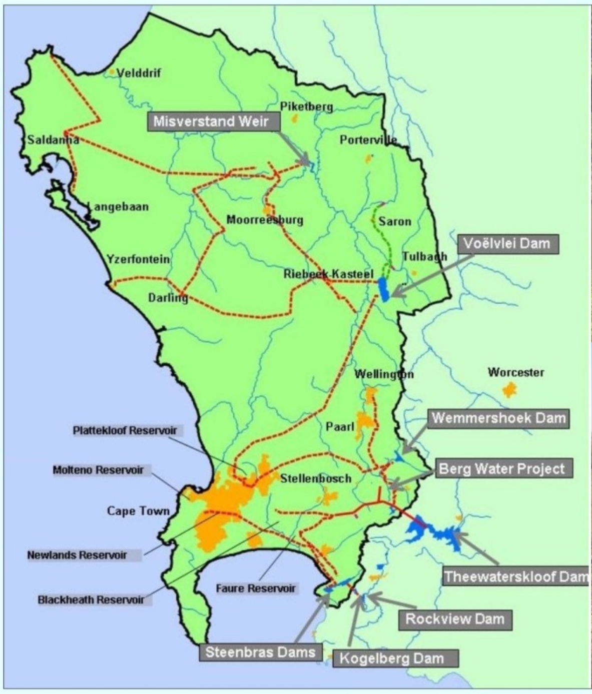
Report No: P WMA 19/G10/00/2413/5

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 3 : Feasibility Studies
Volume 1 : First Phase Augmentation of Voëlvlei Dam

BERG RIVER - VOËLVLEI AUGMENTATION SCHEME




Final

December 2012

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	:	Feasibility Studies First Phase Augmentation of Voëlvlei Dam Berg River-Voëlvlei Augmentation Scheme
Consultants	:	Western Cape Water Consultants Joint Venture
Report status	:	Final
Date	:	December 2012

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EXECUTIVE SUMMARY

INTRODUCTION

The Western Cape Reconciliation Strategy Study (WCRSS) identified the need for augmentation of the Western Cape Water Supply System (WCWSS) by 2019. In July 2008, the Directorate of National Water Resources Planning (D:NWRP) of the Department of Water Affairs (DWA) appointed the Western Cape Water Consultants Joint Venture (WCWC JV) to undertake pre-feasibility level investigations into six potential surface water development options (Phase 1). These were then to be prioritised to identify the two most viable options for further investigation to feasibility study level in Phase 2. The Phase 1 outcome indicated the following two priority schemes.

- Berg River-Voëlvlei Augmentation Scheme (BRVAS);
- Breede-Berg (Michell's Pass) Water Transfer Scheme, abbreviated as the Breede-Berg Transfer Scheme (BBTS).

Both schemes rely on the utilisation of the existing storage capacity in the Voëlvlei Dam, and on the existing capacity of the City of Cape Town's (CCT) pipeline, from their water treatment works (WTW) at the dam, to their Plattekloof reservoir in Cape Town.

These two schemes (BRVAS and BBTS) are likely to be mutually exclusive, unless Voëlvlei Dam is raised and the capacity of the conveyance infrastructure from the CCT WTW to Cape Town is increased. These aspects have been touched on in this study. However the potential to implement both the BRVAS and the BBTS in succession (or collectively) would need to be further investigated, taking the storage and conveyance infrastructure requirements as well as the water requirements into consideration.

This report addresses the BRVAS Feasibility Study, for which the scheme location is shown in **Figure i**. The BBTS Feasibility Study is reported on independently.

DESCRIPTION OF THE SCHEME

The proposed scheme would involve the pumped abstraction of winter water from the Berg River, once the ecological water requirements of the river and the estuary have been met. The ecological Reserve commensurate with a Category D River has been allowed for in the system modelling of the scheme.

According to the report on the Reserve for the Berg River Estuary the required stream flow into the estuary during the summer months should vary between 0.6 and 0.9 m^3/s. As the present day inflows into the estuary are not gauged (although DWA has plans to install a gauge), the present day inflow of 0.3 m^3/s was estimated from the gauged flows below Misverstand Dam, and from the downstream irrigation allocations which will be metered in the near future. In order to provide the required Reserve inflows to the Estuary would require that additional releases of between 0.3 m^3/s and 0.6 m^3/s should be made from Voëlvlei Dam, particularly during the four summer months from December to March. Therefore, the conservative assumption has been made in the system modelling of the proposed scheme that an additional release of 0.5 m^3/s should be made from Voëlvlei Dam for the six summer months.

Two scheme options have been investigated, namely:

- Option 1: 4 m^3/s pump station with a stepped-pump operating rule.
- Option 2: 6 m^3/s pump station with variable speed drives.

Figure ii shows the proposed abstraction site and the proposed rising main route to the Voëlvlei Dam as well as the river crossing location and the preferred location (influenced by water quality considerations) for discharge into the dam.

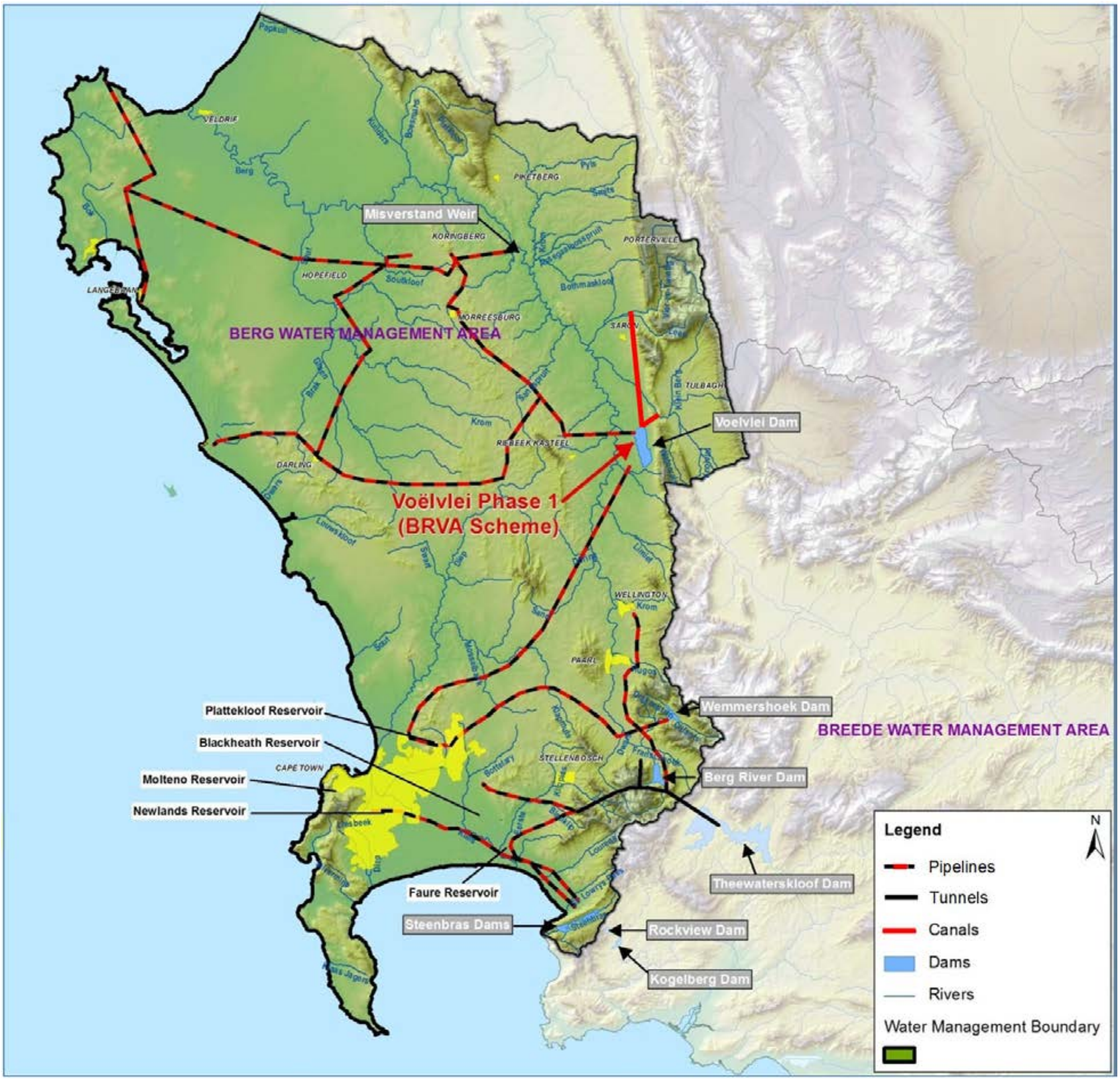

Figure i: Location of the BRVAS

Figure ii: Scheme Layout

YIELD AND SYSTEM ANALYSIS

The yield and system analyses involved the following tasks:

- Introduction of Ecological Water Requirement (EWR) nodes into the WCWSS model.
- Data adjustments to improve the Theewaterskloof Dam and Voëlvlei Dam model inputs.
- Assessment of the Kleinplaas Dam operational inefficiencies.
- Assessment of the Berg River Dam Supplement Scheme operation.
- Development of diversion functions for modelling and operation of the BRVA Scheme.
- Development of proposed operating rules for the scheme to ensure EWR compliance.
- Incorporating historical and projected water requirements.
- Comparison and explanation of updated yield estimates for the system with legacy estimates from previous studies.
- Updating of the WCWSS Planning Model.
- Identifying the possible augmentation target dates.

The 1:50 year incremental yields that would be added to the Western Cape Water Supply System through the implementation of this potential winter abstraction scheme are given in **Table i** for the two pumping options considered. These are based on the hydrology that was updated by the Berg Water Availability Assessment Study (WAAS), which was completed in 2009.

Table i: Incremental Additional Yield (1:50 year) for the BRVA Scheme

Option	1:50 year Incremental yield (10^6 m^3)
Option 1: 4 m^3/s pump station with stepped-pumping rule	23
Option 2: 6 m^3/s pump station with variable speed drives	20

WATER QUALITY CONSIDERATIONS

Water quality management in the Berg River poses a significant challenge in relation to current and future water use opportunities and as such any abstraction of water from the river must be carefully considered in terms of the intended water use. Three fundamental water quality aspects were investigated as part of this feasibility study, namely:

- Winter 2011 flood sampling undertaken to identify the changes in water quality parameters during typical high flow events in the Berg River.
- The assessment of the impacts of nutrient transfers from the Berg River on algal growth in the Voëlvlei Dam, by means of CE-QUAL-W2 modelling.
- The modelling of dispersion and mixing characteristics in the Voëlvlei Dam from water transferred from the Berg River and the optimization of the discharge point location at the dam.

From the above assessments it has been concluded that with the implementation of appropriately developed operating rules to guide the timing of river abstractions in winter, there are no red flags associated with water quality issues that would be prohibitive in terms of scheme implementation.

SCHEME INTEGRATION INTO THE WCWSS

The utilisation of the additional water becoming available from the integration of the proposed scheme into the system could be fully utilised within the existing and planned infrastructure. In particular:

- The CCT is planning a proposed Spes Bona Reservoir and a Spes Bona to Glen Gary Reservoir pipeline which will extend the footprint of the supply area from the Voëlvlei Dam.
- The water requirement projections for the West Coast suggest that by 2020 these will increase by an amount of approximately 3 million m^3/a.
- Possible augmentation of supply to the Lower Berg irrigators to enable their present scheduled allocation to be supplied, subject to the outcomes of the verification and validation process, as well as affordability of the water from this scheme to that sector.

GEOTECHNICAL INVESTIGATIONS

Visual inspections revealed evidence of rock on the left bank of the Berg River at the weir site and core drilling undertaken on the right bank confirmed that the proposed abstraction weir and pump station could be partly located directly on bedrock, which would provide good founding. Geotechnical conditions at the weir site are considered generally favourable, particularly if an adequate length of spillway can be provided in the general area of the rock exposures on the west side of the river channel.

Trial pit investigations were carried out along the proposed rising main alignment and these revealed the presence of materials suitable for machine excavation with a possible need for importation of selected bedding material for pipe laying.

INFRASTRUCTURE PRELIMINARY DESIGN

The preliminary design outcomes for the rising main are based on the recommended use of glass-fibre reinforced polyester (GRP) pipes and are summarised in **Table ii**.

Table ii: Proposed Rising Main

Design Parameter	Parameter Specification	
	4m^3/s Design Flow	6m^3/s Design Flow
Rising Main Length	6300 m	6300 m
Rising Main Properties	1700 mm dia GRP	1900 mm dia GRP

The preliminary design outcomes for the pump station are as summarised in **Table iii**.

Table iii: Proposed Pump station

Design Parameter	Parameter Specification	
	4m^3/s Design Flow	6m^3/s Design Flow
Rising Main Static Pressure	28,0 m	28,0 m
Friction Losses	7,8 m	9,5 m
Inlet Static Pressure	1,8 m	1,8 m
Pump Duty	34,0 m	35,7 m

A southern discharge point into the Voëlvlei Dam, located mid-way between the CCT's and the West Coast District Municipality's (WCDM) WTWs intakes is considered preferred from water quality (blending and settlement) perspectives. It also has advantageous foundation conditions (bedrock).

ENVIRONMENTAL IMPACT ASSESSMENT

The proposed scheme will need to comply with the requirements of all relevant legislation, including (but not limited to):

- The National Environmental Management Act (NEMA);
- The National Water Act (NWA); and
- The National Heritage Resources Act (NHRA).

It will be important for DWA to take into consideration the EIA process timeframes, as it can take up to 18 months (or in some cases even longer) to receive environmental authorisation. An independent Environmental Assessment Practitioner will need to be appointed to ensure compliance with the requirements of Section 17 of EIA Regulations.

Experience gained from interactions with Stakeholders and Interested and Affected Parties (I&APs) on this project, has shown that the proposed scheme is very sensitive in terms of public opinion.

COSTS AND UNIT REFERENCE VALUES

Table iv provides a summary of the capital cost estimates, operation and maintenance cost estimates, as well as the Unit Reference Values (URVs) at 6, 8 and 10% discount rates, for the two diversion options.

Table iv: Cost Estimates

Cost Item	Scheme Component Costs in R(millions) (excluding VAT)	
	4m^3/s	**6m^3/s**
Construction Costs	220,87	249,83
Professional fees	17,20	19,19
Servitude & property	5,04	5,04
Total Capital Cost	**243,11**	**274,06**
Annual Operation and Maintenance Costs	**8,340**	**8,441**
URV at 6% (R/m^3)	**1,31**	**1,67**
URV at 8% (R/m^3)	**1,52**	**1,94**
URV at 10% (R/m^3)	**1,75**	**2,24**

Should ductile iron pipes be selected by DWA as a preferred pipe material to GRP, then the estimated capital cost increase for the scheme will be 24% and 31% for the 4 and 6 m^3/s options respectively.

Apart from having favourable URVs, the BRVA Scheme also has the advantage that it is likely to be the only scheme that could be implemented by about 2018/19 when the growth in water requirement may exceed the available supply from the WCWSS.

SUGGESTIONS OF THE PROJECT MANAGEMENT COMMITTEE

A number of valuable suggestions and comments were made during the course of the 24 Project Management Meetings held over the duration of the study. These include:

1) The **provision for the Reserve** to the Berg River Estuary is currently the biggest constraint influencing the outcomes of the Berg River development options.

2) **Streamflow gauging requirements** for enabling the Reserves in the Berg River and its estuary to be implemented and monitored is critical. This would also enable improved irrigation abstraction monitoring downstream of the Voëlvlei Dam, and improved timing of irrigation releases. Appropriate locations for such a weir (and budget provision) are to be considered by the Western Cape Regional Office (WCRO) of DWA.

3) The BRVA scheme offers an opportunity to environmentally **benefit the Berg River Estuary,** through the implementation of its operating rules (abstractions and releases).

4) Where catchments are already over-allocated, **new licence applications should not be considered,** unless verification and validation show that there is unallocated water.

5) It was recommended that DWA undertake a separate **Feasibility Study of a new Lower Steenbras Dam**.

6) The possible raising of the Misverstand Dam or the improvement of the intake arrangements at the dam for the Withoogte abstraction works so as to increase the utilisable storage have been identified in the Operational Study being undertaken by the DWA Regional Office. A low raising of about 0,5 m could offer significant advantage in the ability to manage the upstream releases and the supply and Reserve requirements of the Lower Berg irrigators and West Coast District Municipality, thereby reducing losses.

CONCLUSIONS AND RECOMMENDATIONS OF THE STUDY

The following conclusions and recommendations are made in relation to the potential implementation of the BRVA Scheme:

1) The **Berg River Reserve** commensurate with a Category D River has been allowed for, and a recommended minimum summer low flow for the estuary of 0,6 m^3/s, of which **0,5 m^3/s (8 million m^3/annum) would be provided out of releases from the Voëlvlei Dam to** supplement the present day inflows (which are ungauged) into the estuary.

2) The proposed **Lorelei abstraction site** is close to a bend on the Berg River which is favourable from a sedimentation management perspective. Geologically this is the only location of those considered at which any rock outcrop is evident for suitable founding conditions. **From a hydraulic and geotechnical perspective** this site is therefore **recommended** as the preferred location for the abstraction weir.

3) The **Lorelei site** also has the **shortest conveyance length** of all abstraction site options considered and enables the rising main to the Voëlvlei Dam to be aligned such that the least possible impact is made on the Renosterveld within the Voëlvlei Conservancy.

4) It is recommended that the **proposed rising main function in reverse** in summer so as to serve as a more efficient release conduit from Voëlvlei Dam through its ability to better control releases and to reduce the extent of water losses currently experienced from the existing outlet canal.

5) Of the two potential abstraction approaches investigated in detail, namely a 4 m^3/s pump station with a step-pump operating, or a 6 m^3/s pump station with variable speed drives, the former appears to be more easily implemented and operated, as well as offering a slightly higher resulting yield (**23 versus 20 million m^3/a**). From an operational perspective, the **4 m^3/s abstraction via a stepped-pumping operating rule** is recommended.

6) In terms of the **water quality related to abstraction of winter water** from the Berg River:
    - A study of water quality changes during the winter floods indicated that high phosphate concentrations occur early in the rainfall season and lower concentrations later in the season. Rainfall that generates surface runoff, wash phosphate containing compounds into the river and this source is gradually depleted as the rainfall season progresses.
    - Phosphate concentrations decrease during a single flood event due to dilution. It is high during the rising limb of a flood and decreases during the falling limb of a flood.
    - Nitrogen concentrations are low early in the rainfall season and high later in the rainfall season. Soft rain that penetrates the soil profile leaches nitrogen compounds from the soil. This is a slower path way resulting in elevated nitrogen concentrations later in the season.
    - Nitrogen concentrations decrease during a single flood event due to dilution. It is high during the rising limb of a flood and decreases during the falling limb of a flood.
    - The salt concentration increases during the rainfall season and is characteristic of the geology of the middle and lower Berg River.
    - The elevated phosphate concentration observed in the Berg River at the start of the rainfall season is probably the result of point source discharges from WWTWs. If it is necessary to avoid elevated phosphate concentrations in the transfer water, then it is recommended that transfers be curtailed during the first few floods of the rainfall season.

7) From a **water quality dispersion perspective** in the Voëlvlei Dam:
    - Bacteria transferred from the Berg River into Voëlvlei Dam will decrease as a result of dilution, dispersion and bacterial die-off.
    - The highest bacterial counts in the Berg River are generally recorded during the winter months, peaking in June.
    - Under normal operating conditions, and transferring the maximum volume of water into the Voëlvlei Dam, there would only be a minor increase in bacterial counts above background at the City of Cape Town abstraction point and at the Swartland abstraction point.
    - Wind currents would push the inflowing plume to either of the two abstraction points depending on the wind direction.
    - There would only be a slight increase in bacterial counts above background at the two abstraction points under those conditions.
    - In a worst-case scenario there would only be a moderate increase in bacterial counts at the Swartland abstraction tower. A worst-case scenario is transferring water at the maximum transfer rate, with the maximum bacterial counts measured in the Berg River, and wind currents driving the plume towards the Swartland abstraction point.
    - At this stage there is no indication of a significant increase in bacterial counts at either of the two abstraction points that would require pumping to be terminated at certain times of the year or flows in the river.

8) In terms of the **impacts of nutrients from the Berg River** water:
   - Voëlvlei Dam has experienced a higher frequency of algal blooms since the drought of 2004/5 changed the character of the dam from a stable clear water dam to a stable turbid system dominated by free-floating algae (phytoplankton).
   - The Cape Town water treatment works confirmed that their cost of water treatment has increased to deal with the increase in taste and odour problems in their treated water, and an increase in filter blocking algae (Melosira).
   - The option to transfer water from the Berg River would, in the short term, probably not have a significant impact on salinity in Voëlvlei Dam.
   - The transfers would probably have a negative impact on the in-lake nitrogen and chlorophyll-a concentrations, leading to increased problems with nuisance algae and the associated cost of treating the water to potable water standards
   - The initial assessment indicated that the algal bloom situation may be maintained or there may even be an increase in the frequency or duration of high algal concentrations.

9) Suitably **accurate survey information is available** from this study for the purpose of undertaking detailed design of this scheme.

10) **Geotechnical conditions at the Lorelei site are generally favourable**, and the weir design can be suitably accommodated at the proposed site. Machine excavation is expected to be possible along the pipeline route. Although there is potential for the use of excavated materials for backfilling. The final pipe type selection will influence the extent of selected fill material available insitu.

11) From an integration perspective, **the proposed Spes Bona Reservoir and the linking pipeline to the Glen Gary Reservoir to be constructed in the near future by the CCT will be necessary in order to enable the full incremental yield of the scheme of 20 million m^3/annum** to be taken up by the CCT. The growth in the West Coast's requirements could also be supplied from the BRVA scheme, depending on the actual growth in water requirements. Supply to irrigation in order to improve their assurance of supply and to relieve the over-allocation from Voëlvlei Dam is also an option, subject to the outcomes of the verification and validation process, and on the affordability of water from the scheme to that sector.

12) For the **6,3 km rising main, a 1700 mm diameter GRP is proposed for the 4m^3/s abstraction option and the same pipe type (1900 mm dia) for the 6 m^3/s option**.

13) The **estimated capital cost of the 4 m^3/s abstraction option is R277 million and that of the 6 m^3/s option R 312 million including VAT**. The corresponding **Unit Reference Values are R1.52/m^3 and R1.94/m^3 respectively for a discount rate of 8% per annum**, and based on the VAT exclusive costs. On the basis of the financial assessment, technical and environmental considerations, the 4 m^3/s option is recommended.

14) Should DWA elect to prescribe ductile iron pipes for the rising main, the overall capital cost increase of the 4 and 6 m^3/s scheme options is estimated to be 24% and 31% respectively.

OVERALL RECOMMENDATION OF THE STUDY

The **Berg River – Voëlvlei Augmentation Scheme** has been found to be a favourable surface water intervention option, albeit only able to augment the Western Cape Water Supply System by about 2-3 years. It is an option that should be considered within the current planning horizon of the Western Cape Reconciliation Strategy as the next possible surface water intervention. Should this scheme proceed to implementation, then it is proposed that the **4m^3/s abstraction, based on a stepped-pumping operating rule**, forms the basis of the scheme design.

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ABBREVIATIONS

BRVA	Berg River-Voëlvlei Augmentation
BRVAS	Berg River-Voëlvlei Augmentation Scheme
CCT	City of Cape Town
c/kWh	cents per kilowatt hour
DEA&DP	Department of Environmental Affairs and Development Planning
DWA	Department of Water Affairs
EAP	Environmental Assessment Practitioner
EIA	Environmental Impact Assessment
EWR	Ecological Water Requirements
GN	General Notice
GRP	Glass-fibre Reinforced Polyester
HIA	Heritage Impact Assessment
HWC	Heritage Western Cape
HFY	Historic Firm Yield
I&APs	Interested and Affected Parties
kWh	kilowatt.hour
LiDAR	Light Detection and Ranging
m^3/s	Cubic Metres per Second
m^3/a	Cubic Metres per Annum
NEMA	National Environmental Management Act (No. 107 of 1998)
NERSA	National Energy Regulator of South Africa
NPV	Net Present Value
NWA	National Water Act (No. 36 of 1998)
SAHRA	South Africa Heritage Resources Agency
SCADA	Supervisory Control and Data Acquisition
STCC	Short Term Characteristic Curves
URV	Unit Reference Value
WAAS	Water Availability Assessment Study
WCDM	West Coast District Municipality
WCWSS	Western Cape Water Supply System
WMA	Water Management Area
WCRSS	Western Cape Reconciliation Strategy Study
WRCS	Water Resources Classification System
WRPM	Water Resources Planning Model
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 (WCRSS) has investigated a range of bulk water supply schemes that could serve towards meeting the growing water requirements that will need to be supplied from the WCWSS. These include options such as desalination, effluent treatment for re-use, groundwater development and possible (albeit of limited size) surface water augmentation options. Investigations into these options are being embarked on by the CCT and DWA towards ensuring that planning, authorisation processes and implementation are timeously carried out so as to meet the projected water requirements on the WCWSS within a planning horizon to 2030.

In July 2008, DWA appointed the Western Cape Water Consultants Joint Venture (WCWC JV) to undertake pre-feasibility level investigations into the potential development of six surface water options (Phase 1), from which two schemes would be prioritised for further study during Phase 2 to feasibility level. The six potential schemes investigated to pre-feasibility level were:

i. The Michell's Pass Diversion Scheme
ii. The First Phase Augmentation of Voëlvlei Dam
iii. Further Phases of Voëlvlei Dam Augmentation
iv. The Molenaars River Diversion
v. The Upper Wit River Diversion
vi. Further Phases of the Palmiet Transfer Scheme

The objective, and outcome achieved by the pre-feasibility phase was that all six potential surface development options were investigated and compared at an equivalent level of study detail to enable a recommendation in terms of those options that warranted further investigation to feasibility level study under this project.

Two of the above-mentioned schemes (i and ii) were prioritised for further investigation to feasibility level. As both of them involve the storage of water in the existing Voëlvlei Dam, the scheme names have been adapted to suit. Furthermore, in discussion with DWA it was recognised that to avoid potential confusion with existing diversion and supplement schemes of similar names, this study would report on the basis of the following schemes, both representing options for the **First Phase Augmentation of Voëlvlei Dam, namely:**

- **Berg River-Voëlvlei Augmentation scheme,** abbreviated as the BRVA Scheme or the BRVAS, which forms the subject of this report.
- **Berg-Breede (Michell's Pass) Water Transfer Scheme,** abbreviated as the BBTS (Breede-Berg Transfer Scheme), which is the subject of its own stand-alone report, also a deliverable under this study.

The WCRSS has identified that small schemes such as this one, only yield sufficient additional water to augment the overall system for about another 2-3 years at best, dependant also on the CCT achieving the objectives of its Water Conservation and Water Demand Management Strategy. The latest reconciliation of water supply and water requirements from the WCWSS is shown on **Figure 1** with the contribution of the potential Berg River abstraction shown.

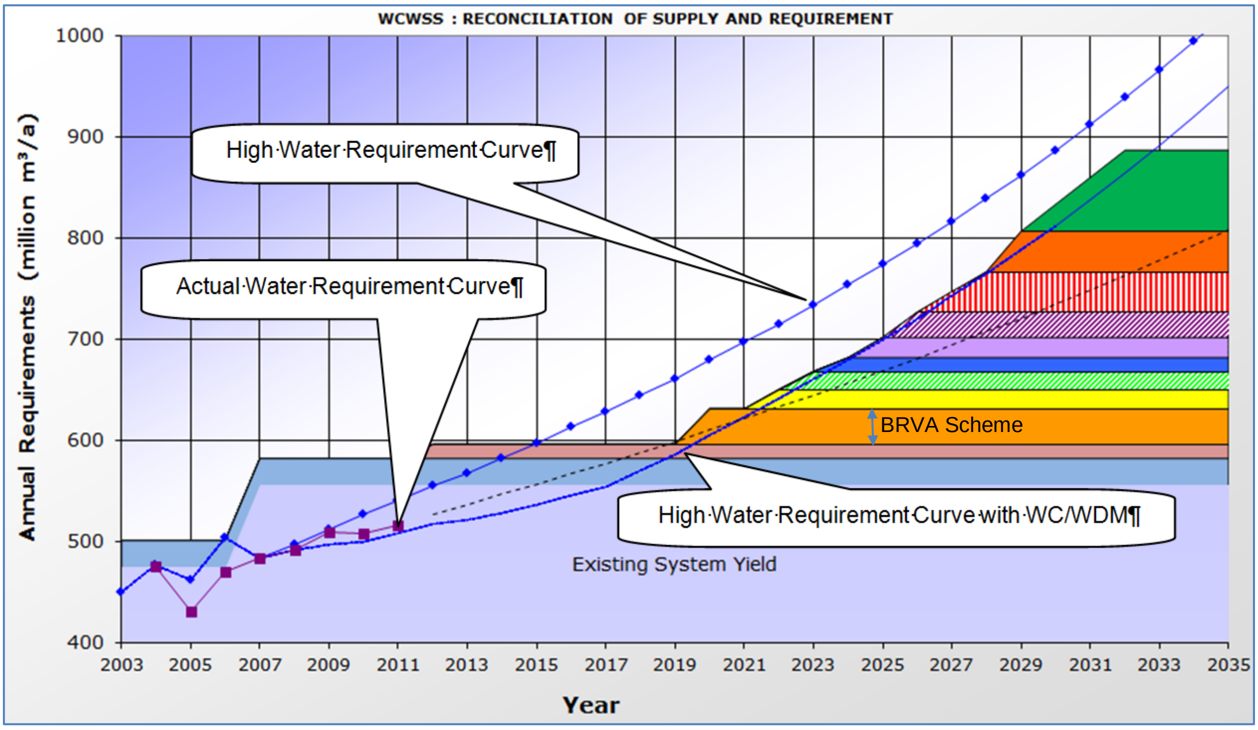


Figure 1: Reconciliation of Water Supply and Requirements (WCWSS)

1.2 PURPOSE AND OBJECTIVES OF THE STUDY

The aim of the feasibility study was to verify the technical, environmental, social, economic and financial viability of this proposed winter abstraction scheme, making use of the existing (un-raised) Voëlvlei Dam, at feasibility level and preliminary design. The study aims to determine the sustainable optimal diversion capacity from the Berg River in winter, after allowing for downstream water requirements, most notably that for meeting Ecological Water Requirements of the Berg River and its estuary, in both summer and winter.

A significant objective of the feasibility study was to also provide catchment-wide Reserve estimates for the Berg River catchment as per the technical requirements of the Water Resources Classification System (WRCS; Government Gazette 31417). This included a Comprehensive Reserve determination for the Berg River Estuary, including a Resource Economics Assessment of the implications of flow change in the Berg River Estuary. The results provide the information not only required in the support of the assessment of potential winter diversion for this study, but also to the various other planning initiatives being undertaken, such as the All Towns Reconciliation Study, which is considering water supply options for the towns, other than Cape Town, in the Western Cape. Furthermore, the generation of catchment-wide Reserve estimates as per the technical requirements of the WRCS will be required for classification in the Berg River catchment, and the data will assist DWA in planning and managing water use and license applications in this catchment.

Agriculture and urban users represent the largest user groups reliant on the Western Cape Water Supply System. There is increasing conflicting opinion between various stakeholders, across both the Berg and Breede Water Management Areas (WMAs) in relation to the strategic approach to water allocation for the benefit to the Western Cape region as a whole. Whilst agriculture on the one hand is the bread basket of the region, the growing water requirements of the urban sector (particularly that of the CCT) also need to be met. A public awareness and engagement process therefore formed a key component of this study in order to ensure that interested and affected parties were involved from the start of the study, in its findings and through to its recommendations.

1.3 THE STUDY AREA

The Study area is effectively that of the Berg WMA as shown in **Figure 2** which also illustrates the extent of the main bulk water supply infrastructure within the WCWSS. The location of the proposed BRVA scheme is shown. It should be noted that the potential for large-scale development of surface water resources in the Western Cape has become very limited, primarily due to the fact that all potential, feasible large dam sites have been developed and that the provision of water for the environment limits the extent of possible development of the resource.

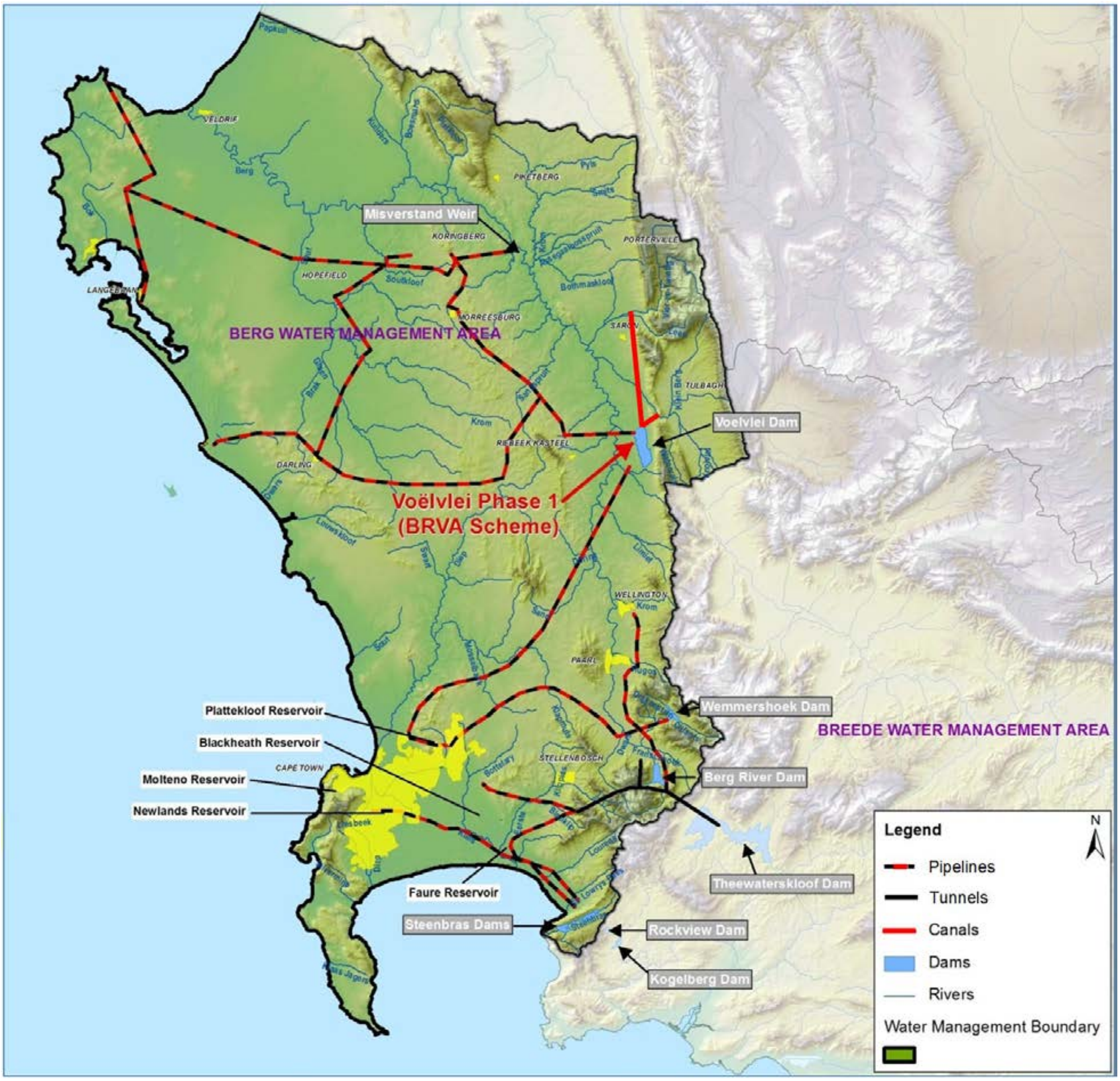


Figure 2: The Western Cape Water Supply System and Proposed BRVA Scheme

2. DESCRIPTION OF THE SCHEME

2.1 EXISTING VOËLVLEI GOVERNMENT WATER SCHEME

The existing scheme consists of a diversion weir on the Klein Berg River (see **Figure 3**), one in the Leeu River and one in the Twenty Four Rivers, and a canal system which carries water from the rivers into the Voëlvlei Dam which is located in a natural depression between the Voëlvlei Mountain range and the Berg River near Gouda.

