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DEPARTMENT OF
WATER AFFAIRS
AND FORESTRY

Feasibility Study for the Raising of Clanwilliam Dam

Main Report

Final

May 2008

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DIRECTORATE OPTIONS ANALYSIS

FEASIBILITY STUDY FOR THE RAISING OF THE CLANWILLIAM DAM

MAIN REPORT

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Department of Water Affairs and Forestry
Directorate Options Analysis

FEASIBILITY STUDY FOR THE RAISING OF THE CLANWILLIAM DAM

APPROVAL

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EXECUTIVE SUMMARY

INTRODUCTION

The Clanwilliam Dam, a mass gravity structure, located on the Olifants River in the Western Cape near the town of Clanwilliam, was originally built in 1935, and was raised in the 1960s. There is a requirement for a better assurance of supply for agriculture from the LORGWS and demand for further water allocations. There is also pressure to allocate additional water to resource-poor farmers in this area. The storage of Clanwilliam Dam is currently only about 30% of the present day mean annual runoff (MAR). The Dam spills almost every year and the allocation for the coming year is dependent not on how much water flowed into the Clanwilliam Dam, but on how late in the season the last rains came.

In order to comply with current dam safety standards applicable for extreme events, the Department of Water Affairs and Forestry (the DWAF) plans to implement remedial measures in the near future. This presents an opportunity to raise the full supply level (FSL), if the marginal cost of raising, over and above the cost of the strengthening, is economically viable.

The aim of the study was to verify the technical, environmental, social, economic and financial viability of raising the Clanwilliam Dam, at feasibility level. The study also aimed to determine the optimal height for such raising, if found to be viable. Four raising options, namely no raising, and 5 m, 10 m and 15 m raisings were considered. Other options for increasing supply volumes for irrigation, including clearing invasive alien vegetation, reducing system losses, implementing water demand management and exploiting the groundwater potential, was evaluated to ensure that the DWAF is aware of the full range of alternatives and implications. An additional objective of this study was to address the need for a comprehensive options assessment process that would identify the preferred suite of development options within the WMA.

SCREENING OF OPTIONS

To gain acceptance for the study of the Raising of Clanwilliam Dam as a specific development option, a review and comparison (so-called screening) of all the potential development schemes (surface and groundwater) in the Olifants-Doorn WMA was undertaken, to determine how the raising of Clanwilliam Dam would influence the viability of other development options, and *vice versa*.

The three most favourable recommended development options were found to be the development of off-channel farm dams, development of groundwater schemes, the raising of Clanwilliam Dam, or combinations of these three options.

The raising of Clanwilliam Dam was considered to be a favourable option because it does not introduce a new suite of associated environmental and social impacts, and it provides flexibility in terms of supplying potential beneficiaries, opportunities and development options for resource-poor farmers (RPFs), the position of new irrigation development and crop variety. This scheme also provides the option of either large-scale RPF development or incremental development over time, depending on the flexibility in terms of funding the scheme.

THE OLIFANTS-DORING COMPREHENSIVE RESERVE DETERMINATION STUDY

A Comprehensive Reserve assessment for the Olifants/Doring Rivers was completed in 2006. This study focused on the riverine and estuarine ecological water requirements (EWR), including a socio-economic assessment of the catchment-wide flow scenarios. EWRs were determined at six EWR river sites, two of these are on the Olifants River, two on the Doring River, and the remaining two on representative tributaries, one being the Rondegat River that flows into Clanwilliam Dam. An EWR site was not selected in the reach of the Olifants River between Clanwilliam Dam and Bulshoek Weir, because the riparian and instream vegetation was severely burnt just before the study. A Preliminary Reserve for the Olifants River, downstream of Bulshoek Weir to the confluence with the Doring River (EWR Site 2), has been approved by the Director General of the DWAF.

The EWR of the ecologically important Olifants River estuary was also determined. A C-category was recommended to stabilise the current negative trajectory and maintaining the PES of the estuary. It was concluded that the estuary could be maintained in its present Category C, even if the Clanwilliam Dam was raised by 15 m, and if the summer base flow EWR was released for the reach between Bulshoek Weir and the confluence with the Doring River.

YIELD ANALYSIS

Because of the severe nature of the drought of 2003 to 2005, which could have changed the reliability of the yield from the dam, the recently observed streamflow records were used to extend the estimated runoff into the catchment, from 1920 to 2005.

As part of this study the following were updated for the catchment upstream of the Bulshoek Weir:

- Land use and agricultural demands;
- Dam capacities (farm and government water schemes);
- Extent of alien vegetation.

The natural MAR of the Olifants River above the Clanwilliam Dam is 356 million m^3. The average supply from the Lower Olifants River Government Water Scheme over the last 25 years was estimated as 174 million m^3/a, although during droughts the supply would have been curtailed. Farmers currently receive water at an unacceptably low assurance of supply. The yield analysis undertaken for this study estimates the current assurance of supply at around the 1:10 year level, although it is likely even lower.

The proposed dam raising could potentially increase the Dam's storage to 100% of the original inflow. If Clanwilliam Dam is raised then the dam will absorb more of the winter streamflows before it spills and, as a result, the spillage over the dam will be reduced and delayed. To meet estuarine Reserve flow requirements, releases from Bulshoek Weir could supplement the streamflow at Lutzville, to maintain the minimum streamflow at 1.5 m^3/s, providing that the baseflow did not exceed natural streamflow.

Various scenarios were analysed, using the WRYM, to determine the historical yields of the system for the existing (unraised) dam and for three different dam raisings. The scenarios also determined the influence on yield of making releases from Clanwilliam Dam, to meet the EWRs downstream of the Bulshoek Weir and at the estuary. Yields were also determined at various levels of assurance of supply for the current dam and the three dam raising options.

The potential for additional diversion from the Olifants River, upstream of Clanwilliam Dam, was assessed by analysing diversions for a range of flows, up to 3 m^3/s. It was concluded that the potential to pump additional water from the upper Olifants River during winter, for use during summer, does not pose any constraint.

WATER QUALITY

An increase in the height of the dam wall would affect the thermal structure and dynamics of the impoundment. The potential impact of raising the dam wall on thermal stratification and release temperatures was investigated as well as the mitigating effects of installing a multi-level outlet structure.

The water quality requirement is predominantly a temperature constraint due to the spawning requirements of the Clanwilliam Yellow Fish. The temperature of water released from the impoundment should be within the range of 18-24°C during the months of October-January. The water being drawn off from a low level in the impoundment, during the spring and summer months, is normally cold (significantly below 18°C). The current impoundment could not meet either the discharge requirement or the temperature requirement for releases, should releases only be made from the bottom outlets. The change of dam design from a gated structure to a solid crest for a raised dam is also likely to exacerbate this situation, as spills will be fewer than with the existing situation.

It was concluded that a raising in the height of the Dam wall should be accompanied by a multi-level outlet structure, which would release water from various levels, thereby allowing water of different temperatures to mix in an attempt to meet the downstream temperature requirements. This would to some extent offset the impacts on reduced flows in the downstream river. Implementation of a multi-level outlet structure is not proposed for the case where the dam wall is not raised, as the dam in most years naturally spills in late winter/early spring, due to its small size relative to the MAR.

A reconnaissance-level assessment of the present nutrient and eutrophication status of the impoundments of the Clanwilliam Dam and Bulshoek Weir was undertaken. It was concluded that the Clanwilliam Dam impoundment is in a good trophic state and it was estimated that, provided the phosphorus loads remain unchanged, there would probably not be a major shift in trophic status if the dam wall were raised. It was further concluded that the raising of Clanwilliam Dam would probably have little impact on the growth of filamentous algae in the lower reaches of the canal system.

GROUNDWATER RESOURCES

The Clanwilliam Dam is located within a roughly N-S trending syncline in the Table Mountain Group (TMG). The main stratigraphic units represented in the study area belong to the TMG and the Bokkeveld Group. The TMG underlies the Bokkeveld in the centre of the valley, extending to significant depths. The TMG comprises three distinct units; the Peninsula Formation, which underlies the Cedarberg Formation that in turn, underlies the Nardouw Group. The dominantly quartzitic units of the TMG are well bedded and contain fractures and joints related to regional faulting. These give the formations what is known as secondary permeability that defines a fractured rock aquifer.

This hydrogeological investigation aimed to investigate the potential to optimise the conjunctive use and management of water in the valley and to identify any key issues and concerns that require further investigation. The aim was therefore to establish the groundwater potential of the TMG aquifers at a higher level of confidence, within the context of the dam raising.

A total of 29 target zones for wellfield development have been identified. These lie within two of the three confined artesian basins herein called the Clanwilliam Trough and the Citrusdal Syncline. The yield of the Peninsula Aquifer and Skurweberg sub-aquifer was modelled for both the CWT and CDS schemes, for various scenarios. A total potential groundwater yield of 132 million m^3/a was estimated for the Peninsula formation and 28 million m^3/a for the Skurweberg formation. Calculated unit reference values (URV) for 2006 ranges between 0.43 and 1.04 R/m^3 for the development of a sub-scheme.

SOILS, WATER REQUIREMENTS AND CROPS

A soils map was compiled for the Olifants River Basin from Keerom, south of Citrusdal, to the coast, and a new soil map legend was compiled. An expert system approach was used to evaluate the potential of the different soil complexes for the production of annual and perennial crops. Based on these evaluations about 2 000 ha are recommended for perennial crops (e.g. citrus and wine grapes) in the southern section of the catchment from Keerom (upper Olifants River) to Bulshoek Weir. Another 19 000 ha are marginally and conditionally recommended provided that subsoil limitations are properly ameliorated. These limitations are relatively easy to ameliorate and with judicious irrigation practices approximately 10 000 ha can be used for economic viable production of citrus and wine grapes. Within the lateral extent of the survey approximately 10 000 ha is available in the Keerom to Bulshoek section for any combination of irrigated annual (tuberous and non-tuberous) and perennial (citrus, wine grapes, mangos) production.

The soils in the surveyed area from Bulshoek to the coast differ greatly from those in the southern section. In this section there is approximately 105 000 ha that can be recommended for the production of perennial crops after amelioration of subsoil limitations.

Methods to ameliorate physical and morphological soil limitations and leaching requirements have been recommended. Net average annual irrigation water requirement for deciduous fruit, citrus and grapes, for various regions, have been recommended. Climatically adapted crops currently grown in the study area, or new crops that can be recommended, have been identified.

To increase the reliability of qualitative soil suitability evaluations based on soil survey and chemical information, as well as the effect of climate, two round-table agricultural workshops were held. Various farmers/producers in the study area, technical advisors and experts in the citrus, grape and vegetable industries were invited to these round-table discussions with the consultant team.

AGRICULTURAL WATER DEMAND MANAGEMENT

The aim of the water demand management investigation was to highlight options available for improved water demand management and to make recommendations on how to improve efficiency and save water, in addition to yield becoming available from a raised dam. The objective of the Water Management Plan (WMP), as the deliverable, is to improve agricultural water management by stimulating self-analysis and forward thinking on the part of farmers, WUA officials, CMA officials, consultants and advisors.

A first version WMP for the Olifants/Doorn CMA was therefore developed as part of this study. One of the major goals of the WMP is to set clear guidelines for communication and water distribution between the WUAs and other stakeholders. It is important for the WUAs to develop their own individual WMPs, using the Olifants/Doring CMA WMP as a guideline. The CMA WMP concentrates on the Olifants and Doring Rivers, and in particular the Clanwilliam Dam and Bulshoek Weir, the Lower Olifants River Canal and Clanwilliam Canal. These form the main elements in the development of the Olifants River and would be influenced by the raising of the Clanwilliam Dam.

Water demand management measures have been identified and discussed as implemented by farmers, irrigation forums/boards of WUAs. Little information is available regarding the irrigation management above the Citrusdal WUA area. Action Plans were developed at desktop level. The Action Plans do not form a complete list of possible activities that the ODCMA has to perform, and it is expected that the CMA would identify further actions.

DAM DESIGN AND COST ESTIMATE

A feasibility level design was conducted by DWAF Civil Design: Dam Safety Surveillance to determine feasible raising options for the Dam and to determine costs and flood levels. A number of spillway configurations were investigated and an outlet works configuration is proposed. The design philosophy was based on long-term structural reliability, minimal operational requirements/predictable operation and minimal maintenance requirements.

The Directorate Hydrological Services of the DWAF conducted a flood frequency analysis for Clanwilliam Dam, in 2005. The 1:200 year flood of 1 705 m^3/s was used as the recommended design flood (RDF). The safety evaluation flood (SEF) is 4 500 m^3/s.

Alkali-aggregate Reaction (AAR) has been identified on the surface of the current structure. Results from geotechnical investigations indicate that adequate aggregate is available from an extension of the existing hard rock quarry for the proposed raising by roller compacted concrete (RCC).

It was calculated that a downstream slope of 0,8:1 horizontal : vertical will ensure a stable structure. At each FSL an ogee and a labyrinth spillway option were investigated. For the three raisings above 105,25 m the option of lengthening the spillway by 21,35 m was also considered.

The outlet capacity required of the Clanwilliam Dam could be limited to the required flow peak required by the river reach between Clanwilliam Dam and Bulshoek Weir, of about 20 m^3/s. The outlet works was however initially designed for a release of up to 36 m^3/s. A proposed multi-level outlet works configuration was designed and costed. The new outlet works would comprise a combination of ϕ 1 200 mm pipes and ϕ 900 mm pipes.

A number of options were analysed and preliminary designs were prepared to an acceptable level of detail for the purposes of this feasibility study. Volumes and quantities were calculated to estimate costs of the various raising options.

AFFECTED ROADS AND OTHER INFRASTRUCTURE

The purpose of this investigation was to assess the impacts on the existing roads and other infrastructure surrounding the dam that would result from the raising of the Clanwilliam Dam wall. The extent of this impact depends on the raising option selected. The following infrastructural issues, arising from the proposed raising of the dam wall, were investigated and costed:

- The re-alignment of Trunk Road 11 Section 4 (hereafter referred to as the N7) to the west of the Clanwilliam Dam.
- The continued provision of access to residences, farmsteads and cultivated land along Divisional Roads 2183 and 1487 and Main Road 539 to the east of the dam. The viability of the farms in terms of the impacts on usable agricultural land is briefly addressed.
- The continued functioning of Divisional Road 2183 as part of an alternative route, in the event that the N7 between Clanwilliam and Citrusdal is temporarily closed.
- The maintenance of access to the Cederberg Wilderness Area, Algeria and other communities in the Cederberg area from the N7 via the causeway across the Olifants River (Main Road 539) and Divisional Road 1487.
- The maintenance of access to farms and residential developments to the western side of the dam via minor road 16/2, the so-called Renbaan Road.
- The replacement of other infrastructural elements in the area around the dam such as built structures, pumping systems and boreholes.
- The loss of land.

The predicted 1:50 year flood levels for each dam raising option were adopted as the minimum elevation criteria for the N7, whilst predicted 1:10 year flood levels were used as the minimum elevation criteria for divisional, main and minor roads.

It appears unfeasible to re-align Divisional Road 2183 all the way along the eastern bank of the Dam up to the intersection with the road to Algeria (DR 1487) to the south so as to maintain through access. Road DR 2182 and a section of the Algeria road (MR 539/DR 1487) would serve as the alternate through-road to the section of the N7, between the Algeria turnoff and the Clanwilliam turnoff, and would need to be well maintained. A structure that can pass a 1:10 year flood should be constructed, to provide access across the Olifants River.

Expropriation of any affected farms in their entirety does not seem necessary.

The consolidated cost estimate for mitigating the impacts on both the roads and other infrastructure are based on 2006 rates for earthworks operations and road construction.

FINANCIAL VIABILITY OF IRRIGATION FARMING

This investigation dealt with the evaluation of the financial viability of existing irrigation farming as well as the envisaged expansion of irrigation farming in relevant regions of the Olifants River system that may utilise additional irrigation water, following the potential raising of the Clanwilliam Dam. The envisaged expansion of irrigation farming addresses the option of the expansion of existing irrigation farms as well as the development of new irrigation farms.

Typical farming situations were modelled for each of the identified regions of the study area, with the assistance of leading farmers and other industry experts, using information becoming available from the study. The financial analyses were done at constant 2005/06 price levels. The financial viability of irrigation farming was evaluated with the aid of a computer model and by applying the decision-making criteria of profitability, affordability and the relative "efficiency" of the utilisation of irrigation water.

Farming practices in the relevant regions of the study area are relatively capital intensive and risky. It is clear from the financial analysis that, given the assumptions made, existing irrigation farming is quite profitable in the relevant regions of the study area. It seems that it will be more viable to expand existing farms than to develop new irrigation farms. In some areas though, the development of new irrigation farms would be profitable. The expansion of citrus farming upstream of the Clanwilliam Dam (i.e. irrigation development on individual farms in Citrusdal) is not envisaged to be profitable, mainly due to the expected relatively high cost of irrigation infrastructure.

Sensitivity analysis showed that, given the small variation in the unit cost of irrigation water that is associated with alternative dam raising possibilities, the water cost *per se* would only have a minor impact on the profitability level of individual farms.

Top-grade managerial and labour skills are preconditions for financial success and any shortcomings in this regard will have a negative impact on the financial results from farming.

