it licenses water abstractions and hydro). Back in the 1930s, there were around 2000 small hydro sites in Norway, which dropped right down with the establishment of the national grid. Interest in small hydro picked up hugely from around 2007, as land owners realised they could claim big land rental from power companies, simply for renting out their water rights on a silent landlord long-term basis. The NVE are struggling to keep up with the number of licences coming in (even with a team of 25!). There are now around 800 small hydro schemes across Norway. With no feed in tariff to skew things, small hydro is invested in purely on economics. This is why the NVE give out licences for 60 years, before they may reassess them! And even then, the NVE is not allowed to change the reservoir head data, but can only request more discharge during the dry season. This has some big repercussions. The older licences have no compensation flow requirements at all, and for some river schemes, such as the Glomma River, near Oslo (the biggest catchment in Norway) – which has around 20 hydro schemes over around 20 km (low head, big flows) – this has meant migratory fish don't stand a chance.

A land owner in Norway owns the head but not the water rights on their land. So if the water is diverted to anther catchment, the land owner has no claiming rights. This goes back to an ancient ruling, for mills and sawmills in particular.

2.3.2 Environmental sensitivities

I thought the NVE would be enforcing fish passes, but quite the opposite. Eirik explained that they now believe that encouraging salmon up such a system will just mean that the fish fry will get killed coming back down again, as they all go through the turbines. Instead, the NVE have felt that it is better to focus on upping populations of perch and pike, which will thrive in these systems.

Another environmental problem the Regulator is grappling with is the eel, which is critically endangered, and is continually getting killed by turbines. The eel migrates along a river system by swimming down at the bottom, under water, whilst migratory fish swim up over the top. So any mitigation put in to assist migratory fish has no benefit to the eel, and dead eels are a real problem.

2.3.3 Site Visit

We visited a fascinating old hydro site, built in 1881, with the current turbine put in in 1940. The owner Andreas Weseel was charming and kindly showed us around. The site illustrates the problem the regulator has perfectly. The licence is obsolete, and consequently Andreas has no low flow requirements to protect the river environment at all, although the river is a protected watershed! The scheme consists of a 200 kW double Francis machine, 10 m height, abstracting roughly 3 m^3/s, from a river that has a flow of around 6 m^3/s. It was originally built for a sawmill, and has a 120 m long intake pipeline.

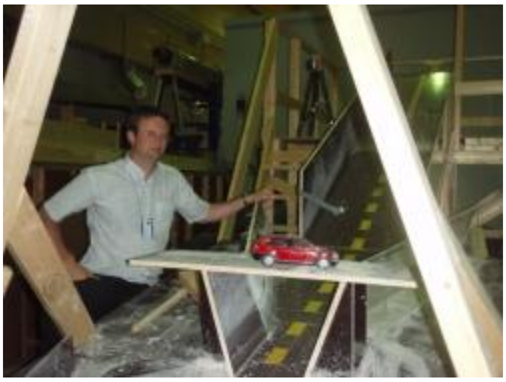
Andreas's operation is typical of the small-business type power industry that is flourishing in Norway, and he keeps his costs down by using some very simple equipment. He uses a small hosepipe with river water to cool the turbine. To stop the turbine spinning, for maintenance, he jams a stick into the swing wheel to stop it turning (because, as he explained, the intake pipe leaks, so even when he shuts it off, the water still flows). Once the fly wheel is stopped, he uses a vacuum cleaner and a paintbrush to clean the generator. This resulted in an extra 5kW output, whilst I was watching. He has also used sections of wood to repair leaking sections of his penstock, which I'd never seen before; apparently the wood survives freezing conditions very well.


Power pylon located in the river bed below the dam wall.

Andreas is wanting to apply for a new licence to add a further high flows turbine. Because this would be a new licence, Eirik explained that he would need to pay tax on the water (due to the fact that there is regulated dam water coming from further upstream). This sounded like a sensible way of charging for regulated water, although Andreas was naturally unhappy with the suggestion. The relationship between regulator and operator seems excellent, that they can have this frank opening discussion.


A section of wooden pipeline in the penstock to Andreas' powerhouse.

2.4 Norwegian University of Science and Technology (NTNU)



Prof Lea in his laboratory.

The Norwegian University of Science and Technology is based in Trondheim, in the north of Norway, so I flew there from Oslo, hoping to find out a bit more about topical research happening on hydro in Norway. I walked from the city centre across the old wooden town bridge (still used by cars!) up to the University campus, where I met with Prof Lief Lea, of the Hydrology section, and several of his PhD students. The department has many international students studying hydro here, as part of the Norwegian international aid programme; many of the operators I subsequently met in Zambia and Tanzania had done training courses here.

2.4.1 Power Production

Lief explained that Statkraft, which produces 40 % of the energy in Norway, is Government owned, and its size creates some problems for the other 235 power companies in the country.

The current trend for run of river and small hydro is not necessarily environmentally justified. The impact of a bigger site is often more discreet (with power houses and associated infrastructure often underground).

2.4.2 Research Projects

Hanna Novik is doing a PhD on trash racks at the intake of hydro plants. She is studying the impact of using a Coanda rack, designed by Dulas (a Welsh firm), to see if it will operate year round under Norwegian conditions. She explained that super–cooled ice water becomes very sticky, and clogs up the trash racks, and is consequently a serious problem.

Lief took me around the department laboratory, which is enormous. There is a simulated fjord, to study the tsunami effect of a landslide into a fjord; and several simulated hydro dams, to help resolve particular site issues. The scaled modeling is a real selling point of their department, and he says that they often get results quicker than by testing a situation theoretically.

Kari Bratveit is doing a PhD on tunnels. In Norway, the penstocks and associated pipelines are often dug straight out of the rock (>3 500 km of it), with no pipelines required, due to the quality of the rock. She is planning to monitor pressure to see the impact, if any of environmental conditions on the tunnels.

2.4.3 Fish Passage

I met with Hans Petter Fjeldstad, who specialises in fish migration and fish passages. Hans Petter explained how eels can crawl up a waterfall like a snake, and consequently can be found in catchments where salmon are not. This makes them a red list species for small hydro in many instances.

There are several things that one can to improve conditions for fish. Inland fish such as pike can be scared away from the turbines using lights and lattices or trash racks. A spill flow over the top of the dam is crucial for migratory fish passage down the river. I thought this was an important point to note with respect to harnessing winter spills- leave some for the fish. Another option to consider is to shut off the turbine for a few weeks in May to allow the smolts to pass down the river safely. There is no point providing fish passage for fish going up rivers, only for the smolts to get destroyed in the turbine coming back down again.

Under the Water Framework Directive, it is important to show continuity of flow, which underpins the safe passage of fish.

2.4.4 Fishability

I also talked to Knut Alfredsen, who is doing research on hydrological modelling. He has linked the fishability of a reach to the variability of the catchment and physical characteristics. Fishability requires more water than just habitat maintenance for fry. Hydro companies have been proactive in engaging with the public on the Surna River at Trolheim kraftverk, where there is a 15 km bypass around the hydro scheme. Knut is concerned that spring floods no longer happen due to the regulation of the flow, and this means that the channels are not cleared, allowing the smolts easy passage downstream. Knut is hoping for variability in the water flow, to simulate a natural environment. Static flows are bad, as that does not resemble real life. This change in understanding still needs to be pushed through in government policy and regulations, but sounds like a real step forward in how water flows may be controlled in the future.

2.5 SINTEF Research Organisation

I met Atle Harby of SINTEF. He runs a research team, looking at hydro issues, and they are closely associated with the NTNU University. Atle told me that the total annual energy production in Norway is 125 TWh. Of that, a vast 75 TWh can be stored in reservoirs (i.e. 7 months' worth). It is because of the enormous size of these reservoirs, that Norway is now seriously selling its services to the UK and mainland Europe, offering energy storage to cover fluctuations in wind supply.

I met with several other researchers at SINTEF. Julian Santerleute talked me through several of the projects. Envidor is a project looking at the impact of hydro water releases on fish. In winter, the water is warmer than the river water (as it's coming from a deep dam) and in summer, often colder. This has impact on the spawning fish. Hydropeaking (i.e. the sudden discharge of a large volume of water from a turbine) also stops stratification happening in dams, as the temperatures are continually being changed.

Peggy Zinke is working on flow modeling, looking at morphological changes in lakes from hydro. She has used a RAMSAR site at the bottom of the Glauma river system (I noted with interest that it is still a RAMSAR site, despite it having 20 odd hydro stations along the stretch of river!) and developed a SSIIM model to show 3D and 2 D effects on substrate.

Julie Chamasson was the final person I talked to. She is looking at mitigation measures for hydropeaking. These include operational measures (such as how to run the plant), and constructional measures (such as levelling the river, to increase the availability of spawning beds).

2.6 Environment Agency (NINA)

I met with Roel May, of NINA (Nork Institut van Naturfarkning). He is doing research as part of the CEDREN project, funded by the government, on all types of Renewables. Roel explained that a new minister of Energy has just come into power in Norway, who is anti-wind energy; however, with large amounts of research funding already committed to wind, Roel suspected the wind programme would continue at full speed anyway (although on land only for the moment). The new minister is very pro-microhydro (which I've already picked up on in many of my other meetings), and Roel stressed that it is crucial to make good site selection for microhydro, by choosing sites with steep gradients that are not fish suitable.

NINA has looked at benthic flora and fauna affected by hydro peaking, including birds, otters and beavers. Roel has been trying to monitor otter populations, but struggling to see them. Consequently, he is now considering marking the populations with GPS collars. NINA has experimented using lights and air bubbles to get fish to avoid the turbines.

Roel showed me his GIS analysis tool, to look for the least-cost pathway for siting powerlines. He has created a raster with various sensitivities (including both construction ones such as slope and environmental, such as national parks or wetlands). It is possible to get local interest groups to then weight these sensitivities appropriately for the specific site. Roel was feeling quite frustrated with Statnet (the state owned grid company), as despite all the research and evidence they are conservative, and slow to change their methodologies in line with current research.

2.7 Nidelva River Schemes

Prof Lief Lea took me to see a really old and a really new site – on the river Nidelva, just a few kilometres inland from Trondheim. The catchment is big, 3000 km^2, with a flow of 110 m^3/s. There have been power houses on the river since 1917, and the original turbines (twin Francis) still operate in the remaining lower power house, and 1 in the upper power house. The power company has recently put in an underground powerhouse on the remainder of the flow, and there is absolutely nothing visible- the intake is just where the old original upper power plant intake was, and then goes underground to the new 4 year old plant. From an environmental footprint point of view, it was very well done.


Hydropower dam constructed on top of an existing waterfall on the river Nidelva.

2.8 Lyse Produksjon Power Company

2.8.1 Background

I flew to Stavanger, where I was to spend a few days visiting some sites run by Lyse Produksjon Power Company. Lyse Produksjon is a Renewables Production company (mainly hydro, but also developing wind farms more recently). Lyse is a public company, owned by the Stavanger and surrounding municipalities. One benefit of this is that abstraction licences granted to Lyse are granted indefinitely (as opposed to if they were privately owned), although licence conditions can still be changed at a review period after 30 years.

