APPENDIX D

DISCUSSION DOCUMENT ON

THE NEED FOR ADDITIONAL GAUGING WEIRS IN THE BIERSPRUIT AND SANDRIVIER NEAR THE CONFLUENCE WITH THE CROCODILE RIVER (WEST)

MOKOLO AND CROCODILE (WEST) WATER AUGMENTATION PROJECT (MCWAP) FEASIBILITY STUDY

REPORT 10: REQUIREMENTS FOR THE SUSTAINABLE DELIVERY OF WATER

Project No. WP9528

APPENDIX D: DISCUSSION DOCUMENT ON THE NEED FOR ADDITIONAL GAUGING WEIRS IN THE BIERSPRUIT AND SANDRIVIER NEAR THE CONFLUENCE WITH THE CROCODILE RIVER (WEST)

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1. BACKGROUND

The Mokolo and Crocodile River (West) Water Augmentation Project (MCWAP) will supply the planned coal mines, coal fired power stations and coal to petroleum plants as well as associated users with raw water. The proposed developments will take place along a roughly east-west corridor between Lephalale and Steenbokpan and will utilise the underlying coal field. In order to support this development water will be supplied directly from the Mokolo Dam on the Mokolo River (Phase 1) and from the Klipvoor, Roodekopjes and Vaalkop Dams along the Crocodile River (West) to the Vlieëpoort Abstraction Works (Phase 2). The water will then be pumped from Mokolo Dam and from the Abstraction Works at Vlieëpoort to Terminal Reservoirs located at of each of the main industrial bulk users.

The existing users along the Crocodile River (West) downstream of the Vaalkop, Roodekopjes and Klipvoor Dams are supplied from the river. These users rely on releases from the above dams and accruals from the catchments downstream of the dams. MCWAP water requirements will also be released from these dams in accordance with a release schedule determined by the MCWAP Authority. The MCWAP Vlieëpoort Works is located some 134 km downstream of the Vaalkop, Roodekopjes and Klipvoor Dams.

The planned releases will take account of bulk user requirements, irrigation requirements, predicted river losses, accruals and IFR releases downstream of Vlieëpoort. At the Vlieëpoort Abstraction Works a pumping control system will ensure that optimum use of water released for the MCWAP is made by adjusting pumping rates to account for variations in river flow resulting from variations to the predicted river losses, irrigation use and accruals. Surplus water in the river will then be stored in an off-channel balancing reservoir for later use.

IFR releases from the Vlieëpoort Works will be managed by means of low level outlets in the weir and a proposed gauging weir, some 400 m downstream of the main works. The IFR required and the associated hydrograph is still to be determined, but could amount to a flow requirement in the order of 25 to 30 Million m^3 per annum (see Figure 1-1). The main uncertainty in this case would be the volume of water migrating downstream through Vlieëpoort in the alluvial aquifer formed by the thick alluvial sediments that fill the river valley. These flows are excluded from the above surface flow figures that were generated from gauging weir data.

