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SPECIAL BULLETIN

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KARIBA DAM: SAFETY

Summary of a talk given to the Zimbabwe History Society by Consultant Engineer, Terry Kabell, as part of Kariba's 50th Anniversary celebrations.

There have been many unfounded and scare-mongering rumours circulating about the safety or otherwise of Kariba Dam, especially given that, due to good rains in the past couple years, the waters of the lake have been the highest recorded for some time.

As a service to the community, The Zambezi Society has summarised a very interesting and reassuring talk recently given by consultant engineer, Terry Kabell on the safety of Kariba Dam.

Terry Kabell is a very experienced engineer who spent many years with Water Development in Rhodesia and then Zimbabwe. More recently he has worked throughout Africa as a consultant, and has been advising the Zambezi River Authority for some 12 years.

Here is a summary of Terry's presentation:

Recent rumours about Kariba being overfull and in danger of collapse are nonsense
Terry began his talk by announcing that recent rumours about Lake Kariba being 110% full and in danger of collapse are nonsense. The Lake is currently 82% full (its highest this year being 83%in July 2009). Up to date information about levels and flows at Lake Kariba and elsewhere on the Zambezi River can be found on the Zambezi River Authority's website at www.zaraho.org.zm – specifically on these links:
Lake Levels: http://www.zaraho.org.zm/lakelavel.html
River flows: http://www.zaraho.org.zm/flows.html

He affirmed that the dam is in no danger of imminent collapse. His presentation, based on a variety of sources include the Zimbabwean and Zambian power authorities, the Zambezi River Authority (ZRA) and a number of highly respected experts worldwide, was, he said, to dispel rumours and to assure people that Kariba Dam, throughout its 50 year history, has been regularly inspected for safety and thoroughly monitored both locally and by international consultants, who have found it to be in a very sound state.

Safety inspections & maintenance

Twice yearly inspections and surveys are carried out on Kariba Dam and every 5 years a special safety inspection is undertaken with experts from French and UK engineering companies who were involved in the orginal design. Other ad hoc inspections are carried out from time to time for specific reasons when required (e.g. the "plunge pool" which has been scoured out of the rock by the water flowing out of the floodgates). Records and archives for the dam dating back to its construction have been rigorously kept by these companies and there is no cause whatsoever for alarm.

Continuous annual maintenance is carried out on the dam, especially on mechanical parts such as the spill gates and stop locks.

There are literally hundreds of instruments in the wall which measure stress, any changes or movement in the wall, water pressure, drainage etc. These are continually inspected, have survived the past 50 years remarkably intact and are still functioning well. (For example, of the 263 original strain meters buried in the concrete of the dam to measure stress in three dimensions, 214 are still operating perfectly).

In 1997, the World Bank commissioned a special investigation of Kariba Dam prior to giving the go-ahead for the construction of the North Bank (Zambian) power station. A very thorough and extremely sophisticated computer-based analysis was carried out by international experts and Kariba was given a clean bill of health and declared quite safe!

Lake storage levels

The total catchment area of Lake Kariba covers some 663 000 sq kms. The biggest inflows of water occur during March/April/May at the end of the rainy season. Flows from the upper catchment in Angola/Zambia usually reach the lake later than those from the lower catchment area in Zambia/Zimbabwe because of the "sponge" effect of the Barotseland Floodplains in western Zambia which hold rainwater and release it slowly over a period of weeks. The greatest danger of massive floods is if both catchment area flows arrive in the lake at the same time.

The dam's usual spill rate per floodgate is 1500 cubic metres per second (cumecs). At capacity each gate spills 9000 cumecs. However, the dam was constructed to withstand much greater flows than this… indeed at the height of the 1956 great flood, 16 000 cumecs were recorded! Overtopping of the dam itself, although catastrophic for downstream communities and damaging to the electrics inside the wall, would not necessarily result in collapse of the dam.