Bjorn Honningsvag who is the head of power generation at Lyse, gave me an overview of their hydro capacity. Of the 28 GW capacity in Norway, Statkraft (which is state owned) has by far the biggest share, with 8.3 GW. Lyse Produksjon comes in around 6th, with a capacity of around 1.5 GW.

Another issue we touched on today, which I haven't noted in the rest of Norway, is the problem with acid rain, particularly on the South West side of the country. Consequently, Lyse is tasked with mitigating this via their hydro schemes, by adding Silica to the water, to bond with free aluminium.

And finally, Bjorn spent some time explaining about the Green Battery concept, which I have been made aware of throughout the country. There are currently two bids on the go, with Lyse in partnership on one of them, to put in high voltage lines from Norway to Germany and the UK.

2.8.2 Site visit to Jossang Kraftverk Hydro Sites

I met up with Håvard Bjordal, Lyse's environmental advisor, and we drove out to the Jorpeland catchment, to visit the hydro schemes in the area. The abstraction licences came up for renewal in 2006, and consequently, after some negotiations, new plants were designed and built, and were only officially opened last week. As a result, the landscaping is still a job in progress.

Landscaping work in progress around Dalavatn dam.

2.8.3 Liarvath Dam

We started at the top of the catchment, visiting Liarvath dam. The regulator allows only a small change in dam heights here, of 4m, and this is highlighted on a big measure stick, so locals can report any issues with breaches in the licence. I thought this was a very sensible way to help enforce licence regulations – by informing locals of the conditions, and keeping them informed. I was impressed. Previously there was no compensation flow requirement from this dam downwards, but with the licence expiring back in 2006, the regulator has now made a requirement for this. Håvard pointed out a waterfall coming down from a high head compensation dam called Svortingsvath, which is currently unutilised for hydro. Its licence allows a much greater height variation of 10 m, and consequently Lyse are considering using it for pump storage. It looks an ideal candidate. Surely this could happen in the UK too on some of the compensation catchment dams?

2.8.4 Power Plants

Further downstream, water is taken out at Dalvatn intake and diverted through a 4.5km tunnel to Jossang hydropower plant (33 MW with 1 Francis turbine). Because of the new compensation flow licence requirement, there is still water in the Jorpeland river, so Lyse decided to put a new small power plant adjacent to the old redundant one, at Dalen 1 (1 small 2.1 MW turbine and a larger 2.8 MW turbine for bigger flows). The Dalen 1 plant still means that water is taken out of the river for about 2 km and I thought the flows upstream looked pretty low. Håvard reassured me that at least they are now higher than they used to be for the past 80 years under the old licence!


Dalen 1 TailRace, submerged to minimise risk to migrating fish.

Dalen powerhouse is sited on the compensation flow into the river channel. There are fishing interests in the area, and one of the concerns is the worry that the migratory anadromous fish will be attracted to the diversion tunnel tailrace, thinking it is the main river channel. It is for this reason that the tailrace is submerged, to minimise this risk.


A rather leaky old dam wall.

We then went to see the big site – Jossang, which is deep underground, and we were shown around by Morten Wangen. The site has such a neat external environmental footprint – just a sliding garage door, and a bit of shock-crete surrounding it. The tailrace is discharged 8m below water surface in the fjord; and the contractors transported the rock waste to local construction sites in the area by boat, avoiding road disruption.

The only visible bit of the underground Jossang hydropower plant.

2.8.5 Acid Rain and Silicon Dosing

We visited a Silicon dosing plant; as part of their licence requirements, Lyse must dose any water going into the river system with Silicon solution, which combines with Aluminium, but is inert and harmless to the ecosystem otherwise. Aluminium is thought to have been a result of acid rain (which was particularly bad in Norway 15/20 years ago, but is improving steadily now), and attacks the gills of salmanoid fish.

Previously the rivers had been dosed by helicopters, using lime, which didn’t sound very effective, dilution-wise. However, this doesn’t happen anymore, and Lyse have built this very neat little dosing system instead.

2.8.6 Fish Pass

We stopped downstream of Dalen 1 Hydro station on the Jorpeland river to inspect the most incredibly ugly civil structure – a massive fishladder rock blasted on the side of the river, constructed by the local fishing club – at least 20 m in height, if not more. The fishing club got government funding to build this, to provide a fish pass for the natural waterfall in the river. The fish ladder does not work (the flow gets too great towards the top), and the fishermen have to come and hand lift the fish out and transport them to the top. I couldn’t help wonder how many of the fish get poached! Lyse have agreed to upgrade the non-functioning fish ladder, together with increasing numbers of spawning beds, by laying down gravels, as part of its environmental commitment in the watercourse.


The fish ladder that doesn't work!

2.9 Findings and Recommendations

- There are no Feed-In-Tariffs in Norway, and yet the micro hydro business is booming. This may be partially down to the fact that hydro licences are issued on such a long term basis, and the head can never be altered. Consequently there is very low risk from an investment point of view. From an environmental point of view, the footprint of a smaller site can be much more damaging than a larger site, with a much smaller power return as well.
- While the licences with longer permit periods do give a stable return, they may have impacted the receiving water courses, with too little compensation flow, and little opportunity for the Regulator to review licence conditions.
- Hydro licences include charges for any additional water that is gained by regulated water (dams). This seemed to be an effective system.
- On modified rivers, the Norwegian Regulator is not trying to reverse conditions by installing fish passes, as is happening on many Scottish rivers. Instead it is focussing more on boosting non-migratory fish populations like pike and perch.
- Eel populations are extremely vulnerable to turbines as they swim downwards, and get sucked into the turbines.
- The privatisation of the power industry has resulted in a thriving small and medium power industry (with 235 power producers in the country). However the government-owned Statkraft is still too big (producing 40 % of the power) and consequently there is still not a level playing field.
- Under the Water Framework Directive, it is important to show continuity of flow. A spill flow over the top of the dam is crucial for migratory fish passage down the river. Another option is to shut off turbines for a few weeks in May to allow the smolts to pass down the river safely. There is no point providing fish passage for fish going up rivers, only for the smolts to get destroyed in the turbine coming back down again. This is relevant for sites wanting to harness winter spill.
- Storing energy is problematic. However, Norway has a solution to this problem with so many of its reservoirs at high head. Although there is not as much opportunity in Britain as in Norway, there is some scope to develop this pumped storage in Scotland.

3 South Africa

3.1 Introduction

I visited sites across South Africa from 16 August 2011 to 26 August 2011, including the following:

- Palmiet Pumped Storage Scheme – Electricity Supply Commission of South Africa (ESKOM)
- Collywobbles/Mbashe Run of River Hydro Scheme – ESKOM
- Amatola Water Board, East London
- Institute of Water Research, Grahamstown
- Drakensberg Pumped Storage Scheme – ESKOM
- Ingula Pumped Storage scheme – ESKOM
- Merino Run of River Hydro Scheme, Bethlehem – Nuplanet
- University of Pretoria / Water Research Commission Project – Hydroturbines on Pressurised Conduits

I am deeply grateful to ESKOM for allowing me access to their sites. So many people gave me their time generously, but in particular Nikite Muller of Amatola Water and Derrick Boltt of ESKOM. Also Marco van Dijk of University of Pretoria for his huge enthusiasm in getting me to see a range of sites. And finally, my parents who were my chauffeurs for over 2000km of site visits – thank you!

Fan aloe in Kirstenbosch gardens

3.2 Palmiet Pumped Storage Scheme

3.2.1 Fynbos

I visited the Palmiet Pumped Storage Scheme, at Grabouw (commissioned in 1988), and was met by Hilton Westman, the ESKOM environmental advisor, who is responsible for maintaining the site's ISO 14001 environmental management system. I was impressed to see the number of school children visiting the site visitor centre, learning about energy. The site is located in the middle of the Koegelberg Biosphere (an internationally UNESCO-recognised nature reserve), due to the sensitivity of the fynbos floral kingdom (one of only six kingdoms, with around 8000 plant species). Fynbos is similar to Scottish upland heather, with the soil being similarly poor to the peaty conditions in many of Scotland's catchments.

Rehabilitated fynbos, 2 years on

Hilton took me to see some of the fynbos that has been rehabilitated above the 750 m long headrace tunnel. He explained how ESKOM use untreated powerline poles to stabilise the banks, as they rot gradually and provide nutrients to the barren soil.

3.2.2 Site Operation

The site operates using two dams, the top Rockview dam, and the bottom Koegelberg dam. Water is released from the top when the National Grid Control (in Pretoria) asks for more power. In theory this is at peak times (morning and evenings), however, the site was still operating at mid-afternoon when we visited.

The site communications officer, Liesel Sherwood-Adcock explained that this is because the South African grid is so over-stretched that the site is now a key player in the grid. Consequently, there is no downtime at the site, and therefore maintenance is a problem.

3.2.3 Water Flow

I met James Douglas who works for Department of Water Affairs (DWA). He controls the compensation flow from the lower dam. The whole site is a joint venture between ESKOM (who are only responsible for the pumping) and DWA. The ESKOM pumped storage site doesn't need an abstraction licence, as the dam and water is owned by Water Affairs. I thought this was an unusual set-up, but I saw the same set up at the Drakensberg pumped storage site later on in South Africa. I wondered how rigid Water Affairs would be at monitoring their own assets.

James said that he typically releases 10 m^3/s from the top dam to feed the powerhouse, with 7.7 m^3/s from the bottom dam. There is no turbine to capture this compensation flow from the bottom dam. This is exactly the sort of location that is being focused on in Scotland now; however, without a feed in tariff perhaps the costs don't yet stack up for smaller turbines in ESKOM. With the country still so short of power; I would think it would be worth at least looking at the payback for this.

There is no compensation flow required from the top dam, and as a result the tributaries I inspected were green and stagnant.

Compensation spill from Koegelberg dam - no turbine.

3.3 Colleywobbles Run of River Hydro Scheme

3.3.1 Background

Looking down towards Mbashe buffer dam, with the silt island clearly visible.

I met up with Dr Nikite Muller of Amatola Water (one of approximately 20 parastatal water boards that provide bulk water across South Africa) and Derrick Boltt of ESKOM. Derrick manages four run of river hydropower schemes in the area, and he took Nikite and me to visit the Colleywobbles scheme. The site has exceptionally bad road access; 2.5 hours east of East London into the formerly independent Transkei (now a part of South Africa), in a rural area primarily with subsistence farming.

3.3.2 Too thick to drink, too thin to plough!

The site highlights one of the key environmental problems that river systems face in South Africa – silt run off. The Mbashe buffer dam is the only dam on the river, and was commissioned in 1984, with a design of 8 million m^3. Three years later, it had silted up by 25 %, and currently its capacity is at 0.5 million m^3. Siltation is a major concern for the integrity of the dam wall, as well as the hydropower plant, with the intake screens doing nothing to stop the fine particles of silt entering the tunnel. As a result, it is necessary to drain the reservoir at least twice a year to scour the silt. The power house has three 14 MW Francis turbines, running at 70 % utilisation. Of that 100 % is in generation mode in the wet summer season, and 30 % in generation mode in the dry winter season (with the rest in regulating voltage). This seemed high, but the site doesn't have the limitation of hands-off flow, or frozen water!