ECONOMIC IMPLICATIONS

A socio-economic impact assessment of the various Clanwilliam Dam raising options was conducted. There are a number of complexities involved, as some individuals and activities will benefit from the dam raising, while others will be either temporarily disrupted or permanently affected in a negative way. A socio-economic impact assessment was needed to analyse and weigh these effects against one another.

Both the Cederberg and Matzikama Municipalities are characterised by vast, rural agricultural and conservation land, with small urban centres. The chief economic activity is agriculture. Poverty is particularly high in the rural areas.

Recognised input-output modelling techniques were utilised to determine the direct and indirect economic impacts of the various alternatives in terms of employment, economic growth and economic opportunities created and lost by each alternative. As not all of the impacts could be quantified, qualitative discussions supplement the results of this modelling process. The results were framed within a national and regional policy context, as well as various international trends regarding sustainable and ethical development. It was determined that positive impacts far exceed the negative ones.

Social benefits of the Clanwilliam Dam raising are important for the poverty alleviation strategies of the study area. Jobs, new sources of income and opportunities for economic advancement are all created. With adequate support in terms of access to transport, training and funding, the project could result in significant improvements in the overall standard of living of the populations of the Cederberg and Matzikama Local Municipalities.

IRRIGATION DEVELOPMENT AND WATER DISTRIBUTION OPTIONS

This investigation focused on the distribution options of additional yield that is made available through the raising of Clanwilliam Dam. The range of available options to productively and cost-effectively use and distribute the additional water was investigated and costed. Advantages and disadvantages of these distribution options were compared to assess their viability. It can be deduced that the availability of land with suitable soil for irrigated agriculture is not a limiting factor to the expansion of irrigation in the study area. The following water use or distribution options were considered:

a) Increased assurance of supply of the LORGWS. LORWUA has expressed the need to increase the overall assurance of supply for the ORGWS.

b) Area upstream of Clanwilliam Dam.
- Expansion of existing farms or new farms (from river and off-channel dams).
- Rosendaal Dam, as alternative combined balancing dam.

c) Area between Clanwilliam Dam and Bulshoek Weir.
- Expansion of existing farms, or development of new farms (pumping from river).

d) Area downstream of Bulshoek Weir to the estuary.
- Expansion of existing farms, or development of new farms in the Melkboom/Trawal area (pumping from canal).
- Expansion of existing farms, or development of new farms in the Klawer/Vredendal area (pumping from canal).
- Additional water supplied through the current main canal.
- Increasing the capacity of the canal system by raising the canal.
- Replacement of the canal system.
- Reducing losses in the canal/refurbishment of the canal system.
- Provision of an additional balancing dam/s along the canal.
- Additional farm dams along canal.
- Releasing water downriver from Bulshoek Weir and pumping into canal sections to use spare capacity in identified canal sections.
- Zypherfontein Irrigation Scheme.
- Supply to the Ebenhaeser community.

e) Provision of water to non-agricultural users.

RESOURCE-POOR FARMERS

The Olifants River Valley is characterised by significant income and social disparities and fluctuating seasonal unemployment. The potential dam raising offers a unique opportunity to make water available to address some of these issues by supporting water allocation reform. The objective of this investigation was to identify ways in which the additional yield made available through the dam raising can be used to meet these objectives and to ensure that the available natural resources of the area are used to the greatest benefit to society.

The investigation comprised a review of existing literature on resource-poor farmer (RPF) initiatives around the country as well as in the particular study area. A small workshop of stakeholders was held to consolidate ideas and this was followed by interviews with selected stakeholders. A number of other studies have already been conducted in the area. Results from these studies were analysed and used to make recommendations on appropriate models for using the additional yield to support RPFs and other Historically Disadvantaged Individuals (HDIs) in the area.

This suite of options that should be considered includes:

- Ensuring the protection of the Reserve, to provide socio-economic benefits such as tourism ventures, or through direct dependence.
- Allocation of additional water to the municipalities. Most of this water would be used to directly support equity needs.
- Allocation of water to ensure availability for municipal commonage schemes.
- Establishment of a development company (DEVCO) to co-ordinate the development of a sustainable broad based black economic empowerment agricultural project.
- Support for joint ventures (JVs) between existing commercial farmers and RPFs.
- Encourage black commercial farmers and investors.
- Encourage existing commercial farmers to provide sufficient land and water to existing farm workers.
- Use allocation of additional water as an incentive to make land available for land reform.
- Retain water "in trust" for future allocation to HDI farmers, or for other development opportunities that may arise in the future.

The main conclusion from this evaluation was that there is potential to use water to support the development of HDIs in the area, but that the solution is not a single large-scale RPF-scheme. Instead a suite of development options is proposed. The proposed development options will require significant engagement by the DWAF and close co-operation with other spheres of government to ensure the success of any initiative.

ENVIRONMENTAL AUTHORISATION

Environmental authorisation is undertaken through the regulatory Environmental Impact Assessment (EIA) process, which comprises two phases, namely the Scoping Phase and the Environmental Impact Report (EIR) Phase. The process ensures investigation, description and assessment of the potential environmental impacts of the proposed project and provides recommendations regarding the potential for mitigation of impacts, and how the positive impacts can be enhanced. The reports produced in this process provide the basis for informed decision-making by the DWAF with respect to which option to pursue, and by the Provincial Department of Environmental Affairs and Development Planning (D: EA&DP) regarding whether or not to authorise the activity and if so, under what conditions.

Activities for which environmental authorisation are being sought include the raising of Clanwilliam Dam by up to 15 m, re-alignment of a portions of the N7 national road and re-alignment of the gravel access road on the eastern side of the dam, to retain maintenance access to the top of the dam wall.

The process was undertaken in terms of Regulation 1182 of the Environment Conservation Act (No. 73 of 1989) which identifies certain activities which "could have a substantial detrimental effect on the environment". These scheduled activities require authorisation from the competent environmental authority. D: EA&DP was granted delegation by the national Department of Environmental Affairs and Tourism (DEAT) to act as the competent environmental authority for this project. It should be noted that the application was submitted under the ECA regulations, despite the fact that regulations these have been superseded by the National Environmental Management Act EIA regulations of 2006 the application is allowed under the transitional arrangements to be completed under the ECA process.

The proposed project therefore requires authorisation from D: EA&DP, following the prescribed EIA process as detailed in Regulation 1183. The Scoping Report Phase identified those aspects that required specialist investigation and assessment during the EIR Phase and was submitted in December 2005. The EIR describes and assesses the potential environmental impacts of the feasible alternatives, as identified during Scoping, and was submitted to D: EA& DP in October 2007, for their review and decision.

Using a tabulated system, each impact has been described according to its extent, magnitude and duration. Mitigation measures are described for each impact to minimise the negative impacts and enhance the positive impacts. The criteria above are used to ascertain the significance of the impact, firstly in the case of no mitigation and then with the most effective mitigation measures in place. Once significance of an impact has been determined, the probability of this impact occurring, as well as the confidence in the assessment of the impact, is determined and documented. Lastly, the reversibility of the impact is estimated.

Public participation forms an integral component of the EIA process. The nature of the public consultation during the Scoping and EIR Phase was comprehensive and was undertaken is accordance with the requirements of Regulation 1183. It included advertising in regional and local newspapers, distribution of background information and draft reports, holding of several public meetings and focus group meetings, and capturing issues in issues trails, which are included in the reports.

FINANCIAL EVALUATION

Capital costs have been determined, with a base year of 2006, to make the dam safe for extreme events (0 m for dam safety), as well as for the raising of the dam by 5 m, 10 m and 15 m.

Four scenarios were formulated, to present various ways in which the Reserve could potentially be implemented, with respect to the potential curtailment of existing uses or reduced assurance of supply, or even the financing of specific structural alterations.

URVs were determined for three scenarios, based on a range of assumptions, for the various dam raising options, and for discount rates of 4%, 6% and 8%, respectively. The lowest URV is approximately at the 9 m raising level. At a discount rate of 6%, a 15m raising would have a URV of R 0.48/m^3.

Incremental URVs have been determined for Scenario 2, which are indicative for the other scenarios as well. Indications are that a raising increment of between the 0-5 m raising and the 5-10 m raising would have the lowest URV, while the 5-15 m incremental raising is on the high side (especially the last 2.5 m incremental raising), and especially so for the higher discount rates. A range of criteria for the selection of the recommended height of raising has been recommended.

Implications were determined for the potential situation where a reduction in yield, as a result of the implementation of the Reserve, needs to be absorbed by the current Olifants River users, which could vary from a 4% reduction in allocations, for dam safety work only, to a 5.8% reductions in allocation for a 10 m or 15 m raising. Water from the scheme would be also very affordable to existing urban water users, without taking the cost of any further downstream infrastructure into account.

A raising level of 13 m seems sensible from a cost perspective, to limit the raising of the last meters of raising that would have significantly higher incremental URVs, when compared with the likely cost of other potential future bulk water development in the catchment (most likely groundwater).

A number of options for financing of the scheme, as set out in the Pricing Strategy, and of emerging farmers, are discussed.

RECOMMENDATIONS

The following key recommendations are made:

Dam raising

i) The DWAF recommends that Clanwilliam Dam be raised by constructing an integral mass concrete structure against the downstream face of the existing mass gravity dam. The method of construction and the type of spillway will be finalised during the detailed design phase. The source/availability of sand still need to be confirmed once environmental authorisation has been received.

ii) A multi-level outlet structure must be built for all dam raising options to ensure that the water quality and temperature requirements of the downstream environment can be satisfied. Since the latest information on the ecological water requirements only became available after the modelling task was completed, it is recommended that a refined release pattern be created for the recommended dam raising height, based on the operating rules of the Dam as well as the ecological requirement and irrigation demands downstream of the Dam.

iii) Further evaluation of the hydropower generation possibilities, and the linking of the future multi-level outlet to the intake of the hydro-power plant are needed.

iv) From a cost perspective, a 13 m raising is recommended. This scheme would have a yield of 69.5 million m^3/a, at a capital cost of R365 million (2006 costs) and a unit reference value of R0.45/m^3, at a 6% discount rate for Financial Scenario 2.

Water use

i) The DWAF should ensure that as much as practically possible of the water made available from the raising of the Clanwilliam Dam goes towards transformation and poverty alleviation in the area.

ii) The LORWUA should indicate to what extent they wish to take up a portion of the increased yield of the ORGWS, to improve the assurance of supply of the scheme.

iii) Any potential identified opportunities for future irrigation would need to be evaluated in terms of the conditions and costs relating to that specific opportunity. Final cost estimates of specific development options must be obtained, based on the cost of the dam, and the available yield for allocation to new irrigation development.

iv) Consideration should be given to establishing an Olifants/Doring River Development Agency, or other relevant implementation vehicle, which could vary in scale of influence, to:

- Develop a common vision for the catchment/scheme;
- Identify possible development opportunities and partnerships;
- Develop an allocation schedule and business plan for ensuring the support of resource-poor farmers and other broad-based black economic empowerment opportunities;
- Co-ordinate and support the proposed developments;

v) The further identification of suitable farms or projects to potentially take up additional water can to a large extent be left to the implementing agency and the potential users of future water requirements, although potential resource-poor farmers would need specific support.

vi) Monitor the progress of the proposed developments and make changes when necessary or in reaction to new opportunities.

vii) A business plan should be developed for the uptake of additional yield from a raised Clanwilliam Dam which should address:

- Funding and cost-related issues;
- Salient features of the raised dam scheme and a summary of the most relevant other supporting information from this study;
- How to meet the objectives of water allocation reform;
- Recommended models for the allocation of water;
- How to convey the message on opportunities to potential future users;
- Mechanisms of support for potential resource-poor farmers;
- A guideline for potential applicants;
- Clarification of the roles and responsibilities that various Government organisations and other organisations would have;

viii) A study should be undertaken into the potential for one (or more) large new schemes for the uptake of additional yield, such as the identified Zypherfontein Scheme. While such a scheme presents the opportunity to settle a larger number of resource-poor farmers on land simultaneously, there may be many pitfalls and sensitivities that need to be carefully unpacked and evaluated. The opportunity for national government to fund (or assist in funding) such a development should be considered, as it could become a flagship development project in support of ASGISA and other government initiatives.

ix) Evaluate applications from non-agricultural users on merit, and make some allowance for the future uptake of non-agricultural use. The uptake of non-agricultural use that can benefit the poor would need special attention to ensure that it does not fall through the cracks.

Other recommendations

Recommendations have also been made regarding the following:

- Other resources;
- Water quality;
- Environmental mitigation measures;
- LORGWS operational rules;
- Operationalisation of the Reserve;
- Monitoring; and
- Financing and implementation of the scheme.

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GLOSSARY AND ABBREVIATIONS

AAR	Alkali-aggregate reaction
ASGISA	Accelerated and Shared Growth Initiative of South Africa
ASR	Alkali-siliceous reaction
BBBEE	Broad based black economic empowerment
CCWR	Computing Centre for Water Research
CDS	Citrusdal Syncline
CAPEX	Capital expenditure
CMA	Catchment Management Agency
CWT	Clanwilliam Trough
ºC	Degrees Celcius
DEVCO	Development Company
D: EA&DP	Department of Environmental Affairs and Development Planning
DRIFT	Downstream Response to Imposed Flow Transformation
ECO	Environmental Control Officer
EC_{dw}	Electrical conductivity of the drainage water
EHI	Estuarine Health Index
EIA	Environmental impact assessment
EIR	Environmental Impact Report
EMP	Environmental Management Plan
ERC	Ecological Reserve category
EWR	Ecological water requirements
FSL	Full supply level
Gasohol	Gasohol is a mixture of 90% unleaded petrol and 10% ethanol (ethyl alcohol) and is a desirable alternative fuel for certain applications.
GDP	Gross domestic profit
GGP	Gross geographic profit
GIS	Geographic information system
GWCA	Government Water Control Area
ha	Hectare
HDI	Historically disadvantaged individuals
HFY	Historical firm yield
I&APs	Interested and affected parties
IRR	Internal rate of return
JV	Joint venture
LORGWS	Lower Olifants River Government Water Scheme
LORWUA	Lower Olifants River Water User Association
mamsl	Metres above mean sea level
MAP	Mean annual precipitation
MAR	Mean annual runoff
me/l	Milli-equivalents per litre
Mm^3/a	million cubic metres per annum
m^3	cubic meter (equal to 1 kilolitre or 1 000 litres)
m^3/a	cubic metres per annum
m^3/s	cubic metres per second
mW	Megawatt
NBS	New business sales
NIR	Net irrigation requirement

NOC	Non-overspill crest
A NPV	Net present value
NWA	National Water Act
ODCMA	Olifants-Doorn Catchment Management Agency
ODDA	Olifants/Doring River Development Agency
ODRBS	Olifants/Doring River Basin Study
OPEX	Operational expenditure
ORS	Olifants River Syncline
ORSA	Olifants River System Analysis
PES	Present ecological state
Ph	Level of acidity or alkalinity
ϕ	diameter
%	percentage
R	Rand
RCC	Roller-compacted concrete
RDF	Resource-poor farmers
RL	Related level
RPF	Resource-poor farmers
SEF	Safety evaluation flood
The DWAF	Department of Water Affairs and Forestry
TMG	Table Mountain Group
URV	Unit reference value
VAT	Value added Tax
WBM	Water Balance Model
WMA	Water Management Area
WMP	Water Management Plan
WODRIS	Western Cape Olifants/Doring River Irrigation Study
WRYM	Water resources yield model
WUA	Water user association

1. INTRODUCTION

1.1 Background and need for the Study

The Clanwilliam Dam, a mass gravity structure, located on the Olifants River in the Western Cape, was originally built in 1935, and was raised in the 1960s by adding 13 crest gates and through the use of pre-stressed cables. The Dam is located near the town of Clanwilliam in the Western Cape, on the Olifants River. Water is released from the Dam, and is diverted at Bulshoek Weir, 24 km downstream, into an extensive canal system. The dam impoundment has a live storage capacity of 122 million m^3, with a historical firm yield of 149 million m^3/a, if no releases are made to meet the downstream ecological Reserve requirements. Its full supply is at reduced level (RL) 105,25 m. The area currently under irrigation from the dam is estimated at about 15 000 ha. Water is also supplied to several towns and to the Namakwa Sands Mine, as well as to some other smaller users.

In order to comply with current dam safety standards applicable for extreme events, the Department of Water Affairs and Forestry (the DWAF) plans to implement remedial measures in the near future. This presents an opportunity to raise the full supply level (FSL), if the marginal cost of raising, over and above the cost of the strengthening, is economically viable. The necessity of a multi-level outlet also needed to be assessed, in terms of downstream water temperature requirements for Clanwilliam Yellow Fish colonies.

Parts of the Olifants/Doorn Water Management Area (WMA) are extensively developed and often experience shortages in meeting water demands. There are frequent shortfalls in the supply to the Lower Olifants River Water User Association (LORWUA), despite the fact that no releases are currently being made from Clanwilliam Dam to meet the requirements of the Reserve. Any new development would have to make provision for the requirements of the Reserve, which may lead to a further shortfall in supply.

1.2 Purpose and objectives of the Study

The Olifants/Doring River Basin Study - Phase II – Possible Raising of Clanwilliam Dam (DWAF, 2003), which formed part of the Olifants/Doring River Basin Study Phase II, concluded that raising the Dam could cost-effectively result in the provision of increased yield and recommended that it be investigated further at feasibility level.