The Zambezi River Authority prefers to control the water-level to a maximum operating level of 1 metre below the roadway on top of the wall - to prevent overtopping and electrical damage. Although the dam has 6 floodgates, they prefer, for various reasons to do with stress levels and potential undercutting, to restrict the spill to 3 open floodgates. Lake levels are carefully calculated with the potential for rainy-season floods in mind, and water is deliberately drawn down from the lake from October each year in order to make sure there is enough storage capacity to cope with a big flood. Telemetry stations in the upper Zambezi catchment areas provide ZRA staff with prior warnings of a potential flood situation. However, nowadays, there is less need for dam spillage than there used to be because of increasing power generation requirements.

An operational mistake in 1997/8 resulted in a potentially dangerous situation because ZRA did not lower the lake level from October as usual. Fortunately the floods that rainy season were not huge and they were able to get away with it.

Challenges

1. The **south bank** of the Kariba Gorge downstream of the dam has been a problem from the time the dam was built. Although the wall is deeply imbedded into the deep-down solid natural rock of the hillside and has been heavily reinforced by buttresses, the top 30 metres of the hillside is composed of a rock which is weak and has tended to slip– a factor which was exacerbated when the hillside was saturated by rain or spray from the open

floodgates. This was a potentially dangerous situation as land slippage could have blocked the dam's underground tunnels. Various measures have been taken since 1978 to stabilize the bank and prevent slip, including the construction of drainage channels. These have been successful. Careful monitoring continues, but it appears that the bank is no longer a danger.

2. Spillway and stop beams – there is mechanical and electrical equipment involved with these, which can give trouble if not properly maintained. The dam was originally designed with just 4 spillway gates each approx. 9 sq m in size. Two more were added after the big floods of 1956 during construction of the dam. Regular testing is carried out on the gates and the hoist mechanism which lifts and closes them. Many people do not realize that the dam wall is sealed only on the downstream side, with the interior being water-filled. The presence of water can cause problems with mechanical and electrical parts and deposits on the concrete surrounding the gates sometimes needs to be removed in order for the mechanism to slide correctly. There is also a recent issue of concrete swelling (see below) which requires attention if it threatens to impede the gate mechanisms. In 1998 a complete refurbishment of the dam's electrics was undertaken, with wire cables being replaced and a stand-by generator provided in case of power failure.

3. Concrete swelling

In the 1980s it was discovered that a chemical interaction between concrete and cement in wet conditions can result in slow, but irreversible "swelling" of the concrete used in dam building. Tests were carried out on samples of concrete from Kariba and it was discovered that the dam was indeed swelling at a small, but noticeable rate. Extra instrumentation was installed and it has been discovered that the crest of the dam is 80mm higher today than when it was first built! Arch dams like Kariba are naturally a little flexible, and it has been noticed that when the lake levels are low, the dam moves up to 50mm upstream and then back downstream again when it fills! Furthermore, the dam now tilts slightly (about 10mm) off the vertical in an upstream direction.

One of the problems associated with this is that it can affect the spillgates, stoplocks and moveable parts. These have to be checked regularly and maintenance carried out (e.g. chipping away of concrete) to ensure that they move freely.

4. Seismic Activity (earthquakes)

A branch of Africa's famous Rift pattern falls diagonally across the Kariba zone – so the area has some susceptibility to seismic activity. Since Lake Kariba began filling behind the dam in 1958, many seismic events have been recorded (no less than 1700 between 1959 and 1999). The biggest ones were early on, as 200 billion tons of extra load was pressed down onto the Earth by the filling waters of the lake. However, most have been very small. Since 1999 there appears to have been much less action

In 2001, a study of the Kariba area to check seismicity was undertaken by experts. Four separate seismograph stations were erected at a distance of some 20 kms away from the dam to map seismic activity, which appears to have been decreasing in recent years. No damage due to seismic activity was seen, even on the problematic South Bank.

5. The "plunge pool" (below the floodgates)

This big hole scoured into the rock downstream of the dam wall by water released from the floodgates was forseen by the designers of the wall. Indeed, the floodgates were designed in such as way as to throw the jet of water out so that the resulting "scour" hole would not endanger the foundations of the dam.