Looking down towards the Hydropower Plant – note the incredible access track.

What makes this site particularly environmentally interesting is that the cliffs around the reservoir house the world's largest Cape Vulture population in the southern hemisphere. It was spectacular. Derrick drove us up the steepest road I've ever been on, to a tiny strip of land, separating the two parts of the river oxbow, and we were at the same altitude as the vultures, soaring on the thermals alongside us. There must have been at least 30 vultures. There are currently no environmental designations on this very special site, which would warrant protection. I subsequently was told that it is the fact that it is mainly subsistence farming in the area that keeps the vultures alive. With the farmers too poor to dip their livestock in tick-dip or to leave out poisoned bait for jackals, the vultures don't die from eating poisoned carcasses.

3.3.3 Licences

No reserve assessment has been done on the Mbashe river, and the site has no abstraction licence. There is an informal agreement with the headman of the local tribe, who can ask for more water if required for stock grazing, in which case ESKOM release water. The site pays a fee for the connected capacity and the outputted capacity, with a seasonal tariff (the dry winter season attracting a higher tariff than the wet summer).

Power lines connecting rural huts.

Reticulation of the grid in more built up areas in the Eastern Cape.

Driving through this rural impoverished landscape, I noted what an excellent job ESKOM have done at electrifying this rural area, since the change to a democratically elected government in 1994. Whilst there is no connected water yet, and every hut had a jerry can outside for collecting water, most huts were connected to powerlines. This has brought with it its own problems – the power load has gone from 50 MW in the area in 1995 (pre-democratic election) to around 400 MW today. This commitment to rural electrification is partially what brought ESKOM to its knees with the serious power outages in the country five years ago.

3.4 Amatola Water Board – Politics and environment

Aloe ferox lining the roads.

I was the guest of Dr Nikite Muller of the Amatola Water Board. Amatola was created in 1995, from the remnants of the old so-called independent homelands of Ciskei and Transkei, as well as part of South Africa, and has a head count of around 400 staff, primarily providing bulk water services to the Eastern Cape.

3.4.1 Laing WTW

One of its sites is Laing dam and WTW, outside King Williams Town, on the Buffalo river. The dam is covered with water hyacinth, *Eichhornia crassipes* (a problem throughout sub-Saharan Africa). However, in this instance, Nikite believed it may be doing some good. There are four major non-complying waste water treatment works, run by the local municipalities, all discharging into Laing dam. Nikite believes that the water hyacinth is at least taking some of the nutrients out of the water, although eutrophication is still an issue. Amatola Water is considering its options to treat hyacinth, and are considering using its removal as a job creation scheme, for what is a very rural high unemployment region.

3.4.2 Constitutional Right to Water

Nikite's boss, Sieg Rousseauw came to meet me too. He explained how lack of payment for services is a massive part of the whole problem with municipalities going bankrupt as the consumers don't pay them for water services. I asked why they couldn't put in pre-paid meters like ESKOM have done on the power side. He explained that this had been trialed by one of the South African water boards, and consumers had successfully taken the board to the high court, stating that it was a breach of a basic human right! Consequently the municipalities are paying water boards for water that they can't bill the consumers for.

3.4.3 Nahoon Water Treatment Works

Nikite drove me out to Nahoon Water Treatment Works, where I met with operators Chris Nair and Frans. The site was commissioned in 1982, and supplies 35 Ml/d to part of East London. I was interested to note that the whole of Amatola Water is accredited to ISO 18000 (Health safety and environmental standards). Water is abstracted from the Nahoon dam, before being passed through the treatment works, and then is pumped to a service reservoir where it is handed over to the municipality for distribution. The site uses no automation, and all the chemicals are manually dosed; this is partially to help train up trainee operators.

Nahoon dam wall, with the water levels just overtopping at the time of the visit.

3.4.4 Dam

An annual compensation flow requirement for the reservoir gives Amatola Water the flexibility to release water as requested by the downstream Farmers' Association. This request must come from the Chairman of the association, to ensure that it is a legitimate request. There is a good working relationship between the association and Amatola Water.

There may be potential to install a turbine on the raw water intake at the Nahoon water treatment works.

This was yet another site with no abstraction licence. Nikite explained that Department of Water Affairs in South Africa is in the process of moving from the historic registered system to licences, and so riparian ownership (automatic ownership of the water with land) is being removed, which is causing problems, especially with farmers. Perhaps if I return in five years, I'll be able to see the progress on these licences, but just now, it feels like water operators have carte blanche in South Africa to use water as they see fit.

3.5 Water Research at Rhodes University, Grahamstown

3.5.1 Institute of Water

I visited the Institute of Water Research in Grahamstown, where I met Dr Sukhami Mantel and Dr Andrew Slaughter, and Prof Jay O'Keeffe. I was interested to find out that Jay had previously done some research on the siltation problems on the Mbashe buffer dam, that I had visited with ESKOM. He explained that the dam had been designed on the river's average sediment loading, but just after completion, a massive flood event had occurred, and brought the silt down that then started the whole problem. Jay mentioned that sediment loading is also an issue elsewhere in the world, in particular Australia, but the catchments are less steep, so it is less of an issue than in South Africa.


Erosion and over-grazing is the scourge of South African rivers.

Sukh and Andrew took me around the institute's laboratories, to show me some of the current research projects. Some of the projects that sounded interesting were toxicology testing on DDT (still used to spray for malaria mosquitoes in South Africa), Roundup herbicide and a Phosphate project.

3.5.2 Working with Water Programme

I caught up with Dr Martin Hill. Martin and is working with biological control in particular on the working with Water programme. This is a Department of Water Affairs sponsored programme, that has been running since the mid 1990's primarily as a job creating scheme, to remove alien invasive species from sensitive river catchments. Martin explained that the scheme needs a commitment from the land manager that once Water Affairs has removed the first round of aliens, further maintenance and removal of growth will be done by the land manager. I wondered if this could be model for some of the catchment management options that Scotland is considering; with the immediate and obvious drawback that cheap labour is just not an option in Scotland.

3.6 Drakensberg Pumped Storage Scheme

3.6.1 Background

This scheme is situated in a remote area of the Northern Drakensberg, utilising water from the Tugela river, which is circulated between the lower Kilburn dam and the upper Driekloof dam, using a 4.5 km waterway. There are four 250 MW Francis turbines, and the site acts as a peaking station for the national grid. The site was commissioned in 1982, and had taken 8 years to build.

3.6.2 Compensation flows – none!

This site is similar to the Palmiet pumped storage scheme I visited near Cape Town, in that it is a joint venture between the Department of Water Affairs and ESKOM, with Water affairs owning the dams, and controlling water flow, and ESKOM only responsible for the pumping of the water. It is unusual in that the water in the lower dam is in a different catchment (the Tugela) to the upper dam (the Vaal). Consequently no flow is allowed from the lower dam to minimise the risk of contamination of fish from one catchment to the other. That seemed to be an effective way of preventing catchment contamination, which I haven't come across previously.

Although there is a spillway and compensation channel from the lower Kilburn dam, they are not normally allowed to operate, to avoid fish contamination between catchments.

3.6.3 Capacity

Elias Ngwenya of ESKOM took me around the site. Elias highlighted that only 1% of South Africa's energy comes from hydro, and a further 1% from pumped storage, with another 4% of imported hydro energy from Lesotho. With South Africa still desperately short of capacity, ESKOM have committed to a further 17 GW to be added to the grid by 2018.

The upper Diepkloof spilling across the low dam wall into the Sterkfontein dam, which is used as a strategic reserve for Gauteng.

Elias took me into the hydropower plant. We drove down the 1km long, 156 m deep tunnel, and went into the control centre to meet Bernard Schirge, the operational manager. Bernard explained that the Tugela water is always dirty from the huge amount of silt going into it (which I've noticed!) but this has no impact on this scheme, as the screens are big enough not to get clogged. Bernard also mentioned that South Africa is too dry for conventional hydro schemes, but pump storage schemes are useful to balance off the coal fired power stations; it is much cheaper to use up grid capacity by pumping water, than to shut down the stations (which takes a long time). In the same way, I think that Scotland will look to offset wind farms with pumped storage too.

Elias Ngwenya showing me the intake from the upper dam.

3.6.4 Water Affairs

The Department of Water Affairs has offices nearby, from where they control the dam levels. I met up with Abie Abrahamse, the chief superintendent of operations. He explained that the capacity for the scheme (upper and lower dams) was 35 million m^3 and that over the 30 years of operating the scheme, Water Affairs had never yet had to supplement water into the ESKOM scheme, due to the high rainfall in the area, which tops up any losses from the scheme. I was amazed by this, as the upper Tugela catchment seems to have so many very large dams on it. But there is no doubt that this scheme seems to work as a closed loop system very efficiently. In fact, Bernard Schirge had mentioned earlier to me that the success of this site, running with a limited volume of water in a closed loop, has given ESKOM the confidence to go ahead with developing new pumped storage schemes like the Ingula site, further around the Drakensberg mountains.

3.7 Ingula Pumped Storage Construction Site

At the top dam, with the lower Bramhoek reservoir and the construction compound visible in the background.

3.7.1 Background

This remote site straddles the watershed between the Free State (near Harrismith) and KwaZulu-Natal. Ingula is the first site that ESKOM has commissioned since the Drakensberg scheme was built back in 1982, and the site is in the middle of construction – due to be commissioned in 2014 (with a 7 year construction period). It will be the 19th biggest pumped storage scheme in the world, with four 333 MW turbines (a total of 1332 MW capacity). There is a head of 441 m with a distance of 4.6km between the upper Bedford and the lower Bramhoek reservoirs.

3.7.2 Compensation Flows

The bottom Bramhoek dam is completed, and was allowed to fill in January 2011, as it was expected to take three years to complete. However, this has been such an exceptionally wet season, that it was full by the end of this first summer! Fifi Meyer was my guide for the day and took me to see the Bramhoek dam spilling. I was interested to note that at this site ESKOM is obliged to compensate water to both the top and the bottom catchments (the bottom dam licence being around 20 l/s in winter and 120 l/s in summer (the wet season). This seemed like a big improvement on the licencing I had noted at the other older Pumped Storage sites in the country.

3.7.3 Sensitivities

As far as being an environmentally sensitive site, this was another great site to visit. The top catchment area is a massive wetland area, eventually feeding the Vaal river, which provides water to Gauteng province. ESKOM were obliged to purchase more land to compensate for the loss of the wetland from the creation of the top Bedford dam, and manage it accordingly; in fact ESKOM plan to apply for UNESCO status for the wetland area, once construction is finished. Three out of five of South Africa's critically endangered birds (including the wattled crane) are found in the wetlands, so there has been a lot of pressure on the project to provide alternative breeding sites.

Artificial bird nesting sites blasted out of the rock, for the Wattled Cranes.

One environmental problem the site has faced is that the fish species found in the top catchment are marginally different to those found in the bottom (*Barbus* or minnow). As ESKOM are obliged to discharge a compensation flow from both reservoirs at this site, they cannot simply run the site as a closed loop as happens at the Drakensberg Pumped Storage Scheme (which thus conveniently avoids the contamination issue). There is thus the real risk that the fish will cross-contaminate the two sites. The site's conservation manager, Peter Nelson noted that although the site has no solution for this problem, the differences between the two fish sub-species is minor, and from a cost benefit point of view is difficult to justify protection.

