INNOVATIVE SYSTEMS TO IMPROVE SPILLWAY CAPACITY, SAFETY AND WITH MINIMAL MAINTENANCE

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ABSTRACT

South Africa has limited potential to build new dams and most of the existing 1500 or so dams need to be rehabilitated to pass revised design floods, in a safe way with minimal maintenance. Further some existing dams need to be raised to increase storage capacity to meet increasing demand and offset losses. South Africa has a potential forthcoming crisis in water supply as well as extreme limitations on the fiscus to meet these demands, and innovative methods are required to meet these challenges. This paper will address the aspects of dam spillway rehabilitation, in a safe way and with minimal maintenance using innovative and tested equipment to achieve this.

1. INTRODUCTION

South Africa is a semi-arid country with an average mean annual precipitation of less than 500mm per annum. Water is therefore a vital resource to this developing country. It is also a limited resource which has to be carefully consumed and managed.

Currently, South Africa has in the order of 2500 category II and III dams, most of which are medium to large dams. South Africa also has limited potential for new dams due to the water resources being almost fully utilized. Although there are two new dams currently being considered, the other major dam work is the raising of the existing Clan William and Hazelmere dams.

All but a few dams were constructed last century, mostly in the period 1960 to 1980. These are a vital asset to this country and need to be protected against failure and neglect.

2. CURRENT CHALLENGES

The current challenges are:

- A large number of aged and aging dam infrastructure, 40% or more of which do not fully meet Dam Safety Office requirements i.e. about 1000 dams!

- Increased risk from a dam failure due to increased human settlements and activities downstream i.e. category I dams may now become category II dams and category II may become category III dams.

- An increasing demand for water due to increasing population, improved living standards, more industrialization and more demand for food. The water demand may double in the next 10 years.

- Spillway capacity is inadequate on most of the older dams due to revised hydrological determinations which all result in larger design floods than what the spillways were designed for.

- Most dams have inadequate or non functioning equipment to provide rapid drawdown to meet dam safety requirements. In fact a large number of dams have suspect bottom outlets and operators are too concerned to open them in case they cannot be closed! Those dams therefore do not have any rapid draw down capability and are vulnerable to piping failures in earth embankments or structural failure for concrete dams and spillways.

- Inadequate funding to attend to these problems due to constraints on the fiscus.

- Significant loss in storage capacity due mostly to sedimentation. On a countrywide average, almost 25-30 % of the original dam storage is lost to sedimentation. Other losses occur in higher than average evaporation as well as losses in piped distribution networks as well as unauthorised usage.

It is therefore a challenge to dam engineers to try and get more out of our existing collection of dams and to make them safe against failure for the ongoing needs of this country.

3. SPILLWAY IMPROVEMENTS

The older dams invariably do not have adequate spillway capacity and are therefore vulnerable to failure from large flood events.

Most of the improvements to the spillways entail cutting a side channel spillway through the adjacent flank or a saddle.

Other spillway improvements entail deepening the existing spillway and providing fixed structures such as labyrinth and piano key type concrete weirs to maintain or even raise the full supply level (FSL). However, these fixed spillway types do not meet the dam safety requirements for rapid drawdown.

Gated spillways do however meet this requirement but most of the gates used previously are electro-mechanical gates which have proved unreliable in some instances as well as a lack of maintenance issue, which is problematic especially in remote areas.

Fuse gated spillways can be used which will fail under extreme floods and the storage in the dam will be lost as a consequence.

However, there are automatic, self–operating spillway gates in operation which serve the purpose well in that the gate open automatically to pass floods and then close again to retain the FSL. These gates are also non electro mechanical and not require operator intervention and minimal maintenance.

The AVIS dam in Windhoek, Namibia, was built in the early 1900s when the country was a German colony. It served as the town's main water supply in the earlier years of Windhoek's existence. It is now more a recreational dam as well as a flood control dam to the downstream built up urban development.

The original spillway was inadequate and the consultant required a side channel spillway cut through the left hand flank.

In order to maintain the F.S.L, automatic TOPS spillway gates were installed. These two gates are 11m long by 3,0m high. They are arranged to open automatically for as little as a 0,15m rise in water level. The gates have already opened twice since 2001 and closed automatically after the flood had passed to retain the FSL.

Photograph 1: AVIS dam, Namibia: Two TOPS gates used to retain FSL in side channel auxiliary spillway.

