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DEPARTMENT OF WATER AFFAIRS
DIRECTORATE : OPTIONS ANALYSIS

PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

Report No 2

PRELIMINARY ASSESSMENT OF OPTIONS

Final

May 2010

Department of Water Affairs
Directorate : Options Analysis

PRE-FEASIBILITY AND FEASIBILITY STUDIES FOR AUGMENTATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM BY MEANS OF FURTHER SURFACE WATER DEVELOPMENTS

APPROVAL

Title	:	Preliminary Assessment of Options
Consultants	:	Western Cape Water Consultants Joint Venture
Report status	:	Final
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STUDY TEAM: Approved for the Joint Venture:

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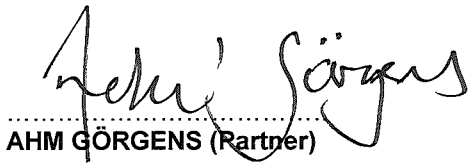

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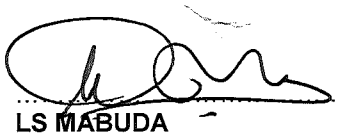

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				Appendix 5: Scheme Operation and Yield Analyses with Ecological Flow Requirements for the Breede-Berg (Michell's Pass) Water Transfer Scheme
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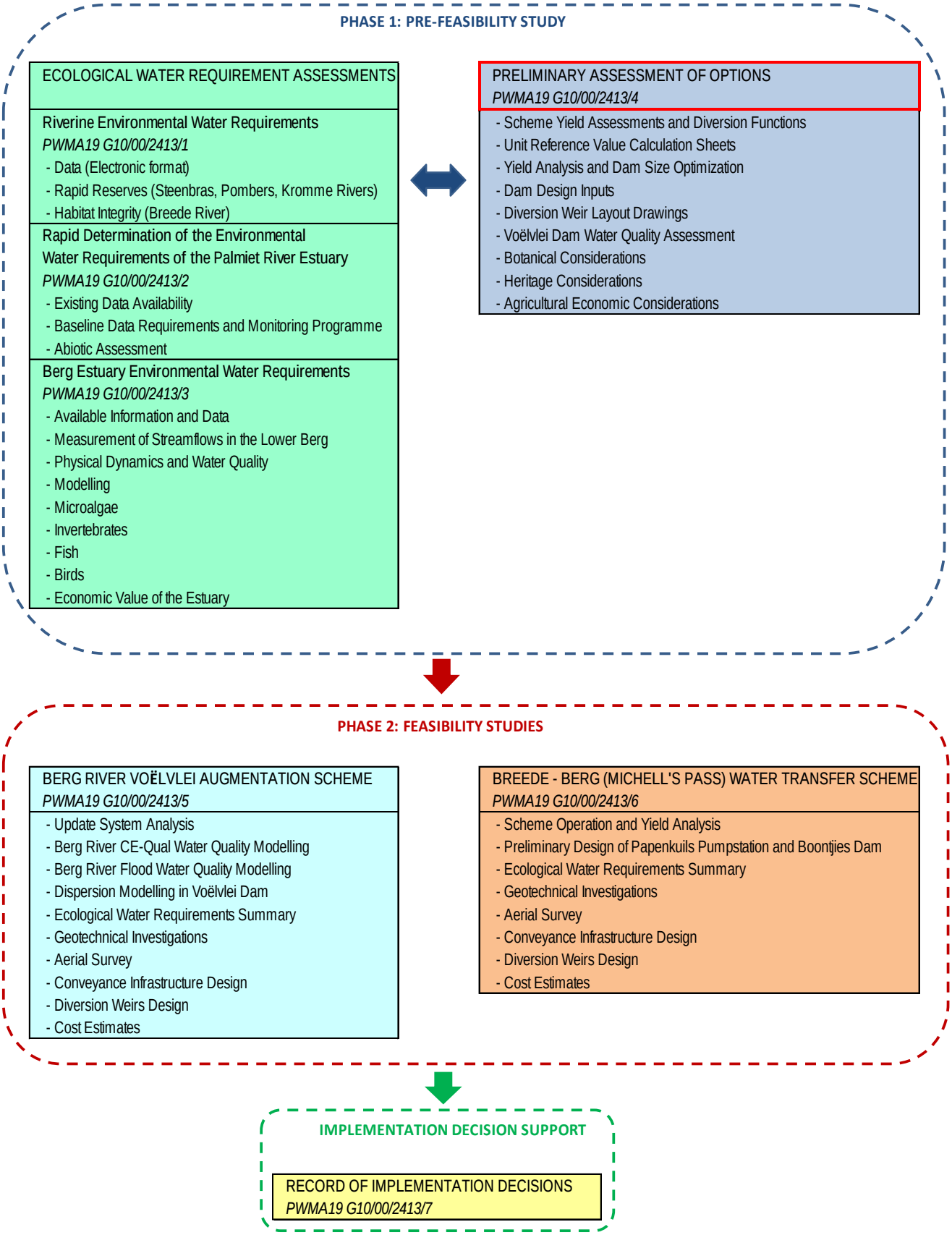
4	**RECORD OF IMPLEMENTATION DECISIONS**		PWMA19 G10/00/2413/7	

STUDY REPORT MATRIX DIAGRAM



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ABBREVIATIONS

AEMC	Attainable Ecological Management Class
BRBS	Breede River Basin Study
CCR	Clay Core Rockfill
CCT	City of Cape Town
c/kwh	cents per kilowatt.hour
CSIR	Council for Scientific and Industrial Research
DEMC	Default Ecological Management Classes
DWA	Department of Water Affairs
EIA	Environmental Impact Assessment
EISC	Ecological Importance and Sensitivity Categories
EWR	Ecological Water Requirements
GRP	Glass-fibre Reinforced Plastic
HFY	Historical Firm Yield
HIA	Heritage Impact Assessment
m^3/s	Cubic Metres per Second
m^3/a	Cubic Metres per Annum
NHRA	National Heritage Resources Act, 1999 (Act No. 25 of 1999)
NPV	Net Present Value
PES	Present Ecological Status
PESC	Present Ecological Status Categories
RCC	Roller Compacted Concrete
SANRAL	South African National Roads Agency Limited
URV	Unit Reference Value
WAAS	Water Availability Assessment Study
WCWSS	Western Cape Water Supply System
WMA	Water Management Area
WRCS	Water Resources Classification System
WRYM	Water Resources Yield Model
WTW	Water Treatment Works

1. INTRODUCTION

1.1 GENERAL BACKGROUND

The Western Cape Water Supply System (WCWSS) serves the City of Cape Town (CCT), surrounding urban centres and irrigators. It consists of infrastructure components owned and operated by both the CCT and the Department of Water Affairs (DWA).

The Western Cape Reconciliation Strategy Study has reviewed the future water requirement scenarios and the reconciliation options for meeting these water requirements within a planning horizon to 2030. That Study has identified potential suites of reconciliation options for meeting water requirement scenarios from the WCWSS. It has identified various alternative implementation options which can offer flexibility in planning, such that possible changes in the projected water requirement scenarios can be accommodated. One set of those implementation options is the potential to further develop the surface water resources of the Berg and Breede Water Management Areas (WMAs).

In July 2008, the Department of Water Affairs appointed the Western Cape Water Consultants Joint Venture to undertake Pre-feasibility and Feasibility level investigations into the potential development of six surface water options, namely:

a) Michell's Pass Diversion Scheme
b) First Phase Augmentation of Voëlvlei Dam
c) Further Phases of Voëlvlei Dam Augmentation
d) Molenaars River Diversion
e) Upper Wit River Diversion
f) Further Phases of the Palmiet Transfer Scheme

Figure 1.1 shows the extent of the WCWSS and the locations of the six augmentation options being investigated, as well as the existing main bulk water infrastructure. **Figure 1.2** provides a more detailed presentation of the existing infrastructure and includes canals, bulk pipelines, dams, tunnels, weirs and water treatment works.

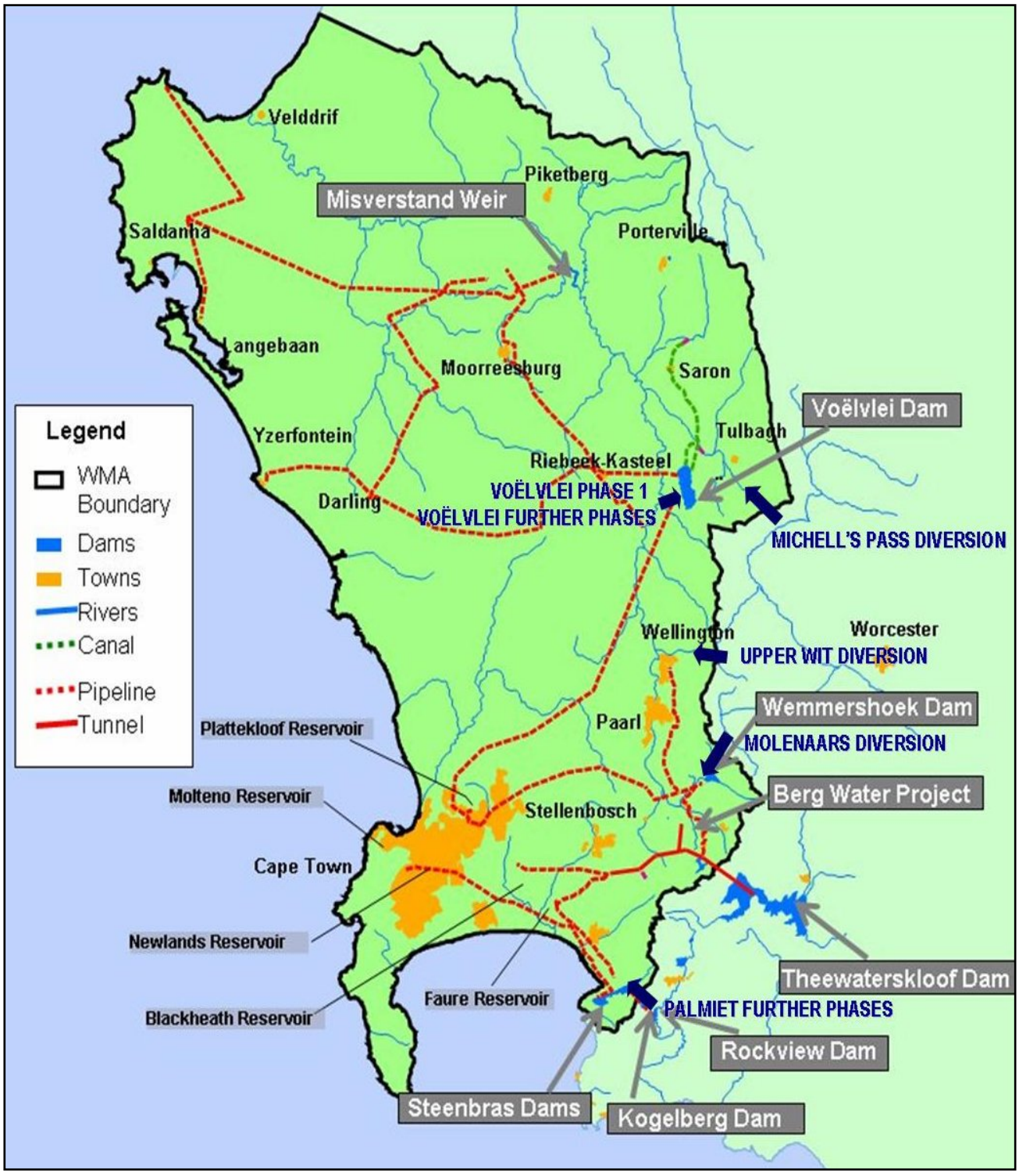

Figure 1.1 The WCWSS and the Location of the Options Being Investigated

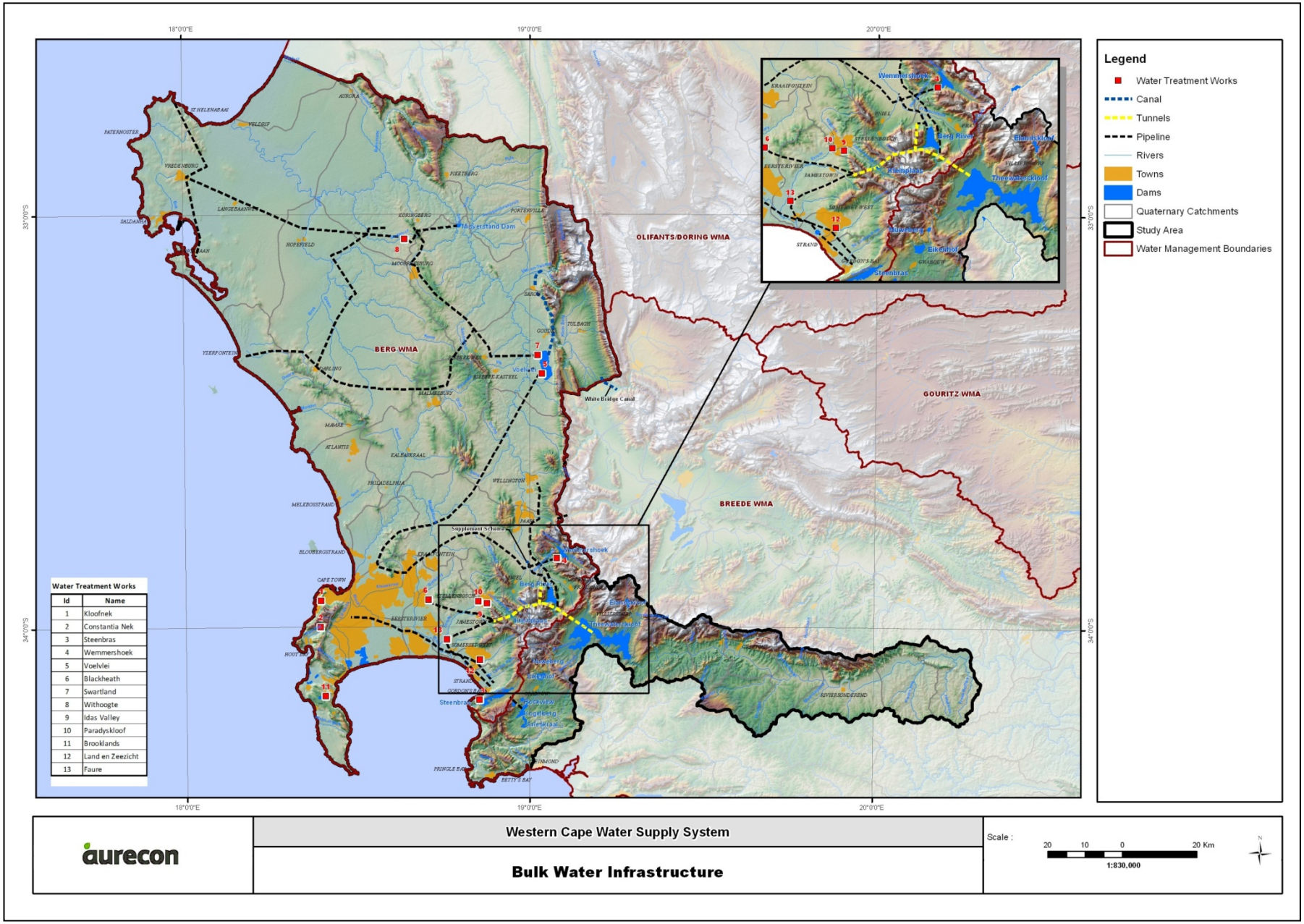

Figure 1.2 Layout of the WCWSS including Existing Infrastructure

2. SUMMARY OF THE KEY OUTCOMES OF THE ECOLOGICAL WATER REQUIREMENT ASSESSMENTS

2.1 INTRODUCTION

Southern Waters Ecological Research and Consulting cc was appointed as party to the Joint Venture to analyse, generate and arrange basin-wide Ecological Water Requirement data for the Breede, Berg and Palmiet catchments in line with the procedures required for the Water Resources Classification System (WRCS) (Dollar et al. 2006). This 'Reserve' task included, Reserve determinations for the Palmiet and Berg Estuaries, Rapid Reserve determinations for the Steenbras, Pombers and Krom Rivers in the Berg system, a basin wide assessment of Habitat Integrity (HI, Kleynhans 1996) for the Breede River system, and a resource economics assessment of the implications of flow change in the Berg River Estuary, which forms part of a Comprehensive Reserve determination for the Berg River Estuary. EWR data for the Breede River estuary is available in the report by DWAF (2003). Southern Waters sub-consulted Anchor Environmental Consultants, on behalf of the WCWC JV, to undertake a comprehensive EWR determination for the Berg River Estuary, including the economic assessment, and CSIR to undertake a rapid EWR determination for the Palmiet River Estuary.

2.2 RIVERS

River nodes were identified as per the procedures for the WRCS and EWR data were extrapolated from representative sites (nodes) to others where data is insufficient. There were 63 river nodes delineated in the Breede River catchment, 10 in the Palmiet and 23 in the Berg River catchments. The desktop reserve model of Hughes and Münster (2000) was used to generate EWR estimates for all nodes in the three river systems. The results were calibrated using the results from past EWR assessments (Breede Catchment: Ewart-Smith and Brown 2002; Louw and Brown 2001; Palmiet Catchment: Brown *et al.* 2000; Berg Catchment: DWAF 1996; Harding and Brown 2002) and some data generated in this study (EWR Report 1, Volume 1, Appendices 3 and 4). The assurance rules together with the time series of natural flows per node were used to construct representative time series' of EWR requirements (EWR Report 1, Volume 1, Appendix 2). Outdated Present Ecological Status (PES) assessments (Kleynhans; 2000) were updated for the Breede River (EWR Report 1, Volume 1, Appendix 4).

The EWR data provided are quantity estimates for each river node and represent the reach upstream of each node. EWRs were provided for a range of ecological conditions at each site to enable scenario assessment and tradeoffs between EWRs and the off-stream use of water from the rivers. An important aspect requiring further attention is the consideration of data at a basin level to ensure that the cumulative contributions of upstream nodes are sufficient to meet the EWRs at downstream nodes and the estuary of each river system (see Section 2.3).

2.3 ESTUARIES

The procedures used for the EWR determination for the Berg and Palmiet estuaries were those that are detailed in Resource directed measures for protection of water resources: Methodology for the Determination of the Ecological Water Requirements for Estuaries, Version 2 (DWAF 2008).

No new data were collected as part of either study. Deliberations for the Berg River were based on information collated and collected during the intensive monitoring programme conducted on the Great Berg system in 2002-2005 (DWAF 2007). Deliberations for the Palmiet River were based on information collated and collected during previous Reserve assessments (CSIR 2000) and subsequent on-going monitoring.

The total economic value of the Berg estuary was estimated to be R75.6 million (EWR Report 3, Volume 1, Appendix I), with by far the largest component of this value being derived from turnover in the property sector (R48.6 million), followed closely by visitor expenditure (R18.3 million) and nursery value (R8.1 million). Subsistence and existence value make relatively small contributions to total economic value. This places the Berg estuary firmly on the upper end of the value spectrum for temperate estuaries in South Africa.

For the Berg Estuary, ten scenarios of future water use in the upstream catchment were considered. Of these, Scenario 7, which is equivalent to the present day flow into the system (396 million m^3/a), but with guaranteed 0.6 m^3/s inflow into the estuary during the dry season, was selected as the recommended EWR for the Berg River Estuary.

For the Palmiet Estuary, six scenarios of future water use in the upstream catchment were considered. Of these, Scenario 6 was recommended for maintenance of the present condition of the estuary. This scenario comprised, *inter alia*, 161.3 million m^3/a for the estuary, with dry season flows of <1.0 m^3/s occurring no more than 22 % of the time, i.e., no longer than 3 months in a year.

2.4 RECOMMENDATIONS

The EWR have been collated, collected or determined to provide for a basin-wide assessment of potential implications of proposed water-resource developments on the Ecological Reserve. However, to date, with exception of the provisions made for the Berg River estuary dry season flows in the Voëlvlei augmentation options, such assessments have been limited to consideration of the Ecological Reserve immediately downstream of each development. It is likely that the cumulative effects of existing and proposed water-resource developments will have impacts on other river reaches, wetlands and the sustainability of the estuaries. It is therefore strongly recommended that any further investigations consider the cumulative impacts of all water-resource development options at a catchment scale.

Furthermore, it is important that these assessments are based on up-to-date information regarding water use in the catchments.

3. GENERAL TECHNICAL APPROACHES

3.1 HYDROLOGY

The hydrologies of the Berg River catchment and Breede River catchment upstream of Brandvlei Dam were updated as part of the recently completed Berg Water Availability Assessment Study (Berg WAAS). This update included extending the rainfall and evaporation data that serve as input to the rainfall-runoff models (Pitman Model). The updated hydrology also took cognisance of the latest available observed stream flows, updated water requirement estimates, urban water demands in the study area and updating the models to include any new impoundments, diversions, transfers and the like. The Pitman Model was recalibrated against the latest observed stream flows at the selected DWA gauging stations within the Study area. The resulting updated catchment hydrology was then used to update the Water Resources Yield Model (WRYM) configured for the Western Cape Water Supply System (WCWSS) so as to enable evaluation of water resource development options and scenario assessments.

The Berg WAAS suite of reports should be referred to for detail.

3.2 DEVELOPMENT OF DIVERSION FUNCTIONS

Several of the proposed schemes include run-of-river diversions into existing or proposed storage dams, either located off-channel, or on rivers in adjacent catchments within the Berg WMA. The locations of the storage dams are often some distance away from the diversion sites themselves and in some cases involve inter-basin transfers.

For the options investigated in this Study, the following involve the use of run-of-river diversions:

- The Michell's Pass gravity diversion into the existing Voëlvlei Dam, via the Klein Berg River and existing Klein Berg diversion structures.
- The Upper Wit River gravity diversion to a proposed dam on the Krom River at Riverlands.
- The Molenaars River pumping diversion via a pipeline to Berg River Dam.
- A pumped diversion from the Berg River into Voëlvlei Dam or into an off-channel settling facility.

Run-of-river diversion schemes tend to involve minimal storage upstream of the diversion weir. In the case of the diversion schemes investigated for this study, weir heights were kept to a minimum to limit their environmental impact, both in terms of upstream inundated areas and in terms of barriers to migration of aquatic biota. However, the use of low weir structures has the effect of providing negligible storage in the impoundment, and thus pumping or diversion of flows can only occur when river flows are high enough to allow diversions to occur. No pumping or diversion of stored water can therefore take place and this in turn enables the schemes to be operated in such a way that the EWRs in the river reach downstream of the diversion site can be maintained. This approach will ultimately be adopted within the operating rules that will be developed during the Feasibility Studies that will be undertaken, based on the recommendations of this Preliminary Assessment of Options Report.

The WRYM runs on a monthly time-step but river flows naturally tend to vary significantly over much shorter time scales, of the order of hours. It is therefore very important to correctly capture and incorporate this variability in the flow patterns so as to enable an accurate evaluation of how much water would be available for diversion. To do this, the WRYM makes use of a relationship called a diversion

function. These diversion functions estimate the monthly diverted volume at the diversion site, 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. This data is fed through a diversion analysis and the resulting diverted flows (and original inflows) are then aggregated to a monthly time-step and plotted against each other. A curve is then fitted that best estimates the diverted monthly volume based on the inflow monthly volume. Error! Reference source not found. contains the detailed development approaches and results of the various diversion functions developed for use in this Study.

For all diversion schemes in this study, water is only diverted when there is surplus available in winter, and after the winter EWRs downstream of the diversion sites have been met. An important factor that has not been addressed, but which is recognised as requiring assessment during the subsequent phase of this study, is the basin-wide impact of the diversions on the EWRs.

3.2.1 Inclusion of the EWRs into the Models

As mentioned previously, the EWRs have been comprehensively updated as part of the Preliminary Assessment Phase of this study. The latest EWRs were taken into account in the derivation of the diversion functions for each scheme assessed. The modelling approach used was to give the EWRs first priority to the water, before any diversion of water could take place. This approach was adopted at the Michell's Pass, the Upper Wit and the Molenaars River diversions. However in the assessment of the recovery pumping required to reinstate the existing yield of the Greater Brandvlei Dam, and for the diversions out of the Berg River (Voëlvlei development options), a stepped pumping rule was implemented in line with recognized approaches adopted in previous studies at these two sites.

For the pumped abstractions from the Berg River, the WRYM flows in the river downstream of the proposed pump station locations converted into flow duration curves for each month of the year, and superimposed onto the equivalent EWR flow duration curves, to assess compliance. Some changes were necessary to achieve compliance, in particular in relation to the number of months in which pumping can take place. It was necessary to reduce this from a May-October period to a June-October period, as it was found that river flows in May dropped below those specified in the EWR, if any pumping takes place.

The flows in the Breede River downstream of the Papenkuils pump station have not yet been checked against the EWR requirement but this will be undertaken in the next phase of the study. The existing pump station capacity of 7,5 m^3/s was checked against the EWR requirement in the Breede River Basin Study (BRBS) and was found to conform to the EWR requirement previously determined.

The EWR was not taken into account in the diversions out of the Klein Berg River, as no Reserve is currently implemented at that site. All flows that are therefore diverted by the proposed Michell's Pass scheme would be intended to for augmentation of Voëlvlei Dam.

3.3 SYSTEM MODELLING

The updated hydrology was used in the Water Resources Yield Model (WRYM) set up for the Western Cape Water Supply System to determine yields for the various proposed schemes. The WRYM set up from the previous Breede River Basin Study was used to determine the augmented pumping capacity required at Papenkuils Pump Station in order to ensure that the yield of Brandvlei Dam would remain unchanged after diversions from rivers in its catchment area.

3.4 BRANDVLEI PUMPING REQUIREMENTS

The existing Papenkuils pumpstation has a capacity of 7,5 m^3/s and abstracts water from the Breede River into the adjacent off-channel Greater Brandvlei Dam. This in addition to the Holsloot and Smallblar diversions forms the primary source of inflow to the dam. Any significant abstraction out of the Breede River upstream of these locations will have an impact on the yield of Greater Brandvlei Dam. The current abstractions at Papenkuils are operated so as to meet a minimum required EWR at the site, before pumping can commence. As a result a reduction in flow in the Breede River from an upstream abstraction effectively shortens the available duration in which the EWR can be met, and consequently the period during which pumping can take place also shortens. This impact on the abstraction at Papenkuils requires mitigation in order to reinstate the current yield of the dam. This can be achieved through the implementation of additional pumping capacity, effectively abstracting the same volume of water in each pumping season, but over a shorter duration, and within the limits of the EWR. This additional pumping requirement has been assessed for each of the schemes involving Breede River diversions. The general approach to undertaking this assessment is as described hereafter.

The historical firm yield (HFY) at Brandvlei Dam was determined using the WRYM for various scheme options upstream of the dam. This was based on the same system model configuration used in the Breede River Basin Study. In order to determine the impact on the yield of Brandvlei Dam, each of the proposed scheme scenarios was then individually compared to the existing system yield, with the current diversions and present day upstream conditions. Two diversion capacities at the Papenkuils pump station were assessed, namely a lower limit pumping capacity of 7 m^3/s and an upper limit pumping capacity of 20 m^3/s. The yield of the system for both of these pumping capacities at Papenkuils was then determined for each of the potential schemes, namely:

- Michell's Pass Diversion;
- Wit River (Gawie-se-Water) Diversion;
- Molenaars River Diversion.

At Michell's Pass, the diversion function was developed for capacities of 3 m^3/s, 5 m^3/s and 8 m^3/s, taking into account a Class D EWR in the river immediately downstream. The yield at Brandvlei was then determined for each of the pumping capacities at Papenkuils, and for each of the Michell's Pass diversion capacities. The Wit River and Molenaars schemes were "switched off" in the model.

At the Wit River diversion site, downstream of the existing Gawie-se-Water diversion, a diversion function was developed for a 4 m^3/s capacity, after allowing for the winter EWR in the Wit River to first be met. This diversion was based on the observed flows at gauging station H1H007 (downstream of the diversion site) with the Gawie-se-Water export added back. The yield at Brandvlei was then determined for each of the two pumping capacities at Papenkuils, with the Michell's Pass and Molenaars River diversions "switched off".

Similarly the Molenaars diversion function was developed for a diversion capacity of 4 m^3/s. The yield at Brandvlei was then determined for each of the two pumping capacities at Papenkuils, with the Michell's Pass and Wit River diversions "switched off". **Figure 3.1** shows a typical result. The specific impacts pertaining to each of the three potential schemes are described in the detailed scheme presentations from Section 4 onwards.

