BENEFITING FROM FLOODS FOR DROUGHT ALLEVIATION AND DAMAGE CONTROL

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ABSTRACT

Southern Africa has and will continue, to suffer from severe droughts and floods. These weather extremes have been exacerbated by global warming. The cost of the most recent drought in Southern Africa is astronomical, not only financially where it can be measured in billions in money terms, but also in human life, environmental degradation and social deterioration.

We have no control over the weather extremes but we can introduce measures to mitigate against the adverse effects of droughts and floods.

This paper explores possibilities of recharging aquifers from flood waters and draws on methods proposed in Queensland, Australia, using automatic water control equipment.

Further, we can equip our major dams with automatic equipment to reduce the effects of flooding. This paper describes these methods and the equipment to be used.

1. INTRODUCTION

Floods and droughts are natural phenomena of weather patterns and engineers take these into account in designing the yield of dams. However, unmistakably these large extremes in the weather pattern are being experienced which have been accentuated by global warming.[1]

Southern African countries have experienced severe and long duration droughts which have affected all aspects of life, the environment and the economy. These are often followed by heavy rainfall and flooding leading to equally devastating consequences[2].

Some examples of this variation in weather include:

- Prolonged drought in the Western Cape, the worst in more than 100 years.
- Drought and then floods in Kwa-Zulu Natal.
- The Orange River at Aliwal North reduced to a series of non-flowing pools in 2015/16 and then becoming a raging torrent as heavy rains fell in the catchment.
- Severe drought in Eastern Cape, followed by floods in 2006 which caused damage to water supply dams from overtopping.

These phenomena of extremes in droughts and floods are here to stay and engineers need to design for them and take advantage of the surplus water from floods to capture most of it in order to survive the forthcoming droughts.

2. SUSTAINABLE WATER SUPPLY AND CLIMATE CHANGE

The keynote speaker at the SANCOLD 2013 conference, Dr George W Annandale warned of the deteriorating storage capacity of our dams globally due to sedimentation.[3] He stated “The decrease in reservoir storage is so significant that the worldwide per capita reservoir storage space is currently equal to what it last was in 1965”.

We are urged to change these undesirable conditions by making the required changes to how new dams are designed and to retrofit, manage and maintain our existing dams in order to increase storage to span multiple year droughts and to meet the increased demand due to population growth. Have we taken this sound advice?

3. WHAT IS THE CURRENT WATER STATUS IN SOUTH AFRICA?

Have we been proactive to provide facilities to secure our water supply so as to offset the adverse effects of future droughts? No: We need to follow the advice given to us by the keynote speaker at SANCOLD 2013 to start storing additional water by whatever robust means possible. Identify the most critical areas where droughts have caused water shortages and retrofit those dams with spillway gates to increase the storage safely to avoid this happening again within the next 20 years and further.

4. "CAPTURING" THE FLOOD WATERS

4.1 Raise existing dams

Flood waters should be stored by raising the dams to gain additional valuable storage to sustain through periods of drought. This is more easily, cheaper and quicker done by fitting automatic spillway gates to existing dam than by conventional ungated spillways.[4] Often long prolonged droughts brought on by the El Niño effect are followed by extreme rainfall and floods caused by the La Niña effect. This excess water generally overflows dams and is lost to the oceans.

4.2 Replace storage lost due to sedimentation

Over the last 50 years, South African dams have lost in the order of 25% collectively of the total capacity to sediment accumulation. A quick calculation made using our water resources of South Africa handbook for the Nelson Mandela Bay metro area shows that a 3m raising of the spillways could increase the storage volume of these dams by 17 %. Considering that sedimentation has reduced this volume, the extra volume stored by raising would at least offset the loss due to sediment.

Un-fortunately heavy rains that occur after a prolonged drought carry huge amounts of sediment eroded off sparsely covered vegetation and denuded land and accumulate in dams to considerably reduce the storage capacity. It is possible to reduce the accumulation of sediment in the dams by installing automatic scour gates in the dam wall.[5]

4.3 Flood routing

Route flood peaks through reservoirs safely using automatic equipment designed to open sequentially and with the flexibility of operation to allow for the draw- down of dam levels ahead of floods by manually opening the gates if required. Ungated spillways lack the flexibility of operation to pre-release water. Modern computer-generated software with satellite coverage, gives a good reliability and assurance of heavy rainfalls and water can be pre-released from our dams to provide additional storage capacity to mitigate the effects of flooding. This is not done at present in RSA and perhaps we should now have the confidence to do so and pre- release water ahead of a known flood arriving at the dam.