In the first 20 years of the dam's history, there was considerable spillage through the floodgates, which which led to the creation of the pool. Between 1982 and 2000, the floodgates were not used, due to low lake levels. Since 2000, the gates have been used very little because of power generation on both the Zimbabwean and Zambian sides of the river.

Currently, engineers are concerned that the plunge pool should not be allowed to scour any deeper and that any cut-back or erosion upstream should be avoided, as this would undermine the foundations of the dam. The pool has been the subject of number inspections (some with divers) and surveys (the latest in 2001) and the profile of

the pool has been fully mapped. Repairs to soft spots have been undertaken using underwater concrete. If the dam is allowed to spill in the next year, the subsequent effects on the plunge pool will be checked and restoration work will be undertaken.

6. Concrete apron at the foot of the dam

In the last 5-yearly inspection of the dam (in 2005), the concrete apron at the foot of the dam wall was raised as a point for investigation. This apron was designed to protect the dam from undercutting by any small spillage or dribbling (as opposed to full flood jets emanating from the spill gates). It is now underwater because of tailwater coming from the power generating turbines. Divers investigating its condition had previously reported that it was breaking up and some repairs with underwater concrete had been undertaken. However, these had not bonded well with the original concrete, and it was decided to undertake an investigation by drying it out and inspecting. In April 2007, over the Easter weekend, both power stations were shut down for 8 hours and the water from the bottom of the dam was removed to reveal the concrete apron. Most of the secondary concrete repairs had broken and washed away, but the original concrete, laid in 1956 was found to be in good condition after 50 years! (What the divers had seen had been the broken up remnants of the original coffer dam – nothing to do with the original apron itself!).

7. Reinforcing steel within the dam

A further concern raised by the 2005 inspection was the condition of the steel plates imbedded in the wall. Although the dam looks like solid concrete, the area around the floodgates is in fact largely solid steel plates covered over with a layer of concrete. Because of the wet conditions prevailing within the wall, there was a chance of corrosion which needed to be investigated. Inspection windows were cut into the concrete to expose the steel plates and reinforcing bars. In all cases, the steel was found to be in perfect condition! The only problem that faced the investigating teams was to ensure that the concrete used to close up the inspection windows was made to a similar strength as that used originally in 1956!

The examples above were given to show the extent to which the authorities ensure that maintenance and corrective measures are undertaken to protect the dam and ensure its safety.

Summary of possible threats

- **Ageing and corrosion**. There are many examples of dams which have existed for hundreds of years. The evidence from inspections so far indicate that Kariba dam is remarkably free of corrosion and is ageing extremely well
- **Overtopping**. If this were to occur, it would cause damage and chaos downstream, but it would not necessarily cause the dam to collapse
- **Undermining of the foundations**. This is a real threat, but, as outlined above, regular inspections and protective measures and maintenance ensure that the likelihood of this happening is reduced.
- **Swelling of concrete.** This is being carefully monitored and corrective measures taken.
- **Earthquake.** A very big earthquake could affect the dam. But it has been designed to withstand such an event. Most of the seismic events recorded have been small and the indications are that activity has decreased in recent years.

Funding and personnel

The costs of maintaining the dam wall are born by the governments of Zimbabwe and Zambia through the Zambezi River Authority. There are challenges. But some 5 years ago, because of the declining economic situation in Zimbabwe, the Authority was authorized to generate its own funds by charging the National power authorities in foreign currency for use of the water passing through their turbines for the production of electricity. This has enabled the costs of maintenance to be covered without being adversely affected by the decline of the Zimbabwe dollar.

The safety of Kariba dam ultimately depends on people. In the 2005 report on Kariba Dam, the expert consultants wrote this paragraph about the numerous staff responsible for the dam:

"In the consultants' very wide experience of other dams in many countries, it is rare to find such an experienced, stable, dedicated, friendly and unified team".

The Zambezi Society has compiled this summary for wide dissemination so that such interesting and reassuring information can be in the public domain. We would like to thank Terry Kabell and salute him and the dedicated staff who work to keep Kariba dam safe and generating our power!

Please pass this Bulletin on to anyone who might be interested in becoming a member of The Zambezi Society and helping us to Keep the Zambezi Wild!