Figure 3: The Existing Klein Berg Diversion Weir

Voëlvlei Dam is state owned and is a source of water for the CCT and local authorities, including users in the West Coast District Municipality (WCDM) from Malmesbury to St Helena Bay. Treated water is supplied to these users via the Swartland Water Treatment Works (owned and operated by the WCDM) at the Voëlvlei Dam. Water is also released from the Voëlvlei Dam via an outlet canal, shown in **Figure 4** into the Berg River from whence abstraction takes place at Misverstand Dam into the Withoogte WTW (also owned and operated by the WCDM).

Figure 4: The Existing Voëlvlei Dam Outlet Canal to the Berg River

The Voëlvlei Dam has a full supply capacity of 172 million m^3 and has a very small incremental catchment of its own (31 km^2), with water being fed into the dam via the diversions and canals described previously. Both canals feeding the dam are concrete lined. The Klein Berg Canal (8 km long) has a capacity of 20 m^3/s whilst that from the Leeu and Twenty Four Rivers (29 km long) has a capacity of 34 m^3/s.

The current assured yield from the Voëlvlei Dam has been estimated to be 105 million m^3/a (ISP, 2005) but indications are that the dam is currently over-allocated.

The CCT owns and operates its own WTW at the Voëlvlei Dam (see **Figure 5**) and incorporates raw water abstraction via an intake structure and pump station, a purification plant, and a high lift pump station which pumps treated water through a single pipeline to the CCT's service reservoir at Plattekloof in the Tygerberg Hills. The city's intake and WTW was completed in 1971 and are located at the southern end of the 6,4 km long reservoir, thus minimising the length of the delivery pipeline to Cape Town. The intake works consists of a reinforced concrete pump station housing five low lift pumps in a dry well which extends well below minimum water level in the reservoir. The pumps can deliver a maximum of 273 Ml/d through the 1,5 m dia, 0,6 km long pre-stressed concrete pipeline to the treatment plant.

Figure 5: The CCT's Water Treatment Works and Low Lift Pumps at Voëlvlei Dam

The treatment plant makes use of upward flow clarifiers and rapid gravity sand filters and has a maximum output of 273 Ml/d. The treated water is fed into a 9,1 Ml capacity clear-water reservoir from whence it enters the conveyance pressure pipeline to Cape Town. The city's high lift pump station is equipped with six pumps each with variable speed motors to enable fluctuations in water requirements to be accommodated. The 80 km pipeline to the Plattekloof reservoir is a 1,5 m diameter pre-stressed concrete pipeline, which has required regular maintenance by the CCT, including repairs due to pipe bursts. The frequency of leaks and bursts has however reduced significantly since the City replaced the vulnerable sections of this pre-stressed concrete pipeline and has a dedicated pipeline maintenance team in place so as to reduce down time of the pipeline due to any bursts or leaks that do occur.

The pipeline integrity is of critical importance to the water supply security to Cape Town. The current spare capacity of 3,16 m^3/s, available in winter only, equates to 20 million m^3/a. This presents a limitation in terms of the extent to which the water supply to the City can be augmented, and either alternative water users that could be supplied from Voëlvlei Dam will need to be considered or the CCT would need to implement increased potable water storage infrastructure as well as increased integration thereof into the existing system. This is further addressed in **Section 6**. Alternative water users could for example include augmentation to the WCDM and possible alleviation of the perceived over allocation from the Voëlvlei Dam.

2.2 PROPOSED BERG RIVER-VOËLVLEI AUGMENTATION (BRVA) SCHEME

2.2.1 Introduction

The ecological Reserve commensurate with a Category D River has been allowed for in the system modelling of the scheme. According to the report on the Reserve for the Berg River Estuary the required stream flow into the estuary during the summer months should vary between 0.6 and 0.9 m^3/s. As the present day inflows into the Estuary are not gauged (although DWA has plans to install a gauge), the present day inflow of 0.3 m^3/s was estimated from the gauged flows below Misverstand Dam, and from the downstream irrigation allocations which will be metered in the near future. In order to provide the required Reserve inflows to the Estuary would require that additional releases of between 0.3 m^3/s and 0.6 m^3/s should be made from Voëlvlei Dam, particularly during the four summer months from December to March. Therefore, the conservative assumption has been made in the system modelling of the proposed scheme that an additional release of 0.5 m^3/s should be made from Voëlvlei Dam for the six summer months.

During the Pre-feasibility assessment, various possible alternative diversion sites were considered and the outcome of that phase was that the Lorelei Diversion site was preferred. Hydraulically the site is close to a river bend which is favourable from a sedimentation management perspective. Geologically this is the only location of those considered at which any rock outcrop is evident for suitable founding conditions (see **Figure 6**), both for the weir and for the pump station. The findings of the geotechnical investigation are summarised in **Section 8** and the detailed geotechnical report is enclosed in **Appendix 8**.

Figure 6: Typical Rock Outcrop at the Lorelei Site

It has been determined in the yield analysis (described in **Section 4**) that when implementing a pumping rule which can be continuously varied in its abstraction rate, a maximum abstraction rate of 6 m^3/s yields approximately 20 million m^3/a. On the other hand a 4 m^3/s abstraction, implemented using a stepped pump rule which can be applied in 1 m^3/s stepped increments, yields 23 million m^3/a. Designs have been undertaken for both of these abstraction rate regimes and the required infrastructure sized accordingly. Cost estimates for both have been determined and are summarised in the financial evaluation in **Section 11**. The cost estimate summaries are provided in **Appendix 12**.

The EWR for the river during winter appears to be the critical component. No summer abstraction is at all possible, with carefully managed abstraction required during 4-5 months in winter. The further advantages of the Lorelei site is that the rising main (maximum diameter of 1,9 m) delivering water from the pump station adjacent to the diversion weir into the Voëlvlei Dam has the shortest conveyance length of all options considered and enables the routing to the dam to be designed so as to have the least impact on the Renosterveld within the Voëlvlei Conservancy, as it can be aligned with areas previously disturbed. The intention is that the rising main pipeline from the Berg River to the Voëlvlei Dam will be used in reverse and under gravity in summer, as a replacement to the existing outlet canal shown previously in **Figure 4.** This will provide for improved control of releases and reduced water losses, which are currently experienced from the outlet canal, particularly at its most downstream end before it discharges into the Berg River. Evidence of these losses can be seen in the unnatural wetland area (see **Figure 7**) that has formed adjacent to the canal primarily due to spillages from it. The proposed general layout of the BRVA scheme includes the 6.3 km long rising main as shown on **Figure 8**.

Figure 7: Wetland Area Adjacent to Voëlvlei Dam Outlet Canal Close to Berg River

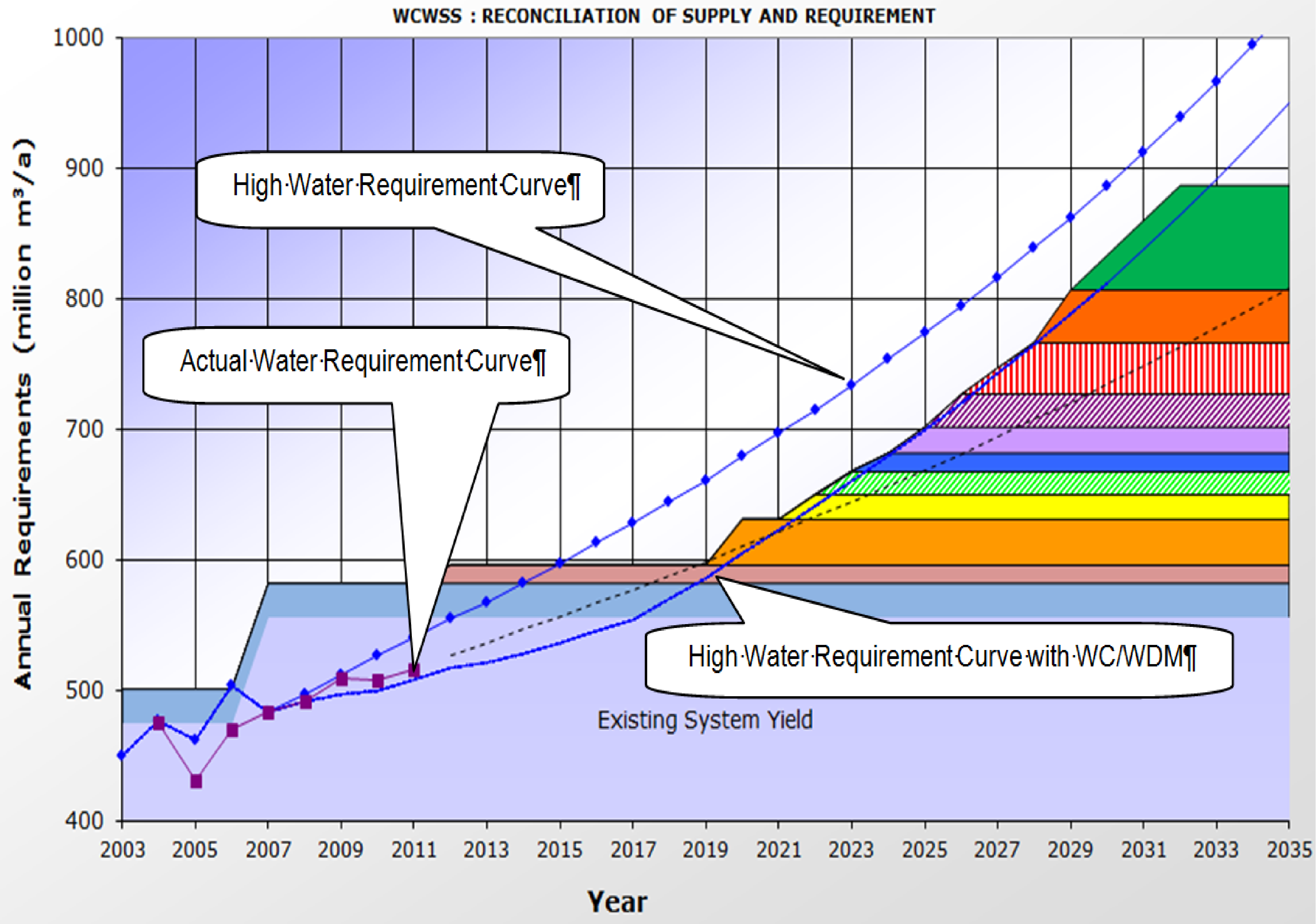


Figure 8: Layout of the Proposed BRVA Scheme

2.2.2 Environmental Reserve Requirement

During the pre-feasibility phase a Class C/D EWR for the river immediately downstream of the site was used to check the impact of the proposed scheme on the flows in the Berg River downstream of the site. At that stage it was identified that the flows in the Berg River would be unacceptably impacted if pumping were to take place in May based on the stepped pumping rule. However it was found that it is impossible to meet a Class C/D EWR because the requirement exceeds the actual present day flows at the site for quite a large part of the time. A revised EWR was therefore derived during this phase of the project, based on a Class D.

The estuary requirement was determined during the pre-feasibility phase to be 0.6 m^3/s during the dry summer months. For the rest of the year, the present-day flows were considered sufficient to meet the estuarine requirements. In the pre-feasibility phase, a release of 0.5 m^3/s was allowed for from the Voëlvlei Dam during the summer months (November to April) to contribute to the estuary Reserve requirement, which is a volume of 8 million m^3/a. In this phase, the estuary Reserve requirement was included in the WRYM as the same flow rate over the same months.

A summary report which captures the key findings and outcomes of the Reserve determinations undertaken during Phase 1 of this Study, which includes the Berg River and its estuary, is provided in **Appendix 7**. The full suite of Reserve Determination Reports forms a stand-alone deliverable.

2.2.3 Winter Operation

The BRVA pumping scheme has been investigated based on several different abstraction capacities, two operating rule regimes and two different EWR requirements using the Water Resources Yield Model (WRYM). From these simulations, options were narrowed down to two, one for each operating rule regime. This was in addition to the equivalent work done during the pre-feasibility phase, and has been necessary in order to accommodate refinements to the EWR requirement assumed in Phase 1. The two options represent the most likely optimal configurations for the two pump rule regimes in which the EWRs can be accommodated. One has a stepped pumping rule and the other assumes a variable speed pumping regime that is able to extract the precise surplus volume of water available after the EWRs have been met. These two options form the basis for the preliminary design of the BRVA scheme and full cost estimates and unit reference values have been developed for each. They are:

- Option 1: a 4 m^3/s pump station with a stepped-pump operating rule that works in 1 m^3/s increments up to a pump station capacity of 4 m^3/s and which allows a base flow of 1 m^3/s to pass the site at all times.
- Option 2: a 6 m^3/s pump station with variable speed drives so that the EWR requirement can be allowed to pass the site at all times, exactly, while the balance will be abstracted up to the pump station capacity of 6 m^3/s.

2.2.3.1 Winter Pumping scheme Option 1

Option 1, which appears to be optimal for the stepped-pumping operating rule, consists of a pump station with a capacity of 4 m^3/s. The operation is based on the stepped-pumping rule which has been proposed previously for this site, both in the pre-feasibility phase of this project and also in previous augmentation studies for Voëlvlei Dam. The stepped-pumping rule works as follows: a minimum flow (spill) of 1 m^3/s is maintained in the Berg River at all times, after abstraction. The pump station has a set of four pumps with each pump having a capacity of 1 m^3/s, so that each pump starts up when the river inflow to the site exceeds the sum of the required environmental base flow of 1 m^3/s and the abstraction, in 1 m^3/s steps. For example the 1 m^3/s pump can start up when the inflow to the site exceeds the threshold value of 2 m^3/s, so that the base flow requirement of 1 m^3/s is met. A second 1 m^3/s pump can then start up when the inflow exceeds 3 m^3/s and so forth until all four pumps are operating. The stepped-pumping rule was modelled for the months of June to October inclusive based on the findings for the impact of the pumping on the EWR during the pre-feasibility phase.

2.2.3.2 Winter Pumping scheme Option 2

Option 2 consists of a different operating regime where a set of variable speed pumps would continuously adjust their pumping rate in the range of 0 to 6 m^3/s. Any flow rate would be able to be pumped, which in turn would allow the EWR to pass the site exactly as required based on the natural flow which would have been estimated for that time (see next section on an explanation of the determination of the natural flow). Option 2 was also modelled for June to October inclusive; however a slight increase in yield may be possible if pumping were extended to May and November. The proviso to this is that there may be water quality issues with the first flush in May. Pumping in these additional months is possible for this scenario because of the variable speed drive set-up and the ability of the pump station to only pump once the EWR has been met first.

2.2.3.3 Operational issues

In Option 1, the 4 m^3/s abstraction via a stepped-pumping rule is relatively simple to implement, as the pumping rule would operate based on a level sensor at the abstraction weir, from which the inflows to the scheme would be determined, the appropriate pumping rate calculated and the appropriate pumps correspondingly switched on and off.

In Option 2, the 6 m^3/s (continuously adjustable) pumping rule would however require an estimation of the natural flow at the site. This would need to be determined through a complex process consisting of a proxy flow gauging station located in a natural catchment that would be representative of the Berg River catchment, and a software model which would be used to convert the observed natural flow at the proxy gauge to a natural flow at the pumping station site. The flow gauging station would have to operate in real time and data would have to be transmitted continuously to the pump station where the natural flow for the pump station would be determined. The natural flow would then be converted to a EWR flow based on the monthly duration curves for the EWR. This would be run continuously and the pumps would continuously adjust their pump rates.

The 4 m^3/s stepped-pumping rule would be a lot simpler to operate and also would not require the complexity of a proxy flow gauge located far away from the site. However Option 2 offers the benefit of meeting the EWR exactly at all times, except when the inflows are less than the EWR requirement. So from a compliance point of view Option 2 may be preferred, albeit practically very difficult to implement and operate.

2.2.3.4 Yields

The 1:50 year incremental yields that would be added to the Western Cape Water Supply System through the implementation of the Berg River Pumping Scheme are given in **Table 1** for the two options considered.

Table 1: Incremental Additional Yield (1:50 year) for the BRVA Scheme

Option	1:50 year Incremental yield (10^6 m^3)
Option 1: 4 m^3/s pump station with stepped-pumping rule	23
Option 2: 6 m^3/s pump station with variable speed drives	20

In both cases, the yields shown are after allowance for the EWR requirements for both the river and the estuary, on the basis that these have been satisfied as "best as practically possible", taking into account that there are present-day flow deficiencies in the current system in certain months.

In summary, whilst the two options above produce very similar yields, there are important implementation considerations that differentiate them from one another. Option 1 (4 m^3/s) is the most simple from an operational perspective, whilst Option 2 (6 m^3/s) offers improved ability to accommodate the required EWR by ensuring that the necessary flow in the Berg River passes the abstraction site at all times. The latter is however far more cumbersome to operate than the 4 m^3/s stepped-pumping rule, which is adjusted in 1m^3/s increment, on the basis of the actual inflow at the site.

2.2.4 Summer Operation

The design of the proposed rising main is such that during the summer months the pipeline can be operated in reverse (under gravity) so that releases can be made from the Voëlvlei Dam to the downstream users including provision for the estuarine EWR (0,5 m^3/s). An outlet structure to the Berg River, located upstream of the abstraction weir and pump station, has been designed to allow the use of the pipeline for this purpose. Furthermore provision has been made for connections into the new pipeline from the existing Swartland canal at the Swartland WTW. These design adaptions will enable the release of water from the Voëlvlei Dam back to the Berg River during summer without incurring water losses as has previously been described.

3. STREAMFLOW HYDROLOGY STUDIES

The monthly streamflow sequences for both naturalised and current-day conditions, used in this study of the BRVA Scheme, were derived from the following DWA Project: “The Assessment of Water Availability in the Berg Catchment (WMA 19) by Means of Water Resource Related Models” (DWAF, 2007; DWAF 2008,) (abbreviated to “Berg WAAS”.) The Berg WAAS, conducted by Ninham Shand in association with Umvoto, was completed in 2009 and comprised, amongst others, a complete update of the streamflow hydrology of the Western Cape System Analysis (WCSA). The WCSA Study incorporated data up to the 1990/91 hydrological year (DWAF, 1993).

The Berg WAAS comprised a comprehensive review and update of the surface water and groundwater hydrology and water use of all the catchments that form part of the greater Western Cape Water Supply System (WCWSS). These catchments include the Berg, Upper Eerste, Palmiet, Steenbras and Upper Riviersonderend Rivers. The primary purpose of the Berg WAAS was two-fold; namely, to provide updated information to support planned feasibility studies for augmentation of the WCWSS, as well as to inform future water allocation decisions in the related catchments.

In the Berg WAAS the original WCSA catchment models were updated by extension of all input data, re-configuration and re-calibration. Land-use and water-use sequences, as well as infrastructure changes after 1990, were determined and thereafter configured in the WRSM2000 catchment model, up to the hydrological year, 2004/05. Monthly rainfall, evaporation and streamflow records after 1990 and up to 2004/05 were processed and thereafter incorporated in the WRSM2000 model. These updates allowed the Pitman rainfall-runoff model imbedded in WRSM2000 to be re-calibrated at selected streamflow gauging sites, using the WCSA Pitman parameters as starting values. The re-calibrated Pitman model parameters were used to generate naturalised monthly streamflow sequences at all points of interest in the WCWSS.

For the yield analyses related to the BRVA scheme, the Berg WAAS naturalised streamflow sequences were incorporated in the WRYM system model of the WCWSS, as described in **Section 4**.

4. YIELD AND SYSTEM ANALYSIS

4.1 OPERATION OF THE WESTERN CAPE WATER SUPPLY SYSTEM

The WCWSS is operated in an integrated manner, with the supply from the individual dams being adjusted to minimise spillage. A large proportion of the incremental yield from the proposed BRVA Scheme will be supplied to the CCT. This additional supply should not increase the risk of spillage of the other dams. The transfer will also take place using the existing Voëlvlei pipeline, the capacity of which could be a constraint. During summer, it is also necessary that releases be made from the Voëlvlei Dam to help freshen the estuary. To address the above matters properly, the integrated WRYM model of the WCWSS was used to evaluate the yield of the proposed schemes to augment the Voëlvlei Dam. The existing integrated model was updated to improve its representativeness, as described below.

4.2 SYSTEM ANALYSIS APPROACH

The following system analysis approach was adopted:

- Reconfigure the Legacy version of the WCWSS model in the latest version of the WRYM code and test for integrity.
- Replace the Legacy naturalised streamflow sequences in the WRYM configuration with the WAAS sequences and compare the resultant yields of the sub-systems and the overall system with the Legacy yields.
- Update and refine the WRYM configuration to include various items such as:
    - Introduce EWR nodes along the Berg River main stem and, with that, a finer discretisation of irrigation demands and farm dam groupings.
    - Use observed monthly evaporations recorded during the three driest years on record at the Theewaterskloof and Voëlvlei Dams (instead of long-term monthly averages).
    - Make certain input data adjustments to the Theewaterskloof Dam model node.
    - Introduce observed inefficiencies in the abstraction of Jonkershoek stream flow at the Kleinplaas Dam.
    - Introduce the latest Reserve requirements at the Berg River Dam Supplement Scheme.
    - Introduce a new node and a diversion function to represent the operation of the BRVAS.
- Perform stochastic WRYM analyses of the overall WCWSS and sub-systems and compare the stochastic yields with the legacy yields.
- Update and refine the existing WRPM configuration for the WCWSS.
- Assess the augmentation target dates with and without the BRVA Scheme.

4.3 INTRODUCING EWR NODES IN THE WRYM CONFIGURATION FOR THE WCWSS

As part of this study additional EWR nodes were introduced into the Legacy WRYM configuration to enable stream flow to be simulated at these EWR sites and compared, if necessary, with the EWR requirements. The introduction of the EWR nodes required that the various components in the current configuration had to be split into portions upstream and downstream of each node site, including:

- Natural stream flow
- Irrigation Reauirements
- Lumped Farm Dams
- Losses

The irrigation requirements and volumes of the lumped farm dams were changed slightly during this process, as is explained below.

Table 2 shows that the modelled irrigation in the Berg River in the current study is about 10% larger than that used in the WAAS study, primarily because the current requirements of the Upper and Lower Berg River Irrigation Boards are based on the water requirements during drought years rather than during average years, to represent a drought scenario.

Table 2: Incremental Irrigation Requirements by Berg River reaches (million m^3/a)

Location	WAAS	Current Study
G1H020	59.8	76.2
G1H008	24.8	23.2
G1H035	5.5	7.4
G1H013	6.1	8.3
24 Rivers	24.5	24.5
G1H003	6.0	5.3
G1H036	74.3	83.9
G1RLLI (reach upstream of Lorelei)	14.5	10.4
d/s G1H013 (incl 6 million m^3/a losses)	16.0	16.0
Total	**231.5**	**255.2**

In the Berg WAAS, the farm dam capacities in the catchments were estimated from records for individual dams if available in the dam safety database, and, for the smaller dams, by using a relationship (established in the WCSA) between the surface area of the dam and the dam volume.

The volumes downstream of the Misverstand Dam were not determined in the WAAS. As part of this study the farm dam capacities downstream of the Misverstand Dam were estimated using the dam safety database, some dam volumes were adjusted, and the individual farm dams were aggregated using the finer spatial resolution required by the EWR sub-catchments. The reworked farm dam storages in the Berg River catchment for the current study are 100.9 million m^3 as opposed to the 97.2 million m^3 used in previous studies.

More details of this discretisation process are included in **Appendix 1** (Updating of the Western Cape Water Supply System Analysis).

4.4 THEEWATERSKLOOF DAM INPUT DATA ADJUSTMENTS

The evaporation and rainfall input data for Theewaterskloof Dam was reviewed, in recognition of the dam's large surface area of approximately 50 km^2 and the following adjustments were made:

- Evaporation – The evaporation for Theewaterskloof was selected from the average of the three driest consecutive years recorded at Theewaterskloof, namely 1981 to 1983, as this will more accurately represent the behaviour of the dam during the dry critical drawdown period.
- Mean Annual Rainfall – The WAAS study erroneously used the average mean annual rainfall of the Theewaterskloof Basin, rather than the rainfall at the dam itself, which is significantly less. During the current study the rainfall value represents the rainfall at the dam itself.

During the WAAS study a careful assessment was made of the various streamflow records related to the Theewaterskloof Dam site. The historical observed streamflow record at the Theewaterskloof Dam comes from a number of different sources of varying degrees of reliability. Initially a gauge, H6H003, was constructed upstream of the (then) proposed dam and this was used for about 6 years (Oct 1967-May 1974) until it was submerged during the construction of the Theewaterskloof Dam. The latter period happened to be one of the driest on record. The WAAS interpretation was that this gauge had under-recorded the high stream flow, leading to depressed simulated inflows and yields during the WCSA and the later Berg River Dam Feasibility Study. The naturalised inflow sequence finally derived during the WAAS resulted in markedly higher stochastic than historical firm yields. In this study, this work was reviewed in detail and the WAAS findings were fully confirmed.

This review of the Theewaterskloof Dam naturalised inflow sequence is fully detailed in **Appendix 1.**

4.5 VOËLVLEI DAM INPUT DATA ADJUSTMENTS

The evaporation input data for the Voëlvlei Dam was reviewed in recognition of its relatively large surface area of about 15 km^2. The evaporation data for the Voëlvlei Dam was based on the average of the three driest consecutive years recorded at the Voëlvlei Dam, namely 1972 to 1974, as this will more accurately represent the behaviour of the dam during the dry critical drawdown periods in the simulations.

4.6 KLEINPLAAS DAM INEFFICIENCIES

The spillage at the Kleinplaas Dam was investigated in more detail, by comparing the actual spillage with the theoretical for the period 1999 to 2010. In theory, the Kleinplaas Dam should have very little spillage because the abstraction capacity of the pipelines supplying the 400 Ml/d Blackheath and the 500 Ml/d Faure WTWs is large. In practice, the abstraction capacity is affected by:

- the closure of the WTWs for maintenance
- the reduced water requirement during winter
- the need to increase the abstraction from other dams which might be at risk of spillage during winter.

The behaviour of the Legacy WRYM configuration was adjusted to reflect the historical spillage at the dam, rather than the theoretically possible abstraction by using an appropriate diversion function to model the spills. This exercise indicated that the system yield would increase by up to 9 million m^3/a if the Kleinplaas Dam inflows were maximally abstracted rather than allowed to spill. The ecological impacts of such a decrease in spills along the Jonkershoek and Eerste Rivers were not assessed in this study.

The full review of the inefficiencies of the operation of the Kleinplaas Dam is described in detail in **Appendix 1.**

4.7 BERG RIVER DAM SUPPLEMENT SCHEME OPERATION

The relative effects on the total system yield of alternative approaches to the simulated operation of the proposed Preliminary Reserve for the Berg River Dam Supplement Scheme were analysed as part of this study. Depending on the approach, the historical firm yield of the total system differs over a range of -4 to +6 million m^3/a relative to the historical firm yield obtained in the original Berg River Dam Feasibility Study. Full details of these analyses are presented in the **Appendix 1**. In this study the more conservative approach of adjusting the Reserve release volumes on a monthly basis was adopted. The relationship between upstream streamflow and abstraction to the Berg River Dam that was developed is presented in **Table 3**.

Table 3: "Diversion" Function for EWR Operating Rule at the Berg River Supplement Scheme

Component	Average monthly pump rate (m^3/s) for a given average streamflow (m^3/s)						
Average monthly streamflow (m^3/s)	0.00	0.90	1.60	4.00	6.50	7.50	10.00
Average monthly pumping rate (m^3/s)	0.00	0.55	0.75	1.30	3.10	3.30	3.40

4.8 COMPARISON OF SYSTEM YIELDS: UPDATED WCWSS MODEL VERSUS LEGACY MODEL

Table 4 documents various changes to the original system yield of the Legacy WCWSS model as the configuration was step-wise updated to include the adjustments described in the above sections:

- Changing the Legacy configuration to a new configuration with finer discretisation of demands had very little impact on the HFY of the total system (see row 2).
- Increasing the evaporation from the Theewaterskloof and Voëlvlei Dams to correspond with the average of the three highest observed consecutive years and changing the spills of the Kleinplaas Dam to match the historical behaviour decreased the system HFY by about 16 million m^3/a (see row 3).
- Including the WAAS naturalized hydrology did not change the historical firm yield (see row 4).
- Adopting the Preliminary Reserve at the Berg River Dam Supplement Scheme reduced the system HFY by 3 million m^3/a (see row 5).
- The Legacy 1:50 stochastic system yield is reduced by 17 million m^3/a by the changes to the Theewaterskloof Dam evaporation and the inefficiencies at the Kleinplaas Dam (see row 8).
- The Legacy 1:50 stochastic system yield is increased by 9 million m^3/a by implementing the fully updated model as per all the above-mentioned changes and introducing the WAAS naturalised stream flow. (see row 9).

Table 4: Comparison of the Updated Model Yields with Legacy Yields from Earlier Analyses

Row No.	Description	System Yield (Million m^3/a)	Change in System Yield (Million m^3/a)
	Historical Firm yields		
1	Legacy HFY (DWA, 2011)	549	
2	Legacy HFY after introduction of EWR nodes and refinements	548	-1
3	Legacy HFY + EWR nodes and refinements + Theewaterskloof and Kleinplaas changes	532	-16
4	Replace Legacy hydrology with the WAAS hydrology		0
5	Adopting Preliminary Reserve EWR at the Berg River Dam Supplement Site		-3
6	HFY of Updated System and WAAS naturalised stream flow – without BRVAS [1]	529	
	1 in 50 Stochastic Yields		
7	Legacy 1:50 Stochastic Yield (DWA, 2011)	570	
8	Legacy 1:50 Stochastic Yield + Theewaterskloof and Kleinplaas data changes	553	
9	1: 50 Stochastic Yield: Updated System and WAAS naturalized stream flow – without BRVAS [1]	579	

[1] Includes impact of adopting the Preliminary Reserve at the Berg River Dam Supplement Site

4.9 DIVERSION FUNCTIONS FOR MODELLING THE OPERATION OF THE BRVAS

The incremental yields resulting from augmenting inflows to the Voëlvlei Dam by the BRVAS were determined for a number of operating rules and pump capacities with the fully updated version of the WRYM for the WCWSS. A diversion function was required at the BRVAS pumping site for each abstraction scenario that needed to be modelled. The EWR of the Berg River reach downstream of the abstraction site was an important determinant of alternative abstraction configurations. The Ecological Class for that reach had been proposed as a “C/D” in 2010 (DWA, 2010). It should be noted that the low-flow EWR for the Ecological Class C/D is currently not met by present-day stream flow at the proposed pump station site.

A diversion function is necessary in the WRYM because the efficiency of a diversion scheme, when modelled on a monthly time-step, is unrealistically high compared with that on a daily or hourly time-step. This is due to the varying nature of the stream flow over short durations, of the order of hours to a few days, where flood flows that exceed the capacity of the scheme spill past the scheme. On the other hand, if the volume of such floods were averaged over a month, it would happen that the average monthly volume passing the point could be diverted to a greater extent in the model than would be possible in reality.

For the BRVAS a daily time-step was used to derive the diversion functions in recognition of the fact that the flows in the Berg River vary over durations which are of the order of several hours to days, given the large catchment size upstream of the proposed pumping site. A daily time-step is therefore sufficient to capture the behaviour of the diversion scheme.

Each diversion function was derived from a daily flow sequence in the Berg River that represented the present-day situation. The impact of the operation of the Berg River Dam and Supplement Scheme had to be taken into account, which posed a dilemma as that scheme had only been in operation for five years, which was the limit of actual observed Berg River stream flow that include its operation.

Because of the lack of an observed time series of sufficient length that included all the present-day development upstream and which was available at the site of the proposed scheme, it was necessary to simulate a daily time-series that had the desired length and which represented the present-day situation so that diversion functions could be determined for the WRYM.

The present-day observed time series at the DWA flow gauging station G1H013, situated downstream of the proposed scheme as well as of the Klein Berg and Twenty-Four Rivers' confluences, pre-Berg River Dam implementation, was scaled to account for the reduction in flow due to the Berg River Dam and Supplement Scheme by applying a factor of 81.4% to the entire flow sequence. This factor was obtained from the WRYM model output of flows at G1H013 for pre- and post- Berg River Dam scenarios.

A spread-sheet model was used to simulate the operation of the Berg River Supplement Scheme on an hourly time-step, based on flows observed at G1H004 (located at the Berg River Dam) and G1H020 (located at Paarl). The modelled pumped flows, lagged to account for travel time, were subtracted from the time-series at G1H013 to obtain a time-series that had the correct "shape" and described the flows, post Berg River Dam, sufficiently accurately at the BRVAS site. This daily time-series was then used, for the period 1 November 1968 to 30 April 1974 (the worst drought on record and the critical period for the WCWSS) to disaggregate the WRYM monthly modelled flows at the BRVAS site.

Diversion functions were then determined for various abstraction scenarios based on the daily time-series derived as described previously, various pumping rules and the EWR. The various abstraction scenarios were:

- A 6 m^3/s capacity pump station with variable speed pumps so that pumping could be adjusted dynamically to allow for the low-flow EWR to pass the site at all times, while pumping the remainder of the flow up to a maximum capacity of 6 m^3/s. Pumping was only modelled for the winter months, May to October, with no pumping during the rest of the year.
- A 3 m^3/s capacity pump station with a stepped pumping rule, so that individual pumps kick in in 1 m^3/s increments, depending on streamflow availability, after a 1 m^3/s baseflow has been allowed to pass.
- A 4 m^3/s capacity pump station with a stepped pumping rule, so that individual pumps kick in depending on inflow availability in 1 m^3/s increments, after a 1 m^3/s baseflow has been allowed to pass in the river.

Figure 9 shows a schematic layout of the proposed BRVA scheme operation.