The Mnjoli dam on the Mbuluzi River in Swaziland has 6 TOPS gates fitted to an auxiliary spillway and one on the service spillway. The TOPS gates raise the FSL water level by 1,5m to give an additional 22 million m^3 of water for irrigation. The service spillway gate has opened and closed a few times since installation in 2009.

Photograph 2: Mnjoli dam service spillway TOPS gate open to pass flood

4. RAPID DRAW DOWN EQUIPMENT

These currently comprise bottom outlet sleeve valves and /or gates. Some gates are spillway electro-mechanical radial and roller gates which serve to draw down the water level in an emergency. The purpose of this equipment is to release water at a high discharge rate to lower the water level relatively quickly to reduce the hydrostatic pressure on a weak zone in the dam embankment or structural element. On a significant number of dams, this draw down equipment is either inadequately sized to serve the dam safety requirements of rapid draw down or has rusted or seized due to non-operation over many years.

These minimal capacity or non-functioning draw down equipment on dams are a serious threat to the safety of those dams and there are a number of such dams in this country. It is therefore important to provide equipment or facilities to draw down water to safe operating levels in order to effect repair measures to the dam. One system which can provide this important function as well as provide flood discharge capacity is to fit automatic scour gates into the existing spillway. The method of retrofitting the gate is indicated in the following diagrams:

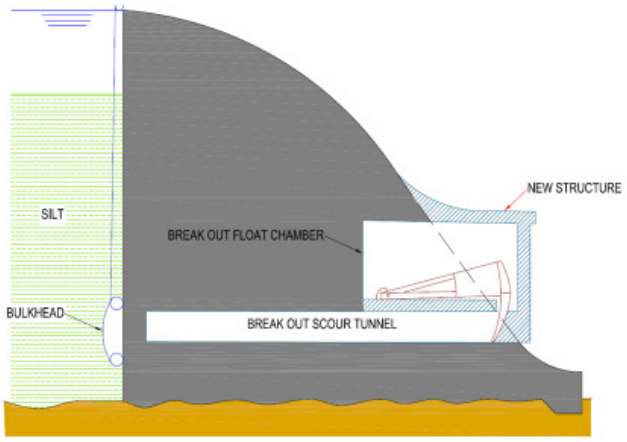

FIG.3.1
BREAK OUT AND BUILD NEW STRUCTURE
AND FIT SCOURGATE

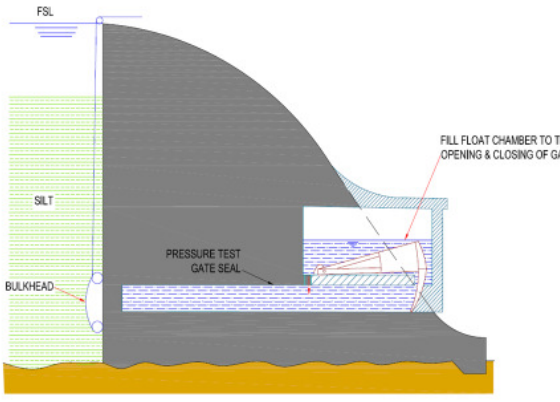

FIG.3.2
WATER TEST SCOUR TUNNEL & GATE

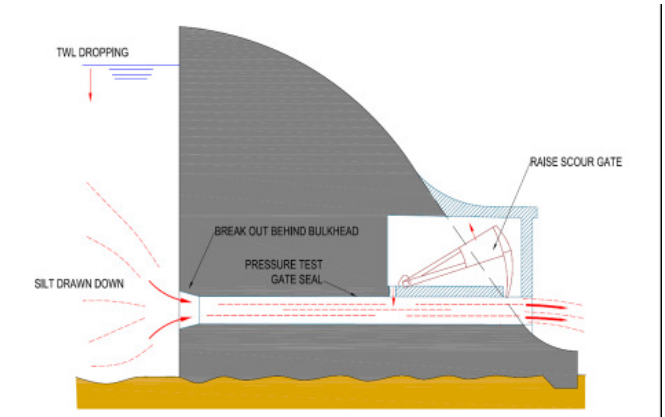

FIG.3.3
SCOUR TUNNEL OPEN TO DISCHARGE SILT

The structural analysis requires careful finite element analysis and the scour gate chamber provides strengthening to the spillway with reinforced structural walls and elements. Construction must be undertaken behind a large bulkhead to allow excavation of the discharge tunnel safely up to the water face.

A number of scour gates have been installed, the biggest to date is on the Matsoku Weir on the prestigious Lesotho Highlands Water Scheme serving Katse dam.