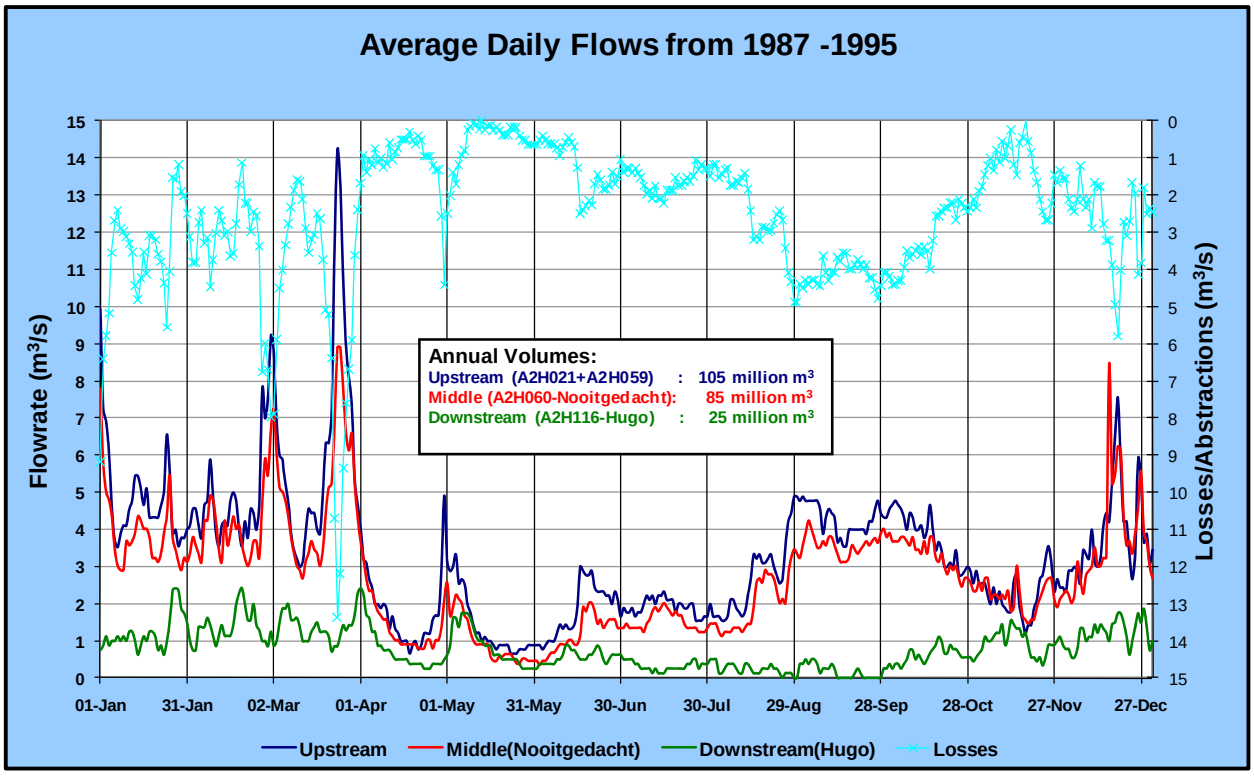

Figure 1-1: Average Daily Flows at Gauging Weirs in the period 1987 to 1995

Referring to the section on river losses in Supporting Report 12, the seepage losses into the aquifer was estimated to be in the order of 23,5 Million m^3 per annum.

2. VLIEËPOORT ABSTRACTION WORKS

The Vlieëpoort abstraction works will initially be equipped to have a pumping capacity of approximately 7 m^3/s, which could increase to as much as 17 m^3/s by the year 2050. The weir will have an OC height of 4,3 m above riverbed level with a gross full supply capacity of approximately 2,0 Million m^3 and surface area at FSL of approximately 1,0 Million m^2. These figures will be confirmed when a detailed survey of the weir basin becomes available in September 2009.

Foundation improvement works at the weir will be required and will take the form of jet grouted piles extending down to bedrock. The foundation improvement works will, however, prevent most of the natural migration of water in the alluvial aquifer below the weir. The weir will therefore effectively form an impenetrable cut-off barrier in the riverbed across the narrow poort.

The weir will be operated at approximately 300 mm below FSL to minimise the impact of flow variations resulting from changes in river loss behaviour, which was estimated to amount to a variation in flow of approximately 2,5 m^3/s (90% percentile of the 7-day average variation in flow). The main factors that would affect variation in river losses are evaporation/precipitation and over/under utilisation of irrigation allocations. These variations in river flows are based on flow measurement data obtained from the Hugo's Weir flow gauging station (A2H116), some 20 km upstream of the proposed Vlieëpoort Weir. Hugo's Weir is an important gauging station as it is located close to the bottom end of the Crocodile Irrigation Board irrigation area.

Additional pumping capacity will be provided for in the Low-lift pump station and additional storage capacity will be provided in the High-lift Pump Station Balancing Reservoir to store these surplus flows for use when shortfalls in flows occur (also refer Supporting Report 12). This arrangement will ensure that water will always be available for MCWAP, but may have a detrimental impact on the river flows downstream of Vlieëpoort.

These potential shortfalls downstream of Vlieëpoort should be avoided with the implementation of a river management plan. The successful implementation of the plan will require accurate real time or near real time measurement of dam releases, river flows, accruals, all abstractions and outflows past Vlieëpoort.

3. EXISTING GAUGING WEIRS

Existing DWA gauging weirs that would be used for the MCWAP Crocodile River (West) River Management Plan are:

- A2H019 (Roodekopjes Dam) in the Crocodile River (West);
- A2H021 (Buffelspoort) in the Pienaars River (will also gauge the flows from the Tolwane or Sandrivier) catchment;
- A2H059 (Atlanta Weir) in the Crocodile River (West);
- A2H060 (Nooitgedacht Weir) in the Crocodile River (West);
- A2H106 (Klipvoor Dam) in the Pienaars River;
- A2H111 (Vaalkop Dam) in the Elands River;
- A2H116 (Paul Hugo Weir) in the Crocodile River (West), and

The closest gauging weir to Vlieëpoort is A2H116 (Hugo's Weir) which is located some 20 km upstream of Vlieëpoort. No other functioning gauging stations exist between Hugo's Weir and Vlieëpoort. Flow gauging station A2H025 appears to have been lost in 1931 and A2H037 in 1982.