An example of the diversion function for the 6 m^3/s pumping scenario is shown in **Figure 10** and the detail of the diversion relationships for the different operating rules and pump configurations is presented thereafter in **Table 5**.

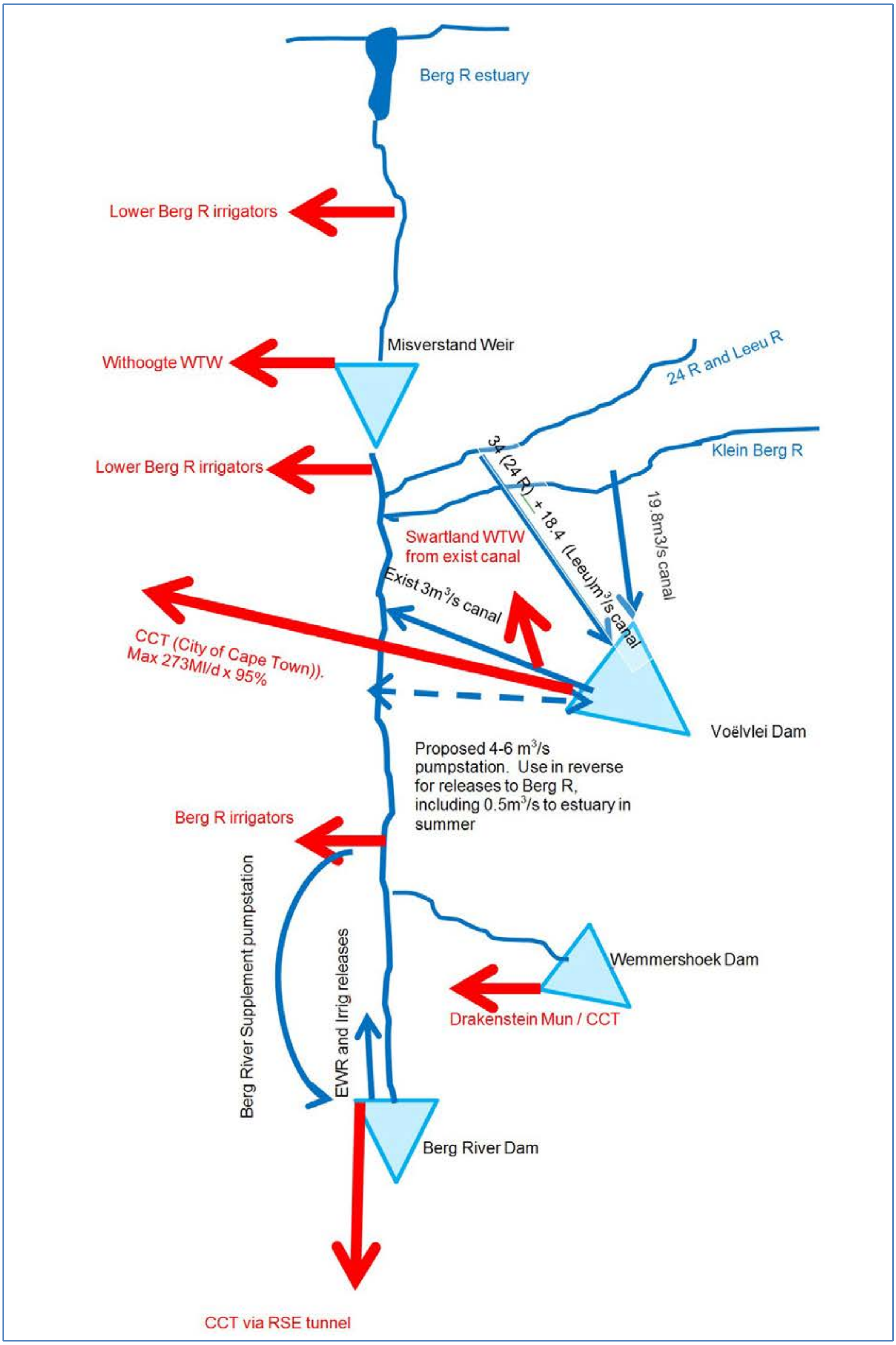


Figure 9: Simplified Schematic Showing the Major Components of the BRVA Scheme

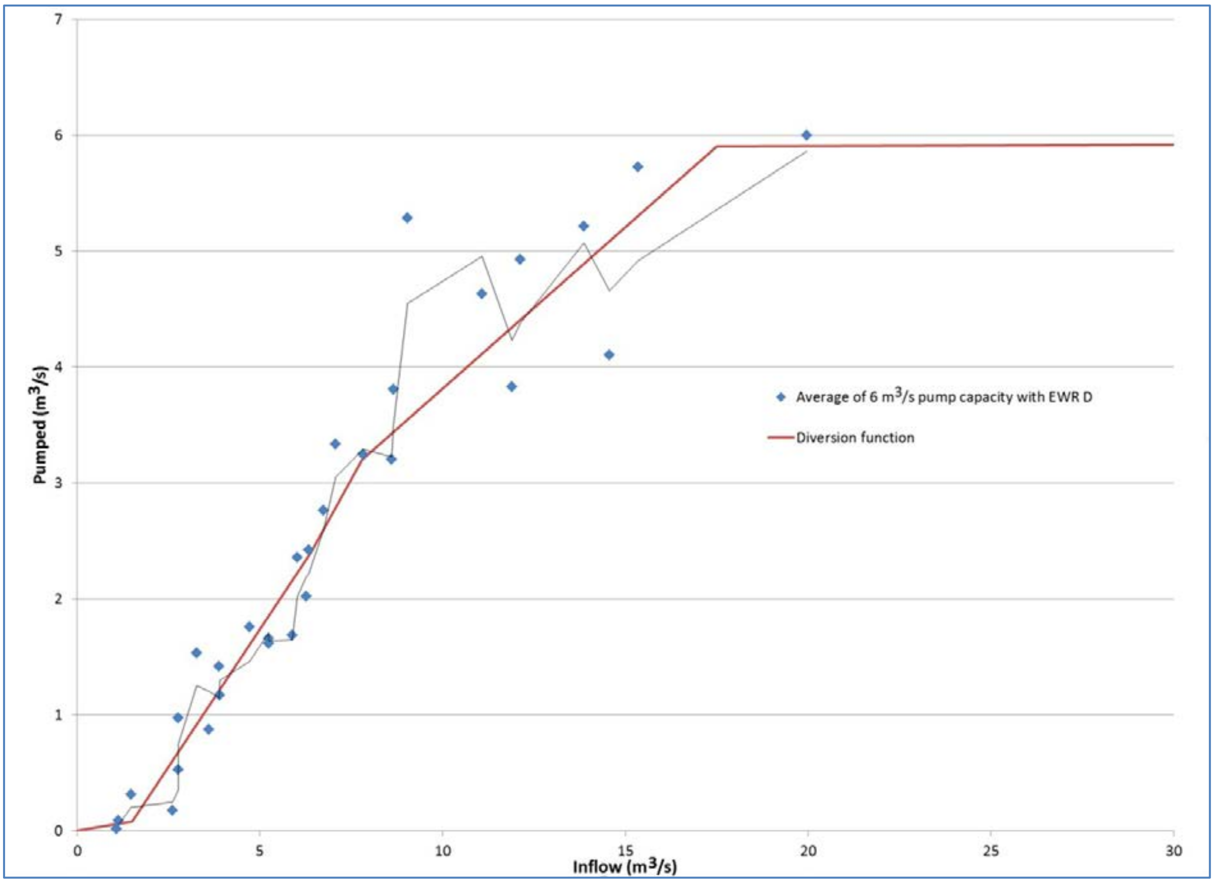


Figure 10: Diversion Function for 6 m^3/s Pump Station with Low-flow EWRs for Ecological Class D Passing Through

Table 5: Relationships between Average Monthly Inflow and Average Monthly Abstraction for Different BRVAS Pump Station Capacities and EWR Requirements

Pump features		EWR	Upstream inflow or abstraction	Relationship between average monthly inflow (m^3/s) and average abstraction (m^3/s)							
Maximum pump station capacity (m^3/s)	Other features										
3		Stepped pumping	upstream inflow	0	1.1	4.7	6	7	8.6	20	99
			abstraction	0	0	2.1	2.7	2.9	2.95	3	3
4		Stepped pumping	upstream inflow	0	1.1	3.8	6	7	8.6	20	99
			abstraction	0	0	2	3.2	3.6	3.8	4	4
6	variable speed drive	Class C/D low-flow	upstream inflow	0	2.5	6	8.5	15	21	21	99
			abstraction	0	0.05	0.8	1.7	3.7	5.5	5.5	6
6	variable speed drive	Class D low-flow	upstream inflow	0	1.5	6.4	7.8	17.5	99		
			abstraction	0	0.08	2.4	3.2	5.9	6		

4.10 BERG RIVER-VOËLVLEI AUGMENTATION SCHEME YIELDS AND OPERATING RULES

4.10.1 Historical Firm and Stochastic Yields

The Comprehensive Determination of the Environmental Water Requirements for the Berg River Estuary (DWA 2010), prepared as part of the current study, recommended that the summer inflows to the Berg River Estuary be increased from the assumed current level of 0.3 m^3/s to between 0.6 and 0.9 m^3/s. The construction of a gauge upstream of the tidal influence of the estuary would be needed to quantify the actual inflows to the estuary. To accommodate this requirement in the WRYM modelling it was assumed that 0,5 m^3/s would be released from the Voëlvlei Dam for six months during summer if the BRVAS is constructed.

The system and incremental yields obtained for the different pumping scenarios for the BRVAS are presented in **Table 6**. The reported yields exclude the aforementioned 0,5 m^3/s summer month environmental release from the Voëlvlei Dam and represent the yield available for urban and agricultural (non-environmental) purposes.

The incremental system yield of the 6 m^3/s pump-station bypassed by class D low-flows is similar to that from the 3 m^3/s and 4 m^3/s stepped pumping rule (between 18 and 23 million m^3/a), while that of the 6 m^3/s pump station bypassed by class C/D low-flows is only about 8 million m^3/a. If the stepped pumping rules should be acceptable environmentally this would reduce the costs, as smaller pumps / pipelines could be used and the operation of the system would be simplified, given that it would be a challenge to estimate the real-time natural streamflow and the class D low-flows at the pump station site.

The yield of the BRVAS could be constrained to the spare capacity of the pipeline from Voëlvlei Dam to Cape Town if the other demands on the Voëlvlei Dam are low. However, if the system is modelled with the summer environmental release to the estuary of 0.5m^3/s added to the current demands of the West Coast and the Lower Berg Water Users Association, then increasing the capacity of this pipeline to more than it's current capacity (3.16 m^3/s reduced to 3.06m^3/s to allow for down time) would not further increase the yield of the proposed scheme.

Table 6: Historical Firm and Stochastic Yields of the Current System and the BRVAS options

Scenario		Historical Firm Yield (million m^3/a)		Long-term Stochastic Yield (million m^3/a)							
EWR Operating Rule	Abstraction capacity (m^3/s)	System yield	Incremental yield	System yield (1 in n-years)				Incremental yield (1 in n-years)			
				20	50	100	200	20	50	100	200
Updated WRYM	0	529	n.a.	623	579	556	533				
Class C/D low-flows	6	537	8	631	587	563	541	8	8	7	8
Class D low-flows	6	549	20	642	599	574	550	19	20	18	17
3 m^3/s stepped	3	548	19	642	597	573	550	19	18	17	17
4 m^3/s stepped	4	553	24	647	602	578	555	24	23	22	22

4.10.2 Compliance in meeting the EWRs

The proposed BRVA scheme consists only of a low weir and therefore has insufficient storage to significantly regulate the river. Therefore, all the proposed options involving this abstraction scheme behave in a similar manner in that abstraction would only commence once the stream flow exceed a minimum threshold, thus enabling a baseflow to always be maintained in the river. Freshettes and floods which exceed the abstraction capacity of the scheme as well as most of the high flows will bypass the scheme, even when it is operating at full abstraction capacity. The unregulated nature of the high flow releases means that in many months the high flows bypassing the proposed scheme will exceed the environmental requirements.

Where the schemes differ from one another is how the minimum threshold is determined, which also affects the schemes' required abstraction capacity. Two methods have been adopted in this feasibility study.

- The **first** requires variable speed drives and uses the standard relationship of natural monthly stream flow to the average monthly environmental baseflow requirements at the abstraction site that is prepared when specifying the reserve environmental stream flow (**see Table 7**) but applies it on a daily basis to determine the minimum threshold for each day. The natural streamflow for the analysis period was determined as part of the hydrological analysis during this study, but in practice the natural stream flow at the site would need to be determined in realtime, taking into account the upstream developments such as the Berg River Dam and Supplement Scheme, Wemmershoek Dam and the upstream irrigation. Determining the natural streamflow might require identifying indicator stations in relatively un-impacted sub-catchments and aggregating/scaling these stream flow to obtain an estimate of the likely natural streamflow at the proposed scheme site.

Table 7: Relationship between Natural Streamflow and EWR Base Flow for a Typical Wet Month (July)

Characteristic	Flows (m^3/s) at different % exceedance values during July									
Percent exceedance	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Natural streamflow (monthly average)	92.5	68.2	58.3	47.5	41.3	32.6	27.8	20.0	14.2	6.7
Corresponding EWR baseflow (monthly average)	4.5	4.5	4.5	4.5	4.5	4.4	4.2	3.9	3.3	2.6

- The **second** uses a set of pumps each with a 1 m^3/s capacity which are switched on in turn as the streamflow downstream of the pump station exceeds 2 m^3/s. The streamflow downstream of the abstraction site thus varies between 1 and 2 m^3/s until the combined capacity of all the pumps is exceeded. This "stepped" method of operation is simpler as it does not depend on an estimated natural streamflow at the site and it was possible to obtain a slightly higher yield than the "variable speed drive" approach using a 4 m^3/s pump station rather than the 6 m^3/s pump station used for the "variable speed drive" approach.

Numerous plots were prepared to compare the impact of the two approaches on the monthly stream flow, and hence the environment, downstream of the pump station. These are all included in **Appendix 1.** Of those, **Figure 11** and **Figure 12** are included here to illustrate the most pertinent points.

In **Figure 11** the total winter flows for the two alternative schemes is compared with the environmental requirements. The figure compares:

- The stream flow downstream of the proposed Berg River pump station assuming variable speed drives with a capacity of up to 6 m^3/s, releasing the class D baseflow EWR (**red dash dot**),
- The stream flow d/s of the proposed Voëlvlei pump station with a stepped pumping rule, transferring 4m^3/s (**red dotted**),
- The class D EWR requirements for total stream flow (**dashed green**)
- The class D EWR baseflows requirements (**solid green**)

In 80% of the years the total stream flow exceed the total environmental requirement. For more than 94% of the years the "stepped" approach exceeds the class D baseflow environmental requirement and for about 99% of the time the "variable speed drive" approach exceeds the class D baseflow environmental requirement. It seems possible that the large surpluses in most years may mitigate the small deficits in the drier years depending on the monthly distribution of the baseflow stream flow in these drier years.

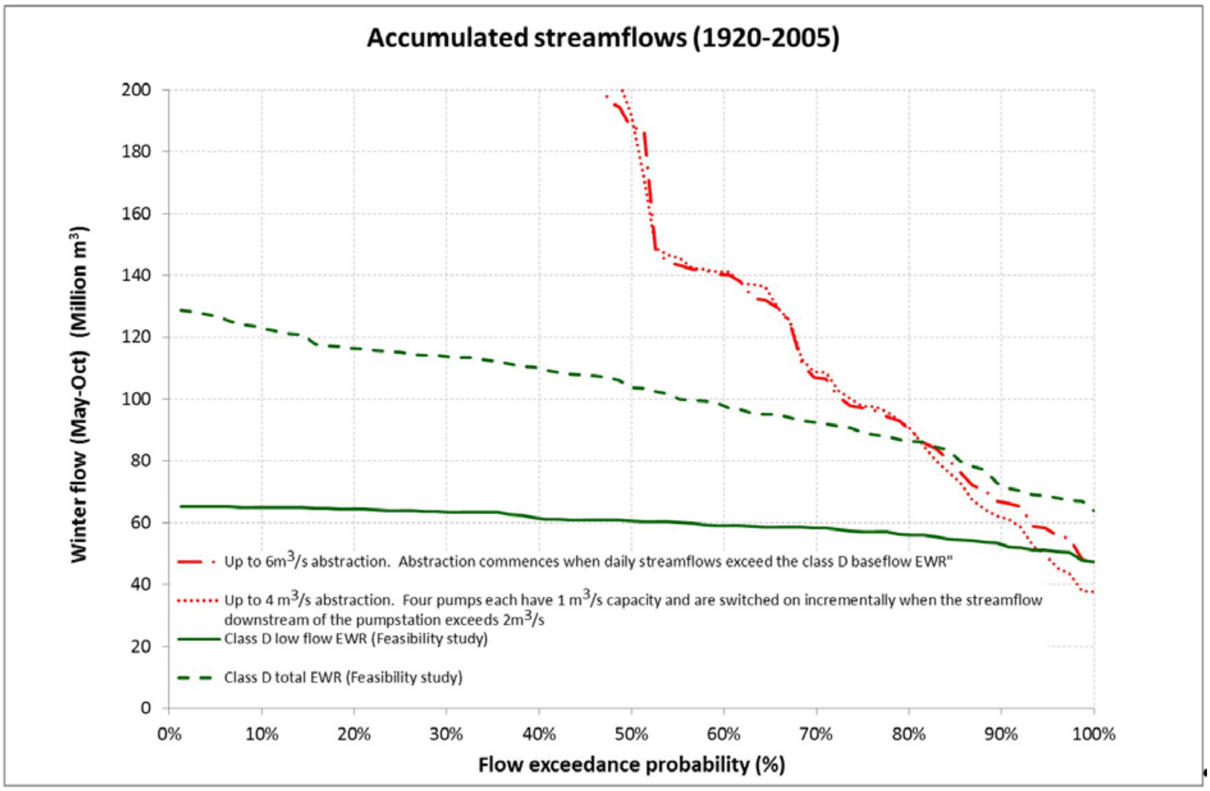


Figure 11: Comparison of the Stream Flow Downstream of Proposed Voëlvlei Pump Station Assuming Variable Speed Drives

The sub-figures contained in **Figure 12** compare the following streamflow distributions downstream of the proposed Berg River pump station:

- The stream flow downstream of the proposed Berg River pump station assuming variable speed drives with a capacity of up to 6 m^3/s, releasing the class D baseflow EWR (**red**),
- The stream flow d/s of the proposed Berg River pump station with a stepped pumping rule, transferring $4m^3/s$ (**green**),
- The class D EWR baseflows requirements (**blue**).

When determining the yields the pump station was assumed to only commence pumping in June, to allow the first environmental freshette to pass through the system and because the initial stream flow may be high in phosphates. Pumping was therefore simulated as starting in June and stopping at the end of October.

Figure 12 shows that the stream flow for the “stepped” pumping rule were slightly less than the baseflow environmental requirements in June (25% of the time), September (18% of the time), July (2% of the time), August (2% of the time) and October (50% of the time). The “variable speed drive” approach is less than the environmental requirements in October (50% of the time).

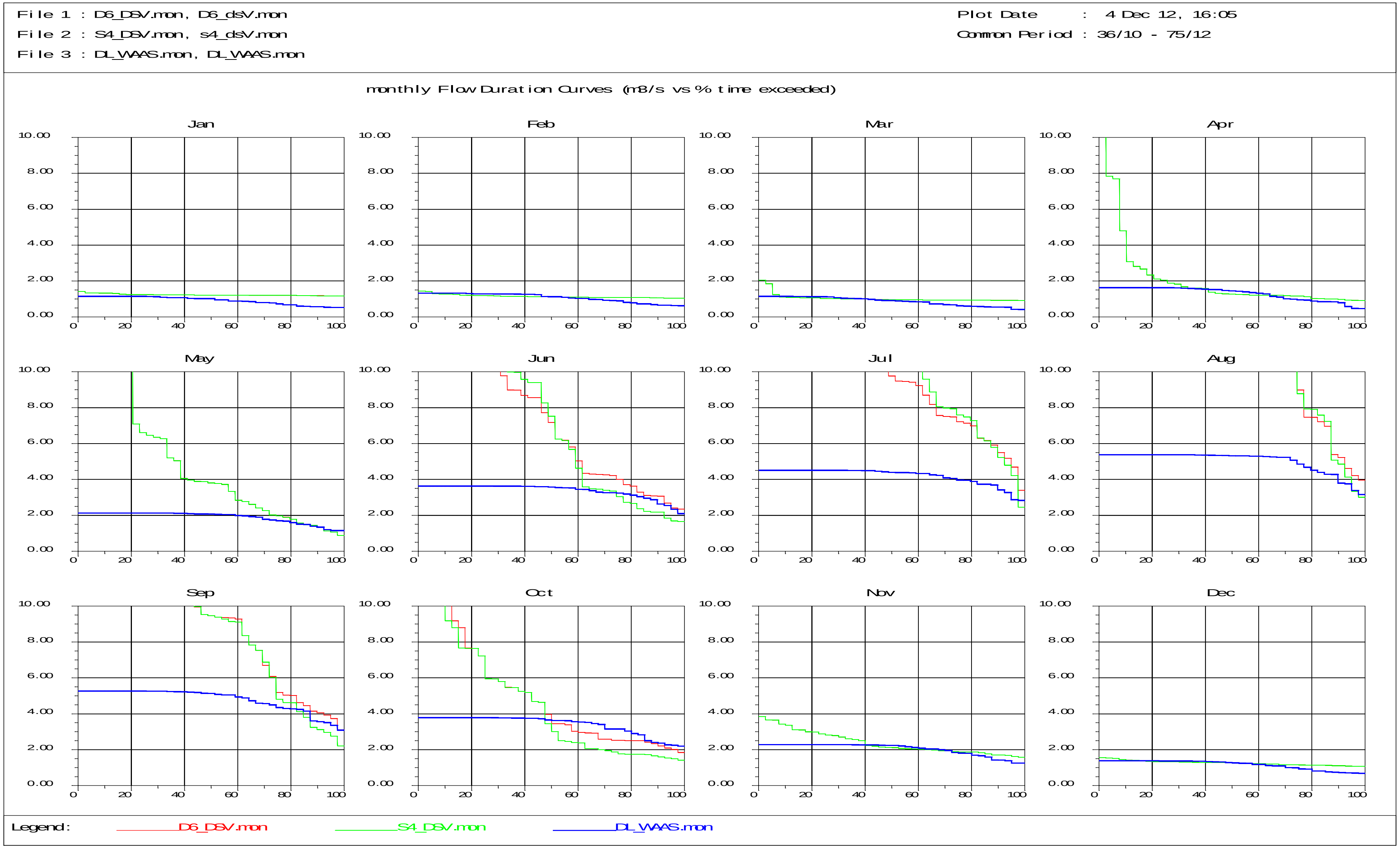


Figure 12: Comparison of the Stream Flow with EWR's Downstream of Proposed BRVAS Pump Station for the 6m^3/s and 4m^3/s Options

4.11 HISTORICAL AND PROJECTED REQUIREMENTS

The following section on the historical and projected demands on the Western Cape System was extracted from the annual update completed in November/December 2011 (DWA, 2011).

The Western Cape Reconciliation Strategy Steering Committee uses in its deliberations an annual baseline requirement growth of 3.1% p.a. from the requirement for the period ending 31st October 2007, as well as a Water Demand Management target of a reduction of 96.7 million m^3/a. At this stage it appears as though the Water Demand Management initiatives to date have achieved about 30% of the latter target.

The historical annual abstractions and projected future requirements adopted for the WRPM analyses are presented in **Appendix 1** and a summary thereof is provided here. The projected requirements are either based on an initial value and an annual growth factor or, where the requirement has reached its allocation, the allocation (capping) value. **Figure 13** and **Figure 14** present the details of the respective requirement projections. In the long-term, the growth of urban centres such as Stellenbosch and Overberg will not be capped and, therefore, have been allowed to increase above their current allocations of 3 and 4 million m^3/a respectively.

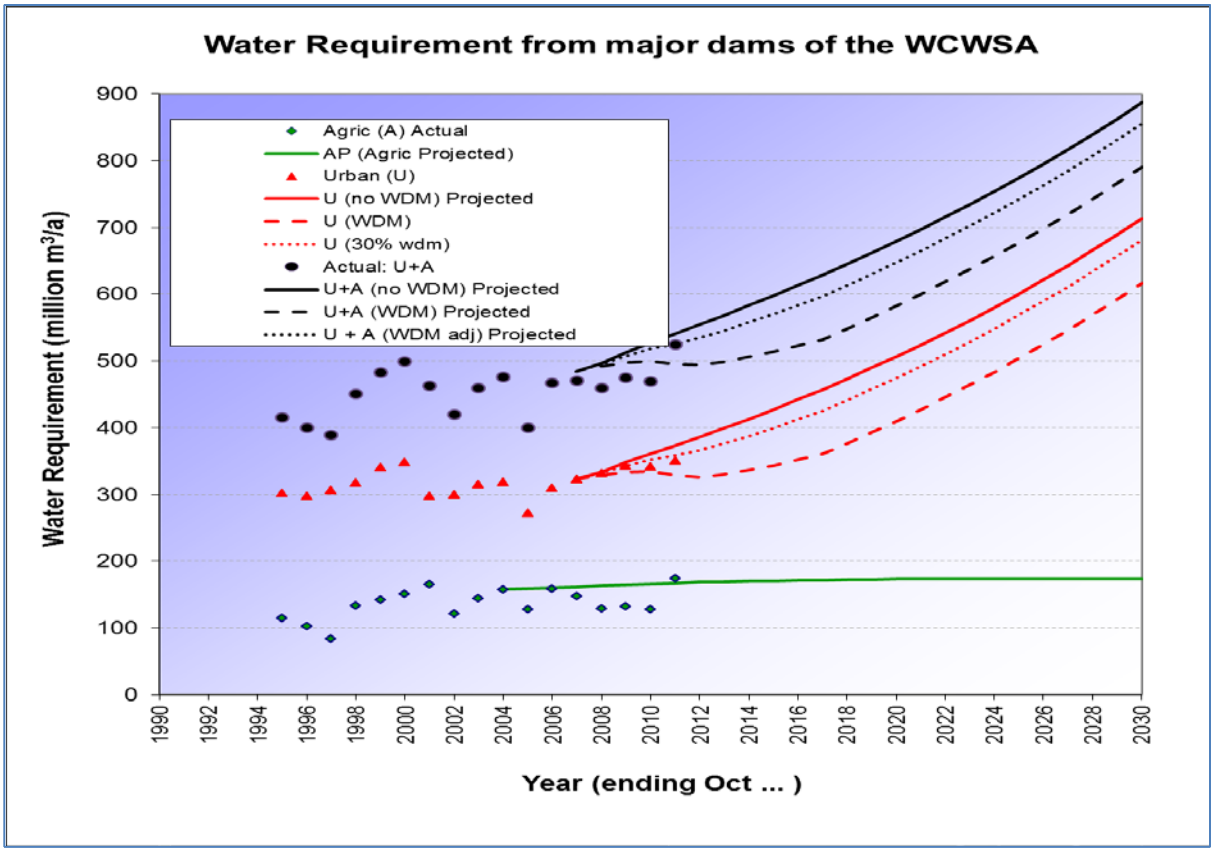


Figure 13: Water Requirement Projection for the Urban and Agricultural Water Requirement Sectors

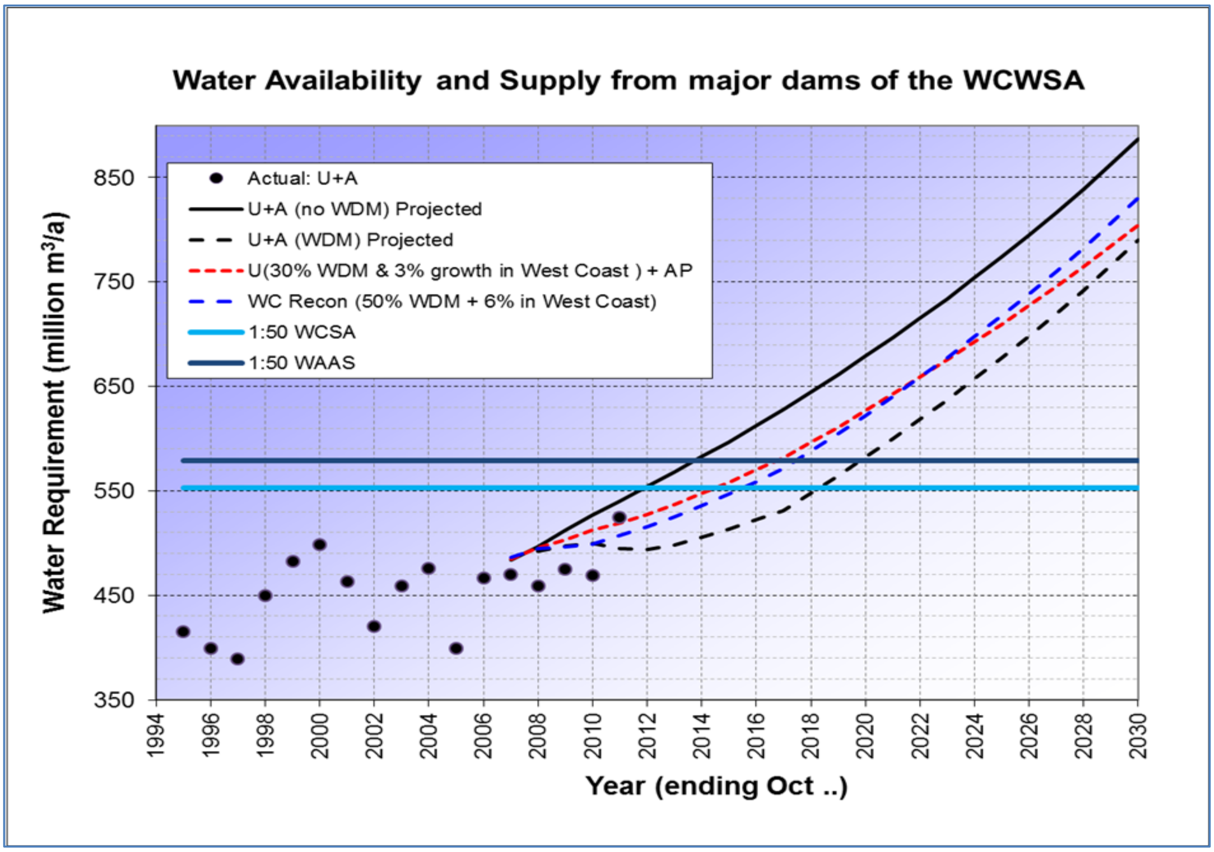


Figure 14: Current Water Availability and Supply from Major Dams of the Western Cape Water Supply Area

In summary, the following are the main assumptions made for the requirement projections:

- Cape Town's Metro requirement (including Paarl/Wellington) without Water Demand Management would grow at 3.1% pa.
- The reduction from WDM would only be 30% of the target reduction.
- Requirements from the Swartland and Withoogte WTW would grow at 3% pa.
- Requirements from Stellenbosch Municipality would grow at 2% pa.
- Requirements of irrigators that have not reached their capping value would grow at 2% pa.

This scenario corresponds with the **red** line in **Figure 14**.

4.12 UPDATING THE WATER RESOURCES PLANNING MODEL (WRPM) FOR THE WCWSS

The Water Resources Planning Model (WRPM) was updated to incorporate most of the WRYM refinements mentioned in the preceding sections, with the exception of the finer discretization of the system to incorporate the EWR nodes, which would have added an unnecessary level of complexity to the model without changing the yields.

The incremental 1 in 50 year stochastic yields of the more feasible BRVA schemes (based on either the class D environmental releases or the stepped pumping rule) listed in **Table 8** are fairly similar and range from 18 to 23 million m^3/a, a range of 5 million m^3/a. At the time when the BRVA scheme is likely to be implemented, this range is less than half a year's growth in the projected water requirement, unless water demand management measures are able to contain the requirement more than is anticipated.

Refer to **Figure 1** which shows the latest reconciliation planning scenario for the WCWSS.

For the purposes of this WRPM analysis, the more conservative 3 m^3/s stepped pumping rule option was selected to model how much the BRVA schemes will help to meet the proposed requirements and delay additional augmentation. The other options, namely the 6 m^3/s pump station operated to skim off surpluses above the class D EWR baseflow requirements, and the 4 m^3/s stepped pumping option, would be slightly more beneficial but would not delay the need for additional augmentation by more than a year.

The Short Term Characteristic Curves (STCC) used by the WRPM for the annual analysis were also re-determined using the updated WRYM system, for both the current situation (with no augmentation of Voëlvlei Dam) and after augmentation (assuming that a 3 m^3/s pump-station operated, using the stepped operating rule). The results are presented in **Table 8**. Interestingly, the STCC yields from the system for the rare situation when the storage is 40% or below on 1st November are less after augmentation of the system, because the Voëlvlei Dam will then be making an 8 million m^3/a release to the Berg River estuary during summer.

Table 8: Short-Term Characteristic Curves (STCC) for the Current System (no BRVAS) and for the BRVAS Scenario of a 3 m^3/s Pump Station Operating in a Stepped Manner

Current system yields without BRVAS (million m^3/a)							
Initial storage on 1st November	**Analysis period (years)**	**Annual risk of failure (1 in n-years)**					
		5	**10**	**20**	**50**	**100**	**200**
100%	6	768	701	649	610	583	561
80%	4	742	680	633	574	545	518
60%	3	676	608	565	517	490	457
40%	2	509	484	464	435	390	367
20%	1	259	242	235	225	223	221
10%	1	140	131	127	121	119	116
BRVAS system yields for 3 m^3/s stepped pumping (million m^3/a)							
Initial storage on 1st November	**Analysis period (years)**	**Annual risk of failure (1 in n-years)**					
		5	**10**	**20**	**50**	**100**	**200**
100%	6	771	712	665	632	600	573
80%	4	749	690	646	587	560	532
60%	3	684	621	578	532	505	469
40%	2	504	479	462	445	398	371
20%	1	254	239	230	221	219	218
10%	1	137	128	124	119	116	114
Incremental yields (million m^3/a)							
Initial storage on 1st November	**Analysis period (years)**	**Annual risk of failure (1 in n-years)**					
		5	**10**	**20**	**50**	**100**	**200**
100%	6	3.0	11.0	16.0	22.0	17.0	12.0
80%	4	7.0	10.0	13.0	13.0	15.0	14.0
60%	3	8.0	13.0	13.0	15.0	15.0	12.0
40%	2	-5.0	-5.0	-2.0	10.0	8.0	4.0
20%	1	-5.0	-3.0	-5.0	-4.0	-4.0	-3.0
10%	1	-3.0	-3.0	-3.0	-2.0	-3.0	-2.0
The negative incremental yield for low initial system storages of 40% or less is because it was assumed that 8 million m^3/a releases would be made from the Voëlvlei Dam for the estuary during summer *if the BRVAS scheme proceeds*. These releases cause the system to fail earlier in the first year.							

