Development of diversion functions, initial estimates of yield based on daily or hourly observed flow time series and yield determination using the WRYM

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1. INTRODUCTION

Several of the six proposed surface water development options include a run-of-river diversion to a storage reservoir located off-channel or on another river some distance away from the diversion point. The diversions investigated were the Michell's Pass gravity diversion to Voëlvlei Dam via the Klein Berg River and existing Klein Berg diversion scheme, the Upper Wit River gravity diversion to a dam on the Krom River at Riverlands, the Molenaars River pumping diversion via a pipeline to the Berg River Dam and a pumping diversion from the Berg River into Voëlvlei Dam.

In the case of the diversion schemes investigated for this study, weir heights were kept to a minimum to minimise their environmental impact in terms of upstream inundated area and barriers to the migration of aquatic biota. These low weirs would provide no storage, and thus pumping or diversion of flows would only occur when river flows are naturally high enough. In addition maintenance of the Ecological Water Requirements (EWRs) downstream of the abstraction site needs to be taken into account in the operating rules.

Whilst the Water Resource Yield Model (WRYM) runs on a monthly time, river flows tend to vary significantly over much shorter time scales (of the order of hours). As such it is very important to capture this variability in flow correctly so as to enable an accurate evaluation of how much water would be available for diversion. The WRYM makes use of a modelling tool referred to as a diversion function. This function estimates the monthly diverted volume at a diversion given a monthly inflow volume in the river at that point. A diversion function is derived using a long time-series of observed daily or where appropriate even hourly flows that are fed through a diversion tool (usually using a spreadsheet) and the resulting diverted flows and original inflows are aggregated monthly and plotted. A curve is then fitted that estimates the diverted monthly volume based on the inflow monthly volume.

Changes in the flows from upstream will influence the diversion function so that a new diversion function needs to be derived for every upstream catchment development scenario that is investigated. The existing Papenkuils, Holsloot and Smalblaar diversions would be affected by the proposed Molenaars diversion, the Klein Berg diversion by the proposed Michell's Pass diversion and the existing pumping diversion into Brandvlei Dam by the proposed Molenaars, Upper Wit and Michell's Pass diversions. These diversions and Ecological Water Requirements (EWR) affect the diversion functions at each site.

A short description of the derivation of the various diversion functions used in this study are provided below. Only winter diversions from May to October (inclusive) and at the Berg River pumping scheme from June to October (inclusive) were modelled as all summer flows are allocated.

2. INCLUSION OF THE ECOLOGICAL WATER REQUIREMENTS

The EWRs were comprehensively updated as part of this study for all the possible diversion sites and numerous other sites. The latest EWRs have therefore been taken into account in the derivation of the various diversion functions. This is ensured by giving the EWRs priority before any water would be diverted at the various diversion sites. For the reinstatement of the existing Papenkuils Pump Station diversions into Brandvlei Dam and for the Berg River pumped diversions, stepped pumping rules were assumed to be implemented. This approach is consistent with previous studies at these two sites.

For the Berg River Pumping Scheme, flow output from the WRYM for the river and estuary downstream of the possible Berg River Pump Station was compared to the EWR requirements using flow duration curves for each month of the year. Some modifications to the abstraction rules were necessary to conform with the EWRs. In particular the number of months in which pumping could take place was reduced from May to October to June to October. This was necessary as it was found that the river flows in May dropped significantly below those specified in the EWR, if pumping took place during this month.

Downstream flows in the Breede River and into the estuary will need to be verified against the EWR requirements during the Feasibility Study Phase. This will require a basin-wide assessment of the EWRs. The existing Papenkuils pumped abstraction capacity was modelled for the installed capacity of 7 m^3/s, and this was checked against the EWR requirement previously established during the Breede River Basin Study, and was found to conform to the EWR at that time.

No allowance was made for the EWRs in the Klein Berg River downstream of the existing diversion weir as no Reserve is currently implemented at that site and all available flow in the Klein Berg River is currently diverted into Voëlvlei Dam.

3. INITIAL ESTIMATES OF THE YIELD OF SCHEMES

The yields of the various schemes involving run-of-river diversions were initially estimated using daily flow time series derived at each of the diversion sites for the critical period of the Western Cape Water Supply System (WCWSS). The critical period in a hydrological sequence is defined as the period in the sequence from when a dam was last full until when it reached its minimum level during the entire sequence. This defines the most severe drought from a water resources perspective.

The period May 1969 to October 1973, which was based on the critical period for the WCWSS, and available observed daily flow data of acceptable quality was used for the initial yield estimates using daily flows. The yield estimates took into account the demand pattern of the WCWSS which is biased towards demand in summer when the available supply from surface water resources is lowest.

Based on the latest updated hydrology from the Berg Water Availability Assessment Study (WAAS), the critical period of the WCWSS has recently been redetermined to be from September 1969 to April 1974.

4. MICHELL'S PASS DIVERSION

4.1 DERIVATION OF DAILY FLOW TIME SERIES AND DIVERSION FUNCTIONS

The period from 1 October 1979 to 30 September 2005 was used for the diversion calculations at Michell's Pass. This period was selected as it reasonably represents the present day state of flows in the Breede River at that site, taking into account upstream water resource developments. The period end date was limited by the availability of a natural flow sequence at the site for determining the EWR, which ended in September 2005.

The diversion function at the Michell's Pass site was derived using observed daily flow data at the DWA gauges H1H006 (existing gauge at the Michell's Pass site) and H1H022 (gauge on the Artois canal). Gaps in the daily data for H1H022 were patched with the long-term monthly average daily flows for the particular month concerned. The daily flows for H1H006 and H1H022 were then summed and any further *gaps (due to gaps in the data at H1H006) were patched based on the observed record at the DWA gauge H1H003 located upstream on the Breede River at Ceres. For the few days in which there was simultaneous missing data at both gauging stations, patching was undertaken manually through interpolation.*

The EWR was determined on a daily basis at the site using the flow-duration curves output from the latest EWR work undertaken as a part of this study. A daily natural flow time series was disaggregated from monthly natural flow data used in the WRYM model. The Present Ecological Class (Class D) was used for the EWR in the diversion calculations.

Figure 1 shows the log-based flow time series (patched, observed or simulated) that was used to determine the diversion functions at the Michell's Pass site.

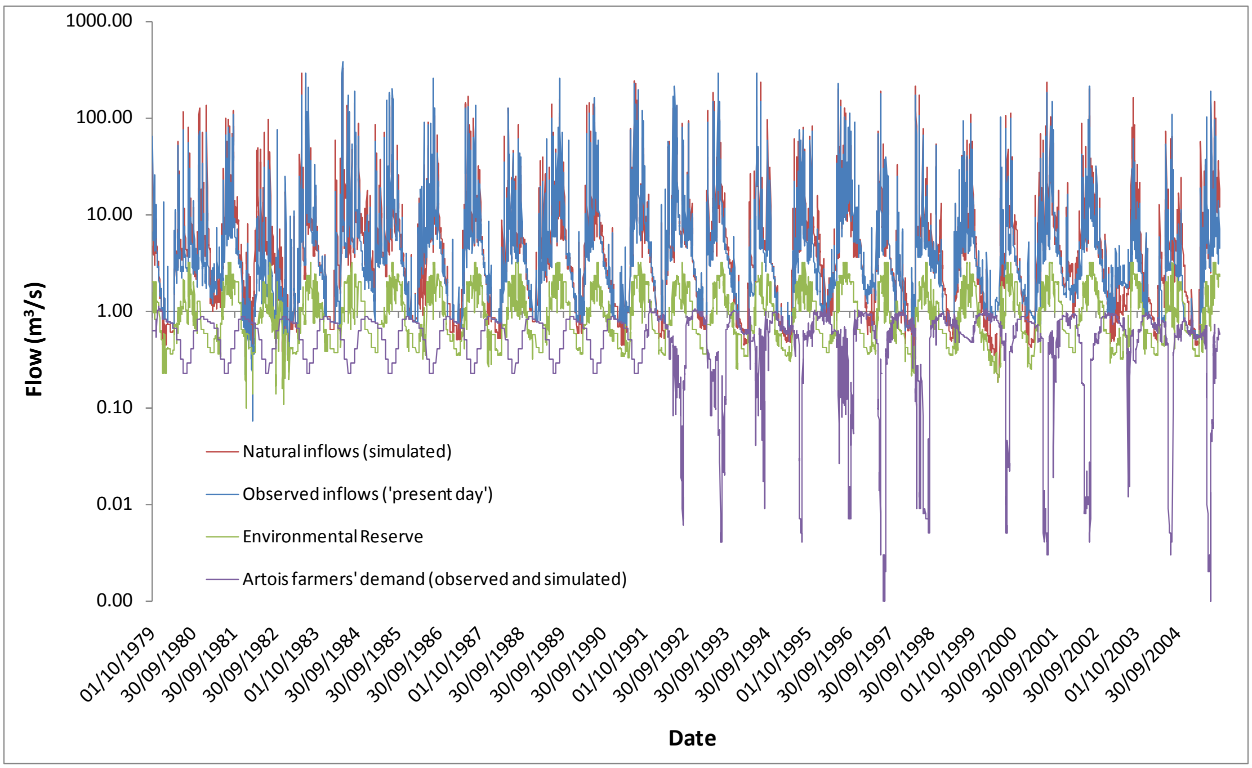

Figure 1 Comparison of flow time series' at the site: natural flows (simulated), observed flows, EWR and irrigation demands (observed and simulated)

The Artois Canal irrigators were given first priority in the diversion calculations on account of their existing entitlements, followed by the EWR requirement for the Breede River downstream of the diversion site. Diversions to the Klein Berg River were calculated on a daily time-step in the following manner:

- *Checking if the Breede River inflows could satisfy the Artois Farmers' demand;*
- *Allocating all available flow up to the demand of the Artois Farmers;*
- *Checking if the remaining Breede River flow meets the EWR;*
- *If YES then diverting water up to the available Breede River flow or capacity of the diversion, whichever is the lesser, into the Klein Berg River;*

- *THEN allowing the remainder to flow down the Breede River – consisting of excess undiverted flows including EWRs.*

This has the effect of implementing the EWR at the site whenever flows are sufficient to satisfy both the Artois Canal irrigation demand and the EWR. No diversions to the Klein Berg River were implemented until this criterion was met, although diversions would occur more frequently for the Artois irrigators as they received first priority, before the EWR.