The aim of the study is to verify the technical, environmental, social, economic and financial viability of raising the Clanwilliam Dam, at feasibility level. The study also aimed to determine the optimal height for such raising, if found to be viable. Other options for increasing supply volumes for irrigation, including clearing invasive exotic vegetation, reducing system losses, implementing water demand management and exploiting the groundwater potential, needed to be evaluated to ensure that the DWAF is aware of the full range of alternatives and implications and would thus be able to make an informed decision.

An additional objective of this study was to address the need for a comprehensive options assessment process that would identify the preferred suite of development options within the WMA.

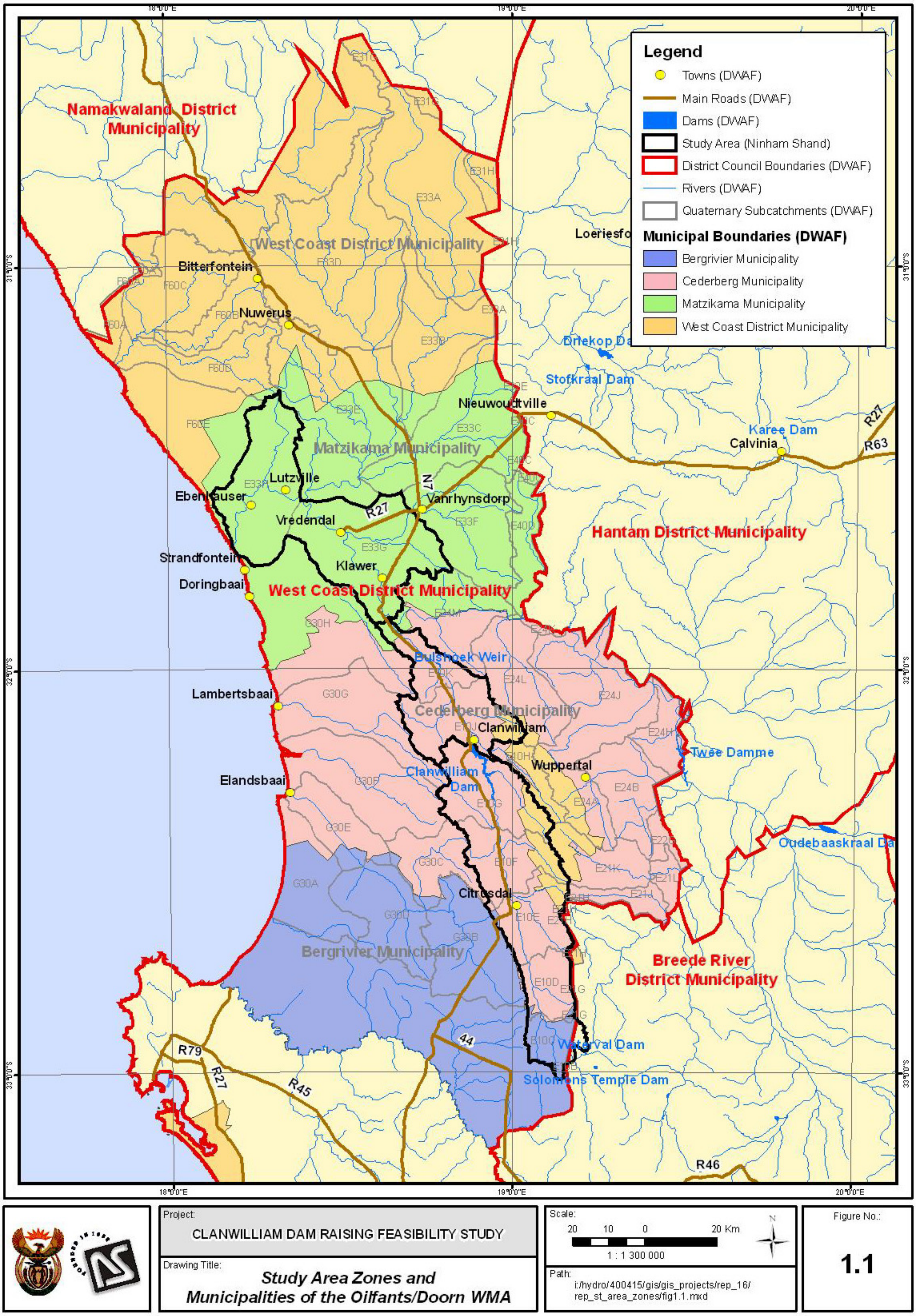


Figure 1.1 Study area and municipalities

Social development needs in the region are very important and the opportunities presented by the raising of the Dam, for resource-poor farmers, needed to be considered and evaluated. This study and its associated public consultation and environmental impact assessment process was informed by the extensive work previously undertaken in the Olifants-Doring River catchments.

1.3 The Study area

The study area is shown in **Figure 1.1**.

1.3.1 The Olifants-Doorn WMA

The Olifants-Doorn WMA is located on the west coast of South Africa, extending from about 100 km to 450 km north of Cape Town. The south-western portion mainly falls within the Western Cape Province, and the north-eastern section falls within the Northern Cape Province. The catchment is characterised by a Mediterranean climate (winter rainfall) from mid-May to the end of August. The summer months, November to February, are very warm and dry, and are characterised by extremely high evaporation losses. Climate variation is extreme as a result of the variation in topography, with summer temperatures reaching 45ºC in the Vredendal/ Koekenaap area. Snowfalls are possible until mid-September in the Cederberg wilderness area.

Although the focus of the Clanwilliam Dam Raising Feasibility Study was on the main stem of the Olifants River, the study needed to take into account WMA-level considerations, such as potential bulk water development initiatives.

Water resources are not evenly distributed throughout the WMA. Most of the surface flows originate in the Cederberg Mountains, located in the relatively small southern central mountainous area of the WMA, where rainfall and snow create runoff during the winter, which is carried to the Atlantic Ocean by the Olifants River and its main tributary, the Doring River. Precipitation varies from up to 1 500 mm/a in the Cederberg Mountains in the southwest, to less than 100 mm/a in the northern coastal areas. The mean annual potential evaporation varies from 1 500 mm/a in the southwest to 2 300 mm/a in the north.

The major river in the WMA is the Olifants River, which rises in the Agter Witzenberg Mountains to the north of Ceres. The mainstream of the river is some 250 km long, initially flowing through a steep narrow valley, but eventually widening and flattening into a wide floodplain downstream of Klawer. Whilst most of the smaller streams of the Olifants River do not flow during summer, the main river is naturally perennial. Summer flow has however become very low as a result of abstraction by irrigators. The catchment area upstream of the Clanwilliam Dam consists of natural mountain streams and rivers.

The quality of water in the Olifants River is good in the higher reaches up to the Clanwilliam Dam and Bulshoek Weir. Downstream of Bulshoek Weir, and particularly downstream of Lutzville, nitrification becomes a problem. During the dry periods of the year, in March and April, just after the irrigation season, the river is at its most polluted.

Flow in the Doring River is highly variable, whilst only small occasional flows occur in the Sout River tributary. The Jan Dissels River is a tributary river flowing into the Olifants River below the Clanwilliam Dam, but upstream of the Bulshoek Weir.

The study area is characterised by vast, rural agricultural and conservation land, being sparsely populated with small urban centres. The chief economic activity is agriculture, which contributes around 45% of the GDP in the Olifants-Doorn Water Management Area. Other economic sectors are largely centred on serving agricultural sector and/or processing agri-products, largely dispersed over the rural areas. The Olifants-Doorn WMA is the least populated WMA in the country. The population is mostly rural and dispersed over a large area, with population concentration in towns such as Clanwilliam and Vredendal. The area has high poverty levels and extreme dependence on agriculture and subsistence activities. Poverty is particularly high in the rural areas. Resource-poor farmers have limited access to good quality agricultural land and have been historically sidelined in terms of access to water.

1.3.2 Irrigation farming

Irrigated agriculture includes citrus, deciduous fruits, grapes, potatoes and summer vegetables. Estimates of the total land under irrigation in the WMA vary, but are more than 50 000 ha, of which almost 50% lies within the upper and lower Olifants areas, with potential for significant expansion. The actual area of land under irrigation each year varies with water availability. Approximately 97% of current irrigated land falls in the Western Cape half of the WMA. Citrus farming in the area is important nationally, as it is the biggest citrus-growing area in South Africa and contributes to the Western Cape’s international exports. Similarly, the area has developed a brand image for its wine, generally known as "Goue Vallei", which is growing in popularity internationally.

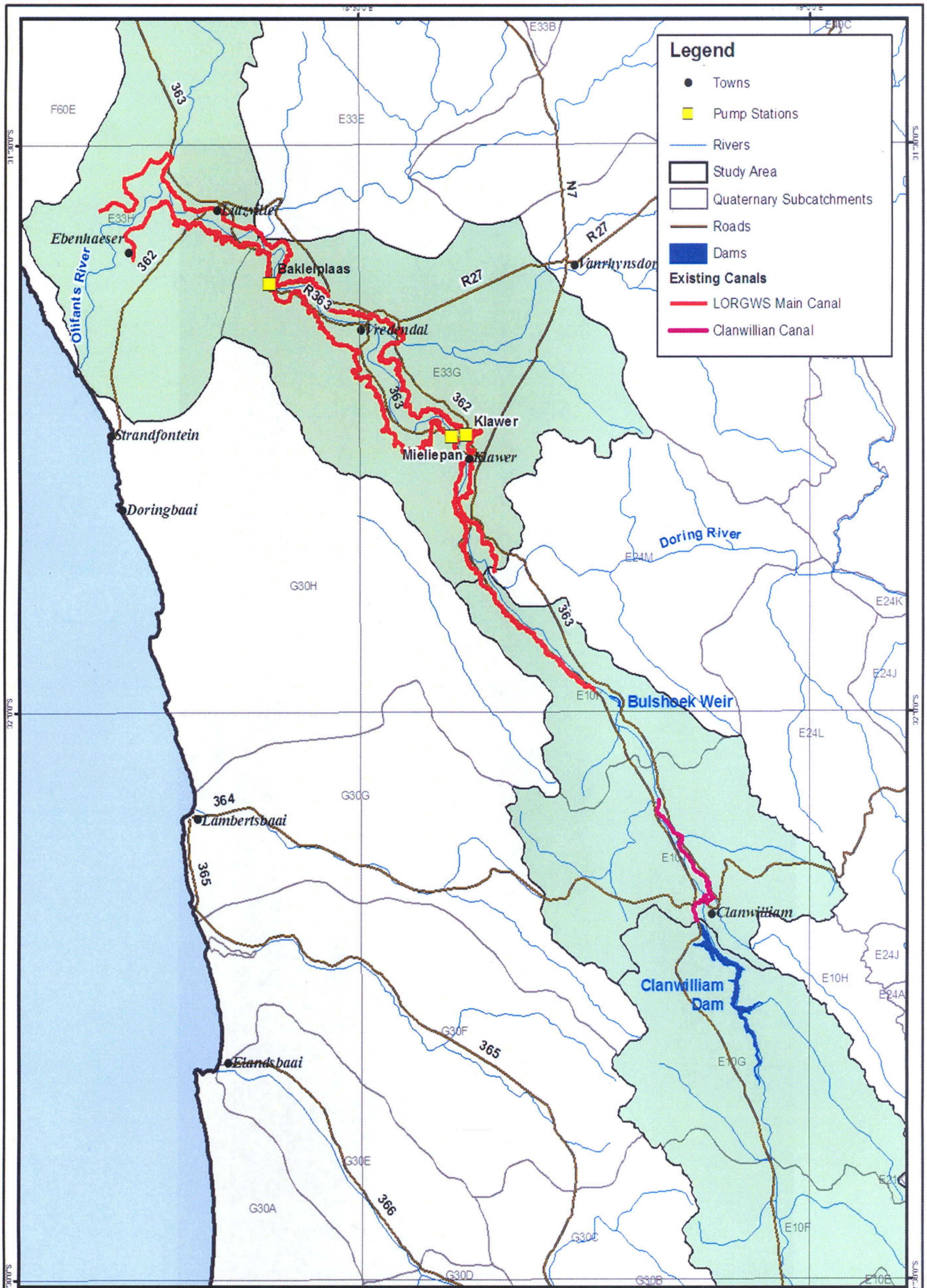
1.3.3 Fishing

The Ebenhaeser and Papendorp communities are examples of rural communities that are particularly vulnerable to poverty, with approximately 3 500 people almost solely dependent on the Olifants River for their subsistence activities of fishing and irrigated agriculture. The estuary at Ebenhaeser is utilised as a nursery for various line-fish. West Coast Fisheries make use of line-fish caught near the mouth of the Olifants River. The impacts of any future bulk water scheme in the catchment of the Olifants River, or its tributaries, on these communities, may be low in terms of economics, but may be high in terms of their livelihoods.

1.3.4 Water infrastructure

Irrigation infrastructure in the WMA consists of irrigation directly out of the river, water pumped out of the river and stored in off-channel dams, and diversions of the river into irrigation canals. There are numerous farm dams throughout the upper Olifants and Doring River catchments.

The Olifants River (Vanrhynsdorp) Government Water Scheme (LORGWS) comprises the Clanwilliam Dam, Bulshoek Weir and a canal system to irrigate land extending along the Olifants River (see **Figure 1.2**). Clanwilliam Dam (see **Figures 1.3** to **1.8**) and Bulshoek Weir are state-owned. Water is released from Clanwilliam Dam (live storage 121,8 million m^3) into the river to flow to Bulshoek Weir (live storage 5,4 million m^3), some 30 km downstream. Downstream of the weir water is distributed by a canal system, consisting of main and distribution canals totalling 186 km in length. Current canal losses are high, and the canals and associated infrastructure are generally in a poor state. The Clanwilliam Canal system, operated by the Clanwilliam Water User Association (WUA), starts at the Dam and supplies water to Clanwilliam town and some 750 ha of irrigation.



Project:
CLANWILLIAM DAM RAISING FEASIBILITY STUDY

Drawing Title:
LORGWS Bulk Water Infrastructure

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Figure No.:
1.2

Figure 1.3 Clanwilliam Dam downstream from right bank

Figure 1.4 Apron below Dam wall

Figure 1.5 Clanwilliam Dam outlet

Figure 1.6 Clanwilliam Dam viewed from down-stream

Figure 1.7 Dam wall crest

Figure 1.8 Three sluices open

Clanwilliam Dam is a 43 m high mass gravity concrete structure with a centrally situated overspill section, and 13 crest gates. The Bulshoek Weir (see **Figure 1.9**) is a gated stone-masonry gravity structure. During dry periods seepage from the Bulshoek Weir is pumped back into the canal supplying water to the Lower Olifants River Water User Association (LORWUA).

During years of drought, the Clanwilliam Dam does not fill up and restrictions are then placed on the irrigation water users. The uncertainty of the quota for the following year causes the farmers to be more conservative in their irrigation development. The planting of permanent crops in the LORWUA area is restricted to 70% of the irrigation area allocated. Considering the history of the scheme, the full quota of 12 200 m^3/ha/a has never been supplied to the farmers. The canal system, which runs full from mid October to end February, is unused for about 12 weeks per year and is operational continuously from about end August to end May. The canal runs full from mid October to end February. The farmers use their off-channel dams (night dams) to store water pumped out of the canal for overnight storage.

The total irrigated area dependent on the Clanwilliam Dam is more than 14 000 ha, while 37 253 ha is irrigated within the Olifants River catchment (excluding the catchment of the Doring River). The bulk of the water goes to the three irrigation areas below the dam, comprising the area served by the Clanwilliam Canal (see **Figure 1.10**) immediately below the Dam, the area along the river between the Clanwilliam Dam and Bulshoek Weir and the area served by the Lower Olifants Canal below Bulshoek Weir. There is some abstraction from the river below Bulshoek Weir as well.

There is a requirement for a better assurance of supply for agriculture from the LORGWS and demand for further water allocations. There is also pressure to allocate additional water to resource-poor farmers in this area.

Figure 1.9 Bulshoek Weir

Figure 1.10 Start of the Clanwilliam Canal

1.3.5 Institutional aspects

The three established WUAs (see **Figure 8.1**) in the Olifants River are the Citrusdal WUA, the Clanwilliam WUA and LORWUA. LORWUA irrigators receive their water from the canal system below Bulshoek Weir.

In the Citrusdal WUA area, upstream of Clanwilliam Dam, farmers have constructed off-channel storage dams (farm dams) from which they irrigate during the low-flow months. These farm dams are filled during the winter by pumping runoff water out of the mountain streams and rivers. In terms of the abstraction conditions, up to 50 % of their water allocation can currently be stored in off-channel storage dams. During summer, these farmers use the water stored in their farm dams.

The water distribution infrastructure in the Clanwilliam Water Users Association area consists of abstraction directly from the Clanwilliam Dam basin, a lined canal from the Clanwilliam Dam, and natural streams and rivers. All water users between the Clanwilliam Dam and Bulshoek Weir are members of the Clanwilliam WUA. Water users abstract their water either from farm dams filled by pumping from the Clanwilliam Canal (or potentially using water directly from the canal), or by pumping directly out of the Olifants River.

Specific releases from the Clanwilliam Dam are only occasionally made for use by towns. No specific releases are generally made for irrigators between Clanwilliam Dam and Bulshoek Weir, because these irrigators intercept some of the releases to the Bulshoek Weir. Their requirements are therefore factored into releases made from Clanwilliam Dam. Potato farmers below the Clanwilliam Dam occasionally need some specific releases in winter, for periods when there is insufficient flow in the Jan Dissels River and/or other tributaries and no spills from Clanwilliam Dam.