4.13 AUGMENTATION TARGET DATES

The projected requirement from the system is compared with the available system yield at a 1:50 year annual risk of failure shown in **Figure 15** for the updated WCWSS model. This indicates that the requirement will exceed the current supply in the hydrological year ending 31 October 2018, so that there would be a risk of restrictions from November 2018. If the BRVAS, comprising a 3 m^3/s pump station with a stepped pumping rule, is introduced in the winter of 2018, then a new augmentation target date follows one year later. Though this scheme would provide an additional 1:50 year yield of about 18 million m^3/a, the annual growth in requirement is about 15 million m^3/a.

The introduction of the larger 4 m^3/s or 6 m^3/s BRVAS options with incremental 1:50 year yields of 23 and 20 million m^3/a respectively, would not really make much difference to the abovementioned augmentation target date.

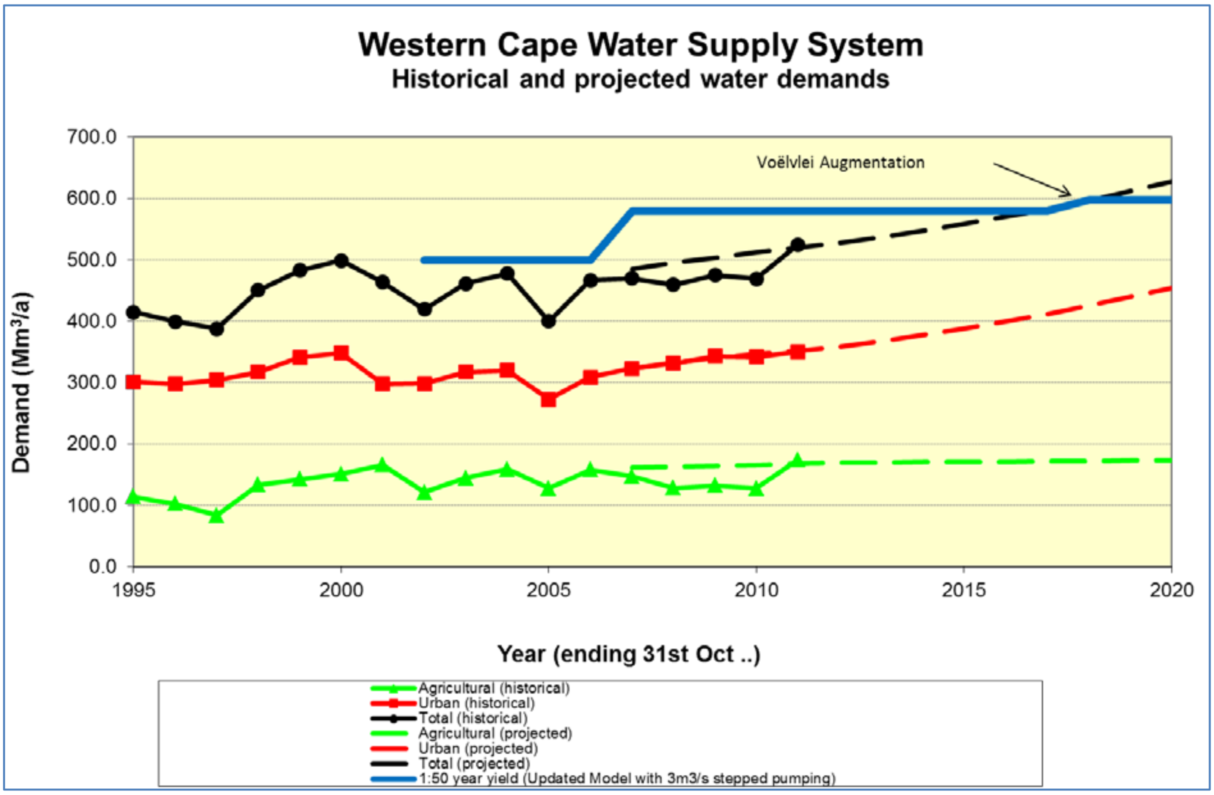


Figure 15: Estimated Augmentation Date using 1:50 year Yields

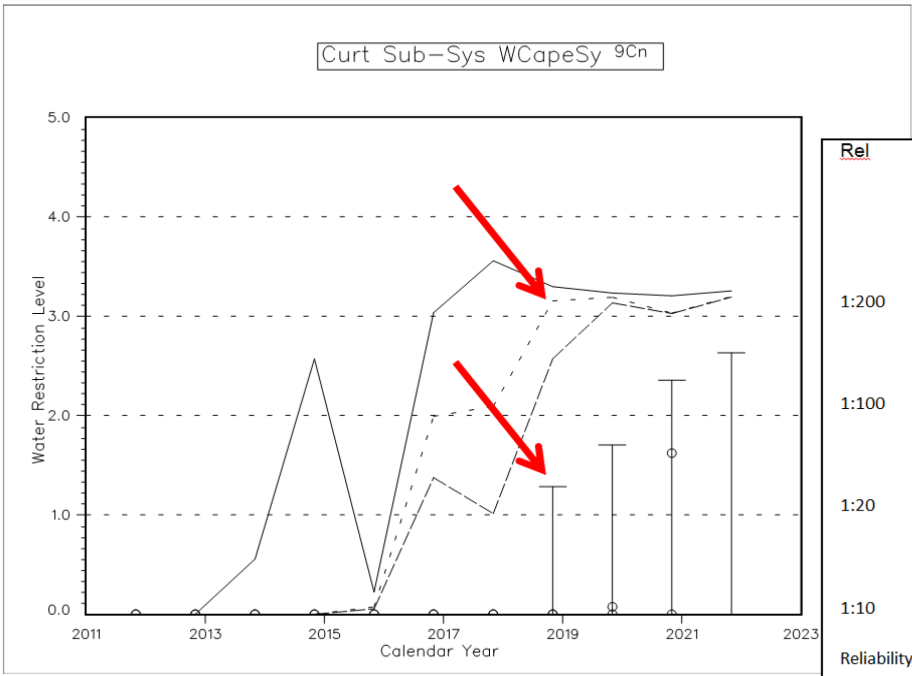
The Water Resources Planning Model was also used to model the behaviour of the current Western Cape Water Supply System with the water requirements growing according to the assumed growth rates. At the end of the rainy season every year, this model is run to assess the water available in the dams for the coming dry summer season and implements restrictions if the available storage is insufficient for the anticipated future requirements.

The restrictions are summarized using a curtailment plot that has time along the horizontal axis and the extent of curtailments along the vertical axis. The extent of curtailments is represented by a number, i.e. a level one curtailment is currently associated with supplying 93% of the urban requirement and 90% of the agricultural requirement, which, if the relative supply to each consumer is taken into account, equates to 92% of the total requirement. It is deemed acceptable that this degree of curtailment occurs up to once in every 20 years. This is illustrated in **Figure 16** where, on the right hand side of the figure opposite the "level 1" curtailment level, the curtailment key indicates that the reliability "rel" is associated with a risk of occurrence of 1:20 years. The percentages of the urban, agricultural and total requirement that should be supplied are given further to the right on the same row.

The magnitude and frequency of the imposed restrictions / curtailments is represented using a box-and-whisker plot, as shown in the left half of **Figure 17**. For instance, if a level 1 curtailment occurred 50% of the time, then the portion of the box-and-whisker representing the 50% occurrence, namely the division splitting the central box into a clear and a dark area, would be placed at the level 1 curtailment level.

The background information given above can be used to determine the risks of restrictions by the decision date of 1 November 2018. The small horizontal bar at the top of the whisker has been highlighted using an arrow. This whisker corresponds to restrictions that occur with a 1:20 annual risk and the extent of the restrictions corresponds to level 1.3 restrictions. Level 1 restrictions correspond to a reduction in the combined requirement of 8% and level 2 restrictions (1:100 risk) correspond to a 19% reduction in requirement, so level 1.3 restrictions would correspond to a reduction of about 11% to 12% using linear interpolation. The problem is that the restrictions that occur with a 1:100 annual risk are more severe than the level 1 restrictions that are tolerable at a 1:20 annual risk. Some intervention is required to increase the available water supply or decrease the projected requirement. The **red arrow** has been used in the diagrams to indicate when the restriction risk becomes unacceptable.

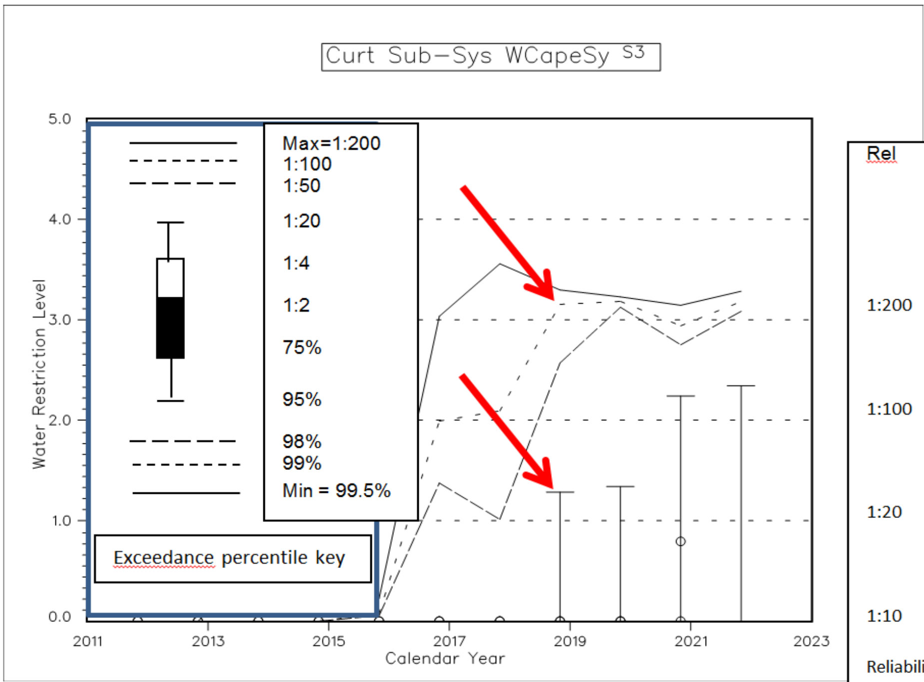
The WRPM was also used to assess the curtailment risks if the commissioning of the BRVAS became delayed until 2020, the results for which are presented in **Figure 17**. If this figure is compared with **Figure 16**, where no augmentation scheme was introduced, then one can see that the augmentation scheme prevents the curtailment risk from increasing in November 2020, basically supplying a year's growth in requirement.



Rel	Urb	Agr	Combined
1:200	71%	50%	64%
1:100	85%	70%	81%
1:20	93%	90%	92%
1:10	100%	100%	100%

Reliability of Supply

Figure 16: Identifying when Augmentation of the Current System Is Required



Rel	Urb	Agr	Combined
1:200	71%	50%	64%
1:100	85%	70%	81%
1:20	93%	90%	92%
1:10	100%	100%	100%

Reliability of Supply

Figure 17: Effect of Commissioning the 3 m^3/s Stepped Pumping Scheme in 2020

5. WATER QUALITY

Water quality in the Berg WMA varies not only between the individual river basins but also within individual river systems. The natural geology, agricultural practices, point, and non-point source pollution all play a role in determining the quality of water in this WMA.

Most of the rivers in the water management area rise from the Table Mountain Group mountain catchments which provide very good quality water with total dissolved solids concentrations of less than 60 mg/l. The Berg River rises in the mountains near Franschhoek and the runoff is characterised by ideal water quality. However, the quality deteriorates in a downstream direction as a result of human activities, such as agricultural activities (river modifications, water abstractions, and runoff from irrigated soils), urban storm water, discharge from wastewater treatment works, and runoff from informal settlements which tend to have no sanitation services. Many of the lower Berg River tributaries are underlain by Malmesbury shales of marine origin and therefore have naturally high salinity concentrations. The shales coupled with agricultural return flows introduce elevated salinities in the middle and lower reaches of the Berg River, as well as in the Diep River.

This has an adverse impact on industrial water use and on crop selection. Furthermore, the potential economic impacts are of great concern where water quality standards in the rivers do not comply with those required by international export markets. Storm water runoff from informal settlements and back-yard dwellings further adds to the water quality impacts in downstream reaches and this has had a notable effect in the Middle and Lower Berg River.

Water quality management in the Berg River poses a significant challenge in relation to current and future water use opportunities and as such any abstraction of water from the river must be carefully considered in terms of the intended water use. Three fundamental water quality aspects have been investigated as part of this feasibility study, namely:

- The assessment of the impacts of nutrient transfers from the Berg River on algal growth in the Voëlvlei Dam, by means of CE-QUAL-W2 modelling.
- Winter 2011 flood sampling undertaken to identify the changes in water quality parameters during typical high flow events in the Berg River.
- The modelling of dispersion and mixing characteristics in the Voëlvlei Dam from water transferred from the Berg River and the optimization of the discharge point location at the dam.

5.1 NUTRIENT TRANSFERS INTO THE VOËLVLEI DAM FROM THE BERG RIVER

This section presents a summary of the configuration, calibration and application of the CE-QUAL-W2 model to the Voëlvlei Dam, for which the detailed report is enclosed in **Appendix 2**.

5.1.1 Background

In 2006 the CE-QUAL-W2 (Version 3.1) dynamic reservoir water quality model was set up for the Voëlvlei Dam as part of a project to develop strategies to address nuisance algal growth problems. When the present study was formulated, concerns were expressed about the potential eutrophication impacts of options to augment the water supply to the Voëlvlei Dam. It was envisaged that the original model setup would be used in the assessment. However, the dam since underwent a significant change in character after the severe drought of 2004-2005 resulting in a change from a stable clear water system to a stable turbid system.

The CE-QUAL-W2 (version 3.6) model was therefore calibrated for a period after 2005 to reflect its new stable state. The detailed modeling report describes:

- the configuration and calibration of the latest version of the CE-QUAL-W2 (Version 3.6) for the period October 2005 to September 2007 (2 years), and

- an initial evaluation of the potential water quality impacts of options to augment the water supply in the Voëlvlei Dam.

5.1.2 The changed water state character of the Voëlvlei Dam

Shallow lakes and reservoirs generally exist in either of two stable states; either a clear water state dominated by rooted water plants, or a turbid state dominated by free floating algae. A change from a clear water, rooted waterplant-dominated system to a turbid, algal-dominated system requires a switch such as the removal of water plants or the introduction of highly turbid inflow. The switch works better if it coincides with an increase in nutrient enrichment. The switch back to a clear water plant-dominated system is usually accomplished through bio-manipulation and works well if it coincides with a reduction in nutrient concentrations.

Figure 29 shows a plot of water levels in the Voëlvlei Dam and the annual pattern of filling during the winter months and draw down during the summer months. However, below average rainfalls in 2003 and 2004 resulted in the dam being drawn down to below 20% of its full supply capacity.

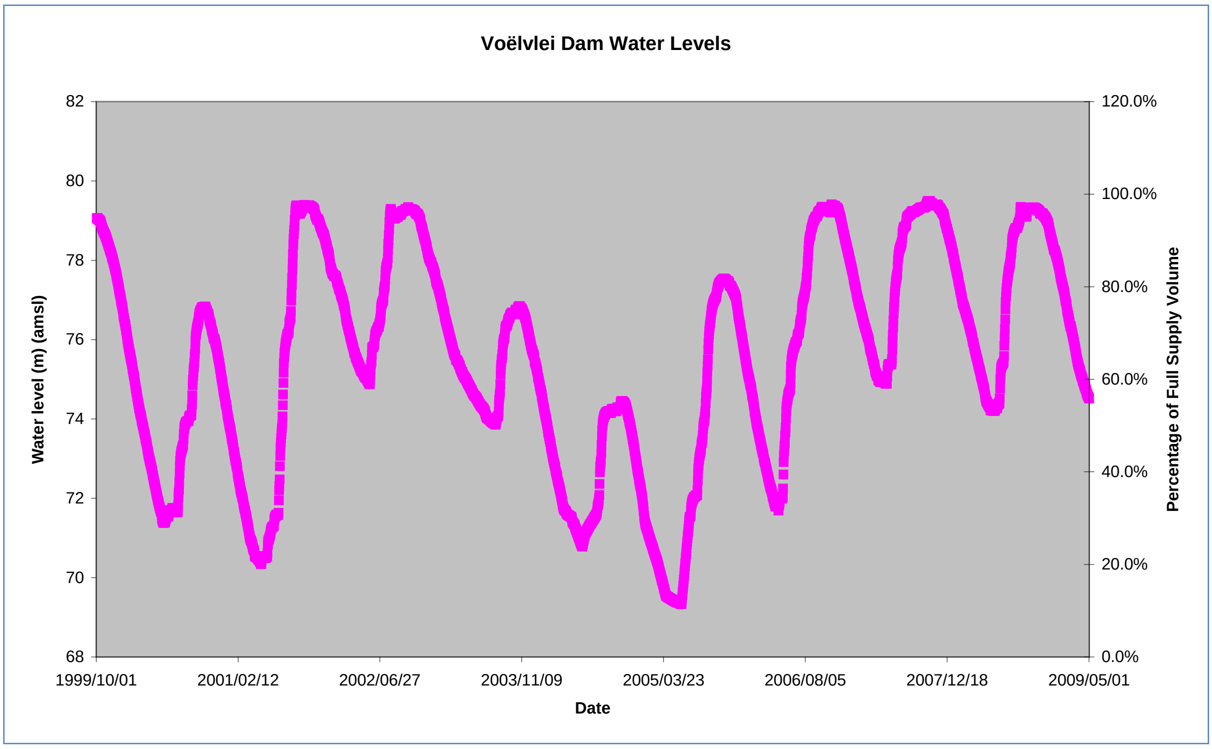


Figure 18: Water Levels in Voëlvlei Dam (October 1999 - May 2009)

During the 2004/5 draw down, turbidity increased rapidly and since then, the turbidity in the dam has remained high (see **Figure 19**). At the same time, the Chlorophyll-a concentration started to increase as a result of higher free-floating algal concentrations (**Figure 20**), and rooted water plants started to disappear from the dam due to high turbidity. The Voëlvlei Dam switched from being a stable clear water system to a stable turbid system. The CE-QUAL-W2 model was therefore applied to the new stable turbid state.

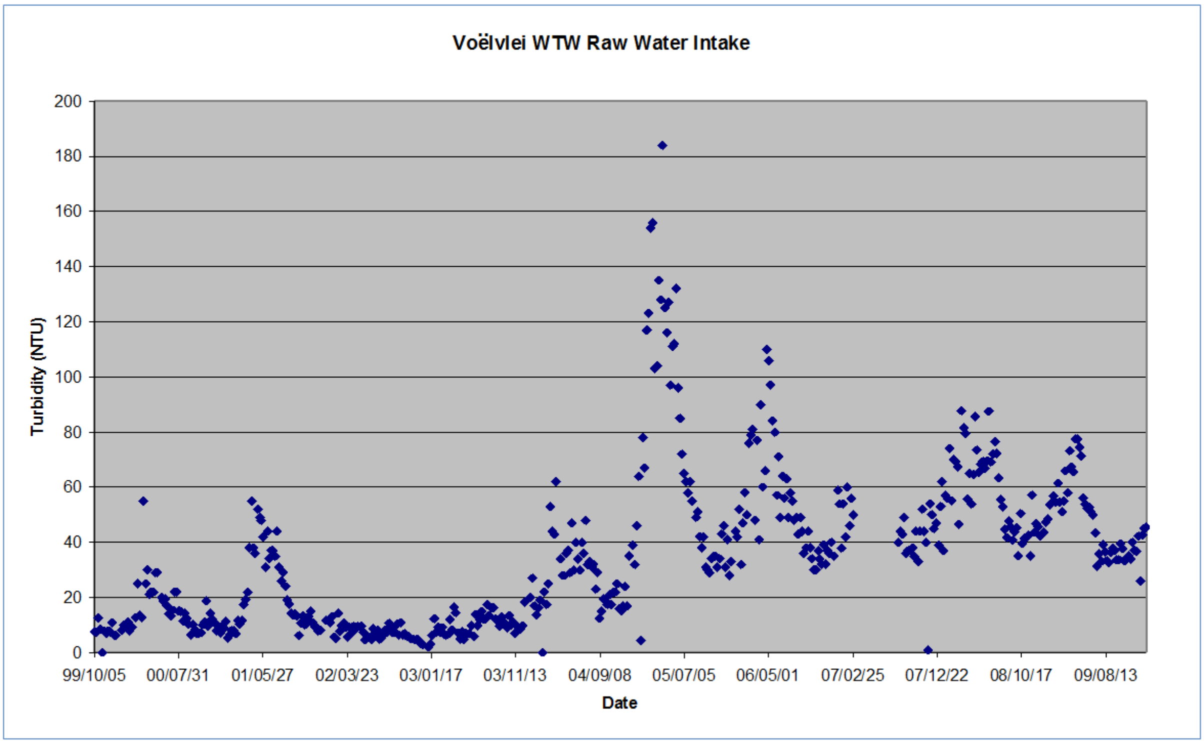


Figure 19: Time Series Plot of Turbidity Measurements in the Voëlvlei Dam Showing the Change in Turbidity State after the Drought of 2004/5.

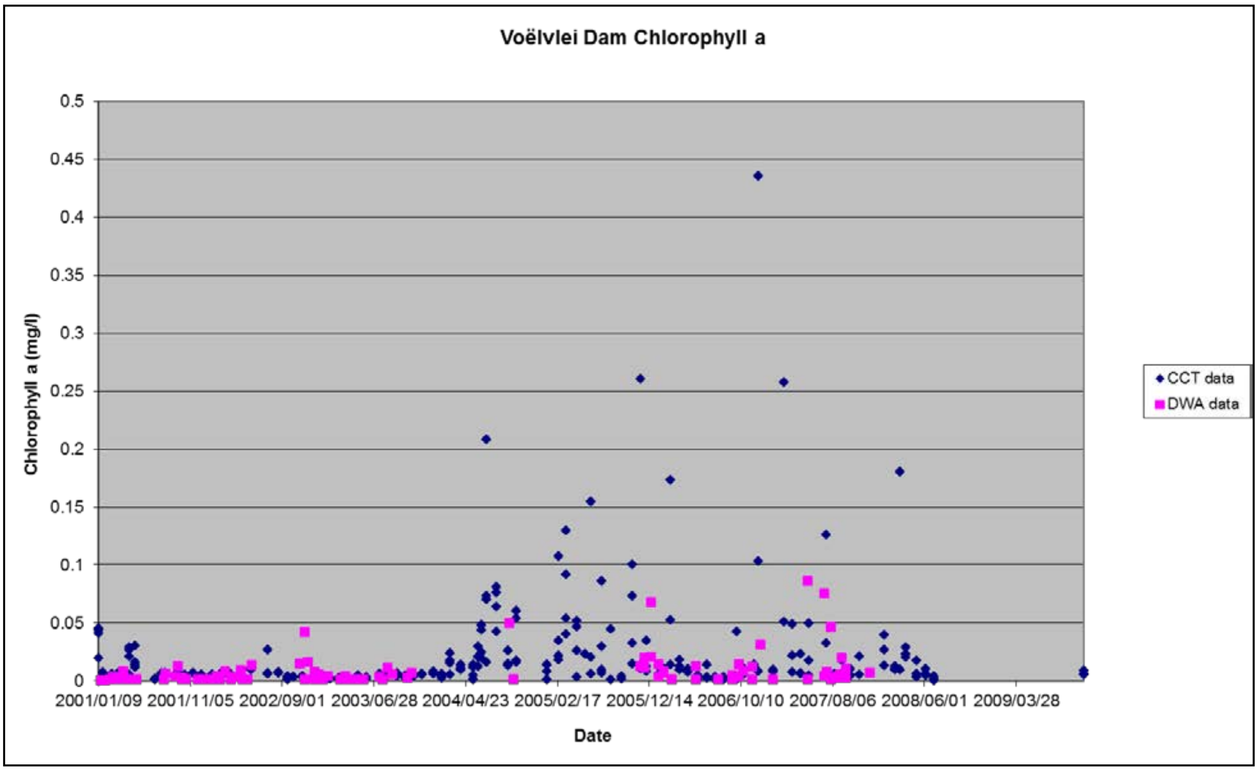


Figure 20: Time Series of Chlorophyll-a Concentrations Recorded in the Voëlvlei Dam (CCT and DWA) Showing the Increase in Free-floating Algae during and after the Drought of 2004/5.

5.1.3 CE-QUAL-W2 Model configuration

CE-QUAL-W2 is a water quality and hydrodynamic model that simulates water quality and biological changes in two dimensions namely longitudinal (along the length of the reservoir) and vertical (in depth).

The model configuration that was originally set up for Voëlvlei Dam was used with two minor changes. The original segment orientations were modified to better approximate the segment orientation of the dam, and the original segments 1 and 2 were combined into a larger segment 2. This was done to resolve a model instability that was encountered when the reservoir levels dropped to very low levels as happened in 2004/5. The top left diagram in **Figure 21** shows the segment orientation, the bottom diagram shows a cross section along the length of the dam illustrating the columns and layers in the dam, and the top right diagram shows a cross section across the width of the dam at Segment 10.

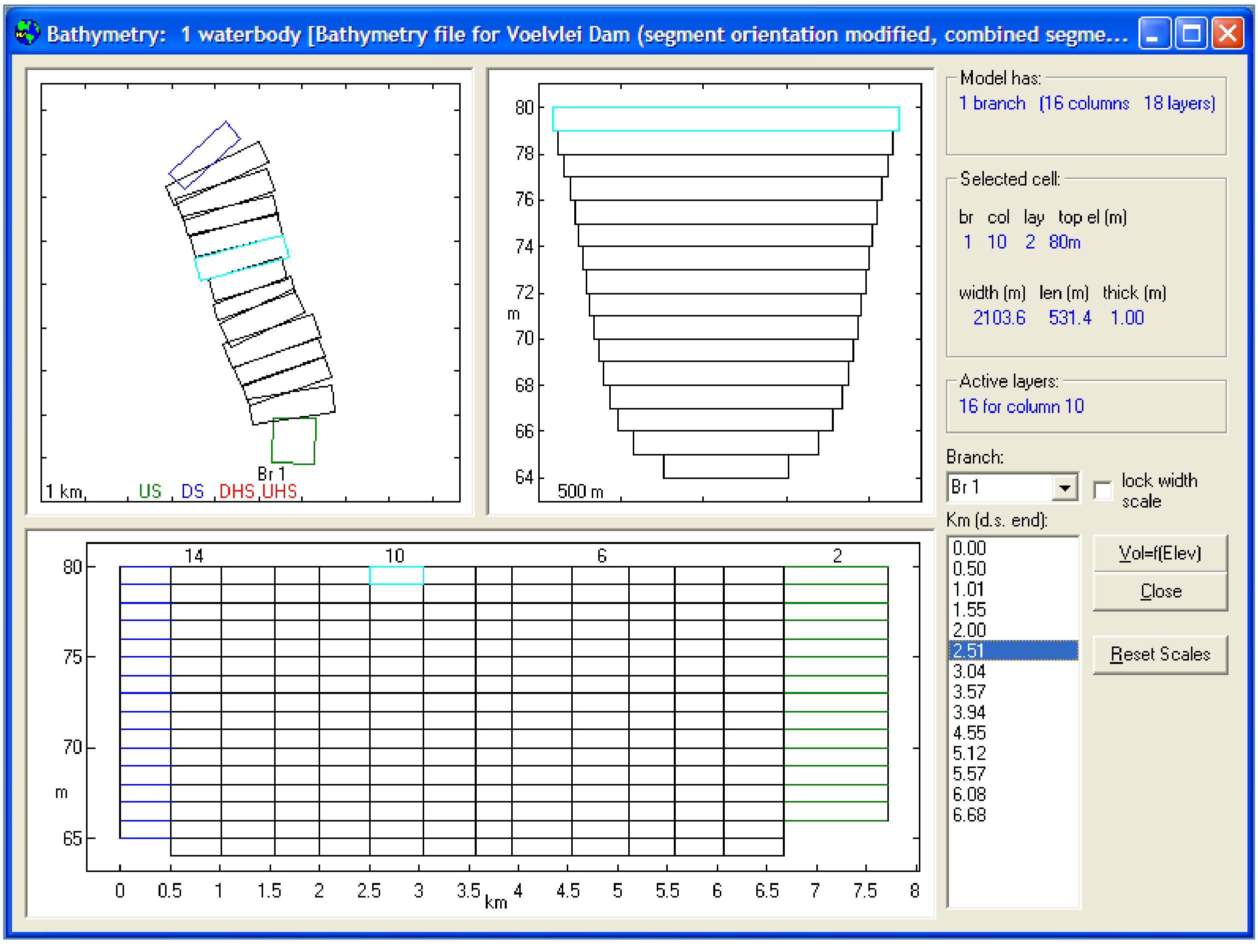


Figure 21: Segmentation of the Voëlvlei Dam.

Model inputs

The major driving forces of the CE-QUAL-W2 model are the inflows, outflows, meteorological data, and inflow concentrations.

- **Meteorological data** - The meteorological time series data consist of hourly air temperature, dew point temperature, wind speed, wind direction, cloud cover and solar radiation. Meteorological input data were assembled from data collected by the SA Weather Service and the Agricultural Research Council at weather stations in the region.
- **Inflow and outflow data** – A daily water balance was compiled using the DWA data for the inflow canals, water abstractions for the CCT and Swartland WTW's, and water levels recorded in the Voëlvlei Dam.
- **Inflow concentrations** – Inflow concentrations were based on DWA observed water quality records in the inflowing canals and the rivers of origin. The mean concentrations in the Twenty-Four Rivers/Leeu River diversion canal were used because an examination of the water quality variables found that the quality varied in a narrow band around the mean, with no discernible temporal trend. The quality of water transferred from the Little Berg River was estimated from

discrete monthly or two weekly chemistry data collected at the gauging weir. The FLUX3 program was used to determine a relationship between flow and concentration for each variable, and a daily concentration time series was then generated using the observed flows in the canal. The water quality variables that were in-filled using concentration: flow relationships were NH_4, NO_3 + NO_2 - N, PO_4 - P, Si, TDS and Cl.

5.1.4 Model calibration

The CE-QUAL-W2 model was calibrated against in-lake data collected from October 2005 to September 2007. This period was specifically selected because it represented the new, turbid state of the Voëlvlei Dam. The model calibration results are summarised as follows:

Water levels

There was a good agreement between the observed and simulated water levels in the Voëlvlei Dam. Towards the end of the simulation period the water levels were under-estimated, probably the result of over-estimating the outflows from the dam. The agreement between the measured dam levels and the simulated dam levels was good enough to accept the bathymetry that had been constructed for the dam.

Water temperature

Without a good profile of temperature throughout the dam it was difficult to judge how well the model simulated the in-lake water temperatures. When compared to the one set of observed temperature data it was found that the model replicated the seasonal pattern and the maxima and minima in the observed data set.

Total dissolved solids

TDS is considered a conservative constituent and was used in the calibration process because it provided some insight into the internal mixing processes. A comparison of the observed and simulated TDS found that there was no consistent over-estimation or under-estimation of the observed data, indicating that no significant sources or sinks were left out of the simulations.

Phosphate concentrations

When modelling algae, the phosphate concentration is probably the most affected water quality constituent because it is constantly being recycled from one form to another in the model. From **Figure 22** it appeared that the high variability in the phosphate concentration was not simulated although it appeared that the model was able to replicate the general pattern in phosphate concentrations.

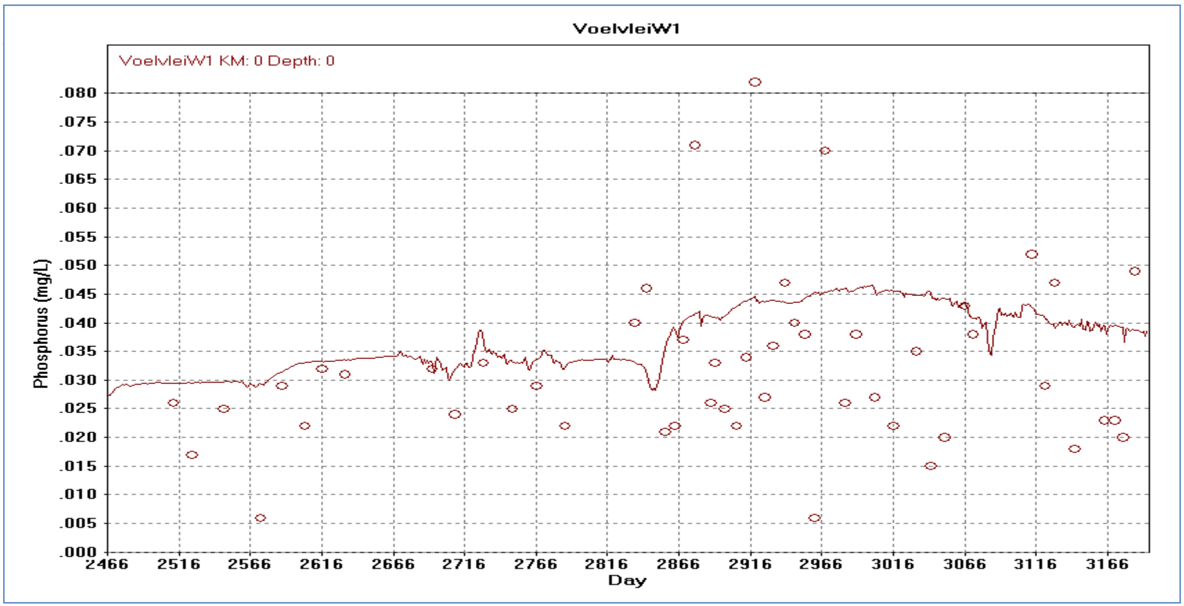


Figure 22: Comparison of Measured and Simulated Ortho-phosphate Concentrations in the Voëlvlei Dam near the Dam Wall (Oct 2005 to September 2007)

The simulation of algal biomass was challenging because algae were not uniformly distributed throughout the reservoir and the observed Chlorophyll–a concentrations of the DWA and CCT were therefore combined to give an indication of the overall algal status of the dam. The algae were modelled as a single assemblage even though observations in the Voëlvlei Dam indicated that the algal assemblage changed through the course of a year. From **Figure 23** it appeared that algal concentrations over the first summer season were somewhat over-simulated. During the summer months there was little to no inflow to the dam and nutrients required for algal growth had to be sourced from internal sources. Simulated outputs indicated that very low algal concentrations were present even during the winter months. The model was able to simulate the general patterns in the dam.