Figure 2 shows an example of the 5 m^3/s diversion function for Michell's Pass.

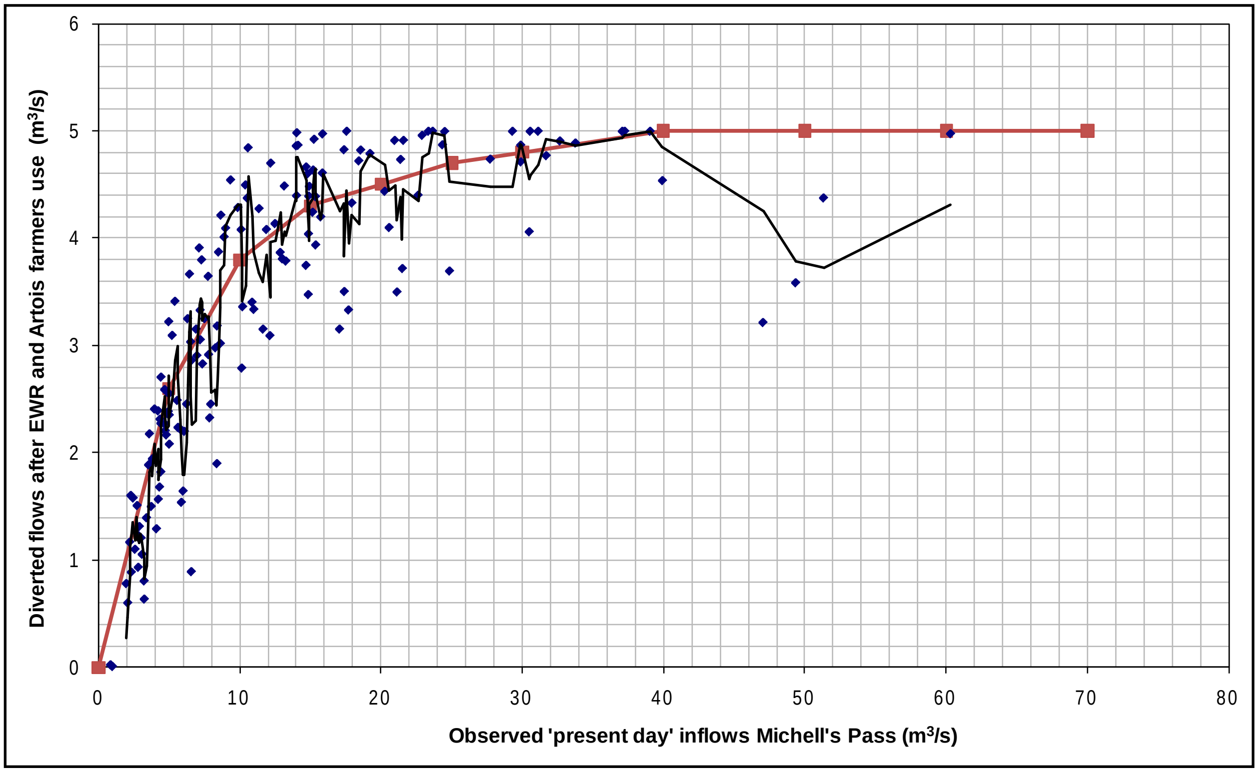

Figure 2 **Example of 5 m^3/s capacity diversion function showing the moving average line in black and the diversion function line in red**

The flows that continued down the Breede River (the balance of undiverted flows including the EWR portion) were routed downstream to the Papenkuils Pump Station, including estimated daily inflows from the incremental catchment downstream of the Michell's Pass diversion site. Another set of diversion calculations were set up at the Papenkuils site to determine the increased reinstatement abstraction necessary to offset the impact on the yield of Brandvlei Dam of the upstream diversions at Michell's Pass. This was required to ensure that the existing yield of Brandvlei Dam is not adversely impacted.

The diverted flows (excluding the Artois irrigation demand) were routed down the Klein Berg River and added to the observed flows at the Klein Berg diversion (DWA gauging station G1H008). These combined flows were then routed at a daily time step through the existing diversion (19.8 m^3/s capacity) into Voëlvlei Dam. This approach was repeated for each of the diversion capacities assessed at Michell's Pass.

4.2 ESTIMATION OF THE YIELD OF THE SCHEME

The scheme yield was estimated using observed flows for the critical period as described earlier. A graph showing the relationship of the yield of the scheme to the diversion capacity is given in Figure 3.

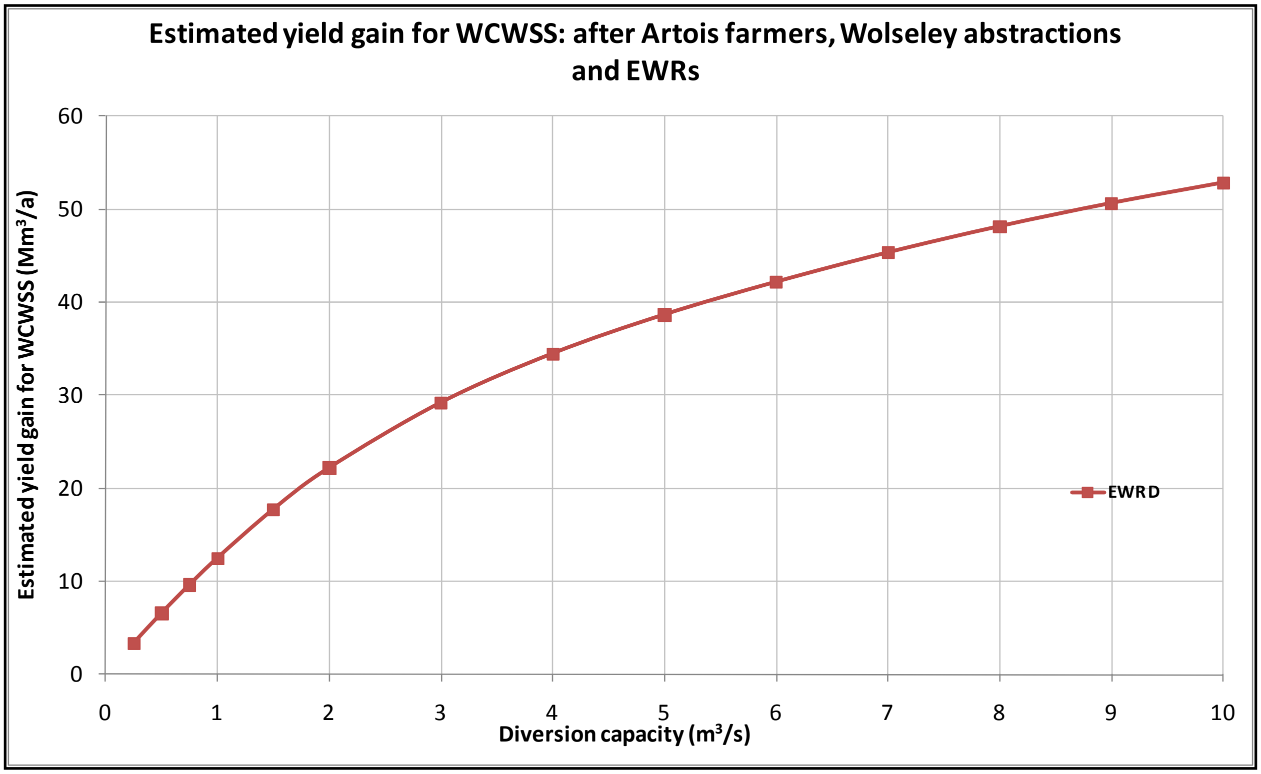

Figure 3 Estimated diversion capacity – yield relationship for the Michell's Pass diversion

5. UPPER WIT RIVER DIVERSION

5.1 DERIVATION OF DAILY FLOW TIME SERIES AND DIVERSION FUNCTIONS

DWA gauge H1H007 located downstream of the possible diversion site on the Wit River was used to derive the daily time series at the site. Since this is an undeveloped mountain catchment, the flows at H1H007 can be regarded as being natural. An exception to this is the influence of the upstream Gawie-se-Water diversion scheme, which diverts an average of about 4.5 million m^3/a (de Kock, 1982), equating to about 9% of the MAR.