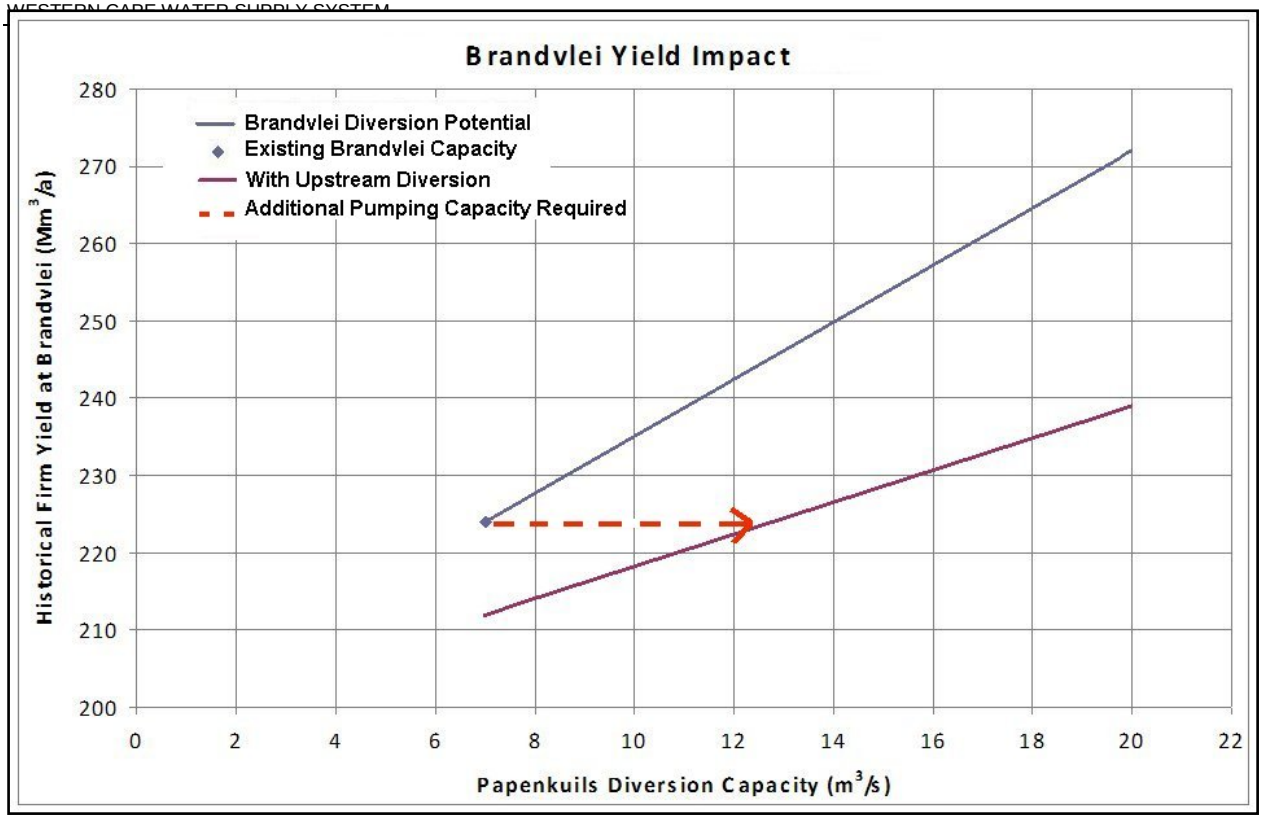

Figure 3.1 Typical reinstatement pumping at Papenkuils pumpstation

The above curve shows a hypothetical example for a particular diversion in the Breede River, upstream of the Papenkuils site. The red arrow indicates that for a current diversion capacity of 7 m^3/s at Papenkuils, an additional 5,5 m^3/s capacity would be required if the existing yield of Brandvlei Dam were to remain unaffected..

3.5 ECONOMIC MODEL

The objective of the costing exercise was to bring previous cost estimates for the options all to the same level of confidence, so as to enable valid cost comparisons to be made. Except for the cost of electricity, all cost estimates were based on the escalation of previous estimates. The technical data for the various options was fed into a spreadsheet-based economic evaluation model, which was developed in-house by the consultants. The economic evaluation for each option was carried out on the following basis:

- Costing base date – 2012 (previous cost estimates all escalated up to 2012) .
- Life time evaluation period – 30 years from date of first expenditure (assumed 2012).
- Discount rate – 6% per annum.
- Costs and benefits discounted to date of first expenditure (2012).
- The yield estimates determined in accordance with the latest Berg Water Availability Assessment Study (Berg WAAS).

The model calculates the following output indices for each scheme:

- NPV - Net Worth of Costs
- URV - Unit Reference Value

The Unit Reference Values are calculated as follows:

$$URV = \frac{Present\ Worth\ of\ costs}{\text{“}Present\ Volume\text{”}\ of\ water\ delivered}$$

- Electricity is costed at a constant value of 75c/kwh

The financial assessment for all options is inclusive of the following:

- Preliminary and General.
- Construction Costs.
- Professional Fees (incl site supervision).
- Environmental Impact Assessment.
- Survey.
- Expropriation / compensation.
- Where relevant, increased pumping at Papenkuils to reinstate the yield of Brandvlei Dam
- Contingencies.
- Operation and Maintenance (including power supply).
- VAT.

3.6 ENVIRONMENTAL, SOCIAL AND HERITAGE ASSESSMENT

A field visit was undertaken with all key members of the team during March 2009 to ensure a comprehensive and robust understanding of the schemes, their environmental, social and heritage context and to understand the various technical proposals and variations that had to be considered.

In April 2009, environmental specialists were required to review and report on environmental information contained in all previous studies undertaken for the six potential development options. This was augmented with information gathered during the site visit. Preliminary information gaps and data requirements were identified for each scheme and discipline.

It was recognised that considerable information was available for certain schemes and that the information could be outdated as the environmental context could have changed over time. The environmental baseline information was therefore updated for all scheme options.

A Prioritization Workshop was held in March 2010 to discuss each scheme in detail, as well as identify possible responses to the environmental, social and heritage opportunities and constraints. During the workshop, each scheme was prioritised based on various technical and environmental criteria agreed on by the technical team.

After the Prioritisation Workshop, specialists were required to update their reports based on the new, revised information presented at the workshop. Specialists were also required to refine information gaps, data requirements and the scope of necessary specialist studies identified.

4. THE MICHELL'S PASS DIVERSION

4.1 SCHEME DESCRIPTION

This inter-basin transfer scheme involves a low level intake structure on the left bank of the Upper Breede River at Michell's Pass, adjacent to the existing DWA streamflow gauge at which the current irrigation diversion (Artois canal) takes place (see **Figure 4.1**).

Figure 4.1 The existing Artois canal irrigation diversion at Michell's Pass

Surplus winter water would be diverted via a low weir (up to 2,5 m high) into a Glass Reinforced Pipe (GRP) pipeline of up to 2,0 m dia. The weir dimensions and pipeline diameter would depend on the diversion capacity of the scheme. The pressure pipeline would transfer the water under gravity over approximately 7,3 km to discharge into the Boontjies River (see **Figure 4.3**), a tributary of the Klein Berg River, from where the water would be diverted into the existing Voëlvlei Dam via the existing Klein Berg Diversion. The use of a low intake weir limits the upstream inundation impact and avoids impacting on the Witels tributary, the confluence of which lies approximately 2,3 km upstream of the proposed weir location.

Provisional designs of the weir structure to enable downstream releases to be made and to ensure that sedimentation and boulder accumulation can be managed, have been undertaken. A typical layout of the diversion weir for an 8 m^3/s diversion is shown in **Figure 4.4**. Weir designs adapted for 3 and 5 m^3/s diversions rates are included in Error! Reference source not found.. The anticipated time frame for implementation of an 8 m^3/s diversion scheme at Michell's Pass is indicated in **Figure 4.2.**

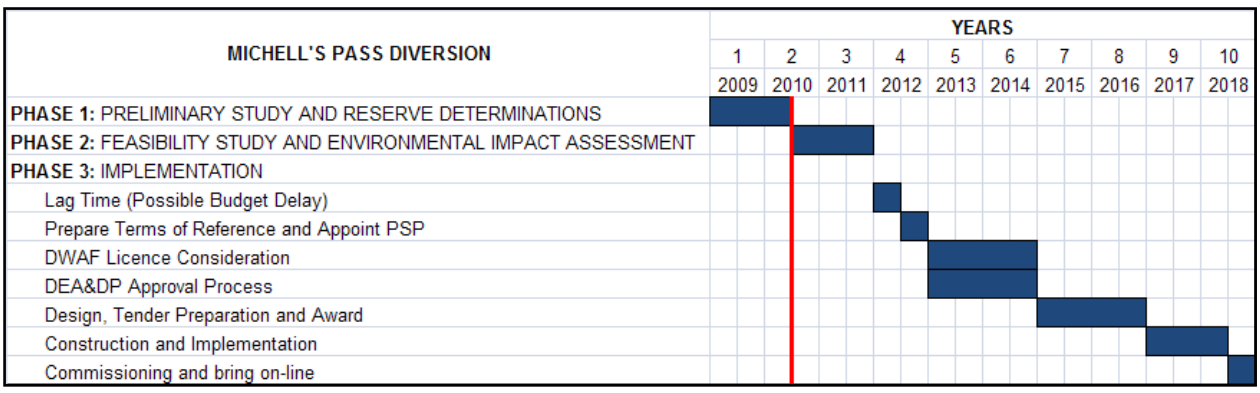

Figure 4.2 Michell Pass Diversion Time Frame

Figure 4.3 The proposed general layout of the Michell's Pass diversion scheme

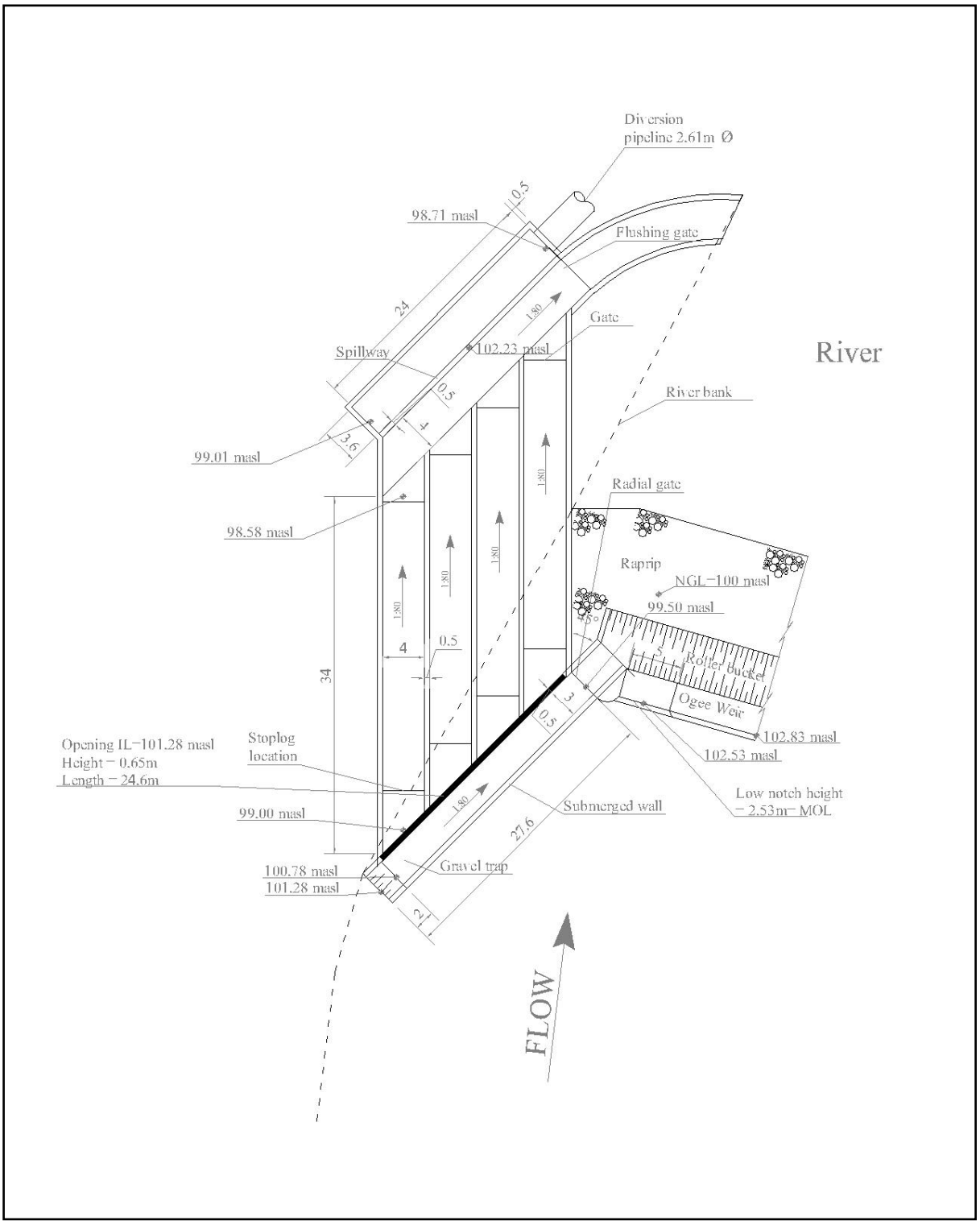

Figure 4.4 Typical layout of an 8 m^3/s diversion weir at Michell's Pass

4.2 YIELD

The results for the potential Michell's Pass diversion are shown for various diversion capacities on **Figure 4.5**.

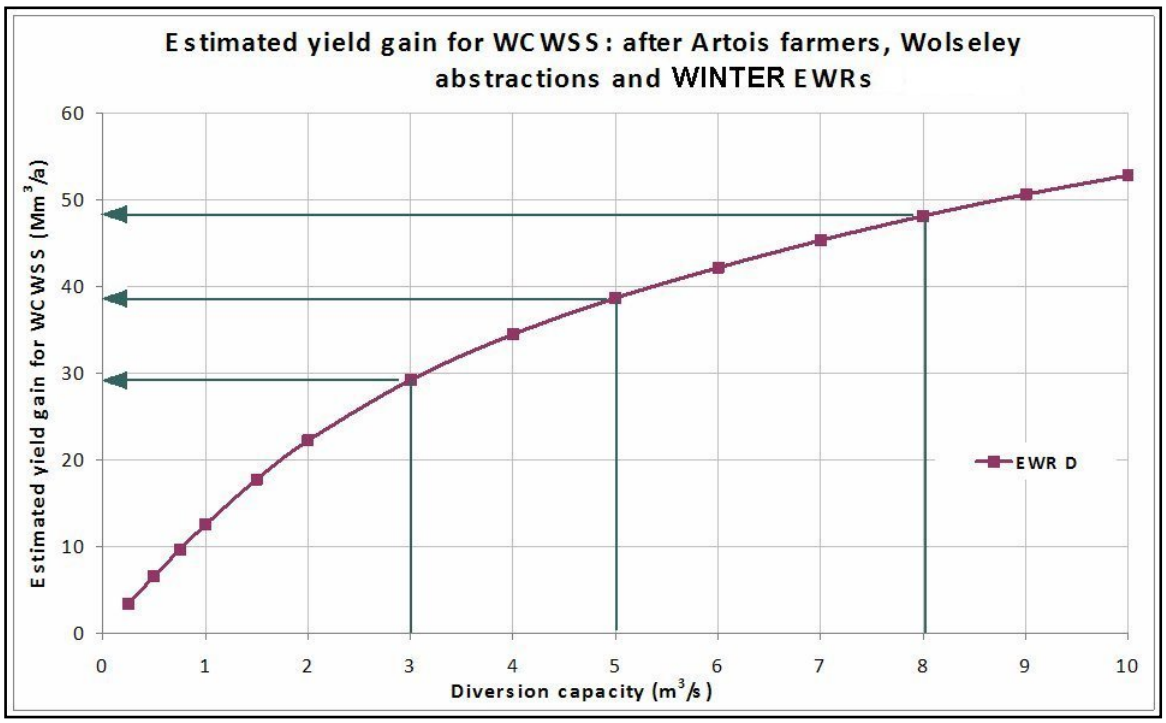

Figure 4.5 Yield estimates for various diversion capacities at Michell's Pass

The figure above shows that after allowing for the needs of downstream users and for meeting the winter EWR requirements, the optimum range of yields appears to be for diversions of between 3 m^3/s and 8 m^3/s. Preliminary designs and cost estimate for the following diversion capacities were undertaken:

- 3 m^3/s diversion yields 29 million m^3/a
- 5 m^3/s diversion yields 39 million m^3/a
- 8 m^3/s diversion yields 48 million m^3/a

During the preliminary assessment, the impact of the potential options on the EWR has only been assessed immediately downstream of the proposed abstraction sites. It has however been recognized and recommended that there is a need during the Feasibility Study to take this assessment to a wider level, and to assess the basin-wide impact of these options on the EWR, i.e. to the Breede River estuary.

4.2.1 Impact on Greater Brandvlei Dam

As explained in Section 3.4 the impact of the proposed abstractions on the current and potential yield of Greater Brandlvlei Dam is an important aspect to address. The current abstractions from the Breede River (at the Papenkuils Pumpstation) into Brandvlei Dam, can be operated at 7,5 m^3/s, in accordance with the downstream EWRs.

In abstracting water upstream (in this case at Michell's Pass), there will be an adverse impact on the volumes of water that can be pumped into Brandvlei Dam, under the current operating rules. To ensure that the current yield of that dam is not adversely impacted, a greater pumping rate would be required to abstract the equivalent volume of water into the dam, under the current operating rule. This additional pumping capacity and its operational requirements have been determined (see **Figure 4.6**), are summarized in **Table 4.1**, and the costs included in the financial assessment of the Michell's Pass Scheme.

Table 4.1 Pumping reinstatement requirements at Brandvlei Dam

Abstraction at Michell's Pass	Additional pumping capacity required at Brandvlei
3 m^3/s	2,5 m^3/s (increase from 7,5 m^3/s to 10,5 m^3/s)
8 m^3/s	7,5 m^3/s (increase from 7,5 m^3/s to 15,0 m^3/s)

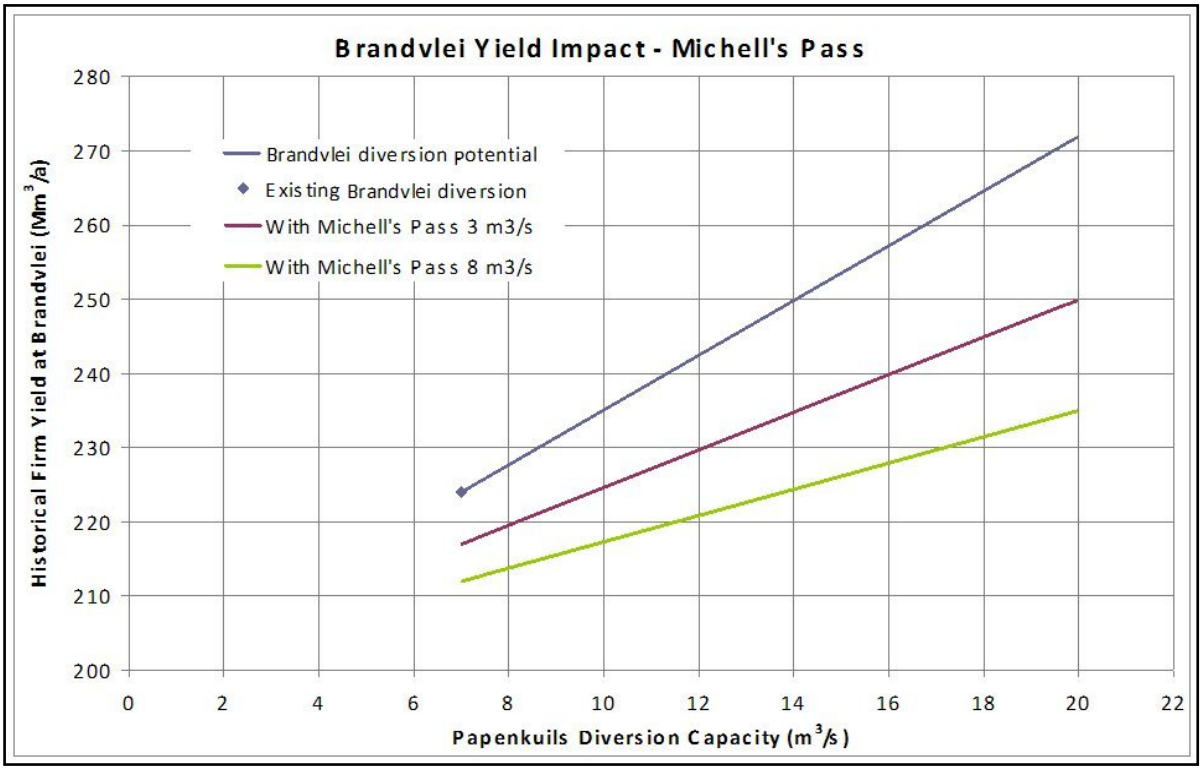

Figure 4.6 Pumping reinstatement for Brandvlei Dam (Michell's Pass Scheme)

4.3 FINANCIAL ASSESSMENT

A summary of the financial assessment of each of the three diversion capacities for which cost estimates were determined is shown in **Table 4.1**. The Unit Reference Values (URVs) were calculated using a discount rate of 6% per annum. Detailed calculation sheets for these URVs are provided in **Error! Reference source not found.**.

Table 4.1 Unit reference values (Michell's Pass diversion)

Item	Michell's Pass Diversion		
	3 m^3/s	**5 m^3/s**	**8 m^3/s**
Total Capital Cost (R million)	411.4	482.1	567.0
Annual Operating Cost (R million)	3.3	4.0	5.2
Net Present Value (R million)	426.2	515.1	621.3
Scheme Yield (million m^3/a)	29.2	38.6	48.1
Unit Reference Value *	**1.44**	**1.32**	**1.32**

*Calculated using a discount rate of 6% per annum

4.4 POTENTIAL WATER DEMAND CENTRES

Storage would be provided in the existing Voëlvlei Dam and the water could be used to supply Cape Town by means of the spare capacity (3,16 m^3/s) in the existing pipeline from the City's Water Treatment Works. This spare conveyance capacity is however only available in winter when water requirements are lower than during the dry summer months. This equates to a potential volume of 20 million m^3/a. The scheme could also be used to supply water to the West Coast Regional Schemes, of which the Saldanha scheme is anticipated to experience significant growth in water requirements (refer to Section 7).

An assessment was also done of the potential to possibly exchange water received by the middle Berg irrigators (from Theewaterskloof Dam), with water becoming available in Voëlvlei Dam. This does not appear viable due to the relatively small irrigation demand within the geographical area that may make such a scheme impractical.

Other potential "users" are described in Section 7. In summary these include:

- addressing the current over-allocation of water from Voëlvlei Dam to the irrigation sector;
- addressing the recent findings in the Berg Water Availability Assessment Study (WAAS) which indicate that the yield of Voëlvlei is 6 million m^3/s less than previously determined.

4.5 POTENTIAL ENVIRONMENTAL IMPACTS

The following environmental issues associated with the proposed Michell's Pass Diversion were identified:

- **Socio Economic**
  - Disruption to farming activities along the pipeline route, which will require compensation.
  - The impact on further irrigation development in the Breede from Brandvlei Dam.
  - Additional pumping capacity will be required at Papenkuils Pumpstation to mitigate the impact of this abstraction on the yield of that dam.

- **Fauna and Flora**
  - The impact on the receiving environment (Boontjies River), such as erosion of the receiving channel, unless protection is provided. Refer to **Error! Reference source not found.** for the Botanical Specialist Report.
  - Whilst there will be an undesirable transfer of small mouth bass from the Breede River into the Boontjies River, this is already occurring via the existing Artois canal.

- **Heritage**
  - Risk of inundation of San Rock paintings and archaeological sites is low due to the low level structure proposed. Refer to **Error! Reference source not found.** for the Heritage Specialist Report.

4.6 POTENTIAL ADVANTAGES

The following potential advantages associated with the scheme were identified:

- This is primarily a gravity water supply scheme with pumping only required to reinstate the yield of the Greater Brandvlei Dam.
- The scheme makes optimum use of existing infrastructure, namely Voëlvlei Dam and the Klein Berg Diversion canals.
- The low weir provides very little storage and as such inundation is negligible, without any impact on the Witels River in particular.

- The diversion would not compromise the winter EWRs, whilst the summer conditions would remain as current.
- The option offers versatility in terms of supplying various possible users, including the CCT and the West Coast.
- There is also potential to augment certain stressed local water supply schemes at Wolseley and Tulbagh.
- The scheduled irrigation water supply to the Artois Irrigators could be better managed than is currently the case, where canal losses are significant.
- The costs are favorable when compared with the other options and the potential yields are also comparatively good.
- The use of a covered pipeline (as opposed to an open canal) will avoid the aesthetic impacts and reduce the extent of water loss.

5. THE UPPER WIT RIVER DIVERSION

5.1 SCHEME DESCRIPTION

This scheme involves the potential inter-basin transfer of surplus winter water from the Upper Wit River (see **Figure** 5.1), a tributary of the Breede River, in the vicinity of Eerste Toll (Bain's Kloof), into the Berg River catchment. This would be achieved by constructing a low level weir (2m high) and intake on the left bank (looking downstream). Once the winter EWR requirements have been met, water would be diverted into a drop structure connecting to a 3m dia tunnel, of about 350m length, under Bain's Kloof.

Figure 5.1 The Upper Wit River

The tunnel would be at a grade of between 2%and 5% and would transfer the water under the catchment divide, discharging into a small valley which feeds the Krom River, a tributary of the Berg River. The water would be stored in a proposed receiving dam (approximately 45m high) on the Krom River at Riverlands Farm, upstream of the Doolhof Farm (see **Figure 5.2**).

Previous studies by DWA and by the former Paarl Municipality have assessed potential dam sites on the Upper Wit River itself. These have however proven to be environmentally unfavorable and as such, for this option, storage has been identified on the Krom River in the adjacent Berg River catchment.

Consideration was given to possibly expanding the existing transfer scheme from the Upper Wit River, namely the "Gawie se Water" diversion channel. This was originally constructed in about 1900 and diverts water year-round across the catchment divide for irrigation in the Krom River Valley. This historical scheme has heritage value and was the first inter-basin transfer scheme implemented in South Africa. Upgrading of that scheme would complicate the location of the receiving dam on the Krom River,

making an alternative site on the Doolhof Farm more attractive from a technical perspective, but with disastrous inundation and heritage impacts.

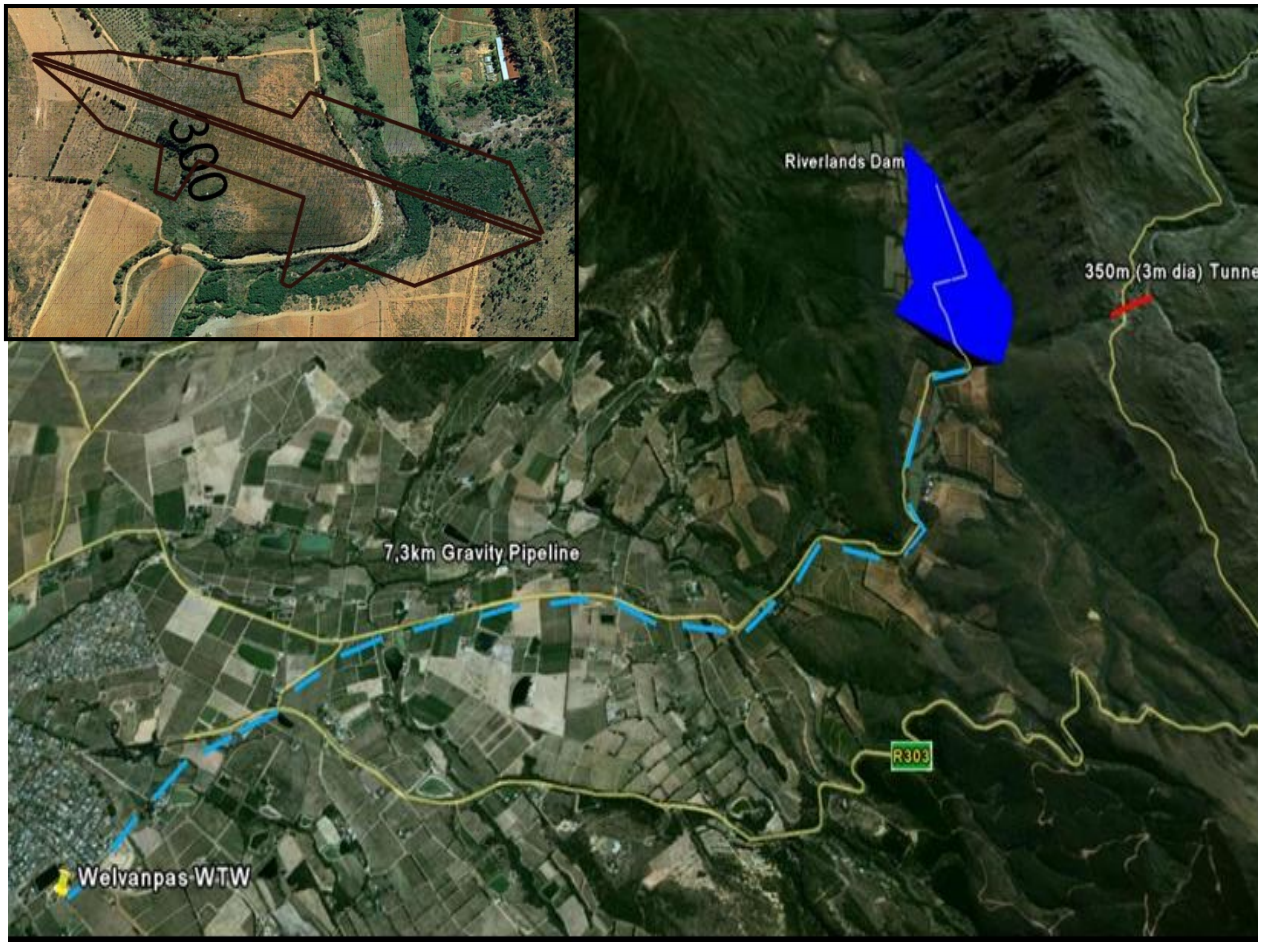

Figure 5.2 The Upper Wit Scheme

The use of a low intake weir limits the upstream inundation impact in the Wit River. Provisional designs of a weir structure to enable downstream releases to be made and to ensure that sedimentation and boulder accumulation can be managed, have been undertaken. The anticipated duration for implementation is shown in **Figure 5.3**. A typical layout of the diversion weir for a 4 m^3/s diversion is shown in **Figure 5.4**.