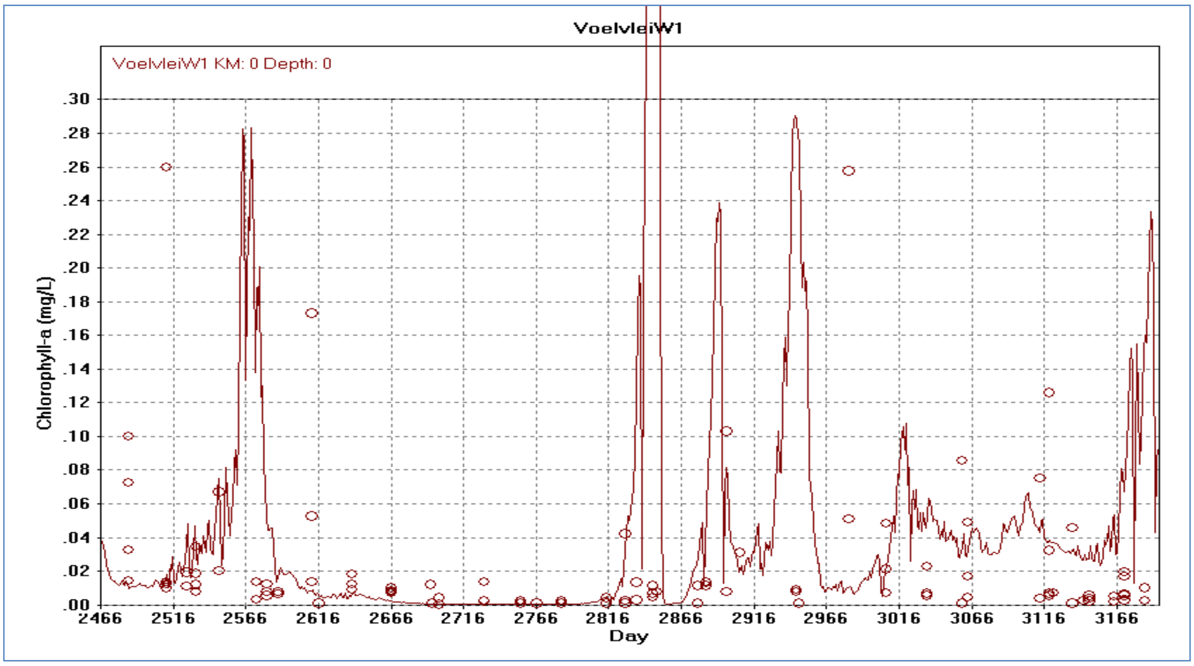


Figure 23: Comparison of Measured and Simulated Chlorophyll-a Concentrations in the Voëlvlei Dam near the Dam Wall (Oct 2005 to September 2007)

5.1.5 Modelled scenarios

An initial assessment was made of the potential impacts on the Voëlvlei Dam if water was transferred from the Berg River into the dam near the CCT abstraction works. The following were changed in the model in order to assess the potential impacts:

- A new inflow was added to the model that discharged into Segment 6. This segment is located next to Segment 5 from which water is abstracted for the CCT treatment works.
- The volumes transferred from the Berg River into the Voëlvlei Dam were based on the Pump rule 10-1 scenario.
- The daily water quality constituent concentrations were estimated by in-filling the observed water quality recorded in the Berg River at Hermon using the FLUX3 programme.
- Average daily inflow water temperatures were based on continuous observed water temperatures at Hermon.
- Rate parameters were left unchanged from the parameters determined in the calibration process.

Comparing the simulated ortho-phosphate concentrations show that, on average, very little change in phosphate concentrations may occur as a result of transferring water from the Berg River into the Voëlvlei Dam. Transferring water from the Berg River would probably increase the nitrate nitrogen concentrations in the Voëlvlei Dam because the N concentrations in the Berg River were higher than in the other rivers feeding into the dam.

A comparison of the simulated Chlorophyll-a concentrations show that elevated chlorophyll concentrations could be experienced with water transferred from the Berg River (**Figure 24**). This was probably due to the elevated nitrate concentrations in the transfer water. The simulated chlorophyll concentrations under the calibration scenario and the transfer scenario were well above the 0.03 mg/l boundary value for hyper-trophic systems.

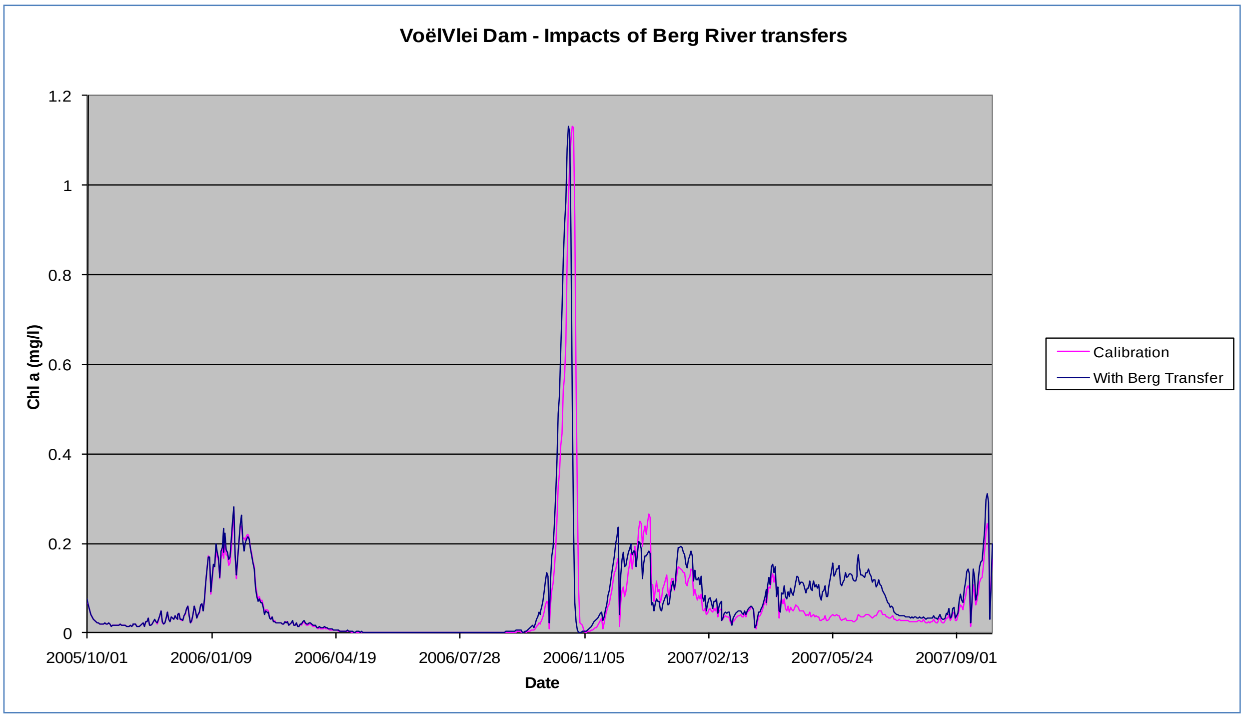


Figure 24: Simulation of the Impact of Transferring Water from the Berg River on Chlorophyll-a Concentrations in the Voëlvlei Dam

5.1.6 Conclusions of the CE-QUAL-W2 Modelling

The option to transfer water from the Berg River would, in the short term, probably not have a significant impact on salinity in the Voëlvlei Dam. However, such a transfer would probably have a detrimental impact on the in-lake nitrogen and Chlorophyll-a concentrations leading to increased problems with nuisance algae and the associated cost of treating the water to potable water standards.

The Voëlvlei Dam has been experiencing more frequent algal blooms since the drought of 2004/5 changed the character of the dam from a stable clear water dam dominated by rooted water plants to a stable turbid system dominated by free-floating algae (phytoplankton). The CCT's water treatment works confirmed that their cost of water treatment has increased to deal with the increase in tastes and odours problems in their treated water, and an increase in filter blocking algae (Melosira).

The initial assessment undertaken in this project indicated that the algal bloom situation may be maintained or there may even be an increase in the duration of high algal concentrations.

5.2 MONITORING WATER QUALITY DURING FLOOD EVENTS IN THE MIDDLE BERG RIVER (WINTER 2011)

The potential transfer of water from the Berg River into the Voëlvlei Dam would occur during the high flow winter rainfall months. Concern has been expressed about the quality of water during the winter periods. This in relation to how the water quality could be expected to vary over a typical rainfall season and during a typical flood event. In order to assess this influence, an experiment was designed to monitor floods during the 2011 rainfall season. The aim of the experiment was to monitor three flood events during the 2011 winter months for water chemistry, nutrients and bacterial counts to determine whether there would be any water quality benefit in timing the abstractions from the Berg River into Voëlvlei Dam.

A monitoring programme was designed, in close collaboration with the WCDM and the CCT to sample a flood early in the season (about May or June), in the middle of the rainfall season (late July or August), and late in the rainfall season (late September or October). The intention was to collect samples during the rising and the receding limbs of the flood hydrograph. To do this, the water levels in Paarl were tracked and when the flow exceeded 7 m^3/s, samplers at the Swartland Water Treatment Works were requested to collect water samples at Sonquasdrift (G1H079) at pre-determined intervals. The samples were analysed for their chemical constituents at the CCT laboratory and for their microbiological content at the WCDM laboratory.

The team managed to sample an early season flood and a mid-season flood but the anticipated flood at the end of September 2011 never materialised (see **Figure 25**).

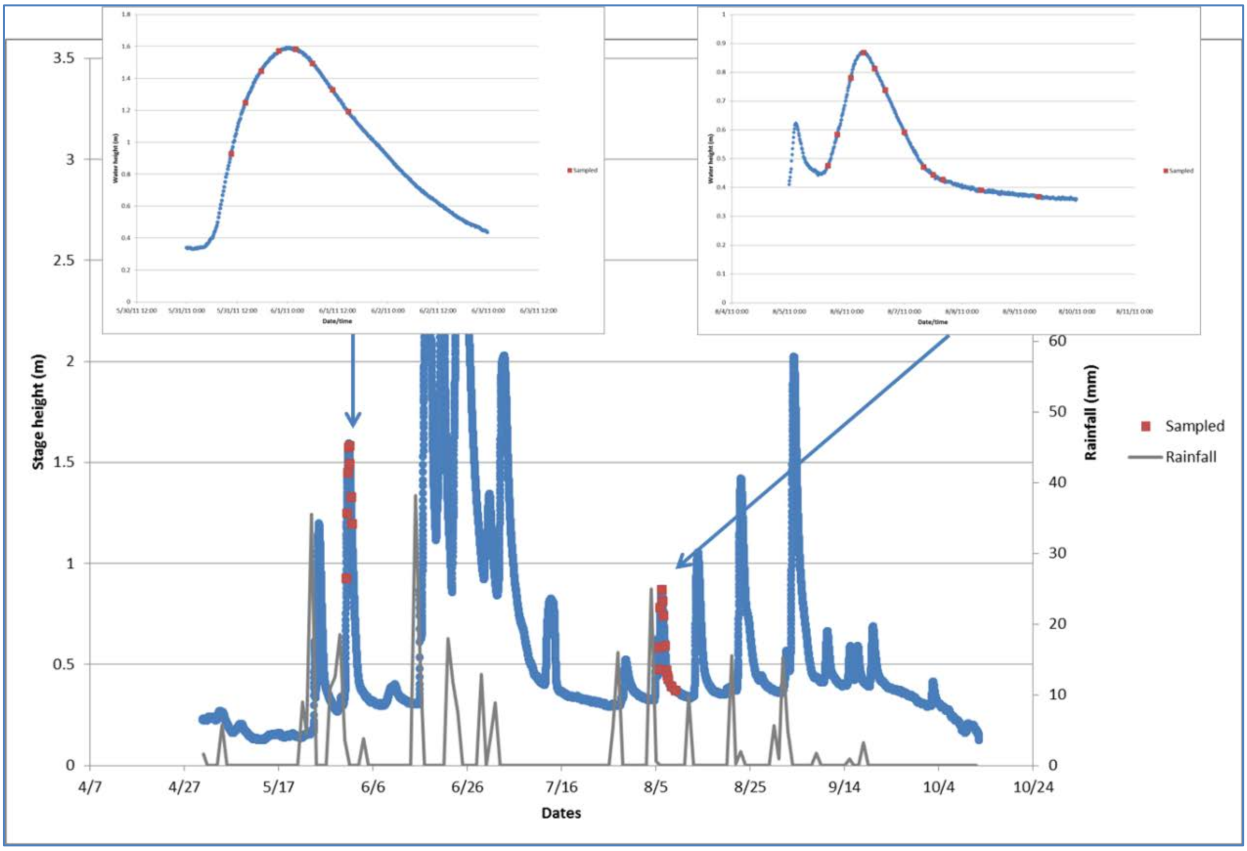


Figure 25: Time Series of Stage Heights Observed at Sonquasdrift During the Rainy Season of 2011

The floods that were sampled are also indicated and the **red dots** indicate when samples were collected. The water quality data was examined for trends over a single flood event and for trends over the rainy season. The detailed report on the monitoring of water quality in the middle Berg River during flood events is presented in **Appendix 3**.

5.2.1 Trends over a single flood event

It was found that salt concentrations decreased during the course of both floods probably as a result of dilution. Phosphate concentrations also decreased during the early season flood as a result of dilution. During the mid-season flood phosphate concentrations initially decreased probably as a result of initial dilution of point sources effluents, but then increased slightly during the receding limb of the flood probably because the dilution also declined. Nitrogen concentrations decreased during the early season flood probably as a result of dilution of point source effluents. During the mid-season flood, there was an increase in N during the rising limb of the flood, and a decrease during the receding limb of the flood which appeared to indicate that non-point source N became the major contributor to the N load to the river. As expected E.coli counts appeared to be somewhat related to turbidity and sediments in the river.

5.2.2 Trends over the 2011 rainfall season

In conventional catchments the concentrations of constituents decrease as the rainfall season progresses and surface pollutants are washed off. The contrary is true for the Berg River catchment. Salts are leached by rainwater from the Malmesbury shales in the catchment as the rainfall season progresses resulting in higher salt concentrations later in the season. The same was found for metals such as aluminium and iron, and to a lesser degree for nitrogen. However, the phosphates, suspended sediments concentrations and E.coli counts were lower later in the season than in the early floods.

5.2.3 Concluding remarks on the Water Quality Monitoring in Flood Events

It was concluded that transfers early in the season would probably result in elevated phosphates, sediments and E.coli, probably close to background concentrations, but lower salt concentrations. Transfers later in the season would probably result in higher salty concentrations but lower phosphates, sediments and E.coli counts. The availability of water may determine the optimum timing of transfers although it may be prudent to start transfers after the first few floods of the season when the general flow in the river has increased.

5.3 DISPERSION MODELLING IN THE VOËLVLEI DAM

This section provides a summary of the assessment of the dispersion of bacteria in the Berg River transfer water in the Voëlvlei Dam. The full report is enclosed in **Appendix 4**.

The CE-QUAL-W2 dynamic reservoir water quality model was set up for the Voëlvlei Dam to simulate the potential impacts of water transfers from the Berg River on water quality in Voëlvlei Dam, and in particular the eutrophication potential of the dam. The Berg River carries high microbial loads during the winter months and concerns were expressed about the impacts that this might have on the quality of water in the Voëlvlei Dam. Notably the impacts on the abstracted raw water for the Swartland WTW and the CCT WTW were of particular concern. The CE-QUAL-W2 model was not suited for modelling near-shore effects in the dam. As such, a simple model was applied to estimate, at a feasibility level, the fate of bacterial contaminants in the Voëlvlei Dam and at the two bulk-water abstraction points.

Near-shore models estimate the dispersion of contaminants in the vicinity of a discharge point. After an initial period of mixing of the discharge, the dispersion of a pollutant is dependent on the transport processes into the lake or reservoir, and on the pollutant's reaction characteristics. For the Voëlvlei Dam application it was assumed that the water column was vertically well-mixed which was indeed the case during the winter months when the transfers would take place.

The Voëlvlei Dam was conceptualised in the model as a rectangular dam which is completely mixed in depth but not so along its length or width. The dispersion of bacteria into the dam was estimated using an equation that estimates the concentration of a constituent at any x, y point in the dam. The dispersion is a function of the bacterial load entering the dam, the water depth at that point, the distance away from the point of entry, current velocity along the shoreline, horizontal diffusion rate, and the bacterial decay rate.

The bacterial load entering the dam was estimated from E.coli counts measured in the Berg River near Saron (see **Figure 26**). It was found that there is a very strong seasonal signal in the E.coli data with low counts in summer and high counts in winter, peaking in June. This indicated that non-point sources of bacteria probably dominated in the middle reaches of the Berg River.

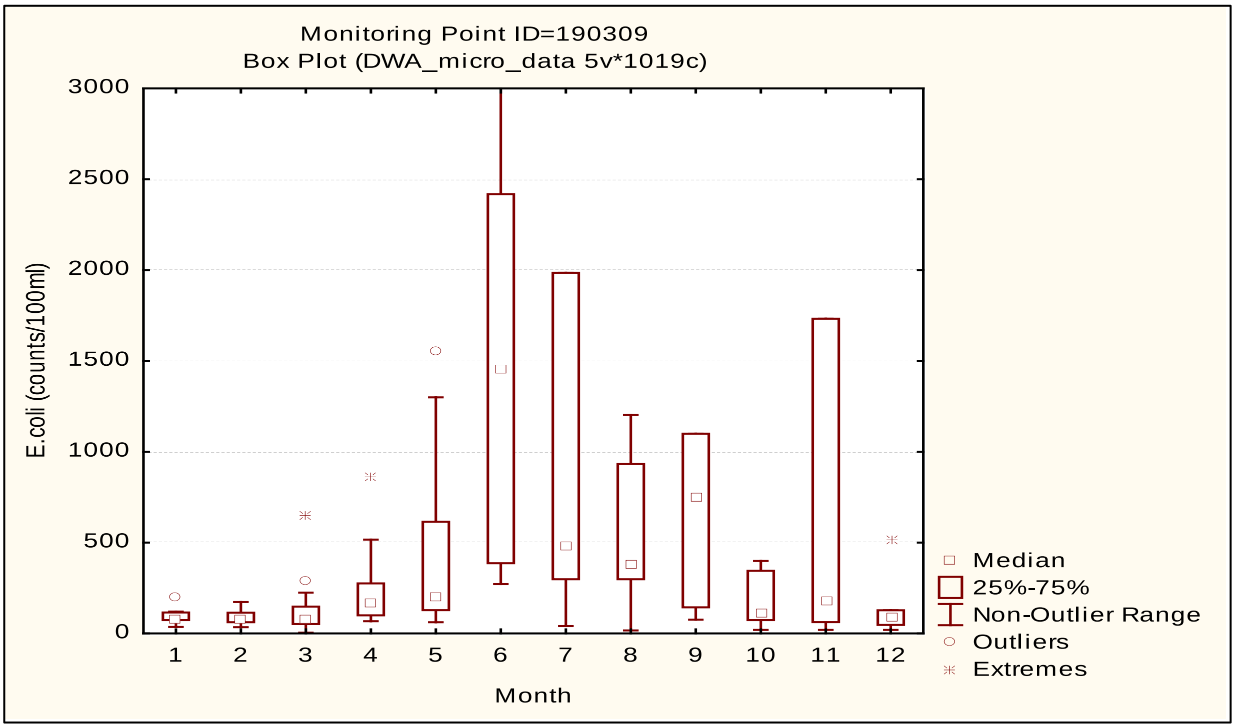


Figure 26: Monthly Box-and-Whisker Plot of E.coli (counts/100ml) Observed in the Berg River near Saron (DWA data)

Figure 27 is a view from the opposite bank (eastern side) of the dam looking towards the inflow on the western side of the dam. The CCT abstraction would be on the left of the diagram, and the Swartland abstraction on the right of the diagram.

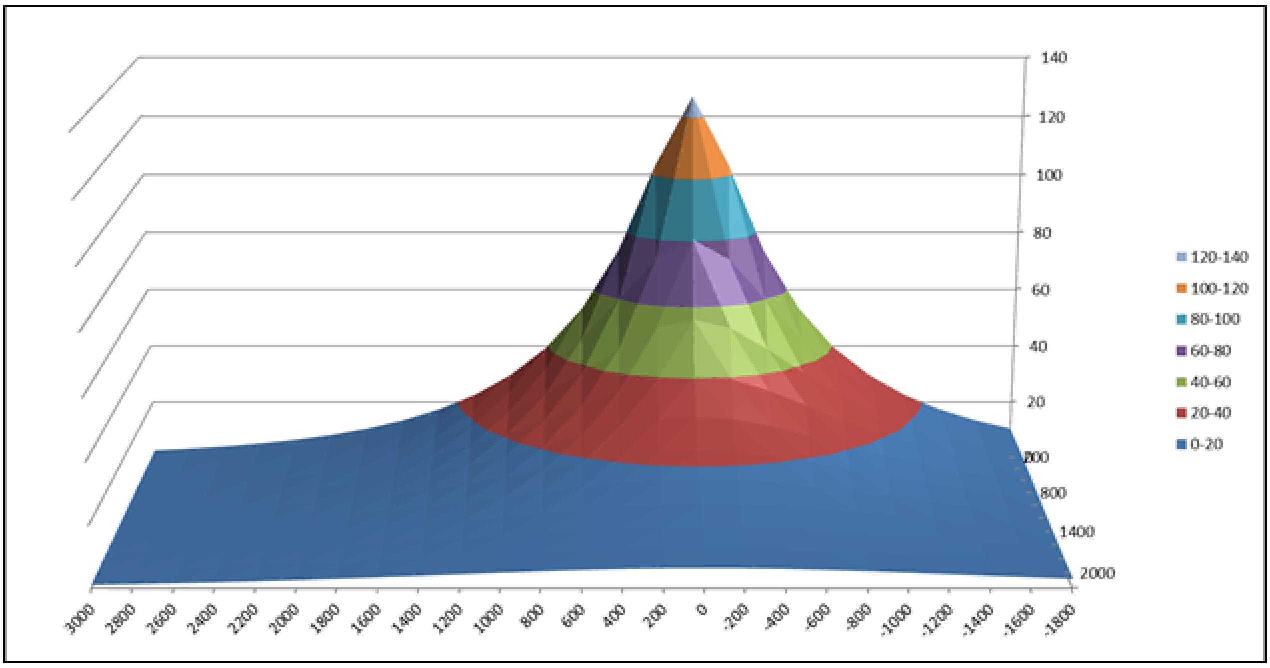


Figure 27: Surface Plot of the Dispersion and Die-off of Bacteria entering Voëlvlei Dam under No Wind Conditions

As shown on **Figure 28**, with no wind, the dispersion would probably be symmetrical around the point of inflow (the middle of the diagram). With a north-westerly wind blowing from right to left, the plume would be directed towards the CCT abstraction (right-hand most diagram on **Figure 28**) and with a south-westerly wind the plume would be directed towards the Swartland abstraction (left-hand most diagram).

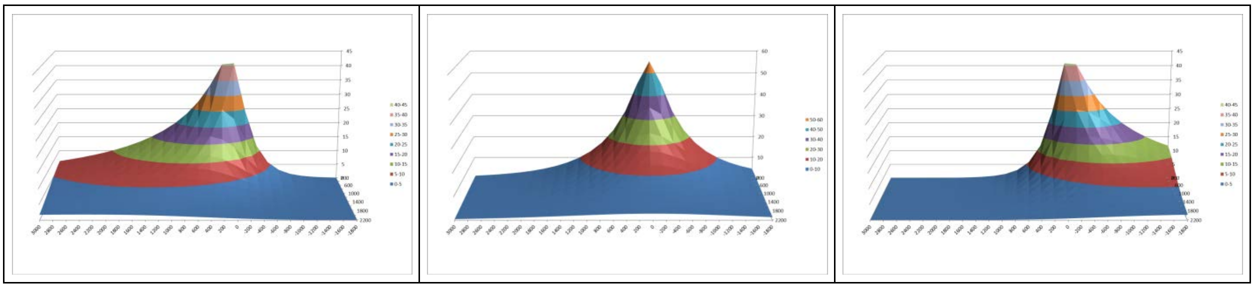


Figure 28: Surface Plot of the Fate of Bacteria Entering Voëlvlei Dam and the Effect of Surface Wind Currents

The first order assessment indicates that, under average conditions, the impacts on the bacterial counts at the CCT abstraction and the Swartland abstraction could be very low, even during the month of June when E.coli counts in the Berg River are at their highest.

However, under extreme conditions, the E.coli counts at the Swartland abstraction could increase by as much as 251 counts/100 ml above background levels. This may occur if the following three events occur simultaneously, namely very high counts occur in the Berg River such as the observed maximum in June, the water level in the Voëlvlei Dam is low (less dilution), and there is a wind blowing towards the Swartland abstraction point.

6. DISTRIBUTION AND POTENTIAL UTILIZATION OF ADDITIONAL WATER - SCHEME INTEGRATION

6.1 INTRODUCTION

The proposed BRVA Scheme would increase the 1 in 50 year yield of the Western Cape Water Supply System (WCWSS) by about 23 million m^3/a to enable the system to meet the future growth in the water requirements which could not be met by the existing sources of supply. **Figure 29** indicates that even if water conservation and requirement management is very successful, this proposed scheme (or another scheme) would be required to augment the supply by about 2020, at latest.

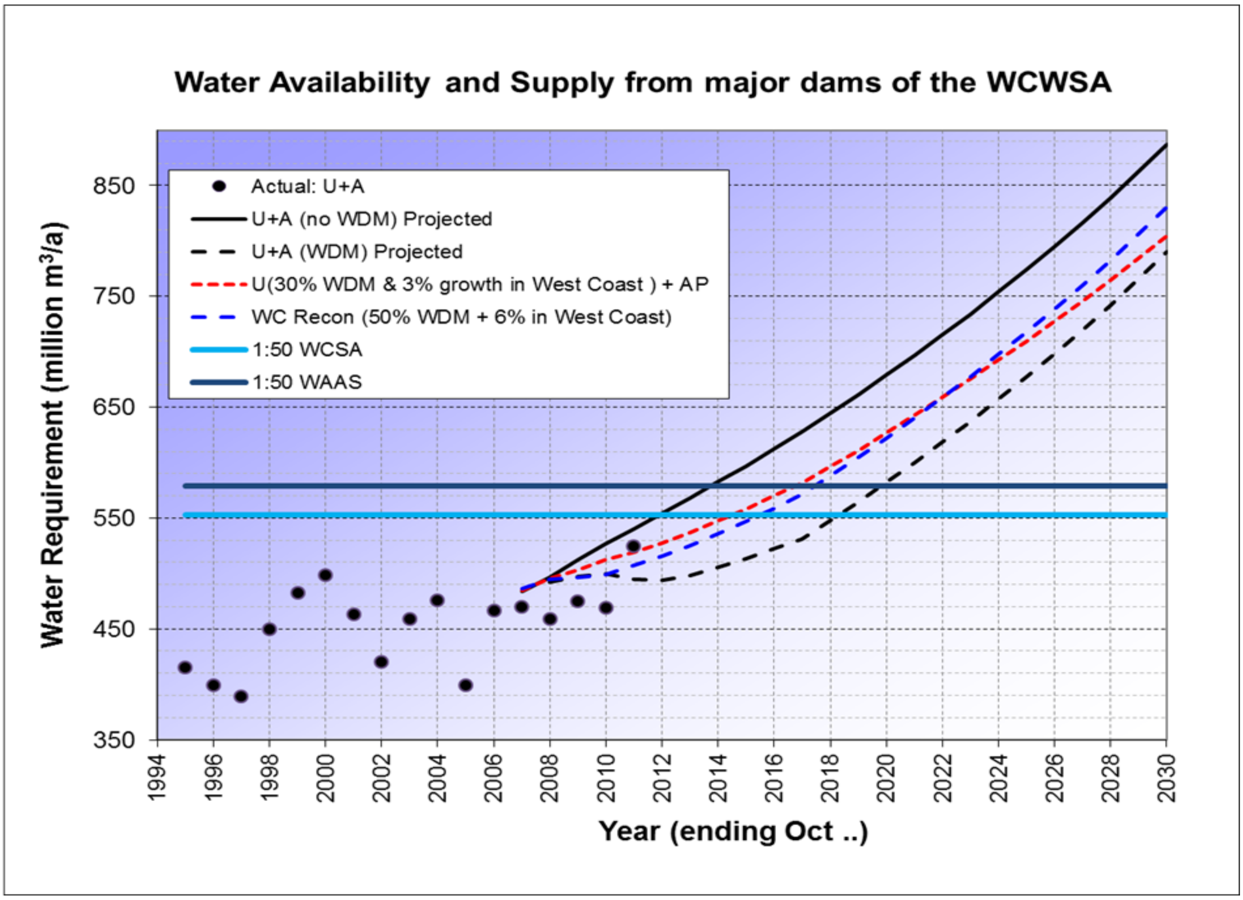


Figure 29: Water Requirement Projection for the Total Supply from the Major Dams

The urban water requirements of the WCWSS that are supplied from the Voëlvlei Dam are those requirements of the CCT which are treated at the Voëlvlei Water Treatment Works and then pumped to the City via the Voëlvlei Pipeline, and those water requirements of the WCDM. The requirements of the WCDM comprise water that is piped from the dam to the nearby Swartland Water Treatment Works and water that is released from the dam into the Berg River for abstraction at the Misverstand Dam and treatment at Withoogte to supply the Saldanha Bay area.

About 18.1 million m^3/a of water is also released from the Voëlvlei Dam into the Berg River to supply the Lower Berg irrigators downstream of Sonquasdrift.

6.2 CITY OF CAPE TOWN

The existing Voëlvlei Water Treatment Works (shown previously in **Figure 5**) of the CCT has a peak capacity of 273 Ml/day, however routine cleaning of the clarifiers reduces the capacity to about 75% of the peak capacity for 21 days per year. Therefore if operated at maximum capacity, the works could supply 273 Ml/day for 344 days per annum and 205 Ml/day for 21 days per annum, providing a theoretical maximum output of 98.2 million m^3/a.

Very few leaks and bursts of the Voëlvlei Pipeline have occurred since the City replaced the vulnerable sections of this pre-stressed concrete pipeline. The City also employs a pipeline maintenance team that is permanently on standby to expeditiously repair any pipe breaks or leaks. Thus down time of the pipeline due to breaks such as that shown in **Figure 30** has been minimised.

Figure 30 Typical Pipe Burst on the CCT's Potable Water Pipeline from the Voëlvlei Dam

It is not anticipated that there would be any problems in treating water that would be pumped from the Berg River into the Voëlvlei Dam to mix with existing inflows from the Klein Berg and Twenty Four Rivers or that there would be problems in operating the pumps on a continuous basis. On the other hand power supply interruptions might be experienced and therefore it has been assumed that the maximum output capacity would be about 88 million m^3/a.

The City has determined that the winter requirements on the Plattekloof Reservoir, which is supplied by the Voëlvlei Pipeline, would be insufficient to fully utilise the potentially available supply. However the City is planning the following works which will probably be commissioned by about 2019 or 2020 when the BRVA Scheme would be required to augment the supply:

- The construction of a large reservoir at Spes Bona which would be supplied from the Voëlvlei pipeline by the existing link pipeline.
- The construction of a second link pipeline from the proposed Spes Bona Reservoir to Glen Garry Reservoir which would enable an augmented supply of 88 million m^3/a from Voëlvlei to be fully utilized during both the summer and winter months.

The City is also considering the possibility of constructing a reservoir at Koeberg to the North East of Melkbos. This reservoir would enable the Voëlvlei pipeline to serve the growing requirements of the West Coast, and by reversing the flow in this pipeline it could also serve a desalination plant sited in the vicinity of Melkbos.

It is concluded that if the proposed BRVAS is implemented by about 2019 or 2020 and the proposed Spes Bona Reservoir and the Spes Bona to Glen Gary pipeline are also constructed then a continuous requirement of about 88 million m3/a could be supplied from the Voëlvlei Dam to Cape Town. **Figure 31** indicates that since 1998 the average annual requirements of the CCT on Voëlvlei Dam have not exceeded about 60 million m^3/a and therefore with the proposed modifications to the bulk supply system the City could probably utilise the full additional yield of about 20 million m^3/a.

However this is unlikely to be necessary as some of the additional yield may be utilised by the WCDM and possibly also by irrigators as discussed hereafter.

Figure 31: Average Annual Supply to Cape Town from the Voëlvlei Water Treatment Works

6.3 WEST COAST GROWTH AND DEVELOPMENTS

Water supplied to the Swartland Water Treatment Works is via a short pipeline from the Voëlvlei Dam and water treated at the Withoogte Water Treatment Works is abstracted from runoff in the Berg River at Misverstand Dam during the winter months, as well as from releases from the Voëlvlei Dam during the summer months. **Table 9** shows the actual annual water volumes supplied from these two works to the West Coast District Municipality.

Table 9: Actual Water Requirements Supplied to the West Coast District Municipality from the WCWSS

Year	Million m^3/a Supplied		
	Withoogte WTW	Swartland WTW	Total
2010	16.52	6.53	23.05
2011	17.03	6.63	23.66
2012	18.09	6.65	24.74

Assuming that 60% of the requirements of the WCDM must be met by releases from the Voëlvlei Dam and that these requirements are growing at the average rate of about 2% per annum then by 2020 the West Coast's requirements on the Voëlvlei Dam will increase by about 3 million m^3/a to approximately 18 million m^3/a and will continue to grow thereafter.

6.4 IRRIGATION REQUIREMENTS

The allocation to the Lower Berg River irrigators is 7 000 m^3/ha/a of which 3 000 m^3/ha/a is released from the Voëlvlei Dam, amounting to 18.1 million m^3/a including provision for losses. The balance of the allocation of 4 000 m^3/ha/a was to be provided by summer run-of-river flows in the Berg River and its main tributaries, namely the Klein Berg River, the Leeu River and the Twenty Four Rivers.

The DWA endeavours to manage irrigation releases from the Theewaterskloof and Berg River Dams to provide a minimum summer flow at Sonquasdrift of about 0.5 m^3/s which provides about 1000 m^3/ha/a to the Lower Berg River irrigators. However to date these flows have averaged between 1.0 and 1.5 m^3/s but may be more closely controlled in the future when the Department's new decision support system is installed. A very small proportion of the summer flows in the tributaries reaches and contributes to the flow in the Lower Berg River and together probably amount to about 500 or 1 000 m^3/ha/a. Therefore the Lower Berg River irrigators currently experience shortfalls in the supply of the balance of their allocation of 4 000 m^3/ha/a as it seems that the Lower Berg has been over allocated.

If the DWA proceeds with the proposed BRVA Scheme then it is a possibility that the Lower Berg irrigators may wish to contribute financially to the proposed scheme in order to augment their present limited allocation to closer to their scheduled allocation from the rivers, of 4 000 m^3/ha/a.

DWA is currently undertaking verification and validation of existing water allocations from the Berg River which may clarify the situation regarding the existing irrigation allocations.

6.5 OTHER INTEGRATION CONSIDERATIONS

A further consideration may be the policing of the proposed summer environmental releases from the Voëlvlei Dam of about 8 million m^3/a to improve the estuarine habitat as it may be difficult to distinguish these releases from the irrigation releases to the Lower Berg Irrigators unless these releases are made as large slug flows.

On the other hand DWA's Decision Support System may enable better control of the summer flows at Sonquasdrift. If these flows could be reduced to less than 0.5 m^3/s then some of the additional yield from the Voëlvlei Dam could be utilised to augment these flows to 0.5 m^3/s and the water that is retained in the Theewaterskloof and Berg River Dams could be utilised to supply the CCT. This would also reduce the additional supply to the City from the Voëlvlei Dam.