The Gawie-se-Water (Pombers Canal) diversion was constructed over 100 years ago to divert water from the Upper Wit River (Breede River Basin) to the Krom River (Berg River Basin) for irrigation purposes. This was the first inter-basin transfer in South Africa. During field investigations in March 2009 the flow was estimated to be about 0.1 m^3/s. The canal was gauged historically by DWA for three years with two years of complete daily data being available, namely 1969 and 1970 when 4.7 and 4.6 million m^3/a were respectively diverted. A monthly regression relationship was derived between the Pombers Canal gauge (G1H022) and the Wit River gauge H1H007, and the Gawie-se-Water flows were extended using this relationship for the full period of analysis.

Figure 4 shows the annual estimated diverted volumes by Gawie se Water from the Upper Wit River

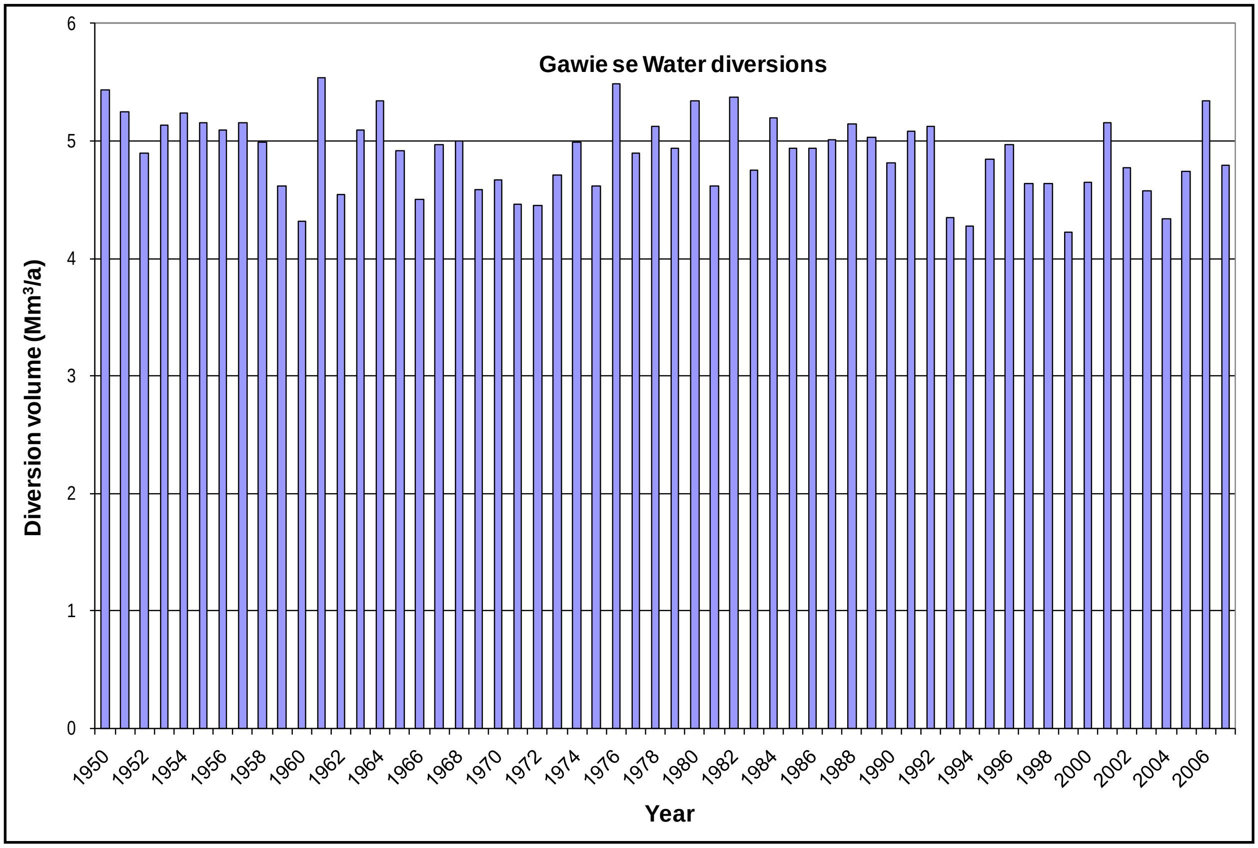

Figure 4 Simulated annual Gawie-se-Water diversions

Observed flows at H1H007 were added to those estimated for the Gawie-se-Water diversion and gaps were patched using the DWA gauge H1H018, located on the Molenaars River in an adjacent catchment. This was achieved using a derived monthly regression relationship between the two gauges.

The 'natural' daily flow record derived at H1H007 was then scaled back to the DWA gauge H1H011 site (Oostenberg, located between Bainskloof Village and the Gawie-se-Water diversion) using the ratio of MAR given by de Kock (1982). This was then further scaled up a short distance downstream to the proposed diversion site (tunnel inlet) at Bainskloof Village, on the basis of catchment areas.

The EWR was determined at H1H007 as part of this study and was scaled back to the site in the same manner as described above for the flows. The PES (Class B) was used for the assessment of the diversion.

The diversions were calculated in a spreadsheet (daily basis) based on various diversion capacities (1 to 5 m^3/s), with diversions only taking place once the EWR had been satisfied. The balance of the flows not diverted (including the EWR), were then routed downstream to the Papenkuils Pump Station, including the estimated daily inflow from the incremental catchment downstream. At Papenkuils a diversion function (for yield reinstatement of Brandvlei Dam) was determined in the same manner as described previously for the Michell's Pass option.

5.2 ESTIMATION OF THE YIELD OF THE SCHEME AND OPTIMISATION OF THE WIT RIVER DIVERSION AND RIVERLANDS DAM

The size of the dam at Riverlands Farm on the Krom River (a tributary of the Berg River) was optimised using a spreadsheet by determining the yields using a daily water balance. The daily inflow time series from the diversion function calculations were routed through the dam for various dam height and diversion capacity combinations. Evaporation losses and rainfall inputs on the reservoir surface were also taken into account and yields were determined for each diversion option. A set of curves was derived from which the optimal diversion capacity and dam capacity could be determined (Figure 5).

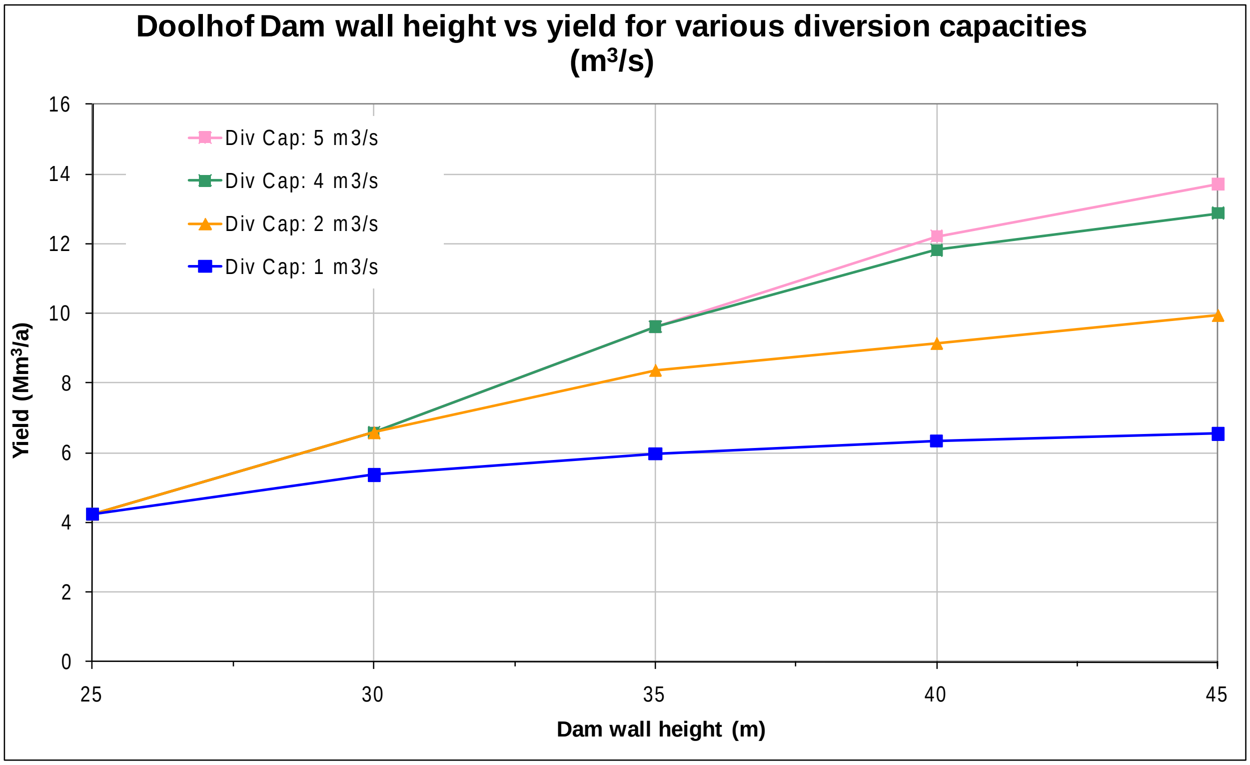

Figure 5 Size of the Riverlands Dam versus yield for various inflow diversion capacities off the Wit River

Figure 5 shows that for this possible scheme, a diversion capacity of 4 m^3/s from the Wit River into a dam on the Krom River with a wall height of 45 m, appears optimal from a yield benefit perspective.