Eleven Catchment Forums were established in the Olifants-Doorn WMA, including the Upper Olifants, Middle Olifants and Lower Olifants, as part of the process to establish the Olifants-Doorn Catchment Management Agency (CMA). The Proposal for the Establishment of the Olifants-Doorn CMA was approved by the DWAF in 2006.

2. SCREENING OF OPTIONS

2.1 Screening process

2.1.1 Need for the Screening Process

A number of surface water and groundwater resource studies have been undertaken within the WMA. Various development schemes were investigated and re-investigated in these studies.

To gain acceptance for the study of the Raising of Clanwilliam Dam as a specific development option, a review and comparison (so-called screening) of all the potential development schemes (surface and groundwater) in the WMA was needed, to determine how the raising of Clanwilliam Dam would influence the viability of other development options, and *vice versa*. The objectives of this screening process were:

- To clarify the policy of the DWAF and its co-operative partners regarding the need for development in the Olifants/Doorn WMA;
- To review the acceptability of the various potential options identified in previous studies in terms of technical, financial, environmental and social criteria;
- To augment existing information with limited specialist inputs where required; and
- To ascertain whether or not the raising of Clanwilliam Dam is a preferable and defendable development option, for further study with a view to implementation.

This process therefore entailed the comparison of the potential raising of Clanwilliam Dam with other potential water infrastructure development opportunities in the WMA.

2.1.2 Specialist Screening-of-Options Workshop

As part of the screening process, a '*Screening of Options'* Specialist Workshop was held on 23 November 2004. It was attended by selected DWAF staff, study team members, selected identified stakeholders and specialists in order to workshop the acceptability of the various surface water development options, as compared to the raising of Clanwilliam Dam. The potential development of groundwater supply schemes and conjunctive use of groundwater in the region were also addressed.

There are a number of potential surface water schemes that could be developed to increase the availability of water within the Olifants and Doring River catchments. **Figure 2.1** on the following page shows where these potential schemes are located.

2.1.3 Stakeholder Screening-of-Options Workshop

The purpose of the Stakeholder Screening Workshop was to discuss and critically evaluate the suite of development options in the Olifants and Doring Rivers catchments and compare these to the potential raising of Clanwilliam Dam, so as to ascertain whether or not the raising of Clanwilliam Dam is a preferable and defendable development option. This key stakeholder workshop was held on 10 February 2005, targeting the WMA Reference Group, where the draft *Screening of Options* Report was presented, so as to solicit further comments and inputs.

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

- Capital to yield ratio;

- Environmental impacts (barrier/sediment, inundation and downstream effects); and
- Beneficiaries (cost, agricultural impact, benefits to users and resource-poor farmer opportunities).

Figure 2.1 Potential surface water and groundwater schemes in the Olifants/Doring catchments

It is important to note that the yields of individual wellfields cannot be compared directly to surface water schemes, as there is a lack of data with respect to groundwater yields. Further data collection is required to enable groundwater schemes to be modelled to determine comparative costs of groundwater scheme development for comparison with surface water development options.

2.1.4 Summary of the Screening Process

The results of the screening process are shown in **Table 2.1** and **Table 2.2**. Yields shown are for 1 MAR dams, except where more detailed evaluations have been undertaken.

Table 2.1 Summary of surface water development options

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

Potential Source	Yield (No Reserve) (Mm³/a)	Capital to Yield Ratio	Environmental Impacts			Beneficiaries			
			Barrier and Sediment	Inundation	Down-stream	Area Supplied	Infra-structure cost	Agric. impacts (environ -mental)	Benefit to users
Olifants River catchment									
Raise Clanwilliam	66	2	1	1	3	Not rated	1	1	1
Rosendaal	14	3	2	3	3	Not rated	1	2	1
Visgat	Not determined	4 (1)	3	4	3	Not rated	1	2	1
Grootfontein	90	3	3	4	3	Not rated	1	2	1
Keerom	100	3	3	3	3	Not rated	1	2	1
Additional farm dams	10	2	1	1	1	Not rated	1 to 2	1	1
Doring River catchment									
Leeu River	Not determined	3	3	Not rated	3	Not rated	3	2	3
Groot River	64	Not rated	4	4	4	Not rated	4	4	4
Aspoort	76	Not rated	4	4	4	Not rated	4	4	4
Reenen		Not rated	Not rated	Not rated	Not rated	Not rated	Not rated	Not rated	Not rated
Melkbosrug	116		4	4	3	Not rated	2	2	2
Melkboom	121	Not rated	4	4	3	Not rated	2	2	2
Brandewyn	50	Not rated	3	3	3	Not rated	2	2	2
Additional farm dams	5	Not rated	1	1	1	Not rated	1 to 2	1	1

(1) Although these values were not determined, this ratio is expected to be similar to that of Rosendaal Dam, except that there would likely be an increased relative capital cost to adequately allow for releasing the Reserve.

Table 2.2 Summary of groundwater development options

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

Schem e name	Yield (Mm³/a)	Unit Reference Value (1) (R/m³)	Capital to Yield Ratio (2) (R/m³)	Scheme	Environmental Impacts
Doring River catchment					
T1a Wellfield (conventional)	5	0.25	2.4	1	2
T1b Wellfield (conventional)	5	0.23	2.1	1	2
Olifants River catchment					
T2 Wellfield **(conventional)**	3.2	0.35	3.5	1	1
T3 Wellfield (conventional)	2.5	0.49	5.7	1	1
T5 Wellfield (ASR)	20 min up to 90	0.82	Not determined	1	1
T7 Wellfield (ASR)	121 (avg.)	0.12	1.2	2 to 3	2 to 3
Citrusdal Trough	50 to 100	Not determined	Not determined	1	1
Clanwilliam Trough	Unknown but comparable	Not determined	Not determined	2	1

(1) The URV takes both capital and operating costs into account.
(2) The yields are conservative estimates.

2.2 Recommended development options

The three most favourable recommended development options for the Olifants-Doorn WMA were:

- the development of off-channel farm dams;
- the development of groundwater schemes;
- the raising of Clanwilliam Dam;

or combinations of the above three options.

The raising of Clanwilliam Dam was considered to be a favourable option because it does not introduce a new suite of associated environmental and social impacts, but rather extends existing impacts. The lower Olifants River has also already been disturbed by the presence of the Clanwilliam Dam and the Bulshoek Weir. In terms of local and international policy and experience, there is strong support for expanding existing agricultural development rather than creating new dispersed agricultural areas. However, as mentioned above, with the exception of groundwater, the raised Clanwilliam Dam could potentially exclude or diminish other development options in both the Olifants and Doring Rivers catchments.

The raising of Clanwilliam Dam provides flexibility in terms of supplying potential beneficiaries, opportunities and development options for resource-poor farmers (RPFs), the position of new irrigation development and crop variety. Other potential development options on the Olifants and Doring Rivers do not appear to provide the same level of flexibility. Furthermore, Clanwilliam Dam can provide relatively affordable water. This scheme also provides the option of either large-scale RPF development or incremental development over time, depending on the flexibility in terms of funding the scheme.

Based on the feedback received at the Key Stakeholder Workshop, it was evident that there is broad support for the abovementioned most favourable development options, and specifically for the raising of Clanwilliam Dam.

There was consensus that the study to confirm the feasibility of the raising of Clanwilliam Dam proceed for the following reasons:

- The remedial work to be undertaken provides the opportunity to raise Clanwilliam Dam;
- The scheme would have relatively low environmental impacts compared to other development options;
- The scheme would provide flexibility with respect to potential beneficiaries;
- The scheme would provide the possibility to make water available for resource-poor farmers;
- The scheme would provide the opportunity to satisfy the ecological Reserve of the Olifants River and Estuary; and
- The scheme would provide the possibility of expanding existing agricultural development rather than creating new unsupported agricultural areas.

3. THE OLIFANTS/DORING COMPREHENSIVE RESERVE DETERMINATION STUDY

Southern Waters Ecological Research and Consulting (DWAF, 2006) completed a Comprehensive Reserve assessment for the Olifants/Doring Rivers in 2006. This study focused on the riverine and estuarine ecological water requirements (EWR), including a socio-economic assessment of the catchment-wide flow scenarios. The Groundwater Reserve was determined in a separate parallel study undertaken by SRK Consulting (DWAF, 2006), and wetlands were excluded.

3.1 Riverine EWR assessment

The Olifants River and its major tributary, the Doring River, are important from a conservation perspective, because they contain a number of species of indigenous and endemic fish that occur in no other river systems, and that are endangered. In addition, reaches of some of the tributaries are virtually unspoiled by human impacts and are of high to very high ecological importance and sensitivity.

The flow modelling showed that present-day flows are generally much lower than the naturalised flows, with dry season low flows considerably reduced relative to the natural levels. Surface flow now ceases in the summer months above Clanwilliam Dam.

3.1.1 EWR Sites

The methodology requires that a set of representative sites be selected along the river, to be studied in detail. The results from those sites can then be extrapolated to similar reaches of river. Six ecological water requirements (EWR) river sites were selected for the Olifants-Doring catchment, as shown in **Figure 3.3**. Two of these are on the Olifants River (relevant details in **Table 3.1**), two on the Doring River, and the remaining two on representative tributaries. EWR Site 1 is shown in **Figure 3.1** and EWR Site 2 in **Figure 3.2**.

Figure 3.1 EWR Site 1 Olifants River at Hex River tributary, looking upstream at the site

Figure 3.2 EWR Site 2 Olifants River at Alwynskop, looking across the river

An EWR site was not selected in the reach of the Olifants River between Clanwilliam Dam and Bulshoek Weir, because the riparian and instream vegetation was severely burnt just before the study. The timing and extent of the burning meant that much of the information that was needed for the EWR determination could not be collected.

Table 3.1 Details of the Olifants River EWR sites

EWR site No.	Description	Natural MAR[1] (Mm^3/a)	Present day MAR (Mm^3/a)
1	N7 downstream of the confluence with the Hex River	332	275
2	Downstream of Bulshoek Weir, just downstream of Cascade Pools	519	Not known

(1) Mean annual runoff.

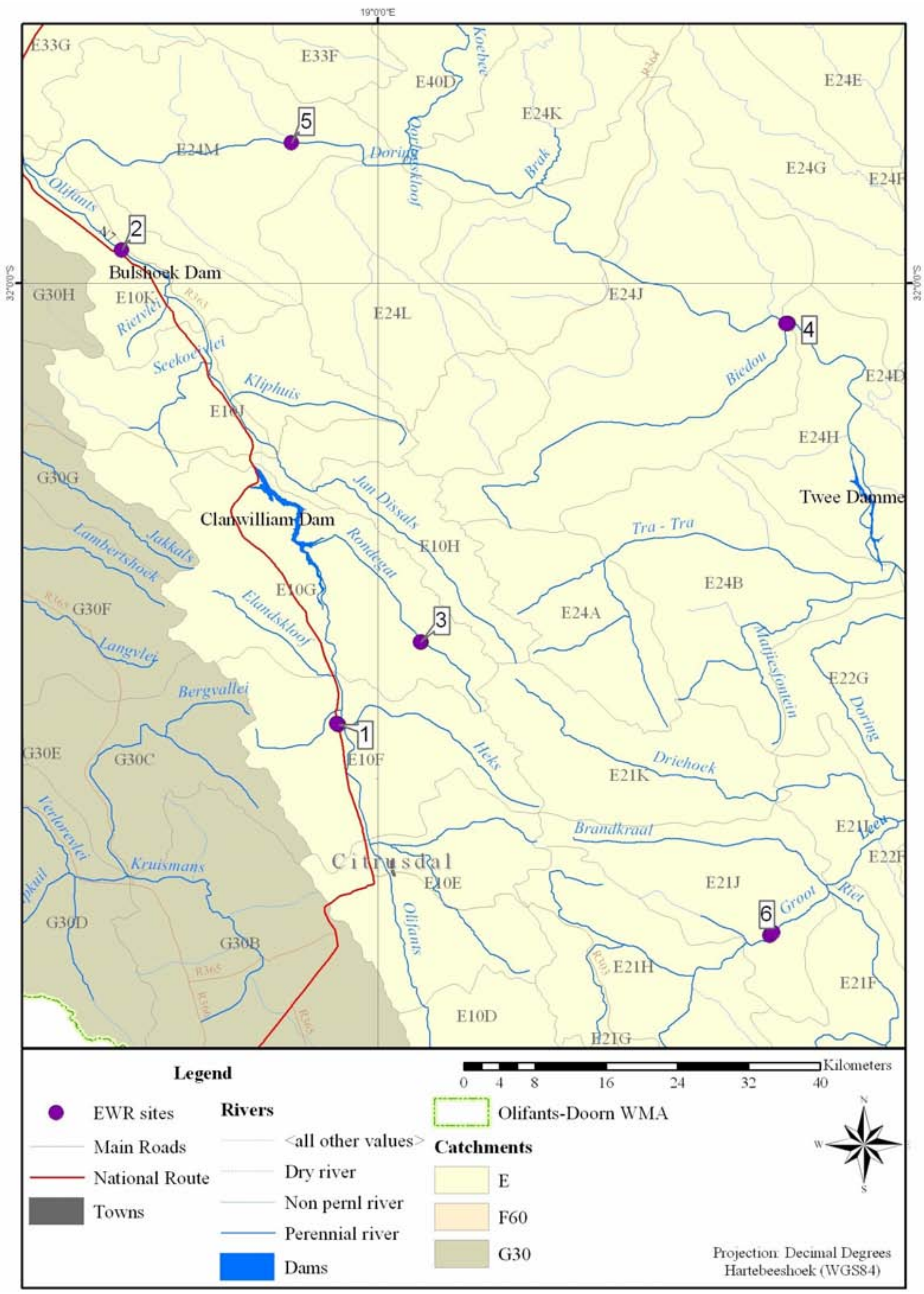

Figure 3.3 Map of the EWR sites in the Olifants-Doring catchment

3.1.2 Methodology

The *Downstream Response to Imposed Flow Transformation* (DRIFT) methodology was used for the riverine ecological assessments. The present ecological state (PES) was determined for each aspect (e.g. freshwater fish) and ecologists then made predictions about the change from that state in relation to a change in flows. PES determines the change in the ecological condition of the river (or river reach) from its natural or unmodified state, and includes all the aspects considered in the study. PES is reported as a category between A and F, with A representing an unmodified system and F representing a highly degraded system. It is very important to note that the lowest Category for which the DWAF would like to manage aquatic ecosystems is a D-Category.

3.1.3 Key issues at the EWR sites on the mainstem Olifants River

The factors affecting the EWR sites on the mainstem of the Olifants River, *viz*. EWR Sites 1 and 2, have relevance to the Clanwilliam Dam Raising Study, as these represent limitations to the ecological condition that can be achieved through the provision of additional flow, especially at EWR Site 2 (downstream of Bulshoek Weir), which is fundamentally changed from its natural state. These two EWR sites are discussed further a follows:

EWR Site 1: The PES of a D-category is driven predominantly by non-flow related issues, such as bulldozing of the channel, cultivation of the alluvial floodplains and encroachment of alien and other riparian vegetation.

- Present day hydrology is reasonable with the notable exception of the summer months, when the naturally perennial Olifants River is pumped dry, sometimes for up to several weeks. There is some opportunity for further abstractions from the river while still maintaining the current state BUT only if some summer flows are re-instated.
- Opportunities for additional abstraction are limited by the fact that the hydrology is currently supporting the D-category condition of the river, whereas other “drivers” of river condition, such as geomorphology are in an E-category. If the hydrological regime is further restricted, this will result in the river deteriorating to an E-category.
- The most reliable way to increase the level of abstraction possible, and still maintain a D-category river, is to implement river restoration aimed at reversing some of the non-flow related geomorphological impacts.
- The present D-category can best be made a C-category by restoration work addressing non-flow related issues.

EWR Site 2: The PES is an E-category with the deviations from the natural state predominantly driven by flow-related issues. These are primarily attenuation of floods and severely reduced dry season lowflows, as a result of Clanwilliam Dam and Bulshoek Weir, which diverts the bulk of the flows into a water supply canal.

- Additional impacts include reduced sediment supply, encroachment of reeds and palmiet, and cultivation of flood terraces.
- Opportunities for improving the PES through releases from Clanwilliam Dam/Bulshoek Weir are extremely limited, and it is highly unlikely that increasing volumes of river flow (which would also severely impact on the economic activity) will improve the state of the river at this site.
- From the perspective of the entire Olifants-Doring River it is recommended that consideration be given to not building a major impoundment or abstraction weir on the

Doring River, but instead maximising the yield from Clanwilliam Dam/Bulshoek Weir, by not releasing a river EWR for the section of river below Bulshoek Weir. A residual flow was rather recommended to maintain the water quality and vegetation in EWR Reach 2. Releases are however still required to ensure that the estuary receives sufficient water to support its ecological functioning.

3.1.4 Summary of EWRs for the river

The EWRs determined for Olifants River main stem EWR Sites are shown in **Table 3.2**. The table shows the EWR averages, excluding the requirements for the ≥ 1: 2 year return period floods, with two options shown for EWR Site 2. Note that additional baseflow of 146 million m^3/a would be needed to improve the Future Condition of EWR Site 2 from its existing E Category to a Category D, which would severely impact on economic activity.