UPPER WIT RIVER DIVERSION	YEARS										
	1	2	3	4	5	6	7	8	9	10	11
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PHASE 1: PRELIMINARY STUDY AND RESERVE DETERMINATIONS											
PHASE 2: FEASIBILITY STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT											
PHASE 3: IMPLEMENTATION											
Lag Time (Possible Budget Delay)											
Prepare Terms of Reference and Appoint PSP											
DWAF Licence Consideration											
DEA&DP Approval Process											
Design, Tender Preparation and Award											
Construction and Implementation											
Commissioning and bring on-line											

Figure 5.3 Upper Wit River Diversion Time Frame

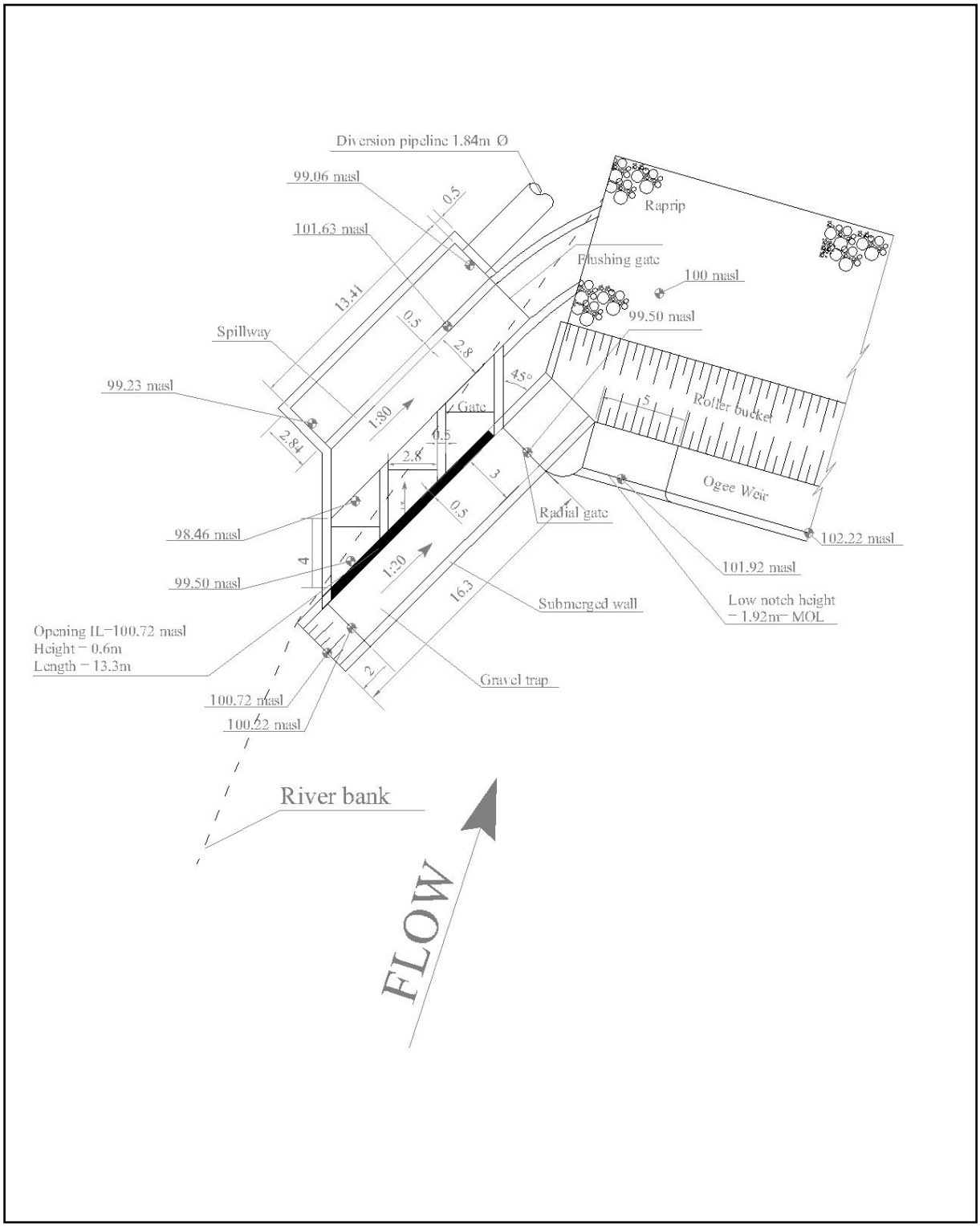

Figure 5.4 Typical layout of a 4 m^3/s diversion weir on the Upper Wit River

5.2 YIELD

The proposed Wit River diversions would only take place once the requirements of the Reserve have been met. Various diversion capacities, corresponding yields and required dam storages (and wall heights) were assessed. As shown on **Figure 5.5**, a 4 m^3/s diversion was found to be optimal, which with a 45m high dam at Riverlands Farm on the Krom River, provides a yield of about 13 million m^3/a, whilst maintaining the existing Ecological Class B of the Wit River. This size of the receiving dam on Riverlands Farm would be such that inundation of approximately 88ha would occur.

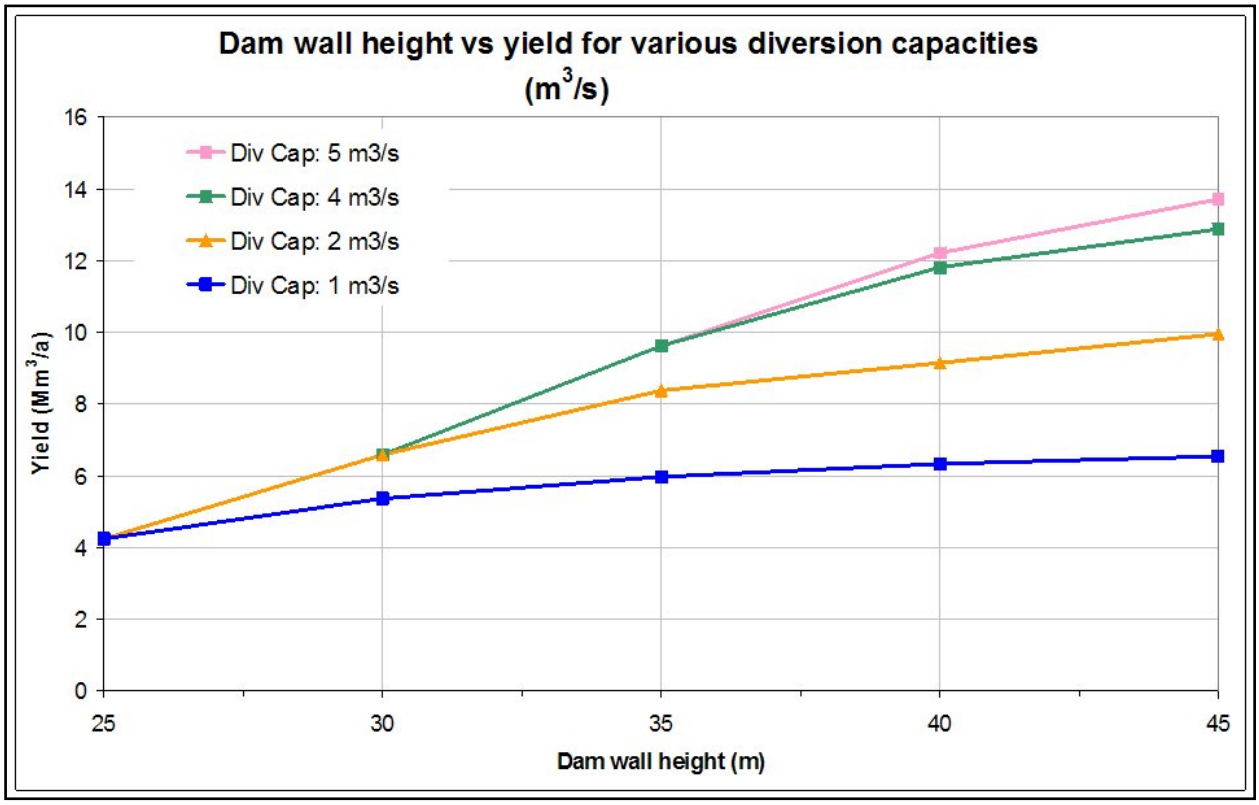

Figure 5.5 Optimization for Upper Wit River diversions and Krom River Storage

5.2.1 Impact on Greater Brandvlei Dam

The impact of the proposed abstractions from the Wit River will adversely impact on the current and potential yield of Greater Brandlvlei Dam, unless additional pumping capacity is installed at the Papenkuils Pumpstation. This additional pumping capacity and its operational requirements have been determined (see **Figure 5.6**), are summarized in **Table 5.1**, and the costs included in the financial assessment of this scheme.

Table 5.1 Pumping reinstatement requirements at Brandvlei Dam

Abstraction at Upper Wit River	Additional pumping capacity required at Brandvlei
4 m^3/s	2,5 m^3/s (increase from 7,5 m^3/s to 10 m^3/s)

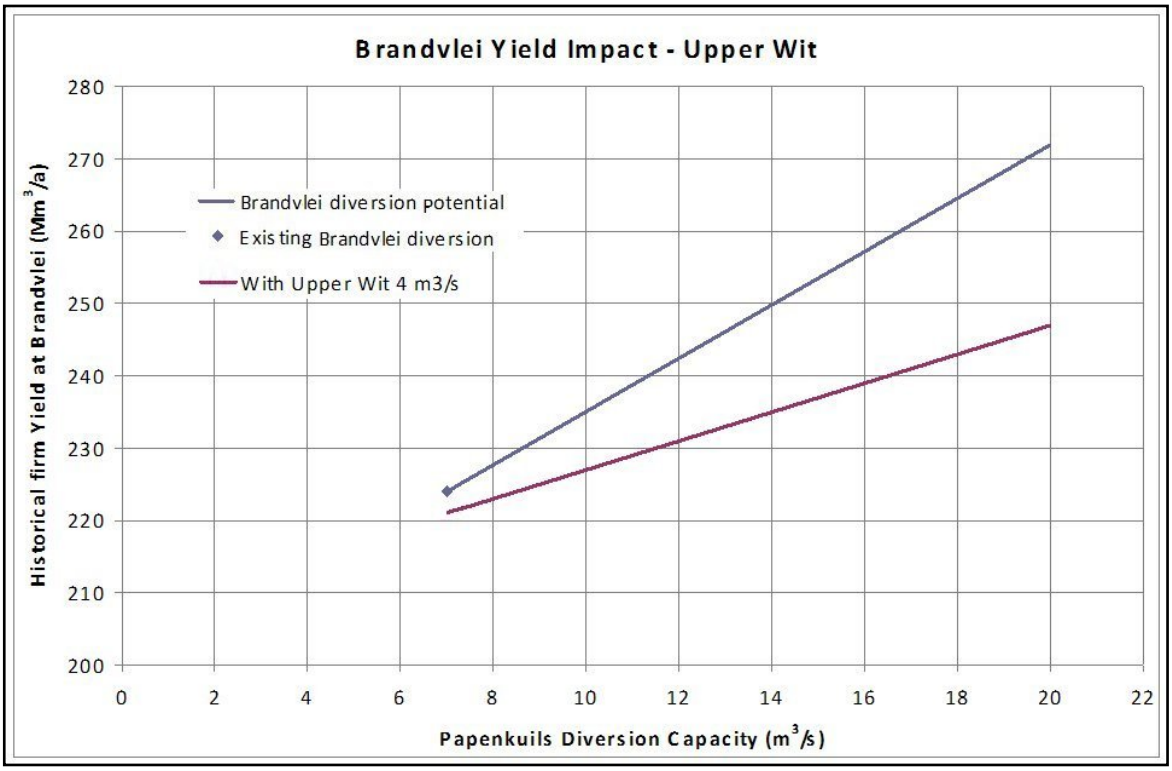

Figure 5.6 Pumping reinstatement for Brandvlei Dam (Upper Wit Scheme)

5.3 FINANCIAL ASSESSMENT

A summary of the financial assessment of both of the supply options, each based on a 4 m^3/s diversion is shown in **Table 5.2**. The detailed Unit Reference Value (URV) calculation sheets are provided in **Error! Reference source not found.**.

Table 5.2 Unit reference values (Upper Wit River diversion)

Item	Upper Wit River Diversion	
	3 m^3/s	**4 m^3/s**
Total Capital Cost (R million)	659.9	777.4
Annual Operating Cost (R million)	3.5	3.8
Net Present Value (R million)	596.8	633.7
Scheme Yield (million m^3/a)	13.0	13
Unit Reference Value *	**4.71**	**5.70**

*Calculated using a discount rate of 6% per annum

5.4 POTENTIAL WATER DEMAND CENTRES

The water could either be released into the Krom River from the dam, through an exchange with the Berg River Irrigators, for water currently allocated to them from Theewaterskloof Dam. Alternatively the water could be piped under gravity to the Welvanpas WTW in Wellington during summer, via a 7,3km GRP pipeline of 600mm dia. The existing WTW would require upgrading. The water then could be used locally to supply Wellington, as well as Paarl via reverse pumping in the existing 450mm dia pipeline between Paarl and Wellington.

A positive spin-off of this scheme is that it would allow for better management of the existing (uncontrolled) irrigation diversion at Gawie-se–water, which currently diverts all summer flow, having negative impacts on the Wit River and on the downstream irrigators.

5.5 POTENTIAL IMPACTS

The following environmental issues associated with the proposed Upper Wit River diversion scheme have been identified:

- **Socio Economic**
  - Inundation of Riverlands Farm (used for horse-breeding).
  - Disruption to farming activities along the pipeline routes, which will require compensation.
  - The impact on further irrigation development in the Breede from Brandvlei Dam.
  - Additional pumping capacity will be required at Papenkuils Pumpstation to mitigate the impact of this abstraction on the yield of that dam.

- **Fauna and Flora**
  - Construction may endanger Boland Granite Fynbos which contains Red Data Book flora.
  - The distribution area of the Breede River redfin fish begins just downstream of Gawie-se-Water. The possible transfer of the Breede redfins into the Krom River would have a significant impact on the Berg River redfins that are genetically “pure”. The risk of hybridization that could occur between the Breede and Berg redfins is likely to be ecologically unacceptable.

- **Heritage**
  - The historic Bains Kloof and Gawie-se-Water are of local heritage significance.
  - Potential impacts on Doolhof farm have been limited by selection of the Riverlands Dam site as an alternative to the initial site at Doolhof.

5.6 POTENTIAL ADVANTAGES

The following potential advantages associated with the scheme were identified:

- Primarily a gravity scheme with some pumping required between Wellington and Paarl.
- No storage is required on the Doolhof Farm.
- The diversion would not compromise the Reserve.
- The option offers versatility in terms of supplying various possible users.
- Potential to better manage the irrigation water supply from the Wit River.

6. THE MOLENAARS RIVER DIVERSION

6.1 SCHEME DESCRIPTION

This scheme involves the potential transfer of surplus winter water from the Upper Molenaars River in the vicinity of the Eastern Tunnel Portal (Huguenot Tunnel) to the Berg River Dam. Two potential options have been investigated, namely:

- Pumping from the Molenaars River.
- Gravity Supply from the Elandspad tributary of the Molenaars River.

Molenaars Diversion

The first option involves a low level intake structure in the Molenaars River downstream of the entrance to the tunnel (from the Worcester side) and located at an existing causeway. Water would be pumped during surplus winter flow periods into a balancing tank above the tunnel entrance, from where it would gravitate into and through the existing 1,3m dia pipeline installed in the tunnel during its construction. From the tunnel portal on the Paarl side the water would be conveyed under gravity over a distance of approximately 30 km via a new GRP pipeline (1,1m dia.) into the Berg River Dam. The left photograph in **Figure 6.1** shows the Molenaars River.

Elandspad Diversion

The second option is an alternative and it involves the potential construction of a low level weir on the Elandspad River (a tributary of the Molenaars) upstream of the existing DWA flow gauging station. This would negate the need for infrastructure to be developed in the Molenaars River itself and would require no pumping. The right photograph in **Figure 6.1** shows the Elandspad River.

Figure 6.1 The Molenaars and Elandspad Rivers

The anticipated duration for implementation is shown on **Figure 6.2**.

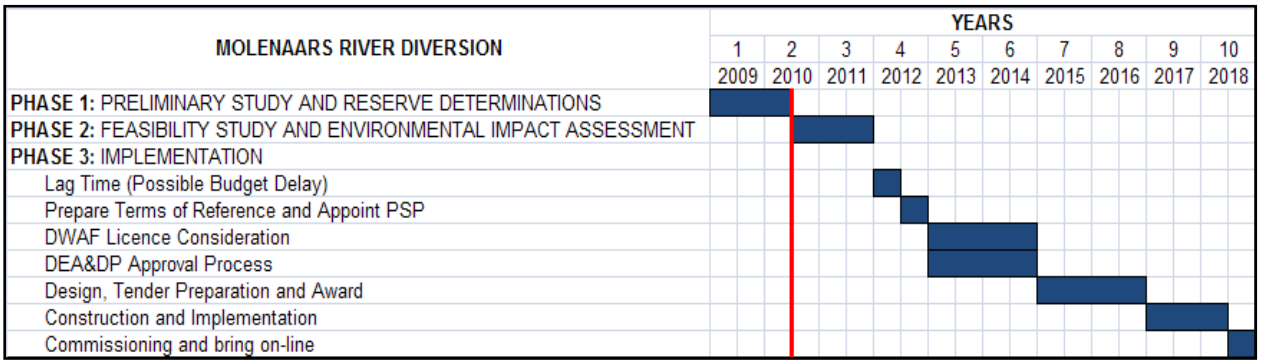

Figure 6.2 Molenaars River Diversion Time Frame

The potential scheme layout is shown in **Figure 6.3**. A typical layout of the potential low level weir proposed for a 4 m^3/s diversion in the Molenaars River is shown in **Figure 6.4**.

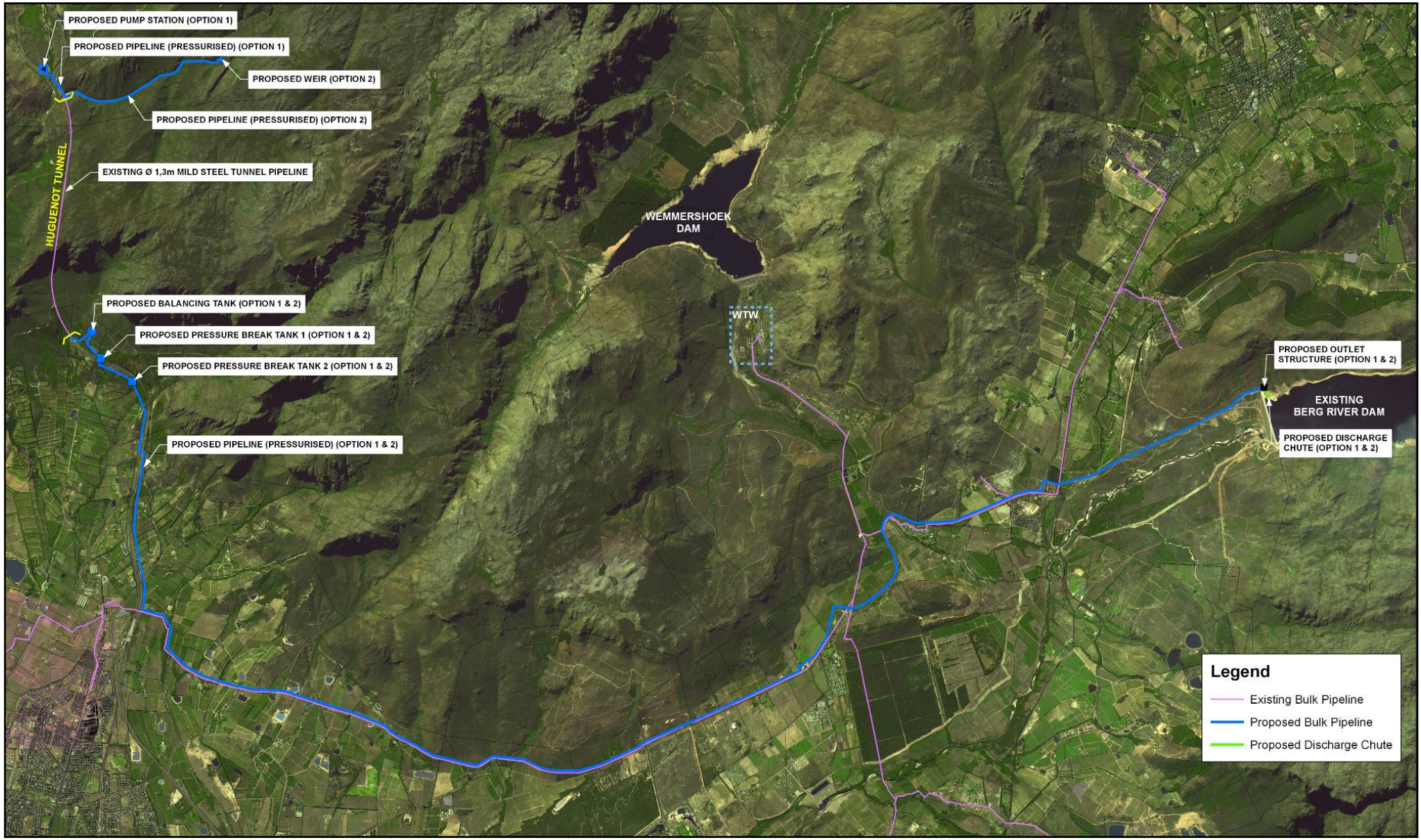

Figure 6.3 The proposed general layout of the Molenaars River diversion options

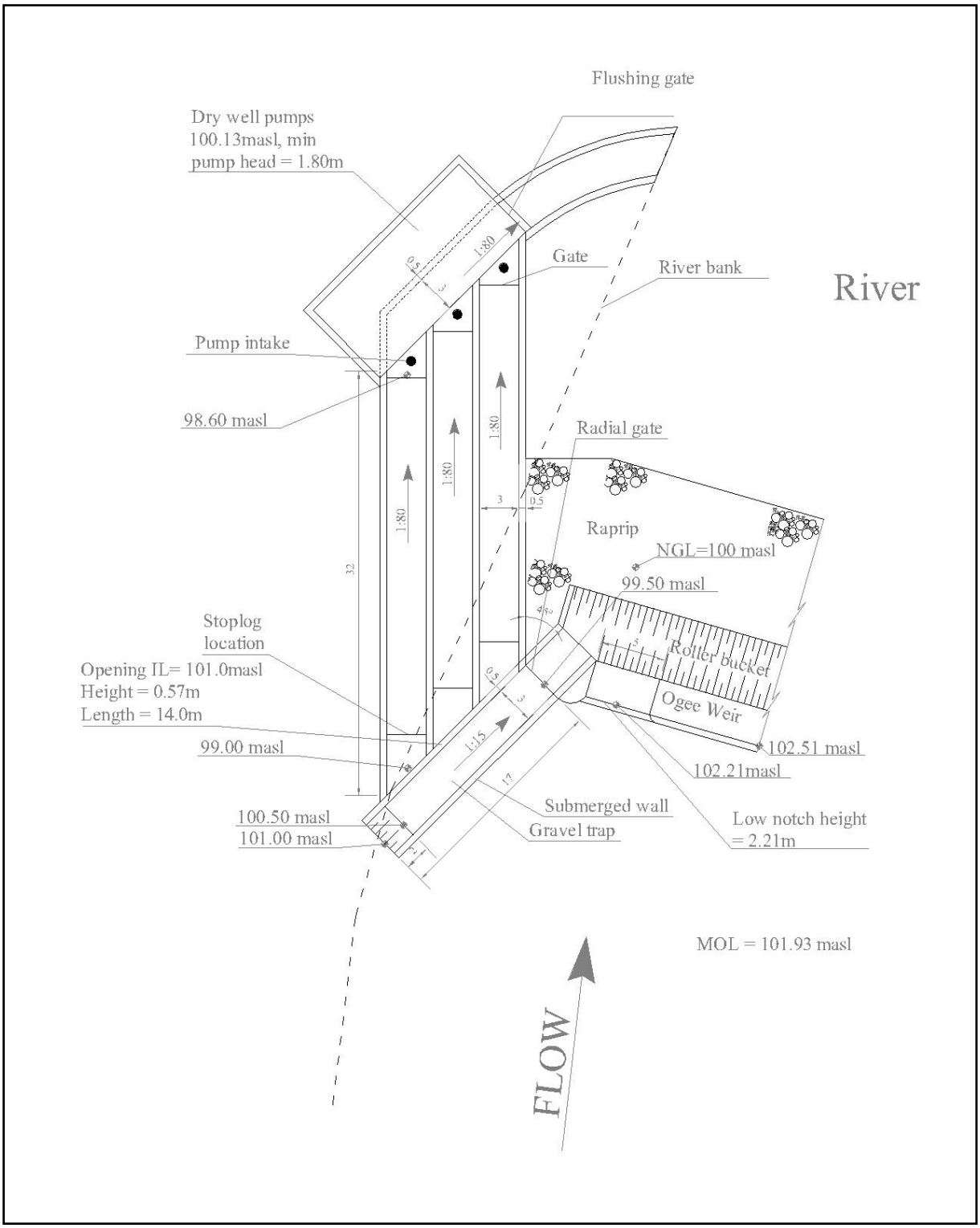

Figure 6.4 Typical layout of a 4 m^3/s diversion weir on the Molenaars River

6.2 YIELD

Potential diversions out of either the Molenaars or the Elandspad Rivers are primarily governed by the downstream EWRs, and by the limited conveyance capacity of the existing pipeline through the Huguenot tunnel. Taking these factors into consideration, indicates that for the pumped abstraction of water from the Molenaars River, the scheme could yield only about 13 million m^3/a for a diversion capacity of 4 m^3/s (limited by the existing pipeline). This assumes that the Ecological Class for the Molenaars River is maintained as a Category **B**.

Similarly, the yields from the alternative option on the Elandspad River (smaller catchment area) would be about 75% of those from the Molenaars diversion, for the same diversion capacities.

6.2.1 Impact on Greater Brandvlei Dam

The impact of the proposed abstractions from the Molenaars or Elandspad Rivers will adversely impact on the gravity canal diversions of the Smalblaar and Holsloot Rivers into Brandvlei Dam, as well on the current abstractions via the pumping scheme at Papenkuils pumpstation.

In order to offset these impacts, it has been determined that the additional pumping capacity that would be required at Papenkuils is as illustrated in **Figure 5.6** and summarized in **Table 6.2**. The related cost estimates have been included in the financial assessment of this scheme.

Table 6.1 Pumping reinstatement requirements at Brandvlei Dam

Abstraction from Molenaars River	Additional pumping capacity required at Brandvlei
4 m^3/s	6,5 m^3/s (increase from 7,5 m^3/s to 14 m^3/s)

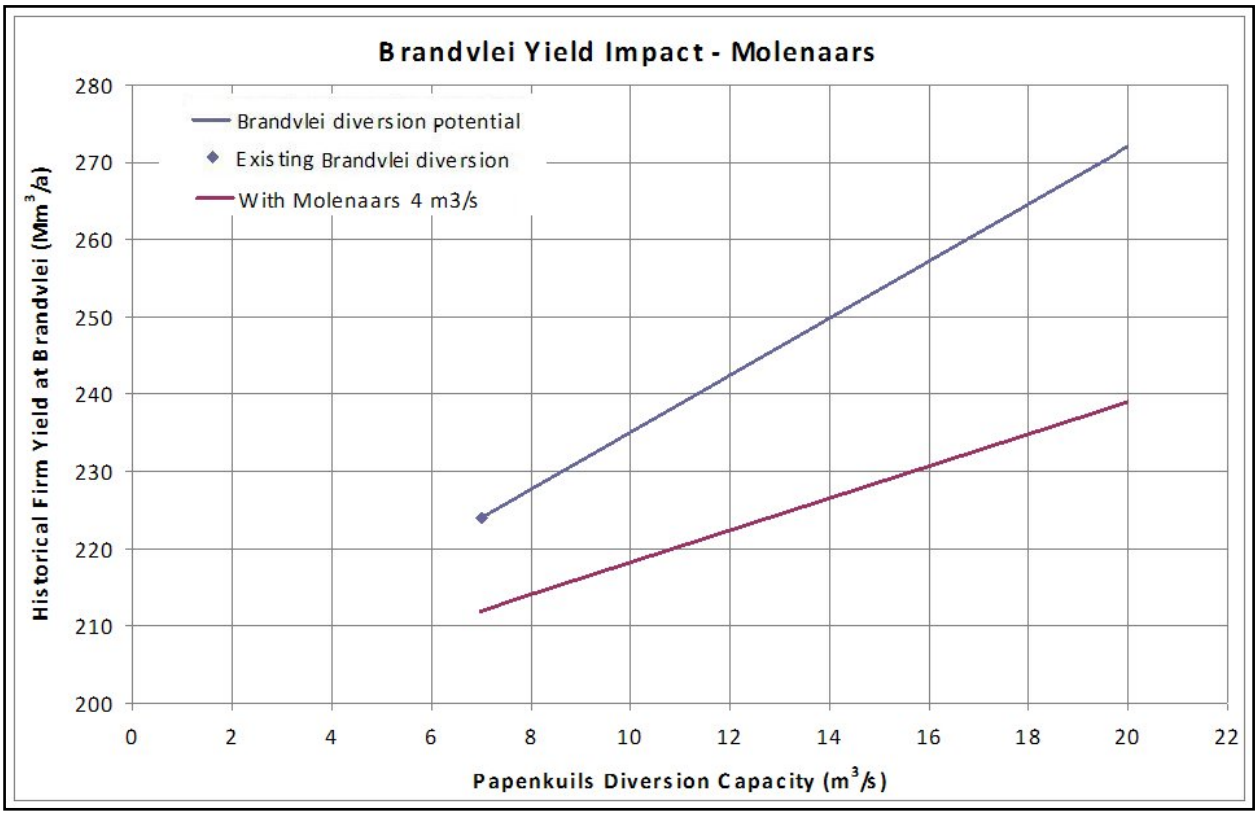

Figure 6.5 Pumping reinstatement for Brandvlei Dam (Molenaars River Diversion Scheme)

6.3 FINANCIAL ASSESSMENT

A summary of the financial assessment of the supply options considered for both a 3 m^3/s and a 4 m^3/s diversion from the Moolenaars and Elandspad Rivers is shown in **Table 6.2** The detailed Unit Reference Value (URV) calculation sheets are provided in Error! Reference source not found..

Table 6.2 Unit reference values (Molenaars diversion options)

Item	Molenaars Diversion	
	3 m^3/s	**4 m^3/s**
Total Capital Cost (R million)	537.3	601.8
Annual Operating Cost (R million)	13.7	15.6
Net Present Value (R million)	612.5	689.1
Scheme Yield (million m^3/a)	11.5	13.5
Unit Reference Value (6%)	**5.05**	**4.84**
Item	**Elandspad Diversion**	
	3 m^3/s	**4 m^3/s**
Total Capital Cost (R million)	471.7	529.7
Annual Operating Cost (R million)	6.5	7.3
Net Present Value (R million)	478.0	536.9
Scheme Yield (million m^3/a)	8.6	10.1
Unit Reference Value*	**5.28**	**5.04**

*Calculated using a discount rate of 6% per annum

6.4 POTENTIAL WATER DEMAND CENTRES

Water becoming available in winter from the scheme would be stored in the Berg River Dam and in this way integrated into the Western Cape Water Supply System. The option of storing the abstracted water in Wemmershoek Dam was also considered but is less favorable due to the limited capacity of the existing pipeline from Wemmershoek Dam to Cape Town. On the other hand, water delivered to the Berg River Dam could be delivered via the Dasbos Pumpstation either into Theewaterskloof Dam, or to Cape Town via the existing tunnel. The proposed Muldersvlei pipeline would enable delivery directly to Cape Town. For these reasons, use of the Berg River Dam for storage purposes offers greater flexibility.