6. MOLENAARS RIVER DIVERSION

6.1 DERIVATION OF DAILY FLOW TIME SERIES AND DIVERSION FUNCTIONS

The Molenaars River catchment also contains very little development and as such the observed flows at the DWA gauging stations on the river can be assumed to be representative of the natural flow condition. Patched observed daily and hourly flow data from gauging H1H018, located on the Molenaars River downstream of the proposed diversion site, were used to determine the diversion functions for this scheme. Gaps in the daily flow record at H1H018 were patched using the observed streamflow record at

H1H007, located in the adjacent Wit River catchment. This was achieved through the development of regression relationships derived from the two streamflow records at these two gauges. The patched observed daily and hourly flows were then scaled back to the two possible diversion site locations (Molenaars and Elandspad sites) using ratios of catchment MAR, determined as part of this study.

The EWR was taken into account for the yield and pumping calculations (at a daily time-step) by disaggregating the monthly EWR flow time series determined at the proposed diversion site to a daily time-step. For the determination of diversion functions and routing of flows downstream to the Papenkuils Pump Station (at an hourly time-step), the EWR was included using the duration curves determined for H1H018 and scaled back to the site. In the models, priority was assigned to the EWR before any pumping or diversion could take place.

Figure 6 shows the inflows and diverted (pumped) flows at the Molenaars diversion site for a possible pump station capacity of 4 m^3/s. Figure 7 and Figure 8 show the average frequency that pumping could occur on a monthly and annual basis for various pumping rates based on the observed daily flow data described above. From Figure 7 it can be seen that most of the pumping would occur from May to September with significantly less pumping occurring in October. The peak abstraction months would be June, July and August which coincides with the peak electricity tariff period which is also in June, July and August, so that pumping costs would be higher than if pumping were able to take place at another time of the year.

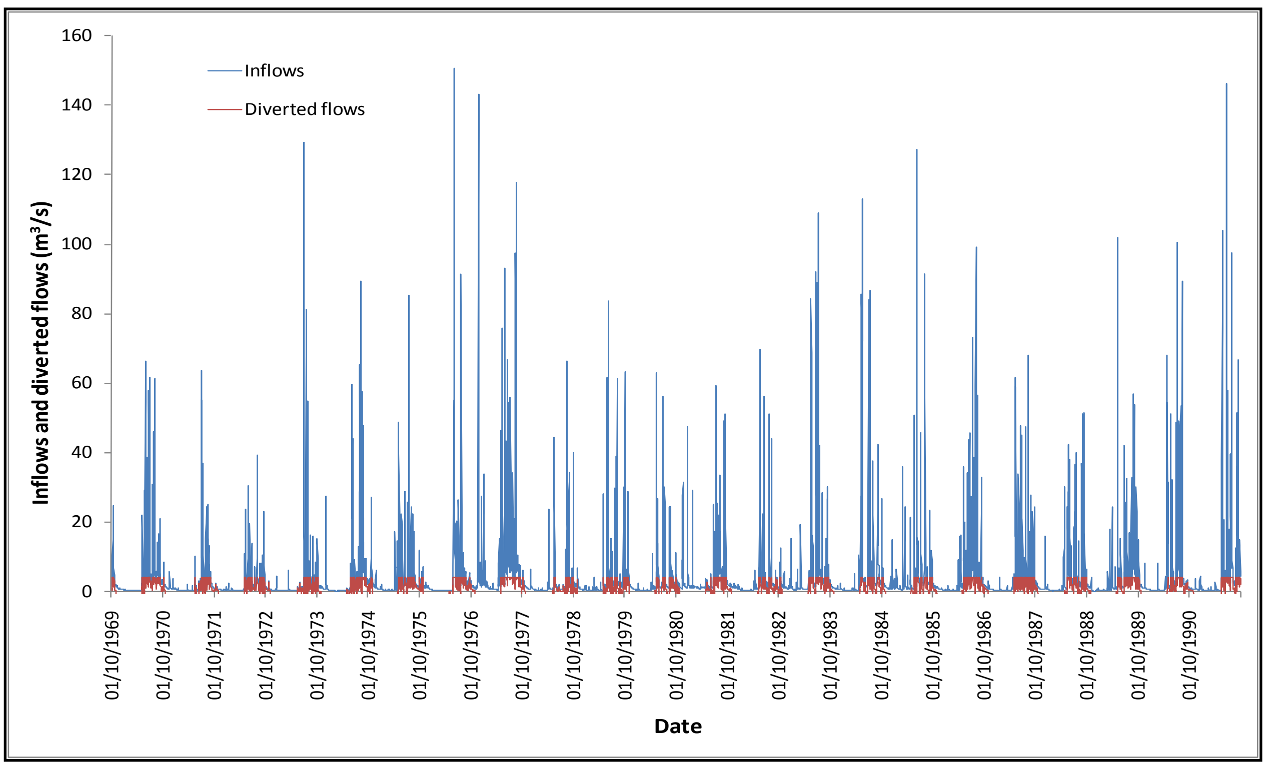

Figure 6 Example of the inflows and pumped flows at the Molenaars River diversion with a capacity of 4 m^3/s

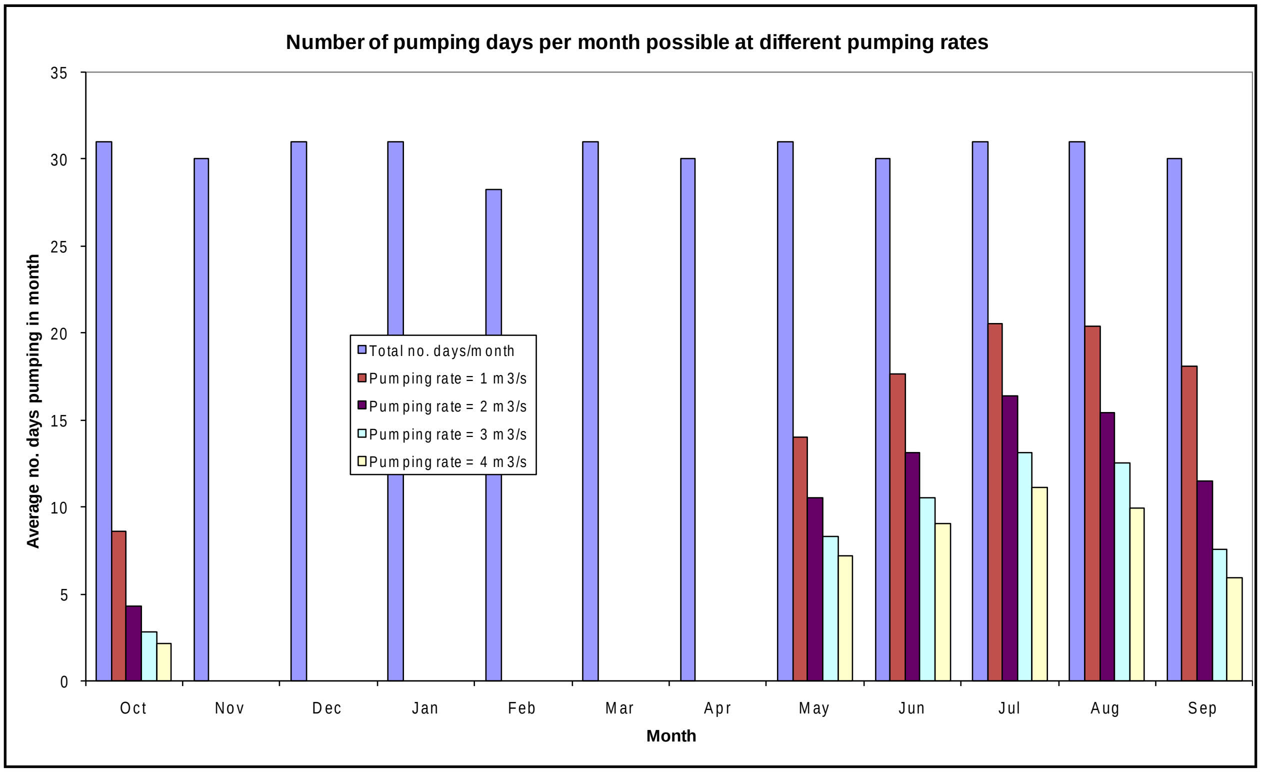

Figure 7 **Average number of days that pumping would be able to occur for each month for different pumping rates (after allowance for the EWRs)**