7. TOPOGRAPHICAL SURVEY INFORMATION

7.1 INTRODUCTION

Preliminary design associated with this feasibility study required more accurate survey data than was available for the study area at the commencement of the project. The preliminary investigations during Phase 1 of the project were based on readily available information such as 1:10000 orthophotos, which provided contour information at 5 m intervals. DWA had made provision for undertaking a topographical survey as part of this study so as to obtain the necessary level of survey information to support preliminary design. Contour intervals of a minimum accuracy of 0,5 m were envisaged as being adequate for this purpose.

A LiDAR survey (with the Fli-Map LiDAR System) and aerial photography using a Digital Mapping Camera (DMC) were undertaken by Fugro Maps South Africa. This spatial data processing company had a proven track record on other projects in which members of this Western Cape Water Consultants Joint Venture had been involved.

The resulting report entitled 'Voëlvlei Dam, Final Report, Fli-Map Aerial Survey/DMC Camera' dated March 2011 is contained in **Appendix 9**, including the digital survey information and output data on DVD.

7.2 AERIAL SURVEY

7.2.1 Description of area surveyed

The Fli-Map LiDAR acquisition was undertaken on 9 January 2011. The coverage of the surveyed area is shown on **Figure 32**. It should be noted that the survey for both the potential BRVA Scheme and the potential Michell's Pass Diversion Scheme was undertaken at the same time, covering a total surveyed area of 1217 ha. The latter scheme forms the subject of its own feasibility study report.

The area surveyed was selected based on the most likely extent of the corridor into which the proposed scheme alignments would be located.

The aerial survey is only suitable for those areas which lie above water surfaces and it is not possible to obtain bathymetric information (survey levels below water surfaces) in this way. At the time of the aerial survey, the water levels in the Berg River were reasonably high. In order to determine river cross section information in the vicinity of the proposed abstraction site, manual topographic survey of three cross sections was also undertaken. These three cross sections were located upstream of, downstream of, and at the proposed weir site, where after their datum was tied in with that of the aerial survey.

7.2.2 Accuracy of the Aerial Survey

Fugro Maps has initially indicated a guaranteed vertical accuracy of within 15 cm. On completion and after analysis of the survey results, it was concluded that the vertical accuracy achieved was in fact within 3 cm (root mean square of the z value is 3 cm). Details of the specific values pertaining to data resolution and accuracy are enclosed in the aerial survey report in **Appendix 9**.

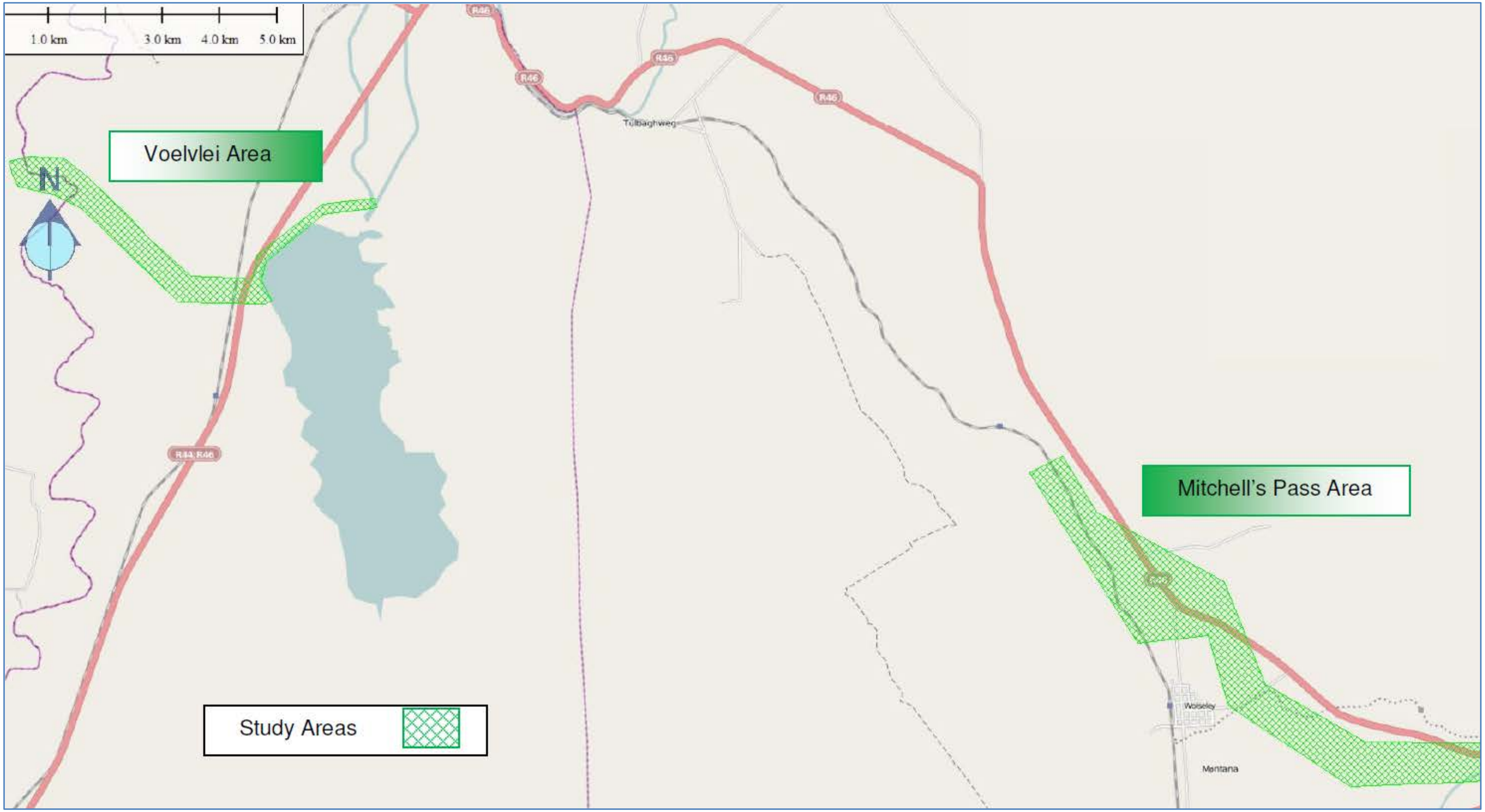


Figure 32: Extent of the LiDAR Aerial Survey Undertaken

7.2.3 Survey Deliverables

The main deliverables of the Voëlvlei Dam component of the survey is a set of 29 maps at a scale of 1:1000 with contours at intervals of 0.5 m. These are available in digital format, and will be submitted on the DVD as part of the final study reporting deliverables.

The following information and topographical features are indicated on each of the 1:1000 maps:

- trees,
- cultivation,
- rivers,
- main, secondary and farm roads,
- erf boundaries,
- areas of cut and fill adjacent to roads,
- buildings,
- railways,
- power line infrastructure,
- pipelines, pump stations,
- irrigation furrows and canals,
- direction of river flow,
- man holes,
- irrigated and other lands,
- erosion features,
- level crossings, and
- X and Y co-ordinate grid lines at 200 m intervals.

The following deliverables from the survey are captured on the DVD that accompanies this report:

- 0.5 m contour intervals in DSF, DGN and DWG format;
- LiDAR (Ground) in an X,Y,Z format
- Imagery (set of 1:1000 aerial photographs) in a Tiff and ECW format (0.15 m resolution)
- 2D Line Mapping (DGN, DWG and DXF format)
- 2D Line Mapping Plans at 1:1000 scale (DGN, DWG, DXF and PDF files)
- 3 additional Cross Sections at the proposed Lorelei Diversion site.

8. GEOTECHNICAL INVESTIGATIONS

8.1 INTRODUCTION

DWA had allowed for a geotechnical investigation to be undertaken in order to provide support to the preliminary design of the proposed weir and pump station, as well as the proposed rising main to the Voëlvlei Dam, and for the ancillary structures. The investigations were undertaken by Fairbrother Geotechnical Engineering cc (FGE) on the basis of a scope of work and pricing schedule developed by the WCWC JV. FGE subsequently appointed R.A. Bradshaw & Associates cc, Consulting Engineering Geologists as the specified independent Professional Service Provider to provide professional services related to the interpretation of the drilled boreholes, excavation of trial pits, laboratory testing, administration of the geotechnical investigations, reporting and liaison with the WCWC JV.

The feasibility level investigations were conducted in May, June and July 2011. They comprised mapping of the bedrock and the exploratory drilling of eight boreholes at the Berg River weir site, and the excavation of nine trial pits along the proposed pipeline route from the Lorelei abstraction site to the Voëlvlei Dam. Laboratory testing of soils and groundwater from the trial pits supplemented the field investigations.

It should be noted the proposed diversion weir site at Lorelei is the only one in the vicinity at which any rock outcropping is exposed in the river channel and on the river bank. The full geotechnical report is enclosed in **Appendix 8** and a summary of the investigation is provided in the following sections.

8.2 EXPLORATORY DRILLING

The initial scope for the drilling programme included drilling of four boreholes, two on each bank, at the proposed diversion weir site at Lorelei. The intention was that the findings of the core drilling would be supplemented by a seismic survey analysis. During the execution of the drilling programme, and based on the initial findings, it was recommended by the intended service provider of the seismic survey, that in this case, further exploratory drilling at targeted locations would yield more reliable information than that of a seismic survey.

As such, after discussion and agreement with DWA, the number and positions of the boreholes was modified based on site conditions, and finally eight boreholes were drilled in the positions shown on **Figure 33**.

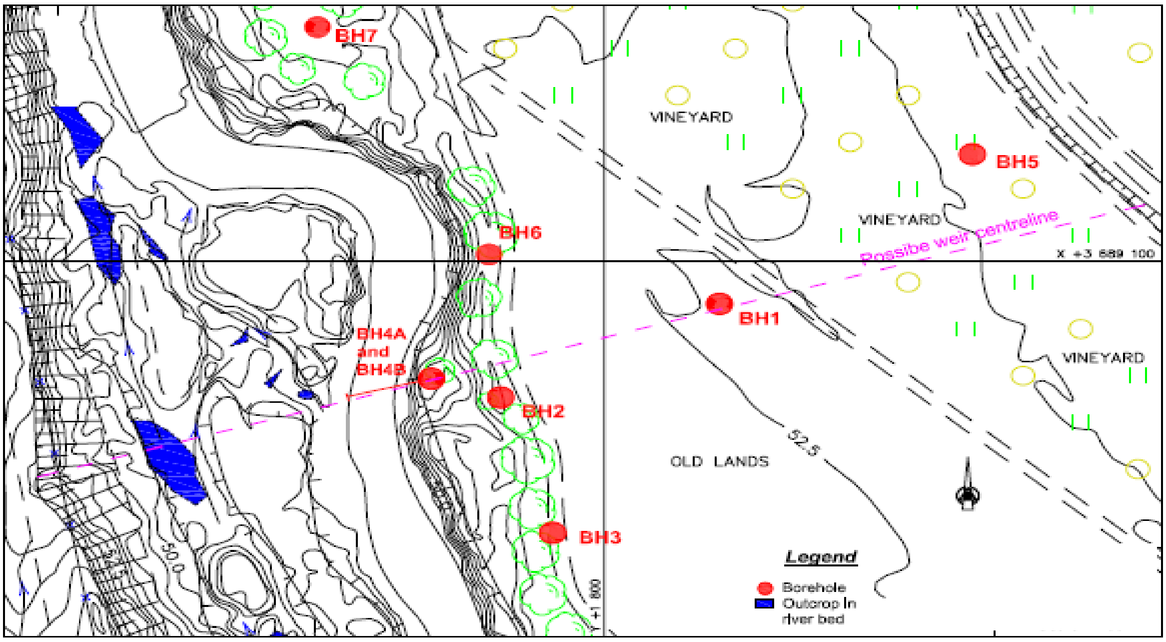


Figure 33: Approximate Locations of the Boreholes Drilled at the Lorelei Site

It is relevant to note that due to landowner objection and refusal for access at the time of the geotechnical drilling, no cores were drilled on the left bank (Goudklip Farm). However, as shown in **Figure 34** below, there is extensive visual evidence of rock outcrop on that bank, dipping towards the river and towards and under the opposite bank, confirmed by the core drilling results on that side of the river.

Figure 34 Typical Rock Outcrop on the Left Bank at the Lorelei Site

The boreholes were drilled using a combination of wash-boring, SPT testing and NWD4 double-tube core drilling. Core logging was undertaken according to standard South African practice and the borehole logs are presented in the Geotechnical Report (see **Appendix 8**). The borehole cores are stored at the DWA premises at the Voëlvlei Dam.

8.3 TRIAL PITTING

Nine trial pits were excavated at selected positions along the proposed rising main route. The positions of these trial pits are shown in **Figure 35** and were based on an approximate spacing of 1 every 500 m, sited to have least impact on existing infrastructure and on private land. A wheel-mounted excavator was used instead of a track-mounted excavator because of landowner preferences. The pits were extended to the practical limit of excavation or refusal. The limit was either at approximately 3 m depth, or at depths at which massive collapse of the sidewalls of the pits prevented deeper excavation without excessive lateral extension of the pits. The soils exposed in the sidewalls of the pits were described according to standard South African practice and the descriptions of the soil profiles are presented in the Geotechnical Report enclosed in **Appendix 8**.

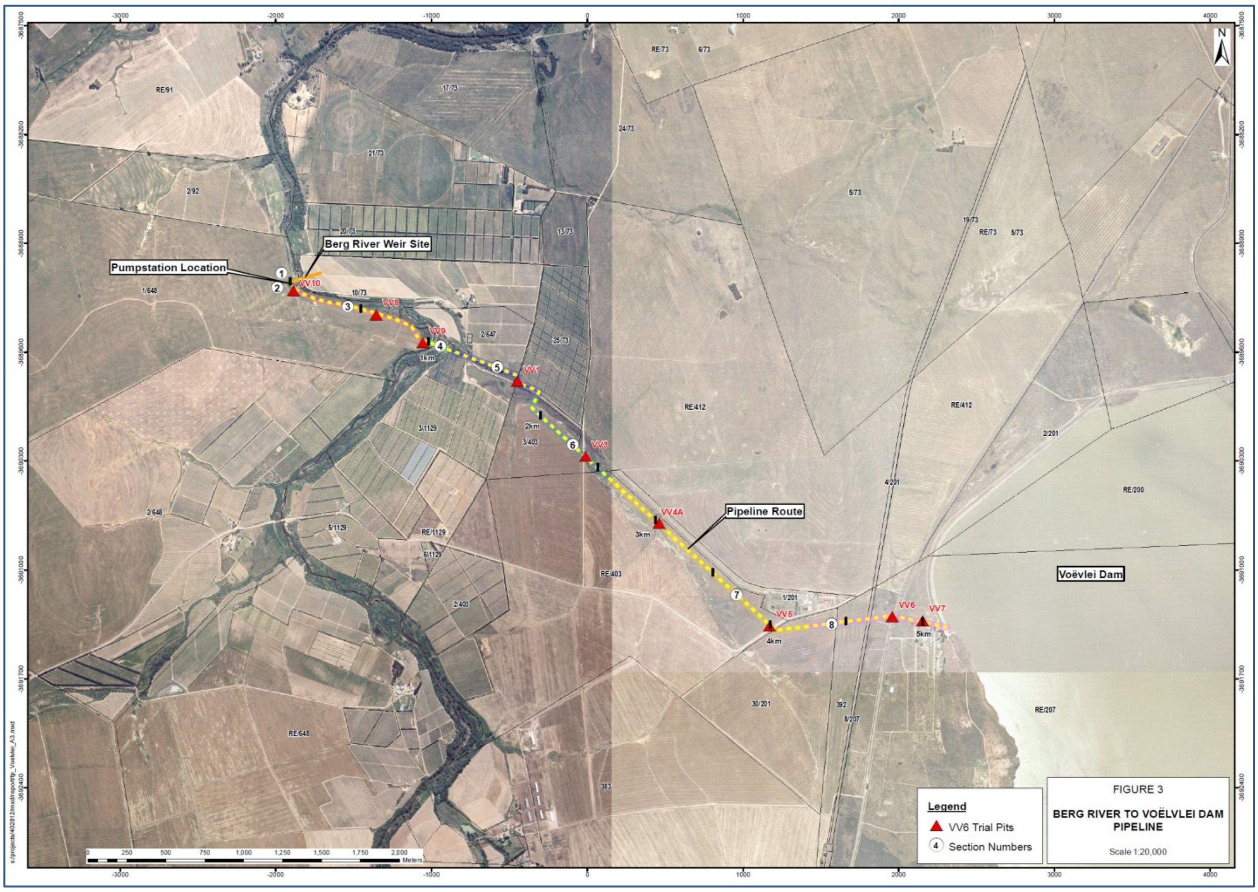


Figure 35: Approximate Locations of the Trial Pits for the BRVA Scheme

8.4 MAPPING AND LABORATORY TESTING

The exposures of rock in the river channel at the Voëlvlei Dam site were mapped using a hand-held GPS instrument to an instrument-indicated accuracy of 3 m.

Disturbed samples were taken from representative soil layers in the trial pits along the pipeline route. Foundation indicator tests were undertaken on certain of these samples, and grading analyses to 0.075 mm sieve size were undertaken on certain other samples. Testing was undertaken by Geoscience Laboratory (Pty) Ltd. The laboratory test sheets are presented in the Geotechnical Report in **Appendix 8**.

8.5 FINDINGS AND RECOMMENDATIONS OF THE GEOTECHNICAL INVESTIGATIONS

An independent review of the Geotechnical Report was undertaken by the JV's independent geotechnical engineering specialist in order to consider the outcomes, results and conclusions. The result of that review was that the geotechnical investigation and its report are considered to be "*very thorough and provides excellent basis for proceeding to the design and costing of the preferred scheme*". The review is included in the Geotechnical Report.

The feasibility investigations provided a general level of information on ground and construction conditions along the pipeline route and for the weir site for the BRVA scheme. This information has been used in the overall evaluation of the most suitable options, to arrive at that proposed.

8.5.1 Weir site

The weir would be partly located directly on bedrock, which would provide good founding. However, the founding level steps approximately 4 m at the eastern edge of the existing outcrop, which will probably require a subsidiary embankment structure on the right flank. Geotechnical conditions at the Lorelei site are generally favourable, particularly if an adequate length of spillway can be provided in the general area of the rock exposures on the west side of the river channel.

8.5.2 Pipeline route

The location of the pipeline route is shown on **Figure 35**. The significant geotechnical factors to consider when assessing construction conditions and costs for the pipeline include:

- Excavation conditions,
- Stability of the sidewalls of the pipe trenches,
- Groundwater conditions,
- Use of excavated material for pipe bedding and backfill, and
- Engineering properties of the backfill.

As shown in the figure, the pipeline route was sub-divided into eight regions or sections of similar soil profile, and therefore similar geotechnical conditions. The anticipated soil profile for each section, together with the interpreted construction conditions and material conditions are summarised in the detailed Geotechnical Report (**Appendix 8**).

Seasonal or local occurrences of groundwater might occur throughout the sections of pipeline east of the river. Groundwater will adversely affect excavation conditions, stability of the excavated slopes in the trenches, and pumping and possibly local de-watering will be required.

Machine excavation is generally expected to be possible along the pipeline route. Approximately half of the route will be excavated in materials in which overbreak can be more easily controlled and narrower excavation profiles could be adopted.

There is potential for the use of excavated materials for selected granular material, selected fill and main fill on the pipeline route. However, it is essential that selective excavation is undertaken and the different materials are kept separate. If all the materials were to be mixed, the resulting mixture would only be suitable for main fill.

8.5.3 Geotechnical Recommendations

The geotechnical investigations undertaken to date have been required by the WCWC JV to support the feasibility studies and the preliminary designs. If this BRVA Scheme progresses to detailed design, then consideration should be given to further investigating the following aspects at a greater level of detail:

i. The routing of the pipeline along the right bank of the Berg River (towards an upstream crossing location), because this appears to have a lesser impact on the affected landowner’s established irrigation and residence, than would be the case if the pipeline were to cross the river at the weir location.

ii. The optimum position for a pump station at the weir site;

iii. The nature of the alluvium and particularly the depth to and the condition of the bedrock at the pipeline river crossings; and

iv. Specific laboratory testing to confirm the suitability of the sandy soils for use as selected granular material.

The main deliverable for the geotechnical investigation is the Geotechnical Report (**Appendix 8**). It contains the necessary descriptions and locations of the boreholes drilled and trial pits excavated, as well as the soil profiles, core logs and test results undertaken at each.

9. INFRASTRUCTURE PRELIMINARY DESIGN

This Section provides a summary of the key design considerations and should be read in conjunction with the preliminary design reports and layout drawings provided in the:

- *Conveyance Infrastructure Preliminary Design Report* (Worley Parsons, October 2012), enclosed in **Appendix 10**.
- *Hydraulic Design of the proposed Berg River Abstraction Works at Voëlvlei Dam* (ASP Technology, May 2012), enclosed in **Appendix 11**.

9.1 INFRASTRUCTURE REQUIREMENTS

The BRVA Scheme would comprise the following additional infrastructure:

- The weir and raw water pump station on the Berg River at Lorelei have been planned so as to minimize the entrainment of sand and silt by the pumps.
- During the winter months the pumps would deliver water to Voëlvlei Dam via a rising main pipeline, 6300 m long and diameter up to 1.9 m. The pumps would be programmed to operate in accordance with the developed operating rules for the eventual scheme.
- This pipeline would be cross connected to the existing outlet infrastructure so that water can be released to the Berg River during the summer months under gravity, thus eliminating the need to utilize the existing canal from which water losses occur.

The CCT's existing Voëlvlei Water Treatment Works, Pump station and Pipeline would supply the City's Plattekloof, proposed Spes Bona and Glen Gary Reservoirs. As discussed in **Section 6** the proposed Spes Bona Reservoir and the linking pipeline to the Glen Gary Reservoir will be constructed by the City to facilitate the operation of their supply system and would not form part of the BRVA Scheme, although these would be essential for its operation.

There would also be no need to change the WCDM's infrastructure however the following modifications to the infrastructure at Withoogte have previously been recommended to improve the operation of this supply system:

- The existing intake arrangements should be improved or a second intake pipeline should be constructed from Misverstand Dam to the Withoogte raw water pump station to enable Misverstand Dam to be drawn down to greater extent so as to facilitate and improve the management of summer flows in the Lower Berg River.
- The second partially constructed clear water reservoir at Withoogte should be completed to provide additional clear water storage for bridging periods when high salinities occur as a result of runoff in the local Maatjies and Sout River tributaries of the Berg River.

In order to accommodate the possible options regarding eventual implementation of the EWRs, two abstraction rates from the Berg River have been considered in the preliminary design and associated infrastructure and costing, namely:

- 4 m^3/s abstraction; and
- 6 m^3/s abstraction.

9.2 SITING ABSTRACTION WORKS AND PUMP STATION

9.2.1 Introduction

Of the three potential diversion sites (Lorelei, Sonquasdrift and Spes Bona), the most favourable from a geotechnical, hydraulic and conveyance infrastructure perspective is the Lorelei Site. The weir can largely be positioned on rocky outcrops and bedrock within the river (unique to this location), therefore ensuring a much more securely anchored structure than the other two (2) locations could offer. The proposed weir position also provides a preferred weir canal off-take on the outside of the river bend and suitable adjacent pump station siting on the left bank on Goudklip Farm (see **Figure 36**).

Figure 36: Potential Pump Station Location on Left Bank of Berg River (Goudklip Farm)

Two alternative options for the pipeline to cross the Berg River from the left to the right bank were investigated, namely a buried pipeline underneath the river or an overhead crossing of the river by means of a pipe bridge. From an infrastructure protection and security perspective, a syphon crossing underneath the river by means of a concrete encased pipeline with gabion river rehabilitation work was considered preferable (see **Figure 37**).

Figure 37: Abstraction Site, Rising Main and Berg River Crossing

9.2.2 Diversion Weir

A two dimensional fully hydrodynamic model based on the LIDAR survey and on roughness estimates was used to simulate the flow patterns and sediment dynamics of the Berg River to aid the design of the abstraction works. The water levels and scour patterns were simulated for the 1 in 2 year, 1 in 10 year and 1 in 100 year floods.

The proposed site on the left bank was found to be ideally located. The flow depth would be about 10.4 m during the 1 in 100 year flood and the flow velocity about 2 m/s when velocities would be lower than during the 2 year flood because of the wide floodplain. The right bank floodplain would be inundated during floods but as the flow velocities would be low and the flow depth shallower, it should be possible to construct a weir/embankment on the floodplain without significantly increasing the flood levels upstream.

The proposed layout of the abstraction works for 6 m3/s pumping capacity is shown in **Figure 38** and **Figure 39**. These works would comprise the following components:

- A Crump Weir
- A protected embankment on the right bank floodplain to be designed to be overtopped
- A boulder trap with a radial gate to flush sediments
- A gravel trap comprising two canals and a dividing wall, with radial gates downstream for flushing.
- An underwater opening would allow water to be diverted to supply the pumps, while keeping floating debris away from the trashracks.
- The pumps would be located in a dry well and flushing durations are expected to be less than 30 minutes.

In order to minimise the increase in upstream water levels, the design would require the use of a hopper and jet pumps which would rely on the main pumps to provide a high head, whereas the preferred solution would be longer sand trap canals downstream of the trashracks that would be flushed by gravity and would also act as pump sumps.

A canoe chute would be provided since the weir would be situated on the route of the annual Berg River Canoe Marathon. A fishway, comprising a vertical slotted fishway or a rock-ramp type, may also be required.

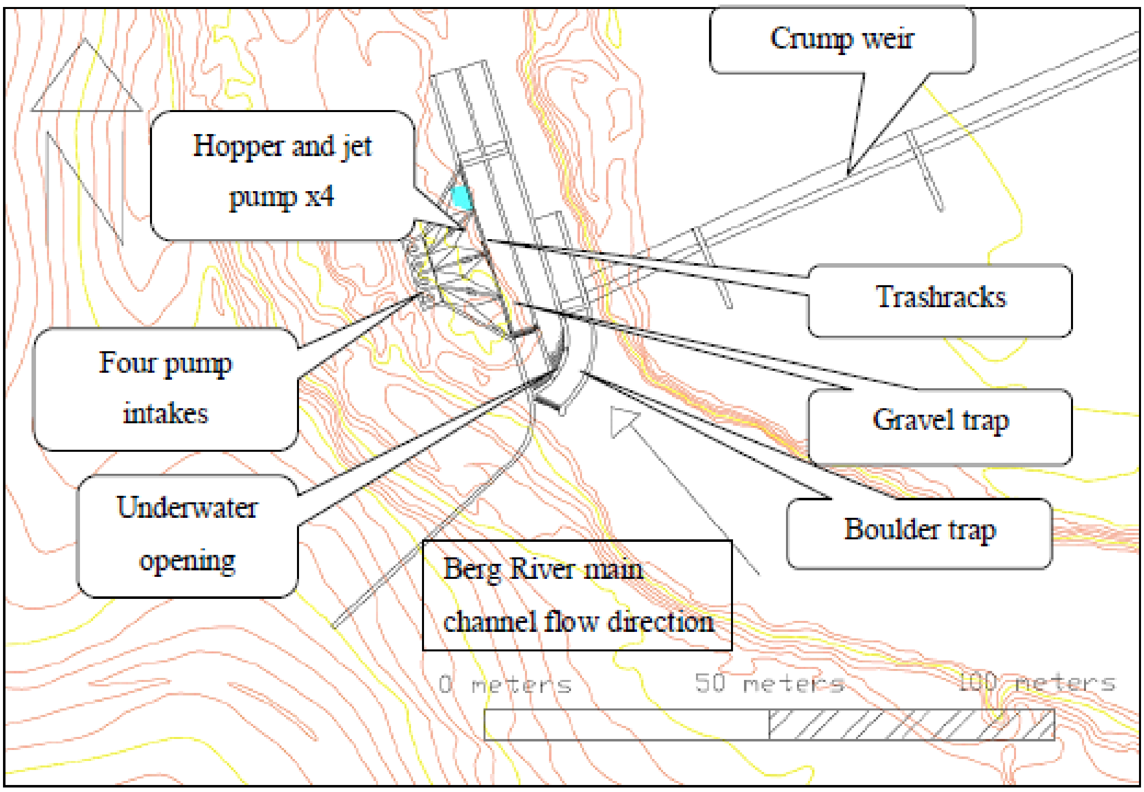


Figure 38 Proposed Abstraction Works and Pump Station

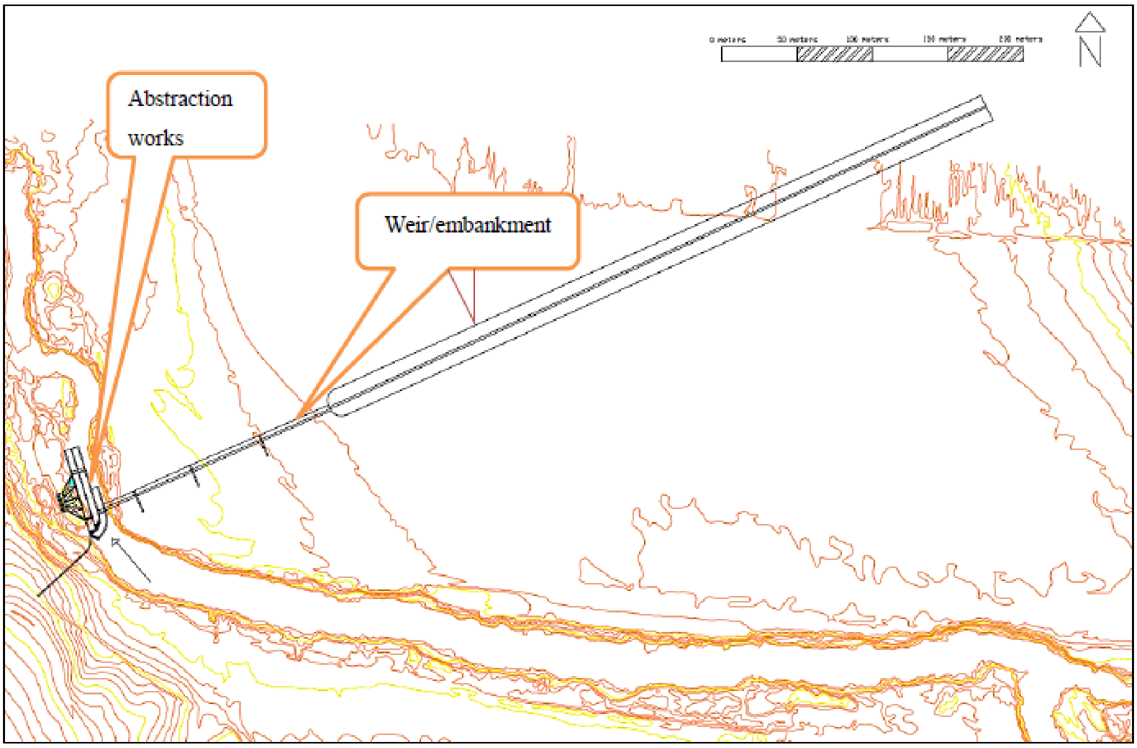


Figure 39 Proposed Abstraction Work, Weir and Embankment

9.2.3 Rising Main Pipeline

As shown on **Figure 40** the three pipeline route lengths for each discharge option into the dam from the Lorelei Diversion site are as follows:

- Pipeline route to Northern Discharge Point = 8 115 m
- Pipeline route to Central Discharge Point = 5 000 m
- Pipeline Route to Southern Discharge Point = 6 300 m (Preferred route)

Although the central discharge point provides the shortest pipeline route option, the selection of the preferred discharge point, and hence the pipeline horizontal alignment is driven firstly by water quality considerations, secondly by the extent of impact on the Renosterveld within the area, and thirdly on the length of the pipeline required. The water quality considerations are further addressed in **Section 9.2.6**.

Design flows of 4 and 6 m^3/s have been considered for the rising main. The average pipe depths required are about 3,5 m with a minimum cover of 1 m. The selected pipe material (described further in **Section 9.2.4**) is glass-fibre reinforced polyester (GRP) with a stiffness of 5 000 N/m². **Table 10** shows the design parameters adopted for the rising main between the diversion weir and Voëlvlei Dam.

Table 10: Rising Main Design Parameters

Design Parameter	Parameter Specification	
	4m³/s Design Flow	**6m³/s Design Flow**
Head Loss calculation	Colebrook White & Darcy-Weisbach	
Rising Main Length	6300 m	6300 m
Rising Main Properties	1700 mm dia GRP	1900 mm dia GRP
Static Head	28,0 m	28,0 m
Dynamic Head	35,8 m	37,5 m
Maximum Flow Velocity	1,762 m/s	2,116 m/s

Air-valves have been allowed for at high points and scour valves at low points to facilitate scouring and drainage of the pipeline. The necessary valves have been allowed for to divert canal water from the Swartland WTW to the Berg River, as well as in-line valves to isolate sections of the pipeline for scouring, isolating and maintenance purposes.