3.7.4 Construction

The construction site has just been awarded ISO 14001, which is a feather in ESKOM's cap. It is such a big geographic site to manage, that it must be challenging to keep on top of all the changing environmental aspects for their register. The site had a maximum of 4500 staff on site, during its peak of dam-building, and there is a large compound for housing and offices. This will all be removed and rehabilitated using topsoil from the dams (which has been removed). It was very windy when I visited the site, and the mud-rock aggregate was being blown around despite regular wetting of the roads, and the batching plant.

Construction of the two inlet tunnels on the upper Bedford dam.

3.8 A privately owned run of river scheme – Merino Power Station

I visited Merino Power station, one of the few private hydro developments in South Africa. ESKOM have only in very recent years encouraged the development of private power schemes, and I met up with PG Needhan of Nu Planet, who did the design.


Bank reinforcement on the side of the river-side of the canal.

The site is still to be commissioned, but all the civil work is completed. The scheme is run by Bethlehem Hydro and is partially owned by a Black Women's group (Hydrowsa), which means the scheme is Black Empowered. This is important if you want to do business with government bodies in South Africa; a similar concept in a way to how the Scottish Government is pushing community group ownership of renewable schemes too.

The site is unusual in that it has guaranteed water supply year round, despite being a run of river scheme – because the water comes from the Lesotho Highlands water project, just as it crosses the border into South Africa. So the flow is a very constant 22 m^3/s, with a 14.3 m head, and a 3.5 MW Kaplin turbine (supplied by BHEL in India).


Standing inside a typical section of the 5m diameter Lesotho transfer pipeline.

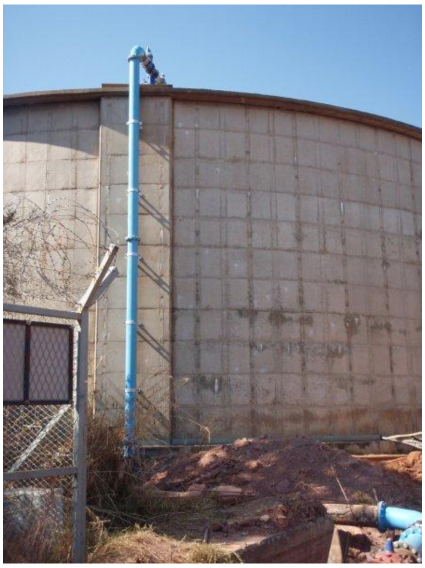
An 800 m long inlet channel has been manually dug alongside the Ash river. Erosion is an issue along the whole Ash river (it didn't use to have a visible flow in it before the Lesotho water, and now it has this very high sustained flow year-round). There were signs of wash along the river, and some seepage coming into the inlet. I wondered if this would cause problems in the long-term, although I noticed that the river bank has been reinforced with boulders along the length of the inlet canal. There is a wetland adjacent to the plant which was identified during the EIA as particularly sensitive, and the water flow through this was not allowed to be impeded.


Inlet canal adjacent to Ash river; note washout in the river.

I was delighted to see that smaller schemes were finally getting a look in, in South Africa, and certainly on this river with guaranteed year-round flows, it makes good payback sense.


The station and location of tailrace.

3.9 Pretoria - Research Projects and Dams



Pipe going into the reservoir, with the turbine on the top.

3.9.1 Break Pressure Tank Pilot Project

Marco van Dijk of the University of Pretoria took me to see the Water Research Commission funded pilot site on downstream pressurised water supply pipes. This is a full scale pilot, using a 16 kW crossflow turbine on the inflow to the Pier van Rynerveld break pressure tank. Water enters the tank at 100l/s, and with 50 m of head, so the site makes a suitable trial to market the concept to municipalities and water boards, to encourage them to do likewise.

The cross flow turbine at the top of the tank.

The site belongs to the City of Tshwane (previously Pretoria) municipality, and that this project has happened, is largely thanks to the driving force of the municipality engineer Adriaan Kurtz. He and the project team have been clever at engaging with the local community to help fund some of the capital investment.

A new Pressure Reducing Valve (PRV) has been added in as a security before the turbine, together with a bypass. These modifications are still being worked on, and the site should go live shortly. I noted the small amount of ground area needed on the site, to make these changes. With this being a pilot site, there are no plans to connect the site to the grid, so any excess energy generated will go via a heat sink to the water in the reservoir. The turbine will power electric fences and lighting in the housing estate.

The modification to the inlet pipes is nearly complete.

I noticed that a new flow meter had been added as part of the project, just after the PRV, which may influence the flow readings. Locating flow meters to give accurate readings is an important part of installing turbines on downstream flow pipes. I also questioned the potential of noise as a problem, with the tank situated right in the middle of a housing estate. There is the possibility that the turbine could be enclosed if this is a problem.

Marco mentioned that several of the bigger water boards in the country, including Durban, Bloemfontein and Johannesburg have done scoping exercises to locate suitable PRV and break pressure tank locations for turbines and eThekwini (Durban) Municipality has already put out an invitation to tender. It sounds like South Africa is looking to be a market leader on this.

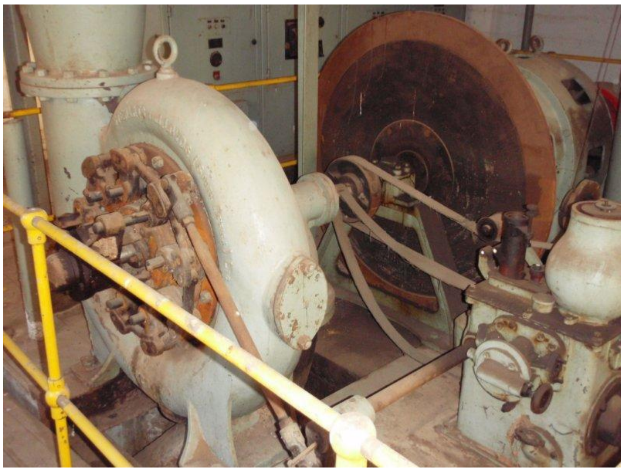
3.9.2 Potential Site Investigation

We drove to the Haartebeespoort dam, to meet up with Adriaan Kurtz (of Tshwane municipality) and Bo Barta (of the Hydropower Interest Group of the Sustainable Energy Society of Southern Africa (SESSA). Over lunch, Bo explained to me the problems with the proposed Feed In Tariffs that were put on the table some years back by ESKOM. Apparently, these were to apply to schemes bigger than 1 MW only (quite different to the smaller schemes that the British government is trying to promote). However, just a few weeks ago, this offer has been effectively withdrawn, which has caused consternation amongst the hydro community in the country.

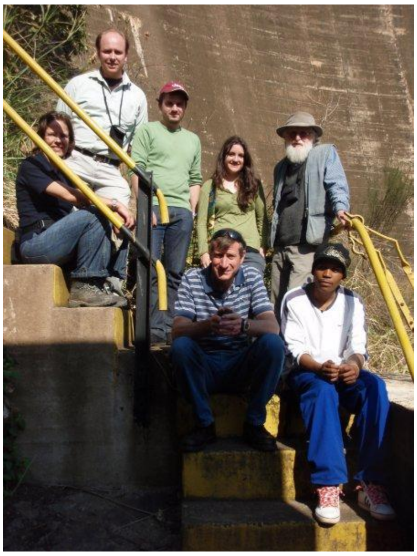

Looking down from the dam wall; note the flow on far side, coming from turbine house.

We walked down to the base of the dam wall (which is a magnificent structure, completed in 1923), with water flowing into the Crocodile river. At the bottom of the wall is a turbine house, still housing a 37 kW Gilkes turbine and Peebles generator, installed in 1924, as well as the plinth for another set if required. How these got down here must have been a feat of engineering – no lifting equipment here!

The units ceased to function in the 1950s, with the advent of the grid and ESKOM. Bo believes that if the site was re-activated, it could easily take a new 100 kW set. The turbines were installed on a canal, which is still used to supply a guaranteed irrigation flow to the surrounding farms. And what is more, there are similar canals on the other side of the river, which could be equally tapped for energy. Bo mentioned how there are hundreds of other similar sites across the country, still with the associated infrastructure, that could be re-connected to the grid.


The 1924 turbine and equipment, all still here!

Again, the usual problem is that the site needs investment, and the dam is owned by the Department of Water Affairs (DWA). It sounds to me like the DWA urgently needs to create its own in-house department focusing on renewables, as there seem to be missed opportunities around the country.



Our tour party – including Marco van Dijk, Adriaan Kurtz and Bo Barta.

On another note, I was interested to see the problems of eutrophication that the dam is facing. The smell of raw sewage was prevalent in the irrigation canal outfall. Apparently this is a problem that has been growing over the last 20 years, with the dam taking the bulk of the (treated and otherwise) sewage outlets of the greater Johannesburg area. The dam has silted up, and Bo is hoping that if a turbine is re-connected, the energy produced could be used to power dredging of the dam.

Note the Trophic status is at a red risk!

3.10 Recommendations and Findings

3.10.1 Palmiet Pumped Storage scheme

- Do a cost analysis of installing a turbine on the compensation flow from Koegelberg dam.
- ESKOM should consider expanding its environmental aspects and impacts register to include water flows i.e. consider the lack of water compensating from the top dam,

and the volume of water compensating the lower water course from the Koegelberg dam.

3.10.2 Colleywobbles Run of River Hydro Scheme

- Undertake modeling on the Mbashe watercourse, to confirm in-river flow requirements.
- Consider registering the land for environmental protection status, due to the unique birding habitat.

3.10.3 Amatola Water Board

- Amatola Water to consider a feasibility study on installing a turbine on the raw water intake at the Water Treatment Works.

3.10.4 Drakensberg Pumped Storage Scheme

- There are catchments in Scotland where it may be possible to use the technique of providing no downstream releases, to keep inter-catchment transfers independent; to minimise contaminations of water bodies.

3.10.5 Ingula Pumped Storage scheme

- There were some excellent environmental good practices that I noted on site, that would be worth implementing elsewhere. I was particularly impressed with the land-management, as a nature reserve of the entire site. Some of this is required by their planning conditions, but ESKOM have embraced this and are making this a flagship site for conservation. There is real opportunity here for eco-tourism and conservation, arm-in-arm with a big energy project.

3.10.6 Merino Run of River Scheme

- The Black Empowerment schemes for part ownership of private hydro schemes could be used as a blueprint for British schemes, to encourage community ownership and engagement.

3.10.7 Pretoria Research Sites

- The project team has engaged with local communities to secure additional funding for their project. For example a local business funded the telemetry costs, with the proviso that it could place a communication mast on the tank. This technique could easily be used elsewhere successfully.
- The work that City of Tshwane (Pretoria) Municipality is doing on turbines on downstream water supply pipes is well worth following for British water companies.
- The dumping of excess heat from turbines into break pressure tanks is something that might be considered in Scotland, to prevent freezing pipes, rather than dumping to load banks.
- Flow meters should be located on straight sections of water pipes, to prevent turbulence interfering with meter readings.
- The Department of Water Affairs should consider creating its own in-house department focusing on renewables on its assets, as there seem to be missed

opportunities around the country. These could be put out to tender for partnership opportunities if in-house funding is an issue.