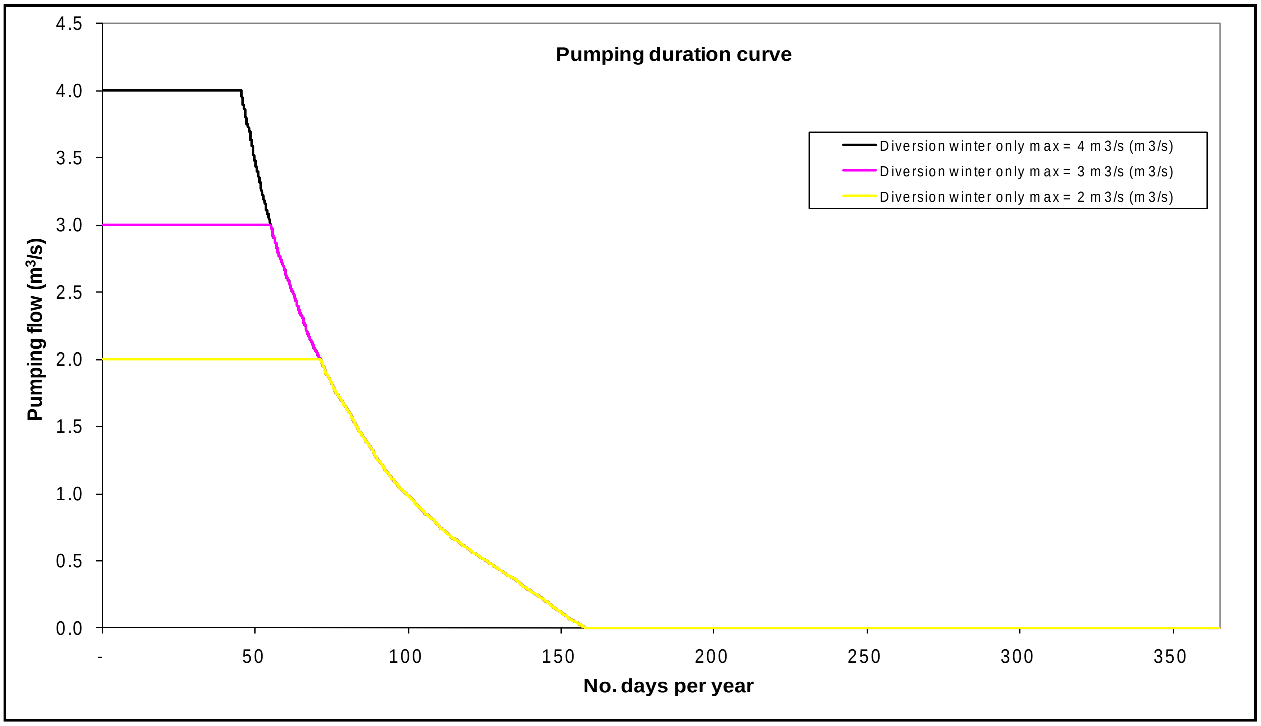

Figure 8 **Duration curve showing the annual pumping frequency for particular rates of abstraction**

Scaled hourly observed flows were used to route the balance of streamflow (including estimated incremental in-flow contributions) through the existing Holsloot and Smalblaar diversions into Brandvlei Dam, and thereafter the remaining flows routed down to the existing Papenkuils pump station. Diversion functions were determined at all of these existing diversion structures for each of the development options considered for the possible Molenaars schemes, so as to evaluate the impact on the present day yield of Brandvlei Dam.

6.2 ESTIMATION OF THE YIELD OF THE SCHEME

The potential scheme yield was estimated using scaled observed flows for the critical period as described earlier. The resulting relationship of the yield of the scheme to diversion capacity is given in Figure 9.

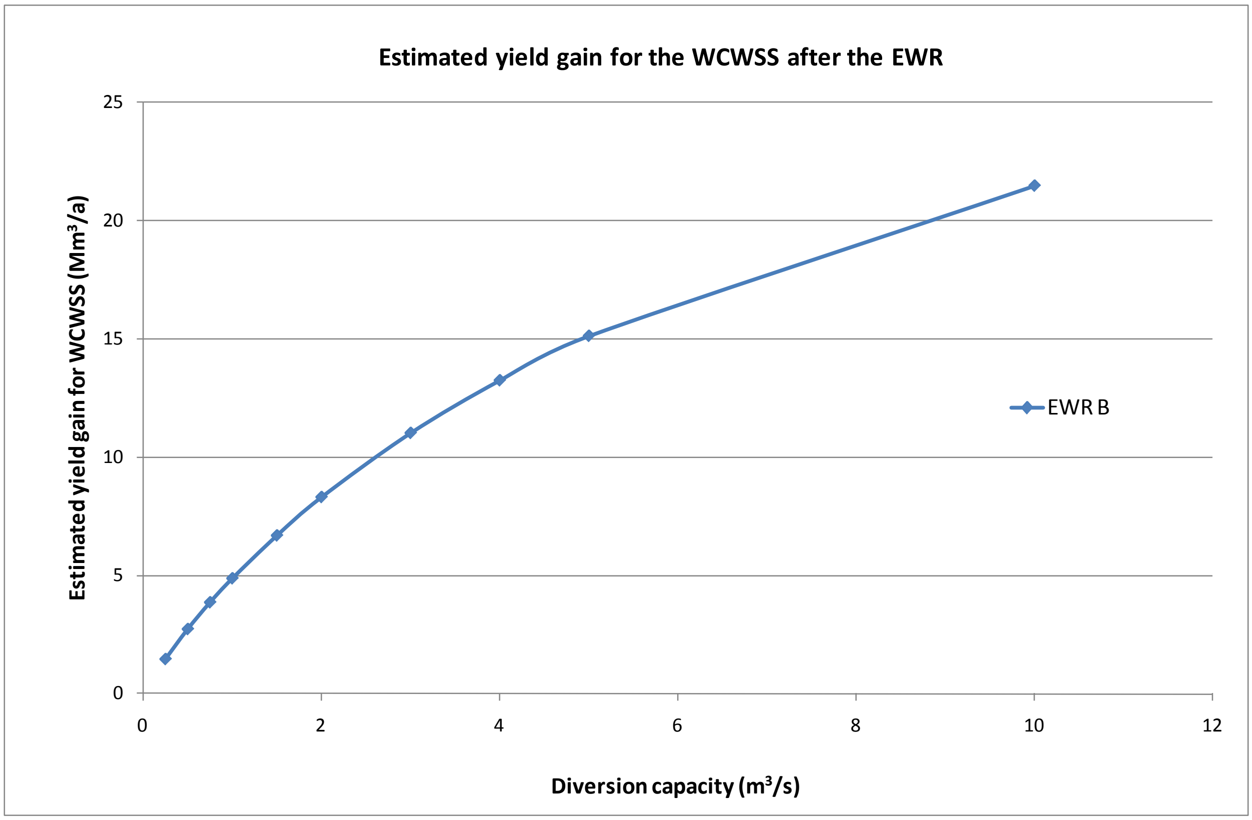

Figure 9 Estimated diversion capacity – yield relationship for the Molenaars River diversion

7. BERG RIVER PUMPING SCHEME TO VOËLVLEI DAM

7.1 DERIVATION OF DAILY FLOW TIME SERIES AND DIVERSION FUNCTIONS

Monthly simulated present day flows for the Berg River, from the WRYM, were disaggregated to a daily time-step using daily observed flow data at the DWA gauging stations G1H036 and G1H013, both located on the Berg River in the region of the Voëlvlei Dam.

Three stepped pumping rules were implemented in the diversion tool and their compliance checked against the EWR requirement at the possible diversion site. The three stepped pumping rules consisted *of pumping step increments of 1 m^3/s, with a minimum flow of 1, 3, or 5 m^3/s ensured in the river at all times. Pump station capacities varying from less than 1 m^3/s and up to 10 m^3/s were modelled by applying the stepped pumping rules. Figure 10 illustrates the application of the stepped pumping rules investigated for a pump station with a capacity of 10 m^3/s.*

