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Innovative technology contributes to sustainable development at Ruti dam

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Innovative technology has recently been used for heightening the Ruti dam, located in a semi-arid region of Zimbabwe. The additional storage capacity will be used to irrigate an extra 350 ha of communal farmlands. This paper emphasizes the role played by the project to improve the livelihood and to reduce poverty by ensuring a regular source of income to local communities from greater irrigation.

Zimbabwe's Ministry of Rural Resources and Water Development (MRRWD) signed, on 30 December 1998, a contract with Hydroplus for the supply and installation of the fusegate system, with Safege being retained for engineering design and supervision of the works. The design was initiated in September 1999, and site works started in May 2000. The project was commissioned in February 2001.

The very large (693 m) spillway required the installation of 256 fusegates, 1.5 m high by 2.7 m wide, in a labyrinth crested configuration. A noteworthy feature was the use of buttresses to strengthen the masonry saddle spillway.

At Ruti, the fusegate system allowed for increasing the full supply level by 1.6 m without any restriction in the discharge capacity of the spillway. The storage capacity has been increased by $25.7 \times 10^6 m^3$ (a 20 per cent increase in the pre-existing storage).

Agriculture based on irrigation

Zimbabwe is a landlocked country in the Southern Africa region, with an area of more than 390 000 km^2. It is bordered by Zambia, Mozambique, South Africa and Botswana (see Fig. 1).

Climatic conditions are largely sub-tropical, with one rainy season between November and March. Rainfall reliability decreases from north to south and also from east to west. Only 37 per cent of the country receives adequate rainfall for agriculture.

Rainfalls over the catchment are fairly scarce, with an average of 820 mm/year. The region is subject to periodic seasonal droughts, prolonged mid-season dry spells and unreliable starts of the rainy season. Irrigation plays an important role in sustaining crop production.

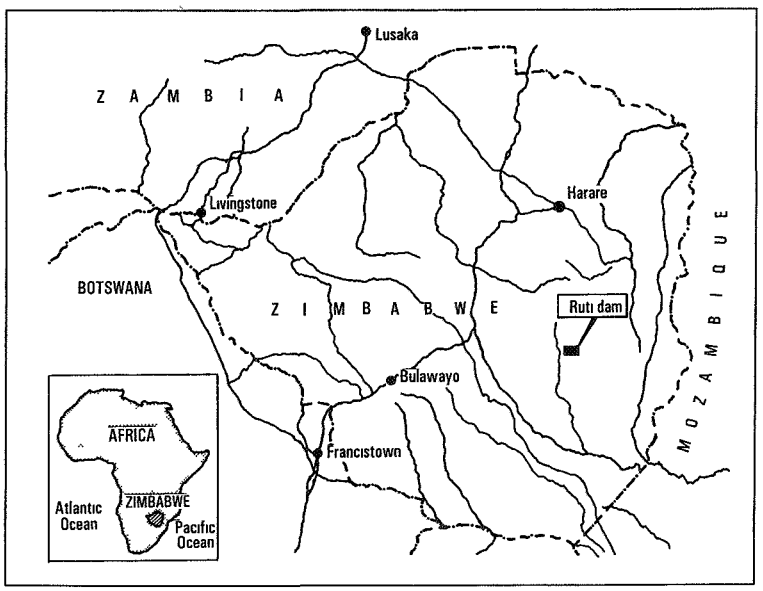


Fig 1 Location of the Ruti dam (Source Atlas Mondial ENCARTA, Microsoft)

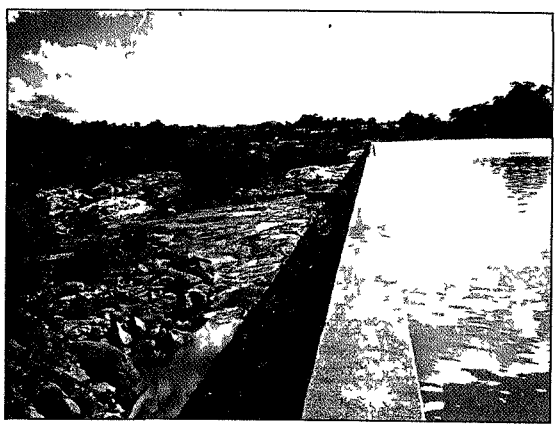
Ruti dam: a strategic component of local development

Ruti dam is on the Nyazvidzi river, approximately 80 km from the confluence with the Save river, about 40 km south east of Buhera. It consists of a conventional zoned embankment with a fairly thick impervious core. The upstream and downstream slopes are 0.5(horizontal)/1(vertical). The minimum width of the core is 4 m at the pre-existing full supply level.