9.2.4 Selection of Pipe Material

Buried piping must resist internal pressure, external loads, differential settlement and the corrosive action of soils. The profile, flow velocity, size and stiffness of the pipe all affect the design. Various pipe materials are available on the market and those considered for this large diameter pressure application included mild steel, ductile iron and GRP. A comparison undertaken between these pipeline materials identified that, for the purpose of this preliminary design, GRP pipes are considered the preferred pipeline material. Their advantages include flexibility, light weight and corrosion resistant properties. A cautionary approach is required when considering the selection of bedding and backfill material as this pipe type is more susceptible to backfill properties than mild steel (MS) or ductile iron (DI). It is understood that in the event of implementation, DWA may prefer that Ductile Iron pipes be used in the detailed design rather than GRP. The estimated impact on the capital cost of such a choice is indicated in **Section 11.1.**

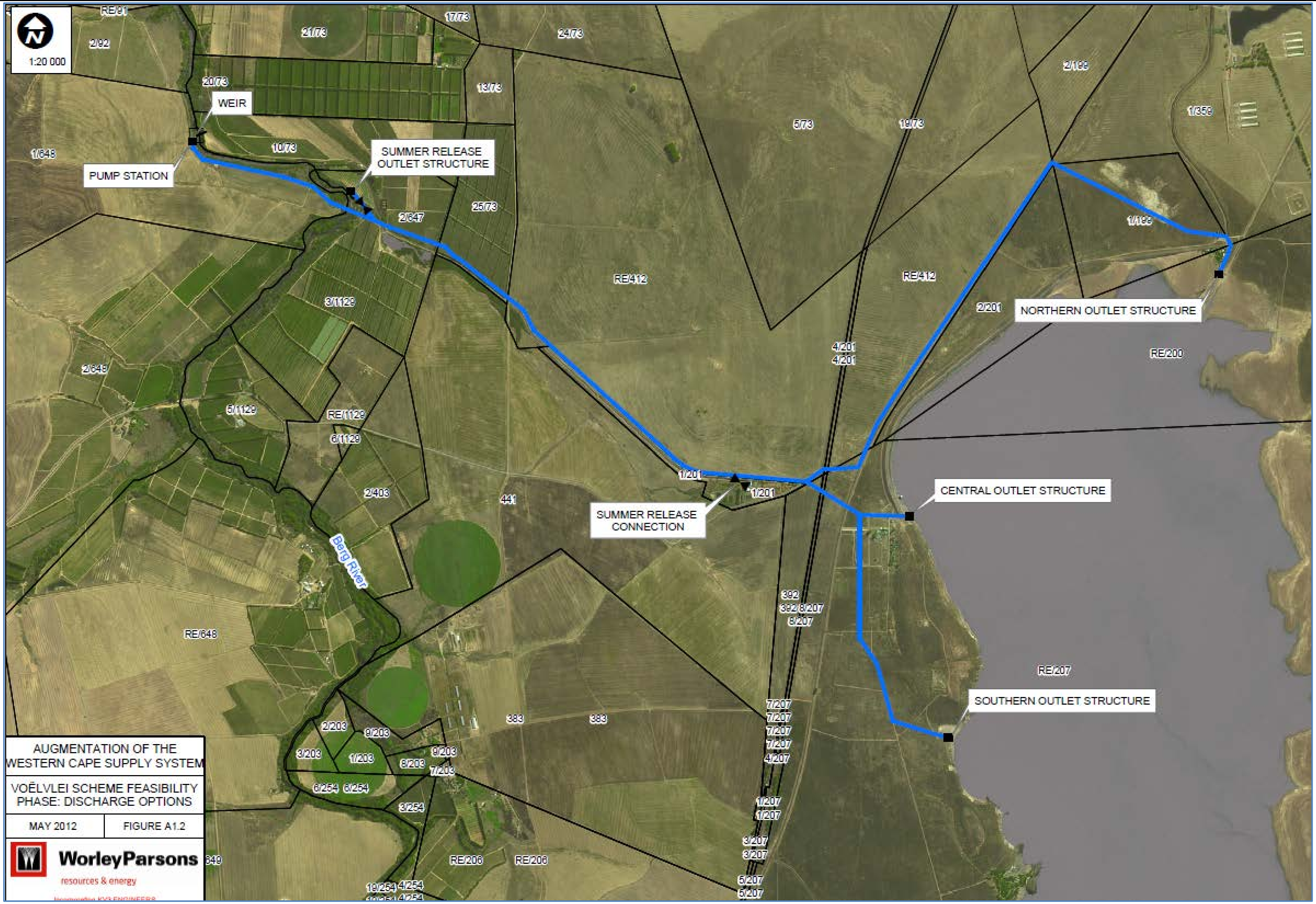


Figure 40: Potential Outlet Structure Locations for Discharge of Berg River Water into the Voëlvlei Dam

9.2.5 Pump Station Design

Table 11 shows the design parameters for the pump station.

Table 11: Design Parameters for the Pump station

Design Parameter	Parameter Specification	
	$4 m^3/s$ Design Flow	$6 m^3/s$ Design Flow
Abstraction	Raw water from the Berg River in winter	
Rising Main Static Pressure	28,0 m	28 m
Friction Losses	7,8 m	9,5 m
Inlet Static Pressure	1,8 m	1,8 m
Pump Duty	34,0 m	35,7 m

During the winter abstraction period, water from the Berg River will flow into the sump at the pump station. A level transmitter on the diversion weir will provide an input value for the flow calculation to determine the amount of water to be abstracted and pumped to the Voëlvlei Dam, where after the pumping will commence according to the approved operating rules for the scheme.

At the commencement of pumping, the pipeline could be partially empty and as such, the first pump will start by means of a variable speed drive and slowly fill the pipeline until water is discharged into the dam. Flow will be measured at the pump station in order to monitor the volumes abstracted and the abstraction rates.

For the 6 m^3/s abstraction option, as the winter flow in the Berg River increases, a second variable speed drive pump will start to increase the abstraction rate. The rest of the pumps will follow until a maximum of $6m^3/s$ is achieved. The pump(s) speed can then be adjusted to provide the permissible flow as defined by the operating rules for the 6 m^3/s abstraction. This adjustment can be made locally at the pump station, or remotely via a SCADA system. A fifth pump will be installed as a back-up.

The 4 m^3/s abstraction is based on a step-pumping operating rule, allowing a minimum flow (spill) of 1 m^3/s past the abstraction point down the Berg River at all times, after abstraction. The pumps are in sets each with a 1 m^3/s capacity. Each pump starts up when the river inflow to the site exceeds the sum of the required environmental base flow of 1 m^3/s and the abstraction, in 1 m^3/s steps.

For both options, a SCADA system would be provided for remote monitoring of the pumping system status (site unknown at this stage), including the pumps' operational status, flow, system pressure, dam level, etc. If so required, the system can also be utilised to provide a remote control facility.

9.2.6 Selection of Preferred Discharge Point into the Voëlvlei Dam

Three alternative discharge points (see **Figure 40**) for the delivery of the raw Berg River water into the dam were investigated, namely:

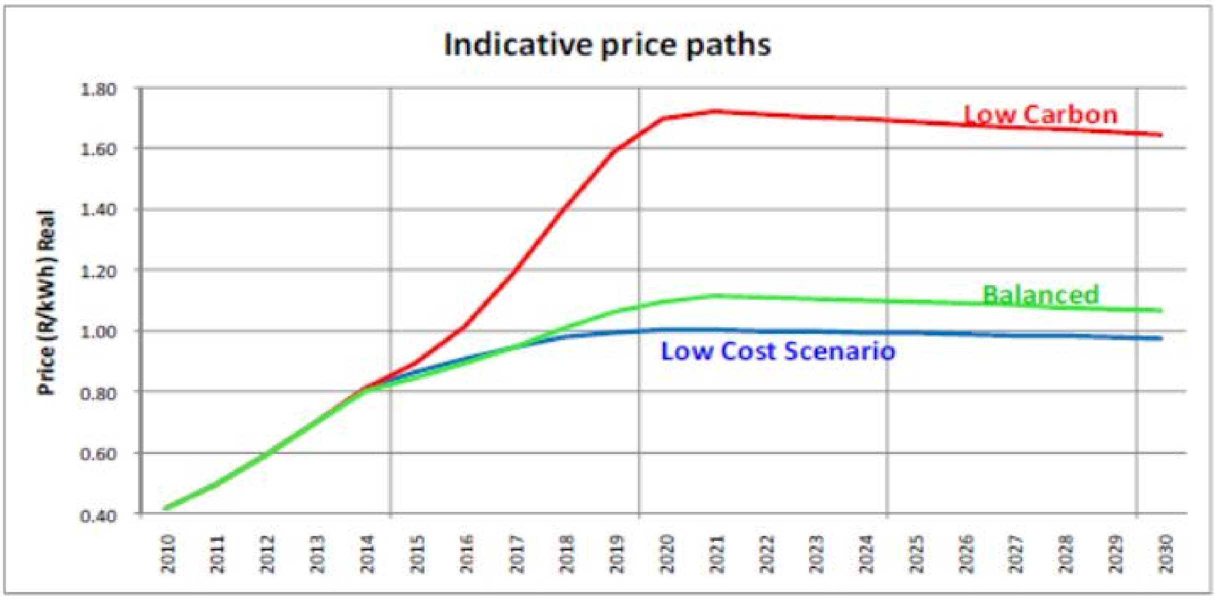
- A Northern Discharge Point (close to the existing canal inlets)
- A Central Discharge Point (close to the existing Swartland intake works)
- A Southern Discharge Point (between the existing Swartland and CCT intake works)

The Dispersion Modelling described in **Section 5.3** formed the basis for the selection of the preferred discharge point, namely the southern-most location. This location enables optimal diffusion and blending to take place sufficiently far away from the Swartland and CCT intake works. The distance offers reduced risk of short-circuiting at either of the two intake works, ie intake of raw water with high Berg River water quality characteristics, before opportunity for dilution and blending in the reservoir.

The southern discharge point also offers other advantages such as being in a secluded bay with bedrock, which is favourable for design of the discharge structure foundations. The resulting rising main pipeline route is also shorter than that which would be required to reach the northern site and the alignment has the lowest impact of all three options on the environmentally sensitive Renosterveld. A secluded bay also offers improved settlement opportunity for the suspended solids plume that is expected to occur.

9.3 ELECTRICITY COST CONSIDERATIONS

The Executive Summary of the Draft Integrated Electricity Resource Plan for South Africa - 2010 to 2030 IRP 2010 dated 22 October 2010 compiled by the Department of Energy describes nine future electricity generation scenarios that were investigated and evaluated in accordance with a multi-criteria decision making framework (MCDF). The criteria used for evaluating the scenarios were CO_2 emissions, price path peak, average water consumption, uncertainty factor, localisation potential and regional development. This MCDF process led to the selection of the Balanced Scenario which would achieve a price path similar to that of the Low Cost Scenario shown in **Figure 41** as well as the Low Carbon Scenario, all based on 2010 costs. Both graphs assume an average tariff of R0.42/kWh in 2010.



Ref: Executive Summary of the Draft Integrated Resource Plan for South Africa – 2010-2030 IRP 2010; Department of Energy

Figure 41: Electricity Prices for Balanced, Low Cost and Low Carbon Scenarios in 2010

Some of the conclusions contained in the Draft Integrated Resource Plan are as follows:

- The Revised Balanced Scenario provides a significant reduction in carbon emissions while allowing only a marginal increase in the price to the electricity consumer.
- Importantly, the Revised Balanced Scenario provides for localisation of renewable technologies.
- The increase in renewable capacity does not come at the expense of security of supply.
- Regional development (e.g. the increased reliance on the Zambezi River) does pose a minor risk to security of supply.

Since the Draft Integrated Resource Plan was published in 2010, NERSA has granted Eskom average tariff increases of 24.8% for 2010-2011, 25.8% for 2011-2012 and 16% for 2012-2013. In November 2012 Eskom requested NERSA to approve further tariff increases of 16% per annum for the next 5 years however an increase of only 8% per annum was approved by NERSA. Never the less it has been assumed that future electricity price increases will be necessary to provide Eskom with a tariff at least equal to the Low Cost Scenario price of R1.00/kWh for 2010 shown in **Figure 41**. This corresponds to an average price of about R1.19/kWh in 2013 values based on an assumed inflation rate of 6% per annum from 2010 to 2013.

The future electricity tariffs for year round pumping and for pumping during the winter months from May to October have been based on the average annual price or R1.19/kWh as described above and on Eskom's Megafllex Tariffs for 2012/2013 shown in **Table 12**. These tariffs were increased pro rata to correspond to the projected future average year round price of R1.19/kWh.

Pumping from the Berg River

Since the pumping of raw water from the Berg River would take place over a 6 month period during the winter months, when flow is available in the Berg River as described in **Section 2.2.3,** the average tariff for pumping from May to October would be 140 cents/kWh based on the average of the increased tariffs for the High Requirement Season and the Low Requirement Season as shown in **Table 12**.

Pumping from Voëlvlei to Cape Town

The pumping of treated water from Voëlvlei to Cape Town would take place throughout the year for which the electricity tariff would be about 119 cents/kWh, however these costs were not included in the URV calculations.

Table 12: Eskom Tariffs

SEASON	Eskom 2012-2013 Megaflex Tariffs (cents/kWh)							Future Increases %	Increased Future Tariff (cents/kWh)
	Electrification and Rural Subsidy	Reactive Energy Charge	Environmental Levy	Peak (25 hrs per week)	Peak (47 hrs per week)	Peak (96 hrs per week)	Average Tariff		
Low Demand Season: Sep to May (273 days)	.0456	0.00	0.03	60.35	36.92	25.84	34.15	285%	96.8
High Demand Season: June to Aug (92 days)	.0456	0.09	0.03	216.33	56.18	29.98	65.20	285%	184.8
River Pumping Tariff May to Oct							49.68	285%	140.8
Pipeline Pumping Tariff Jan to Dec							41.98	285%	119.0

10. ENVIRONMENTAL CONSIDERATIONS

10.1 ACTIVITIES FOR AUTHORISATION

The environmental process for the proposed BRVA Scheme will need to fulfil the requirements of all relevant legislation, including but not limited to:

a) National Environmental Management Act, 1998 (Act No. 107 of 1998);

b) National Water Act, 1998 (Act No. 36 of 1998); and

c) National Heritage Resources Act, 1999 (Act No. 25 of 1999).

10.1.1 National Environmental Management Act, No. 107 of 1998

NEMA, as amended, establishes, *inter alia*, the principles for decision-making on matters affecting the environment. Section 2 sets out the National Environmental Management Principles which apply to the actions, including decision-making, of organs of state that may significantly affect the environment. Furthermore, Section 28(1) states that "Every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring, or, in so far as such harm to the environment is authorised by law or cannot reasonably be avoided or stopped, to minimise and rectify such pollution or degradation of the environment.".

In terms of the EIA regulations, promulgated in terms of Section 24 of NEMA, certain activities are identified, which require authorisation from the competent environmental authority, in this case the Department of Environmental Affairs and Development Planning (DEA&DP), before commencing. Listed activities in Government Notice (GN) No. 545 require Scoping and EIA whilst those in GN No. 544 and 546 require Basic Assessment (unless they are being assessed under an EIA process). Due to the nature and extent of the proposed BRVA Scheme, a full EIA process will be required.

10.1.2 National Water Act, No. 36 of 1998

The National Water Act (NWA) (Act No 36 of 1998) provides for the sustainable and equitable use and protection of water resources. It is founded on the principle that the National Government has overall responsibility for and authority over water resource management, including the equitable allocation and beneficial use of water in the public interest, and that a person can only be entitled to use water if the use is permissible under the NWA. The Act also distinguishes between various types of water use[1] in Section 21 which may require a Water Use Licence or a General Authorisation.

The proposed augmentation scheme will require an Integrated Water Use Licence that allows for the following[2]:

- Diversion of surplus winter water from the Berg River to the Voëlvlei Dam;
- Increase of the Voëlvlei Dam's storage capacity (when the dam is raised); and
- Replacement of the existing permit issued to the Voëlvlei Dam under the previous Water Act of 1956 (Act No 54 of 1956), to allow for the additional water to be taken from the dam (i.e. the CCT and any other user).

10.1.3 National Heritage Resources Act, No. 25 of 1999

In terms of the National Heritage Resources Act (No. 25 of 1999) (NHRA), any person who intends to undertake "*any development … which will change the character of a site exceeding 5 000 m^2 in extent*", *"the construction of a road…powerline, pipeline…exceeding 300 m in length"* or *"the rezoning of site*

[1] Taking water from a water resource, storing water, impeding or diverting the flow of water in a watercourse and altering the bed, banks, course or characteristics of a watercourse.
[2] The Integrated Water Use Licence would also include the existing lawful water use at Voëlvlei Dam.

larger than 10 000 m^2 in extent…" must at the very earliest stages of initiating the development notify the responsible heritage resources authority, namely the South African Heritage Resources Agency (SAHRA) or the relevant provincial heritage agency, i.e. Heritage Western Cape (HWC). These agencies would in turn indicate whether or not a full Heritage Impact Assessment (HIA) would need to be undertaken.

Section 38(8) of the NHRA specifically excludes the need for a separate HIA where the evaluation of the impact of a development on heritage resources is required in terms of an Environmental Impact Assessment (EIA) process. Accordingly, since the impact on heritage resources would be considered as part of the EIA process, no separate HIA would be required. SAHRA or HWC would review the EIA reports and provide comments to DEA&DP, who would include these in their final environmental decision. However, should a permit be required for the damaging or removal of specific heritage resources, a separate application would have to be submitted to SAHRA or HWC for the approval of such an activity.

10.2 THE ENVIRONMENTAL IMPACT ASSESSMENT PROCESS

NEMA requires that the EIA process be undertaken by a suitably qualified and experienced independent Environmental Assessment Practitioner[3] (EAP). Due to Aurecon and WorleyParsons's involvement with the technical aspects of the project, neither party's in-house environmental specialists are considered to be independent. Therefore an external independent EAP will need to be appointed[4].

A very important component of the EIA process is the requisite specialist studies and the following studies were identified during the pre-feasibility studies as being necessary: Agriculture, Aquatic, Botanical, Heritage and Social. Specialists that were involved during the pre-feasibility studies should preferably also be involved in the EIA process due to their existing understanding of the project.

In terms of timeframes, it is anticipated that the EIA process will take approximately 11 months until the submission of the Final EIA Report. However, activities and timeframes involving the authorities, such as approval of the Scoping Report, cannot be guaranteed. It is anticipated that DEA&DP will take 3 to 7 months to make a decision on the Environmental Authorisation, followed by the statutory appeal period. Experience shows that there are many variables within an EIA process, which have the potential to delay progress towards specified milestones, most notably the requisite input of technical information from the applicant, the stakeholder (including public) participation process, specialist input and authority review.

10.3 PUBLIC PARTICIPATION

10.3.1 Introduction

Effective and equitable engagement with stakeholders contributes to the identification of key issues of concern and possible solutions, as well as accessing relevant local or traditional knowledge. Through engaging stakeholders proactively, proponents and decision-makers are able to understand and clarify the degree to which other stakeholders will be willing to accept any trade-offs which may be required. This ensures more informed decision-making and ultimately sustainable development.

10.3.2 Preliminary Public Notification Of The Study

The public participation process was undertaken in both Afrikaans and English to accommodate the language preferences of the local communities. Newspaper advertisements to notify the public that the study had commenced were placed in a number of local and regional newspapers as indicated in **Table 13**. The public database developed during the WCWSS Reconciliation Strategy Study was also used to notify the broader public that the study had commenced. This database was updated and maintained throughout the study.

[3] Section 17 of GN No. R543

[4] Five EAPs were contacted for proposals to undertake the necessary work. Of these only three companies responded. Unfortunately DWA was unable to sub-contract the EIA investigation to Aurecon's current contract and the normal procurement process will need to be undertaken.

Table 13: Summary of Advertisements Placed to Notify the Broader Public of the Commencement of the Study

NEWSPAPER	DATE
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;
- CapeNature; and
- Potentially affected municipalities.

Notifications were also specifically addressed to the Berg and Breede CMA Reference Groups and the Water User Associations in the Berg and Breede WMAs.

10.3.3 Meetings

A number of public and stakeholder meetings were held during the course of the project. The first two public meetings were held at the beginning of Phase 1 at two different geographic centres, namely Worcester and Grabouw, as these locations are in reasonably close proximity to the potential schemes. 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 meetings were advertised in the Worcester Standard and the Overstrand Herald in November 2010.

Two Stakeholder Committee Meetings were also held pre and post an Options Prioritisation Workshop that was held in March 2010. The Stakeholder Committee comprises national, provincial and local authorities, WUAs, conservation authorities, emerging farmers and other statutory bodies that have direct connections with the water sector.

A separate meeting was held with potentially affected landowners to identify issues and concerns regarding the proposed layouts of the BRVAS and the BBTS.

A summary of the public and stakeholder engagement process (public and stakeholder meetings and workshops) is provided in **Table 14** below.

Table 14: Summary of Public and Stakeholder Meetings during the Course of the Study

MEETING TYPE	TARGET GROUP	LOCATION	DATE
Public Meeting	Interested & Affected Parties (I&APs)	Elgin-Grabouw Country Club, Grabouw	5 March 2009
Including landowners, authorities and Water Users Associations (WUAs).			
Public Meeting	I&APs	Protea Cumberland Hotel, Worcester	7 March 2009
Committee Meeting	Water sector stakeholders	Department of Agriculture, Elsenberg	31 March 2009
Including national, provincial and local authorities, WUAs, conservation, emerging farmers and statutory bodies.			
Options Prioritisation Workshop	Water sector representatives & project specialists	Nelson's Creek Wine Estate, Paarl	25 March 2010
Including Municipalities, Catchment Management Agency, CapeNature, CSIR, Department of Agriculture and DWA (National and Regional).			
Committee Meeting	Water sector stakeholders	Department of Agriculture, Elsenberg	15 April 2010
Public Meeting	I&APs	Tri Active (Green Mountain Lodge), Elgin Valley	4 December 2010
Public Meeting	I&APs	Protea Cumberland Hotel, Worcester	4 December 2010
Stakeholder Meeting	Potentially affected landowners	Dutch Reformed Church, Wolseley	2 March 2011
Focussed specifically on Breede Berg (Mitchell's Pass) Water Transfer Scheme and the Berg River Voëlvlei Augmentation Scheme			

10.3.4 Newsletters

Newsletters were sent to all registered Interested and Affected Parties and members of the Stakeholder Committee in November 2011 and March 2013 in order to keep them informed about the status of the project until the required EIA process commences.

10.3.5 Conclusions

Experience gained from interactions with Stakeholders and Interested and Affected Parties (I&APs) on this project, has shown that the proposed scheme is very sensitive in terms of public opinion. It is therefore of great importance to Stakeholders and I&APs that continuity between the Preliminary Phase and the EIA process is ensured. The existing Stakeholder and I&AP databases will therefore be provided to the appointed independent EAP to ensure that all registered parties are informed about the EIA process.

10.4 ALTERNATIVE ALIGNMENTS CONSIDERED

The NEMA Regulations[5] require that "*alternatives to the proposed activity that are feasible and reasonable*" be identified and considered during the EIA process. Alternatives can include activity alternatives, site alternatives, design or layout alternatives, technology or operational alternatives, as well as the "no-go" option.

10.5 WAY FORWARD FOR EIA

The proposed BRVA Scheme will need to comply with the requirements of all relevant legislation, including (but not limited to) NEMA, NWA and NHRA. Specialist input and assessments will be required to provide the decision-making authorities with sufficient information to make an informed decision. Some of the requisite studies may need to be completed during a specific season to ensure a comprehensive assessment of potential impacts on the environment, e.g. botanical assessment. These studies should thus be carefully planned to prevent any unnecessary delays to the project programme. It is also important to ensure that project information provided to specialists and the EAP does not change significantly during the EIA process as it could potentially necessitate the revision of assessments. It is therefore recommended that a design freeze should be applied to the project to prevent unnecessary costs and programme delays during the EIA process.

Furthermore, it is important for DWA to take into consideration the EIA process timeframes when undertaking forward planning to meet future water requirements, as it can take up to 18 months (or in some cases even longer) to receive environmental authorisation. However, activities and timeframes involving the authorities cannot be guaranteed and should be considered as variable in the programme.

An independent EAP will need to be appointed to ensure compliance with the requirements of Section 17 of EIA Regulations. Once the EAP has been appointed, a public meeting should be undertaken to allow the Western Cape Water Consultants to present the technical findings to update Stakeholders and I&APs on the current project status and way forward. The meeting will also familiarise Stakeholders and I&APs with the EAP and EIA process that will be undertaken.

[5] Section 27 (e) (iii) of R543

11. DETERMINATION OF UNIT REFERENCE VALUES (URVS) AND FINANCING OPTIONS

11.1 CAPITAL COSTS

Appendix 12 provides the detailed cost estimates and costing schedules for the various components of the scheme. These costs have been based on detailed Bills of Quantities and rates, drawing on unit rates from similar recent projects. In summary, the key capital costs associated with the possible 4 m^3/s and a 6 m^3/s diversion scheme options for the BRVA Scheme are shown in **Table 15** below.

Table 15: Summary of Capital Cost Estimate for the BRVA Scheme

Cost Item	Scheme Component Costs in R(millions)	
	4m^3/s	**6m^3/s**
Weir at Lorelei	35.12	35.12
Berg River Pump Station (Mech/Elec)	38.33	48.09
Berg River Pump Station (Civil)	6.25	6.25
Rising Main to Voëlvlei Dam	120.94	137.50
Voëlvlei Dam outlet structure	0.05	0.05
Berg River protection	0.11	0.11
Contingencies (10% of above)	20.08	22.71
SUB-TOTAL CONSTRUCTION COST	**220.87**	**249.83**
Professional fees	17.20	19.19
Servitude & property	5.04	5.04
TOTAL CAPITAL COST EXCL. VAT	**243.11**	**274.06**
VAT @ 14%	**34.04**	**38.37**
TOTAL CAPITAL COST INCL. VAT	**277.14**	**312.43**

Note: The VAT EXCLUSIVE amounts are used for the Unit Reference Value Calculations shown in **Section 11.3.**

Ductile Iron Pipe as an Alternative to GRP:

Should ductile iron pipes be selected by DWA as the preferred pipe material for the 6300m long rising main, then the increase in the capital cost for the above two options is estimated as follows:

- 4m^3/s: **~24%** increase from R277 to R344 million.
- 6m^3/s: **~31%** increase from R312 to R410 million

11.2 OPERATION AND MAINTENANCE COSTS

Operation and Maintenance (O&M) costs (**Table 16**) were included in the URV calculations as a constant annual cost, based on the following widely used general estimates for costing of these items:

- Civil O&M cost at 0.5% of the civil capital cost
- Mechanical and electrical O&M cost at 4% of the mechanical and electrical capital cost

Table 16: Operation and Maintenance Cost Estimates

Cost Item	Annual Operation and Maintenance Costs R(millions)	
	$4m^3/s$	$6m^3/s$
Civil Maintenance	0,894	0,985
Mechanical and Electrical Maintenance	1,686	2,116
Electrical Energy	5,760	5,340
TOTAL PER ANNUM	**8,340**	**8,441**

The O&M costs were calculated using the percentages above applied to capital costs that include preliminary and general items and contingencies, but exclude the costs of professional fees (for design, recoverable expenditures, construction supervision and site occupational health and safety supervision), servitude and property, and VAT.

Additionally, allowance was made for refurbishment of the pump station mechanical and electrical equipment every 15 years, through an estimated refurbishment cost of 60% of the initial capital cost for this equipment. The capital costs on which these costs were based included preliminary and general items and contingencies, but excluded the costs of professional fees, property and servitude and VAT.

11.3 UNIT REFERENCE VALUES

The technical data for the two diversion options was fed into a spreadsheet-based economic evaluation model. The economic evaluation for each option was carried out on the following basis:

- Costing base date – 2012
- Life-time evaluation period – 30 years, starting 2013
- Discount rates – 6%, 8% and 10% per annum
- Costs discounted to date of first expenditure (2015)
- The yield estimates determined in this study

The model calculates the following output indices for each scheme:

- PV – Present Worth of Costs
- URV - Unit Reference Value

The Unit Reference Values are calculated as follows:

$$URV = \frac{\textit{Present Worth of costs}}{\textit{``Present Volume'' of water delivered}}$$

- Electricity is costed at 130 c/kWh

The financial assessment is inclusive of the following:

- Preliminary and General;
- Construction Costs;
- Professional Fees (including site supervision);
- Expropriation / compensation;
- Contingencies; and
- Operation and Maintenance (including power supply).

The financial assessment is exclusive of VAT.

The yields and URVs for the different discount rates are summarised in **Table 18** to **Table 23** the outputs of the Financial Model showing the calculation of the Unit Reference Values based on the capital and operating costs described above are provided, and on the yield for each of the two diversion capacities.

Table 17: Summary of Yields and URVs for the Two Scheme Options for Various Discount Rates

Scheme option	**Yield (million m^3/a**	**Discount rate (per annum)**		
		6%	**8%**	**10%**
4 m^3/s	23	R 1.31	R 1.52	R 1.75
6 m^3/s	20	R 1.67	R 1.94	R 2.24

Table 18: Unit Reference Value Output Calculation for 4m^3/s Scheme at 6% Discount Rate

VOELVLEI PHASE 1 - BULK WATER COSTS

Scheme : Pumping Scheme of 4m^3/s, step pumping rule

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	23	mcm/a	After Riverine and Estuary Reserves
Demand Growth	2%	p/a	
Years to Full Supply	3.1	Years	

CAPITAL COST COMPONENTS

	CIVIL	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Lorelei	33.45		1.67	35.12	42.52
Berg River Pump Station (Mech/Elec)		36.50	1.83	38.33	46.40
Berg River Pump Station (Civil)	5.00		1.25	6.25	7.57
Rising Main to Voëlvlei Dam	96.75		24.19	120.94	146.42
Voëlvlei Dam outlet structure	0.05		0.00	0.05	0.06
Berg River protection	0.10		0.01	0.11	0.13
Contingencies (10% of above)	13.54	3.65	2.89	20.08	
SUB-TOTAL CONSTRUCTION COST	148.89	40.15	31.84	220.87	
Professional fees				17.20	
Servitude & property				5.04	
TOTAL CAPITAL COST EXCL. VAT	196.71	46.40		243.11	243.11
VAT @ 14%	27.54	6.50		34.04	
TOTAL CAPITAL COST INCL. VAT	224.25	52.90		277.14	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	0.894	
	(4% Mech & Elec) =	1.686	
	Annual total =	2.580	
		Lorelei	
ELECTRICITY:	Power Required :	2250	kW
	# Days Pumping :	82	days
	Unit Rate :	130.00	c/kWh
	Electricity Consumption Costs :	5.8	Rmill/yr

WATER REQUIREMENTS / **COSTS**

CALEN. YEAR	YEAR	Supply (10^6m^3)	NPV of Supply	LORELEI WEIR	PS MECH / ELEC	PS CIVIL	RISING MAIN	OUTLET STRUCT	RIVER PROTECT	MAINT	ENERGY
2013	1										
2014	2										
2015	3			21.26	23.20	3.78	73.21				
2016	4			21.26	23.20	3.78	73.21	0.06	0.13		
2017	5	11.50	9.109							1.29	2.88
2018	6	23.00	17.187							2.58	5.76
2019	7	23.00	16.214							2.58	5.76
2020	8	23.00	15.296							2.58	5.76
2021	9	23.00	14.430							2.58	5.76
2022	10	23.00	13.614							2.58	5.76
2023	11	23.00	12.843							2.58	5.76
2024	12	23.00	12.116							2.58	5.76
2025	13	23.00	11.430							2.58	5.76
2026	14	23.00	10.783							2.58	5.76
2027	15	23.00	10.173							2.58	5.76
2028	16	23.00	9.597							2.58	5.76
2029	17	23.00	9.054							2.58	5.76
2030	18	23.00	8.541							2.58	5.76
2031	19	23.00	8.058		25.29					2.58	5.76
2032	20	23.00	7.602							2.58	5.76
2033	21	23.00	7.172							2.58	5.76
2034	22	23.00	6.766							2.58	5.76
2035	23	23.00	6.383							2.58	5.76
2036	24	23.00	6.021							2.58	5.76
2037	25	23.00	5.681							2.58	5.76
2038	26	23.00	5.359							2.58	5.76
2039	27	23.00	5.056							2.58	5.76
2040	28	23.00	4.769							2.58	5.76
2041	29	23.00	4.499							2.58	5.76
2042	30	23.00	4.245							2.58	5.76
DISCOUNT RATE @		6.00%	242.00	36.78	60.16	6.54	126.63	0.05	0.11	27.14	60.57

UNIT REFERENCE VALUE = 1.31 R/m^3

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period			
	(224.25)	30.022	
b) Mech./Elec equipment - 15 year period			
	(52.90)	7.767	37.789
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		0.894	
ii. Mech./Elec. (4%)		1.686	
b) Energy costs		5.76	8.336
TOTAL ANNUAL COST:			**46.125**

UNIT COST OF WATER = 2.01 R/m^3

Table 19: Unit Reference Value Output Calculation for 4m³/s Scheme at 8% Discount Rate

VOELVLEI PHASE 1 - BULK WATER COSTS

Scheme : Pumping Scheme of 4m³/s, step pumping rule

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	23	mcm/a	After Riverine and Estuary Reserves
Demand Growth	2%	p/a	
Years to Full Supply	3.1	Years	

CAPITAL COST COMPONENTS

	CIVIL	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Lorelei	33.45		1.67	35.12	42.52
Berg River Pump Station (Mech/Elec)		36.50	1.83	38.33	46.40
Berg River Pump Station (Civil)	5.00		1.25	6.25	7.57
Rising Main to Voëlvlei Dam	96.75		24.19	120.94	146.42
Voëlvlei Dam outlet structure	0.05		0.00	0.05	0.06
Berg River protection	0.10		0.01	0.11	0.13
Contingencies (10% of above)	13.54	3.65	2.89	20.08	
SUB-TOTAL CONSTRUCTION COST	148.89	40.15	31.84	220.87	
Professional fees				17.20	
Servitude & property				5.04	
TOTAL CAPITAL COST EXCL. VAT	196.71	46.40		243.11	243.11
VAT @ 14%	27.54	6.50		34.04	
TOTAL CAPITAL COST INCL. VAT	224.25	52.90		277.14	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	0.894	
	(4% Mech & Elec) =	1.686	
	Annual total =	2.580	
		Lorelei	
ELECTRICITY:	Power Required :	2250	kW
	# Days Pumping :	82	days
	Unit Rate :	130.00	c/kWh
	Electricity Consumption Costs :	5.8	Rmill/yr

WATER REQUIREMENTS				COSTS							
CALEN. YEAR	YEAR	Supply ($10^6 m^3$)	NPV of Supply	LORELEI WEIR	PS MECH / ELEC	PS CIVIL	RISING MAIN	OUTLET STRUCT	RIVER PROTECT	MAINT	ENERGY
2013	1										
2014	2										
2015	3			21.26	23.20	3.78	73.21				
2016	4			21.26	23.20	3.78	73.21	0.06	0.13		
2017	5	11.50	9.109							1.29	2.88
2018	6	23.00	17.187							2.58	5.76
2019	7	23.00	16.214							2.58	5.76
2020	8	23.00	15.296							2.58	5.76
2021	9	23.00	14.430							2.58	5.76
2022	10	23.00	13.614							2.58	5.76
2023	11	23.00	12.843							2.58	5.76
2024	12	23.00	12.116							2.58	5.76
2025	13	23.00	11.430							2.58	5.76
2026	14	23.00	10.783							2.58	5.76
2027	15	23.00	10.173							2.58	5.76
2028	16	23.00	9.597							2.58	5.76
2029	17	23.00	9.054							2.58	5.76
2030	18	23.00	8.541							2.58	5.76
2031	19	23.00	8.058		25.29					2.58	5.76
2032	20	23.00	7.602							2.58	5.76
2033	21	23.00	7.172							2.58	5.76
2034	22	23.00	6.766							2.58	5.76
2035	23	23.00	6.383							2.58	5.76
2036	24	23.00	6.021							2.58	5.76
2037	25	23.00	5.681							2.58	5.76
2038	26	23.00	5.359							2.58	5.76
2039	27	23.00	5.056							2.58	5.76
2040	28	23.00	4.769							2.58	5.76
2041	29	23.00	4.499							2.58	5.76
2042	30	23.00	4.245							2.58	5.76
DISCOUNT RATE @		8.00%	188.92	35.11	56.90	6.25	120.89	0.05	0.10	21.19	47.28
						UNIT REFERENCE VALUE =				1.52	R/m³

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period			
	(224.25)	30.022	
b) Mech./Elec equipment - 15 year period			
	(52.90)	7.767	37.789
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		0.894	
ii. Mech./Elec. (4%)		1.686	
b) Energy costs		5.76	8.336
TOTAL ANNUAL COST:			46.125

UNIT COST OF WATER = 2.01 R/m³

Table 20: Unit Reference Value Output Calculation for 4m^3/s Scheme at 10% Discount Rate

VOELVLEI PHASE 1 - BULK WATER COSTS

Scheme : Pumping Scheme of 4m^3/s, step pumping rule

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	23	mcm/a	After Riverine and Estuary Reserves
Demand Growth	2%	p/a	
Years to Full Supply	3.1	Years	