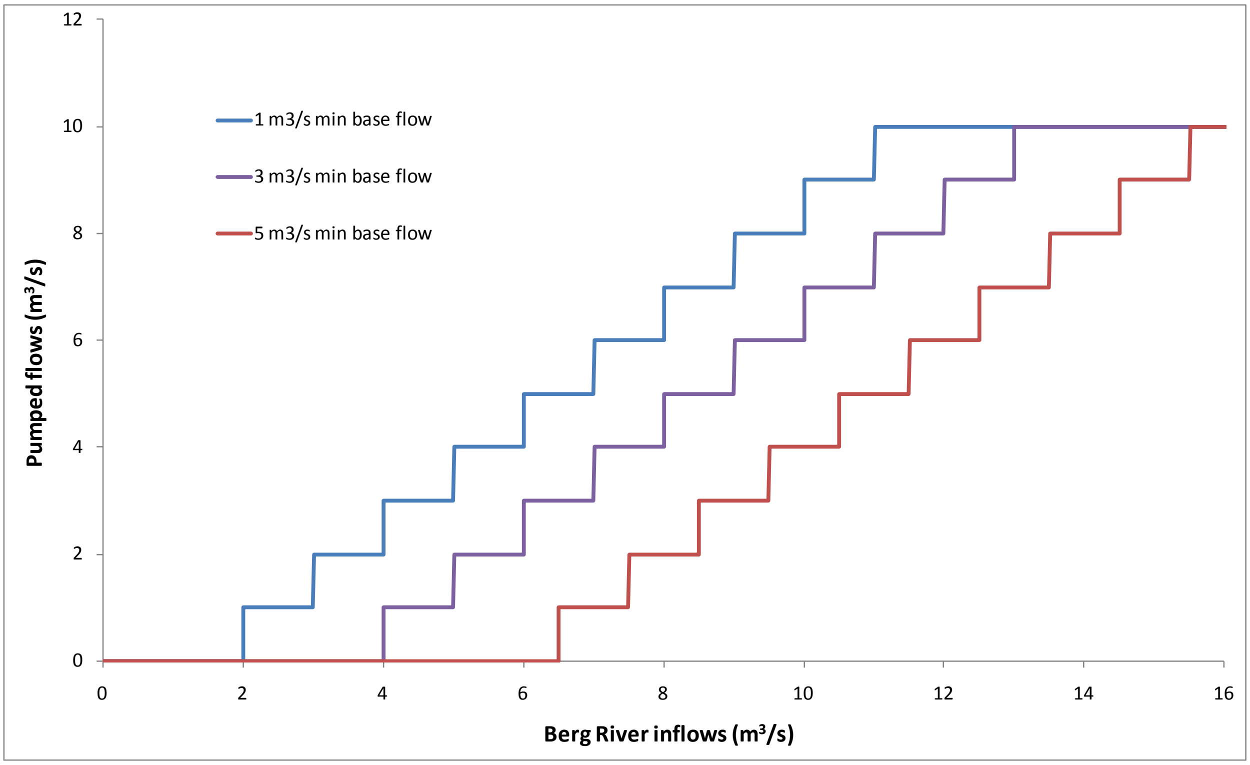

Figure 10 Stepped pumping rules (Berg River abstraction) for a 10 m^3/s abstraction

Diversion functions were then determined and iteratively improved using the WRYM by comparison with the daily diverted flows. Compliance with the EWR was checked by deriving flow duration curves for the remaining flow in the Berg River for each month of the year (after abstraction), and these were compared to the flow duration curves required for the EWR (see Figure 11).

It was initially found that abstraction from the Berg River during May reduced the remaining streamflow to a monthly flow volume that was less than that required to meet the EWR in that month. Therefore the abstraction was modified to commence in June and run until end October. It was found that the yield of the possible scheme was not significantly impacted by the loss of 1 month of abstraction in May, and that the EWR was able to be met during the reduced abstraction period.

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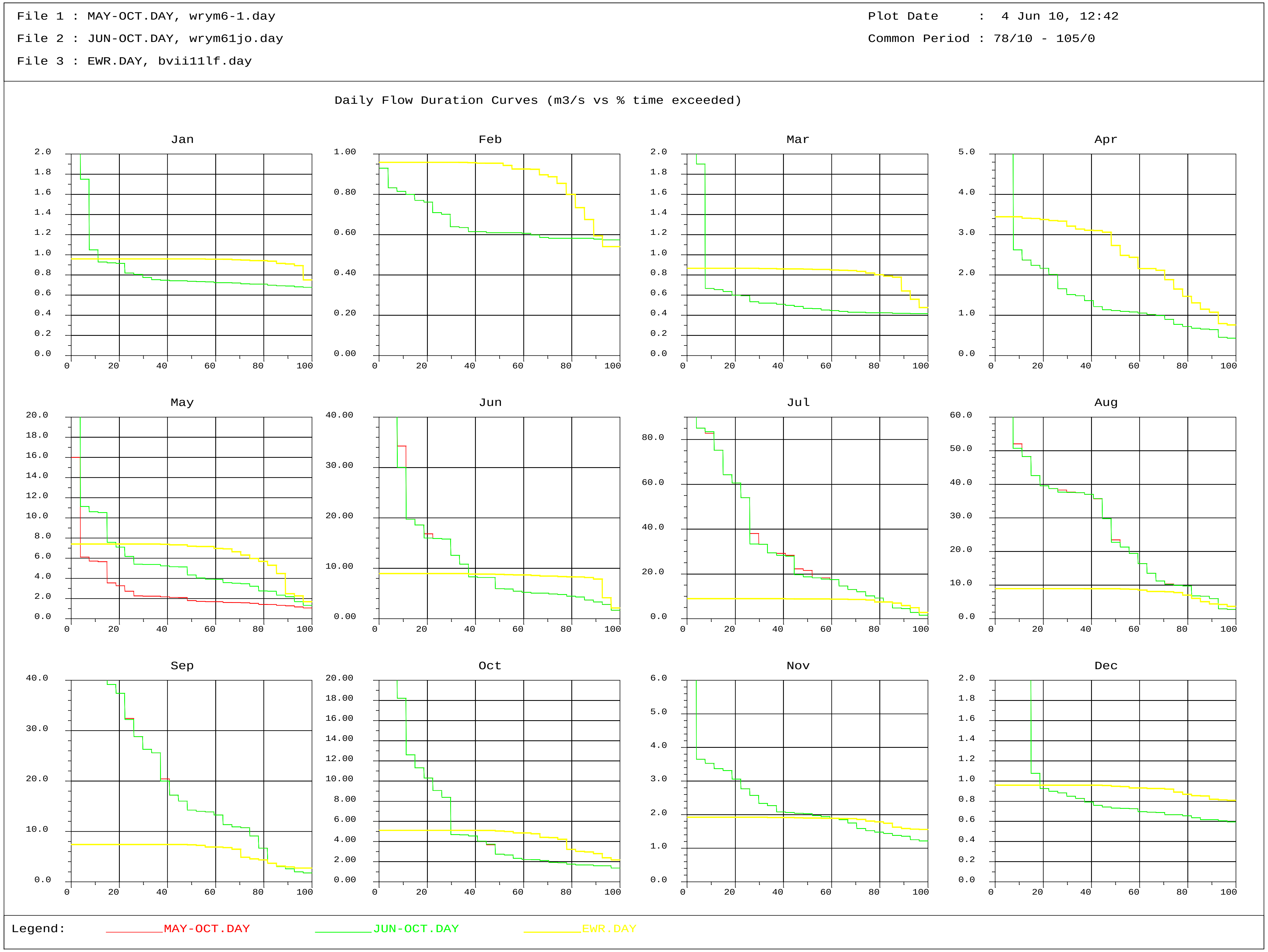

Figure 11 **Monthly flow duration curves comparing the flows in the Berg River just downstream of the proposed pumping scheme for the scenario of pumping May-October inclusive (MAY-OCT.DAY), pumping June-October inclusive (JUN-OCT.DAY) and for the Ecological Water Requirement (EWR.DAY)**

7.2 OPTIMISATION OF BERG RIVER PUMPING, YIELD DETERMINATION AND RAISING OF VOËLVLEI DAM

Multiple scenarios were tested using the WRYM for the possible Berg River pumping scheme into Voëlvlei Dam. These included assessing the following infrastructure related scenarios to determine if they would have any significant impact on the yield of the Voëlvlei Dam system:

- *An increase in the existing pipeline capacity to Cape Town;*
- *An increase in the storage capacity of Voëlvlei Dam (ie. raising Voëlvlei Dam); or*
- *A larger pump station on the Berg River.*

Pump rules referred to hereunder and explained in the previous section, were defined as:

- *Pump Rule 1: minimum base flow in the Berg River of 1 m^3/s to pass the site at all times*
- *Pump Rule 3: minimum base flow in the Berg River of 3 m^3/s to pass the site at all times*
- *Pump Rule 5: minimum base flow in the Berg River of 5 m^3/s to pass the site at all times*

The results are presented in Figure 12.