Dam raising using gates on an existing spillway must be tested for dam safety requirements and compliance with the discharge required. Automatic spillway gates such as TOPS gates can address the challenges faced by dam designers who have to weigh the risk of mechanical, operator and backup system failures.

Automatically actuating spillway gates are designed and installed to overcome the risks associated with electro-mechanical equipment. This technology was not available or recognised in 1990 at the time of the compilation of the Flood hydrology for Southern Africa SANCOLD handbook and some of the concerns raised by Prof Alexander in Chapter 10 can now be addressed and solved using this innovative solution for dam raising and flood control. These are listed below from paragraph 10.7:

- Equipment failure
- Communication breakdown
- Operator incompetence.

5. DIVERTING FLOOD WATERS FOR MANAGED AQUIFER RECHARGE

In 2015, Amanziflow was contacted by an independent hydrogeologist from NSW, Australia for a proposal using automatically actuating equipment to divert flood flows in certain seasonal rivers in semi -arid areas of Australia into off-channel storage depressions suitable for aquifer recharge. Fixed weirs were not considered due to rapid siltation of the containment and electro-mechanical gates could not be relied upon in the remote areas under consideration. The requirements therefore were as follows:

- The equipment should be fully automatic due to remote sites.
- The equipment should be flexible to pass sediment in floods to prevent siltation.
- They must not rely on electrical supply.
- They must not rely on regular maintenance and be robust and able to withstand extreme temperatures and weather conditions.

The equipment also had to have a proven track record. An automatic TOPS gate was installed on the Runde river, Zimbabwe in 2005 to keep the abstraction weir free of sediment build up by actuating automatically during floods. Further a combination of automatic crest and scour gates has been operating for more than 30 years, at the Tswasa weir on the Groot Marico River, to remove sediment and store additional water. These gates as well as other automatic equipment at other sites have been working well and gave the required confidence for this application in Australia.

In Australia, managed aquifer recharge (MAR) in 2008 contributed 45 Gl/year to irrigation supplies and 7 Gl/year to urban water supplies across Queensland, Southern Australia, Western Australia and the Northern territories. Where aquifers are mapped there are prospects for MAR using rainwater, storm water and reclaimed water.[6]

The system proposed is illustrated in figure 1 and consists of

- A flexible barrage to raise the water level to
- Divert water to sediment ponds and then
- Pass clear water to a bio-filter pond for further natural treatment before
- Pumping to boreholes to recharge the aquifer