4 Lesotho

4.1 Introduction

I visited the Muela Hydropower Plant operated by the Lesotho Highlands Development Authority on Wednesday 24 August 2011.

I am grateful to Rentseng Molapo and Mrs Palesa Mohapi of the Lesotho Highlands Development Authority for their time and assistance.

4.2 Lesotho Highlands Development Authority

Lesotho's national flower –the spiral aloe, or Aloe polyphilla.

I met Rentseng Molapo, the plant manager of the Muela Hydro Power Plant. This plant was added as an extra by the Lesotho government, to the water transfer scheme that was funded by South Africa, transferring water from water-rich Lesotho to water-scarce Gauteng province in South Africa. Water is transferred via gravity from the Katse dam, via a 47 km long, 5m diameter tunnel to Muela Hydro Power Plant. The water goes through three 24 MW Francis turbines and into the Muela tailrace dam. The water then is transferred again by gravity via a 38 km tunnel into South Africa. The site is very high; Katse dam is at an altitude of 2053m, and Muela at 1775m, with a head of 26 bar at the plant.

4.2.1 Micro Hydro Potential

The Muela dam has a small compensation flow requirement. With a dam wall of 50 m, I noted that this would make a good hydro location if rainy season spill flows were considered, but Rentseng explained that funding is problematic. There is however, a mini hydro on the compensation flow from the Katse dam (500 kW), so this has at least been considered at other sites.


The Muela dam, showing the dam wall and intake to the gravity tunnel to South Africa.

Lesotho has to import power from South Africa, and also relies on South Africa to regulate voltage. Consequently, Lesotho is planning a pumped storage peaking plant on the Katse dam at some point, to limit dependence on South Africa.

4.2.2 Silt

I was interested that the HPP has a 100 % efficiency; with the Katse dam being 180 m deep, water doesn't freeze, and there are no leaves for blockages. Here at the Muela dam, silt does cause blockages on the intake tunnel across to South Africa, below the HPP. The screens are currently too big to stop blockages coming in from the local Muela catchment.

All around the site, I could see evidence of silt run off. With such a mountainous country, and obviously fast run off, trying to control silt must be key for water providers and hydro generators. Rentseng explained that the Lesotho Highlands Development Authority works with local farmers and the community to control silt intake, but there has been slow progress.


Erosion evident wherever I went.

4.2.3 Fish sensitivities

Another environmental sensitivity that the project has had to deal with is the Maluti minnow (the world's smallest freshwater fish), only found in one of the feeder catchment dams. The cost effective solution has been to install screens on the outlets of the feeder tributaries of the dam, to prevent larger fish entering the tributaries, thus providing protection for the minnow for breeding at least in the tributaries.

4.2.4 Leaks

I visited the dam and inspected the tailrace. It looked surprisingly green with algae, which I was puzzled about. Rentseng wondered if this was due to a recent 2 month shut down in the transfer pipe. One other problem that I noticed at the plant is the seepage of water from the pipe. Rentseng mentioned that there is possibly a leak in the 47 km inlet pipe. However, it is not possible to shut it down for repairs, as Lesotho is committed to transferring water to South Africa. There is a bypass for the HPP itself, but not for the inlet, and there seems to be a fair amount of water seeping into the plant.

4.2.5 Findings and Recommendations

- Silt is presenting a serious issue, both for sustainable land management of the country's catchments, and for the water transfer scheme. There is no easy solution for this but the Lesotho Highlands Development Authority needs to consider appropriate incentives to encourage farmers to avoid burning too early in the season to retain topsoil.

5 Zambia

5.1 Introduction

I was in Zambia from 28 August 2011 to 3 September 2011, and visited the following sites:

- Kafue Gorge
- Kariba North
- Victoria Falls.

I am deeply grateful to ZESCO for allowing me access to their sites.

I would like to acknowledge the assistance of Dennis Banda of ZESCO, who took me around the sites, and was so helpful over the week facilitating the site visits. Also thanks to Victor Mundende for supporting and planning the visit, and Mr Musonda Chibulu for allowing it.

5.2 ZESCO

ZESCO has around 4000 employees, and has a hydro capacity of around 1700 MW. Almost the whole country is the catchment of the mighty Zambezi River, and consequently, drought is uncommon.

I met up with Bonje Muyunda and Robam Musonda of the environmental team. With 40 % of all water in Southern Africa within the Zambian area, their team is more concerned about flood management than drought prevention.

The key sites that ZESCO manage include:

- Kafue gorge – 990 MW
- Kafue Lower (still under development) – 750 MW
- Kariba North – 690 MW
- Victoria Falls – 108 MW.

An independent Zambezi River Authority manages abstraction limits from the Kariba Basin between Zimbabwe and Zambia. Recently a Zambezi River Basin Commission has been drawn up to look at all the water within the Zambezi, and while its neighbouring countries have signed, Zambia has stalled, as there is a much greater impact on the country. With virtually all its inland rivers flowing into the Zambezi, the impact could be much more serious.

ZESCO has not yet used Cleaner Development Mechanisms (CDM) funding for any of its hydrostations. Apparently it is in the process of doing so for Itezhitezhi (ITT) power station, which is a site being developed on the upper Kafue. The staff I met with in ESKOM in South Africa were doing several CDM funded projects, and it would be worth pursuing for the proposed small hydro sites.

5.3 Kafue Gorge Regional Training Centre

Denis Banda at the hydro training centre.

Dennis took me to the training centre, which has become a centre of excellence for hydropower training in the southern African region. With input from NorAid (Norwegian Aid), the centre has flourished, and it really impressed me. I took away the course schedule, and noted some courses:

- High voltage regulations
- Power plant operation and control
- Operation and Maintenance
- Turbine Dynamics and Operations

The site has world-class facilities and the course diversity looks excellent.

5.4 Kafue Gorge Hydro Power Station

I met with Samuel Sindesi, the head of operations at Kafue Gorge. ITT (Itezhitezhi) header dam was built much further up the Kafue catchment, to control release of flow down to the plant's intake dam, Kafue dam. Although the two sites are 400 km apart, Kafue dam is only 6m lower in height than Kafue. The flat land in between, called the Kafue flats, is an internationally recognised wetland. It takes water between three and four months to get from ITT dam down to the Kafue dam.

As a result silt is no issue in the Kafue dam, as the water moves so slowly that it settles out any sediment. However, what is a major problem is the build-up of water weed (hyacinth) on the slow moving Kafue dam. This is exacerbated by the presence of a fertilizer factory (Nitrogen Chemical Zambia) and the Zambia sugar refinery, both located in the Kafue flats, and discharging eutrophic effluent into the river.

Mats of hyacinth, phragmites and buffalo grass floating next to the dam.

The hyacinth clogs the intake screens to the headrace tunnel. In 2009, the situation got so bad that no water got through at all, and the plant was shut down three times. The situation is now managed by manually dredging the dam, and there are mini-mountains of hyacinth drying out all around the dam, waiting until they are sterile enough to be used for fertilizer. The plant controls the Kafue dam, and is currently releasing a 7.2 m^3/s compensation flow (although from what I gather, this can be reduced in dryer periods). The dam is currently releasing at 130 m^3/s to increase capacity for the impending rainy season (November – March).

The crane on an endless cycle of lifting hyacinth weed out of the intake area.


Booms installed recently at water inlet, to minimise hyacinth blocking the screens.

There is an effective conservation area in the 14 km zone between the plant and the dam, with the whole area being managed by ZESCO, in conjunction with the department of forestry. The mopane woodland is pristine and there was no evidence of exotics. The area would make an ideal game conservation area, as the high site security would help protect the game from poaching.

5.4.1 Hydropower Plant


View of the station.

Water goes through a 10km headrace tunnel and then drops 500m into six 165 MW Francis turbines. We drove down to the inlet tunnel and Samuel pointed out the location of a mudslide that occurred in 2005, when heavy rains induced a mud slide down the steep mountain sides. The mud used the access road and tunnel as a conduit, and went straight into the plant, and got into the turbines, damaging them. Channels have been built to prevent this re-occurring, although there is a risk that this could reoccur further up the access road.

5.4.2 Water and Drainage

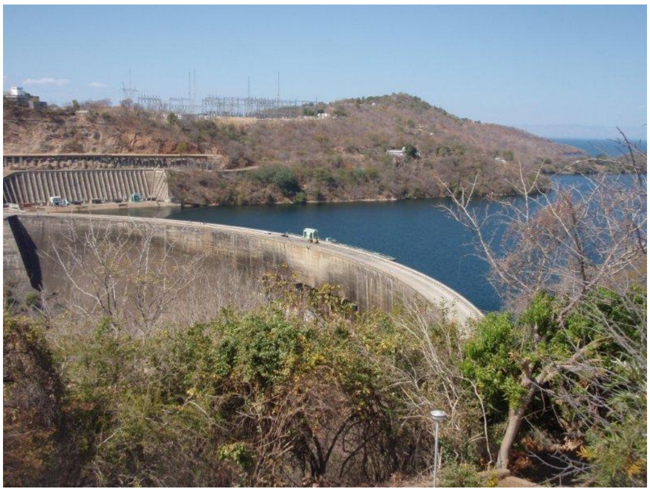
The site has no oil separators for the water drainage sump. Furthermore, one of the transformers recently blew a valve, and the housing room is covered in oil. When we went in, workers (with no breathing apparatus) were using paraffin and peat to clean up the oil, and the smell of hydrocarbons was overpowering.

The turbine cooling water uses fresh water from the intake tunnel and is discharged at around 34^{o}C via the tail race.

Mr Denis Banda and Mr Samuel Sindesi.

5.5 North Kariba Hydro Power Station, Zambia

The power station is right next to the Zambian side of the dam wall, and there is a second identical plant on the Zimbabwean side. Mahaku Maloza, the project engineer for North Kariba Power Station gave me a useful overview presentation. The site is the second largest hydropower plant in ZESCO, and was commissioned in 1976.



The dam wall acts as the border between Zimbabwe and Zambia.

5.5.1 Zambezi River Authority

All water flows from Kariba dam are controlled by the Zambezi river authority, which monitors levels, flow and the dam structure itself. The organisation dictates the water volume that can be used by each power station, and ZESCO normally pays a tariff based on flow. The flow meters are currently out of order, so ZESCO currently pays their tariff based on power produced. This tariff is used by the authority to maintain the dam, and associated infrastructure. Every five years, the chair of the Zambezi river authority swaps between Lusaka in Zambia and Harare in Zimbabwe.

5.5.2 Lake Kariba

Lake Kariba has such a big surface area that flooding hasn't been much of a problem. The Zambezi river authority communicate with the downstream Cahora Bassa dam in Mozambique if they release water, as downstream has much more of an issue with flooding.