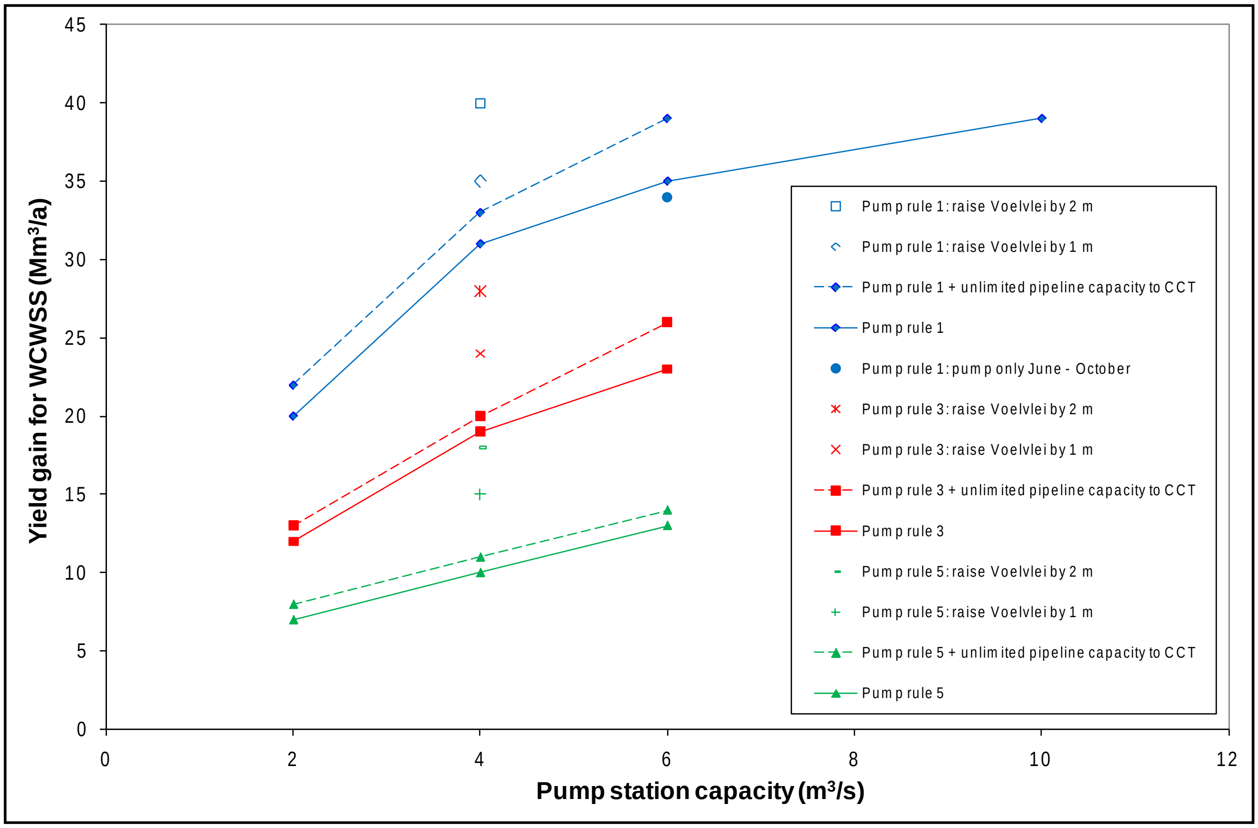

Figure 12 **Yield gain for the Western Cape Water Supply System (WCWSS) due to pumping from the Berg River into Voëlvlei Dam, raising of Voëlvlei Dam and augmentation of the pipeline capacity to Cape Town**

The results shown on **Figure 12** *indicate that:*

- *The yield of the system is particularly sensitive to the pumping rule adopted;*
- *Increasing the pump station capacity would have a positive impact on the yield from the system but a law of diminishing returns exists with the consequence that a pump station of the order of 10 m^3/s capacity would not result in a large increase in yield over that of one with a capacity of 6m^3/s. Conversely for example, there is a significant increase in yield when increasing the abstraction from 2 to 6 m^3/s. This is shown clearly by the convex shape of the curves;*
- *Increasing the pipeline capacity to Cape Town, even .to an unlimited capacity, would not have a very significant impact on the yield assuming Voëlvlei Dam is retained at its current FSL, if compared to other options of augmenting yield such as increasing pump station capacity. For example with Pump Rule 1, the increase in yield would be 2 million m^3/a with a pump station capacity of 4 m^3/s and with Pump Rule 5 the increase in yield would be 1 million m^3/a. With Pump Rule 1 and a pump station capacity of 6 m^3/s, the increase in yield would be 4 million m^3/a. These results show that the present day pipeline capacity does not act as a significant bottleneck under increasing abstractions from the river into the present day Voëlvlei Dam, but that the benefit of augmenting pipeline capacity increases with increasing water inputs into the dam, represented either by a more beneficial pumping rule (Pump Rule 1) or a larger pump station capacity;*
- *A low raising (up to 2m) of Voëlvlei Dam by means of a parapet wall avoids the need for major engineering works on the dam wall, although some works will also be required on the existing Klein Berg diversion canal. Despite the raising resulting in an increase in yield (for example for a 2 m raising with Pump Rule 1, the yield increases by 9 million m^3/a), this is not as significant as may be expected considering the increase in storage from a 2 m raising is 31 million m^3. The yield could perhaps improve with an increase in the pipeline capacity to Cape Town (requiring further investigation during the Feasibility Study);*
- *Changing the pumping rule from that of pumping from May to October to that of pumping from June to October would result in only a small decrease in yield and would allow for the EWR to be met. For example by removing May from the pumping regime, the yield from the augmentation scheme would decrease by only 1 million m^3/a (3%) for a 6 m^3/s pump station operated on Pump Rule 1.*

8. BRANDVLEI DAM – YIELD REINSTATEMENT PUMPING REQUIREMENTS

The Papenkuils Pump Station currently abstracts water from the Breede River and conveys it into the adjacent off-channel Brandvlei Dam. This abstraction had to be modelled in order to determine how much additional pumping capacity would need to be installed at Papenkuils to offset the impact of any proposed upstream diversions on the yield of Brandvlei Dam. Essentially, greater abstraction capacity would be necessary running over a shorter duration so as to abstract the same volume of water as is currently the case, and remaining compliant with the EWRs immediately downstream.

Stepped increases in pumping were investigated at 2.5m^3/s increments with a minimum base flow of 2.5 m^3/s allowed in the river. This is an approach adopted by Ninham Shand in a 2009 Study for the Central Breede Water Users Association which investigated the potential to increase the yield of the Brandvlei Dam through improved operating rules and increased pumping capacities at Papenkuils. Pump station capacities of 7 m^3/s (the existing capacity), and up to 20 m^3/s were investigated.

Flows were routed from the proposed upstream schemes to the existing Papenkuils diversion site using two different models. The Molenaars model was run on an hourly time-step and accommodated the Smalblaar and Holsloot diversions which would be impacted on by the possible Molenaars schemes. The Michell's Pass/Wit River model which runs on a daily time-step was used for the possible Michell's Pass and Upper Wit diversion options.

Water not diverted from the Molenaars scheme was routed to Papenkuils on an hourly time-step via the Smalblaar and Holsloot diversions. Water not diverted from the Upper Wit and Michell's Pass schemes was routed on a daily time-step, due to their longer distance from Papenkuils and hence greater level of attenuation of floods. The routings took into account incremental inflows from all parts of the catchment upstream of Papenkuils as well as the existing Holsloot and Smalblaar diversions so as to assess the reinstatement pumping required at Papenkuils to retain the existing yield of the dam.

The WRYM was then run with the various diversion functions and the yield for Brandvlei Dam was determined for a) the present day pump station capacity of 7 m^3/s*, and b) a pump station capacity of 20* m^3/s*. The graphs produced from this analysis are given in Figure 13, Figure 14 and Figure 15. They were used to determine the required increase in pumping capacity to maintain a desired yield of Brandvlei Dam for the various possible upstream schemes.*

It is relevant to note that the potential impact of scheme development in the Molenaars affects the existing Holsloot, Smalblaar and Papenkuils abstractions. As such the extent of reinstatement pumping required at Papenkuils is (as would be expected) significantly more than that for the Michell's Pass or Upper Wit options, neither of which impact on the Smalblaar and Holsloot diversions.

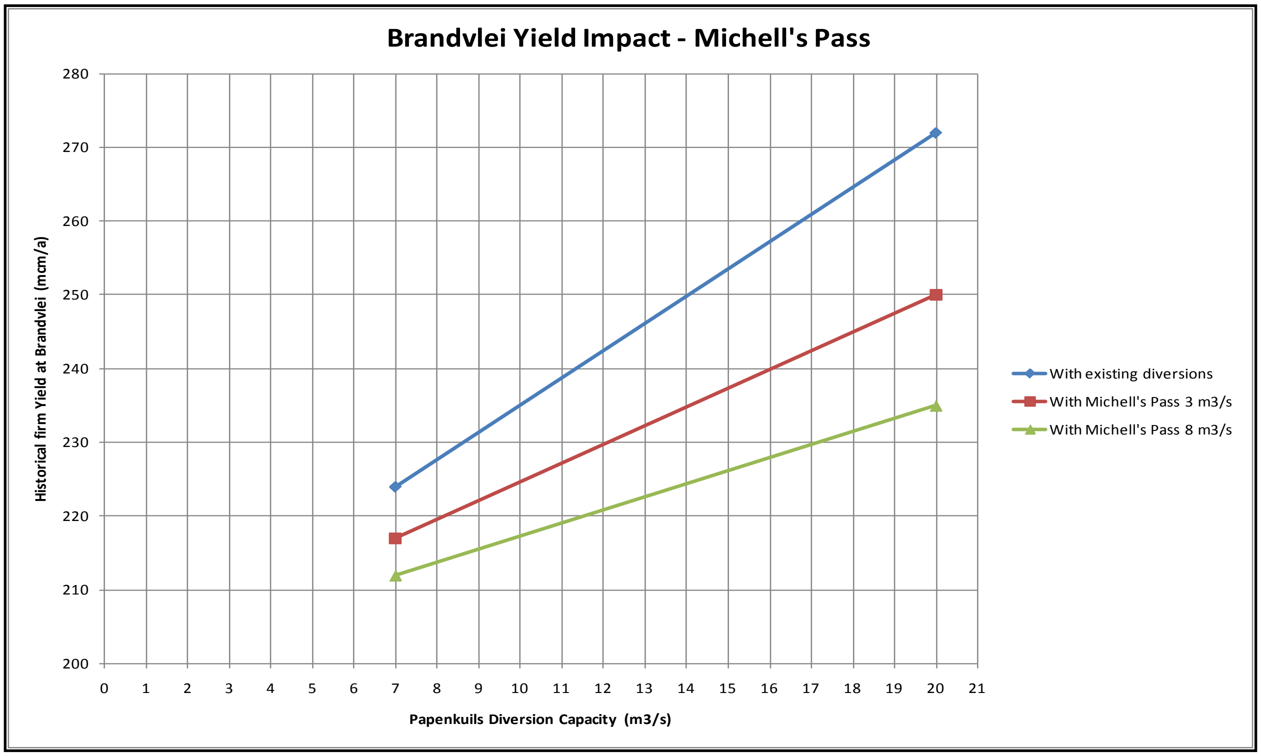

Figure 13 **Curves showing pumping capacity at Papenkuils Pump Station and the yield at Brandvlei Dam for the proposed Michell's Pass scheme upstream**

