Orange River Losses Study - Summary of Phase 1

EXECUTIVE SUMMARY

The Orange River Losses Project was commissioned as a result of recent studies which indicated that the river losses occurring from the Orange River downstream of P K Le Roux Dam are relatively large and that they must therefore be included in any water resources assessment of the Orange River. It was concluded that the losses must be quantified accurately in order to operate the Orange River system in such a manner as to avoid wastage or shortfalls at the river mouth.

The Orange River is the largest river in Africa south of the Zambezi, with a total catchment area in excess of 1 million km^2. More than half of the catchment is inside South Africa, with the remainder in Lesotho, Botswana and Namibia.

By Southern African standards the natural water resources (i.e. water available before any developments took place) of the Orange River are large at approximately 11 500 million m^3/a. This figure is of purely academic interest, however, since due to the major developments that have already taken place in the basin, the remaining available resources of the Orange River are now estimated to be in the order of 6 500 million m^3/a.

Most of the development in the Orange River Basin has taken place in the Pretoria/Witwatersrand/Vereeniging (PWV) area which forms the industrial heartland of South Africa, producing over 50 % of South Africa's Gross National Product (GNP). The water demand in this area is increasing rapidly, not only because of the growing industrial demands, but mainly to the rapidly rising urban population and associated improvement in the living standards.

Several major interbasin transfers already exist to supplement the limited water resources available to the PWV area. As the demands continue to increase, however, the need for additional resources grows. The Lesotho Highland Water Project (LHWP) is the latest, largest and most ambitious water transfer project to be undertaken in Africa and is currently one of the largest water projects being undertaken in the world. When

completed it will enable in excess of 2 210 million m^3/a of water to be transferred from the upper reaches of the Lesotho Highlands to the PWV area in the Vaal River Basin.

In view of the limited water resources of the Orange River and the imminent implementation of Phase 1 of the LHWP, the South African Department of Water Affairs and Forestry (DWA&F) recently (1993) commissioned a study to assess the water resources of the Orange River and to evaluate the likely impacts of the LHWP on these resources.

The study was initiated in 1988 by BKS Inc. using state of the art analysis techniques developed during the Vaal River System Analysis (a joint venture with BKS, ACRES, SSO and DWA&F). The major system analysis results for the Orange River were first presented in 1992 and finalised in 1993 (McKenzie, 1993).

The results from the study indicated that the water resources of the Orange River are significantly less than originally estimated.

In the original water balance estimate there was a surplus of 1 078 million m^3/a even after full implementation of the LHWP. This can be compared to the updated estimate showing a 842 million m^3/a deficit. The difference of 1 920 million m^3/a (i.e. 1 078 + 842) is due to several factors including more reliable streamflow data over the last 20 years from the two major dams as well as a revision of the net river losses.

Obviously these figures are of major concern to the DWA&F and also to the governments of Namibia and Lesotho who both have considerable involvement in the water resources of the Orange River. As a result, it was decided to look at certain key elements considered in the water resource assessment where doubts were expressed regarding the reliability of the initial estimates made during the study. The river loss downstream of P K le Roux Dam was identified as a key component requiring detailed analysis and this led to the current study of the Orange River losses, the first phase of which is presented in this report.

From the results obtained during the course of the Orange River Losses Study it was concluded that:

- *The evaporation losses occurring from the Orange River are likely to be higher than the 800 million m^3/a initially estimated using the Symons Pan evaporation values. The evaporation calculated using the Bowen Ratio technique suggests that the evaporation from the river is in fact higher than pan evaporation. Unfortunately this conclusion is based on a very short period during which the pan evaporation measured at four different pans showed considerable scatter. It is not yet possible to confirm that the river evaporation is higher than pan evaporation throughout the year although the initial indications suggest that this is the case.*

Using the Symons Pan evaporation figures available along the Orange River it is estimated that the total net evaporation losses occurring along the full length of the river are in the order of 960 million m^3/a. The basis for this estimate is given in ***Table 1.***

Table 1: ***Summary of net evaporation losses from the Orange River.***

Reach	From	To	Length (km)	Areas for evaporation (km^2)			Precipitation (mm/a)	Gross Evapo-ration (mm/a)	Net Evapo-ration (mm/a)	River Losses	
				Water surface	Vegeta-tion	Total				10^6 m^3/a	m^3/s
1	PK le Roux	Orange/Vaal	186	24,9	8,7	33,6	300	2 200	1 900	63,8	2,02
2	Orange/Vaal	Boegoeberg	283	59,9	19,4	79,3	230	2 340	2 110	167,3	5,30
3	Boegoeberg	Kakamas	236	74,3	24,4	98,7	150	2 590	2 440	240,8	7,63
4	Kakamas	20°E Meridian	77	12,6	5,4	18,0	100	2 700	2 600	46,8	1,48
5	20°E Meridian	Vioolsdrif	315	78,9	13,6	92,5	100	2 600	2 500	231,2	7,33
6	Vioolsdrif	Orange/Fish	135	32,9	3,8	36,7	50	2 400	2 350	86,2	2,73
7	Orange/Fish	Orange Mouth	145	52,8	7,7	60,5	50	2 100	2 050	124,0	3,93
Total			1377	336,3	83,0	419,3	-	-	-	960,1	30,4