The Hugo's Weir gauging station (and weir itself) will need upgrading to the standard of the other DWA gauging weirs along the Crocodile River to ensure that data of comparable quantity and quality is available for use in the proposed river management system.

The Sandrivier and Bierspruit confluences are located downstream of Hugo's Weir and upstream of Vlieëpoort (refer to Figure 5-1). This means that the contributions made by the Sandspruit and Bierspruit to the flow in the Crocodile River (West) are not known other than through run-off calculations and cursory visual observations.

4. BIERSPRUIT AND SANDRIVIER

The Bierspruit and Sandrivier are the only two remaining significant water courses along the Crocodile River (West) downstream of Roodekopjes Dam that have not been dammed (or gauged). Note that relatively small dams, the Bierspruit Dam and Sandrivierspoort Dam, is located in the head waters of the Bierspruit and Sandrivier, respectively. Flood attenuation along these water courses occurs mainly on the Crocodile River (West) flood plain and a detailed hydrological analysis will be required to estimate the resulting flood hydrographs. These floods are, however, large when compared to the capacity of the Abstraction Works (refer to Table 4-1). The impact of the Abstraction Works on flows passing through the Works during flood events would consequently be minimal.

The floods emanating from the Sandspruit and Bierspruit catchments could therefore have a significant impact on river flow patterns and riverine environment along the Crocodile River (West) downstream of Vlieëpoort, both through surface flows in the river channel and sub-surface flows in the alluvium surround. An assessment to of the overall water balance has indicated that these two rivers may well be, on balance, essential for the replenishment of the alluvium aquifer downstream of Vlieëpoort.

Table 4-1: First Order Estimate of Flood Hydrology

Catchment		Flood Hydrology Comparison (1)							
	Q (m^3/s)	1:2	1:5	1:10	1:20	1:50	1:100	1:200	RMF
	Vol (2)								
Crocodile River (West) at Vlieëpoort (3)		752	1 746	2 498	3 249	4 243	4 995	5 741	7 456
		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sandrivier A = 1 680 km^2 i_{ave} = 1:260, c = 0,3 t_c = 19,3 hours		117	217	309	427	600	784	959	1 369
		12,2	22,6	32,6	N/A	N/A	N/A	N/A	N/A
Bierspruit A = 2 605 km^2 i_{ave} = 1:560, c = 0,3 t_c = 30,8 hours		121	225	321	442	812	1 049	1 270	1 782
		20,1	37,4	53,3	N/A	N/A	N/A	N/A	N/A

Notes:

1. Flood estimates determined by RMF method for the floods larger than 1:50 (K = 4) and the alternative rational method for the smaller floods.
2. Estimated total flood volume in million m^3 per event.
3. Ignoring attenuation in upstream dams.

During the more localised rainfall events when the flow contributions from these tributaries could be significant when compared to the normal flow in the Crocodile and the pumping capacity of the Abstraction Works, the situation with respect to flows passing Vlieëpoort could be different.

The construction of the Vlieëpoort Weir will result in the attenuation of the smaller or shorter return period floods (less than 1:2 year return period events) and may well prove to have a negative impact on riverine conditions downstream of Vlieëpoort. A flood control system should therefore be designed to either bypass such floods, or simulate such floods downstream of Vlieëpoort.

The maximum flood attenuation capacity of Vlieëpoort Abstraction Works is estimated to be approximately 700 000 m^2 x 0,6 m = 420 000 m^3 per event. Flood routing calculations should be undertaken to confirm this estimate.

Referring to Table 4-1 above, it seems clear that the Vlieëpoort Abstraction Works will have little impact on the flood hydrology downstream of the Works as these floods would pass over the weir without much attenuation. Only the more frequent floods resulting from localised rainstorms would be affected by the abstraction weir. These floods could also be used to contribute to the IFR and provide an indication of the flow hydrograph that would simulate natural flows.

The smaller floods would also be an important source for the replenishment of the alluvium aquifer downstream of Vlieëpoort, the main source of water for the downstream Makoppa farmers.