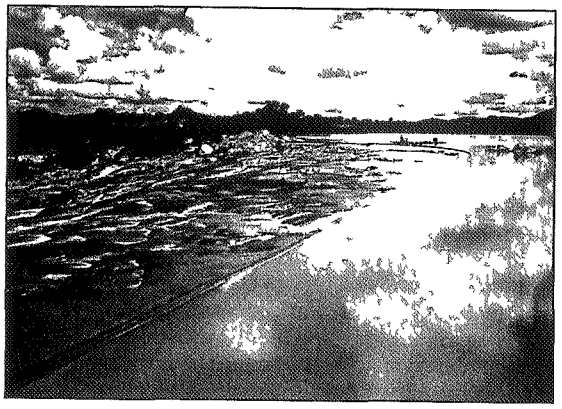
The pre-existing yield was fully committed to downstream irrigation at several schemes located in the Communal Lands and the extension of the Chisumbanje Irrigation scheme by some 800 ha. As such, the reservoir constitutes a key component for local communities' development.

Ruti dam is characterized by a large catchment area (2485 km^2), which ensures a large volume of inflow in relation to the reservoir volume; the dam has been overspilling almost every year since its completion. The studies undertaken by the Ministry of Rural Resources and Water Development have underlined the great potential to increase the dam storage capacity.

The additional storage is to be used to irrigate high



The saddle spillway before the upgrade



The main spillway before the upgrade

added value paprika crops in anticipation of a decline in the international demand for tobacco, which still constitutes the largest foreign currency earner in Zimbabwe. It will also reduce the exposure of the neighbouring population to the erratic and unreliable nature of the rainfalls.

The Ruti dam is unique by its spillway sills: the combined length is 693 m. Considering the length of the spillway sill, the scope of options to raise the full supply level was particularly limited.

As an alternative to conventional heightening, Hydroplus proposed to apply the fusegate system to raise the full supply level by 1.6 m without increasing the height of the embankment. The resulting increase in capacity (24.7×10^6 m^3 from 125.9×10^6 m^3 to 151.6×10^6 m^3) enhances the useable yield by 6.9×10^6 m^3 at the 10 per cent risk level.

The Zimbabwe Ministry of Rural Resources and Water Development has implemented the project through a soft loan of Euro 1.52 million from the French authorities , and through the Ministry's own budget for an amount of Euro 0.68 million in local currency. The modifications of the spillway sill, required to accommodate the fusegates, were part of another civil works contract managed directly by the Ministry under the supervision of Safege.

The fusegate system

The fusegate system has been used successfully in the last decade to optimise storage or increase the capacity of spillways to improve safety. It has been applied to existing and new dams, as well as in river flood management schemes. The design of the system and its method of operation have been described by Falvey and Treille [1995[1]]. Lempérière [1995[2]] and Aït Alla [1997[3]] also previously analysed the system cost benefits in achieving extra storage and improving dam safety.

Unlike classical heightening of a spillway, the fusegate system does not involve any disturbance to the environment, as the modifications are accomplished within the limits of the existing spillway. It also offers the advantage to limit the necessary drawdown of the reservoir during construction, therefore avoiding the wastage of the precious water already stored behind the dam.

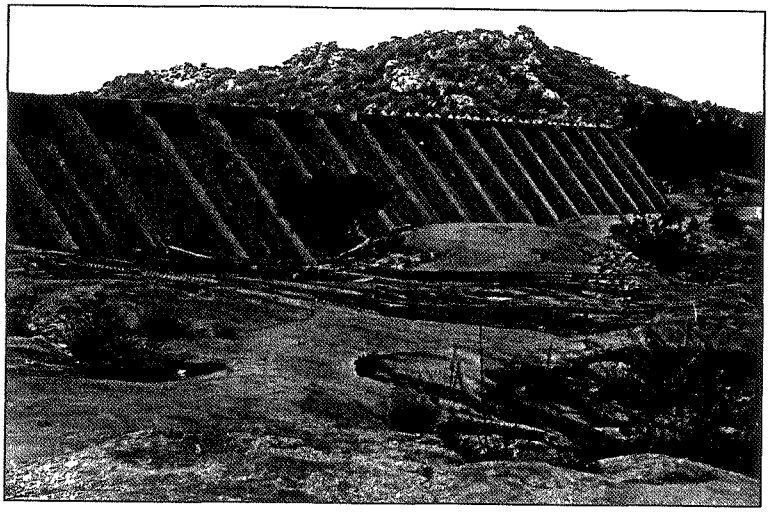
Consequently there are significant benefits to such an application, achieved without the major civil construction works.