Table 3.2: The Baseflow EWR for the Olifants River main stem sites

Site	Portion of the EWR	PES	Future condition	Mm^3/a	%nMAR
EWR Site 1	TOTAL (Volume), excl. ≥1:2 year return period floods	D	D	88	26%
EWR Site 2	TOTAL (Volume), excl. ≥1:2 year return period floods	E	D	*c*. 194	38%
			Maintain PES (E)	48.3	9%

3.2 Estuarine EWR assessment

3.2.1 Current situation

The Olifants River estuary, located approximately 250 km north-west of Cape Town, is one of only three permanently open estuaries on the west coast of South Africa, together with the Berg and Orange Rivers estuaries. In terms of conservation importance the estuary is rated the second most important system in South Africa. As the mouth of the Olifants River is permanently open, a tidal influence of up to 36 km upstream (during spring tides), i.e. the causeway at Lutzville, feeds the estuary. The productivity of the estuary is, thus, particularly sensitive to decreases in river flow, flood frequency and water quality. Degradation of the estuary has significant impacts for west coast fish and thus the fishing industry. The estuary also plays an important role in bird migration and conservation of waterbirds. The estuarine boundary is shown in **Figure 3.4**.

The estuary itself is still relatively undeveloped, but its condition is affected by a reduction in freshwater flows and variability. It was estimated that the MAR has been reduced by approximately 34% relative to natural conditions. The summer flow is also of a poor quality as it is strongly influenced by return flow from irrigation along the river, when river flow is low. The Olifants Estuary is considered to be highly important and has been targeted as a Desired Protected Area.

3.2.2 Present ecological state

As was the case for the river PES, the estuarine PES or Estuarine Health Index (EHI) is based on scores assigned by the relevant ecologists to a series of variables. The EHI score for the Olifants

Estuary translates into a PES of C, i.e. moderately modified. The condition of the estuary is however declining (i.e., on a negative trajectory) as a result of the extremely low base flows (<1 m^3/s) during the summer months.

3.2.3 Summary of EWRs for the estuary

The volume of the EWR associated with stabilising the current negative trajectory and maintaining the PES of the estuary in a C-category, and the recommended ecological Reserve category (ERC) (B) are shown in **Table 3.3**. Note that additional flow of 203.3 million m^3/a would be needed to improve the estuary to a Category B.

Table 3.3 The volume of the EWRs for the Olifants Estuary

Site	Present Ecological Status	EWR (Mm^3/a)	Recommended Ecological Condition	EWR (Mm^3/a)
Estuary	C	597.0	B	800.3

It was concluded that the estuary could be maintained in its present Category C, even if the Clanwilliam Dam was raised by 15 m, and if the summer base flow EWR was released for the reach between Bulshoek Weir and the confluence with the Doring River, taking into account that the summer return flows from irrigation below Bulshoek Weir to the estuary would increase with increased usage.

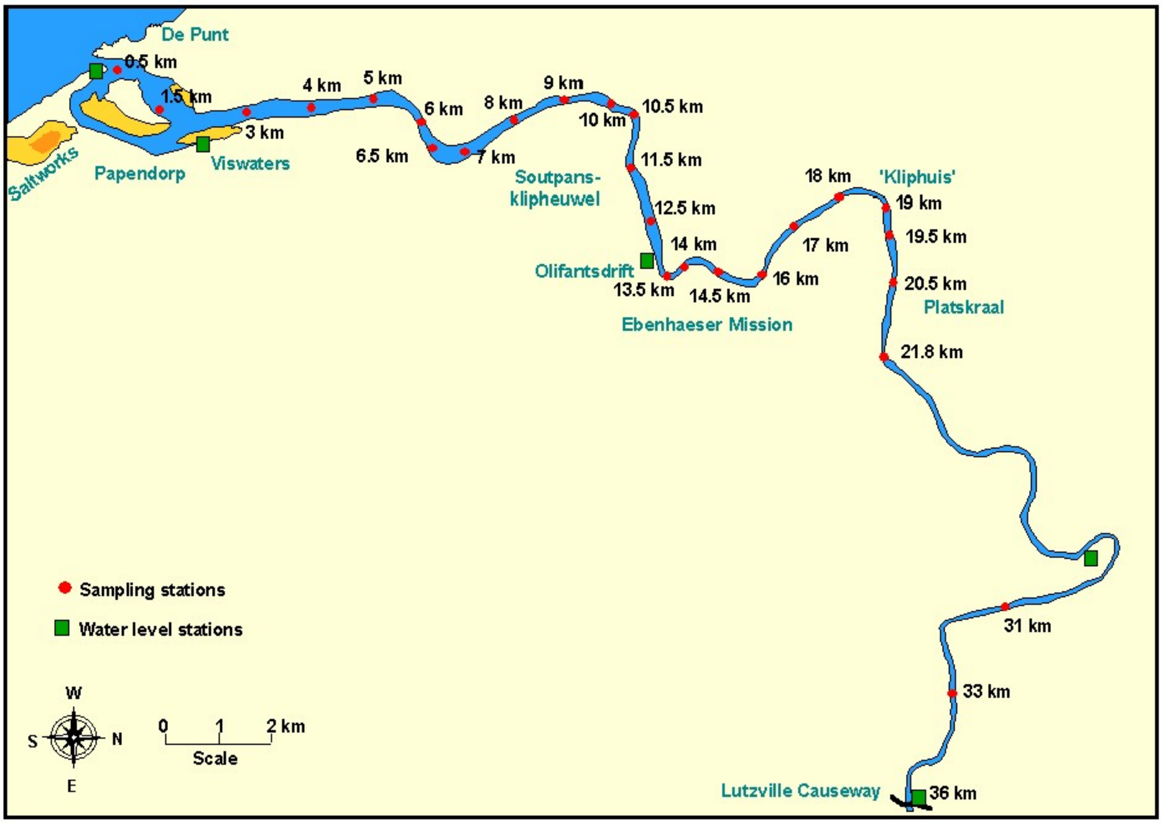

Figure 3.4 Map showing boundaries of the Estuary

3.3 Reserve Study recommendations

The recommendations from the study is summarised as follows:

- Maintain the ecological integrity of the Doring River, and in so doing ensure sustainable utilisation of the Olifants estuary, i.e., no dams or major weirs are allowed in the Doring or Groot Rivers;
- Maintain the ecological integrity of key tributaries on both the Olifants and Doring Rivers, thereby ensuring variability of flow in the main stems, as well as provision of refuges and source areas;
- Undertake some river rehabilitation aimed at reducing non-flow related impacts in the mainstem Olifants River between the Olifants Gorge and Clanwilliam Dam, thereby improving overall river condition in this reach;
- Undertake some river rehabilitation aimed at reducing water quality impacts in the mainstem Olifants River downstream of the confluence with the Doring River. This would also improve the quality of water entering the estuary;
- Undertake estuary rehabilitation measures, mainly aimed at controlling over-fishing;
- Make Reserve releases from Clanwilliam Dam/Bulshoek Weir, in a manner that would maximise water supply from the system;
- Accept non-compliance to a Category D, for the stretch of the Olifants River between the Bulshoek Weir and the confluence with the Doring River.

On the basis of these recommendations a Preliminary Reserve for the Olifants River, downstream of Bulshoek Weir to the confluence with the Doring River (EWR Site 2), has been approved by the Director General of the DWAF.

4. YIELD ANALYSIS

The yield analysis evaluation was done to determine the yield from the system for the various dam raising scenarios, considering the ecological water requirements resulting from the *Olifants/Doring Catchment Ecological Water Requirements Study* (DWAF, 2005).

4.1 Hydrology

4.1.1 Stream flow

Because of the severe nature of the drought of 2003 to 2005, which could have changed the reliability of the yield from the dam, the recently observed streamflow records were used to extend the estimated runoff into the catchment, from 1920 to 2005. These historical streamflows were not naturalised, as explained in the System Analysis Report, Report No. P WMA 17/E10/00/0607. The hydrological sub-catchments, as determined in previous studies, were retained.

4.1.2 Rainfall

The initial hydrology prepared as part of the Olifants River System Analysis (ORSA), 1990 used rainfall records available from a number of sources. Subsequently, the Computing Centre For Water Research (CCWR) was disbanded and most of the DWAF's rainfall gauges in the area were closed. This study reviewed data from the available rainfall stations, although the intention was not to calibrate the catchments. A large proportion of the rainfall data used in the Olifants River System Analysis was based on "public appeal" data that was collected by the CCWR, and now seems to have been lost.

The steep mountain ranges that flank the Olifants River intercept the rainfall and make a major contribution to the runoff from the catchment. However, the rainfall gauges are located near urban and agricultural centres and do not measure the mountain rainfall which must be deduced from rainfall on either side of the mountains. Although the inflow to the Clanwilliam Dam is well represented, the actual runoff in certain reaches is probably underestimated because the rainfall was under-estimated. Rain gauges located in the mountains or at the extremities of the catchment would improve the modelling of the rainfall/runoff relationship in the catchment.

Although the rainfall stations were not used with the Pitman Model to calibrate the catchment, a representative set was used to estimate the relative monthly and annual rainfall upstream of Clanwilliam Dam. The average mean annual precipitation (MAP) at the Northern, Central and Southern portions of the catchment were determined. The values of the northern, central and southern portions were in turn averaged to obtain the monthly rainfall (as a % of MAP) for the catchment upstream of Clanwilliam Dam. This was used to develop a monthly relationship between rainfall and inflow, which could be used to identify outliers in the inflow record.

4.2 Modifications introduced in this Study

part of this study the following were updated for the catchment upstream of the Bulshoek Weir:

- Land-use and agricultural demands;
- Dam capacities (farm and government water schemes);
- Extent of alien vegetation;

4.2.1 Agricultural demands

Aerial photographs were used to digitise the areas of crops off aerial photos, and field verification was undertaken. The areas of permanent crops are accurately represented using this approach, but areas of annual crops are difficult to quantify.

The updated estimate of the average irrigation demand upstream of Clanwilliam Dam is 95.7 million m^3/a. The demand from the river and the Clanwilliam Canal, between Clanwilliam Dam and Bulshoek Weir is 21.6 million m^3/a, which includes the observed flow in the canal of 11.6 million m^3/a.

4.2.2 Invasive alien vegetation

Information on the extent of and water use by invasive alien information was updated, based on the latest available information, including the clearing activities of Working for Water upstream of Clanwilliam Dam. For comparative purposes, the areas were condensed to equivalent fully infested areas. The fully cleared area corresponds to 1 004 ha and the remaining infestation to 1 979 ha, which correspond to annual stream flow reductions of about 4.9 and 8.9 million m^3/a, respectively. These are significant volumes of water that could be used for other purposes.

Currently, low flows in the river tend to be intercepted by riparian irrigators, so removal of the aliens is not expected to have a significant influence on the yield from Clanwilliam Dam. Infestation was also significantly less for the period from 1935 to 1990, which was used to naturalise the observed stream flow into Clanwilliam Dam when the hydrology was prepared for the ORSA. The inflow sequences to Clanwilliam Dam were therefore not adjusted to take account of the updated alien infestation information.

4.2.3 Dam volumes

The updated combined volume of the farm dams upstream of Clanwilliam Dam is 34.3 million m^3. The gross volume of Clanwilliam Dam is 123.7 million m^3 and that of Bulshoek Weir is 5.4 million m^3. **Table 4.1** shows the gross and net storage capacities for the current Clanwilliam Dam, as well as for the raising options.

Table 4.1 Capacity of current and raised Clanwilliam Dam

Dam Raising Option	Elevation (m)	Gross storage volume (Mm^3)	Net Storage volume (Mm^3)
0 m	105.25	123.7	121.8
5m	110.25	186.3	184.4
10 m	115.25	266.0	264.1
15 m	120.25	364.0	362.1

It is estimated that future siltation should not reduce the storage of Clanwilliam Dam by more than 5 million m^3 over the next thirty years, even if the dam is raised by 15 metres.

The yield of farm dams filled from pumping from the main stem of the Olifants River, upstream of Clanwilliam Dam, was estimated as 9.2 million m^3/a.

4.3 Operation of the LORGWS

4.3.1 Upstream of Clanwilliam Dam

Farm dam sizes were restricted to 6 000 m^3/ha for the areas falling within the previous Government Water Control Area (GWCA). Under the previous Water Act of 1956 a dam of up to 250 000 m^3 could be constructed in the tributaries outside the GWCA without a special permit.

As soon as the Olifants River starts flowing in winter, the farmers can pump water from the river to their dams and they must stop when the flow in the river is insufficient, normally around the end of October. During summer the farmers abstract water according to a weekly cycle. The abstraction of water by the upstream users obviously impacts on the water available from the Clanwilliam Dam for downstream irrigators.

4.3.2 Conjunctive operation of Clanwilliam Dam and Bulshoek Weir

Figure 4.1 charts the annual gross water supply, from 1980 to 2006, to the major consumers. About 27% to 30% of the inflow to the Lower Olifants River and Clanwilliam Canals is lost through seepage and evaporation.

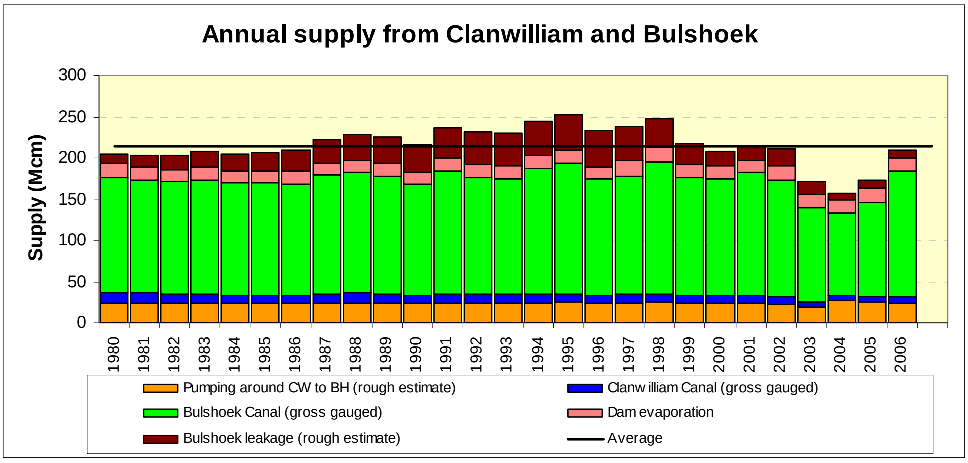

Figure 4.1 Historical annual supply from Clanwilliam Dam and Bulshoek Weir

4.3.3 Use between Clanwilliam Dam and Bulshoek Weir

The use from pumps along the Jan Dissels and the Olifants Rivers, together with transmission losses along that reach, is 21.6 million m^3/a. It is estimated that leakage from Bulshoek Weir reduced from 1.25 m^3/s down to the current 0.25 m^3/s, as a result of recent work undertaken by the DWAF's Construction Directorate.

4.3.4 Use from the Lower Olifants River Canal

The LORWUA currently have a theoretical allocation of water from Clanwilliam Dam/Bulshoek Weir of 116 million m^3/a (9 491 ha, each receiving 12 200 m^3/ha). The average inflow to the canal for the period from 1990 to 2006 was 139 million m^3/a, but after deducting losses of 37 million m^3/a (27%) and non-irrigation use of about 9.6 million m^3/a, the remainder left for irrigation is about 92 million m^3/a, about 80% of the theoretical allocation.

Two quotas are used by LORWUA, namely an annual quota of 12 200 m^3/ha and a weekly quota of 325 m^3/ha. LORWUA have limited the capacity of the balancing dams along the canal to 35% of each farmer's allocation. The Ebenhaeser Balancing Dam near the end of the west branch of the Bulshoek Canal has a capacity of 140 000 m^3.

4.3.5 Use downstream of Bulshoek Weir

Irrigators downstream of the Bulshoek Weir requested a concession from the Minister of Water Affairs to use the water leaking from the Weir. In 1963, the Minister granted a concession allowing existing riparian members of the LORGWS to irrigate an additional 10 morgen (8.6 ha) using this water. It was spelt out that this was a temporary concession and that the state could continue with developments upstream in the river without compensating these irrigators in any way. There is, however, significant uncertainty about the extent of this use, despite a study undertaken by the DWAF to clarify this.

Total return flows from the areas served by the Lower Olifants River Canal upstream of Lutzville are estimated as approximately 2 m^3/s, of which 0.5 m^3/s are above the confluence with the Doring River. The volume of farm dams downstream of the Bulshoek Weir is relatively small.

4.3.6 Curtailment

The maximum storage provided by Clanwilliam Dam is currently only about 30% of the present day MAR. The Dam spills almost every year and the allocation for the coming year is dependent not on how much water flowed into the Clanwilliam Dam, but on how late in the season the last rains came. When Clanwilliam Dam stops spilling a portion of the available storage is kept in reserve and the remainder is distributed amongst the various users to meet their requirements until the start of winter, about mid-May.

4.4 Modelling of the historical system

Inflows to Clanwilliam Dam were inferred using the "reverse mass balance" method. Inflows were then compared with historical inflow determined in the Olifants River System Analysis (ORSA). For the system analysis the streamflows generated during the original ORSA were retained because, following evaluation, they were deemed to be acceptable. The development of a naturalised set of flows was not requested. The natural MAR of the Olifants River above the Clanwilliam Dam is 356 million m^3.