6.5 POTENTIAL IMPACTS

The following environmental issues associated with the proposed Molenaars and Elandspad River diversion schemes have been identified:

- **Socio Economic**
  - Due to the pristine nature of the proposed site, this scheme has the potential to invoke very strong resistance from the public.
  - There would be a negative impact on the gravity canal diversions of the Smalblaar and Holsloot Rivers into Brandvlei Dam, unless reinstatement of the yield is implemented through augmentation of the pumping from the Breede River at Papenkuils pumpstation.

- Potential future irrigation development in the Breede River Valley would also be impacted.

- **Fauna and Flora**
  - The impact of inundation on the flora is likely to be small due to the low level of the proposed weir. However the pipeline to the Berg River Dam would pass through critically endangered vegetation on the Paarl side of the tunnel, such as Swartland Alluvium Fynbos. Public opposition is likely to be high.
  - There are a number of wetlands along the Elandspad River that are of great ecological importance.
  - The relatively small diversion capacity would have minimal impact on the Papenkuils Wetland.
  - The transfer of Molenaars River water into Wemmershoek Dam would be undesirable as it would allow for the transfer of small mouth bass into the small tributaries of the Wemmershoek River. These tributaries are pristine and are critically important for aquatic conservation purposes.
  - A basin-wide assessment of the impacts of abstraction on the EWRs (notably the Breede River Estuary) has not been undertaken and such an assessment is vital.

- **Heritage**
  - The possibility of impacts on San rock art at the weir and pumpstation site is small due to the low level nature of the proposed weir, although this would need to be verified as part of a Heritage Impact Assessment.
  - Similarly the pipeline route to Berg River Dam will need to be subject to a full Heritage Impact Assessment.

6.6 POTENTIAL ADVANTAGES

The following potential advantages associated with the scheme were identified:

- Pipework through Huguenot Tunnel is already in place and use is made of existing storage.
- Storage in the Berg River Dam offers some reduced risk in the event of the Riviersonderend tunnel being closed.

7. 1ST PHASE AUGMENTATION OF VOËLVLEI DAM

7.1 SCHEME DESCRIPTION

This potential scheme involves the pumped abstraction of winter water from the Berg River, once the requirements of the ERW have been met. A number of diversion sites and scheme operational aspects have been previously investigated by DWA and by the CCT, at various levels of detail. Since those investigations, the water quality characteristics within the dam have changed (refer to specialist report in Error! Reference source not found.). For the current purpose of this study, the Spes Bona and Lorelei sites are best suited for the proposed options. Zonquasdrift was also considered but the former two sites proved preferable for alignment of pipelines and limiting the impacts on the Voëlvlei Conservancy. Their respective locations are shown on **Figure 7.1**.

For direct transfer and storage of water in Voëlvlei Dam, abstraction rates of 2 m^3/s, 4 m^3/s, 6 m^3/s and 10 m^3/s have been assessed as well as various pumping rules which determine how much water is left in the river for meeting the EWR. In this regard it has been determined that the Estuarine Reserve high flow requirement is adequately met for all diversion rates considered. A provision of 0,5 m^3/s (8 million m^3/a) from each scheme has been allowed in summer to provide for the recommended baseflow into the Estuary, which would not be impacted by the scheme but which is currently inadequate for the Estuary.

The EWR for the river during winter appears the critical component. No summer abstraction is possible and carefully managed abstraction during 4-5 months in winter will be necessary. Of the many permutations and scenarios considered, it has been determined that a maximum abstraction rate of 6 m^3/s during 5 winter months, with a minimum remaining flow of 1 m^3/s in the river, meets the EWR requirement for the Berg River and Estuary. This diversion appears optimal from the Lorelei site as it has the shortest conveyance length (delivery pipeline to the dam) and the least impact on the Renosterveld within the Voëlvlei Conservancy, as it can be aligned with areas previously disturbed.

Alternative

Berg River water quality will have an adverse impact on the stored water quality in Voëlvlei Dam. The outcomes of the water quality assessment **(**Error! Reference source not found.) indicate that the extent of the impact is not yet significant enough to foreclose storing Berg River water in the dam. However, should the Berg River water quality further deteriorate then storing water in the dam may not be possible at all. In this case, abstraction at Spes Bona would be preferred, with pre-treatment and balancing storage provided, and direct uptake by the CCT during winter. The yield of such a scheme would be limited by the available capacity in the existing pipeline to Plattekloof reservoir (approximately 20 million m^3/a).

The two potential scheme layouts are shown on **Figure 7.1**. A typical layout of the potential low level weir proposed for a 6 m^3/s diversion in the Berg River is shown in **Figure 7.3**.

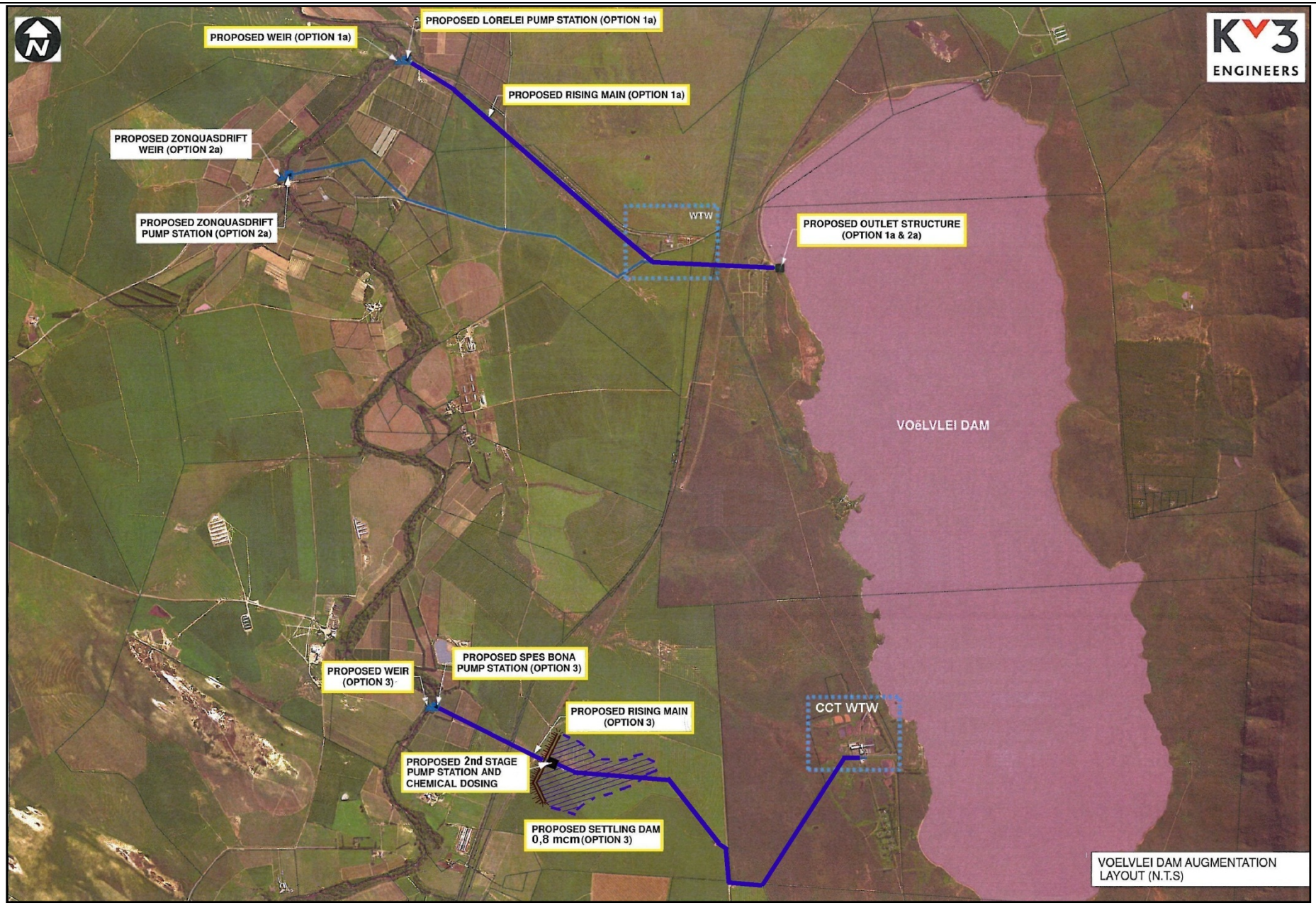

Figure 7.1 The proposed layout of the Voëlvlei Phase 1 options

The anticipated time frame for implementation is as shown on **Figure 7.2**.

VOËLVLEI PHASE 1	YEARS									
	1	2	3	4	5	6	7	8	9	10
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
PHASE 1: PRELIMINARY STUDY AND RESERVE DETERMINATIONS										
PHASE 2: FEASIBILITY STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT										
PHASE 3: IMPLEMENTATION										
Lag Time (Possible Budget Delay)										
Prepare Terms of Reference and Appoint PSP										
DWAF Licence Consideration										
DEA&DP Approval Process										
Design, Tender Preparation and Award										
Construction and Implementation										
Commissioning and bring on-line										

Figure 7.2 First Phase Voëlvlei Augmentation Time Frame

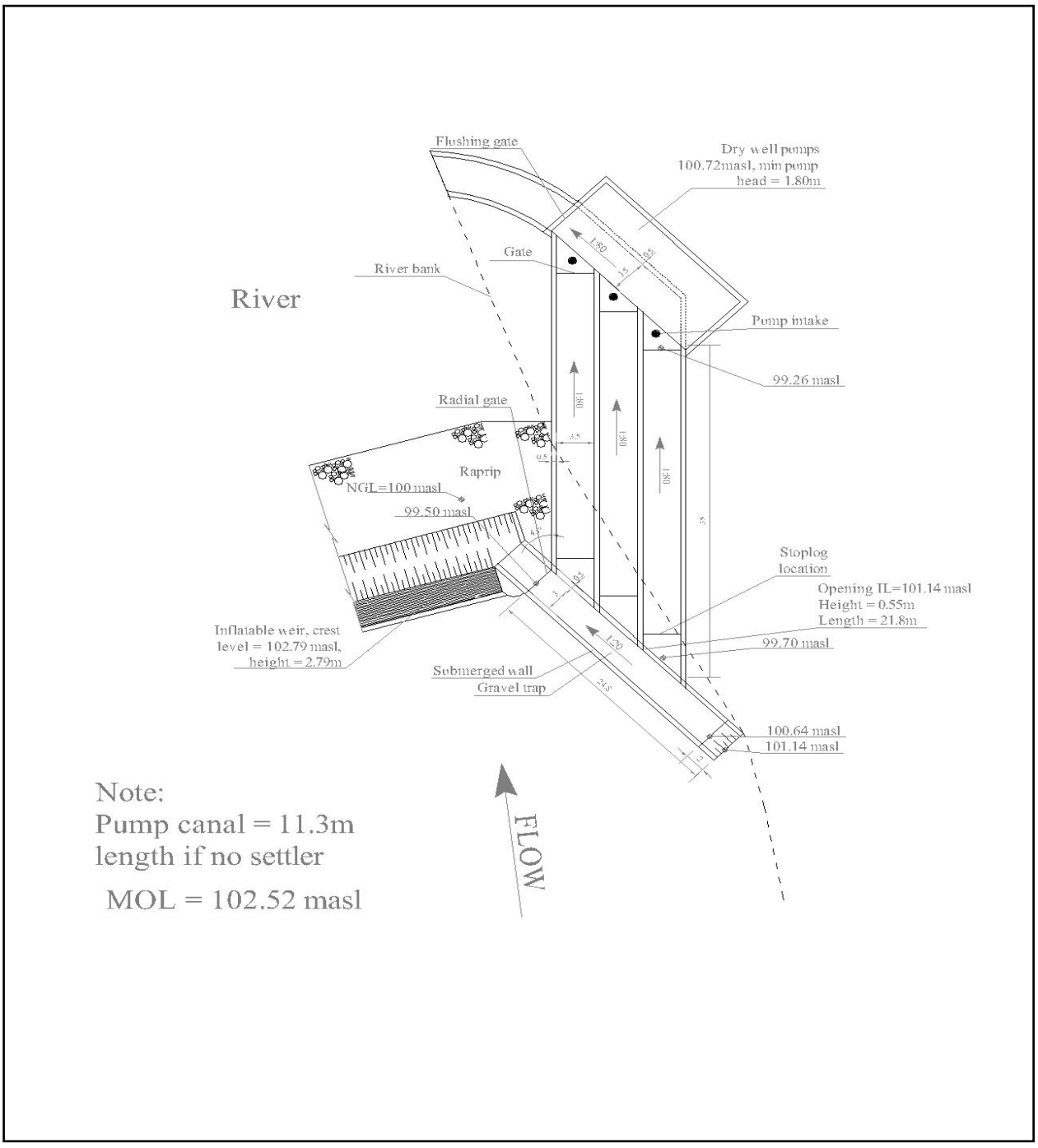

Figure 7.3 Typical layout of a 6 m^3/s diversion weir on the Berg River

7.2 YIELD

The scheme yields after allowing for releases of 0,5 m^3/s in summer (8 million m^3/a) to contribute towards the Estuarine baseflow, and allowing for a minimum winter flow of 1 m^3/s for the Berg River EWR are as follows:

- 6 m^3/s diversion into Voëlvlei (34 less 8 million m^3/a): 26 million m^3/a
- 3,1 m^3/s diversion for direct use by CCT: 20 million m^3/a

7.3 FINANCIAL ASSESSMENT

A summary of the financial assessment of the supply options considered for a 6 m^3/s diversion with storage in Voëlvlei Dam, and for the option of direct uptake without storage in the dam is presented in **Table 7.1** The detailed Unit Reference Value (URV) calculation sheets are provided in Error! Reference source not found..

Table 7.1 Unit reference values (Voëlvlei Phase 1)

Item	Voëlvlei Phase 1	
	6 m^3/s into Existing Dam	**3.2 m^3/s Direct to CCT**
Total Capital Cost (R million)	268.1	262.9
Annual Operating Cost (R million)	9.9	8.8
Net Present Value (R million)	333.3	321.3
Scheme Yield (million m^3/a)	26.0	20.0
Unit Reference Value *	**1.22**	**1.53**

*Calculated using a discount rate of 6% per annum

7.4 POTENTIAL WATER DEMAND CENTRES

For the option involving storing Berg River water in Voëlvlei Dam, the potential demand centres that could be supplied include the City of Cape Town, the growing West Coast region, and addressing any irrigation over-allocation from Voëlvlei Dam. Furthermore the recently determined yield of Voëlvlei Dam is 88 million m^3/a (Ref: Berg WAAS), a decrease of 6 million m^3/a from previous estimates. The West Coast DM is currently implementing a Study to assess its options in terms of bulk water supply. That Study reports anticipated growth in water requirements, based on 2009 requirements, as shown on **Figure 7.4** below.

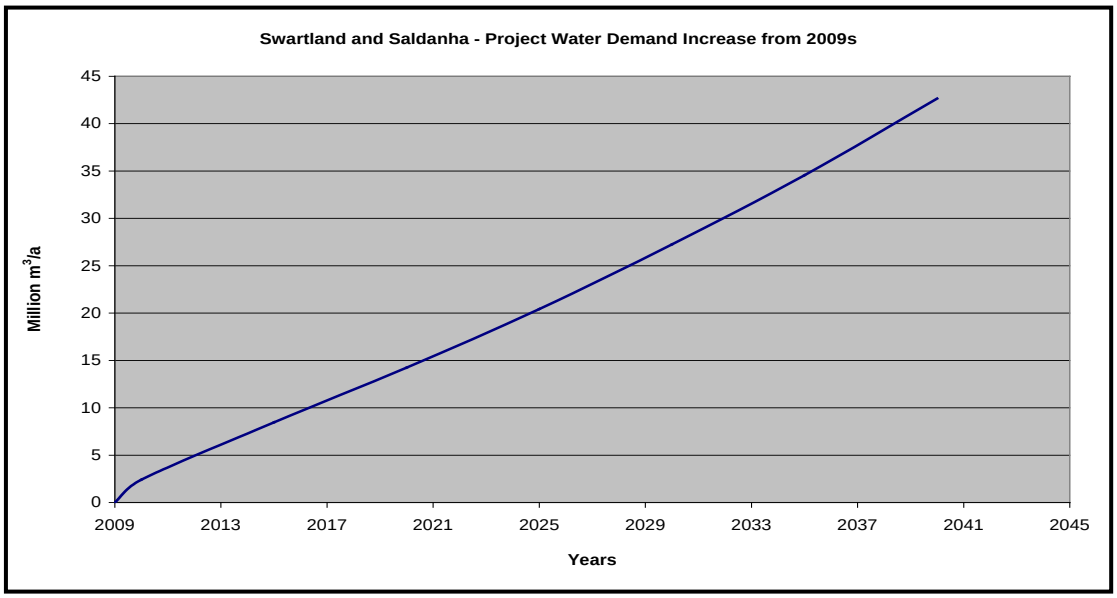

Figure 7.4 Projected Growth in West Coast Requirements

The potential water requirement increases (by 2018) that could absorb the additional yield are approximately as follows:

Swartland and West Coast:	12 million m^3/a
Reduction in latest Yield Estimate:	6 million m^3/a
City of Cape Town:	20 million m^3/a (defined by pipeline capacity)
Water requirement increase by 2018:	38 million m^3/a

This indicates that there will be sufficient demand to utilise the additional yield that may become available from this scheme, without augmenting the pipeline capacity to Cape Town. Furthermore the current allocations to irrigators from the dam are over-allocated, albeit at a lower assurance of supply. For the alternative option of direct supply to Cape Town without storage in Voëlvlei all the water would be used by the CCT.

7.5 POTENTIAL IMPACTS

The following environmental issues associated with the Phase 1 Augmentation of Voëlvlei Dam were identified:

- **Socio Economic**
  - If the abstraction of surplus winter water from the Berg River does not affect irrigation activities downstream, this option should not have significant negative impacts.
  - May have a negative impact on recreational activities (e.g. canoeists/Voëlvlei Yacht Club) during the construction period.
  - May have a slight impact on the water quality in Misverstand Dam and therefore on the supply to Saldanha.

- **Fauna and Flora**
  - The vegetation in the areas to be effected by the pipeline route from the Berg River and the settling facility would require a botanical assessment.
  - Rehabilitation of certain areas would be required.
  - The endangered Geometric Tortoise, whose habitat is threatened, is found within the adjacent Voëlvlei Nature Reserve.

- **Heritage**
  - The future EIA process will have to address the disturbance of archaeological sites on the shale derived soils of the Berg River Valley.
  - It will also be necessary to gather baseline information on the built environment.

7.6 POTENTIAL ADVANTAGES

The following potential advantages associated with the scheme were identified:

- The options incorporate existing infrastructure namely the Voëlvlei Dam, the CCT's WTW, and the existing pipeline to Cape Town.
- Storage in Voëlvlei Dam offers opportunity to supply both the CCT and the West Coast.

8. FURTHER PHASES OF VOËLVLEI DAM AUGMENTATION

8.1 SCHEME DESCRIPTION

The Further Phases of the Voëlvlei Augmentation Option would involve the abstraction of water as described in Phase 1, namely at 6 m^3/s, with additional storage being made available in Voëlvlei Dam by means of a low raising of the existing dam wall.

Analysis of the potential yield benefit that could be achieved, coupled with the extensive earthworks that would be required for a conventional raising in excess of 2 m, and taking cognisance of the existing Klein Berg and Twenty Four Rivers diversions into the dam, indicate that from an engineering and cost perspective, a raising of no more than 2 m seems favourable. This could be achieved by means of a concrete parapet wall constructed along the length of the embankment. The use of a parapet wall (up to 2 m) eliminates a massive earthworks undertaking and provides a more cost effective and relatively simple solution to that of a conventional dam raising.

A 2 m raising also limits the impacts on the existing diversion canals which feed water into the dam from the Klein Berg and Twenty-Four Rivers. It would however be necessary to replace a 4,5 km section of the Klein Berg Canal (existing capacity of 19,8 m^3/s) with a new, re-aligned section.

The time frames for potential implementation are as indicated in **Figure 8.1**. If both Phase 1 and Phase 2 were to be implemented, these would need to be considered within an integrated time frame. This will be assessed in the next phase of this Study (Feasibility), should these options both appear favourable.

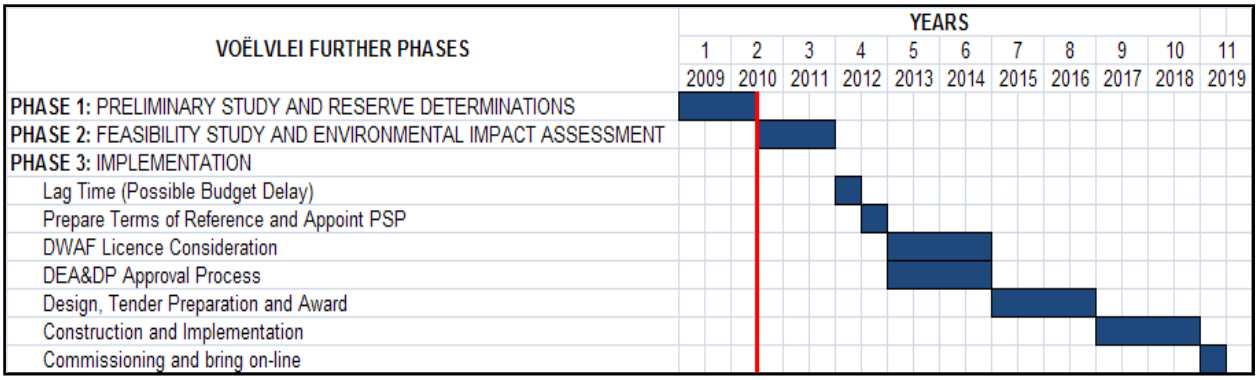

Figure 8.1 Voëlvlei Further Phases Time Frame

8.2 YIELD

By providing a 2 m raising of the Voëlvlei Dam wall and limiting the abstraction from the Berg River to 6 m^3/s (as per Phase 1), the potential yield (after allowing for the EWR (river and estuary) is about:

- 6 m^3/s diversion into Voëlvlei (43 less 8 million m^3/a):= 35 million m^3/a

Note that the EWR has been subtracted from the yield of Voëlvlei Dam in order to illustrate the net effect of implementing the required low flows to the estuary and river from the Dam.

It is relevant to note that the net increase between Phase 1 and Phase 2 is only about 9 million m^3/a for a 2m raising (35 million m^3/a with raising vs. 26 million m^3/a without raising). This relatively low increase (for the significant increase in storage) is due to the higher evaporation and the length of the carry-over

period (four years) during a 1 in 50 year drought. Furthermore, 6 m^3/s remains the upper limit in terms of what can be diverted from the Berg River in winter, whilst first meeting the EWR requirements for the river. As such, significantly bigger raisings would similarly not achieve substantially large enough increases in yield to warrant raising the dam to heights above 2 m, for which conventional (and costly) approaches would be required. The exception being the case if both the Voëlvlei Phase 1 and Phase 2 options were implemented together, in addition to the Michell's Pass diversion scheme.

8.3 FINANCIAL ASSESSMENT

The financial assessment for the complete scheme is shown in
Table 8.1. The marginal (incremental) benefit and cost implications of raising the dam are also shown to illustrate the effect of the raising and the 4,5 km canal re-alignment.

Table 8.1 Unit reference values (Voëlvlei Phase 2)

Item	Voëlvlei Phase 2	
	6 m^3/s into Raised Dam (+2m)	**Incremental (Dam Raising)**
Total Capital Cost (R million)	686.0	417.8
Annual Operating Cost (R million)	11.0	1.0
Net Present Value (R million)	707.4	374.1
Scheme Yield (million m^3/a)	35.0	9.0
Unit Reference Value *	**1.92**	**3.95**

*Calculated using a discount rate of 6% per annum

8.4 POTENTIAL WATER DEMAND CENTRES

The potential water requirement increases (by 2018) that could absorb the additional yield are about:

Swartland and West Coast:	12 million m^3/a
Reduction in latest Yield Estimate:	6 million m^3/a
City of Cape Town:	20 million m^3/a (defined by pipeline capacity)
Water requirement increase by 2018:	38 million m^3/a

This indicates that there will be sufficient demand to utilize the additional yield that may become available from this scheme, without augmenting the pipeline capacity to Cape Town.

If any of the Michell's Pass diversion options, as well as either of the Voëlvlei options appear favourable for more detailed assessment in this Study, then it will be necessary in the subsequent phase of the Study to assess these options in an integrated manner. This is necessary in order to determine the phasing of options, the possible replacement of the Cape Town pipeline, and the overall additional yield to the system, which will not be the same as the sum of each of the potential individual schemes.

8.5 POTENTIAL IMPACTS

The following environmental issues associated with the potential subsequent phases of the Augmentation of Voëlvlei Dam were identified:

- **Socio Economic**
  - If the abstraction of surplus winter water from the Berg River does not impede irrigation activities downstream, this option should not have significant negative impacts.
  - May have a negative impact on recreational activities (e.g. canoeists/Voëlvlei Yacht Club) during the construction period.
  - The existing pipeline to Cape Town would require about R700 million to replace. The CCT is currently operating and managing this adequately but the infrastructure is old and operational and maintenance challenges are common.

- **Fauna and Flora**
  - The vegetation in the areas to be effected by the pipeline route from the Berg River, the settling facility, and the increased inundation area of the raised dam would require a botanical assessment.
  - Rehabilitation of certain areas would be required.
  - The endangered Geometric Tortoise, whose habitat is threatened, is found within the adjacent Voëlvlei Nature Reserve.
  - The water quality in Voëlvlei Dam is a critical consideration in terms of how the system will be operated and how it could be rehabilitated into its former clear water state. This is described in more detail in the specialist water quality report (see Error! Reference source not found.).
  - There is currently no monitoring of the low flows into the Berg River Estuary, although DWA have undertaken an investigation into possible sites for a low flow gauge upstream of the estuary.

- **Heritage**
  - Future EIA process will have to address the disturbance of archaeological sites on the shale derived soils of the Berg River Valley.
  - It will also be necessary to gather baseline information on the built environment.

8.6 POTENTIAL ADVANTAGES

- This option incorporates existing infrastructure (Voëlvlei Dam, the CCT's WTW, and the existing pipeline to Cape Town).
- The CCT and the West Coast could be supplied from the scheme.
- The proposed rising main from the Berg River could be used as a gravity pipeline during summer to make releases from Voëlvlei Dam, presently made via the existing outlet canal which experiences significant losses.

9. FURTHER PHASES OF THE PALMIET TRANSFER SCHEME

9.1 SCHEME DESCRIPTION

The potential of raising either the Upper or the Lower Steenbras Dam has been considered. However from an environmental, financial, technical and integration perspective, it became clear during initial assessments that raising the Lower Steenbras Dam was much more feasible. The primary reasons for this are:

- Extensive earthworks and a very long crest would be required to raise the upper dam.
- The CCT has indicated that the disruption to the existing water supply would be significantly more severe if the upper dam were to be raised.
- The proposed N2 toll road (being implemented by the South African National Roads Agency Limited (SANRAL)) would require relocation if the upper dam were raised. The costs associated with the relocation will need to be considered within current planning by SANRAL of a possible new road alignment as part of a potential toll road. Assuming that does not go ahead, then the costs for realignment of the N2 may need to be borne by the dam raising project.
- The existing Steenbras Pumped Storage Scheme which operates out of the upper dam would require extensive civil, mechanical and electrical alternations.

The two options assessed with regards to the raising of the Lower Steenbras Dam are as described hereafter.

9.1.1 Dam Raising and Optimization of Palmiet River Abstractions

This option involves increasing the winter abstractions from the Palmiet River (via the existing Palmiet Pumped Storage Scheme), but within the EWR requirements. Currently, in most years, the existing licensed abstraction cannot be realized due to the lack of spare storage capacity in the Steenbras Dams, and associated risk of spilling. During winter, the demand on the system is at its lowest, and as such the draw-down is limited which in turn limits the storage becoming available to receive the Palmiet transfers.

Raising the existing Lower Steenbras Dam by about 20 m would create a Fully Supply level equal to that of the existing upper dam (370 masl). **Figure 9.1** shows a plan view of the footprint of a potential rockfill embankment structure (Lower Steenbras Dam) and **Figure 9.2** shows the embankment cross section and possible spillway configuration. **Figure 9.3** shows the Full Supply Area of a Greater Steenbras Dam resulting from a 20m raising of the lower dam. This would increase the storage capacity by about 120 million m^3. The proposed scheme would rely on optimizing the transfers from the Palmiet Pumped Storage Scheme, as well as the utilization of runoff into the dam from within its own catchment area. If the WCWSS is operated in a balanced manner, then this additional storage at Steenbras will enable increased supply from the system, through reducing the risk of spilling at other dams, such as Wemmershoek and the Berg River Dam.

Both rockfill embankment and rollcrete dam design options have been considered (refer to specialist report in Error! Reference source not found. and Error! Reference source not found.). The latter proved to be more than 20% more expensive. As such, a rockfill embankment option involving use of excavated quartzitic sandstone of the TMG, and excavated clay from Bokkeveld shales found in the upstream reservoir basin has been proposed.

A pumpstation and rising main would have to be constructed close to the drawn down headwaters of the raised Lower Steenbras Dam in order to deliver the water into the Upper Dam. These costs have been allowed for in the financial assessment.