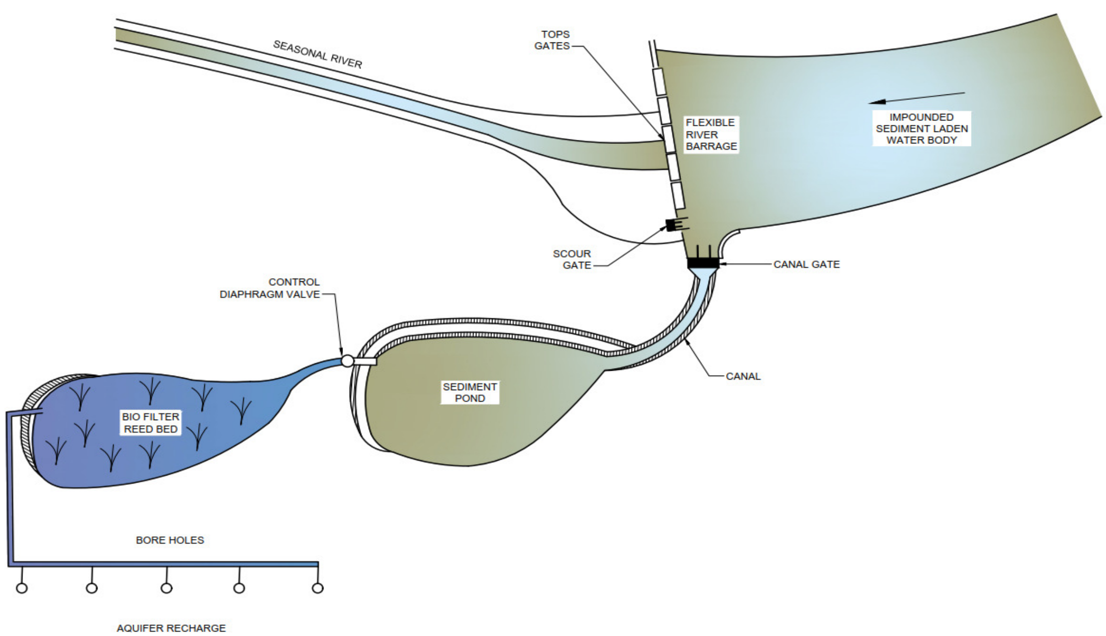

Figure 1. Schematic plan of aquifer recharge

5.1 A gated barrage across the river to raise the water level by as little as 3m

The barrage must be flexible to open in floods to pass sediment laden flood waters downstream as shown in Figures 2&3 below. Automatic self-regulating TOPS gates are proposed which will automatically open in floods and close again after the flood has passed to retain the full supply level (FSL). A fixed weir would only silt up and raise the high flood levels and is therefore unsuitable.

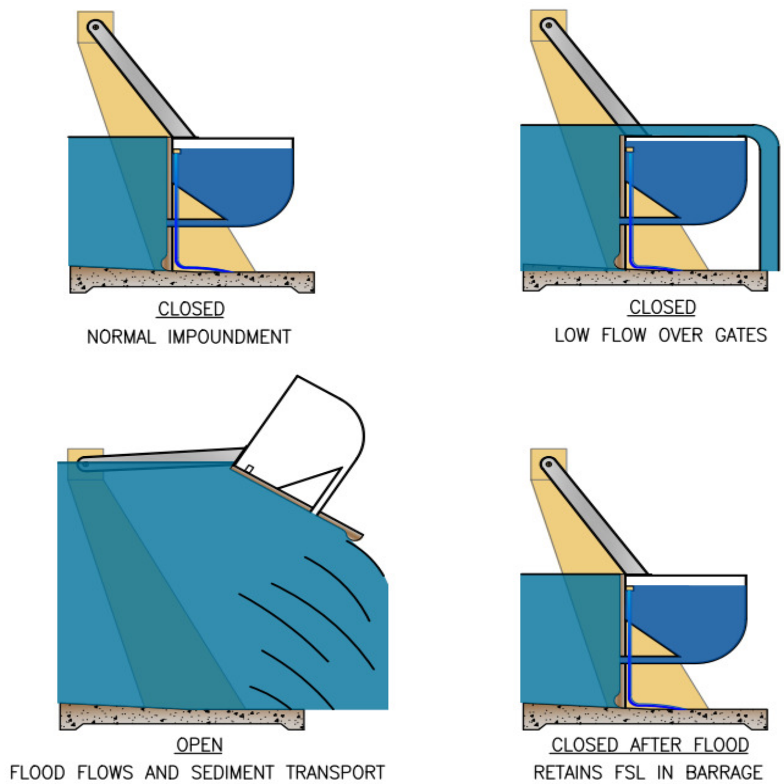

Figure 2. Automatic barrage gates

Figure 3. Runde Weir TOPS gate as an effective barrage gate to remove sediment

5.2 An automatic scour gate

It is important to divert sediment laden water down the river before it enters the canal offtake**.** An automatic self- operating scour gate is positioned at the river offtake which will open in floods to pass sediment downstream before the sediment laden water enters the canal. It will close after the flood has passed to retain the FSL in the barrage. This is shown in Figure 4 below.