5. ADDITIONAL GAUGING WEIR AND MONITORING REQUIREMENTS

5.1 General Requirements

All flow and level monitoring, be it at boreholes or gauging weirs, should be done in conjunction with meticulous monitoring of river and borehole abstractions as well as water releases from the upstream dams (Klipvoor, Roodekopjes and Vaalkop) and other accruals that may occur downstream of the dams. The main tributaries that would account for these accruals would be the Bier Spruit and Sandrivier and, to a much lesser extent, the Blinkwater Spruit. The Blinkwater Spruit joins the Crocodile River (West) near Koedoeskop, approximately 60 km upstream from Vlieëpoort. Because the confluence of this spruit is located approximately midway between Nooitgedacht gauging weir (A2H060) and Hugo's Weir, accruals from the Blinkwater Spruit should be quantifiable with relative ease.

5.2 Gauging Weirs

Additional gauging weirs, one each near the confluence with the Crocodile River (West) and the Bierspruit and Sandrivier, would be required to determine the flood hydrographs for the two rivers. Real time monitoring of flood events in these rivers will allow the river management staff at Vlieëpoort to pass or simulate the floods through Vlieëpoort.

The gauging weir design should aim to provide reasonably accurate measurement of low flows in the Sandrivier and Bierspruit. The siting of such gauging stations should be such that:

- Flow measurement is done as close as possible to the respective confluences with the Crocodile River to measure surface flows.
- The gauging stations are located above the 1:100 year return period flood levels in the Crocodile River (West) in order to avoid drowning out of the weirs during major flood events.
- In addition an assessment of the geomorphology of these rivers should also be undertaken to determine whether benefit would be gained from locating additional gauging weirs immediately upstream of where these rivers enter onto the Crocodile flood plain. Flow measurements at these stations would be indicative of the contributions made by these rivers to the flow in the Crocodile alluvial aquifer.

Possible locations of such structures are indicated in Figure 5-1 and Figure 5-2 below.

Because of the wide flood plain of the Crocodile River (West) and the possible ease of outflanking of the structures it may well be prudent to locate the gauging weirs at the road crossing bridges. Photographs of these locations are given in Figure 5-3 and Figure 5-4.

The proposed locations of the gauging weirs are:

- On the Bierspruit at the road bridge near the Rhinolite Mine on gravel road between the R510 and the Dwaalboom Road.
- On the Sandrivier at the bridge on R511.

These gauging weirs will offer direct support to the river management plan (for release and abstraction planning discussed in **Appendix E** of Report 10). The two other possible gauging weir locations indicated on Figure 5-1 and Figure 5-2 could be used to determine the contribution of these rivers to the flow in the aquifer. At this stage quantification of these contributions were not considered essential as their contribution to the aquifer would effectively be overshadowed by the contribution of the continuous MCWAP water releases.

5.3 Borehole Monitoring

Quantification of the flow in the Crocodile River (West) alluvial aquifer would be difficult unless extensive geo-hydrological modelling is undertaken. It may also be possible to undertake geophysical measurements (for example with flux, acoustic or electrical methods) or more direct measurements using borehole flow meters to improve estimates of water movement in the aquifer through Vlieëpoort.

A more practical approach would be to undertake continuous borehole water level monitoring to record levels both upstream and downstream of the Vlieëpoort Abstraction Works. Such monitoring would have to start well in advance of the proposed MCWAP construction work to establish base line conditions.

Continued borehole water level monitoring would be required after construction of the abstraction works to confirm the adequacy of releases from the Abstraction Weir to recharge the aquifer downstream of Vlieëpoort.