Figure 9.1 Plan Layout of Potential Rockfill Dam, Saddle Dam and Spillway

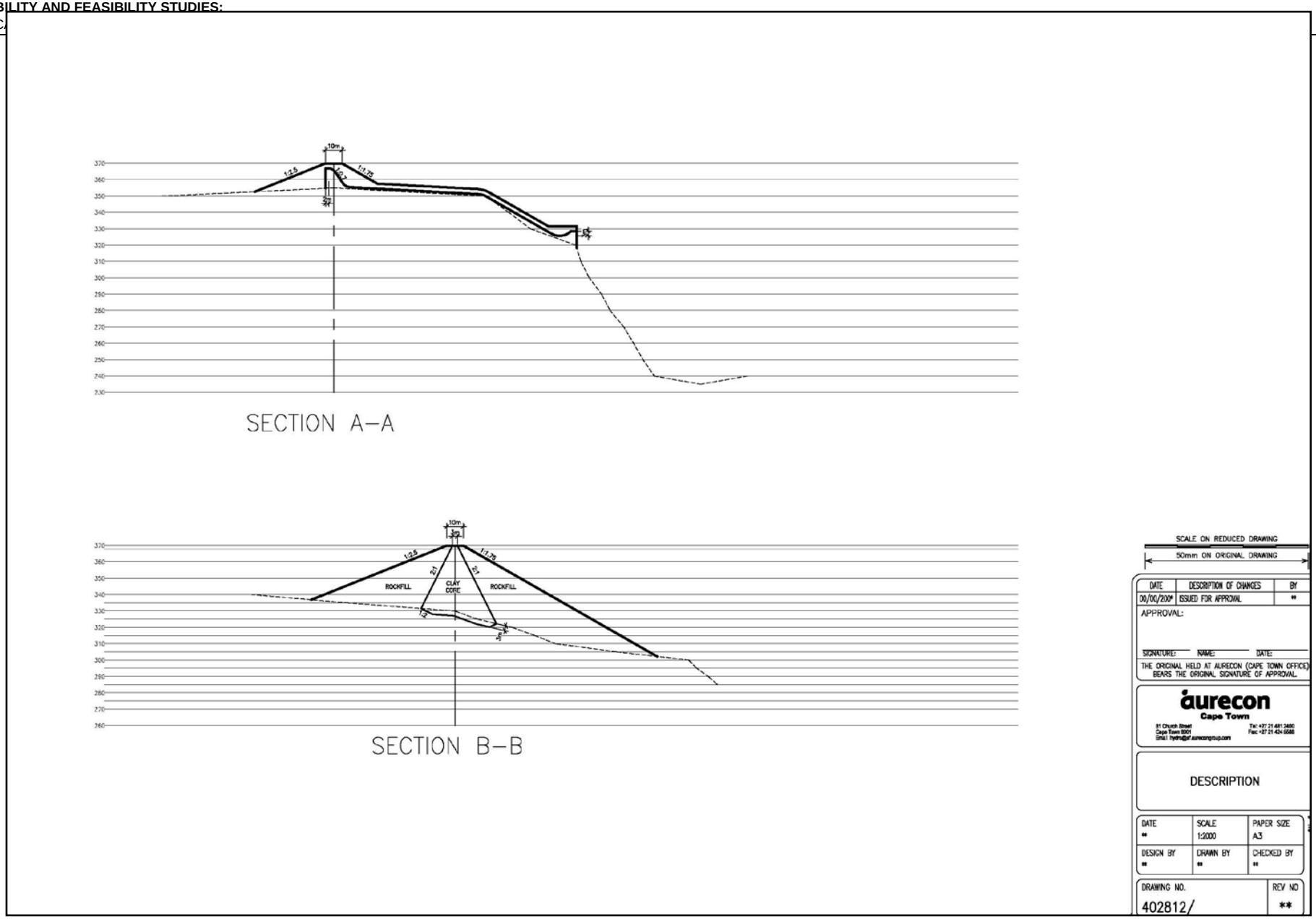

Figure 9.2 Possible Spillway Sections

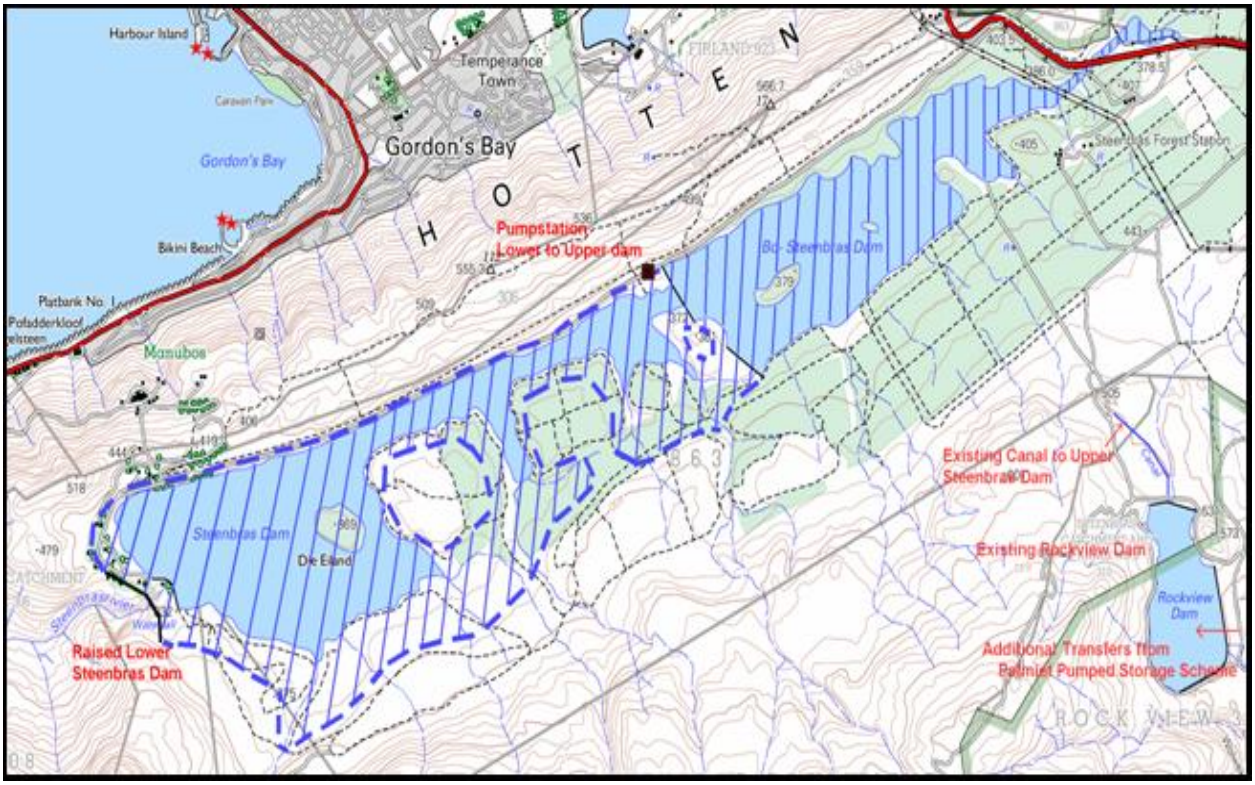

Figure 9.3 The Full Supply Footprint Area of a Raised Lower Steenbras Dam

The likely implementation time frame for the raising of the Lower Steenbras Dam is as indicated in **Figure 9.4**.

RAISING LOWER STEENBRAS DAM	YEARS											
	1	2	3	4	5	6	7	8	9	10	11	12
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2019
PHASE 1: PRELIMINARY STUDY AND RESERVE DETERMINATIONS												
PHASE 2: FEASIBILITY STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT												
PHASE 3: IMPLEMENTATION												
Lag Time (Possible Budget Delay)												
Prepare Terms of Reference and Appoint PSP												
DWAF Licence Consideration												
DEA&DP Approval Process												
Design, Tender Preparation and Award												
Construction and Implementation												
Commissioning and bring on-line												

Figure 9.4 Lower Steenbras Dam Time Frame

9.1.2 Alternative with Campanula Dam

The option of a 45 m high dam at Campanula on the lower Palmiet River has, in various previous studies, been red-flagged as a non-starter. This is reflected in the fact that it no longer appears as an option within the Western Cape Reconciliation Strategy. The scheme was however included in the TOR for this Study. As such it has been assessed. The results are presented for completeness, but this option will not be considered as part of the Feasibility Study, even if the raising of Lower Steenbras Dam proves favourable for further consideration.

The potential further development of the Palmiet transfer scheme involves the possible construction of an earth embankment dam on the Palmiet River at the Campanula site, in close proximity to the existing DWA gauging station. This dam would be approximately 45m high and would inundate irrigated orchards

and potentially irrigable lands which have yet to be developed. The dam's construction would impact on the area towards the northern boundary of the Kogelberg Biosphere Reserve.

The Campanula Dam would need to be equipped with an appropriate environmental release structure and could function in one of two ways.

- Firstly it could serve to supply the required EWR to the Palmiet Estuary, whilst the abstractions from the middle Palmiet River are fully maximized (beyond the requirements of the EWR).
- Alternatively, a pipeline and pumpstation would deliver water from the Campanula Dam into the Kogelberg Dam, and then via the Palmiet Pumped Storage Scheme into the Greater Steenbras Dam.

Figure 9.5 shows the layout of the potential transfer scheme from a possible 45m high Campanula Dam.

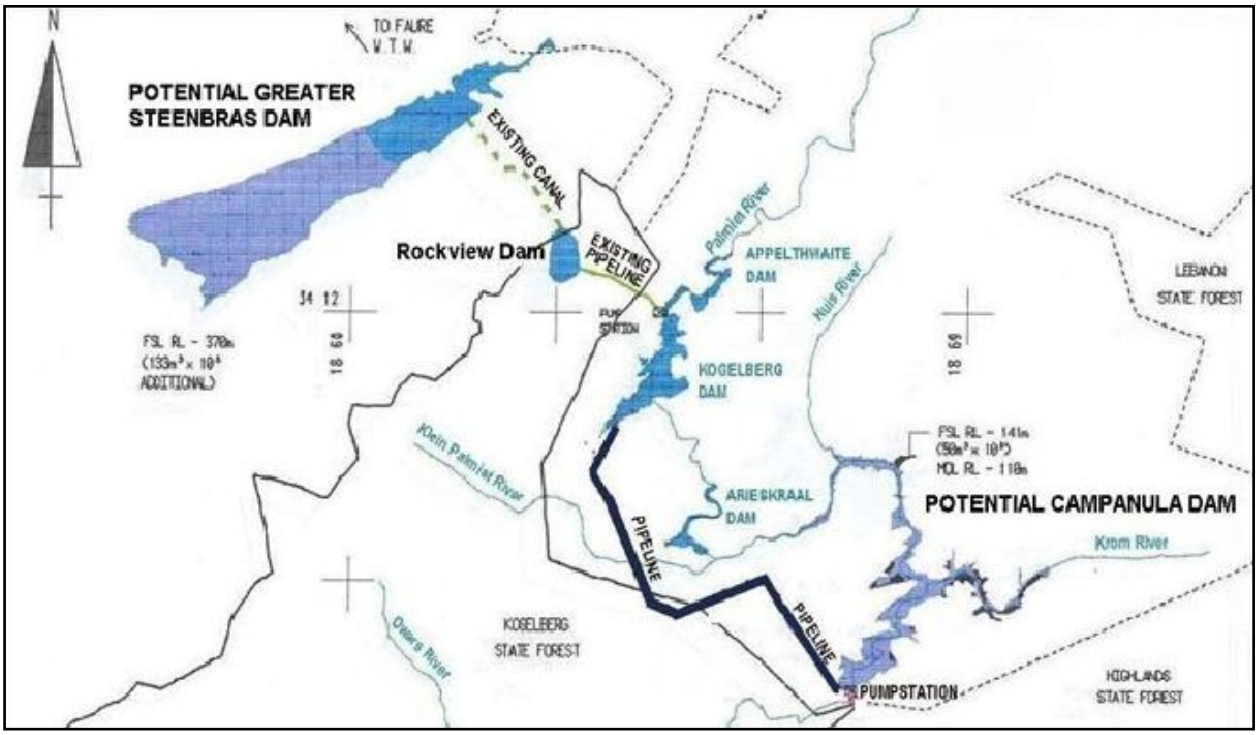

Figure 9.5 Transfers from the Potential Campanula Dam

The likely extent of the resulting upstream inundation is shown on **Figure 9.6**.

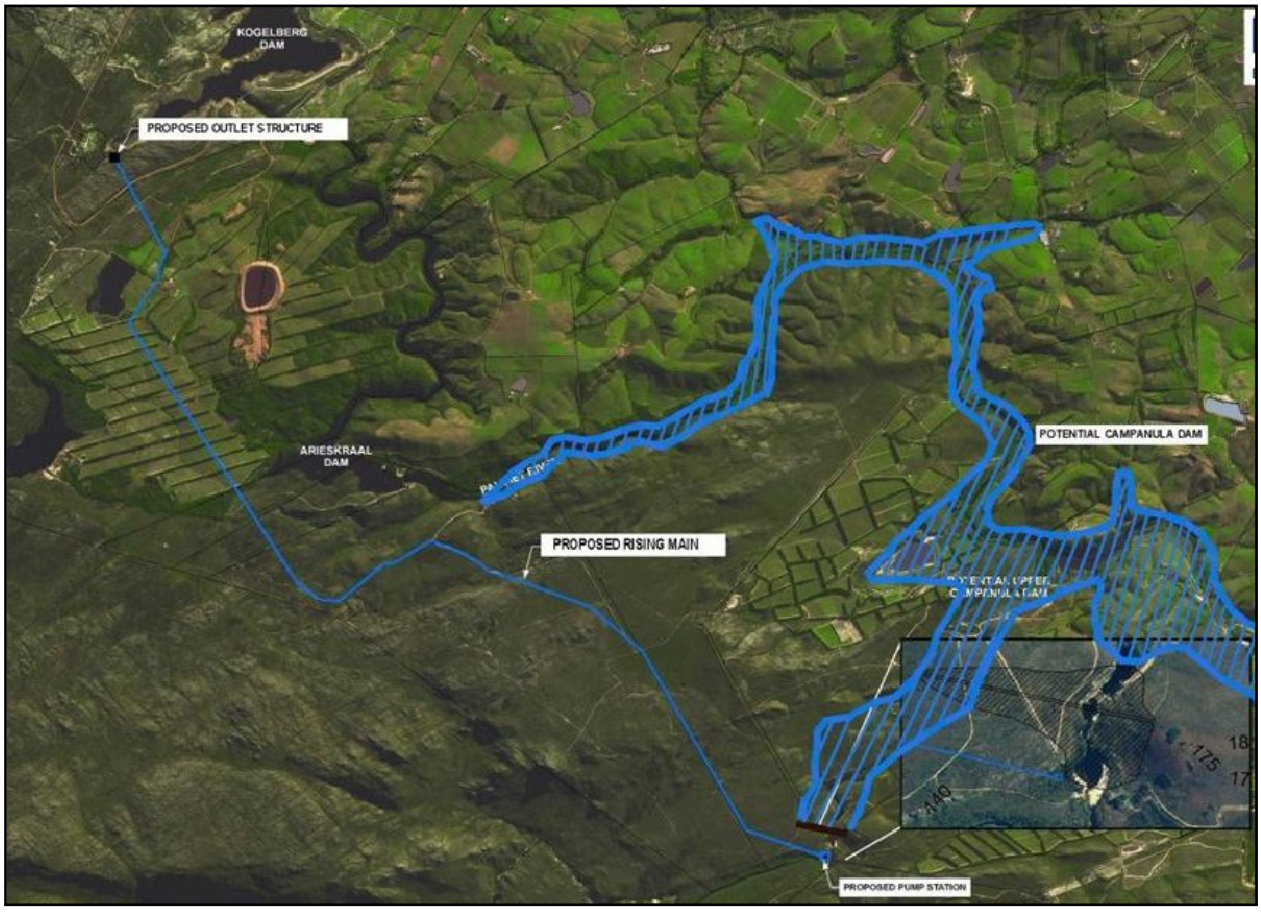

Figure 9.6 Inundation Impact of the Potential Campanula Dam

9.2 YIELD

The yield estimates have been determined as follows:

- Raised Lower Steenbras Dam and increased abstraction from the Palmiet River: 23 million m^3/a
- Add Campanula Dam (additional 10 million m^3/a): 33 million m^3/a.

9.3 FINANCIAL ASSESSMENT

The financial assessment for the raising of the Lower Steenbras Dam is shown in **Table 9.1**. The incremental effect of the Campanula Dam on its own is also indicated.

Table 9.1 Unit reference values (Further Phases – Palmiet Transfers)

Item	Palmiet Development Options		
	Raise Lower Steenbras Dam	Raise Lower Steenbras & Campanula	Incremental Campanlua
Total Capital Cost (R million)	784.1	1228.3	444.2
Annual Operating Cost (R million)	16.4	25.8	9.5
Net Present Value (R million)	808.3	1278.0	465.6
Scheme Yield (million m^3/a)	23.0	33.0	10.0
Unit Reference Value *	**3.48**	**4.10**	**4.84**

*Calculated using a discount rate of 6% per annum

The incremental URV is relatively high due to the fairly high capital cost associated with a relatively small increase in yield (10 million m^3/a).

9.4 POTENTIAL WATER DEMAND CENTRES

The potential areas of supply would be the CCT. Water becoming available from this scheme would be transferred to the CCT's Faure WTW. The existing raw water pipeline to Faure has adequate spare capacity to deliver the water becoming available from these options.

9.5 POTENTIAL IMPACTS

The following environmental issues associated with the potential further development of the Palmiet transfers have been identified:

- **Socio Economic**
  - For the potential raising of Lower Steenbras Dam, there will be no impact on irrigated agriculture.
  - The potential Campanula Dam would inundate some existing irrigated orchards and would significantly impact on the expansion of irrigation farming.
  - The potential Campanula Dam is likely to invoke very strong resistance from landowners and the general public due to its location with regards to the Kogelberg Biosphere and Palmiet River.
  - If the Campanula option were to be considered further, then it is recommended that a socio-economic assessment be undertaken to address issues that may delay the Environmental Impact Assessment (EIA) process and/or result in appeals.

- **Fauna and Flora**
  - Critically Endangered Elgin Shale Fynbos, including wetland communities, will be inundated.
  - Wetlands at the Lower Steenbras Dam are recognized as habitats of very high importance for the endangered Bokkeveld Shale Fynbos.
  - Conveyance infrastructure associated with the Campanula option would transverse through a portion of the Kogelberg Biosphere and segregate that portion from the rest of the core area, with negative impacts on critically endangered vegetation, of national importance.

- **Heritage**
  - Raising of Lower Steenbras Dam will result in the potential destruction of the historic dam wall (which was raised in 1954), a number of historic buildings, associated structures and cultivated landscape.
  - A full heritage impact assessment will be required. This will need to include the built environment, landscape, archaeology, paleontology.
  - The construction of a dam at Campanula is unlikely to have serious heritage implications.

9.6 POTENTIAL ADVANTAGES

- The options incorporate existing infrastructure namely Upper Steenbras Dam, the Palmiet Pumped Storage Scheme, and the existing pipeline to Faure Water Treatment Works.
- Increased storage in a Greater Steenbras Dam introduces improved flexibility in operation of the WCWSS as a whole and reduced risk in spillage from other sources.

10. GENERAL PUBLIC ENGAGEMENT DURING PHASE 1

10.1 PRELIMINARY PUBLIC NOTIFICATION OF THE STUDY

The public participation process was undertaken in both Afrikaans and English to accommodate the predominant language preferences of the local communities. The public database developed during the WCWSS Reconciliation Study was also used to notify the broader public of the commencement of the study. This database was updated and maintained throughout the study. Newspaper adverts were placed in the following newspapers:

- Die Burger: 14 February 2009
- Paarl Post: 19 February 2009
- Witzenberg Herald: 19 February 2009
- Overstrand Herald: 20 February 2009
- Weekend Argus: 14 & 15 February 2009
- Worcester Standard: 19 February 2010
- Caledon Kontreinuus: 20 February 2009

Letters of notification were sent to relevant authorities including the:

- Department of Agriculture (Western Cape);
- Department of Environmental Affairs and Tourism;
- Western Cape Department of Environmental Affairs and Development Planning;
- Department of Transport and Public Works;
- Heritage Western Cape;
- Department of Local Government and Housing;
- Eskom;
- Cape Nature; and
- Potentially affected municipalities.

Notification was also specifically addressed to the Berg and Breede CMA Reference Groups and Water User Associations of the Berg and Breede WMAs.

10.2 PHASE 1 PUBLIC MEETINGS (4 MEETINGS)

The first two public meetings were held at the beginning of Phase 1 in two different geographic centres, namely Worcester and Grabouw, as these locations are in reasonably close proximity to the potential schemes. During these meetings the Project was introduced and preliminary public comment was obtained on the schemes. Minutes of the meetings are attached in Appendix 10.

At the end of Phase 1 (December 2010) a second round of public meetings was held in Worcester and Grabouw to present the findings and recommendations to the public. These included the proposed selection of schemes to be studied at Feasibility level during Phase 2 of this study, as well as the way forward for the rest of the study. These meetings also provided a foundation for public engagement and preliminary input to the design stage, which would commence at the start of Phase 2.

As the overall project spans a long period, the opportunity to engage with the Further Phases will again be advertised. This advertising will be aimed only at newspapers (Phase 1 newspapers) which serve the areas directly affected by the schemes being studied, including three additional local newspapers identified during a public meeting in March 2009, i.e.:

- District Mail
- Grabouw Herald
- Overberg Venster

11. PRIORITIZATION PROCESS

11.1 PRIORITISATION PROCESS

The Prioritization Workshop took place on 25 March 2010 at Nelson's Creek outside Wellington to conclude the Preliminary Phase of this Study. The purpose of the Prioritisation Workshop was to discuss and critically evaluate a suite of technical and environmental criteria for each Scheme[1], thereby assisting in identifying which of the six schemes should be further investigated to feasibility level during the second Phase of this Study.

Participants were invited based on the objective of the workshop to involve a small group of persons, able to provide technical water resource planning inputs to the process, whilst ensuring that the interests of both the Berg and Breede WMAs were represented. The wider stakeholder group was involved during the subsequent Stakeholder Committee meeting that took place on 15 April 2010 where the outcomes of the workshop were presented for discussion (Refer to Annexure 11)[2].

11.1.1 OBJECTIVES OF THE PRIORITIZATION WORKSHOP

The objectives of the workshop were to:

- Present and discuss the findings of the Preliminary Assessment Phase;
- Present latest information on each option to allow for an apples-for-apples comparison;
- Prioritise which option/s should be further investigated in this Study and to what level of detail; and
- Augment the existing information with specialist inputs from the DWA and other key stakeholders.

Some aspects that were considered during the evaluation of the options:

- The importance of additional storage for the Western Cape System;
- The scarcity of remaining surface water development options as a source in the Western Cape;
- The timing and implementation of a scheme;
- The ability of the existing infrastructure to accommodate the additional yields; and
- The water demand centres that could be supplied from the additional water becoming available.

11.1.2 STARTER DOCUMENT AND PRIORITISATION TABLE

A Starter Document was provided to all members of the technical team and provided a summary of the background information for each Scheme to familiarise themselves with this Study and its objectives. A table containing the various technical and environmental criteria was also distributed among the specialists (agricultural economics, botany, freshwater ecology and heritage) to complete prior to the workshop and to provide motivations for their ratings which were debated during the workshop.

[1] It is relevant to note that it had previously been agreed with DWA that the workshop would not follow a formal multi-criteria decision analysis approach but would be based on a simplified rating system which had been used previously on other similar studies.
[2] During the initial Stakeholder Committee meeting it was requested that farmer unions should also be invited to serve on the Committee. Based on this request, invitations were mailed to farmer unions identified by the Western Cape Department of Agriculture on 16 November 2009.

11.1.3 CRITERIA FOR EVALUATION OF OPTIONS

The screening of options was based on a number of proposed technical and environmental variables captured in a matrix format.

A four-point scale was used to evaluate all options in terms of the following variables:

- Yield and cost;
- Technical considerations (URV, integration into the water supply system and ecological water requirements); and
- Environmental impacts (inundated aquatic environment, interbasin species transfer, impact on irrigation users, loss of arable land, expropriation costs, impact on indigenous vegetation, heritage resources and likelihood of public opposition).

Workshop participants rated each of the above variables using the following scale as follows:

Low Impact/ Low Cost	Medium Impact/ Medium Cost	High Impact/ High Cost	Very High Impact/ Very High Cost
1	**2**	**3**	**4**

During the workshop, the Prioritisation Table was presented with the initial ratings made by the technical team. Each criterion was debated and some received a revised rating based on the participants' consensus. All information was captured in matrix and key reasons for the ratings decided on were included (refer to Annexure11). In addition, the following changes were made to the table:

- Exclusion of Yield, Cost, Downstream Aquatic Environment and Expropriation Cost as separate criteria i.e. these were subsumed into other criteria);
- Dividing of the Michell's Pass Diversion Scheme into two options according to the potential yields considered;
- Renaming of:
    - Integration into Water Supply System **to** Integration into Water Supply System / Operational Aspects;
    - Ecological Water Requirements **to** Compromising Basin Wide EWR;
    - Impact on Irrigation Users **to** Impact on Potential Downstream Irrigation; and
    - Loss of Arable Land **to** Impact of Loss of Arable Land.

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11.2 SUMMARY OF PRIORITIZATION PROCESS

Table 11.1 provides a summary of the rating outcomes of the Prioritization Process.

Table 11.1 Rating Outcomes of the Prioritization Process

Colour Rating Index	Low Impact/ Low Cost 1		Medium Impact/ Medium Cost 2		High Impact/ High Cost 3		Very High Impact/ Very High Cost 4	

Scheme	Technical Considerations			Environmental Impacts						
	Unit Reference Value (R/m^3)	Integration into Water Supply System / Operational Aspects	Compromising Basin Wide EWR	Inundated Aquatic Environment	Interbasin Species Transfer	Impact on Potential Downstream Irrigation	Impact of Loss of Arable Land	Impact on Indigenous Vegetation	Heritage Resources	Likelihood of Public Opposition
Michell's Pass Diversion (8 m^3/s)	1	1	3	2	3	4	2	1	1	3
Michell's Pass Diversion (3 m^3/s -5 m^3/s)	1	1	2	2	3	2	2	1	1	2
Upper Wit River Diversion	4	2	2	3	3	2	3	3	3	2
Molenaars Diversion	4	4	2	2	2	2	2	3	1	3
Molenaars Alternative (Elandspad)	4	2	2	3	2	2	2	4	2	3
Voëlvlei Dam: Phase 1	1	2	1	1	1	2	2	1	1	1
Voëlvlei Dam: Further Phases	2	1	1	2	1	2	2	2	2	2
Palmiet Development: Raise Lower Steenbras Dam (20m)	2	1	2	1	1	1	1	4	3	3
Palmiet Development: Adding Campanula Dam (45m)	3	3	4	3	1	1	4	4	2	4

The combined scores for each scheme are shown in **Table 11.2**, where the options are presented in order of most-preferred to least-preferred for further investigation.

Table 11.2 Prioritisation of Schemes for Further Investigation

	Scheme	Combined Score
1	Voëlvlei Dam Phase 1	13
2	Michell's Pass Diversion (3 m^3/s - 5 m^3/s)	17
3	Voëlvlei Dam Further Phases	18
4	Palmiet Development: Raised Lower Steenbras Dam	19
5	Michell's Pass Diversion (8 m^3/s)	21
6	Molenaars Diversion	25
7	Molenaars Alternative: Elandspad River	26
8	Upper Wit River Diversion	27
9	Palmiet Development: Adding Campanula Dam	29

The pertinent aspects influencing the scores that have been attributed to the various options and on which the above outcomes are based, are summarised in the conclusions hereafter.

12. CONLUSIONS AND RECOMMENDATIONS

12.1 CONCLUSIONS

12.1.1 Engineering and Financial

All of the **Michell's Pass** and **Voëlvlei Dam** development options proved **very favourable**, with URVs of less than R2/m^3. This is attributed to both sides of the URV calculation, where on the one hand the scheme costs are lower than other options, and on the other, the yields obtained are higher.

The possible raising of **Lower Steenbras Dam** is **relatively capital intensive** (~R780 million) but does offer a reasonable yield (23 million m^3/a) in comparison with the remaining small diversion options, and a resulting URV of R3,5/m^3.

The **Molenaars** and **Upper Wit River** offer relatively **small yields** (maximum 13 million m^3/a) with resulting URVs ranging between R4,5/m^3 and R5,5/m^3.

The **Campanula Dam** only offers a **relatively small** incremental yield of 10 million m^3/a for a **significant capital investment** of about R450 million, with an incremental URV of close to R5/m^3.

The above indicates that from financial and water availability perspective, the development options around Voëlvlei Dam seem to be the most favourable, followed by the possible raising of the Lower Steenbras Dam.

12.1.2 Integration into the Existing Western Cape Water Supply System

With the exception of the Molenaars diversion and Campanula Dam options, integration into the existing Western Cape Water Supply System is relatively uncomplicated for the remaining options. The **Molenaars** is **complicated** by the fact that it is located at a relatively significant distance from the Berg River Dam and that significant pumping (with associated operational challenges) would be required. Similarly, the **Campanula Dam** integration is **challenging** with respect to its location and integration within the Palmiet Pumped Storage Scheme, as well as substantial pumping and related operational requirements in a remote area.

A critical component usually associated with the rating of water resource development options is the timeframe to implementation and the potential to phase the development of the schemes, both in relation to their own components and in relation to one another. This criterion has not been rated as part of the Preliminary Assessment due to the fact that:

- All the diversion schemes will take a similar duration to implement;
- None of the options offer any significant opportunity for phasing;
- The implementation, timing, sequence and integration of potential multiple schemes are not part of the scope of the Preliminary Assessment but will form a key component of the Feasibility Study Phase.

Through the Prioritization Process and associated debate, it has been concluded than an integrated assessment to the phased development of options involving Voëlvlei Dam and Michell's Pass is required in Phase 2 of this Study. It has also been concluded that the Campanula Dam be excluded from any further consideration.