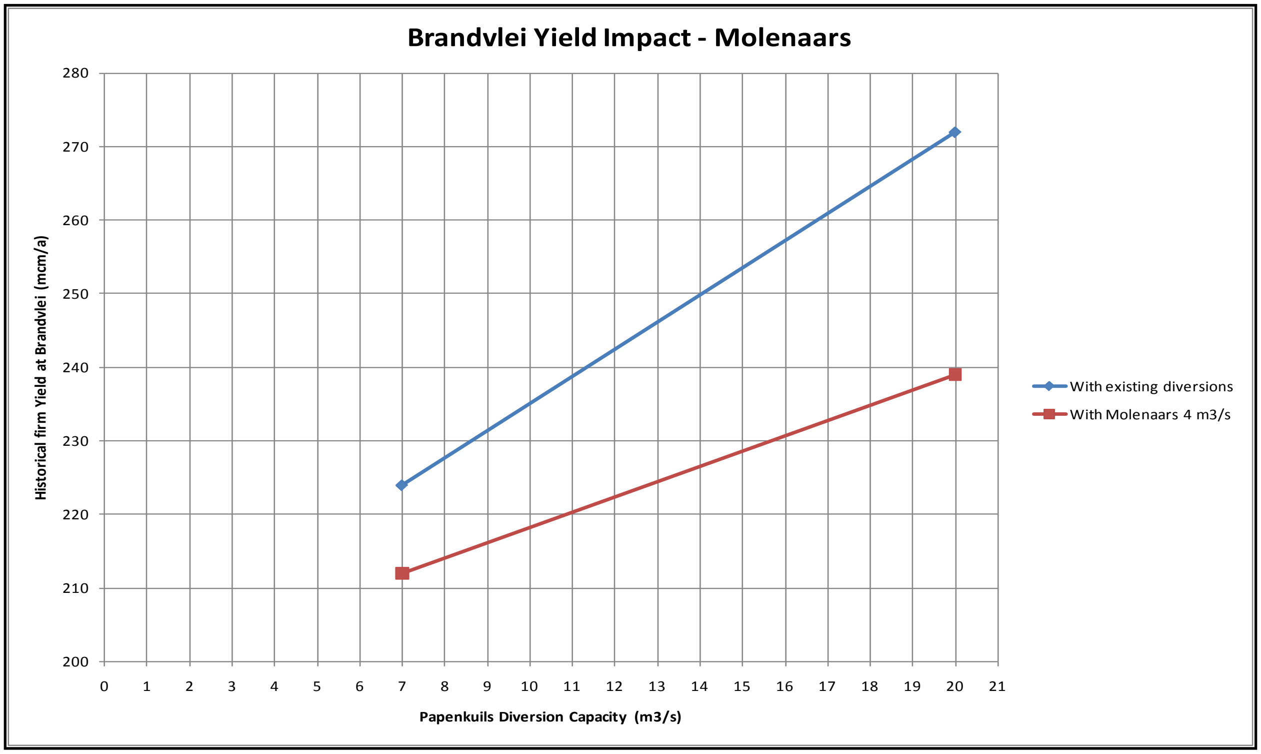

Figure 14 **Curves showing pumping capacity at Papenkuils Pump Station and the yield at Brandvlei Dam for the proposed Molenaars River scheme upstream**

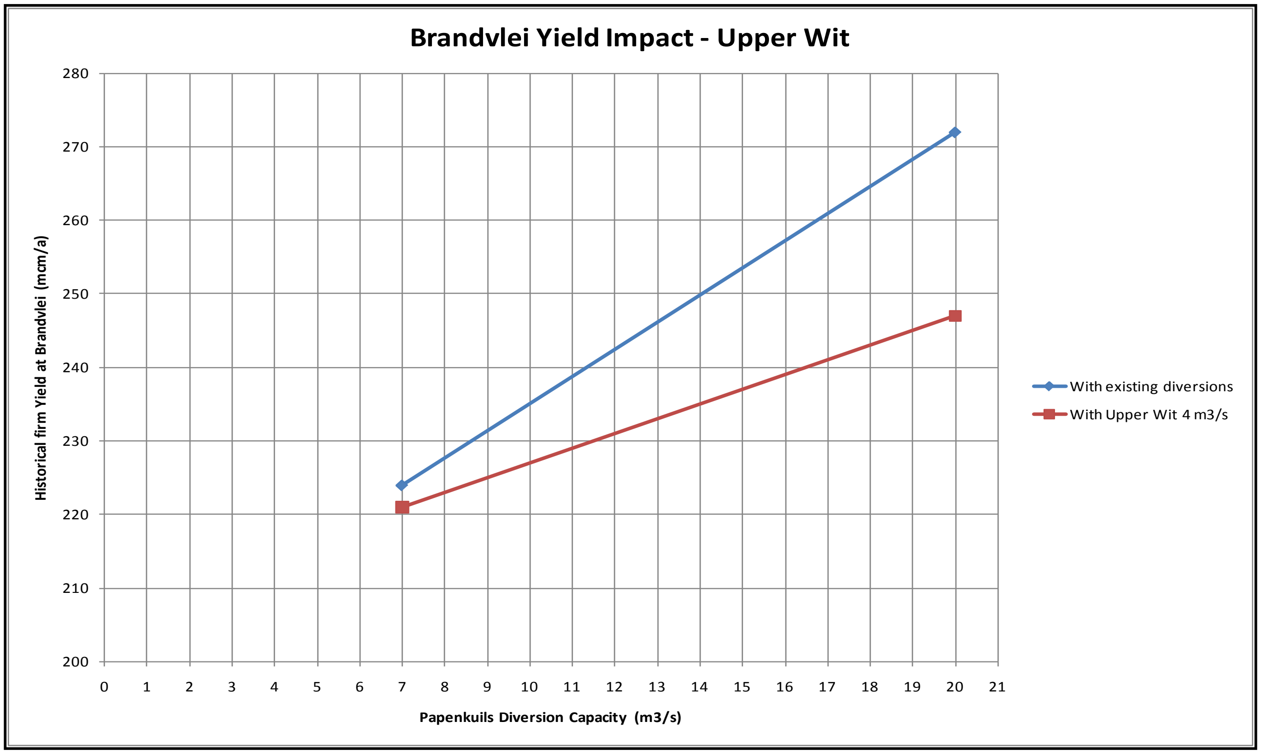

Figure 15 **Curves showing pumping capacity at Papenkuils Pump Station and the yield at Brandvlei Dam for the proposed Upper Wit River scheme upstream**

9. CONCLUSIONS AND RECOMMENDATIONS

This report describes the initial work done to screen the options that include run-of-river diversions. Methods that make use of daily or hourly flow time series, generally based on observed flow time series from DWA gauges located close to the proposed scheme sites were used to derive diversion functions for the WRYM and to determine initial estimates of the yields of the schemes.

Whilst the initial intention of this Study was to undertake a basic Preliminary Assessment only during Phase 1, based on available information, deviation from that approach has been essential. It has been necessary to proceed to pre-feasibility level study (at least) for all options, in order to be able to equitably compare the various diversion options with one another. A further factor influencing this need has been that some of these options have previously been investigated to varying degrees of detail. The Voëlvlei Augmentation for example was investigated to Feasibility level by the CCT in 2000, but without the current understanding of the EWR. On the other hand, the Upper Wit diversion has never been previously investigated in its proposed form as a run-of-river diversion.

Consequently, the most basic level of assessment at which these schemes could be reasonably compared with one another is at a pre-feasibility level. This has required a significant amount of Yield modelling to be done as part of Phase 1, something that had initially been intended as part of the "pre-feasibility" tasks in Phase 2. As a result, this pre-feasibility analysis undertaken in Phase 1 is more than detailed enough to a) base decisions on which options be studied further at feasibility level, and b) to meet the study requirements for pre-feasibility level assessment of all options. It should be noted that the *same level of detailed assessment has therefore also been adopted for the pure “dam-based” schemes, notably the Raising of Lower Steenbras Dam and the Campanula Dam option.*

10. REFERENCES

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