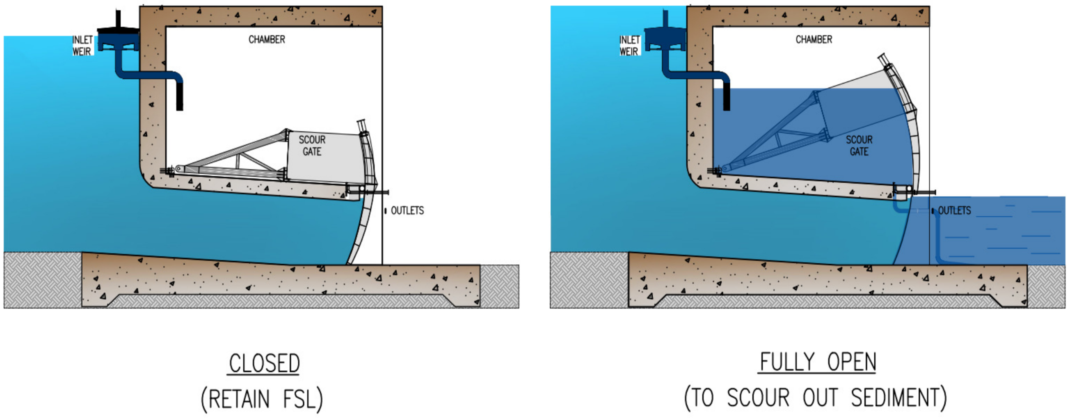

Figure 4. Scour gate operation

Figure 5. Tswasa weir on Groot Marico River with scour and crest gates.

5.3 An automatic canal regulating

The canal gate will control the flow in the canal and close off when the sediment dam is full. This is shown in Figure 6.

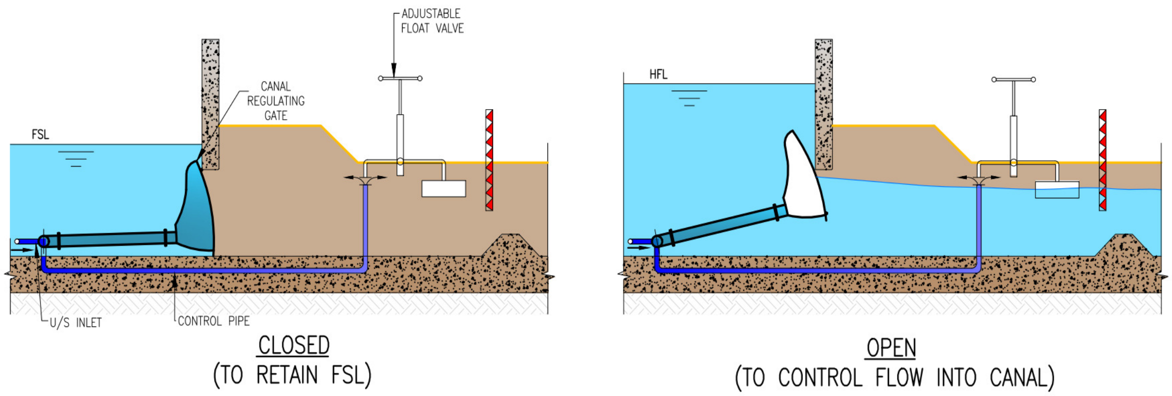

Figure 6. Canal gate operation.