5.5.3 Hydro Power Station

The site has a net head of 92 m, with four Francis turbines manufactured by Voest. Originally the site had 600 MW installed, but once the current rehabilitation (which started in 2001) of the turbines is complete, it should increase to 720 MW. Two things made for an unusual site visit here: - the fourth and final turbine is in the middle of its rehabilitation, and so has been taken to pieces; and secondly, the site is in the process of a US$400 million extension project, to add turbines 5 and 6.

A standby 1MW diesel generator is needed to start the plant if it goes down. Alternatively, there is a line to the hydropower plant on the Zimbabwean side of the dam which can be used.

5.5.4 Rehabilitation Project

Workers underground in the plant working on the runner for Turbine 4, as part of the rehabilitation project.

The time needed to manufacture the runners for the rehabilitation of the generators was 18 months, which had delayed the rehabilitation project. Another learning point from the rehabilitation project was that when turbines 1 and 2 were rehabilitated, the runners were not replaced, so that the turbines could not generate their maximum output. This was rectified for turbines 3 and 4.

5.5.5 Extension Project

The tailrace being built for Turbines 5 and 6.

Coffer dam with works on inlet to the new turbines 5 and 6.

5.5.6 Drainage sumps

As with Kafue gorge, there was no oil separator in the drainage sumps. There was also a large flow of water coming from Turbine 3, which has a large leak and consequently dewatering pumps are required when Turbine 3 is running. Unfortunately the leak has been there for a long time, and was not resolved during the rehabilitation.

A big fire occurred at the station in 2009. The air chillers have been replaced since then, and a fire hydrant system is currently being installed. The cooling water is not recycled, but is discharged below the tail race.

We drove over to the batching plant, where rock is being crushed and sorted for the extension project. It was extremely dusty and there was no dampening of the area. I did notice water being sprayed on the area nearer the works however.

5.5.7 Contaminated Soil

Rows of rusting drums containing PCB contaminated soil.

ZESCO had some years back replaced their old transformers which contained Polychlorinated Biphenyl (PCBs) which is now banned, as dangerously carcinogenic. Furthermore, a contractor had spilled some drums containing PCB oils. All the soil that was contaminated was collected into drums and all the contaminated protective clothing was collected, and all of this waste is now stored in rusting drums, waiting to be exported to a suitable waste site (not available in Zambia).

5.5.8 Private Hydro Development

I had a telephone conversation with Daniel Rea, who has been doing some work with a charity, called Zengamina Hydro, in the North West Province. This is a 700kW run of river scheme, currently running at about 30% capacity and increasing steadily on an island grid. The scheme fills a gap for power capacity, as ZESCO's grid does not extend that far. ZESCO have made the strategic decision not to include that far remote corner of the country on to the national grid, and they themselves are looking to develop some small hydro instead in the area. The scheme has a website as follows: http://www.nwzdt.org/?page_id=22

5.6 Victoria Falls Run of River Hydro Scheme

View looking down to the three hydro stations.

Victoria Falls hydropower station is located in a UNESCO world heritage site (declared in 1989), and, surrounded by game parks, it has some unusual environmental issues to deal with. How many hydro stations have had a hippopotamus trapped and drown at the inlet screens? And as far as environmental sensitivities, it is located in close proximity to one of the world's biggest tourist destinations. This would be a challenge for any country to deal with, and I commend Zambia for managing the balance between the needs of tourism, conservation and power generation!

Abraham Sashi, the power station manager, gave me an overview of the scheme. The site is an odd mixture, as it has been upgraded several times over its history. Originally commissioned in 1938, with just two 1MW turbines, it was subsequently expanded in 1956, and a further two more 3MW turbines were added (station A). In 1968, an additional power station B was built close to the old site, with six 10MW turbines. Finally in 1972, a third and final power station C was built adjacent to Power Station A, with four 10 MW turbines. From 2003-2005, the site was rehabilitated, and serious consideration was given to increasing the capacity further. However, at this point the Ministry of Tourism stepped in, with concerns that the splendour of the falls would be diminished with the reduced water flows, and any further expansion has been shelved. This leaves the site with a total capacity of 108MW, all Francis turbines, with a 5km intake pipe to the 107m high penstocks. Mr Sashi estimated the site has a utilisation of around 87 %, which seemed high to me, considering the dry season (Oct-Dec), and the site having no header reservoir.

The site supplies power to the Southern Province of Zambia, and has a power purchase agreement to supply power to both Namibia and Botswana. It also has an emergency line over to Zimbabwe, to supply power if needed. The site runs in island mode from the main grid frequently (as there is work being done on the connecting line near Kafue), and uses a 660kW standby diesel generator with UPS to restart the site.

There are some key lobby groups that ZESCO engages with:

- Zambia Wildlife authority (manages the game reserves in the area)
- National Heritage conservation Commission (interacts on behalf of the world heritage site)

- Livingstone Tourism Association (represents the numerous hotels in the area).

The key pressure is on how much water ZESCO can abstract. ZESCO has no licence requirements for their abstractions at the site. I was disappointed that the seemingly effective Zambezi River Authority that controls water abstraction for the power stations on the Kariba dam, does not enforce water controls further up the Zambezi. It seems like a natural extension of their powers, and I would hope that this might happen at some point.

Currently ZESCO is committed at low flow periods (below 400 m^3/s) to reduce capacity from 108MW to 35-45 MW. However, for the past two years, this has not happened in practice, as the power requirements for Zambia have been such that ZESCO has had to renege on this.


Boom in front of intake to prevent hyacinth entering intake.

A site operation engineer, Lioko Sitali, took me around the site. The two intakes for the scheme are 500 m upstream of Victoria Falls, adjacent to where the tourists go to view the falls. Water hyacinth is a serious problem for the intake, especially towards the end of the dry season, with low flows. Lioko explained that the hyacinth can both float and sink, rending the floating pontoons that they have erected around the intake ineffective. The fact that it both floats and sinks means that it blocks the manual intake screens easily from the bottom and from the top. A trash rack is used continually in the dry season to remove the hyacinth, but once it is compacted at the bottom of the screens, the trash rack is useless, and an employee would have to enter the intakes to unblock them, not a pleasant sounding job.

This scheme is a true run of river scheme, with no weir or buffer dam. Consequently, silt is a major issue, as the water comes straight from the river. A series of two silt ponds on each of the two intakes has been designed, with valves that drain the silt into the Second Gorge. Originally, this silt drained adjacent to the main Victoria Falls gorge, but due to concerns from UNESCO about visual impact on the falls, this outfall has now been moved. One of the valves was jammed shut during our visit, and I could see a noticeable build-up of silt in the water. The intakes are shut once a year, during the dry season, to allow for the silt ponds to be emptied.

Build-up of silt in the far settling pond.

A key issue is the volume of water coming through the intake. Originally this was manually controlled, but since the rehabilitation in 2005, there are automatic sluice gates, which control the volume of water entering. This ensures that not too much water goes into the plant, as previously this was being spilt further down, again causing a visual impact, and detracting from the main falls.

We walked down to the plant at the bottom of the gorge. It was evident that rock falls from above are a real concern. Gabion baskets and netting have been used, but there is evidence of numerous rock falls.

The intense force of the water in the gorge also causes problems at the tailrace. The chicken-wire fencing holding the gabion baskets together continually rusts, and releases the rocks. Consequently an ongoing and hazardous maintenance job is replacing and remaking the gabion baskets.

Workers replacing gabion baskets – an ongoing battle.

We saw an oil separator installed at the top of plant C, which seemed an odd location. It looked far too clean to have ever been used.

The three adjacent sites have waterproof doors. These doors and a high-level walkway between the plants were installed after the great flood of 1957, when the water reached unprecedented levels. This means that the plants can continue generating, with operators entering and exiting the plants via their roofs, which I thought was innovative.

Dennis Banda and Leoko Sitali on the high-level walkway.

We caught the lift back up, instead of climbing the stairs. At the top of the gorge, we inspected the new control room, that controls all three power houses remotely. It must have had a huge positive impact on the operators and looks excellent.

We saw the switchyard, and Lioko explained how the perimeter of this has now been electrified to stop playful monkeys coming to investigate and getting electrocuted on the wires, and causing a short circuit.

5.7 Recommendations and Findings

5.7.1 General

- Consider Cleaner Development Mechanism funding as a potential for the proposed small hydro developments.
- The Zambian hydro training centre and capacity building is of international standards. That could be shared; I think other countries would be interested in their programmes.
- Consider adding an environmental module to the hydro training programme (something covering waste management, reduce, recycle, reuse etc).
- Water hyacinth is causing a serious problem on the intakes of many of the hydro power stations. Some water companies aerate reservoirs with blowers to prevent algal bloom build-up. Could this be considered here?

5.7.2 Kafue Gorge

- The harvested water hyacinth is currently being stored in windrows (compost-style furrows). Hyacinth makes excellent compost, and it should be possible to treat it a little more, to provide good compost. It should be chopped up (is that feasible?) and stored in long rows to allow it to dry out.
- The high security area between the dam and the power station is in pristine condition as a conservation area. Would ZESCO consider stocking it with some game, as part of their environmental management commitment? For example ESCOM are doing similarly in South Africa at the new Ingula power station, where they have a big land holding.

- Consider investing in some environmentally friendly oil spill kits, such as DRIZIT or similar, for cleaning up oil spills. And provide personal protective equipment for oil spill clean-up (masks, gloves).
- Consider investing in a rope mop skimmer or similar, to remove oil from the water sump.

5.7.3 North Kariba Hydropower Plant

- Dust seems to be a big problem with the current extension project. Would it be possible to extend the road dampening exercises during construction?
- Ensure that the fines from the batching plant cannot be washed down into the Zambezi; the site is very close. In the event of a heavy rainfall event, is there any drainage at the batching site to protect the river from debris?
- Consider putting up a sign board warning people about changing water levels at the dam, and below the dam. Several housing and hotel developments have been built right on the water level.
- Consider investing in a rope mop skimmer for the water sump.
- Make it a priority to remove the PCB contaminated drums from site. The state of the drums is now putting the safe storage of the PCBs at risk. Transport of PCBs would fall under the Basel Convention with the Environmental Council of Zambia (ECZ) the focal point for this.
- Consider recycling the cooling water as part of the upgrade.
- The Kafue gorge hydro station seems to have taken a bold step forward by having a minimum in-river (compensation) flow guaranteed. This is definitely a step in the right direction for ZESCO; are they planning to do it on other sites? It is much better environmentally to have a steady minimum flow, to allow habitats and fauna to establish themselves.

5.7.4 Victoria Falls Hydropower Plant

- The Zambezi River Authority seems to be taking an excellent role in both diplomatic relations and environmental control on Lake Kariba (and the water quality there looks excellent, or is that just a coincidence?); could they not extend their arm up the Zambezi for issues at Vic falls power station, or on the proposed Batoka gorge station? They already have all the politics in place for it, and it would facilitate cross-border discussions.
- The Vic Falls intake is a source of dispute between the hotels and the hydro station, with the hotels wanting reduced generation during low flows. A key problem seems to be that the intakes have been constructed right against the left (Zambian) bank, whilst the bulk of the water flows naturally on to the right (Zimbabwean) bank. It might be possible to reduce flow into the existing intake, whilst developing a further intake /pipe possibly screened by the islands, feeding into the intake. The issues seems to be more about trying to redistribute the remaining water flows down the falls than about reducing generation, which is not a viable solution currently.