The historical inflow sequence derived was checked to see how accurately it simulated the historical behaviour of the system. The simulated historical trajectory generally compares very favourably with the actual trajectory. The average supply from the LORGWS (Clanwilliam Dam and Bulshoek Weir) to users over the last 25 years was estimated as 174 million m^3/a, although during droughts the supply would have been curtailed.

4.5 Meeting ecological water requirements

In its natural state the MAR of the Olifants River was 1 055 million m^3/a. During winter about half the streamflows were provided by the Doring River tributary, while during summer the Doring River dried up and the perennial Olifants River provided the estuarine baseflow. Developments in the Olifants River catchment as a whole have reduced the streamflow by 32%.

The proposed dam raising could potentially increase the Dam's storage to 100% of the original inflow. If Clanwilliam Dam is raised then the dam will absorb more of the winter streamflows before it spills and, as a result, the spillage over the Dam will be reduced and delayed.

To meet estuarine summer Reserve flow requirements, releases need to be made from Bulshoek Weir to supplement the streamflow at Lutzville, to increase the streamflow to about 1.5m^3/s. However, proper management is required to ensure that irrigators located downstream do not intercept these ecological releases. In addition to the need for baseflows from the Olifants River, the estuary also requires flood flows during winter. During early winter the Doring River provides these high flows, as the Clanwilliam Dam currently impounds the streamflows in the upper Olifants River until it starts to spill.

4.5.1 Upstream of Clanwilliam Dam

The raising of the Clanwilliam Dam will obviously not impact the reach upstream of the Clanwilliam Dam, but the management of this reach could affect the Clanwilliam Dam. This river reach is in a D ecological Category (EWR Site 1 at Citrusdal).

During the summer months, the naturally perennial Olifants River can be pumped dry, sometimes for up to several weeks. The pumping from boreholes located alongside the river has aggravated the situation. One option to reduce the pumping from the river is to increase the storage of winter water for use in summer. Unless proper controls are in place this might not reduce the summer pumping but will only further reduce the streamflow entering the Clanwilliam Dam.

4.5.2 Between Clanwilliam Dam and Bulshoek Weir

The Dam intercepts winter highflows and releases water for irrigators downstream. During summer, Clanwilliam Dam releases up to 8 m^3/s, significantly more than natural summer baseflow, down to the canal at the Bulshoek Weir. In winter, the Dam releases about 0.5 m^3/s to irrigators, who do not receive accruals from the Jan Dissels River, located just downstream of the Dam. The flow regime is therefore already highly modified, and it cannot be reversed to better replicate the natural flow regime.

The multilevel outlet works proposed for the raised Clanwilliam Dam will be able to provide the triggers to encourage the spawning of the Clanwilliam Yellow Fish during spring. Freshettes released from the Dam for fish spawning could be captured in Bulshoek Weir, and could potentially be released in combination with releases for irrigation.

4.5.3 Between Bulshoek Weir and the Doring River confluence

The environmental flow requirement for the 18 km long reach between the Bulshoek Weir and the confluence with the Doring River could significantly affect the viability of any proposed raising of the Clanwilliam Dam. There was unanimous agreement from the ecologists that the attainment of a D-category at EWR Site 2 in this reach was unrealistic, and a 'residual flow' was instead recommended, to maintain this river reach in a category E, provided the Doring River remained undammed and thus remained able to provide the bulk of required ecological flows at the estuary.

The principle adopted was that no releases for high flow requirements would be made from Bulshoek Weir for the downstream reach. The option of meeting Drought EWR requirements for the downstream reach for the 0 m raising option, and meeting the Baseflow EWR requirements for the 5, 10 and 15 m raising options was adopted.

4.5.4 Estuary

The present ecological state of the estuary was assessed as a Category C but is worsening. Improved management, reducing the impact of the non-anthropogenic activities, could help to maintain the estuary as a Category C. The baseflows entering the estuary should be maintained at approximately 1.5 m^3/s.

4.6 System analysis

4.6.1 Scenarios analysed

Various scenarios were analysed, using the WRYM, to determine the historical yields of the system for the existing (unraised) dam and for three different dam raisings of 5, 10 and 15 m. The scenarios also determined the influence on yield of making releases from Clanwilliam Dam, to meet the EWRs downstream of the Bulshoek Weir and at the estuary.

Flows from the Doring River were assumed to supply the winter flood requirements at the estuary. A minimum summer baseflow of 1.5 m^3/s was maintained at the causeway at Lutzville. During the peak summer irrigation months, up to 1.2 m^3/s is supplied by return flows from irrigation along the Lower Olifants River Canal. Shortfall in the baseflow was augmented by modelled releases.

4.6.2 Yield

From **Table 4.2**, when compared to the current system, with a drought EWR implemented (historical firm yield (HFY) of 133 million m^3/a) the increase in HFY is 32, 59 and 73 million m^3/a, respectively. When compared to the current system with no EWR implemented (HFY of 149 million m^3/a), the increases in the HFY are 16, 43 and 57 million m^3/a, respectively.

Table 4.2 Yield analysis results

Scenario	Recurrence interval	Absolute yield				Increase in yield with regard to current system yield			
		Dam raising				Dam raising			
		0 m	5 m	10 m	15 m	0 m	5 m	10 m	15 m
No EWR	1 in 5 yrs	185	235	274	305	-	50	89	120
	1 : 10	175	219	248	275	-	44	73	100
	1 : 20	169	197	234	263	-	28	65	94
	HFY	149	184	213	227	-	35	64	78
Drought EWR	HFY	**133**	169	199	214	-	36	66	81
Baseflow EWR	1 in 5 yrs	168	213	254	279	-	45	86	111
	1 : 10	161	196	225	254	-	35	64	93
	1 : 20	156	184	213	242	-	28	57	86
	HFY	128	**165**	**192**	**206**	-	37	64	78
Full EWR	1 in 5 yrs	161	203	238	266	-	42	77	105
	1 : 10	154	183	207	239	-	29	53	85
	1 : 20	142	160	195	218	-	18	53	76
	HFY	124	157	172	187	-	33	48	63

The yield for the situation where the baseflow EWR is supplied is shown in **Figure 4.2**.

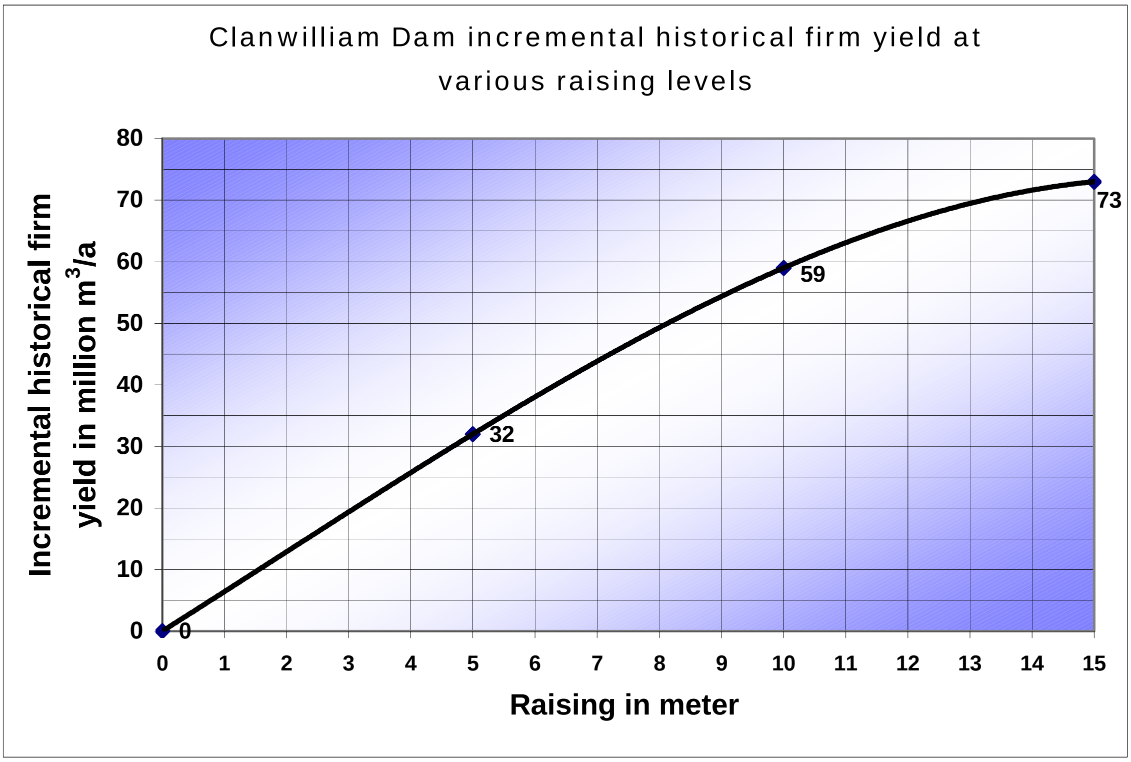

Figure 4.2 Incremental historical firm yield of a raised Clanwilliam Dam (determined as Baseflow EWR firm yield less Drought EWR firm yield for unraised dam)

When the dam size is increased, the operation of the Clanwilliam Dam will need to be changed from using almost all of the available water each summer to allowing for a carry-over from year-to-year for drought years.

4.7 Historical and stochastic yields

An analysis of assurance of supply, for the crrent system and for the Dam raising options, is shown in **Figure 4.3**.

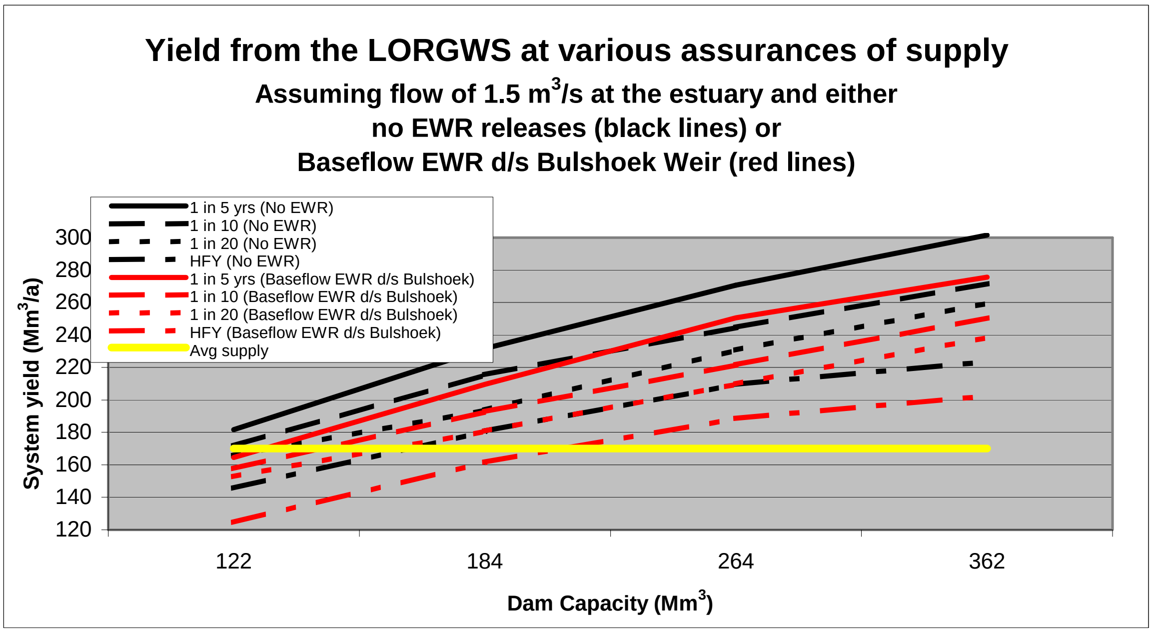

Figure 4.3 Yield from the LORGWS at various assurances of supply

4.8 Diversion potential and rules upstream of Clanwilliam Dam

The potential for additional diversion from this river reach was assessed by analysing diversions for a range of flows, up to 3 m^3/s, from daily flows, for a 72-year period. It was concluded that the potential to pump additional water from the upper Olifants River during winter, for use during summer, does not pose any constraint.

It is recommended that the increased pumping of winter water, for storage and use during summer, be encouraged, to significantly limit the pumping from the river during the summer months, to improve the ecological condition of the upper Olifants River. This requires a change in the licence condition for current abstraction from the Olifants River upstream of Clanwilliam Dam, strict enforcement of limited pumping during summer, and potentially outlawing of boreholes in, or close to, the riverbed, that affects river flow.

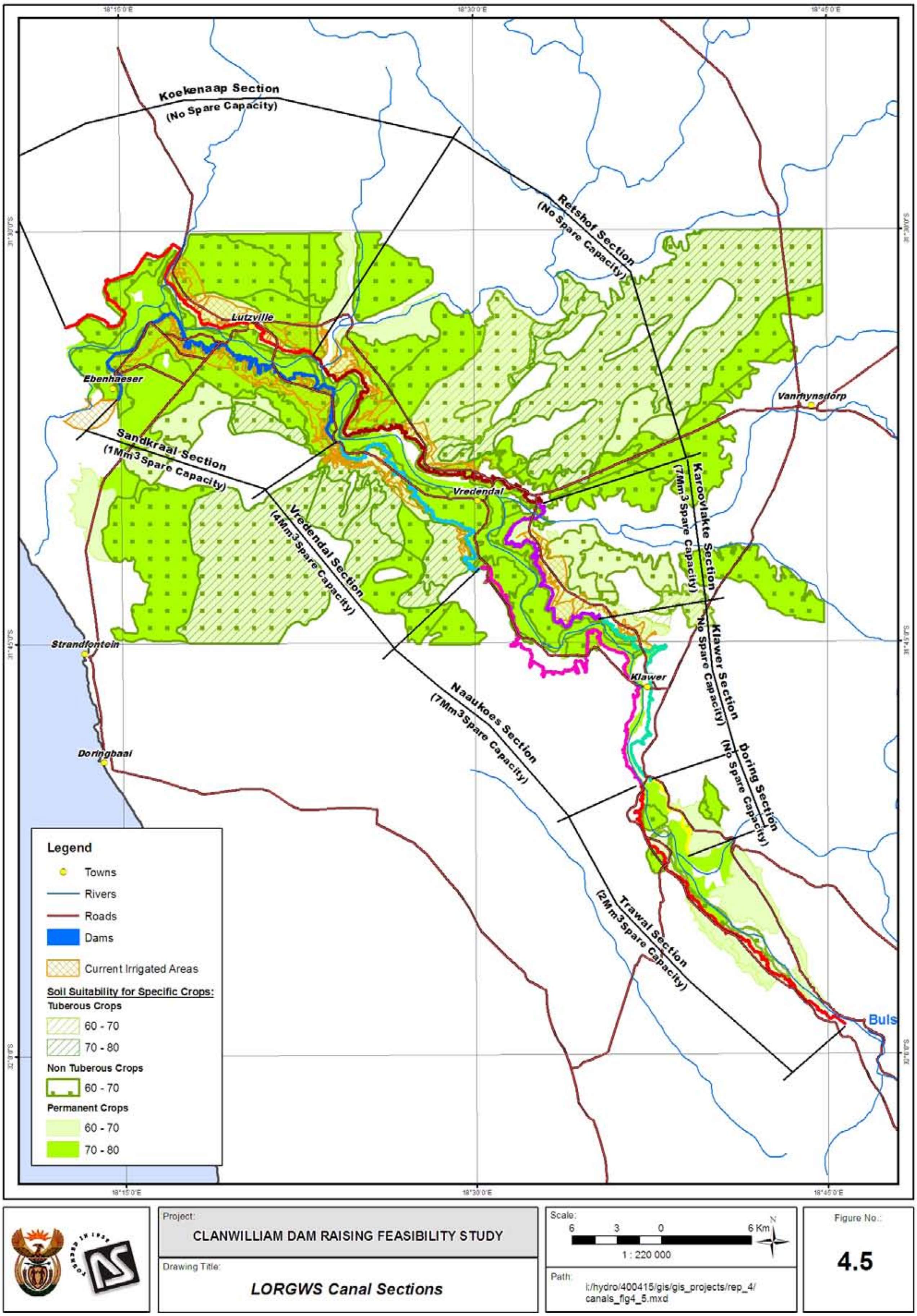

Figure 4.4 Spare capacity in LORGWS canal sections and soil suitability for specific crops

4.9 Distribution of additional water

The capacity of the Lower Olifants River Canal system is constrained by the capacity of the upper reach of the left bank main canal and the upper reach of the main branch canal on the right bank, but there is additional spare capacity lower down in both cases. Spare capacity in canal sections is illustrated in **Figure 4.4**. To access the spare capacity lower down the canal, water can be released down the Olifants River, from the Bulshoek Weir, and pumped back into the canal lower down, before the water becomes too saline. It was estimated that up to an additional 87 km^2 could potentially be irrigated if additional water is pumped into the Naaukoes and Karoovlakte reaches. These releases down-river would blend with the saline irrigation return flows but the resultant water in the canal could still be acceptable, if pumping took place above the Karoovlakte reach of the canal, provided that the water for the Vredendal section is pumped in further upstream at Naaukoes.