Fusegates

Fusegates are free-standing gravity blocks placed side by side on a spillway sill to form a watertight barrier. Each unit is designed to tip at a precise reservoir elevation, allowing the spillway to pass the design flood In most cases, first tipping of a fusegate is designed for floods less frequent than the 100 year flood.

In the case of high floods, the tilting sequence may be controlled very accurately by adjusting the level of each water inlet Tilting of the fusegates progressively increases the spillway discharge in a calculated manner, thus accommodating the maximum possible floods without risk of overflow

Contrary to other spillway control systems, no electrical or mechanical power is needed at the time of operation during major floods Inspection and maintenance requirements are therefore minimal.



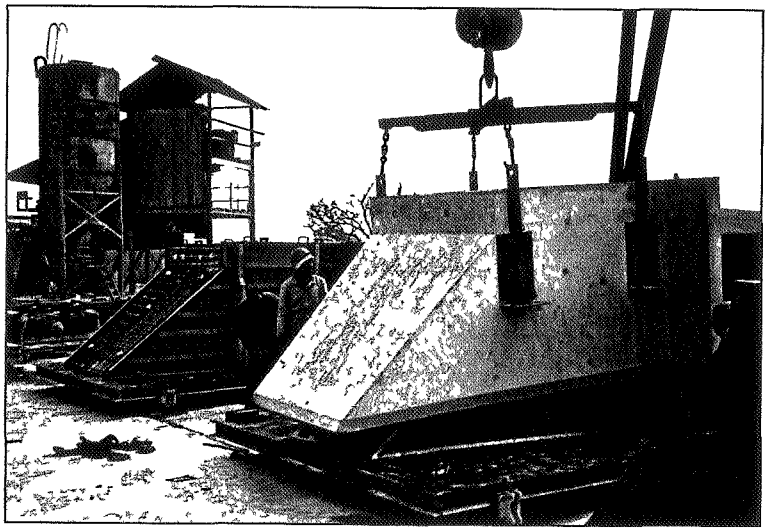
Downstream view of the saddle spillway with the masonry buttresses, before the installation of fusegates

Main features of the fusegate system

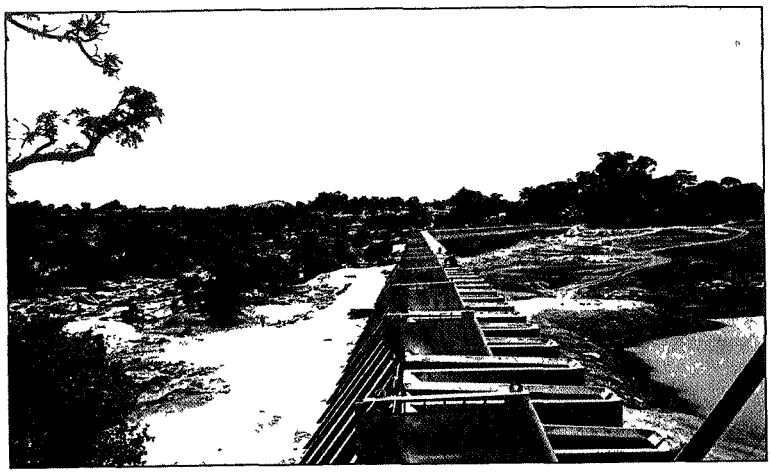
Ruti dam spillway consists of two uncontrolled sections located on the right flank of the dam, with a combined length of 693 m. The sections are hereafter defined as the main and saddle spillways.