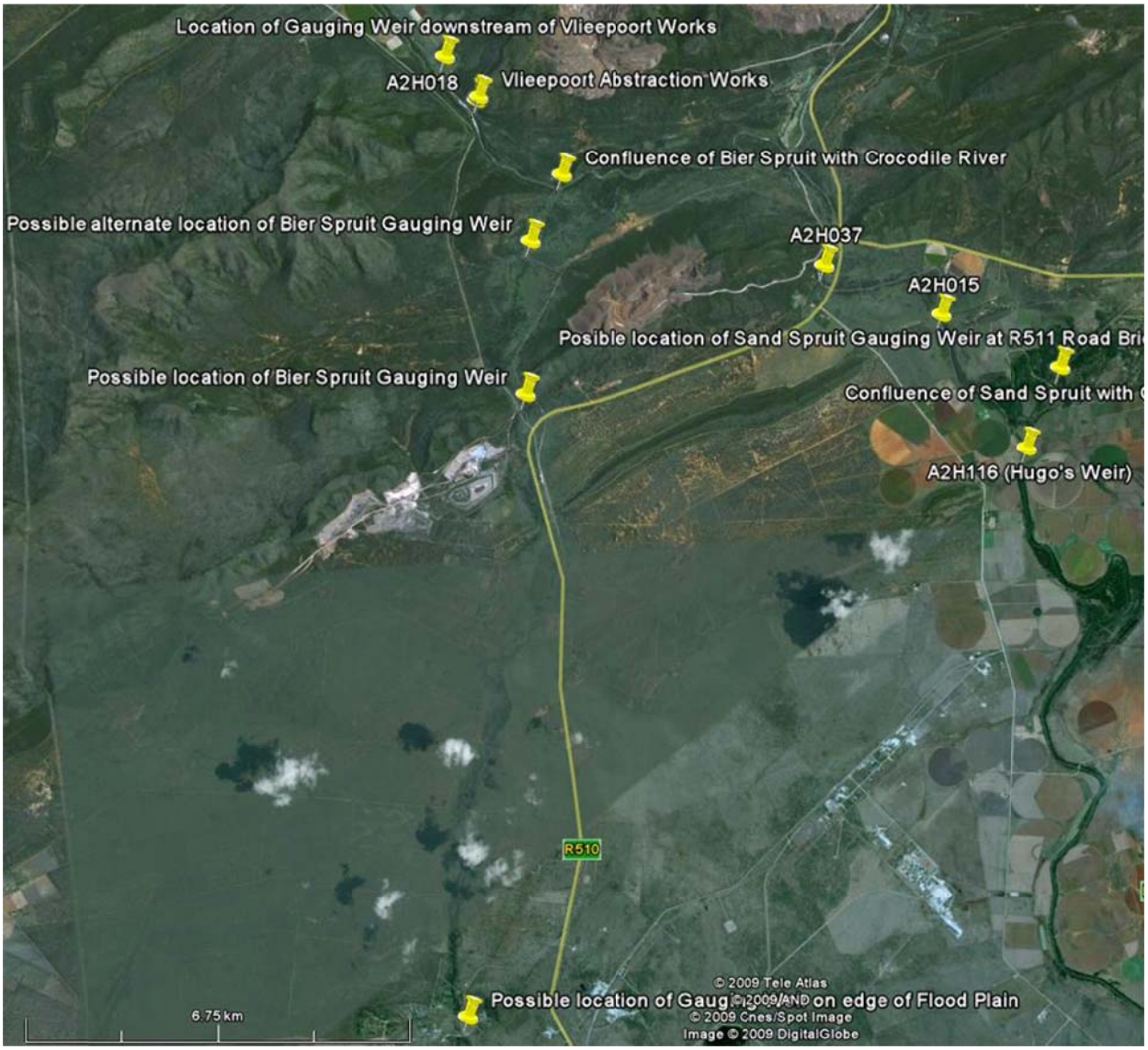

Figure 5-1: Plan View of Possible Gauging Weir Locations along Bierspruit

Figure 5-2: Plan View of Possible Gauging Weir Locations along Sandrivier

Figure 5-3: Bierspruit Road Bridge near Rhinolite Mine on Gravel Road between R510 and Dwaalboom Road

Figure 5-4: Sandrivier Bridge on R511

6. CONCLUSIONS AND RECOMMENDATIONS

Surface water flows and alluvial aquifer flows that pass through Vlieëpoort are the main contributor to the water volumes required for maintenance of the present riverine environment and for legal water use requirements downstream of Vlieëpoort and down to the Limpopo River.

River flows between the supply dams (Klipvoor, Roodekopjes and Vaalkop Dams) and downstream to A2H116 (Hugo's Weir) can be fairly well quantified by flow measurements taken at existing DWA gauging weirs. Flows in the alluvial aquifer have been derived using the water mass balance (at effectively A2H116) and no direct flow measurements are available.

Downstream of A2H116 and upstream of Vlieëpoort two major tributaries join the Crocodile River (West), being the Sandrivier and the Bierspruit. The actual flow contributions of these tributaries to surface flows past Vlieëpoort and replenishment of the alluvial aquifer is unknown. In order to measure these flows it is recommended that a gauging weir should be constructed in each of these rivers near their respective confluences with the Crocodile River (West). The gauging weirs should be located such that they are protected against outflanking and sufficiently are far away enough from the Crocodile River (West) that flow measurements would not be affected by floods in the Crocodile River (West). The existing road bridge on the R511 crossing of the Sandrivier and the bridge crossing of the Bierspruit on the district road connecting the R510 and Dwaalboom Road appear ideal for this purpose.

It is also recommended that borehole water level monitoring be instituted at Vlieëpoort to compliment surface flow measurements and to ensure that the alluvial aquifer downstream of Vlieëpoort would not be negatively impacted on by the proposed Vlieëpoort Abstraction Works.