5. WATER QUALITY

5.1 Introduction

Two water quality related studies were identified for further investigation. These related to potential changes in the thermal structure of the impoundment and potential changes to the eutrophication status of the impoundment and the canals system of the LORGWS, and entailed:

- An increase in the height of the Dam wall would affect the thermal structure and dynamics of the impoundment. The potential impact of raising the Dam wall on thermal stratification and release temperatures needed to be investigated as well as the mitigating effects of installing a multi-level outlet structure.
- Users raised concerns about the potential impacts on eutrophication. Raising the Dam wall would affect the water residence time in the impoundment, which may in turn affect its trophic status. Concerns were also raised about the potential impacts on algal problems experienced in the canals of the LORGWS.

5.2 Potential impacts on the thermal regime of Clanwilliam Dam

With an increase in the Dam height, water quality related concerns such as thermal stratification and unsuitable temperatures of released water could become a reality and would thus have to be quantified before the actual raising of the Dam. The water quality requirement is predominantly a temperature constraint due to the spawning requirements of the Clanwilliam Yellow Fish. The temperature of water released from the dam should be within the range of 18-24^{o}C during the months of October-January. The water being drawn off from a low level in the impoundment, during the spring and summer months, is normally cold (significantly below 18^{o}C). The current Dam could not meet either the discharge requirement or the temperature requirement for releases, should releases only be made from the bottom outlets. The change of dam design from a gated structure to a solid crest for a raised dam is also likely to exacerbate this situation, as spills will be fewer than with the existing situation.

The current structure is a "bottom-release outlet structure", where water is released from the bottom of the impoundment only. It was therefore proposed that a raising in the height of the Dam wall should be accompanied by a multi-level outlet structure. The alternative, "multilevel outlet works" is considered more sophisticated and more viable in terms of meeting ecological water quality requirements. This entails having release structures at various levels, allowing water from different depths (and therefore different temperatures, salinity and so on) to mix in an attempt to meet downstream water quality requirements.

In addition, a case with one less multi-level outlet was also modelled and showed that the desired target temperature of 18ºC could still be attained, provided that the dam water level at the beginning of November was at 105 mamsl or higher.

The temperature-related changes that could be expected from the raising of the Dam, as well as the mitigating effects of installing a multi-level outlet structure, was investigated by using the CE-QUAL-W2 two-dimensional, laterally averaged, hydrodynamic and water quality simulation model. The original daily volumes released from the bottom outlet structure were split amongst the various off-takes in the multi-level outlet structure to ensure that not only cold bottom waters were released and in an attempt to reduce the depth of stratification that may accompany the raising of the Dam. An example of this output is depicted in **Figure 5.1**, where the in-lake temperature for the bottom outlet scenario**,** shows that bottom releases would assist in destratifying the reservoir, due to the release of colder water and subsequent intrusion of warmer water from the upper layers in the reservoir, for the 15 m raising option.

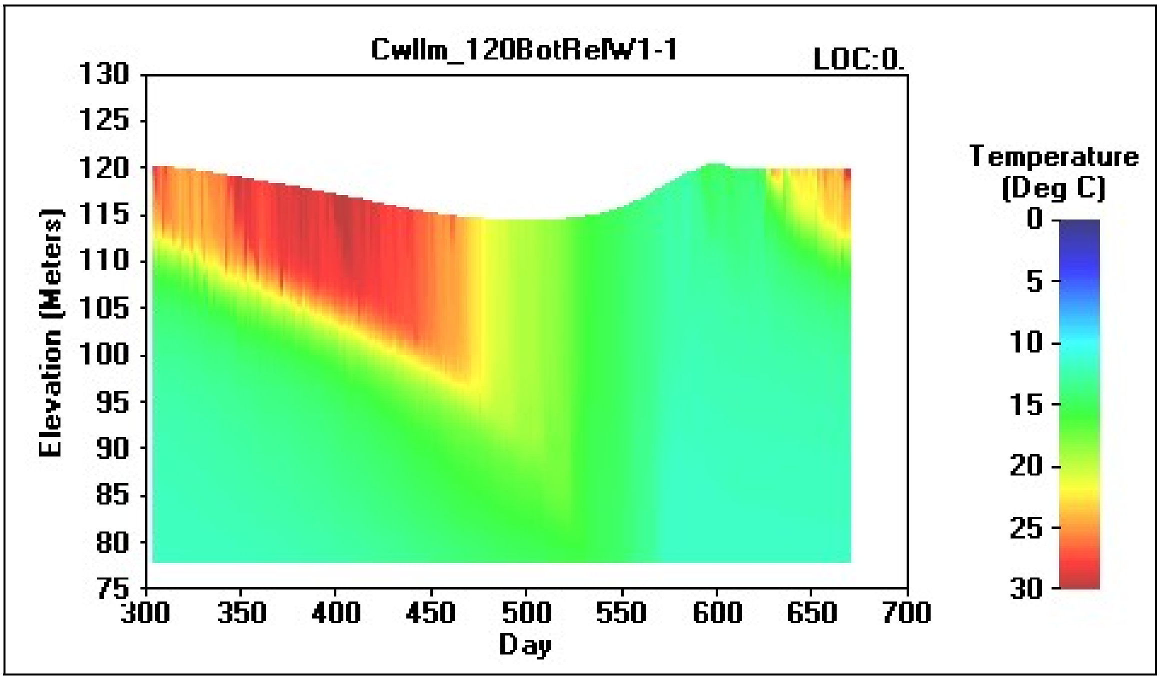

Figure 5.1 In-lake temperature conditions for bottom-release scenario (15m raising)
(Julian day 300 = 27 October 1994)

The in-lake temperature conditions for the multi-level offtake structure for a 15 m raising are shown in **Figure 5.2**. As before, a cooling of the hypolimnion is experienced towards the end of summer.

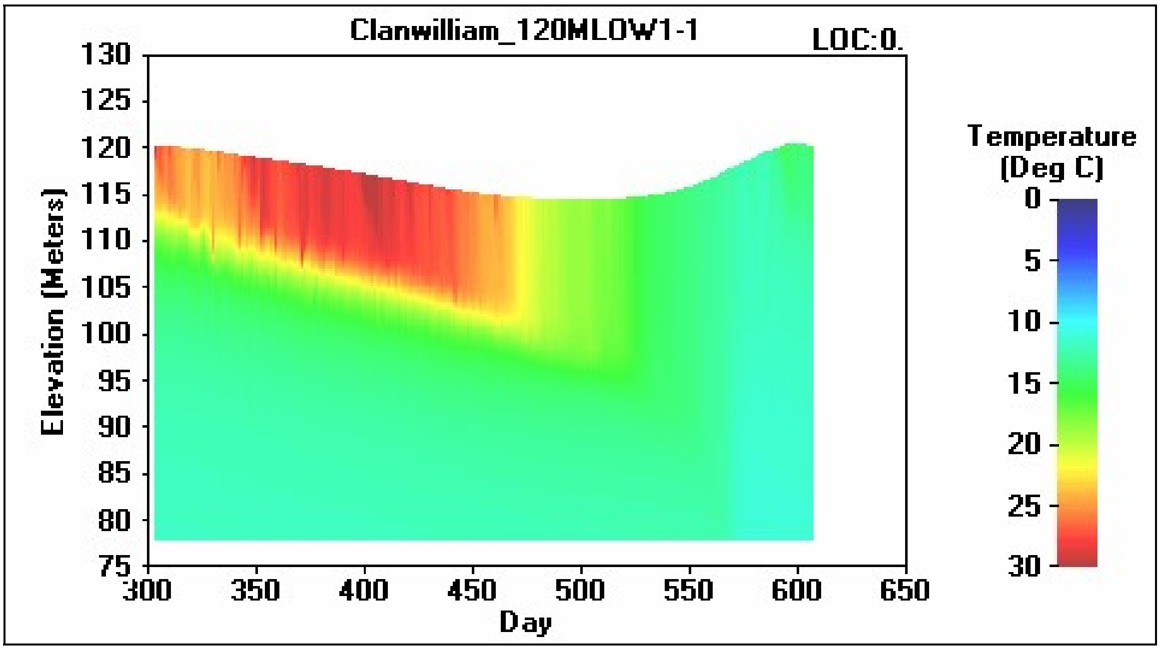

Figure 5.2 In-lake temperature conditions for multi-level offtake scenario (15m raising)
(Julian day 300 = 27 October 1994)

Based on the aforementioned release heights and the assumption that the impoundment was full at the beginning of November, and taking into account the specific release volumes from each height, it was found that the target temperature of 18ºC downstream of the Dam could be met during the early parts of November, for all the scenarios. The additional outlet configuration modelled also showed that the desired target temperature of 18ºC could still be attained, provided that the dam water level at the beginning of November was at 105 mamsl or higher.

It was concluded that a raising in the height of the Dam wall should be accompanied by a multi-level outlet structure, which would release water from various levels, thereby allowing water of different temperatures to mix in an attempt to meet the downstream temperature requirements. This would to some extent offset the impacts on reduced flows in the downstream river. Implementation of a multilevel outlet structure is not proposed for the case where the Dam is not raised, as the dam in most years naturally spills in late winter/early spring, due to its small size relative to the MAR.

The temperature of the Dam releases, with and without the multi-level outlet structure, is depicted in **Figure 5.3**, which shows that it would be possible to meet the downstream temperature requirements, in the appropriate time period, using a multi-level offtake structure with off-takes at defined levels. This was, however, based on the assumption that the impoundment was full on the first of November and that the highest available outlet could be used to make the releases during early November.

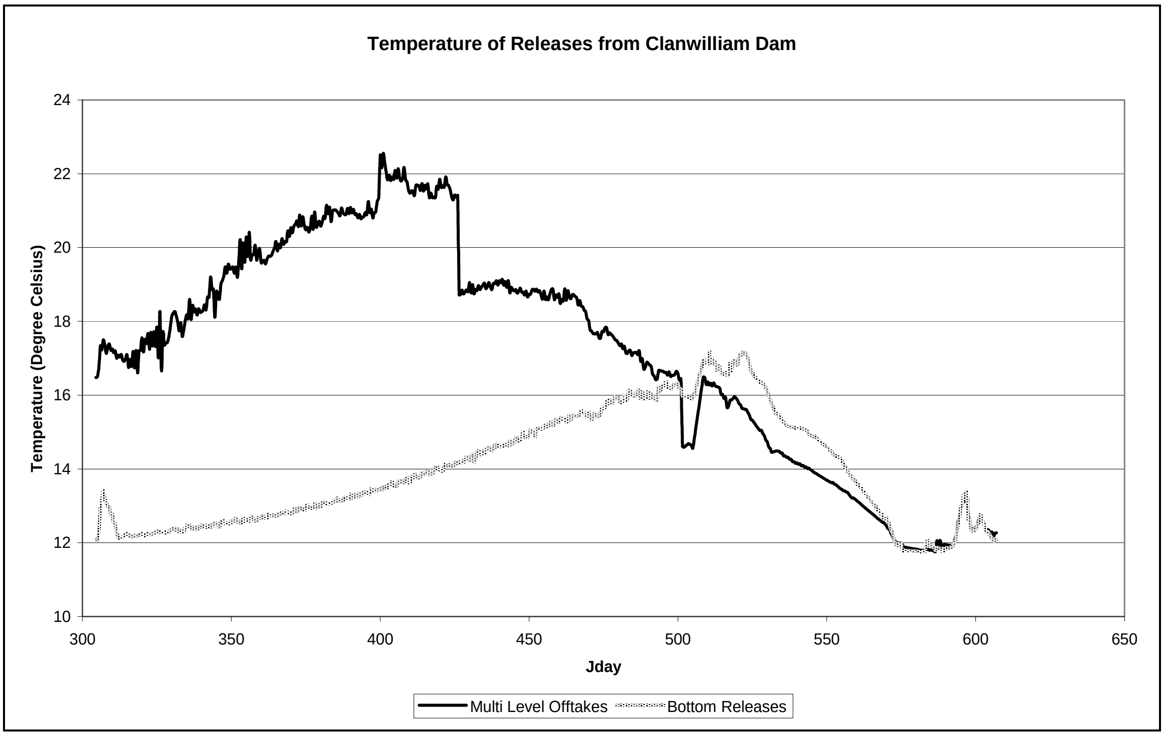

Figure 5.3 Temperature of dam releases for a 15m raising
(Julian day 300 = 27 October 1994)

Reducing the number of offtakes below 110 mamsl could lead to the target temperature not being met at the beginning of November, especially if the Dam does not reach its full supply level during the winter months.

5.3 Potential impacts on the eutrophication status of Clanwilliam Dam

A reconnaissance-level assessment of the present nutrient and eutrophication status of the impoundments of the Clanwilliam Dam and Bulshoek Weir was undertaken, using available monitoring data and published or anecdotal information. The assessment included a synthesis of data and information that was available about the growth of filamentous algae in Bulshoek Weir and specifically in the canal system of the LORGWS. Assessment of the potential impacts of the dam raising on the eutrophication status of the impoundment was undertaken using simple, management-oriented assessment tools.

5.3.1 Algal growth potential in Clanwilliam Dam and Bulshoek Weir

Based on the water quality data records available at Clanwilliam Dam and at Bulshoek Weir, from 1998 to present, it was concluded that both impoundments could be classified as being oligo-mesotrophic. This means that in terms of nutrient enrichment, the impoundments are in an unenriched to moderately enriched state. The chlorophyll-*a* concentrations that have been collected at the impoundments since 2005, as part of the National Eutrophication Monitoring Programme, confirm these conclusions.

The potential impacts of raising Clanwilliam Dam on its trophic status were modelled using the simple web-based Nutrient Enrichment Assessment Protocol for South African reservoirs. It was found that if the phosphorus loads into the Clanwilliam Dam impoundment remain the same as present day loads, but the water residence time increased from 0.34 to 1.04 years, then a slight increase in the chlorophyll-*a* concentrations can be expected. It is estimated that by raising the dam wall by 10 m, the impoundment may on average still be in an oligo-mesotrophic state, with maximum chlorophyll *a* values bordering on eutrophic conditions. By raising the dam wall by 15 m, it is estimated that the impoundment may on average remain in an oligo-mesotrophic state, although the maximum chlorophyll-*a* concentrations could fall within eutrophic conditions.

It was concluded that Clanwilliam Dam impoundment is in a good trophic state and it was estimated that, provided the phosphorus loads remain unchanged, there would probably not be a major shift in trophic status if the dam wall is raised. If an increasing trend is detected in the inflowing nutrient loads, then the potential impacts on the trophic state of the impoundment should be estimated and, should it result in a major shift from an oligo-mesotrophic state to a meso-eutrophic state, a nutrient management plan should be developed and implemented for the catchment.

5.3.2 Filamentous algae in the irrigation canals

Discussions with staff of LORWUA confirmed that problems with filamentous algae in the canals date back to at least the early 1980s. The problem of nuisance algae used to occur in the lower reaches of the canal system in the Lutzville area. However, over time the problems have progressed in an upstream direction and these now occur from about the Vredendal area. The LORWUA has implemented an annual treatment programme to prevent the filamentous algae from reaching problematic proportions. The programme involves dosing the canals with a copper sulphate compound and the location, frequency and severity of treatments are guided by the algal biomass observed in the canal system during the high irrigation months (October to February). Research on filamentous algae in canals concluded that there was a weak link between nutrient availability, and, algal growth and that these algae could grow even under very low nutrient concentrations, if other limiting factors such as suitable substratum, flow velocity and underwater light climate were favourable.

It was concluded that the raising of Clanwilliam Dam would probably have little impact on the growth of filamentous algae in the lower reaches of the canal system. The current use of the canal system is very close to its design capacity and there appears to be little scope for transporting more water through the system without major modifications to the canal system. The implication in terms of filamentous algal growth is that there would probably be little change from the current situation and the current impacts would probably continue.

Given that the raising of Clanwilliam Dam would probably not have a significant impact on the filamentous algal growth dynamics in the lower reaches of the canal system, no further mitigation measures are required.

6. GROUNDWATER RESOURCES

6.1 Geological and hydrogeological context

The Clanwilliam Dam is located within a roughly N-S trending syncline in the Table Mountain Group (TMG) known as the Olifants River Syncline (ORS). NW-SE-striking faults crossing the area form sub-parallel, continuous, interconnected systems, extending over distances of more than 100 km. Together, these systems constitute "megafault" zones and are also known as hydrotects since they are the preferred flowpaths for groundwater in the TMG Aquifers.

The main stratigraphic units represented in the study area belong to the TMG and the Bokkeveld Group. The TMG underlies the Bokkeveld in the centre of the valley, extending to significant depths (~4 km below ground). About 25 km upstream of the Clanwilliam Dam one finds a 40 km stretch of sandy alluvium, while downstream sandy alluvium is present for 15 km north of the Dam wall. The TMG comprises three distinct units; the Peninsula Formation, which underlies the Cedarberg Formation that in turn, underlies the Nardouw Group. The Cedarberg Shale separates the more dominant quartzitic units, which are also aquifers, and generally acts as an aquiclude, i.e. it limits movement of groundwater between the two quartzitic aquifers. The Peninsula Formation dominates the high lying areas that also receive the most rain as well as intermittent snowfalls. The Nardouw Group forms the lower lying hills on the valley sides. There are three distinct lithologies in the Nardouw Group.