It should be noted that the values given in ***Table 1*** *are based on the available Symons Pan evaporation values estimated from various gauges in the vicinity of the Orange River. Unfortunately the gauges are not situated directly adjacent to the river and are usually several kilometres from the water surface. The recent work carried*

out by Forestek indicates that there can be a significant difference between the tank evaporation at the waters edge and that only a few kilometres away. This aspect will have to be considered in the subsequent phases of the study.

- *From the water balance analysis carried out using the gauged flows it is clear that the irrigation return flows are significant and must be included in any river loss evaluation. These return flows were disregarded in the original loss estimate and will more than compensate for the higher evaporation. The return flows will depend to a large degree on the application method and scale of irrigation. It is thought that the return flows are in the order of 10 % to 40 % of the water applied. With the available information it is not possible to quantify the return flows with more accuracy since the abstractions are not known accurately and the lag time associated with the return flows is also an unknown factor at this stage. In the event that the return flows are found to be in the order of 30 % for example, this will result in the net river losses decreasing from the 960 million m^3/a mentioned in* ***Table 1*** *to 720 million m^3/a.*

- *The analyses indicate that aerial photographs can be used to provide realistic estimates of both the water surface areas as well as the areas of sand banks and riparian vegetation. By analysing photographs of the same river reach at different flow rates it is also possible to evaluate the influence of flow rate on surface area. In the case of the Orange River the surface areas vary little as long as the flow rate remains within the normal release limits.*

  Satellite images can also be used to estimate the various areas and once processed, the images can be incorporated into a GIS which allows considerable information to be obtained very quickly. The satellite images also have the advantage that they can be obtained at short notice without the expense of flying along the river to take aerial photographs and the subsequent processing of more than 100 photographs.

  Unfortunately problems often occur when processing the satellite images resulting in areas which may be unrealistic due to misinterpretation of certain types of vegetation. For example, it is often difficult to distinguish between riparian vegetation and nearby irrigation. In such cases it is essential to verify the results

which usually involves making use of the aerial photographs and undertaking site visits to selected areas. It is therefore often more economical to base the areas on the aerial photographs and only use the satellite images in cases where the additional information from the images is required. Unfortunately the final processed areas from the satellite images were not available for inclusion in the first phase of the study but should be available for subsequent phases.

- *Losses as a result of transpiration from riparian vegetation are significant and the total area of such vegetation is estimated to be more than 80 km^2 (i.e. 25 % of water surface). It is estimated that the water lost via the riparian vegetation is similar in magnitude to that lost directly from a free water surface. Such losses will naturally depend upon the type of vegetation (i.e. reeds or trees) and availability of water. For the purpose of the first phase of the study, however, this assumption was accepted.*

Until more detailed and reliable information becomes available, it is recommended that the losses from the Orange River be based on Symons Pan evaporation values with no pan to lake corrections. It is further recommended that return flows of 30 % be used in the calculation until more reliable information on the return flows is obtained during subsequent phases of the study. This assumption leads to a net river loss in the order of 720 million m^3/a which is very similar to previous estimates in which the return flows were neglected. It should be noted that the return flows depend on the irrigation efficiency and method of application. If irrigation efficiency is improved the return flows will decrease while the losses will remain unchanged. For this reason, the two components should be considered separately.

Due to the importance of the irrigation return flows it is recommended that this issue be addressed during the subsequent phases of the project. The lag of the return flows is also of great interest since this can influence the magnitude of the releases required to support the various water users along the Orange River. It is possible that the use of tracers can help to quantify the volume and timing of irrigation return flows and this will be investigated during the next phase of the study.

Ideally the Bowen Ratio technique should be used continuously for a period of at least a year in order to evaluate the reliability of the pan evaporation values. Unfortunately the expense of such an exercise is outside the budget of the Losses Study and it cannot be included as part of the subsequent work. It may be beneficial to the WRC or DWA&F, however, to pursue this line of study in view of the importance of reliable evaporation data in the South African context.

The single set of manual flow gaugings undertaken by DWA&F has proven to be extremely valuable and it is recommended that further gaugings be undertaken to provide additional base information both on the Orange River and other suitable rivers where losses are known to be a problem. A regular exercise similar to that carried out in the first phase of the study should be carried out until such time that the losses have been quantified with the desired accuracy. It is only with such information that the study can successfully quantify river losses with any degree of reliability. Additional gaugings are already being planned for 1994 and beyond.

The possibility of dilution gauging or using tracers will also be investigated to determine if such techniques can be applied successfully in the Orange River and other rivers where losses must be evaluated.