Photograph 3: 60m^3/sec discharge from a 3m wide x 2m high scour gate: Matsoku weir, Lesotho

The schematic operation of the scour gate is shown in figure 1 for the Luika Dam, Tanzania to close off a 2,3m wide by 1,3m high scour tunnel under 12m head of water.

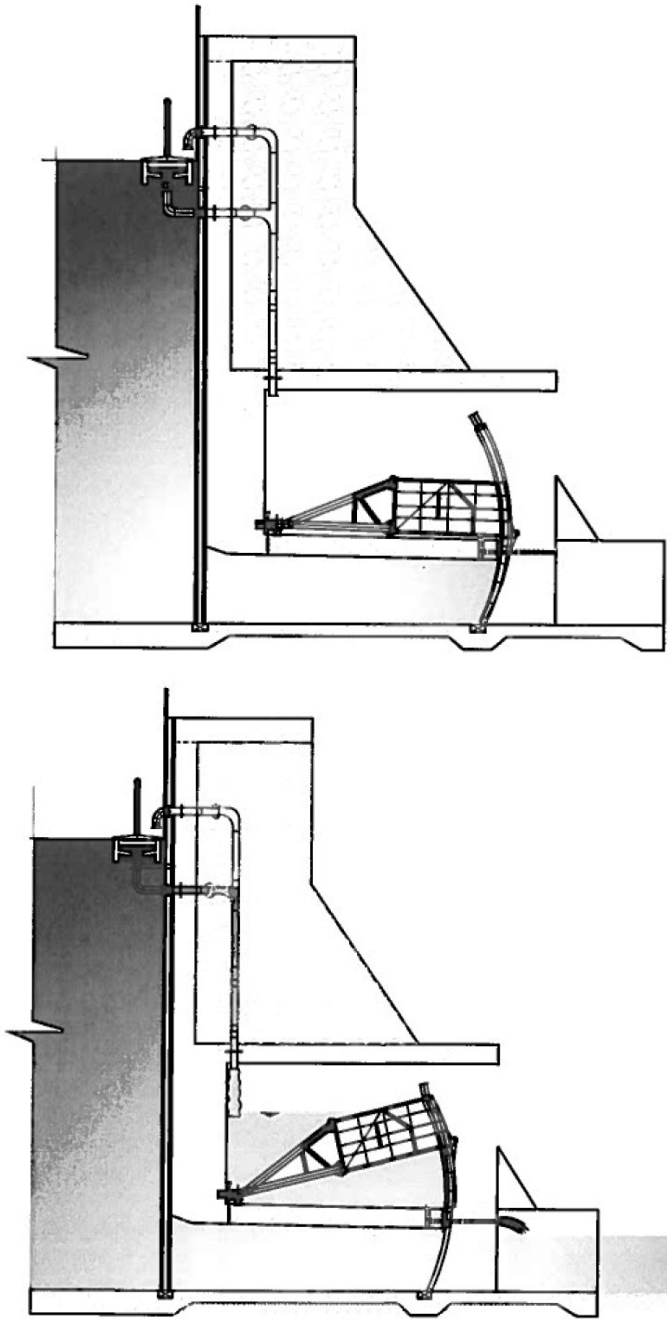

Figure 1: Luika Dam Scour gate, closed and **open to discharge 50m^3/sec**

5. RELIABILITY OF AUTOMATIC SELF ACTUATING GATES

- These suite of gates are developed in South Africa for African conditions.
- They require little to no maintenance. There are no electro mechanical parts requiring maintenance.
- There is no requirement for operator involvement to actuate the gates.
- The gates will open automatically with increasing WLs to pass floods and close automatically to retain the F.S.L, all without loss of storage in the dam.
- The gates are reliable, have built in redundancy, and have been proven at a number of installations over a period exceeding 30 years.
- They are generally more cost effective and quicker to install than fixed type of spillways.

6. CONCLUSION

Lack of sufficient water is the Achilles heel of South Africa's economic growth.

This valuable water supply is stored in a large number of aging dams, most of which are vulnerable to damage or failure from large storm events.

The two most important aspects that need to be addressed are:

- improved spillway capacity and
- reliable and adequate rapid draw down equipment

A range of automatic equipment can and has been used previously to address these problems and should be considered by dam engineers to improve dam safety for existing dams.

They also are more cost effective than fixed spillway modifications and under the current financial limitations, will be able to address more dams than fixed spillway for the funds available.