OPERATIONAL MODEL OF THE ORANGE RIVER

EXECUTIVE SUMMARY

Introduction

The Orange River is one of South Africa's most important water resources and its catchment covers a significant portion of Southern Africa. Vanderkloof Dam, the last major storage structure on the river, is 1400km upstream of the river mouth where the furthest downstream users obtain their water.

Gariep Dam is located just upstream of Vanderkloof Dam. Gariep Dam is mainly used to support Vanderkloof Dam as there is almost no additional runoff entering the Orange River between the two dams. Upstream of Vanderkloof Dam the water in the Orange River is used to supply both the demands in the Orange River basin and to augment the supply of water to other catchments through inter-basin transfer schemes. One of these schemes is the well known Lesotho Highlands Water Project, in which water is transferred from the upper reaches of the Orange River to the Vaal River catchment in order to augment the supply of water to Gauteng, the industrial and economic centre of South Africa. Water is also transferred from Gariep Dam, on the Orange River, through the Orange-Fish tunnel to the Eastern Cape for use in the Fish and Sundays River basins.

In the catchment downstream of Vanderkloof Dam there are agricultural, industrial, urban and mining developments which obtain their water from the Orange River. In addition to these demands there are important environmental requirements along the river and at the river mouth which must also be satisfied. The catchment downstream of Vanderkloof Dam is extremely arid and the only reliable source of water in the lower reaches of the river are the releases made from Vanderkloof Dam.

Motivation for the research

As the water requirements on the Orange River catchment continue to grow, the water in the catchment is becoming ever more valuable. It is therefore becoming increasingly important to optimise the releases from Vanderkloof Dam, in order to supply the downstream demands whilst minimising any excess releases, so as to conserve the valuable resource in Vanderkloof and Gariep dams.

The major difficulty in optimising the releases from Vanderkloof Dam is that it can take several weeks for water released from the dam to reach the river mouth where the domestic,

industrial and environmental demands must be satisfied. The time taken for the releases to reach the mouth depends on the prevailing conditions in the river in relation to the amount of water released. Releases during low flow conditions may take up to 6 weeks to reach the mouth. It is evident that there can be no quick relief from any shortages that might be experienced along the lower Orange River through additional releases from Vanderkloof Dam. Due to the nature of these demands any water shortages would have a major impact, both economic and environmental.

For this reason it was decided to develop a tool which could be used to help determine the required releases from Vanderkloof Dam. A hydraulic model of the Orange River was developed to be used by the decision makers to simulate and then evaluate various proposed release scenarios.

Motivation for the development of a real time hydraulic model

There are several potential challenges in modelling the Orange River downstream of Vanderkloof Dam:

- *The length of the river is 1400km.*
- *Due to the remote terrain through which the river flows the abstractions from the river are not recorded in real time and it is not possible to include accurate abstraction data in the river model*
- *The return flows from irrigation along the river are also uncertain*
- *Losses from the river are also significant. Evaporation losses depend on the surface area of the water and therefore the local flow conditions.*
- *Inflows from tributaries are not recorded in real time.*

In order to overcome these difficulties and improve the modelled results, it was decided to investigate the inclusion of real-time data in the hydraulic model. Real time conditions, either stage or flow, are recorded at several sites along the Orange River . By incorporating these data into the model at several points on the river the simulated flows would be corrected to the actual flow conditions. Not only would this improve the accuracy of the model but the difference between the modelled and recorded flows could be used to quantify the net inflow or abstractions from river reaches between the real time stations.

Objective of the research

The aim of the project was to develop a decision support tool for the operation of the Orange River downstream of Vanderkloof Dam. This tool would be based on a calibrated hydraulic model of the river. Flows from the Vaal River into the Orange River were to be included in the model. The model would be used to simulate various possible release scenarios so that

the resultant river conditions could be assessed before a decision is made regarding the release schedule.

Another aspect of the study was to investigate the possibility of linking the hydraulic model to the network of telemetry stations on the Orange River. The objective was to include the real time stage and discharge data recorded at these stations in the hydraulic model and to assess whether the forecast flow conditions on the river could be improved by including such data.

In order to satisfy the basic objective of the study the following tasks were conducted:

- *Set up a hydraulic model of the Orange River downstream of Vanderkloof Dam using the ISIS hydro-dynamic model*
- *Calibrate the model for low flow conditions using historical data*
- *Modify the code of the ISIS engine so that real time recorded stage and flow data can be incorporated into the model*
- *Develop a graphical user interface (GUI) to facilitate the exchange of data between the real time network and the hydraulic model*
- *Investigate the effect of including the real time data on the simulated flows*
- *Test the effectiveness of the decision support system*

Background to the study

Various detailed studies have been made of the Orange River:

- *The Orange River System Analysis (ORSA) was completed in 1990. An important conclusion of the study was that the existing water demands downstream of Vanderkloof Dam would not be met if the proposed 5 phases of the Lesotho Highlands Water Project were to be fully developed. The study highlighted the importance of evaporation losses from the river as well as the difficulty of releasing the correct amount of water from Vanderkloof Dam to supply the demands downstream of the dam without allowing too much water, over and above the environmental requirements, to spill into the Atlantic Ocean*
- *In the Orange River Replanning Study (ORRS) a framework was established for the future development of the river and the utilisation of its water.*
- *The problem of determining the losses from the Orange River were addressed in the Orange River Losses Study Phase 1. The aim of this study was to determine the losses from the Orange River downstream of Vanderkloof Dam.*
- *The purpose of the River Losses Study – Phase 2 (RL2) was to investigate the processes driving evaporation losses from rivers in order to refine previous estimates of losses from the Orange River between Vanderkloof Dam and the river mouth and*

also to determine a general methodology for estimating losses from other South African rivers. In order to verify the methodology proposed in the RL2 study a hydraulic model of the lower reaches of the Orange River, between Blouputs and Brandkaros, was prepared. In order to accurately model the evaporation from the river, which is dependent on the surface area of the river and therefore also on the flow, an evaporation module was developed for the hydraulic modelling package.

- *During the course of this study it became clear that a hydraulic model of the Orange River would be a useful decision support tool for the operation of the river and the determination of the releases from Vanderkloof Dam. The development of such a tool was a logical continuation of the model established for the RL2 study.*

Technological Developments

In order to successfully model the Orange River several major and innovative developments were made to the ISIS software:

- *The real time hydraulic unit. This development is a novelty in river modelling and was developed and tested as part of this project. This unit forces the simulated values in the model to match the actual stage and flow conditions recorded at several points on the river, thereby improving the accuracy of the model.*
- *An adaptive timestepping routine. This routine allows a relatively long timestep to be used for the simulation. If instabilities occur the timestep is reduced until a solution is found, or the minimum timestep is reached. The longer timestep results in shorter computational times. This unit is now available in the commercial releases of ISIS.*
- *A decision support tool was developed which will be used by the operators of Vanderkloof Dam to help determine the required releases from the dam in terms of quantity and timing. The tool will be used by the operators to simulate proposed release scenarios on a what if basis, given the current river conditions and expected downstream water requirements. The system would be made up of three components: A real time model of the Orange River, which will continuously update the simulations of the river using the real time data recorded on the river, so that a best estimate of actual flow and stage will be available at every computational node of the model. Once the real time model has been updated with the most recent data, the second component, the forecast model, is intended to simulate the scheduled releases from Vanderkloof Dam, giving a best estimate of future conditions on the river. The third component is to be used to simulate any proposed release scenarios, so that it can be determined whether they meet the required downstream flow requirements.*

- *A Graphical User Interface. This development was made to facilitate the exchange of data from the bank of real time recorded data, which are available from the South African Department of Water Affairs and Forestry, and the hydraulic model.*

Conclusions and Recommendations

The strategy determined in this study will provide a rational basis for the operators of Vanderkloof Dam to determine a discharge release pattern to ensure that the various demands downstream of Vanderkloof Dam are satisfied. As the model is based on sound hydraulic principles rather than simplified routing methods the users can be confident in the simulated results, provided that the real time data are accurate and available. The use of real time data further improves the simulation because unmodelled events such as localised inflows can be taken into account.

One shortcoming of the project is that although the methodology has been developed and tested on historical data it has not been possible, to date, to test the process sufficiently on real time data. This is due to the lack of available accurate real time data. The following recommendations can therefore be made:

- *The acquisition of real time data from the Orange River should be improved. The real time telemetry network must be well maintained so that accurate and up to date information is available.*
- *It is recommended that the real time data are made available on an FTP site, so that the data do not have to be e-mailed to interested parties. Alternatively the full set of information should be made available on the website. At present only the average readings for every hour are included.*
- *It is also strongly recommended that the releases from Vanderkloof Dam are made available in real time. This will require co-operation between Eskom and the Department of Water Affairs and Forestry.*
- *During the simulation procedure it was concluded that the data at Zeekoebaart were inaccurate. It is recommended that this inaccuracy be investigated further and corrected.*

Future Extensions to the Project

Various possible extensions to the project have been identified. They have not been investigated as part of this study but would be logical and useful developments:

- *An automatic calibration routine could be developed as an extension to the real time hydraulic model. This routine would compare the actual conditions recorded on the river to the flows simulated by the model and automatically adjust the model parameters to improve the calibration of the model. This might be beneficially combined with a Kalman filter.*

- *Extending the cross sectional data in the model to include detail for high flows so that the model could be used as a flood management tool.*
- *Water quality modelling could also be included in the simulations*
- *Modelling of the instream flow requirements of the river is a natural extension of the modelling process.*