12.1.3 Inundated Aquatic Environment

The Dwars River has largely been modified through extensive engineering and channelization works, as well as agricultural activities. However, the construction of the **Michell's Pass diversion** weir could have significant negative impacts on rare foothill rivers in the area that were recently restored. Furthermore, the impact of diverting water into the Boontjies River was not assessed. Consequently the inundation impact on the aquatic environment was rated as **medium impact** for all diversion rates (8 m^3/s, 5 m^3/s and 3 m^3/s).

The **Wit River Diversion Scheme** would have an impact on the Krom River and on its small tributary which would receive the transferred water at the downstream end of the proposed tunnel. The increased flow would cause incision of the channel and natural habitats would be lost. Furthermore, the indigenous redfin occur within the Krom River. The lower Krom River is in fairly poor condition having being heavily impacted by agricultural activities, erosion and alien vegetation. However, the scheme could also have a positive impact on the Wit River by restoring the summer flow that is currently absent (see adjacent photograph of absent flow downstream of the existing diversion weir). Based on this information, the inundation impact was rated **high impact significance** for this option.

The **Molenaars River** has undergone relatively little modification with ecosystem functions mostly unchanged. This river is considered to be the best condition large foothill river in the Western Cape. There is a fear that the construction of an intake weir would impede the movement of species within the river and as a result have a negative impact on the ecosystem functions of the river. Therefore, the inundation impact of a diversion weir in the Molenaars River was rated as **medium.** The **Elandspad Alternative to the Molenaars Scheme** was rated as having a **High impact** due to the pristine foothill / mountain stream condition of the Elandspad River (see adjacent photograph). This option would not only disturb natural areas but may also impede the movement and distribution of species.

Due to the disturbed nature of the Berg River, no significant additional impacts on the aquatic environment are anticipated for Phase 1 of the Voëlvlei Dam scheme. However, The Further Phases would involve the raising of the dam wall and thus increase the inundation area that includes critically endangered Renosterveld. It was therefore recommended that the inundation area of the Further Phases should be further investigated. Furthermore, it would be very important to monitor the baseflow release to

the Berg River Estuary that is the fourth most important estuary in South Africa to ensure its requirements are met. **Phase 1 and the Further Phases of the Voëlvlei Dam Scheme** were rated as **low and medium** respectively**.**

The raising of the **Lower Steenbras Dam** wall would result in the inundation of wetlands. No additional impacts on the aquatic environment were anticipated and the option received a rating of Low. However, the **Campanula Dam option** would inundate a significant section of the lower Palmiet River. This section of the river is considered to contain very rare Fynbos species and it was therefore decided to rate the inundation impacts for this option as **high impact.**

12.1.4 Interbasin Species Transfer

The **Michell's Pass Scheme** involves the diversion of water from the Breede River system to the Berg River system. The impact of species transfer (flora/seeds, fauna, invertebrates, etc.) on these systems could not yet be quantified and it was noted that small mouth bass were absent at the waterfall. This Scheme was initially rated as having a **high impact** because of possible interbasin species transfer on the Breede and Berg Rivers**.** However, since there is an existing water transfer scheme into the Boontjies River via the existing Artois diversion at the Mitchells Pass site, these impacts will have already occurred, so the net additional resulting impact would be low.

The **Wit River Diversion Scheme** also involves the transfer of water from the Breede River system to the Berg River system. However, it was indicated that the location for this option was critically important to reduce the likelihood of species being transferred between the systems. It was also indicated by CapeNature that a location upstream in the Upper Wit River would be preferable as this would reduce the chance of transferring species into the Berg River, notably avoiding the potential hybridization of the Breede and Berg indigenous Redfin species. This Scheme received a rating of **high impact.**

A precautionary rating of **medium** was allocated to both the **Molenaars Diversion and Elandspad Alternative options** for the transfer of water to the Berg River Dam, despite the occurrence of existing transfers. The impacts associated with these two options could not be quantified and the necessity to investigate the transfer of invertebrates was highlighted.

No impacts with regards to the interbasin transfer of species are associated with the **Voëlvlei Dam options** as this option does not involve the transfer of water between catchments. A rating of **low impact** was thus awarded.

No impacts with regards to interbasin transfer of species are associated with the raising of the Lower **Steenbras Dam as well as the Campanula Dam options** as these options do not involve the transfer of water between catchments. The Campanula Dam option would however involve the transfer of water from the Palmiet River to the Steenbras Dam. A **rating of low impact** was thus awarded to both options.

12.1.5 Impact on Potential Downstream Irrigation

The diversion of water from the Dwars River would have a negative impact on the existing and future irrigation developments in the Breede River Valley, despite additional pumping to the Brandvlei Dam. Immediately downstream of the proposed scheme is the existing **Artois Irrigation Scheme**, currently reliant on diversions from the Dwars River into the Artois canal (see adjacent photograph). Ensuring ongoing supply to these irrigators (in accordance with their lawful use) will be a pre-requisite.

The National Water Act, 1998 (Act No. 36 of 1998) legally requires all schemes to meet the EWR of the entire system involved. It would thus be necessary to take into consideration the interaction among schemes in the same system, as well as the impact on tributaries of the Breede River. In order to fully quantify this impact, it was recommended to conduct a cost-benefit analysis. Based on these considerations, the **Michell's Pass Diversion Scheme** received a rating of **very high** and **medium** for the **8 m^3/s** and **3 m^3/s to 5 m^3/s abstraction options** respectively.

The **Upper Wit River Diversion Scheme** would reduce the availability of water for potential downstream irrigation schemes in both the Berg and Breede Rivers. This impact would however need to be investigated via a cost-benefit analysis. One option to reduce the impact on irrigation would be to store summer flow in a dam since water would also be taken away from Gawie-se-Water. The Upper Wit River Diversion therefore received a rating of **medium impact.**

The **Molenaars Diversion** and alternative option would have a negative impact on the yield of the Brandvlei Dam and thus potential downstream irrigation. It would thus be necessary to conduct a cost-benefit analysis that takes into consideration additional pumping required for the Brandvlei Dam. Therefore, a rating of **medium** was allocated to both options.

The **Voëlvlei Dam** requires winter flushes to improve its water quality and to clean the dam. The quality of the water released would thus be of great importance. Furthermore, this Scheme could result in the loss / reduction of winter water abstraction and storage thereof downstream for summer irrigation. Proper management would therefore be extremely important for this Scheme to function optimally with minimal impact on irrigation users. A rating of **medium impact** was thus decided upon.

The **Steenbras Dam** does not supply water for irrigation purposes and is thus not applicable to this impact. Therefore a rating of l**ow impact** was awarded. The **Campanula Dam** option would inundate existing apple orchards and vineyards located adjacent to the river. The extent of the inundation area is shown schematically on **Figure 12.1**, for a range of potential full supply levels. This potential dam would have a **low impact** on potential downstream irrigation.

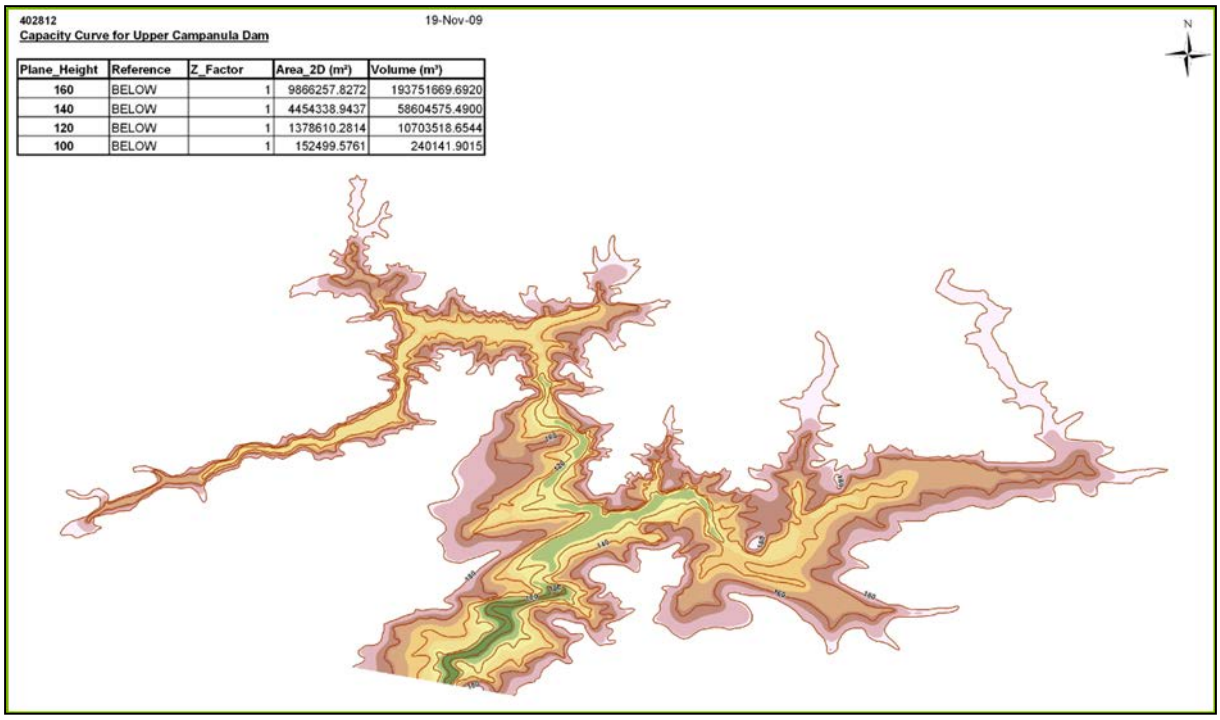

Figure 12.1 Potential Inundation Areas for the Proposed Campanula Dam

12.1.6 Impact of Loss of Arable Land

A servitude and permanent maintenance access road would be required for a section of the **Michell's Pass Diversion** pipeline. Farming activities in the area may range from year-cropping (e.g. vegetables) to perennial-cropping (e.g. orchards and vineyards). The area impacted would however be limited and a rating of **medium impact** was thus agreed upon.

The **Upper Wit River Diversion** would result in the inundation of the Riverlands Farm. Currently the property is being used for horse breeding, whereas the surrounding land use consists of intensive crop production. It would thus be necessary to determine the suitability of the soils for intensive crop production as well as the availability of irrigation water to determine the exact impact of this scheme on the loss of arable land. Based on the above, the impact of this scheme was rated as **high**.

The **Molenaars Diversion** and alternative option would not result in the loss of arable land. However, as mentioned in 13.2.3 this scheme would impact on the availability of water for potential downstream irrigation. Therefore a rating of **medium** impact was agreed upon.

Phase 1 of the **Voëlvlei Dam Scheme** would require a limited area for the construction of a pipeline servitude, settling dam and pump station. The Further Phases on the other hand would inundate approximately 50 ha of arable land with a low agricultural potential. Therefore both options received a rating of **medium impact**.

The raising of the **Lower Steenbras Dam** would not result in the loss of arable land as the area that would be inundated is not used for any agricultural or forestry activities. A rating of **low impact** was thus allocated. The construction of a dam at **Campanula** would inundate an area of approximately 415 ha of which 120 ha is estimated to be of existing apple orchards and vineyards. This option therefore received an impact rating of **very high**.

12.1.7 Impact on Indigenous Vegetation

The pipeline route for the **Michell's Pass Diversion** would be critical as it could potentially cut through Breede Alluvium Fynbos (endangered), Breede Shale Renosterveld (vulnerable) and Breede Shale Fynbos (vulnerable). An assessment of the vegetation would thus be required to determine the presence and densities of any Red Data Book flora and the pipeline route could be aligned to avoid sensitive areas. This scheme was therefore rated as having a **low impact**.

The proposed canal from the Krom River tributary and Riverlands Dam for the **Upper Wit River Diversion** would most likely be constructed through Swartland Shale Renosterveld (critically endangered), Boland Granite Fynbos (endangered), Cape Winelands Shale Fynbos (endangered) and North Hex Sandstone Fynbos (least threatened) which contains Red Data Book flora. Furthermore, a vegetation assessment and evaluation of the Kromme River tributary would be required to determine the effect of the raised and changed flow levels on the Fynbos and riparian vegetation, as well as some wetlands occurring en route, as well as the downstream environment. The scheme was rated as having a **high impact**.

The **Molenaars Diversion Scheme** has the potential to impact on riparian wetlands, Swartland Alluvium Fynbos (critically endangered), Boland Granite Fynbos (endangered), Hawequas Sandstone Fynbos (least threatened) and Western Coastal Shale Band Fynbos (least threatened). It is therefore recommended that the pipeline route should be critically assessed as it has the potential to impact on the above mentioned endangered vegetation and Red Data Book flora, especially with regards to the proposed weir on the Elandspad River. The options were rated as **high** and **very high** for the **Molenaars Diversion** and **Elandspad Alternative** respectively.

The vegetation in the areas to be effected by the pipeline route from the Berg River and the extension of the treatment works for the **Voëlvlei Dam phases** would require a botanical assessment as the literature does not contain adequate site-specific information outside the Voëlvlei Nature Reserve. Furthermore, the Further Phases would result in the loss of about 50 hectares of Critically Endangered Swartland Shale Renosterveld that is of a very good quality and the habitat of the endangered Geometric Tortoise. It is thus most likely that threatened Red Data Book flora and fauna would be present in the inundated areas. Therefore the impacts of the two phases were rated as **low** and **medium** respectively.

Critically Endangered Elgin Shale Fynbos, including wetland communities, will be inundated by the proposed raising of the **Lower Steenbras Dam**. The proposed pipeline from the Palmiet River to the raised Lower Steenbras Dam would sever a section of the internationally important and renowned Kogelberg Biosphere. In addition the area surrounding the Upper and Lower Steenbras Dams has received the highest rating (CBA1) of the City of Cape Town's Biodiversity Network Plan. Some areas supporting undisturbed natural Kogelberg Sandstone Fynbos and some disturbed Fynbos riparian vegetation will also be damaged or lost for both Scheme options. Furthermore, it is highly likely that threatened Red Data Book plant species would be present in the areas affected by the options. This will

have to be assessed on site beforehand as the literature does not contain adequate site specific information via monthly collection visits over a full year (preferable) to collect adequate information about species present in the affected areas. Furthermore, the proposed pipeline and servitude for the Campanula Dam option would have a massive impact on the indigenous vegetation and Kogelberg Biosphere. Both options were rated as having a **very high impact**. These ratings would stay the same even should the pipeline from the Palmiet River to the Lower Steenbras Dam not be constructed.

12.1.8 Heritage Resources

There is a possibility of San Rock Painting and open scatters on the river bank and valley of the Dwars River, as well as ephemeral Late Stone Age material in the ploughed fields of the Tulbach Valley. No built environment elements are found in the landscape, however the area is of scenic significance. The cultural landscape elements of the Tulbach Valley are important and residents of the area are highly sensitized to heritage issues. Any Heritage Impact Assessment (HIA) for this area must take into cognizance the visual and landscape impacts of any development in the area. Thus, any future EIA process will have to take into consideration the possibility of inundation of San Rock Paintings and the disturbance of archaeological sites, as well as the sensitive qualities of the Tulbach Valley cultural landscape. The options for the **Michell's Pass Diversion Scheme** were rated as having a **low impact**.

The **Wit River Diversion Scheme** is located in an area that is contextually sensitive and would require the consideration of heritage issues in the overall design. The site is also located in close proximity to the historic Bains Kloof Pass as well as the Gawie-se-Water transfer scheme (see adjacent photograph) which is of local heritage significance. Furthermore the Doolhof Farm, which is adjacent to the Riverlands Farm, is an historic site. Any development proposals will need to be accompanied by a thorough Heritage Impact Assessment that considers cultural landscape issues, industrial archaeology, historical archaeology, palaeontology, built environment and intangible heritage. Furthermore, the local heritage authority is likely to request restrictions and strict conditions to development activities in the area. This scheme was rated as having a **high impact.**

Previous surveys of the **Molenaars** Valley in the Du Toits Kloof Mountains indicate that the area is rich in San rock art with paintings occurring in unlikely places such as on the sides of large boulders. The proposed weir infrastructure is unlikely to impact San rock painting sites as the Scheme will not raise the water level. This will however need to be verified through a field survey. The pipeline route to the Berg River Dam will need to be subjected to a full Heritage Impact Assessment (HIA) and may increase the **low impact** rating it received. The **Elandspad Alternative** was rated as having a **medium impact** due to rock shelters with San art that is located close to the river.

The **Voëlvlei Dam phases** have a good chance to impact on disturbed scatters of Early and Middle Stone Age material as well as ephemeral potential Khoekhoen sites. Environmental Impact Assessments will have to address the disturbance of archaeological sites (especially Early and Middle Stone Age sites as well as ephemeral Khoekhoen sites). It will also be necessary to gather baseline information on the built environment. The Voëlvlei Dam phases were rated as having a **low and medium impact respectively** due to the uncertainty of the location of archaeological sites in the Berg River Valley.

The raising of the **Lower Steenbras Dam** will inundate and possibly destroy the historic dam wall (see adjacent photograph) that was built in 1921, a number of historic buildings and associated structures, as well as the cultivated landscape that is legally protected by the National Heritage Resources Act, 1999 (Act No. 25 of 1999) (NHRA). A full HIA will therefore be required. This will include the assessment of the built environment, the landscape, an archaeological study and palaeontology.

No heritage sites have been documented for the area impacted by the Campanula Dam.

However the impact on the natural heritage landscape that is also protected in terms of the NHRA is of concern for this option. These options received a rating of **high** and **medium (precautionary) impact** respectively.

12.1.9 Likelihood of Public Opposition

The likelihood of public opposition for the **Michell's Pass Diversion** will depend on the yield as well as the local communities' perception of the Scheme. The cultural landscape elements of the Tulbach Valley are important, especially as a recreational area, and residents of the area are highly sensitized to heritage issues. Public opposition is very likely should the Reserve, including estuary requirements not be fully met. Furthermore, farmers have been known to strongly oppose water transfer schemes in the area. This Scheme was rated as having a **high impact for the 8 m^3/s option, and a medium impact for the 3 m^3/s to 5 m^3/s options**.

The original **Upper Wit River Scheme** proposed entailed the inundation of the historic Doolhof wine farm. This would have resulted in the displacement of farm workers, unemployment, loss of historic buildings, etc. and generate strong public opposition. However, a field trip in March 2009 revealed the adjacent farm, Riverlands, would be a more suitable site with less environmental impacts. It was also found that the perennial Upper Wit River had no summer flow and the possibility exists that this Scheme could re-instate summer flows in the river. Should this be the case, the Scheme would most likely have the support of CapeNature and fly-fishermen. This Scheme was rated as having a **medium impact**.

The Molenaars River system has a high aesthetic and ecological value and is also considered to be one of South Africa's prime trout fishing rivers. It is highly likely that fly-fishers, a powerful stakeholder group in South Africa, would oppose the construction of a weir in both the Molenaars and Elandspad Rivers should the weir have a negative impact on the trout. It is thus recommended to critically look at the impacts of any infrastructure in the rivers that could impede the movement of faunal species. Both the **Molenaars Diversion and Elandspad Alternative** were rated as having a **high impact**.

It is most likely that Phase 1 of the Voëlvlei Dam Scheme would not generate public opposition as this option involves already disturbed areas. However, should the pipeline route and/or the inundated area (Further Phases) impact on the critically endangered Renosterveld, strong opposition can be expected from CapeNature as well as the public. It is also likely that recreational canoeist would oppose the construction of a weir in the Berg River that is very popular among canoeists for its yearly canoe

marathon. Based on the above, **Phase 1 and the Further Phases received a rating of low and medium impact** respectively.

Both the Palmiet Development Options (raising of the **Lower Steenbras Dam and the Campanula Dam**) are likely to generate strong public opposition. The City of Cape Town has put in place very strict biodiversity plans to protect endangered vegetation and wetlands and would strongly oppose the raising of the Lower Steenbras Dam that would inundate the critically endangered Elgin Shale Fynbos as well as wetlands. Furthermore, any development impacting on the internationally important and renowned Kogelberg Biosphere would also be strongly opposed by numerous organisations such as CapeNature as well as the public. In addition, landowners have already indicated they would strongly oppose the Campanula Dam option or any other option that would impact on the Kogelberg Biosphere. Therefore, the raising of the Lower Steenbras Dam and Campanula Dam options received a rating of **high and very high** respectively.

12.2 RECOMMENDATIONS

Based on the discussions, specialist inputs, ratings and outcomes of the Prioritisation Workshop, the following recommendations were agreed to regarding the way forward for the Feasibility Study Phase of this project.

12.2.1 A Focus on Voëlvlei Dam

As indicated previously, three potential schemes are reliant on the use of storage in Voëlvlei Dam, namely:

- Michell's Pass diversion;
- Berg River abstraction (Voëlvlei Phase 1); and
- Voëlvlei Raising (Further Phases).

It therefore appears a logical step in the study to further investigate these to feasibility level, in an integrated manner, taking cognizance of various questions influencing their potential implementation, which will include (but are not limited to) the following:

- What would be the advantage of an integrated scheme with respect to the additional yield to the overall system?;
- What would be the sequential approach and timing in terms of phasing of the various schemes?;
- Which demand centres would be supplied and how would these schemes be integrated with the Cape Town Metropolitan area and the West Coast demand centres?;
- How would the current operation and management of the Voëlvlei pipeline to Cape Town be affected, and when would a second pipeline to Cape Town be required?; and
- What upgrades would be required at the CCT's Voëlvlei WTW?

12.2.2 Raising Lower Steenbras Dam

With regard to the raising of the Lower Steenbras Dam option, it was recommended that raising the dam by 20 m, by means of a Clay Core Rock fill (CCR) dam or Roller Compacted Concrete (RCC) dam, and increasing the abstractions from the Palmiet Pumped Storage Scheme should be investigated at Feasibility level. No further consideration would be given to the Campanula Dam option. This selection was strongly influenced by the feedback received from the public and Stakeholder Committee.

The Feasibility Study of the Lower Steenbras Dam would need to take cognizance of various questions influencing its implementation, which would include (but are not limited to) the following:

- What would be the timing implications in relation to the potential Voëlvlei development options;
- What would the advantage be in terms of yield benefit from the overall system?
- How would the additional water be utilised by the CCT, taking the winter utilization and distribution constraints into account;
- What would be the implications to the CCT's operation during construction and how could these be mitigated?

13. ADDENDUM – BREEDE ECOLOGICAL WATER REQUIREMENT IMPACTS

13.1 EWR APPROACH DURING THE PRELIMINARY ASSESSMENT OF OPTIONS

During the Preliminary Assessments the EWRs collated, collected or determined for the Breede System, were limited to consideration of the Ecological Reserve immediately downstream of each development option and at the Papenkuils Pump Station. It was reported that it would be likely that the cumulative effects of existing and proposed water-resource developments would have impacts on other river reaches, wetlands and the sustainability of the estuary. It was therefore strongly recommended that any further investigations consider the cumulative impacts of all water-resource development options at a catchment scale.

River nodes were identified as per the procedures for the Water Resources Classification System (WRCS), and EWR data were extrapolated from representative sites (nodes) to others where data was insufficient. There were 63 river nodes delineated in the Breede River catchment. The desktop Reserve model of Hughes and Münster (2000) was used to generate EWR estimates for all nodes in the river system. The results were calibrated using the results from past EWR assessments (Breede Catchment: Ewart-Smith and Brown 2002) and some data generated in this study (EWR Report 1, Volume 1, Appendices 3 and 4).

The EWR data provided were quantity estimates for each river node and represented the reach upstream of each node. EWRs were provided for a range of ecological conditions at each site to enable scenario assessment and tradeoffs between EWRs and the off-stream use of water from the rivers. An important aspect emphasized to require further attention was that consideration of data at a basin level is necessary to ensure that the cumulative contributions of upstream nodes are sufficient to meet the EWRs at downstream nodes of river systems and at the estuary.

During the Preliminary Assessment Phase of the Pre-feasibility and Feasibility Studies, the potential implementation of the Michell's Pass scheme for various diversion capacities was assessed. It was found that reasonably good yields and low capital costs could be achieved, under the following conditions:

- Continued provision of summer water to the existing Artois irrigators;
- Recovery pumping at Brandvlei Dam to ensure the current yield is not adversely effected;
- Meeting the winter EWRs at the closest downstream IFR site (confluence of Upper Wit River) and at Papenkuils;
- No provision for summer EWRs from the scheme due to the lack of storage (as the scheme would provide no additional storage).

  Southern Waters (a member of the Western Cape Water Consultants Joint Venture) raised concern that provision was not made for the summer EWRs, as this would be a new scheme, and as such there was an obligation to provide for the Reserve throughout the year (not only the winter component thereof). As mentioned above, it was also recommended that the basin-wide impacts of the proposed scheme be assessed and that the scheme impacts on the EWRs in the middle and lower Breede River reaches be assessed, as well as at the estuary.

13.2 APPROACH TO ASSESSING DOWNSTREAM IMPACTS

13.2.1 Scenarios Assessed

During July 2010, the latest EWRs for the Breede River became available and based on these, an assessment of the downstream impacts from a potential Michell's Pass Scheme and potential expansion of irrigation from Brandvlei Dam were assessed.

The Water Resources Yield Model (WRYM) for the Breede system was run for various scenarios in order to check the simulated flows against the latest EWR requirements at key EWR nodes in the Breede River catchment. For each of the following scenarios, the historical firm yield (HFY) at Brandvlei was determined and simulated flows were extracted at the relevant EWR sites. These were analysed using a flow-duration frequency analysis to determine the percentages of time within each scenario, during which the EWRs would be being met:

- Status quo ie. the existing system as it is currently operated (SQ) including the diversion (pumping) of 7 m^3/s at Papenkuils,
- Diversion at Michell's Pass of 5 m^3/s, existing diversion of 7 m^3/s at Papenkuils (Mp5-7),
- Diversion at Michell's Pass of 5 m^3/s, diversion of 15 m^3/s at Papenkuils (Mp5-15),
- Diversion at Michell's Pass of 5 m^3/s, diversion of 30 m^3/s at Papenkuils (Mp5-30),
- Diversion at Michell's Pass of 5 m^3/s, diversion of 40 m^3/s at Papenkuils (Mp5-40).

The Reserves as provided by Southern Waters for four sites on the Breede main stem for winter and summer are shown in **Table 13.1**. It should be noted that at each of these nodes the Target Ecological Class (Breede–Overberg CMA) corresponds with the Present Ecological Status, and consequently the EWRs correspond.

Table 13.1 Winter and Summer EWRs at selected Nodes in the Breede

EWR Node	Site Location	Target EC	PES	Reserve Total(1)	% of Nat MAR	Reserve Winter(2)	Reserve Summer(3)
Nviii1	Upstream of Brandvlei Dam	D	D	116.69	24.9%	77.52	6.34
Nvii8	Le Chasseur	C/D	C/D	414.63	38.3%	277.64	29.86
Ni2	Middle Breede upstream of confluence with Riviersonderend	C	C	314.19	26.4%	176.39	18.68
Niii4	Lower Breede – last EWR node upstream of estuary	B/C	B/C	670.74	36.4%	357.54	58.72

Notes 1) Annual EWR required for Target Ecological Class.
2) Winter EWR required for winter Target Ecological Class for June, July and August.
3) Summer EWR required for summer Target Ecological Class December, January and February.

At each of the EWR sites shown in **Table 13.2**, for each potential development scenario, the Reserve flows for winter and summer were calculated for each year (1928-1990), as follows:

- 3 Winter months (sum of the monthly flows for June, July and August)
- 3 Summer months (sum of the monthly flows for December, January and February)
- 6 Winter months (sum of the monthly flows for May to October)
- 6 Summer months (sum of the monthly flows for November to April)

These were plotted as flow duration curves against the corresponding flow duration curves for each development scenario, so as to obtain an indication of when the EWRs were and were not being met, as well as the duration of the flows for each scenario.

13.3 RECENT HISTORY OF BREEDE HYDROLOGY

The Breede River catchment hydrology and land-use information varies both in reliability and age. During the recent Berg WAAS, it was found that the flow record at the mainstem gauging station at Brandvlei Dam, H4H006 was completely unreliable. The result is that the incremental naturalised flows available from the Berg WAAS for the Breede at Brandvlei Dam need to be regarded as highly uncertain and of low reliability.

This type of uncertainty is a general concern in the middle reaches of the Breede River, where catchment model calibration has proved very challenging in the past. This is related to the absence of suitable sites for stream flow gauging along the Middle Breede mainstem and to the complexity of the operation of the existing irrigation schemes below Brandvlei and in some of the tributaries of the Middle Breede. The majority of the system hydrology was last updated in 1990 (see **Table 13.2**).

Table 13.2 Breede River Hydrology Studies

Study	Completion	Hydrology	Comment on Hydrology
Breede River Basin Study	2000	1990	Selected catchment hydrology updated to 1997/1998.
Breede Internal Strategic Perspective	2000	1990	No update of hydrology.
Central Breede Water User Association Study	2004 and 2009	1990	No update of hydrology. EWRs updated by Southern Waters.
Berg Water Availability Assessment Study	2009	2004	Updated to 2004, to Brandvlei only – but low confidence. Challenges experienced with irrigation routine and return flows (WRSM 2000, WQT module). WQT problem currently being attended to by DWA.
Western Cape Feasibility Study and Pre-feasibility Study	Current	1990	No update of hydrology. BRBS model was used in Preliminary Assessments due to low confidence in Breede Hydrology (WQT related).
Breede Catchment Management Strategy	Current	1990	No update of hydrology. Updated EWRs from Southern Waters (July 2010).