- The Vic falls is in a unique position at the bottom of the falls; have they considered eco-tourism using the trolley-car to take tourists down?
- The off-grid islanded schemes (both private and ZESCO run) in the rural north-west areas seem to be an innovative way of approaching resolving providing power to remote communities without overstretching the national grid. This should be promoted.
- The eutrophic effluent is coming into the intake of the Vic falls power station from the primary settling ponds of the sewage works; could they move / extend the outfalls of the sewage works into the main flow of the Zambezi, to minimise hyacinth build-up?
- Confirm if the oil separator on plant C works.

6 Tanzania

6.1 Introduction

Over the period of 3 September 2011 – 9 September 2011, I visited sites on the Pangani River Basin, as well as some meetings including:

- Hale Hydro Power Station
- Pangani Falls Power Station (new and old)
- Katani Biogas Plant
- Nyumba ya Munga Power Station
- Nyumba ya Munga Water Officer
- Kikuletwe Springs and Old Power Station
- Hans Lottering (private energy consultant in Tanzania)
- Pangani Water Officer.

I am deeply grateful to TANESCO for allowing me access to their sites.

I would like to acknowledge the assistance of Boniface Njombe, for supporting this trip, Patrick Lewisia for being my guide for the first part of my travels, Pakaya Mtamakaya for allowing me to stay at the TANESCO guesthouse, and John Skauki for being my guide on the second part. Also thanks to Costa Rubagumya, Charles Mwaiko and Oswald Luambano, and numerous others for their time and assistance.

6.2 TANESCO

TANESCO employs between 5000 and 6000 staff, and has a capacity of 580 MW, with around 55 % hydro, and 45 % thermal power stations (this was previously more on the hydro but has swung in recent years). There is currently a power crisis in Tanzania, with the drought in East Africa impacting Tanzania too. The last two rainy seasons have been poor, and the hydro header dams are at critical levels. The country has been load shedding since the beginning of this year, around 300 MW short on average. Consequently TANESCO are under political pressure, and are currently commissioning two new thermal plants in Dar es Salaam.

Tanzania does have natural gas reserves just offshore of Dar, but the pipeline that connects the fields to the gas power station is undersized, and is too expensive to resolve in the short term.

6.2.1 TANESCO Hydro Capacity

I met with Costa Rubagumya of TANESCO at their Ubongo Headquarters. He talked me through their seven key hydro plants:

- Hale (commissioned 1964) – 21 MW (currently shut for rehabilitation)
- New Pangani (commissioned 1994) – 68 MW (a previous adjacent site was built in 1935, which is now closed down at this site)
- Kidatu (commissioned 1975) – 200 MW
- Kihanse (commissioned 2000)- 180 MW (this site has potential to expand)

- Mtera (commissioned 1968) – 80 MW
- Nyumba ya Munga (commissioned 1969) – 8 MW

The two key river basins being abstracted in Tanzania are the Pangani basin in the north, and the Rufiji basin in the south. TANESCO have got three old smaller run of river sites (<10 MW) that are in need of rehabilitation. To raise the necessary funding for this, these plants are being offered as Independent Private Partnerships with a 2 year rehabilitation period, followed by 15 years of operation, before the assets must be handed back to TANESCO.

6.2.2 Regulations

I met with Hans Lottering, a private energy consultant in Tanzania. TANESCO is regulated by the Electricity and Water Utility Regulatory Authority (EWURA). A key problem is that the rates are set by the regulator – currently at 7 US cents/kWh. With TANESCO operating costs running at around 6 US cents/kWh, the margins are not enough to attract private investment which is desperately needed to increase capacity.

With several undeveloped potential hydro schemes in the country, it is frustrating that TANESCO has been unable to attract investment. TANESCO has committed itself to public private partnerships, and until the rates are increased to make investment more attractive, TANESCO will struggle to attract the investment it requires.

6.2.3 Standard Power Purchase Agreement

The regulator EWURA has recently agreed to a Standard Power Purchase Agreement (SPPA) for private investors producing up to 10MW of 102 Tanzanian Shillings (6 US cents)/kWh, with a guaranteed period of 15 years.

The rate has been made more attractive for rural off-grid areas, to encourage developers to invest in these as islanded sites. With only 13% of the country having access to power, this is a positive initiative.

6.2.4 Cleaner Development Mechanism (CDM) and Joint Initiatives

CDM was developed to encourage wealthier countries to invest in cleaner technology in developing countries, to offset their carbon load. The methodology of calculating the baseload of the country has penalised a hydro-biased energy market like Tanzania. Because the country used to be heavily hydro-dependent with a low carbon footprint, it has not attracted as much funding as for example South Africa, which is heavily coal-dependent.

6.3 Hale Power Station and associated Sites

6.3.1 Pangani Basin

I met the Pangani station manager, Pakaya Mtamakaya. Although Hale is currently undergoing rehabilitation, Pakaya is also responsible for the New Pangani Falls hydro scheme just 10 km lower down the Pangani river. Both sites are under hydrological pressure, with not enough water being released from the Nyumba ya Munga reservoir further up the catchment.

The Pangani river starts in the Kilimanjaro region, and runs for 432 km before it discharges into the Indian ocean. The basin is under severe water pressure, with big increases in the local population, and irrigation. There are several wetland areas upstream of the hydro plants, and the feasibility of draining or channeling them is discussed. The publication acknowledges that draining of the swamplands would impact on the biodiversity, but comments that it would increase the amount of water available downstream for hydropower. I was surprised that this was even considered, but the situation is obviously critical.

Having separate ministries of water and energy has meant that there is no joined up thinking when it comes to a holistic view of water resource planning.

6.4 Hale Power Station

This site is currently closed for rehab, and has a net head of 63 m, with two 10.5 MW English Electric turbines, one of which failed in 2003. The second turbine developed a fault with its runner last year, and it was subsequently decided to shut the whole plant for rehab. The plant is a run of river scheme, with roughly 5 km stretch of river affected. There is a small reservoir at the intake, which releases a compensation flow to feed the sisal biogas power plant further downstream. There has not been enough water coming down the river to operate the plant at capacity for some years. The intake does get blocked with debris during the rainy season, but water hyacinth is not a big problem at the site. A trash rack is used during the rainy season.

Water spilling from the Hale reservoir, as the site is shut for rehabilitation.

We went down the lift to inspect the plant. There is no access tunnel, so all equipment had to go down a shaft. It is proposed to blast an access tunnel as part of the rehab. There is no oil sump, and cooling water is not recirculated.

The tailrace comes out of its 670 m tunnel, into a canal which then enters the Pangani River.


Tailrace exits into a canal, and then into the Pangani river.

6.5 Katani Biogas Plant

I visited the neighbouring biogas plant (Katani Ltd). This site is a sisal factory, preparing sisal plants for processing. The sisal fibres are stripped from the leaves, using water to both transport and wash the product. The pulpy by-product is a waste product, and in 2007, a digestor was commissioned using the pulp to make methane, which runs two 150 kW generator (combined total of 300 kW).

The digestor is too small to take all the waste product, so a pulpy soup is flushed back into the Pangani river – just a few kilometers upstream of the New Pangani Falls Hydro Intake. This nutrient-rich load may be contributing to the weed problem at the intake.


Sisal by-product flowing into the Pangani river.

6.6 New Pangani Run of River Hydropower Plant

Charles Mwaiko, the electrical supervisor at New Pangani, took me around this site. It has two 34 MW Francis turbines and was commissioned in 1994, with funding, contractors and equipment from Nordic countries (Sweden, Finland and Norway). This site replaced the original (Old Pangani Falls site) station which was built in 1932, although originally it had been hoped to operate both.

The site has a 1.8km single intake tunnel, with both a flap gate and sluice gate, to reduce hyacinth and silt entering the intake. Charles operated the trash rack for me to see it in use, and up it came with a load of weed. The flap gates looked like a good design to help flush the weed down river, and thus bypassing the intake.

The flap gate on the side, catching weed.

A compensation channel was built as part of the intake pond's design, but the water levels are so critically low this year that the site is not discharging any water. The compensation flow is operated in the rainy season only, and consequently, when I saw it today, there was 5km of river with little or no water in it.

The trash racks in operation catching weed.

The dam's controls have to be operated manually, as the computer connecting it to the control room has been out of order for the past five years.

We drove down the access tunnel to the plant. It has 178 m head, and was pleasantly cool inside, after the heat outside. The cooling water is recirculated.

We inspected the tailrace, which is an 800 m tunnel coming out of the cliffs into a reinforced canal, that joins the Pangani river. The cliffs above the tailrace have been shotcreted, and reinforced with bolts, and look extremely robust.

6.7 Old Pangani Falls Hydro Power Station

I visited the original Pangani site, built in 1932 by the British, an almost identical-looking plant to the one built at Victoria Falls two years later.

When New Pangani came on-stream in 1995, it was hoped that the old site could continue operating as well. It was quickly discovered that there wasn’t nearly enough water, and since then the water levels in the Pangani basin have been dropping steadily.

We caught the still-working funicular down to the station, and it was fascinating to see all the turbines still in situ, although the building is now derelict.

It is hoped that this site might either provide a training site, or a museum at some point.

6.8 Nyumba ya Munga Site Visit

Oswald Luambano took me around this site. The reservoir was built by the Ministry of Water for irrigation in 1964. The power house was built as an add-on by TANESCO, and commissioned in 1969. With the dam owned and operated by Ministry of water, there is a tension between the two directorates. The Water Ministry needs to keep the huge demands of upstream and downstream agriculture happy; sugar and rice plantations, both heavy water users, are taking more water out of the Pangani River than is sustainable.

Nyumba ya munga, just visible on the horizon through the semi-arid vegetation.

The site employs around 10 technical staff, and 30 support staff, and is an important job provider in the region.

6.8.1 Drought

Notwithstanding the overly-heavy irrigation uses, the area is also suffering a drought. The last two seasons have been dry, with the last bad drought in 2006. The reservoir currently has 33 days of hydro generation at capacity left in it, and consequently only one of the two 4 MW

Francis (Gilkes) turbines are operating, and even that is only generating 3 MW. The site has a relatively small head of 27.4m.

The water levels are dropping 0.01m every day.

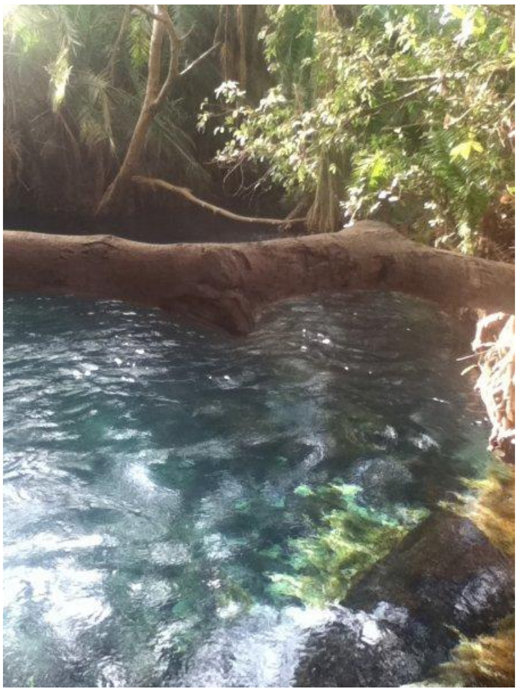
6.8.2 Reservoir

The reservoir is reasonably close to the Pangani's source, and the water is noticeably clean, and has no algal or weed problems. The reservoir has no compensation flow valves, and releases water via the spill way. A small water treatment plant takes water from the intake for the TANESCO employees.