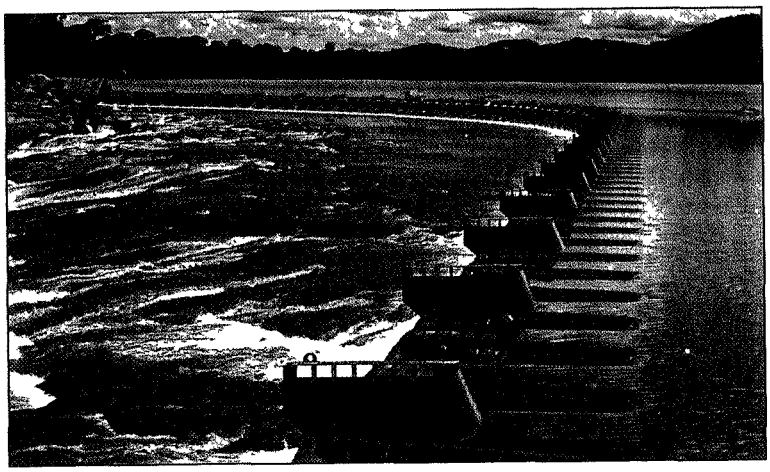
On this project, 256 fusegate units were required to increase the full supply level.

To ensure the long-term safety of the dam, the probable maximum flood (slightly more than 6000 m^3/s) had to be passed 0.5 m below the existing embankment crest level. This requirement was met by installing 1.5 m-high by 2.7 m-wide labyrinth-shaped units placed on a new concrete sill constructed 0.1 m above the pre-existing full supply level.



Pre-casting of the fusegates at Fort Concrete fabrication yard





The spillways after the upgrade: the saddle (top) and main dam (below)

The full supply level has then been raised by 1.6 m. This ensures that the new full supply level remains below the top of the clay core, for safe performance of the embankment, and offers the optimum solution taking into consideration the water storage requirements, construction cost and hydraulic performance.

The sill needed to be flattened and widened to accommodate the fusegates. Whereas the modification on the main spillway was quite straightforward, the saddle spillway masonry wall called for a more ingenious solution because of its height and thinness. The innovative solution developed by Safege involved the construction of buttresses on the downstream face of the wall. As such, the saddle spillway structure constitutes one of the few recent examples worldwide of a masonry buttress dam.

In addition, this solution is adapted to the local context, which is characterized by the availability of both high and low skilled workers, while heavy construction equipment is scarce, and the unemployment rate is high. Therefore the technical solution is perfectly adapted to the social context, and provides income to a large number of local workers, who have been employed throughout the entire course of the construction.

Contrary to other spillway control systems, the use of the fusegate technology allowed for a large portion of the works to be undertaken locally. The 256 fusegate units were diligently fabricated in pre-cast concrete by Fort Concrete, a Zimbabwean contracting company, within only three months.

Another advantage of pre-casting the fusegates is that the operation can run concurrently with the civil works modifications, so as to minimize the overall contract duration and avoid interface problems.

Once the spillway modifications were complete, the fusegate units (weighting 4.4 t each) were transported to the dam site for their installation on top of the sill. The latter operation was undertaken by another Zimbabwean contracting company, Murray and Roberts.

In February 2001, only one and a half years after work had commenced, the fusegates formed a watertight barrier and were ready to impound additional water in the reservoir. One month later, water started to spill over the fusegates crest.

Hydraulic performance of the fusegate system

Flood designation (as per Ministry data)	Max. inflow (m^3/s)	Max. outflow (m^3/s)	MWL above fusegate crest (m)	Cumulative no. of fusegates to tip
1:100 year flood	1771	1735	0.71	0
Before first tipping sequence	2081	2037	0.82	0
1:2000 year flood	4313	4509	1.07	206
PMF	6068	5971	1.39	256

Hydraulic design

For the safety of the downstream population, it is vital to ensure a progressive release of the water during major floods. Extensive flood routing simulations were undertaken to mitigate the environmental impact of the rotation of the fusegate units. It appeared that requirements could be met by considering seven tipping sequences. Such an arrangement also allows for triggering only the tipping of the fusegates required to pass a given flood safely.

The hydraulic performances of the fusegate system as engineered is summarized in the Table below.

Flood routing simulations show that the first group of fusegates would rotate only for a 1 in 150 year flood. Because of the very low probability of that event, the benefits of the system over a sufficiently long period of operation greatly outweigh the inconvenience of losing the first group of fusegates and the corresponding loss of water.

The probable maximum flood (PMF) triggers the tipping of all the fusegates and is thus passed with an adequate dry freeboard. No works were necessary on the dam embankment.

Sustainable development

Whereas the Government of Zimbabwe has completed the first stage of the project by increasing the storage capacity, the development of the irrigation network had to be postponed, mainly as a result of economical difficulties associated with the worldwide and local economic slow down.

Heightening Ruti dam corresponds to a sustainable development rationale. This is not only because access to equitable and sustainable water improves livelihood and contributes to poverty reduction, but also because this is a financially viable project supported by the local communities.