13.4 RESULTS OF ASSESSMENT

13.4.1 Nodes Presented

The three EWR sites highlighted in **Figure 13.1** have been selected for presentation of the outcomes of the preliminary analysis of the EWRs using the existing Yield Model of the Breede River, as these reflect typical positions in the upper, middle and lower Breede River. These three sites are:

- Nviii1
  - EWR site downstream of the Breede River confluence with the Upper Wit River, and upstream of Greater Brandvlei Dam.
- Nvii8
  - EWR site at Le Chasseur (at DWA gauging station H4H017), and downstream of Greater Brandvlei Dam.
- Niii4
  - EWR site downstream of the Breede River confluence with the Buffeljags River, and upstream of the Breede Estuary

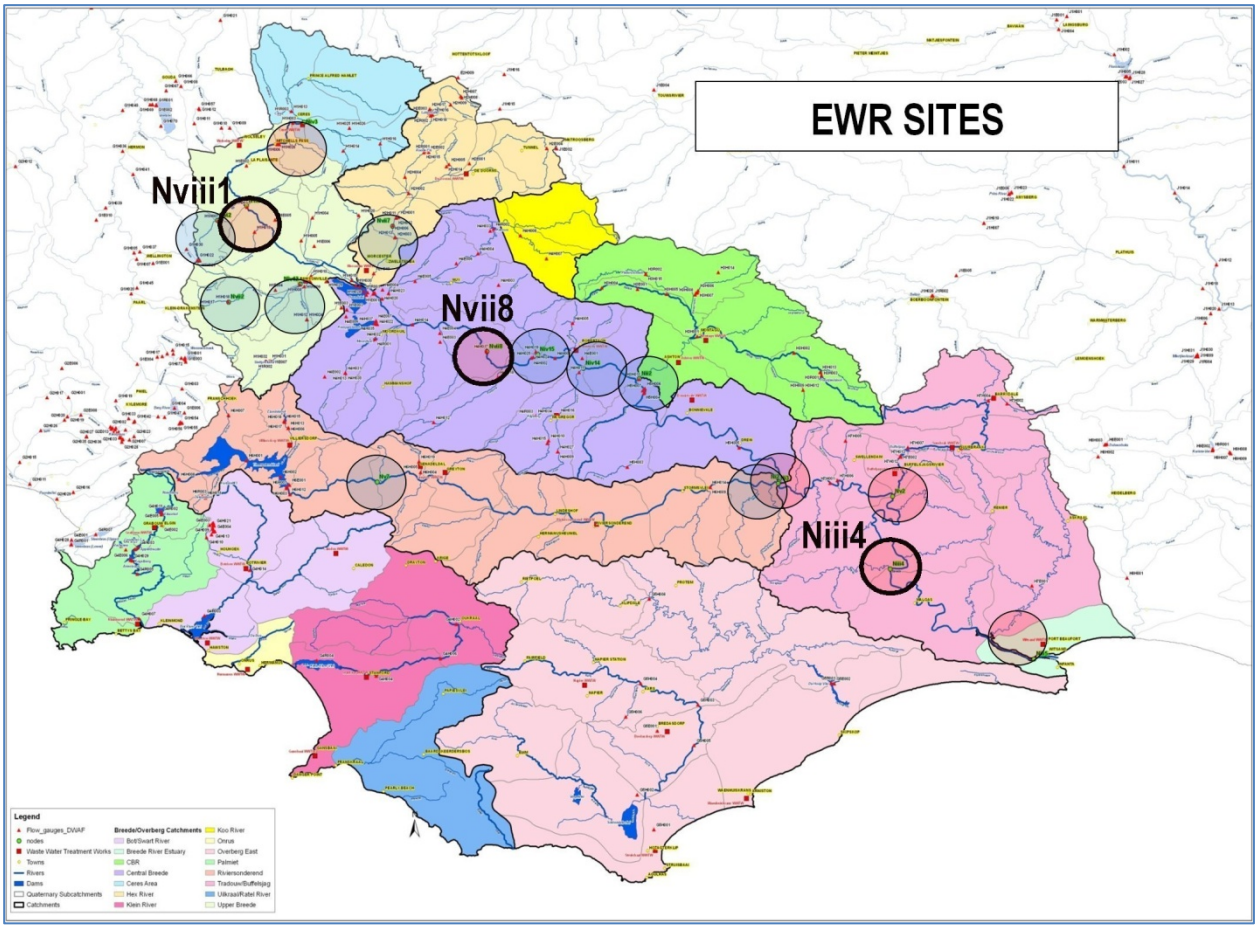

Figure 13.1 The Selected Breede EWR Sites

13.4.2 The Abstraction Scenarios

The 7m^3/s abstraction at the Papenkuils pumpstation into Brandvlei Dam represents the current day operation of that scheme. This is governed by an operating rule requiring that a minimum flow of 2,5m^3/s must first be allowed before any abstraction at Papenkuils can take place.

In addition to the current operation, the potential abstraction of 5 m^3/s from Michell's Pass has also been assessed, as well as further possible abstractions at Papenkuils into Brandvlei Dam, up to 15 and 30 m^3/s in total. This was necessary in order to account for the possible further irrigation development in the Middle Breede River, from water supplied out of an augmented Brandvlei Dam.

13.4.3 Yield Reinstatement at Brandvlei

Any potential abstraction from the Breede River at Michell's Pass during winter will reduce the flow further downstream at Brandvlei. This will consequently reduce the period during which the 2,5m^3/s pre-abstraction flow requirement at Papenkuils can be met. In turn the period during which the abstractions into Brandvlei may take place will be shortened, which will adversely impact the existing yield (and any potential augmentation) of the dam.

To offset the impact of the upstream diversion, additional pumping capacity at Brandvlei would be required just to recover the yield of that dam, whilst remaining within the EWR operating rules. In other words, a greater abstraction capacity over a shorter permissible pumping period is required. **Error! Reference source not found.** shows the typical extent of additional reinstatement pumping that would be required at Papenkuils to reinstate the Brandvlei yield for various scenarios. The **red arrow** shows that:

- for a 3m^3/s Michell's Pass diversion, the existing 7m^3/s abstraction into Brandvlei would need to be increase by about 2,5m^3/s to ensure the current yield of the dam is retained;
- interpolating for a 5m^3/s Michell's Pass diversion, the existing 7m^3/s abstraction into Brandvlei would need to be increase by about 4,5m^3/s to ensure the current yield of the dam is retained.
- for an 8m^3/s Michell's Pass diversion, the existing 7m^3/s abstraction into Brandvlei would need to be increased by about 6,5m^3/s to ensure that the current yield of the dam is retained;

For increased diversions into Brandvlei, the recovery pumping requirement would further increase as shown in **Figure 13.2.**

The **black arrow** shows that:

- if the existing Brandvlei abstraction were to double from 7 to 14 m^3/s, with a 3m^3/s abstraction at Michell's Pass, then an additional 6m^3/s abstraction capacity at Papenkuils would be necessary. This to ensure that the same yield from Brandvlei would be obtained, as for a scenario without Michell's Pass;
- interpolating from the graph for a 5m^3/s Michell's Pass Diversion, and considering a doubling of the current Brandvlei abstraction from 7 to 14 m^3/s, then an additional 9,5m^3/s pumping capacity at Papenkuils would be necessary. This to ensure that the same yield from Brandvlei would be obtained as for the scenario without Michell's Pass.

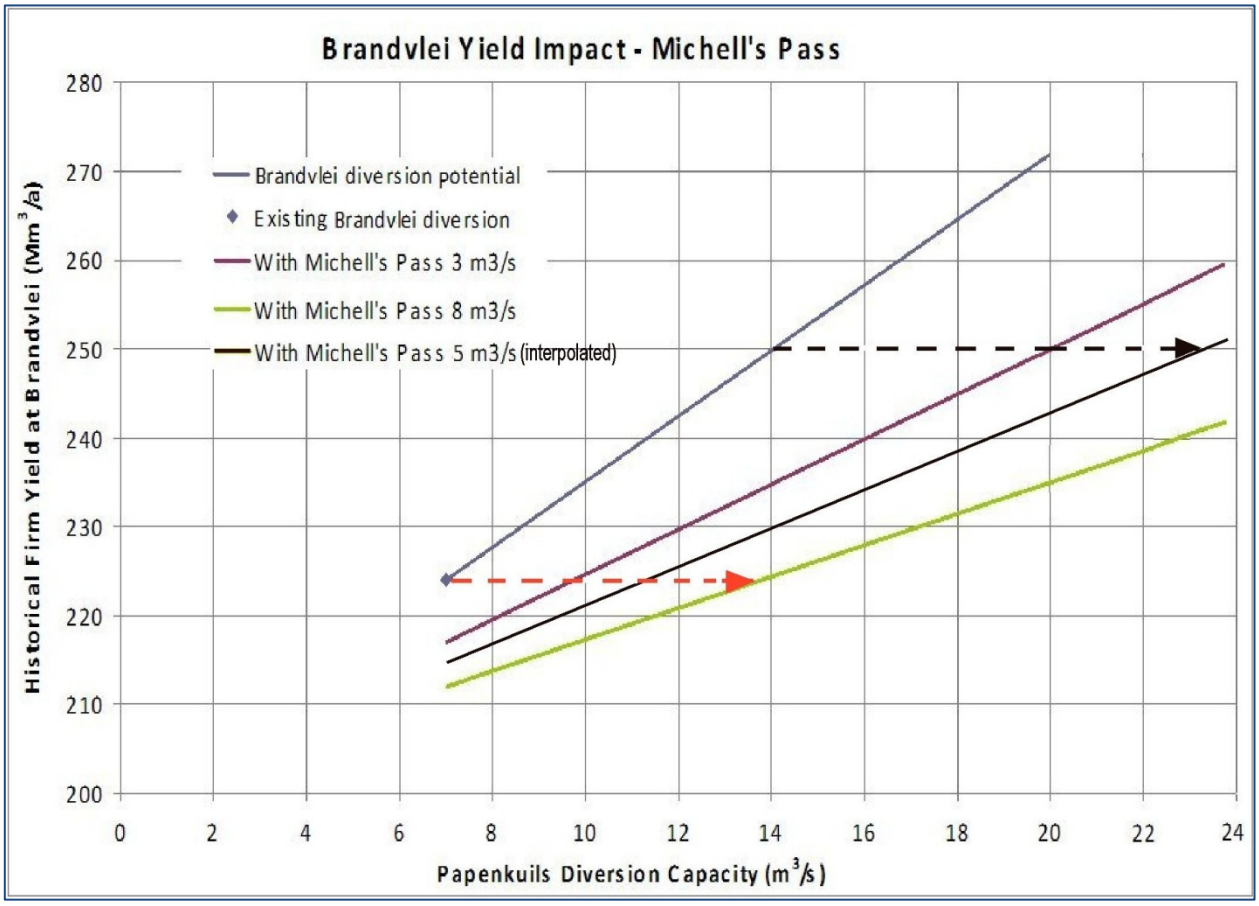

Figure 13.2 Brandvlei Yield Reinstatement Pumping

13.4.4 Flow Duration Frequency Curves

The EWRs required during the various monthly-periods assessed (eg 3 winter months, 3 summer months, 6 winter months, 6 summer months) were summed for that period, during each of the years from 1928-1990. These summed period-flows were then ranked and plotted as an EWR flow duration frequency curve (denoted as a **blue line** in the figures that follow).

Each of the development scenarios, based on the proposed 5m^3/s Michell's Pass diversion, and varying Brandvlei abstractions, were then modelled in the WRYM to determine the resulting streamflow at each EWR site. As was undertaken for the EWRs, the streamflows were also summed over the period being assessed, ranked, and plotted against the EWR flow duration frequency. In so doing it is possible to determine the extent to which each development scenario does, or does not, comply with the EWRs. It also provides an indication of the duration (% time) in which there is compliance.

13.4.5 The Upper Breede (Site NViii1, downstream of proposed Michell's Pass Scheme)

Figure 13.3 and **Figure 13.4** compare the cumulative present day 3 and 6-month summer flows respectively with the EWRs at this site, there being no proposed summer diversions.

Comment on Site Nviii1 Summer Flows

Figure 13.3 shows that during the critical summer 3-month period (December to February), the EWRs downstream of the proposed Michell's Pass site are only met for less than 30% of the time. This effectively represents the current-day summer flow condition, without any abstraction at Michell's Pass as the proposed diversion scheme would only divert flows during the winter months. Furthermore, being upstream of Brandvlei, there is no impact at this site of abstractions or releases at Brandvlei. The proposed 5m^3/s abstraction at Michell's Pass is a winter diversion scheme and as such would have no impact on the current day situation at this site. A contributing factor to this is the existing lawful use of summer water by the Artois irrigators via the existing run of river diversion at Michell's Pass.

Figure 13.4, shows that the situation improves substantially when considering a longer summer period of 6-months (from November to April) due to the effects of the early rains that typically can occur in March and April in the Western Cape.

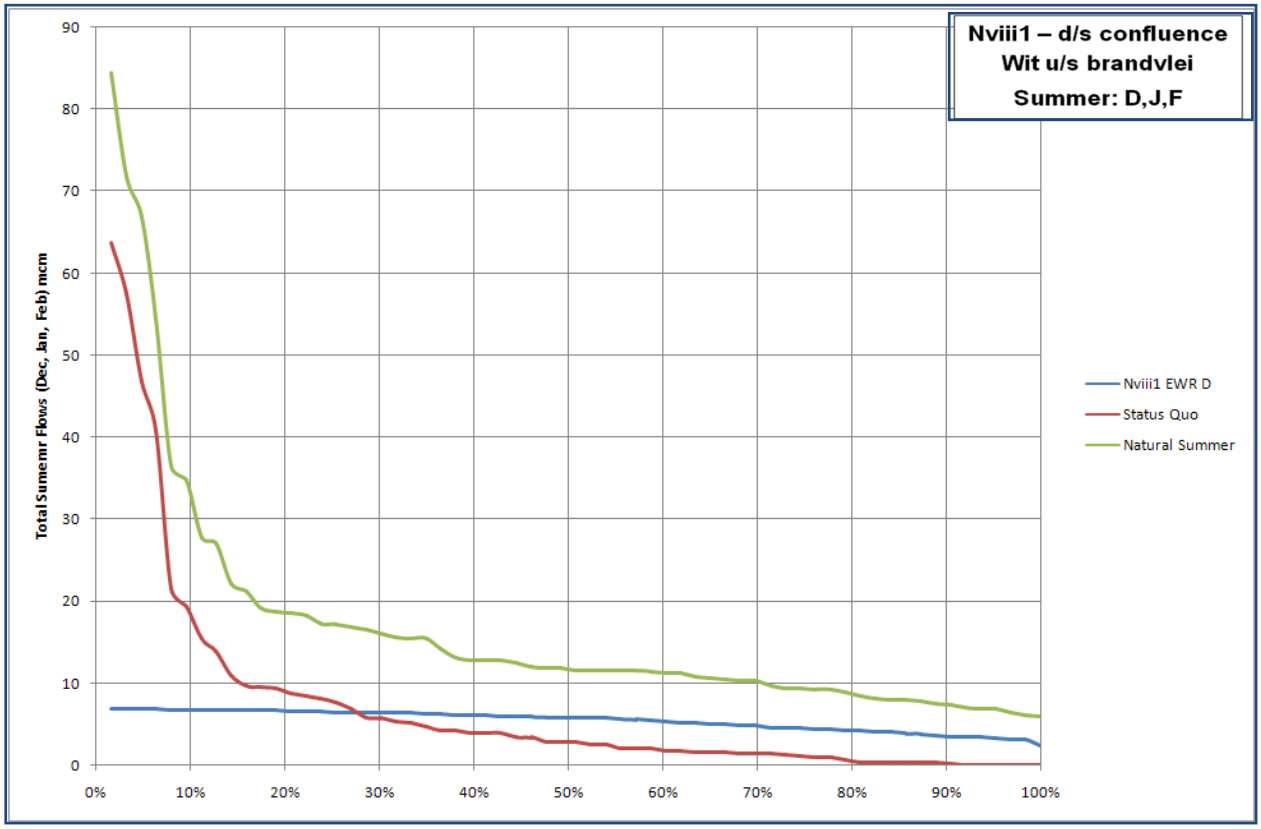

Figure 13.3 Site Nviii1 (3 Month Summer Flows)

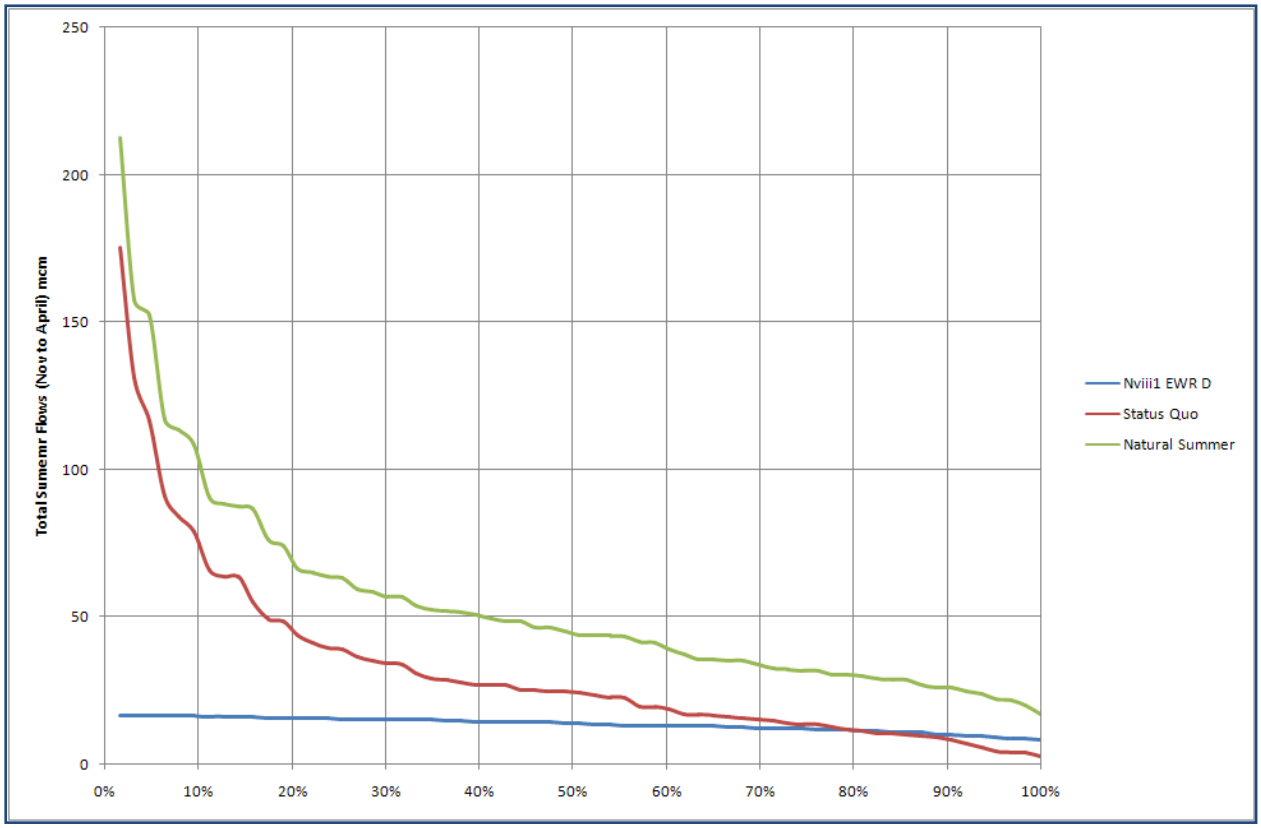

Figure 13.4 Site Nviii1 (6 Month Summer Flows)

Comment on Site Nviii1 (Winter Flows)

Figure 13.5 and **Figure 13.6** confirm the findings of the Preliminary Assessments in which it is shown that during both the 3-month (June to August) and 6-month (May to October) winter periods, a $5m^3/s$ diversion at Michell's Pass would not impact on the winter EWR requirements immediately downstream, ie at the Nviii1 EWR site, which is located a short distance downstream from Michell's Pass.

In the figures, the **red line** shows the status quo at this site, and the **green line** shows the natural winter flow at the site. The **purple line**, shows the result of the $5m^3/s$ abstraction at Michell's Pass. The **blue line** indicates the EWR requirement. The abstraction of water at Papenkuils into Brandvlei has no effect on this upstream EWR site.

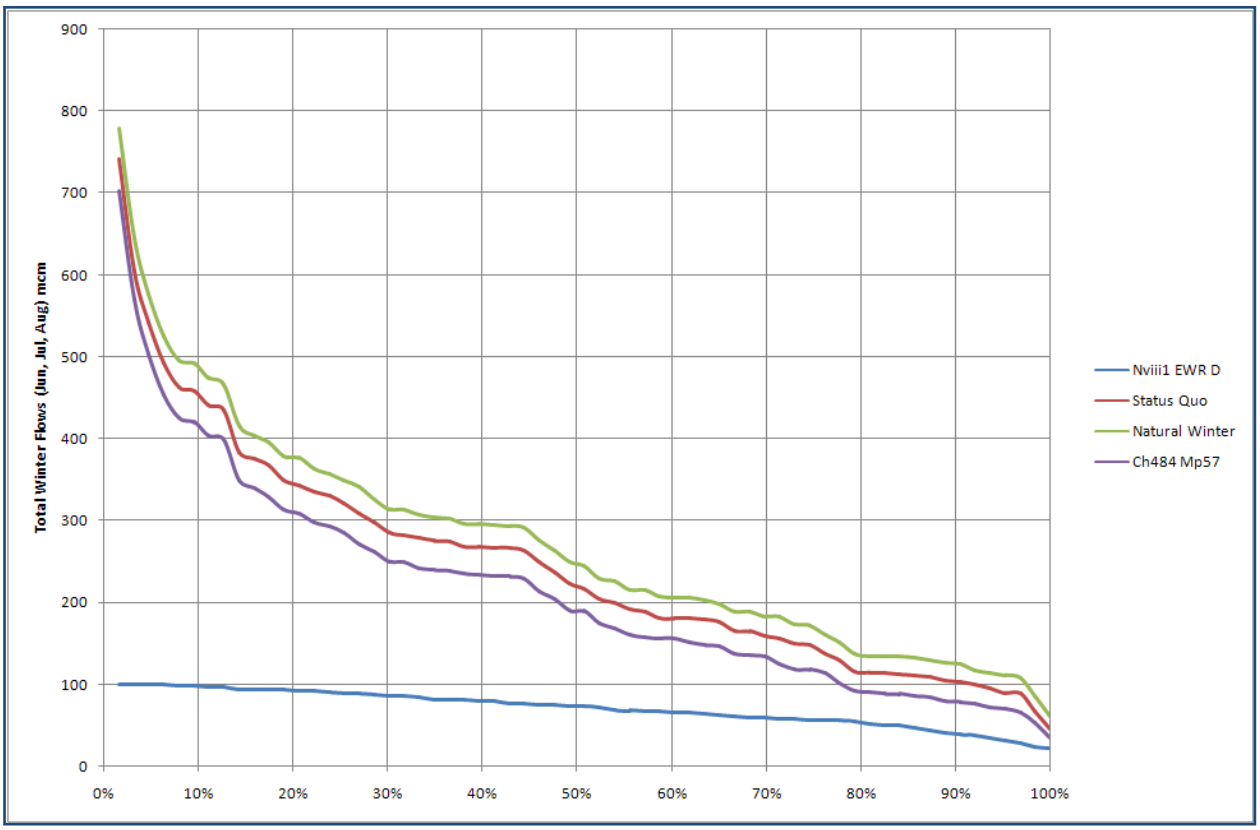

Figure 13.5 Site Nviii1 (3 Month Winter Flows)

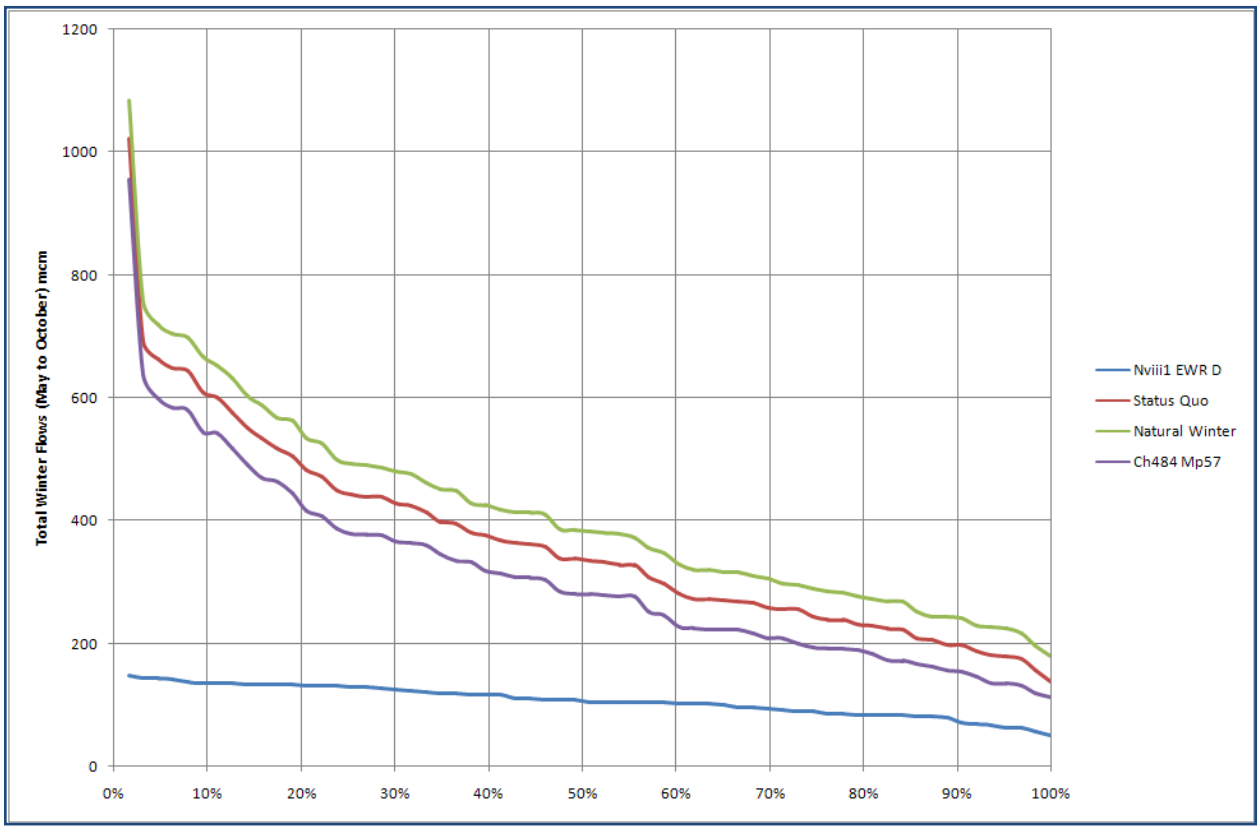

Figure 13.6 Site Nviii1 (6 Month Winter Flows)

13.4.6 The Middle Breede (Site Nvii8, at Le Chasseur)

Figure 13.7 and **Figure 13.8** compare the cumulative present day 3 and 6-month summer flows respectively with the EWRs at this site, there being no proposed summer diversions at Michell's Pass or at Brandvlei Dam.

Comment on Site Nvii8 Summer Flows

Figure 13.7 and **Figure 13.8** show the 3 and 6-month summer flows at Le Chasseur (EWR Site Nvii8). Both figures indicate a significant surplus of summer water in the system (well above the EWR requirement in summer). This is due to the use of the Breede River as a conduit for irrigation releases from Brandvlei Dam to irrigators downstream of Le Chasseur. Furthermore, these two figures show that no abstraction is taking place within the model during summer at Brandvlei or at the proposed Michell's Pass scheme, both of which are winter abstraction schemes .