I met the local Water Officer, Mr Thomas Kilavu. He explained that TANESCO have a seasonal abstraction limit at the dam, of 16.57 m^3/s during the dry season and 28 m^3/s during the rainy season. The Ministry of Water has two gauging stations on the river, one at the tailrace of the Nyumba ya Munga power station and one below the main irrigation area.

6.9 Kikuletwe Springs and Old Power House

John Skauki, the station manager at Nyumba ya Munga, drove me to the Kikuletwe springs. According to the Pangani Water Officer, these contribute a steady 10 m^3/s to the Pangani River.


The clear waters of the Pangani Spring.

There are 10 artesian springs, all starting in the Great Rift Valley, feeding the Pangani, and their flow is constant year round. The springs are a very special environmental area, and currently have no protection around them. They are used as a recreation area by local people.

It was this spring water that German farmers had tamed and canalised in 1937, and built the run of river Kikuletwe Hydro Power Station. It consists of three Voith turbines, 250 kW, 350 kW, and a 750 kW (with double runners unusually, built to spec.).


The abandoned intakes for the plant.

In the 1970s, when foreign assets were nationalised, the power station was handed over to TANESCO. It ran for a short while, but was then neglected as it was considered too small to be useful to the national grid. Now, the site stands abandoned and unused; however with the current power crisis, TANESCO are looking for a Public Private Partnership to take this site over. Its location, so close to the springs, means that it would be able to operate year-round, regardless of the water crisis facing the other Pangani River Power Stations. There are other potential small sites (with one 13 MW potential site 2km downstream) that have been previously identified, in close proximity to this one.


John Skauki (middle) and his staff at the old power house.

6.10 Pangani Water Basin Officer

6.10.1 River Basin Board

I met Mr Basso, the Pangani Water Officer, hoping to find out more about the apparent water crisis in the Pangani River Basin.

There are nine river basin boards across Tanzania, sitting under the Ministry of Water, as implemented in 1991. The Pangani Water Office allocates water permits for the Pangani basin, with domestic water consumption getting first priority. Mr Basso estimates that 80 % of the Pangani river water goes on the upper catchment, for irrigation of water-intensive crops such as rice and sugar cane. A water crisis has been developing across the Pangani over the past 20 years and it is reaching a crisis point.

The rainfall varies hugely across the basin, with the upper wet mountainous areas, up to 2000 ml/annum, the middle arid area around the Nyumba ya Munga reservoir receiving 300-500 ml/annum and the lower downstream areas around 1000ml/annum.

6.11 Recommendations and Actions

6.11.1 Generic

- It is positive that a power purchase agreement has been made, and this should be pursued actively, particularly for the rural off-grid areas.
- Cleaner Development Mechanism funding is available for developing new hydro schemes. With the recent swing in Tanzania's supply from hydro to thermal, it may be possible to get the original baseload of country re-evaluated, which would give more opportunity for funding.
- Having separate ministries of Energy and Water is a particular problem for water users on the water-stressed Pangani River basin, as well as the country as a whole, during times of drought, as at present. It is recommended that if it is not possible to combine these ministries, then closer collaboration needs to be established urgently.

- The water crisis on the Pangani is reaching a climax, although it was always an issue, with the Pangani River basin catchment officer post established back in 1991. The urgency of the current situation needs to be conveyed to the government, and to the Ministry of Water.

6.11.2 Hale Power Station

- It is understood that a closed-circuit cooling water system will be introduced as part of the rehabilitation. Anything that can reduce water consumption is desirable, so ensure that this is in the specification.

6.11.3 New Pangani Station

- The site has a problem with weed entering the intake. Previously, biological control programmes have been attempted (apparently unsuccessfully), and currently, weed is kept under control manually, by regular clearing with the trash racks. The site has good physical controls in place. It may be worth considering spot treatment using chemical control, during bad periods.
- The dam's controls have the potential to be accessed remotely, which may improve response time to water levels. These have not been functioning for the past five years, and priority should be given to repairing these.
- TANESCO to discuss with Katani Biogas Plant, and /or Ministry of Water, the option of Katani installing a settling pond for the waste water, prior to discharge to the river, to minimise carbon load going in to the Pangani River.

6.11.4 Old Pangani Power Station

- There is so much scope to use this site both for tourism and for training. It has the potential to be a regional centre, a bit like the Kafue Gorge Training Centre in Zambia. TANESCO should be encouraged to consider this urgently, before the dilapidation of the buildings gets too serious. It may be worth contacting the original turbine providers, to see if they would be interested in supporting the maintenance of this site.

6.11.5 Nyumba ya Munga

- The site is an important job provider in an otherwise impoverished area, and TANESCO should make every effort to support this site.

6.11.6 Kikuletwe Springs

- Consider putting some protection around the springs. There are TANESCO staff stationed at the old power house; so they presumably do patrol the springs as well. Consider erecting signage adjacent to the springs, listing rules of using the site (e.g. stating that the property belongs to TANESCO, and no camping, no litter, no illegal abstractions?).
- The steady year-round flow of the springs makes the old power house ideal for development. This should be pursued.

6.11.7 Pangani River Basin Office

- Lobby the Pangani River Basin to consider the impact of the intensive agriculture up-stream. The river basin is in crisis, and the Ministry should be considering implementing a drought order.

7 Conclusions

In the context of a world hungry for energy, environmental needs sometimes must get sidelined. However, the recent change in Britain towards renewable energy has seen a re-investment in old hydro sites, long-forgotten. Consequently, I set out on this study-tour, hopeful that I could document environmental practice that could be adopted for British hydro sites. I believe my observations may also be of use to overseas aid organisations.

7.1 Environmental Impacts

A lot of attention in Britain is focussed on migratory fish and potential mitigation such as fish ladders. In Norway, focus is given to conserving non-migratory fish such as perch and pike, on those rivers that have numerous hydro developments. Eel populations are vulnerable to turbine blades, and protecting their populations is of great concern in Norway. In the UK, eel populations have already crashed, and I believe their conservation around hydro sites will become important.

The environmental footprint of a smaller site can be much more damaging than a larger site, with a smaller power return as well. In Norway, many larger hydro sites have been sited all underground, with very little visual impact.

The Water Framework Directive requires a continuity of flow. There is no point providing fish passage for fish going up rivers, only for the smolts to get destroyed in the turbine coming back down again, and consequently a downstream as well as upstream flow is important to maintain.

The opportunity for using the high security of power sites to protect vulnerable species has been taken up on several South African sites. There is real opportunity for eco-tourism and conservation, arm-in-arm with a big energy project, and this could developed at British sites.

Minimising contamination of water from different catchments has been achieved in South Africa by not releasing downstream flows. This could be a useful technique to adopt in British catchments.

7.2 Licence Requirements

Licences with longer permit period do give a stable return and consequently give rise to a stable industry, such as in Norway. However, they may have impacted the receiving water courses, with too little compensation flow, and little opportunity for the Regulator to review licence conditions. Hydro licences in Norway include charges for any additional water that is gained by regulated water (dams). This seemed to be an effective system, and may be worth implementing.

7.3 Pumped Storage Schemes and Network Sites

Storing energy is problematic. However, a solution is to pump water up to high head reservoirs, to be released to generate energy at a moment's notice, using pumped storage schemes. Pumped storage may provide a solution to Scotland having to dump excess wind energy.

The dumping of excess heat from turbines into break pressure tanks is something that might be considered in Scotland, to prevent freezing pipes, rather than dumping to load banks.

Developing specific training courses for turbine operators has been extremely successful in Zambia, and should be encouraged in the UK.

7.4 Financing

In Norway, there were no financial incentives, and yet the micro hydro business is booming. This may be partially down to the fact that hydro licences are issued on such a long term basis, and the head can never be altered. Consequently there is very low risk from an investment point of view.

Zambia has embraced Chinese investment, and is consequently able to forge ahead with hydro development. It is currently expanding its North Kariba power station, whilst on the other side of the dam wall, the Zimbabwean South Kariba power station is under-invested and is limping along.

7.5 Items specific for African Sites

Weeds, and in particular water hyacinth, are a massive problem on the intakes of many African sites, and maintaining a weed-free zone around the intakes in crucial to keep the sites operating. The options are physical removal (which most sites were doing), biological (using insects to control population) and chemical (spraying).

Several of the schemes I visited in African countries were abstracting a large volume of water leaving little for the environmental requirements of the river. Whilst power shortages are critical all over the continent, the need for power must to be balanced against environmental needs.

I visited two South African power plants that have been designated as RAMSAR sites, and are extremely environmentally sensitive. The opportunity for eco-tourism and conservation, together with big energy projects could be further developed on the Zambian and Tanzanian sites, in particular where the high security can protect against poaching.

In particular, the Pangani river Basin in Tanzania is in crisis, despite having a dedicated river basin office, to authorise abstraction licences. It appears that intensive agriculture upstream has partially caused this problem, and a balance between agriculture and hydropower urgently needs to be found.

Globally, there is a shortage of power, and this is particularly evident in Sub-Saharan Africa, where more and people are being connected to the grid. Power stations are expensive long-term projects to build, and consequently there is a huge need for more power stations, preferably low-carbon. Tanzania used to be 85 % dependent on hydropower, and is now down to around 55%.

I found no examples of Cleaner Development Mechanism funding used for hydro sites in Zambia or Tanzania, and yet both of these countries have opportunities for further hydro development, in particular in Tanzania, where the swing to thermal power is noticeable. This is because diesel-powered thermal plants are being installed, as they are cheaper and quicker to bring on-stream. I visited derelict hydro sites in Tanzania that need investment – surely this would be a better environmental solution in the long term!

7.6 Summary

The Scottish government is busy laying out its plans for becoming a *Hydro Nation*. I hope these recommendations will assist Scotland and the UK in moving firmly towards more hydropower, confident in the knowledge that it is possible to develop hydro whilst protecting the environment.

8 References

Hydropower development in Norway (1992) by Vidkunn Hveding. Published by Norwegian Institute of Technology.

The provision of a detailed study and investigation for the desiltation of dam weir in Mbashe dam in the southern region (2011). Alasdair J Murray SSI Engineers and Environmental Consultants.

A high level scoping investigation into the potential of energy saving and production / generation in the supply of water through pressurized conduits (2010). Prof S J van Vuuren, University of Pretoria. WRC Report No. KV 238/10.

Lesotho Highlands Water Project – Sustainable Development. CD produced by Lesotho Highlands Development Authority.

Kafue Gorge Power Station - Ten Years of development. ZESCO, Zambia.

Pangani basin, A situation Analysis, published by the International Union for Conservation of Nature (2009)