CAPITAL COST COMPONENTS

	CIVIL	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Lorelei	33.45		1.67	35.12	42.52
Berg River Pump Station (Mech/Elec)		36.50	1.83	38.33	46.40
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Rising Main to Voëlvlei Dam	96.75		24.19	120.94	146.42
Voëlvlei Dam outlet structure	0.05		0.00	0.05	0.06
Berg River protection	0.10		0.01	0.11	0.13
Contingencies (10% of above)	13.54	3.65	2.89	20.08	
SUB-TOTAL CONSTRUCTION COST	148.89	40.15	31.84	220.87	
Professional fees				17.20	
Servitude & property				5.04	
TOTAL CAPITAL COST EXCL. VAT	196.71	46.40		243.11	243.11
VAT @ 14%	27.54	6.50		34.04	
TOTAL CAPITAL COST INCL. VAT	224.25	52.90		277.14	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	0.894	
	(4% Mech & Elec) =	1.686	
	Annual total =	2.580	
		Lorelei	
ELECTRICITY:	Power Required :	2250	kW
	# Days Pumping :	82	days
	Unit Rate :	130.00	c/kWh
	Electricity Consumption Costs :	5.8	Rmill/yr

WATER REQUIREMENTS / **COSTS**

CALEN. YEAR	YEAR	Supply (10^6m^3)	NPV of Supply	LORELEI WEIR	PS MECH / ELEC	PS CIVIL	RISING MAIN	OUTLET STRUCT	RIVER PROTECT	MAINT	ENERGY
2013	**1**										
2014	2										
2015	3			21.26	23.20	3.78	73.21				
2016	4			21.26	23.20	3.78	73.21	0.06	0.13		
2017	5	11.50	9.109							1.29	2.88
2018	6	23.00	17.187							2.58	5.76
2019	7	23.00	16.214							2.58	5.76
2020	8	23.00	15.296							2.58	5.76
2021	9	23.00	14.430							2.58	5.76
2022	10	23.00	13.614							2.58	5.76
2023	11	23.00	12.843							2.58	5.76
2024	12	23.00	12.116							2.58	5.76
2025	13	23.00	11.430							2.58	5.76
2026	14	23.00	10.783							2.58	5.76
2027	15	23.00	10.173							2.58	5.76
2028	16	23.00	9.597							2.58	5.76
2029	17	23.00	9.054							2.58	5.76
2030	18	23.00	8.541							2.58	5.76
2031	19	23.00	8.058		25.29					2.58	5.76
2032	20	23.00	7.602							2.58	5.76
2033	21	23.00	7.172							2.58	5.76
2034	22	23.00	6.766							2.58	5.76
2035	23	23.00	6.383							2.58	5.76
2036	24	23.00	6.021							2.58	5.76
2037	25	23.00	5.681							2.58	5.76
2038	26	23.00	5.359							2.58	5.76
2039	27	23.00	5.056							2.58	5.76
2040	28	23.00	4.769							2.58	5.76
2041	29	23.00	4.499							2.58	5.76
2042	30	23.00	4.245							2.58	5.76
DISCOUNT RATE @		10.00%	150.45	33.55	53.88	5.97	115.51	0.05	0.10	16.88	37.65

UNIT REFERENCE VALUE = 1.75 R/m^3

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period			
	(224.25)	30.022	
b) Mech./Elec equipment - 15 year period			
	(52.90)	7.767	37.789
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		0.894	
ii. Mech./Elec. (4%)		1.686	
b) Energy costs		5.76	8.336
TOTAL ANNUAL COST:			**46.125**

UNIT COST OF WATER = 2.01 R/m^3

Table 21: Unit Reference Value Output Calculation for 6m³/s Scheme at 6% Discount Rate

VOELVLEI PHASE 1 - BULK WATER COSTS

Scheme : Pumping Scheme of 6m³/s, complying with Class D EWR

(COSTS IN MILLION RAND, INCLUDING VAT)

(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	20	mcm/a	After Riverine and Estuary Reserves
Demand Growth	2%	p/a	
Years to Full Supply	2.9	Years	

CAPITAL COST COMPONENTS

	CIVIL	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Lorelei	33.45		1.67	35.12	42.38
Berg River Pump Station (Mech/Elec)		45.80	2.29	48.09	58.03
Berg River Pump Station (Civil)	5.00		1.25	6.25	7.54
Rising Main to Voëlvlei Dam	110.00		27.50	137.50	165.92
Voëlvlei Dam outlet structure	0.05		0.00	0.05	0.06
Berg River protection	0.10		0.01	0.11	0.13
Contingencies (10% of above)	14.86	4.58	3.27	22.71	
SUB-TOTAL CONSTRUCTION COST	163.46	50.38	35.99	249.83	
Professional fees				19.19	
Servitude & property				5.04	
TOTAL CAPITAL COST EXCL. VAT	216.03	58.03		274.06	274.06
VAT @ 14%	30.24	8.12		38.37	
TOTAL CAPITAL COST INCL. VAT	246.28	66.15		312.43	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	0.985	
	(4% Mech & Elec) =	2.116	
	Annual total =	3.101	
		Lorelei	
ELECTRICITY:	Power Required :	3000	kW
	# Days Pumping :	57	days
	Unit Rate :	130.00	c/kWh
	Electricity Consumption Costs :	5.3	Rmill/yr

WATER REQUIREMENTS				COSTS							
CALEN. YEAR	YEAR	Supply ($10^6 m^3$)	NPV of Supply	LORELEI WEIR	PS MECH / ELEC	PS CIVIL	RISING MAIN	OUTLET STRUCT	RIVER PROTECT	MAINT	ENERGY
2013	**1**										
2014	2										
2015	3			21.19	29.01	3.77	82.96				
2016	4			21.19	29.01	3.77	82.96	0.06	0.13		
2017	5	10.00	7.921							1.55	2.67
2018	6	20.00	14.945							3.10	5.34
2019	7	20.00	14.099							3.10	5.34
2020	8	20.00	13.301							3.10	5.34
2021	9	20.00	12.548							3.10	5.34
2022	10	20.00	11.838							3.10	5.34
2023	11	20.00	11.168							3.10	5.34
2024	12	20.00	10.536							3.10	5.34
2025	13	20.00	9.939							3.10	5.34
2026	14	20.00	9.377							3.10	5.34
2027	15	20.00	8.846							3.10	5.34
2028	16	20.00	8.345							3.10	5.34
2029	17	20.00	7.873							3.10	5.34
2030	18	20.00	7.427							3.10	5.34
2031	19	20.00	7.007		31.74					3.10	5.34
2032	20	20.00	6.610							3.10	5.34
2033	21	20.00	6.236							3.10	5.34
2034	22	20.00	5.883							3.10	5.34
2035	23	20.00	5.550							3.10	5.34
2036	24	20.00	5.236							3.10	5.34
2037	25	20.00	4.940							3.10	5.34
2038	26	20.00	4.660							3.10	5.34
2039	27	20.00	4.396							3.10	5.34
2040	28	20.00	4.147							3.10	5.34
2041	29	20.00	3.913							3.10	5.34
2042	30	20.00	3.691							3.10	5.34
DISCOUNT RATE @		6.00%	210.43	36.65	75.32	6.52	143.49	0.05	0.11	32.62	56.14

UNIT REFERENCE VALUE = 1.67 R/m³

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period			
	(246.28)	32.971	
b) Mech./Elec equipment - 15 year period			
	(66.15)	9.713	42.684
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		0.985	
ii. Mech./Elec. (4%)		2.116	
b) Energy costs		5.34	8.436
TOTAL ANNUAL COST:			**51.120**

UNIT COST OF WATER = 2.56 R/m³

Table 22: Unit Reference Value Output Calculation for 6m³/s Scheme at 8% Discount Rate

VOELVLEI PHASE 1 - BULK WATER COSTS

Scheme : Pumping Scheme of 6m³/s, complying with Class D EWR

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	20	mcm/a	After Riverine and Estuary Reserves
Demand Growth	2%	p/a	
Years to Full Supply	2.9	Years	

CAPITAL COST COMPONENTS

	CIVIL	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Lorelei	33.45		1.67	35.12	42.38
Berg River Pump Station (Mech/Elec)		45.80	2.29	48.09	58.03
Berg River Pump Station (Civil)	5.00		1.25	6.25	7.54
Rising Main to Voëlvlei Dam	110.00		27.50	137.50	165.92
Voëlvlei Dam outlet structure	0.05		0.00	0.05	0.06
Berg River protection	0.10		0.01	0.11	0.13
Contingencies (10% of above)	14.86	4.58	3.27	22.71	
SUB-TOTAL CONSTRUCTION COST	163.46	50.38	35.99	249.83	
Professional fees				19.19	
Servitude & property				5.04	
TOTAL CAPITAL COST EXCL. VAT	216.03	58.03		274.06	274.06
VAT @ 14%	30.24	8.12		38.37	
TOTAL CAPITAL COST INCL. VAT	246.28	66.15		312.43	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	0.985	
	(4% Mech & Elec) =	2.116	
	Annual total =	3.101	
		Lorelei	
ELECTRICITY:	Power Required :	3000	kW
	# Days Pumping :	57	days
	Unit Rate :	130.00	c/kWh
	Electricity Consumption Costs :	5.3	Rmill/yr

WATER REQUIREMENTS / **COSTS**

	CALEN. YEAR	YEAR	Supply ($10^6 m^3$)	NPV of Supply	LORELEI WEIR	PS MECH / ELEC	PS CIVIL	RISING MAIN	OUTLET STRUCT	RIVER PROTECT	MAINT	ENERGY
	2013	**1**										
	2014	2										
	2015	3			21.19	29.01	3.77	82.96				
	2016	4			21.19	29.01	3.77	82.96	0.06	0.13		
	2017	5	10.00	7.921							1.55	2.67
	2018	6	20.00	14.945							3.10	5.34
	2019	7	20.00	14.099							3.10	5.34
	2020	8	20.00	13.301							3.10	5.34
	2021	9	20.00	12.548							3.10	5.34
	2022	10	20.00	11.838							3.10	5.34
	2023	11	20.00	11.168							3.10	5.34
	2024	12	20.00	10.536							3.10	5.34
	2025	13	20.00	9.939							3.10	5.34
	2026	14	20.00	9.377							3.10	5.34
	2027	15	20.00	8.846							3.10	5.34
	2028	16	20.00	8.345							3.10	5.34
	2029	17	20.00	7.873							3.10	5.34
	2030	18	20.00	7.427							3.10	5.34
	2031	19	20.00	7.007		31.74					3.10	5.34
	2032	20	20.00	6.610							3.10	5.34
	2033	21	20.00	6.236							3.10	5.34
	2034	22	20.00	5.883							3.10	5.34
	2035	23	20.00	5.550							3.10	5.34
	2036	24	20.00	5.236							3.10	5.34
	2037	25	20.00	4.940							3.10	5.34
	2038	26	20.00	4.660							3.10	5.34
	2039	27	20.00	4.396							3.10	5.34
	2040	28	20.00	4.147							3.10	5.34
	2041	29	20.00	3.913							3.10	5.34
	2042	30	20.00	3.691							3.10	5.34
DISCOUNT RATE @			8.00%	164.28	34.99	71.24	6.23	136.98	0.05	0.10	25.47	43.82

UNIT REFERENCE VALUE = 1.94 R/m³

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period			
	(246.28)	32.971	
b) Mech./Elec equipment - 15 year period			
	(66.15)	9.713	42.684
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		0.985	
ii. Mech./Elec. (4%)		2.116	
b) Energy costs		5.34	8.436
TOTAL ANNUAL COST:			**51.120**

UNIT COST OF WATER = 2.56 R/m³

Table 23: Unit Reference Value Output Calculation for 6m^3/s Scheme at 10% Discount Rate

VOELVLEI PHASE 1 - BULK WATER COSTS

Scheme : Pumping Scheme of 6m^3/s, complying with Class D EWR

(COSTS IN MILLION RAND, INCLUDING VAT)
(SUPPLY IN MILLION CUBIC METERS PER YEAR)

Yield	20	mcm/a	After Riverine and Estuary Reserves
Demand Growth	2%	p/a	
Years to Full Supply	2.9	Years	

CAPITAL COST COMPONENTS

	CIVIL	MECH & ELEC	PRELIM & GENERAL	TOTAL	TOTAL INCL FEES & PROPERTY
Weir at Lorelei	33.45		1.67	35.12	42.38
Berg River Pump Station (Mech/Elec)		45.80	2.29	48.09	58.03
Berg River Pump Station (Civil)	5.00		1.25	6.25	7.54
Rising Main to Voëlvlei Dam	110.00		27.50	137.50	165.92
Voëlvlei Dam outlet structure	0.05		0.00	0.05	0.06
Berg River protection	0.10		0.01	0.11	0.13
Contingencies (10% of above)	14.86	4.58	3.27	22.71	
SUB-TOTAL CONSTRUCTION COST	163.46	50.38	35.99	249.83	
Professional fees				19.19	
Servitude & property				5.04	
TOTAL CAPITAL COST EXCL. VAT	216.03	58.03		274.06	274.06
VAT @ 14%	30.24	8.12		38.37	
TOTAL CAPITAL COST INCL. VAT	246.28	66.15		312.43	

ANNUAL COST COMPONENTS

MAINTENANCE:	(0.5% Civil) =	0.985	
	(4% Mech & Elec) =	2.116	
	Annual total =	3.101	
		Lorelei	
ELECTRICITY:	Power Required :	3000	kW
	# Days Pumping :	57	days
	Unit Rate :	130.00	c/kWh
	Electricity Consumption Costs :	5.3	Rmill/yr

WATER REQUIREMENTS				COSTS							
CALEN. YEAR	YEAR	Supply ($10^6 m^3$)	NPV of Supply	LORELEI WEIR	PS MECH / ELEC	PS CIVIL	RISING MAIN	OUTLET STRUCT	RIVER PROTECT	MAINT	ENERGY
2013	**1**										
2014	2										
2015	3			21.19	29.01	3.77	82.96				
2016	4			21.19	29.01	3.77	82.96	0.06	0.13		
2017	5	10.00	7.921							1.55	2.67
2018	6	20.00	14.945							3.10	5.34
2019	7	20.00	14.099							3.10	5.34
2020	8	20.00	13.301							3.10	5.34
2021	9	20.00	12.548							3.10	5.34
2022	10	20.00	11.838							3.10	5.34
2023	11	20.00	11.168							3.10	5.34
2024	12	20.00	10.536							3.10	5.34
2025	13	20.00	9.939							3.10	5.34
2026	14	20.00	9.377							3.10	5.34
2027	15	20.00	8.846							3.10	5.34
2028	16	20.00	8.345							3.10	5.34
2029	17	20.00	7.873							3.10	5.34
2030	18	20.00	7.427							3.10	5.34
2031	19	20.00	7.007		31.74					3.10	5.34
2032	20	20.00	6.610							3.10	5.34
2033	21	20.00	6.236							3.10	5.34
2034	22	20.00	5.883							3.10	5.34
2035	23	20.00	5.550							3.10	5.34
2036	24	20.00	5.236							3.10	5.34
2037	25	20.00	4.940							3.10	5.34
2038	26	20.00	4.660							3.10	5.34
2039	27	20.00	4.396							3.10	5.34
2040	28	20.00	4.147							3.10	5.34
2041	29	20.00	3.913							3.10	5.34
2042	30	20.00	3.691							3.10	5.34
DISCOUNT RATE @		10.00%	130.82	33.43	67.46	5.95	130.89	0.05	0.10	20.28	34.90
							UNIT REFERENCE VALUE =		2.24		R/m^3

UNIT COST OF WATER

FIXED COST:			
Interest and capital repayment @ 12% per annum :			
a) Civil Infrastructure - 20 year period			
	(246.28)	32.971	
b) Mech./Elec equipment - 15 year period			
	(66.15)	9.713	42.684
OPERATING COST:			
a) Maintenance :			
i. Civil works (0,5%)		0.985	
ii. Mech./Elec. (4%)		2.116	
b) Energy costs		5.34	8.436
TOTAL ANNUAL COST:			**51.120**

UNIT COST OF WATER = 2.56 R/m^3

11.4 COMPARISON OF URVS FOR SCHEMES

The proposed BRVA scheme is one of the few remaining surface water schemes that can be developed to supply the growing water requirements of the WCWSS. This scheme would make extensive use of existing infrastructure, namely the existing Voëlvlei Dam and the existing water treatment works and pipeline to Cape Town as well as the existing infrastructure of the WCDM. Although water must be pumped from the Berg River into the Voëlvlei Dam and must also be pumped after treatment to Cape Town, the Unit Reference Value (URV) for the 4 m^3/s and 6 m^3/s options of R 1.31/m^3 and R 1.67/m^3 respectively, at a discount rate of 6% per annum as determined above, are relatively low compared with the URVs of other recent schemes. The URVs determined for this Feasibility Study, based on pumping water into the Voëlvlei Dam, are similar to the URV of R1.22/m^3 which was determined for the Prefeasibility Study, also at a discount rate of 6% per annum.

The URV's of the other schemes that have been investigated, generally in less detail, are as follows:

- Two alternatives for the Michells Pass Diversion scheme which would also deliver water to Voëlvlei have been investigated to feasibility level.
  - The option that includes the Boontjies River Dam to enable the environmental summer flows that were previously diverted by the irrigators to flow down the Breede River would have a URV of R1.98/m^3 at a discount rate of 6% per annum and would yield about 36 million m^3/a.
  - The option without the Boontjies River Dam and no summer environmental flow releases to the Breede River, which corresponds to the existing condition, would have a URV of 1.37/m^3 at a discount rate of 6% per annum and would yield about 36 million m^3/a.
- The URV of the Steenbras Augmentation Scheme was determined by the Prefeasibility study to be R3.48/m^3 at a discount rate of 6% per annum and the scheme would yield about 23 million m^3/a.
- The CCT has recently commissioned the feasibility study of a desalination scheme. Estimates based on previous studies indicate that the URV at a 6% discount rate will be of the order R7-R8/m^3 (based on 2009 electricity prices), and up to about R12-R13/m^3 (with anticipated electricity price increases) for a scheme that would supply about 83 million m^3/a.
- The CCT also plans to commission a feasibility study of the potable use of recycled waste water. Previous estimates indicate that this scheme would have a URV of about R5-6/m^3 (at a 6% discount rate) for a scheme that would also yield about 83 million m^3/a.
- The feasibility study of the Table Mountain Aquifer has entered the pilot wellfield phase and is expected to yield about 5 million m^3/a and have a URV of R1,9/m^3 (also at a 6% discount rate).

11.5 MOTIVATION FOR INVESTING IN THIS SCHEME

Apart from having a favourable URV as described in **Section** Error! Reference source not found. above, this BRVA Scheme also has the advantage that it is likely to be the only scheme that could be implemented by about 2018 when the growth in water requirement may exceed the available supply from the WCWSS. This is because the feasibility study will be completed in 2013 and the EIA is expected to be completed in 2014. In contrast, the potential Michell's Pass Diversion scheme for example has a number of associated challenges involved with its feasibility. Although this forms the subject of its own report as a deliverable of this study, it is relevant to highlight the main challenges of the Michell's Pass Diversion which at this stage are understood to be:

- Uncertainty in the hydrology of the Breede River and the need for a Breede WAAS;
- Uncertainty in the ability to meet the EWRs without the need for an "EWR" dam;
- Development of further water supply schemes in the Breede WMA is not in alignment with the objectives of the BOCMA's Catchment Management Strategy;
- Significant social objection has been raised to increased inter-basin transfers out of the Breede WMA.

The probable timetable for implementation of the BRVA Scheme (should it go ahead) is likely to be as shown in **Figure 42.**

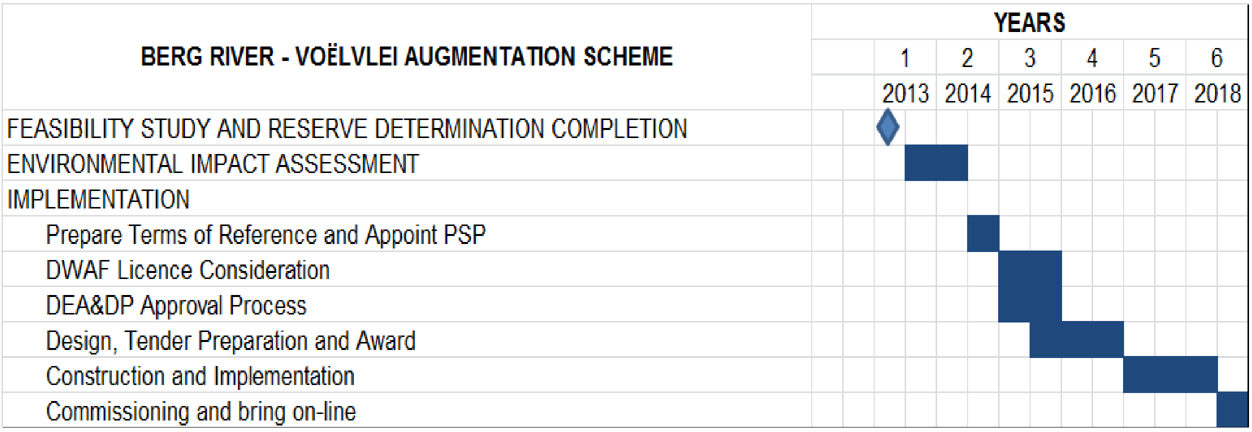

Figure 42: Potential Implementation Timeframe for the BRVA Scheme

11.6 FINANCING OPTIONS FOR THE SCHEME

11.6.1 Introduction

A key factor in the financing of future water resource infrastructure is the issue of ownership. If the asset is owned by the DWA then the finance charges for the creation of the asset would fall under the Pricing Strategy for Raw Water Use Charges. If the asset is owned by the Municipality (CCT) the governing legislation would be the Municipal Financial Management Act (MFMA). In the case of this scheme it is unlikely that the assets will be owned by the Municipality as the scheme would be integral components of DWA's existing assets.

11.6.2 Assets Owned By DWA

There are a number of options set out in the Pricing Strategy for the financing of Water Resource Infrastructure.

11.6.2.1 Return on Assets (ROA)

This charge reflects payment towards the development and betterment capital value of waterworks on government water schemes. It is determined by fixing a charge to earn a specific rate of return on the current depreciated replacement value of the infrastructure.

ROA is based on the social opportunity cost of capital to government and this should approach the level necessary to fund the annual capital expenditure budget requirement for the development of new waterworks and betterment of existing infrastructure from the fiscus.

In terms of the proposed revised Pricing Strategy, once a ring fenced provision account for ROA has been established, ROA revenue will be applied to the funding of water resource development, prioritised as follows:

(i) Planning and feasibility of future augmentation

(ii) Betterment

(iii) Social projects

The scheme would fall into the category of "Planning and feasibility of future augmentation schemes" and the costs would ultimately fully be recovered by the water uses.

11.6.2.2 Government schemes funded off-budget

Water management institutions such as the Trans-Caledon Tunnel Authority (TCTA), which are directed by the Minister of Water and Environmental Affairs to implement and fund government water schemes off-budget, are entitled, by the National Water Act (NWA), to raise loans to finance the development of new water resource infrastructure, and should therefore be able to service these loans through cost recovery charges. These institutions, in consultation with stakeholders, can on a project by project basis determine the extent of charges as determined by the proposed financing model. The primary charge will be the Capital Unit Charge (CUC). An example of this funding arrangement is the construction of the Berg Water Project to augment water to the CCT. The CCT has an Agreement with DWA who in turn has an Agreement with TCTA. The loans are raised by TCTA on the strength of these Agreements and the end users (ie CCT's consumers) pay for the full cost of the Berg Water Project.

11.6.2.3 Schemes Owned by CMAs and WUAs

Catchment management agencies and water user associations can also levy charges for the development and use of waterworks. These charges, in terms of the Pricing Strategy, must take inter alia the following into account:

(a) Recovery of overheads/management, operations and maintenance costs;

(b) Recovery of capital costs and the servicing of loans. Water management institutions are entitled by the Act to raise loans to finance new water supply infrastructure, and should therefore be able to service these loans through cost recovery;

(c) Reasonable provision for the depreciation of assets, which can be placed in a reserve fund for utilisation at the appropriate time for refurbishment.

Charges levied by water management institutions may be levied on a proportional or differential basis, depending on the relevant constitution, or if so directed by the Minister to give effect to the provisions regarding the rendering of financial assistance in terms of the NWA.

11.6.3 Municipal Asset

Should the asset be owned by the Municipality, it would have to form part of their long-term capital expenditure programme and would have to be specifically budgeted for. A municipal water asset would be recovered through the water tariffs. The governing legislation would be the Municipal Financial Management Act (MFMA).

12. SUGGESTIONS OF THE PROJECT MANAGEMENT COMMITTEE

During the course of the Study, 24 Project Management Committee (PMC) Meetings were held (once every 2-3 months), and official meeting minutes were recorded at each. The meetings were well represented by official study stakeholders including:

- The DWA Directorates of Options Analysis, National Water Resource Planning, Water Resource Planning Systems, National Water Resource Infrastructure (Southern Operations), Resource Directed Measures and the DWA Western Cape Regional Office,
- The DWA Chief Directorates of Integrated Water Resource Planning and Resource Directed Measures,
- The Western Cape Provincial Department of Agriculture, and
- The City of Cape Town.

In addition to the project management function of the PMC meetings, a number of valuable suggestions were proposed during the course of these discussions. These have been extracted from the relevant meeting minutes and are presented below in chronological order of the respective meeting dates:

1) It was concluded that the **provision for the Reserve** to the Berg River Estuary is currently the biggest constraint influencing the outcomes of the Berg River development options in this study.

2) The study would liaise directly with D:NWRP regarding the strong recommendation to consider **streamflow gauging requirements** for enabling the Reserves in the Berg River and its estuary to be implemented and monitored. It was further recognised that whilst the Berg WAAS has made many monitoring recommendations regarding data acquisition, these did not cover operational related matters such as implementation of the Reserve. The importance of this monitoring is three-fold, namely Reserve compliance monitoring, irrigation abstraction monitoring downstream of the Voëlvlei Dam, and improved timing of irrigation releases.

3) It was concluded that despite the fact that a component of the uncertainty in the middle Breede hydrology is related to poor streamflow gauging, the recommendation remains that a **Breede WAAS** is urgently required in order that the surface water development options in that system can be equitably compared (at equivalent levels of confidence) to those in the Berg WMA.

4) The study recommended that in view of the importance of providing a **low flow gauge upstream of the Berg River Estuary** to be able to monitor base flow, appropriate locations for such weir be considered by the WCRO, and the WCRO make budget available to investigate this.

5) The study concluded that of all the options investigated in this Study, including those assessed in the Phase 1 pre-feasibility study, the options involving Voëlvlei Dam augmentation offer an opportunity to environmentally **benefit the Berg River Estuary**.

6) The study drew the conclusion that the deteriorating state of rivers (nationally) was a significant concern and that implementation of Reserves, and monitoring thereof are significant problems. Recommendations in previous studies (including the Internal Strategic Perspectives) need to be implemented. In particular where some catchments are already over-allocated, **new licence applications should not be considered,** unless verification and validation show that there is unallocated water.

7) **Meeting the EWRs is a year-round obligation** and that any new scheme should provide for the summer and winter EWRs, regardless of whether or not the summer EWR was currently being met. This approach has been adopted in the assessment of the proposed BRVA Scheme.

8) It was recommended that DWA undertake a separate **Feasibility Study of a new Lower Steenbras Dam**.

9) It was concluded in the Berg WAAS that the **pump meters at The Theewaterskloof Dam** were not adequately calibrated and that it is a recommendation that this be undertaken so as to more reliably determine the volumes of water pumped from the dam. DWA acknowledged that these pump meters were supposed to have been upgraded during the construction of the Berg River Dam but as a result of delays and budgetary constraints, this had not happened.

10) The **possible raising of the Misverstand Dam** has been identified in the Operational Study being undertaken by the DWA Regional Office. A low raising of about 0,5 m could offer significant advantage in the ability to supply a greater requirement to the Lower Berg and West Coast, thereby reducing the supply “pressure” on the pipeline to Cape Town. This is a recommendation for implementation, subject to on-going monitoring of how the projected water requirements along the West Coast actually materialise.

13. CONCLUSIONS AND RECOMMENDATIONS

13.1 CONCLUSIONS AND RECOMMENDATIONS OF THE STUDY

Based on the information presented in this report and its accompanying Appendices, the following conclusions and recommendations are made in relation to the potential implementation of the BRVA Scheme:

1) The **Berg River Reserve** commensurate with a Category D River has been allowed for, and a recommended minimum summer low flow for the estuary of 0,6 m^3/s, of which **0,5 m^3/s (8 million m^3/annum) would be provided out of releases from the Voëlvlei Dam**.

2) The proposed **Lorelei abstraction site** is close to a bend on the Berg River which is favourable from a sedimentation management perspective. Geologically this is the only location of those considered at which any rock outcrop is evident for suitable founding conditions. **From a hydraulic and geotechnical perspective** this site is therefore **recommended** as the preferred location for the abstraction weir.

3) The **Lorelei site** also has the **shortest conveyance length** of all abstraction site options considered and enables the rising main to the Voëlvlei Dam to be aligned such that the least possible impact is made on the Renosterveld within the Voëlvlei Conservancy.

4) It is recommended that the **proposed rising main function in reverse** in summer so as to serve as a more efficient release conduit from Voëlvlei Dam through its ability to better control releases and to reduce the extent of water losses currently experienced from the existing outlet canal.

5) Of the two potential abstraction approaches investigated in detail, namely a 4 m^3/s pump station with a step-pump operating, or a 6 m^3/s pump station with variable speed drives, the former appears to be more easily implemented and operated, as well as offering a slightly higher resulting yield (**23 versus 20 million m^3/a**). From an operational perspective, the **4 m^3/s abstraction via a stepped-pumping operating rule** is recommended.

6) In terms of the **water quality related to abstraction of winter water** from the Berg River:
    - A study of water quality changes during the winter floods indicated that high phosphate concentrations occur early in the rainfall season and lower concentrations later in the season. Rainfall that generates surface runoff, wash phosphate containing compounds into the river and this source is gradually depleted as the rainfall season progresses.
    - Phosphate concentrations decrease during a single flood event due to dilution. It is high during the rising limb of a flood and decreases during the falling limb of a flood.
    - Nitrogen concentrations are low early in the rainfall season and high later in the rainfall season. Soft rain that penetrates the soil profile leaches nitrogen compounds from the soil. This is a slower path way resulting in elevated nitrogen concentrations later in the season.
    - Nitrogen concentrations decrease during a single flood event due to dilution. It is high during the rising limb of a flood and decreases during the falling limb of a flood.
    - The salt concentration increases during the rainfall season and is characteristic of the geology of the middle and lower Berg River.
    - The elevated phosphate concentration observed in the Berg River at the start of the rainfall season is probably the result of point source discharges from WWTWs. If it is necessary to avoid elevated phosphate concentrations in the transfer water, then it is recommended that transfers be curtailed during the first few floods of the rainfall season.

7) From a **water quality dispersion perspective** in the Voëlvlei Dam:
   - Bacteria transferred from the Berg River into Voëlvlei Dam will decrease as a result of dilution, dispersion and bacterial die-off.
   - The highest bacterial counts in the Berg River are generally recorded during the winter months, peaking in June.
   - Under normal operating conditions, and transferring the maximum volume of water into the Voëlvlei Dam, there would only be a minor increase in bacterial counts above background at the City of Cape Town abstraction point and at the Swartland abstraction point.
   - Wind currents would push the inflowing plume to either of the two abstraction points depending on the wind direction.
   - There would only be a slight increase in bacterial counts above background at the two abstraction points under those conditions.
   - In a worst-case scenario there would only be a moderate increase in bacterial counts at the Swartland abstraction tower. A worst-case scenario is transferring water at the maximum transfer rate, with the maximum bacterial counts measured in the Berg River, and wind currents driving the plume towards the Swartland abstraction point.
   - At this stage there is no indication of a significant increase in bacterial counts at either of the two abstraction points that would require pumping to be terminated at certain times of the year or flows in the river.

8) In terms of the **impacts of nutrients from the Berg River** water:
   - Voëlvlei Dam has experienced a higher frequency of algal blooms since the drought of 2004/5 changed the character of the dam from a stable clear water dam to a stable turbid system dominated by free-floating algae (phytoplankton).
   - The Cape Town water treatment works confirmed that their cost of water treatment has increased to deal with the increase in taste and odour problems in their treated water, and an increase in filter blocking algae (Melosira).
   - The option to transfer water from the Berg River would, in the short term, probably not have a significant impact on salinity in Voëlvlei Dam.
   - The transfers would probably have a negative impact on the in-lake nitrogen and chlorophyll-a concentrations, leading to increased problems with nuisance algae and the associated cost of treating the water to potable water standards
   - The initial assessment indicated that the algal bloom situation may be maintained or there may even be an increase in the frequency or duration of high algal concentrations.

9) Suitably **accurate survey information is available** from this study for the purpose of undertaking detailed design of this scheme.

10) **Geotechnical conditions at the Lorelei site are generally favourable**, and the weir design can be suitably accommodated at the proposed site. Machine excavation is expected to be possible along the pipeline route. Although there is potential for the use of excavated materials for backfilling. The final pipe type selection will influence the extent of selected fill material available insitu.

11) From an integration perspective, **the proposed Spes Bona Reservoir and the linking pipeline to the Glen Gary Reservoir to be constructed in the near future by the CCT will be necessary in order to enable the full incremental yield of the scheme of 20 million m^3/annum** to be taken up by the CCT. The growth in the West Coast's requirements could also be supplied from the BRVA scheme, depending on the actual growth in water requirements. Supply to irrigation in order to improve their assurance of supply and to relieve the over-allocation from Voëlvlei Dam is also an option, subject to the outcomes of the verification and validation process, and on the affordability of water from the scheme to that sector.

12) For the **6,3 km rising main, a 1700 mm diameter GRP is proposed for the 4m^3/s abstraction option and the same pipe type (1900 mm dia) for the 6 m^3/s option**.

13) The **estimated capital cost of the 4 m^3/s abstraction option is R277 million and that of the 6 m^3/s option R 312 million including VAT**. The corresponding **Unit Reference Values are R1.52/m^3 and R1.94/m^3 respectively for a discount rate of 8% per annum**, and based on the VAT exclusive costs. On the basis of the financial assessment, technical and environmental considerations, the 4 m^3/s option is recommended.

14) Should DWA elect to prescribe ductile iron pipes for the rising main, the overall capital cost increase of the 4 and 6 m^3/s scheme options is estimated to be 24% and 31% respectively.

13.2 OVERALL RECOMMENDATIONS

The Berg River – Voëlvlei Augmentation Scheme has been found to be a favourable surface water intervention option, albeit only able to augment the Western Cape Water Supply System by about 2-3 years. It is an option that should be considered within the current planning horizon of the Western Cape Reconciliation Strategy. Should this scheme proceed to implementation, then it is proposed that the **4m^3/s abstraction, based on a stepped-pumping operating rule**, forms the basis of the scheme design.

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