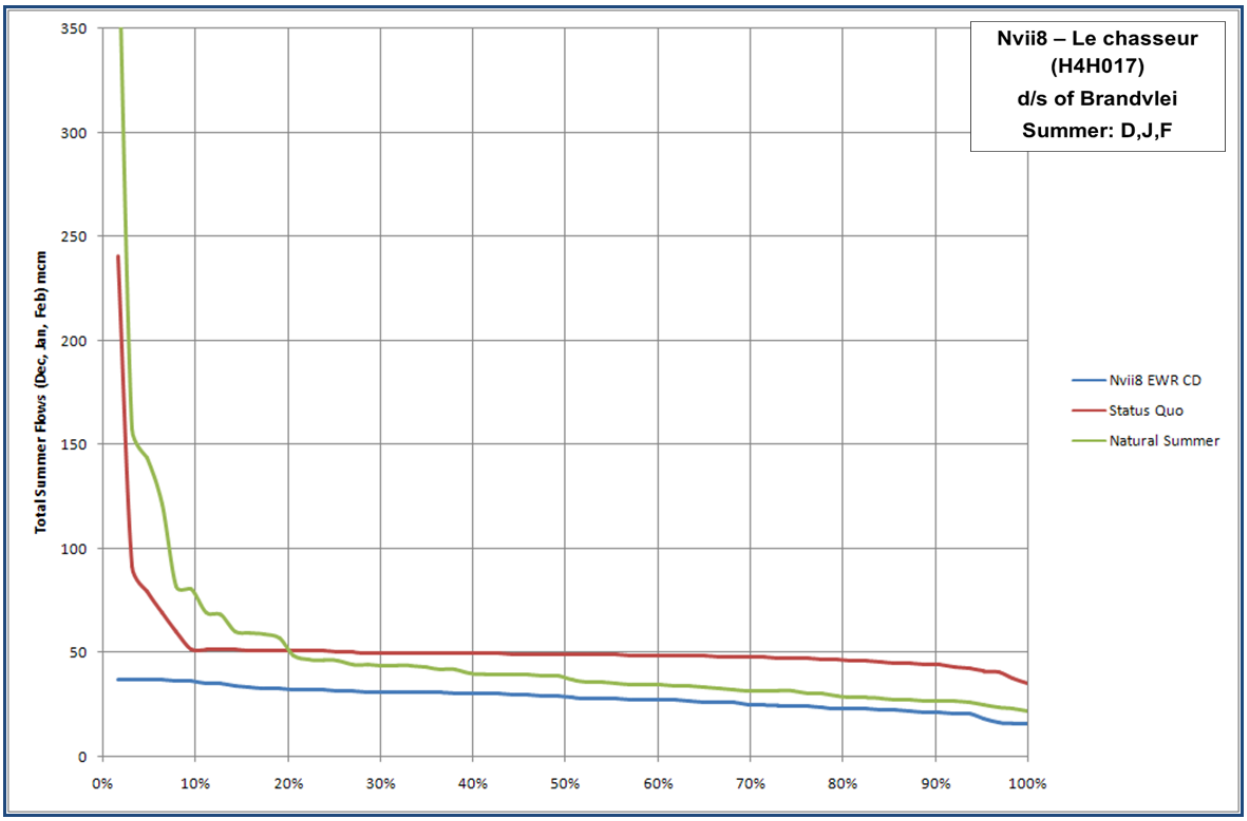

Figure 13.7 Site Nvii8 (3 Month Summer Flows)

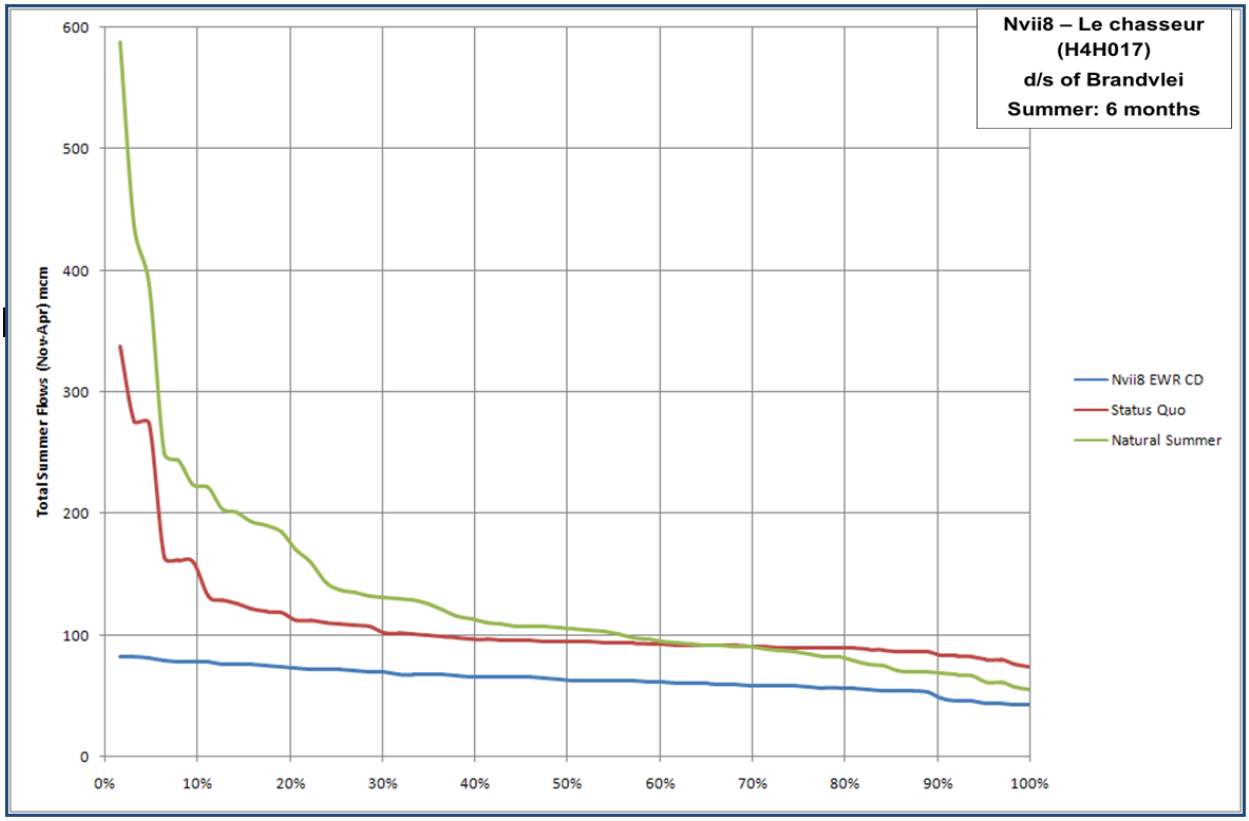

Figure 13.8 Site Nvii8 (6 Month Summer Flows)

Comment on Site Nvii8 (Winter Flows)

Figure 13.9 and **Figure 13.10** show the effects of the Michell's Pass Diversion ($5m^3/s$) together with increasing scenarios of pumped abstraction at Brandvlei, from the current abstraction of $7m^3/s$, up to potential 15 and $30m^3/s$ abstractions. The percentage of time for which the winter EWRs for each scenario are not met are summarised in **Table 13.3**.

Table 13.3 Impact of Scheme development on Winter EWRs in the Middle Breede

PES = C/D at Le Chasseur

Abstraction Scenario	**% of time that EWRs are not met**	
	3 Winter Months (June–Aug)	**6 Winter Months (May to Oct)**
Status Quo ($7m^3/s$ at Brandvlei)	39%	35%
$5m^3/s$ abstraction at Michell's Pass PLUS abstraction into Brandvlei Dam of:		
$7m^3/s$ - current	40%	45%
$15m^3/s$ - potential	45%	46%
$30m^3/s$ - potential	48%	47%

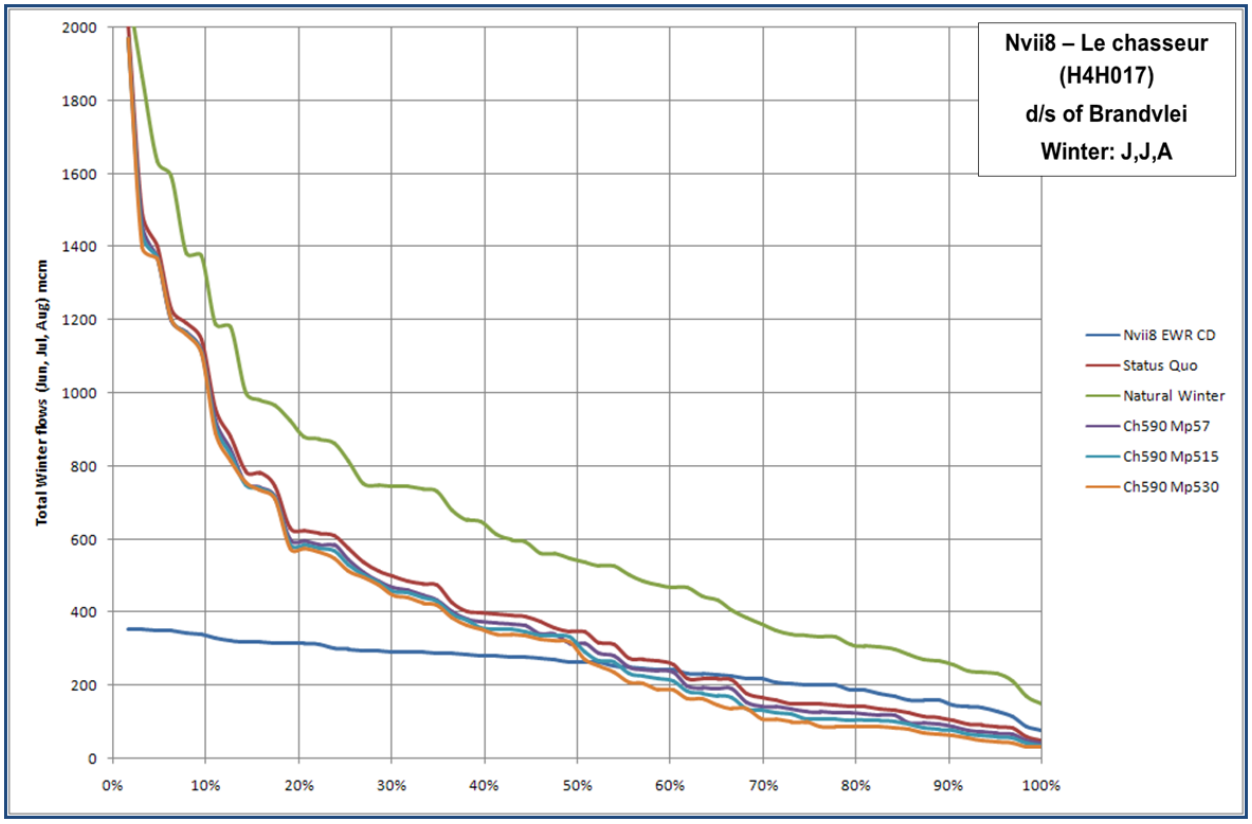

Figure 13.9 Site Nvii8 (3 Month Winter Flows)

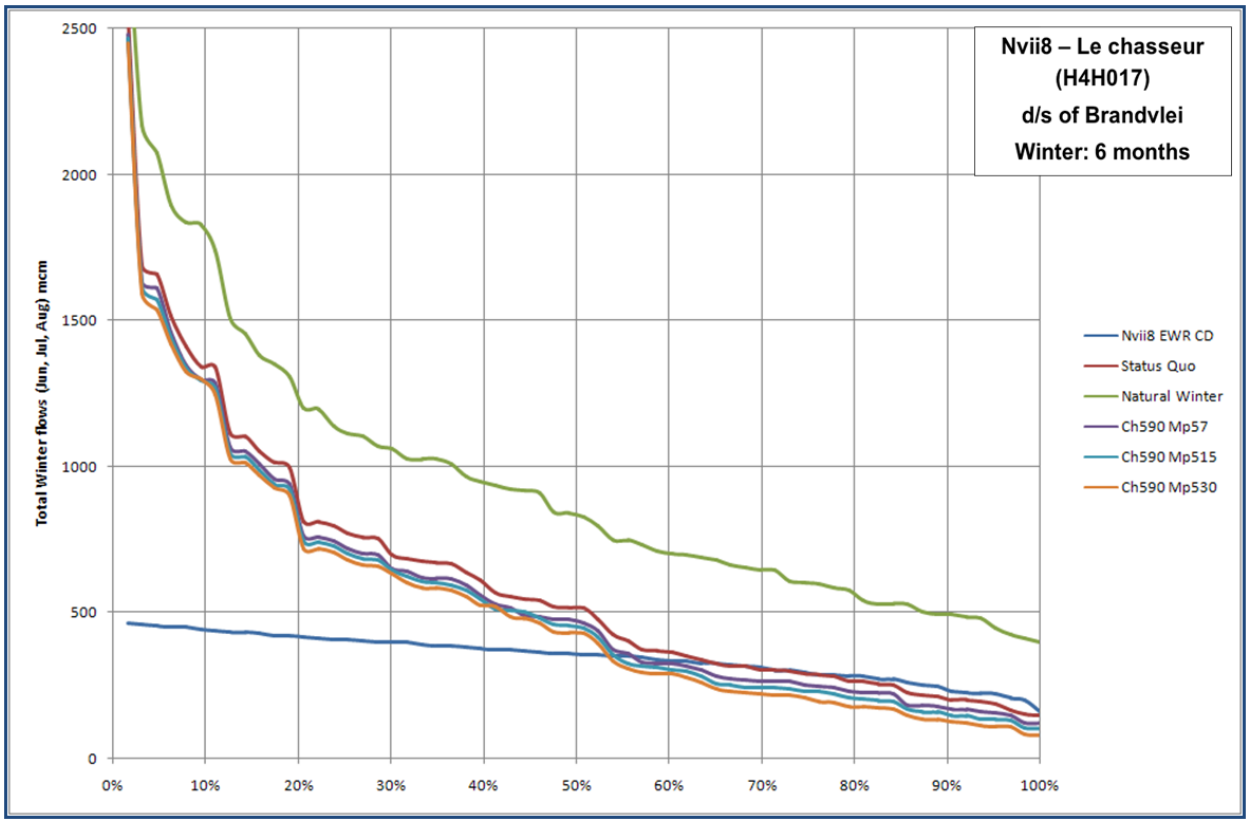

Figure 13.10 Site Nvii8 (6 Month Winter Flows)

13.4.7 The Lower Breede (Site Niii4 Downstream of Buffeljags Confluence)

Figure 13.11 and **Figure 13.12** compare the cumulative present day 3 and 6-month summer flows respectively with the EWRs at this site, there being no proposed summer diversions at Michell's Pass or at Brandvlei Dam.

Comment on Site Niii4 Summer Flows

Figure 13.11 and **Figure 13.12** show the 3 and 6-month summer flows at this site which is located on the Breede River just downstream of the confluence with the Buffeljags River, and is the most downstream EWR site on the Breede River. As can be seen the present day summer EWRs are met for less than 15 % of the time during the driest 3 summer months and for less than 25% of the time when considering the 6-month period (November to April). This is without any impact from either the abstractions into Brandvlei or from the proposed Michell's Pass Diversion, both of which are modelled as winter diversion schemes only. The effects of considering a lower ecological class than that targeted (Class B/C) by the CMA is also shown, namely for a Class C and a Class D.

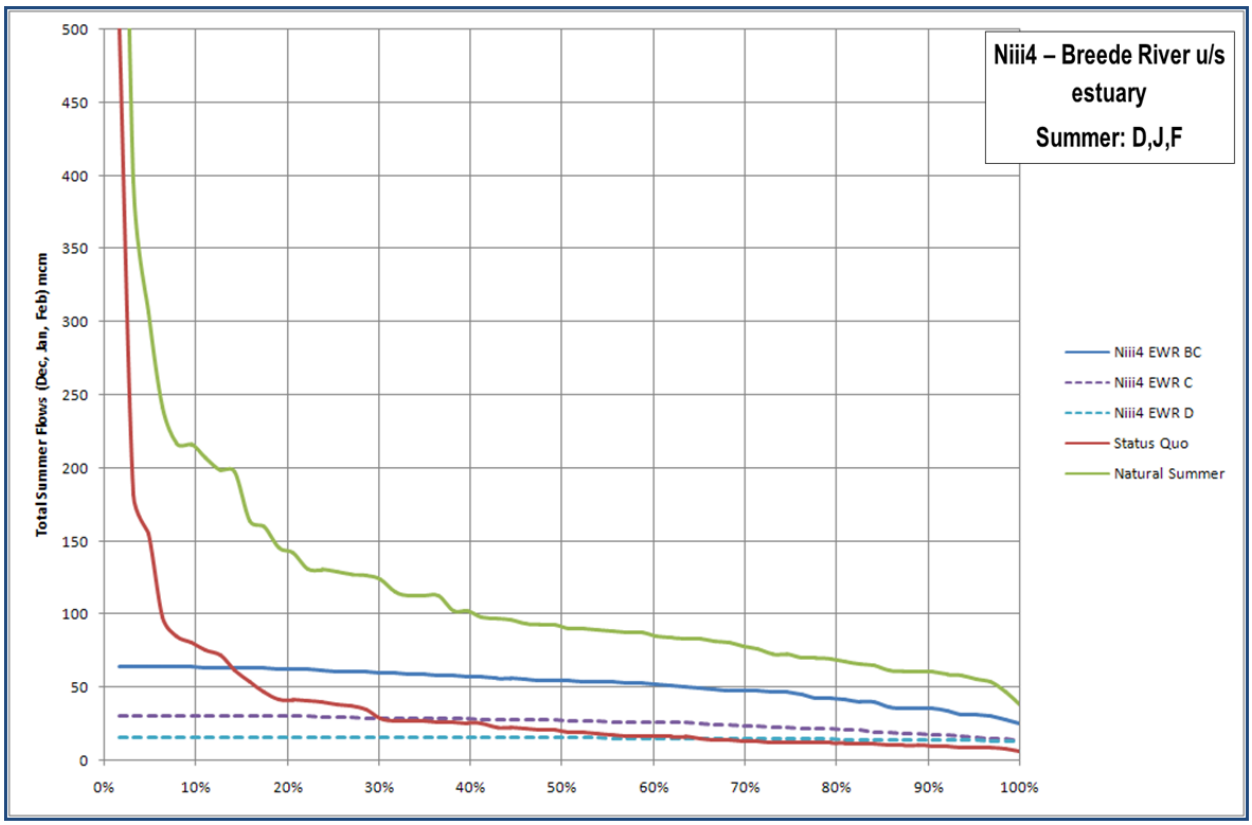

Figure 13.11 Site Niii4 (3 Month Summer Flows)

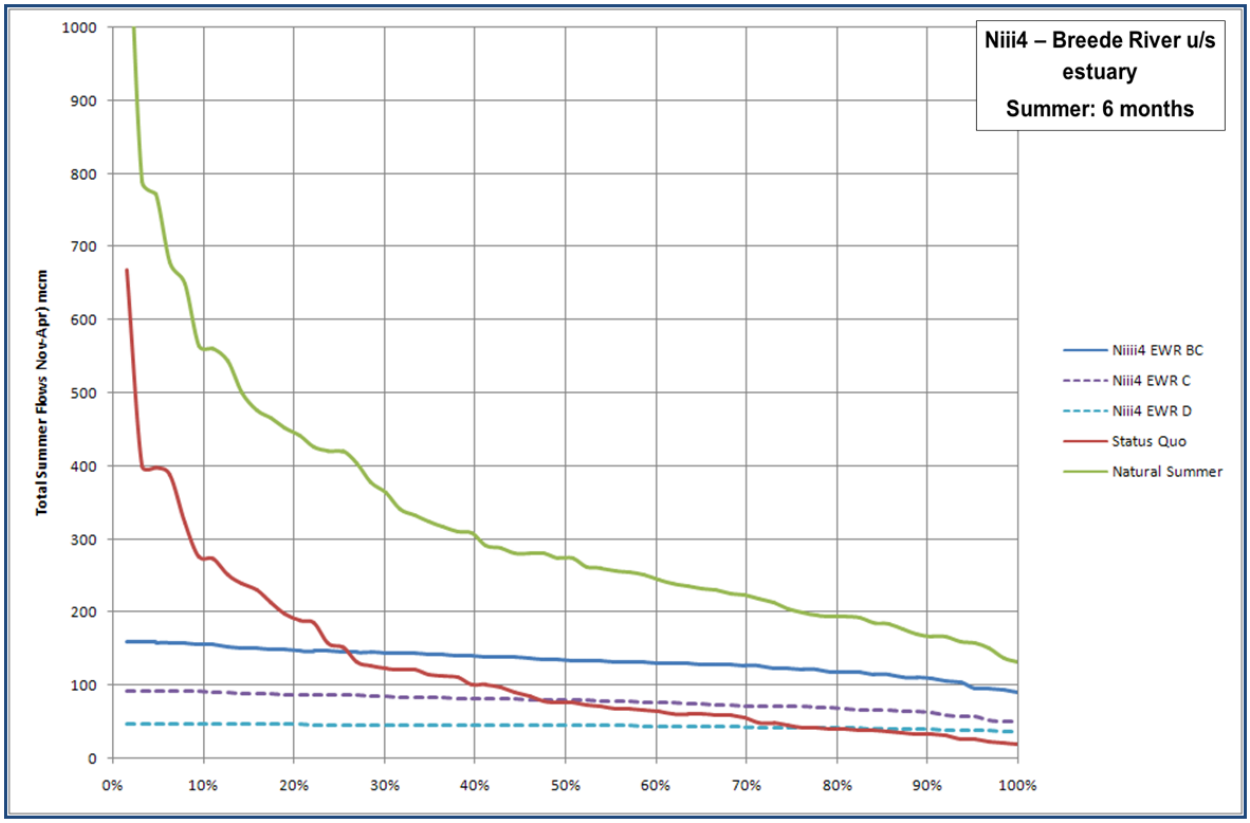

Figure 13.12 Site Niii4 (6 Month Summer Flows)

Comment on Site Niii4 (Winter Flows)

Figure 13.13 and **Figure 13.14** show the effects of the Michell's Pass Diversion ($5m^3/s$) together with increasing scenarios of abstraction at Brandvlei from the current winter abstraction of $7m^3/s$, up to a potential 15 and $30m^3/s$ abstraction. The percentage of time for which the winter EWRs for each scenario are not met are summarised in **Table 13.4**

Table 13.4 Impact of Scheme development on Winter EWRs in the Lower Breede

PES = B/C at this site

Abstraction Scenario	**% of time that EWRs are NOT met**	
	3 Winter Months (June–Aug)	**6 Winter Months (May to Oct)**
Status Quo ($7m^3/s$ at Brandvlei)	38%	37%
$5m^3/s$ abstraction at Michell's Pass PLUS abstraction into Brandvlei Dam of:		
$7m^3/s$ - current	40%	38%
$15m^3/s$ - potential	40%	45%
$30m^3/s$ - potential	42%	50%

This site is the most downstream EWR riverine site (upstream of the Breede Estuary). Indications are that the Estuarine EWR requirement (once updated) is likely to be even higher than that of this river node. This suggests that the findings presented in the above table are likely to be even less desirable in terms of being able to meeting the Estuarine EWRs.

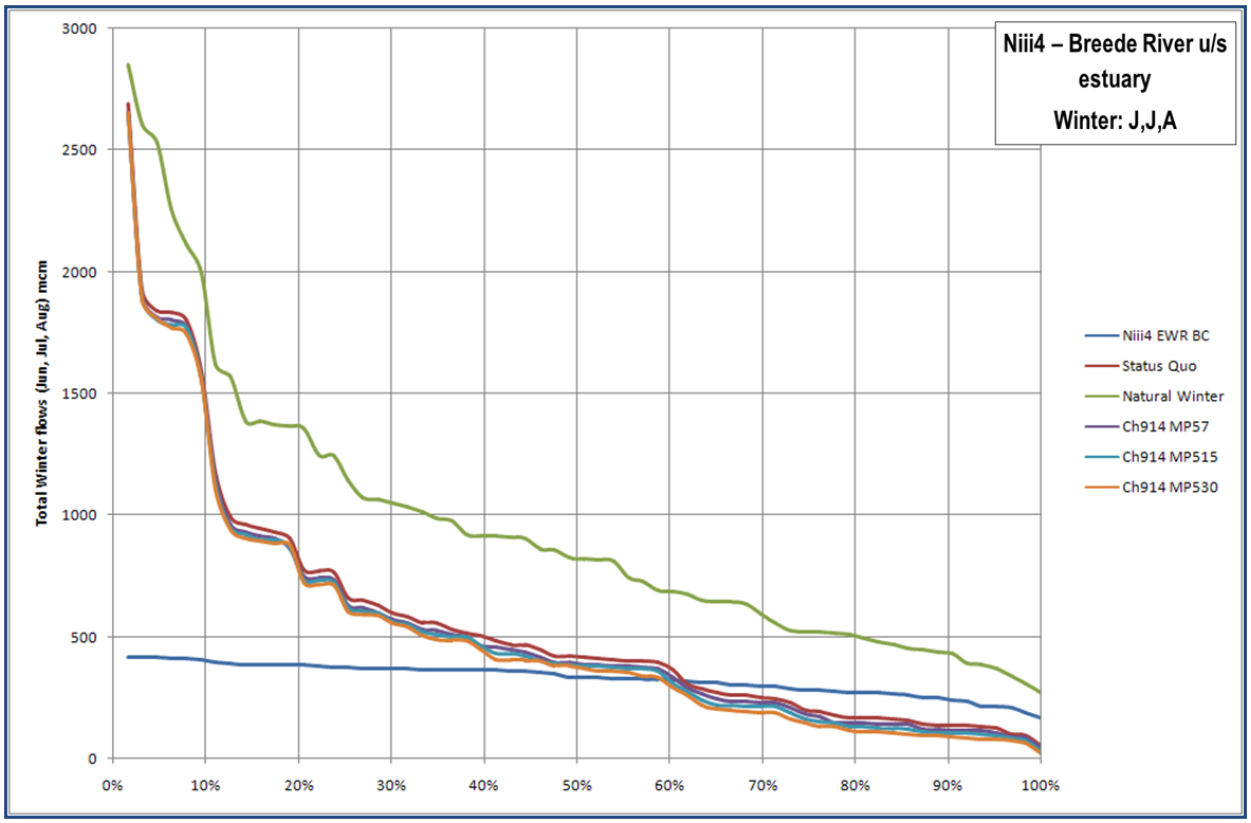

Figure 13.13 Site Niii4 (3 Month Winter Flows)

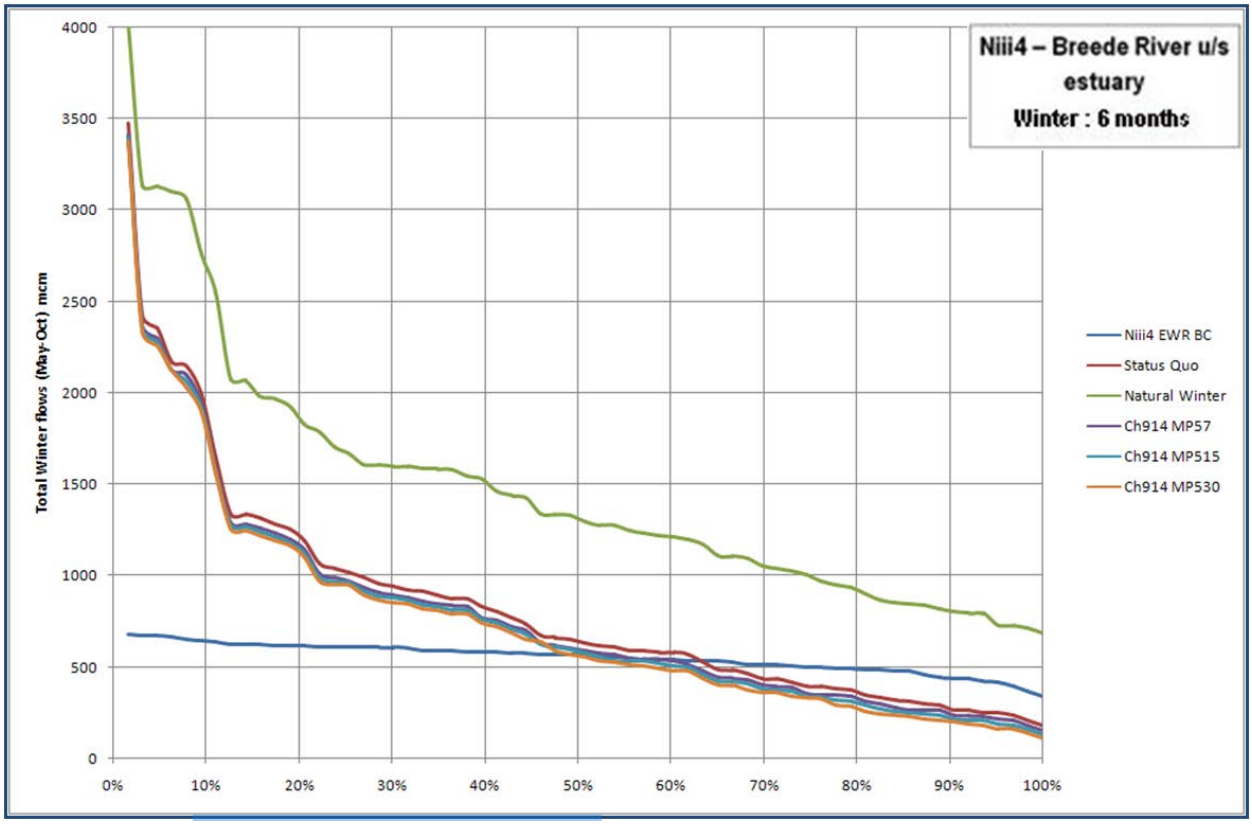

Figure 13.14 Site Niii4 (6 Month Winter Flows)

13.5 CONCLUSIONS AND RECOMMENDATIONS IN RELATION TO THE EWR IMPACTS

The following overall conclusions can be drawn from the findings for the summer status quo flows which would not be affected and for the proposed 5m^3/s winter diversion at Michell's Pass, for various pumping scenarios at Brandvlei, and for increasing the pumping capacity at Brandvlei from 7 m^3/s to maintain the current yield of the dam.

- The Status Quo summer flows in the Breede River would not be affected by the proposed 5 m^3/s winter diversion at Michell's Pass.
- Summer EWRs upstream of Brandvlei are currently not met (and would not be improved by the proposed winter diversion at Michell's Pass, increased summer flows being considered to be essential for maintaining the overall PES of this reach of river if winter diversions are made at Michell's Pass).
- Winter EWRs upstream of Brandvlei are currently met and would not be affected by the proposed Michell's Pass diversion.
- Summer EWRs downstream of Brandvlei at Le Chasseur are currently met due to summer releases for irrigation.
- Winter EWR Requirements downstream of Brandvlei at Le Chasseur would be met for about 50 to 60% of the time for certain pumping scenarios.
- Summer EWR requirements upstream of the estuary are currently not met.
- Winter EWR requirements upstream of estuary are currently not met and would be adversely affected by the proposed Michell's Pass diversion.
- There are little or no surplus flows in Breede Catchment for any additional developments if the EWR requirements are to be met.

The following overall recommendations are made:

- The Breede River Hydrology, including the lower reaches, requires updating through a Water Availability Assessment Study before decisions on large-scale allocations of water are taken.
- The Breede Stakeholders will ultimately have to decide on the Ecological Classes that are to be targeted through the Breede CMS.
- Based on the PES, the EWRs at some sites are currently not being met and if those Ecological Classes are to be upheld, then there is limited opportunity for water resource development, or additional irrigation.
- The specified EWRs are a fairly high proportion of the natural MARs (refer to **Error! Reference source not found.**). This may be to compensate for the non-flow related activities (bulldozing/clearing of river banks) which are taking place and which require additional flows to mitigate their impacts. If management of the resource can reverse these impacts, then it may be possible to reduce the EWR and improve the opportunity for some development in the Breede.
- Interventions such as Invasive Alien Plant clearing have shown to be beneficial and implementation thereof should be extended in this system.
- If water is to be made available to the resource poor, then the options of water trading with existing lawful users, and or compulsory licensing may need to be considered.
- Water quality has not formed part of this assessment but is recognized as an extremely important component of the EWR. Management interventions towards reducing the salinity, nutrient and contaminant concentrations would enable a reduction in the need for freshening releases.
- The hydrology on which these assessments are based is unstable, particularly in the Middle and Lower reaches of the mainstem Breede River. However, this need not preclude the Michell's

Pass option from being taken to Feasibility Study under this appointment, but a conservative approach should be adopted in the use of the existing hydrology. It is strongly recommended that DWA prioritize undertaking a full Breede WAAS.

- During the Michell's Pass Feasibility Study (Phase 2), further yield modelling at pre-feasibility level is considered as essential, so as to determine the value of operating rules that restrict diversions to only those winter months with flows above certain thresholds. These thresholds are to be optimised in terms of compliance of Breede flows with EWRs in the Middle and Lower Breede mainstem, while maximising the yield of Voëlvlei Dam at its current full supply.

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