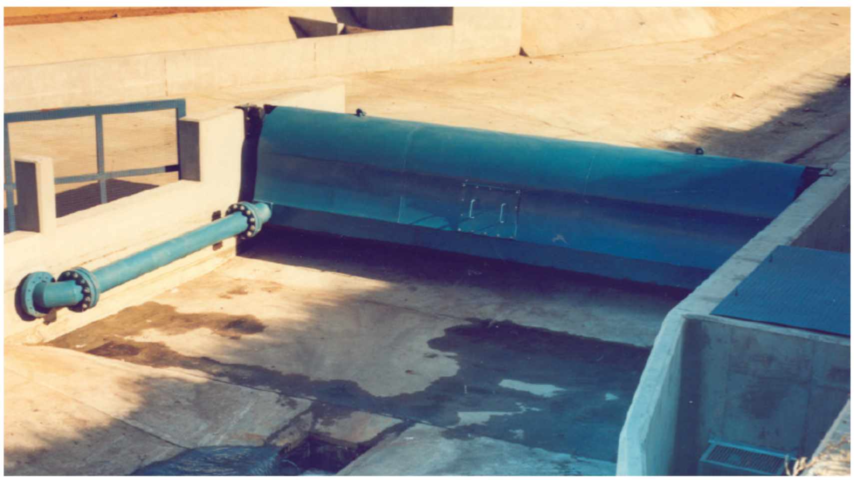

Figure 7. Robinson canal regulating gate

5.4 A sediment pond

The sediment laden water is led into a sediment dam which is sized to provide at least 3 to 4 days of storage to settle out colloidal silt. The sediment can also be excavated out later to provide excellent material for crop production, especially over rocky surfaces.

5.5 An automatic outlet valve

An automatic diaphragm valve (DV) will discharge water with very little colloidal sediment from the sediment pond at a controlled rate to a bio-filter pond. The automatic diaphragm valve is set to allow the water level (WL) in the sediment pond to rise without discharge so that fine sediment can settle out over a long period of time. Once the WL reaches the FSL, the DV opens to discharge and draw down the WL to the lower WL and will then close to allow the sediment pond to fill again. Water discharging radially from the DV becomes aerated and water quality is improved.

This action of closing off is important to provide "dead" water for full settlement to occur, rather than have a continuous through flow.

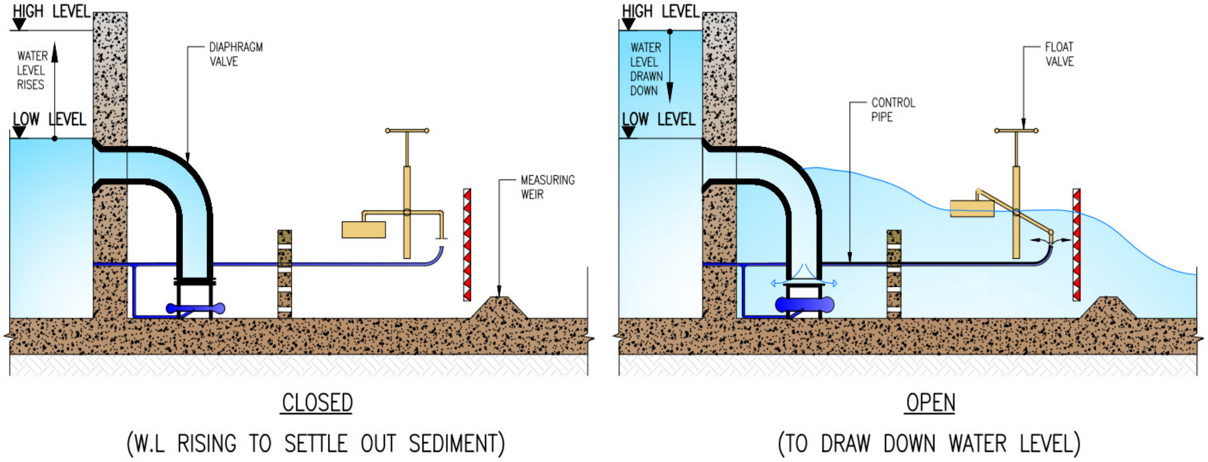

Figure 6. Automatic control valve to control discharge from sediment dam

Figure 7. Typical DV to control outflow to bio-filter pond

5.6 A bio- filter pond

The bio-filter is the last natural treatment to “polish” the water to remove any last traces of colloidal sediment, chemicals, E-coli and other bacteria.

- It is an artificial reed bed and wetlands which is very effective in cleaning the water.
- The clean water from the bio- filter is then pumped to boreholes to recharge the aquifer.

- This must be done over a large area to spread the recharge evenly over the aquifer.

Figure 8. Typical wetland to clean water for recharge of aquifers

6. CONCLUSION

Floods are destructive as well as transporting large amounts of sediment into our dams, but the flood waters need to be harnessed to benefit drought stricken prone areas. This should be done by:

- Raising dams to capture the floodwaters and
- Diverting flood waters to recharge underground aquifers.

Automatic self-actuating equipment, which is not reliant on electrical or mechanical operation, is best suited to achieve these objectives.

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