The increase in capacity enhances the useable yield by 6.9×10^6 m^3 at the 10 per cent risk level. In the region where Ruti dam is located, it is normally sufficient to sustain 600 ha of overhead irrigation or 350 ha of flood irrigation.

In spite of the light granitic soils which are best suited to overhead sprinkler irrigation, the local commu-

nities discarded this option because of problems associated with the maintenance of pumped schemes and instead selected a flood irrigation system.

The additional water will be distributed by gravity to 350 ha of newly cultivated land divided into 1 ha plots. The Government of Zimbabwe intends to select 350 families from the area to undertake irrigation of a plot. It is envisaged that each family will split the plot into two of 0.5 ha. One division could be used for food crops for local family consumption, and the other for cash crops for sale and income generation.

Several successful dry land paprika schemes are already functioning in the communal areas of Zimbabwe, and participants will be encouraged to grow paprika as the irrigated cash crop instead of the traditional tobacco. In this region of Zimbabwe, the irrigation of paprika crops increases the production from 2 t per hectare to 4.8 t per hectare and makes it possible to cultivate a higher value paprika. The net return of irrigated paprika is typically in the range of US$ 12 300 per ha, compared with US$ 2420 per ha with non-irrigated paprika crops (figures given in 1998 at the time of the agricultural study). A rough calculation shows a 0.5 ha irrigation plot could result in an annual net income of US$ 6150 per family plot. An additional winter crop could also be grown to improve incomes further.

The cost of the overall irrigation project is US$ 2.2 million. Each participating family will be required to contribute on average US$ 6285 towards the implementation of the scheme. Approved communal farmers can borrow funds at a preferential rate with no collateral. Thereafter the scheme will run communally, but each member will be responsible for the cultivation and maintenance of their individual plots.

Conclusion

Improvement of access to water and reduction of poverty in Africa is a major concern for the local governments. However, feasible projects are scarce because of financial and technical constraints. The heightening of Ruti dam is an outstanding example of a successful project, considering the combination of an innovative technical solution, financial support from the French authorities, as well as the firm willingness of the Government of Zimbabwe.

The technical constraints were solved by the use of the fusegate system, which leads to an increase in the storage capacity of 20 per cent without requiring any works on the dam embankment. The particularly long spillway necessitated the installation of 256 fusegate units to form the watertight barrier on top of the existing spillway sills. This challenging project was completed within one and a half years, thanks to good collaboration between the French and Zimbabwean Authorities, and the contractor/designer.

The additional storage will be used to extend the irrigation land area in the vicinity of the dam and further downstream. It will also ensure a regular source of income to the local communities involved in the project. As such, the project is promoting sustainable development. ◊

References

1. **Falvey, H.T., and Treille, P.**, "Hydraulics and Design of the Fusegate", *ASCE Journal of Hydraulics Engineering*; July 1995.
2. **Lempérière, F.**, "Cost Effective Improvements in Rill Dam Safety", *Hydropower & Dams*; January 1995.
3. **Ait Alla, A.**, "Achieving Economies through Innovative Spillway Design", *Hydropower & Dams*; June 1997.

Bibliography

Chevalier, S. and Rayssiguier, J., "Optimization of Existing Dams", ICOLD 2003, *Proceedings*; Q81– R19, p529.

K. Kyrou, and Rayssiguier, J., "Increase in Storage Capacity at Xyliatos Dam, Cyprus", *Hydropower & Dams*, Issue 4; September 2001.

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Albert Muyambo graduated in Civil Engineering from Loughborough University of Technology, UK. He has 29 years of experience in feasibility studies, design and construction of water resources projects. He has mainly been involved in the design and construction of dams with the Ministry of Rural Resources and Water Development of Zinbabwe, but has also undertaken consultancy for the Food and Agricultural Organisation in Zambia on feasibility studies and design of dams. In June 2000 he was appointed Planning Director of the Zimbabwe National Water Authority, a parastatal organization under the Ministry of Rural Resources and Water Development. In this role, he was in charge of the planning, design and construction of all water conservation works in Zimbabwe. In March 2003 he was appointed Chief Executive Officer of the Zimbabwe National Water Authority (ZINWA).
He is a member of the Zimbabwe Institution of Engineers, a gazetted engineer for large dams in Zimbabwe and Chairman of the Zimbabwe National Committee on Large Dams (ZIMCOLD).

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