The dominantly quartzitic units of the TMG are well bedded and contain fractures and joints related to regional faulting. These give the formations what is known as secondary permeability that defines a fractured rock aquifer. There are three aquifers in the TMG. These are the Peninsula Aquifer (1 300 m thick), the Skurweberg Aquifer (120 m thick) and the Rietvlei Aquifer (120 m thick). The latter two are two of three units in the Nardouw Group. The composite thickness of the TMG is ~ 1.8 km. The Cedarberg Shale is ~ 100 m thick.

This hydrogeological investigation aimed to investigate the potential to optimise the conjunctive use and management of water in the valley and to identify any key issues and concerns that require further investigation. The reason for this is that an earlier study indicated that conjunctive use could increase the yield of the Clanwilliam Dam (before raising the wall) by at least 45 million m^3/a if the TMG Aquifers were to be developed. The aim was therefore to establish the groundwater potential of these aquifers at a higher level of confidence, within the context of the dam raising.

Two formations, *viz*. the Peninsula and the Skurweberg are preferred aquifer targets and are to a limited extent explored by the farming sector at present. The farming sector has primarily developed the Rietvlei Aquifer. The farmers use the groundwater to augment surface water supplies or for use as an emergency supply during summer, largely for the irrigation of citrus crops in the areas upstream and downstream of the Dam.

The available data suggests that the regional groundwater flow direction in the study area is in a NNE direction, driven by a head at the altitude of the high mountains of the eastern limb of the syncline where the aquifers are exposed and recharged. It is heated at depth in the base of the syncline and emerges in parts at hot springs and seep zones on the western limb, at discreet sites on the Sandveld and directly into the ocean at Velddrif and Elandsbaai (Redelinghuys).

There is a component of flow northward along the fold axis of the ORS. The more local scale groundwater flow regime is controlled by local scale faulting and fracturing with a dominant east west trend, resulting in the interaction between the Clanwilliam Dam water and the local groundwater.

6.2 Hydrogeological analysis

A total of 29 target zones for wellfield development have been identified (see **Figure 6.1**). These lie within two of the three confined artesian basins herein called the Clanwilliam Trough (CWT) and the Citrusdal Syncline (CDS). Each of the two basins is considered as a separate scheme and target zones falling within the two schemes have been grouped accordingly (see **Table 6.1**). The CWT is subdivided into three potential sub-schemes for development (also called phases) containing 4, 4 and 2 target zones, respectively. The CDS is subdivided into four phases containing 6, 7, 2 and 4 target zones, respectively. Each target zone can comprise one or more wellfields.

Table 6.1 Target zones for wellfield development grouped according to schemes

Scheme	Sub-scheme/Phase	Target Zone	ID
Clanwilliam Trough	A	1	CWT1
		2	CWT2
		3	CWT3
		10	CWT10
	B	6	CWT6
		7	CWT7
		8	CWT8
		9	CWT9
	C	4	CWT4
		5	CWT5
Citrusdal Syncline	D	1	CDS1
		2	CDS2
		3	CDS3
		4	CDS4
		18	CDS18
		19	CDS19
	E	5	CDS5
		6	CDS6
		7	CDS7
		8	CDS8
		15	CDS15
		16	CDS16
		17	CDS17
	F	13	CDS13
		14	CDS14
	G	9	CDS9
		10	CDS10
		11	CDS11
		12	CDS12

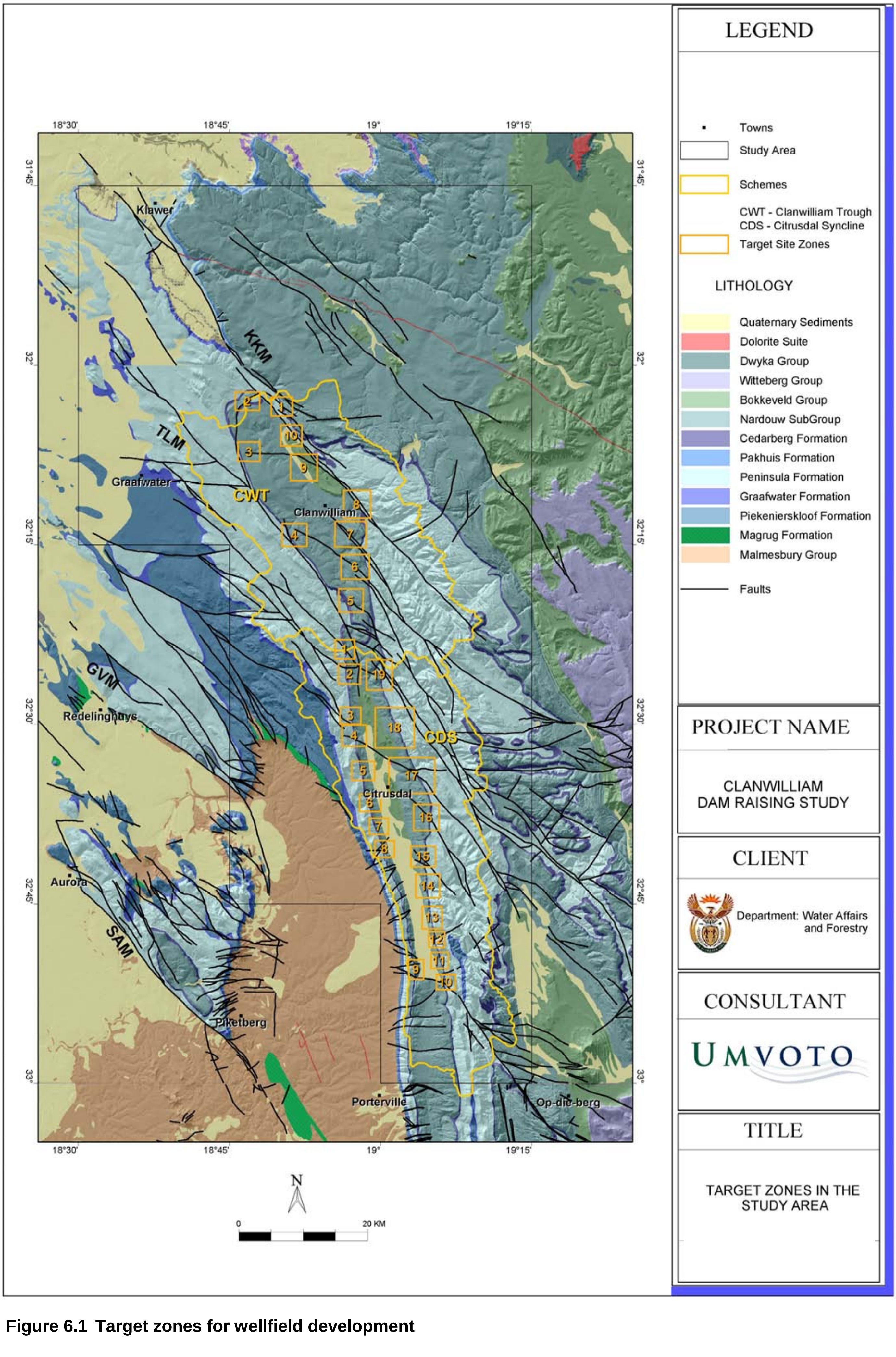

Figure 6.1 Target zones for wellfield development

Modelling of the separate storage for the Peninsula Aquifer and the Nardouw Aquifer was undertaken, using an in-house model, calculated rock volumes and aquifer volumes based on physically correct data. Particular attention was paid to the apparent thickness variations of the aquifer around major fold structures and faults.

The total solid material volume of the Peninsula Aquifer is 3 trillion (10^{12}) m^3. A very low assumed porosity (0.05) yields a saturated pore volume for the Peninsula Aquifer in the study area (2 308 km^2) of 146 billion (10^9) m^3. The amount of water stored in the confined portions of the Peninsula Aquifer is estimated at 47 billion m^3.

Recharge to the deeper part of the Peninsula Aquifer takes place in the mountainous area on the eastern limb of the Olifants River Syncline. The MAP in these zones is greater than 1 000 mm/a and the elevation is ~ 1600 mamsl. From here the groundwater flows in a NW direction along preferred flow paths known as hydrotects.

The recharge to the Peninsula Aquifer was calculated using several methods (e.g. GIS based Water Balance, Chloride Mass Balance, Isotopes), resulting in a conservative estimate of 236 million m^3/a. Taking baseflow requirements and current groundwater use into account, up to 160 million m^3/a are available for groundwater abstraction in the long-term. The yield of the aquifer further depends on the dynamics between recharge, storage and discharge, and the management of the storage capacity.

The storage yield model used the results from the storage model to calculate the yield of the Peninsula Aquifer and Skurweberg sub-aquifer for both the CWT and CDS schemes in various case scenarios. Since the groundwater abstraction is proposed for the confined portion of the aquifer only, the regional hydraulic head decline due to abstraction depends upon the storativity of the aquifer.

The volumes of water elastically released from confined storage, due to a 1 m head or pressure decline causing mainly porosity reduction (aquifer compression), are just a small fraction, less than 0.01% of the total amount of subsurface water, *viz*., 5.56 million cubic meters only.

6.3 Groundwater schemes and wellfields

The total volume of water stored in the confined portions of the Peninsula Aquifer and Skurweberg sub-aquifer are tabled below (see **Table 6.2**) together with the yield (water available for abstraction) of these basins given a regional drawdown in the piezometric surface of 1, 5, 10, 20 and 50 m. How much water to actually abstract is an aquifer design and management decision and would take into consideration:

- Impacts of abstraction;
- Social factors;
- Economic advantages;
- Advantages (environmental and yield) arising from conjunctive use;
- Water saving arising from conjunctive use; and
- Additional yield from conjunctive use (~30%) and impacts (this additional yield is obtained only from dam development).

The yield or volume of water abstracted that would result in a 1, 5, 10, 20 or 50 m hydraulic head decline is never greater than 1.2% of the total pore volume (see **Table 6.2**).

Table 6.2 Yield of the CWT and CDS scheme basins

Scheme	Rock Volume	Pore Volume	Volume per head decline of :									
			1 m		5 m		10 m		20 m		50 m	
	Mm^3	Mm^3	Mm^3	%	Mm^3	%	Mm^3	%	Mm^3	%	Mm^3	%
CWT	465,748	23,287	2.78	0.02	13.88	0.12	27.77	0.24	55.54	0.48	138.84	1.20
CDS	495,240	24,762	2.92	0.02	14.62	0.12	29.25	0.24	58.50	0.48	146.24	1.19

Table 6.3 Yield Estimation per groundwater scheme (Mm^3/a)

Scheme	Aquifer	Water in Storage (confined)	Recharge	Baseflow	Groundwater Use	Yield for 20m head decline	Groundwater Yield
CWT	Peninsula	23,088	81.8	16.1	3.6	55.05	67.4
	Skurweberg	200	11.7	1.7	0.3	0.49	11.2
CDS	Peninsula	23,758	118	45.8	7.8	56.09	64.4
	Skurweberg	1,004	24.6	6.7	0.9	2.41	17
Total	Peninsula	46,846	199.8	61.9	11.4	111.14	131.9
	Skurweberg	1,203	36.4	8.3	1.2	2.89	28.2

The average estimated cost of wellfield development is R 30.8 million (Rm) per Target Zone, yielding an average of 4.3 million m^3/a. On average, there are three Target Zones per sub-scheme.

Except for the most costly sub-scheme, the URV ranges between R 0.43/m^3 and R 0.76 /m^3 for the development of a sub-scheme. Sub-scheme E is the most costly with a URV of R 1.04/m^3.

Table 6.4 Costs per sub-scheme in the Clanwilliam Trough Scheme

CWT	Sub-Scheme			
Scheme details	**A**	**B**	**C**	**Total**
Yield (Mm^3/a)	18.3	22.7	22.9	64
Total Development Costs (Rm)	97	174	104	377
Annual Running Costs (Rm)	1.76	2.27	2.16	6.19
URV (R/m^3)	0.49	**0.67**	**0.43**	**0.53**

Table 6.5 Costs per sub-scheme in the Citrusdal Syncline Scheme

CDS	Sub-Scheme				
Scheme details	**D**	**E**	**F**	**G**	**TOTAL**
Yield (Mm^3/a)	14.9	16.8	13.2	15.9	61
Total Development Costs (Rm)	132	212	77	99	521
Annual Running Costs (Rm)	1.53	1.82	1.28	1.54	6.18
URV (R/m^3)	**0.76**	**1.04**	**0.53**	**0.56**	**0.73**

7. SOILS, WATER REQUIREMENTS AND CROPS

7.1 Soil survey

A soils map was compiled for the Olifants River Basin from Keerom, south of Citrusdal, to the coast. The lateral extent of the area covered was average about 60 m above the level of the river or existing canals or an agreed horizontal distance away. The soils map is based on:

i) The extensive reconnaissance soil survey of the Citrusdal valley from the Clanwilliam Dam south as far as Keerom,
ii) The extensive, more detailed Western Cape Olifants/Doring River Irrigation Study (WODRIS; Provincial Government Western Cape, 2003),
iii) Data from other soil studies; and
iv) Expert knowledge.

The next step was to develop a new soil map legend. A simple two-level legend, consisting of an upper level of soil groups and a second level of soil complexes, was compiled. Twelve soil groups were defined. Soil groups were subdivided into soil complexes based on selected soil properties. In addition to the description of the different soil complexes, the dominant (occupies more than 60% of the map unit) and subdominant soil forms and families were determined. There is a pronounced difference in the dominant soil complexes between the southern and northern sections of the basin.

7.2 Soil suitability for irrigated crop production

Soils in the Olifants River Basin have a variety of naturally occurring soil properties that restrict the ability of plant roots to develop and absorb water and nutrients. These include physical and morphological as well as chemical limitations. Based on experience the degree to which any particular soil property might act as a limitation was qualified as none, low, moderate, severe or variable in the various soil complexes.

An expert system approach was used to evaluate the potential of the different soil complexes for the production of annual and perennial crops. Five classes were used. Three soil specialists with a sound knowledge of irrigation farming in the Olifants River Basin evaluated the potential, primarily physical, of soil complexes for irrigated crop production of annual and perennial crops, before and after amelioration of subsoil limitations.

Based on these evaluations about 2 000 ha are recommended for perennial crops (e.g. citrus and wine grapes) in the southern section of the catchment from Keerom (upper Olifants River) to Bulshoek Weir. Another 19 000 ha are marginally and conditionally recommended provided that subsoil limitations are properly ameliorated. About 8 600 ha of this class has a potential rating that is near the upper limit of the conditionally recommended class. The main limitations in this class are wetness and shallow underlying weathering rock combined with low clay content. These limitations are relatively easy to ameliorate and with judicious irrigation practices approximately 10 000 ha can be used for economic viable production of citrus and wine grapes. Within the lateral extent of the survey approximately 10 000 ha is available in the Keerom to

Bulshoek section for any combination of irrigated annual (tuberous and non-tuberous) and perennial (citrus, wine grapes, mangos) production.

The soils in the surveyed area from Bulshoek to the coast differ greatly from those in the southern section in terms of the dominant limitation(s). Deep, well-drained red sandy soils (soil complexes A 1 and A 2) can be highly recommended for irrigated tuberous and non-tuberous crops without any subsoil amelioration measures. However, these soils are only conditionally recommended for perennial crops due to the very sandy nature and risk of sandblasting. The very shallow soils on dorbank of the F 1 soil complex are totally unsuitable for the production of tuberous crops even after loosening of the hardpan. Non-tuberous crops are conditionally recommended while perennial crops are recommended on these soils after amelioration of subsoil limitation. In this section there is approximately 105 000 ha that can be recommended for the production of perennial crops after amelioration of subsoil limitations, in particular hardpans, and provision is made for leaching and drainage to remove soluble salts from saline environments. Most of the areas recommended for perennial crops can also be used for irrigated non-tuberous annual crop production. In addition to these areas, certain soil complexes that are not recommended for perennial crops, due the very sandy nature of the soils, can be recommended for irrigated tuberous crops.

7.3 Amelioration of physical and morphological soil limitations

Deep soil tillage is used to ameliorate depth limiting dense or hard horizons (e.g. cemented hardpans, dense clay layers, weathering rock and wetness), to mix horizons of varying and different texture, and to eliminate unfavourable chemical conditions (e.g. acidity, salinity) by means of deep placement of ameliorants. The necessity and ideal depth for a specific type of tillage was specified for each soil complex.

Wetness is not a serious natural limitation in the northern section of the Olifants River Basin. In the southern section drainage is essential on soils that are subject to natural or man-induced wetness. If the saline drainage water is dumped into the natural streams and rivers it could lead to eutrophication and salinisation of the lower reaches of the rivers.

Most of the producers/farmers that took part in the Commercial Farmers Workshops considered drainage as a non-essential measure. The estimated leaching requirement (based on soluble salt load and inherent drainage conditions) and recommended deep soil tillage practice and cost were specified for ten dominant soil complexes in the northern and southern sections of the Olifants River Basin.

7.4 Chemical soil composition and ameliorants

During the WODRIS a total of 372 samples were analysed for pH measured in water (pHWater) and resistance (in ohms); of these 174 were analysed in detail. Topsoil samples were analysed for trace elements (Cu, Zn, Mn, B). The results were used for various cation ratio, soluble sodium and lime and gypsum requirement calculations. The soluble sodium content and ameliorant requirement were also determined for each profile to a depth of 900 mm. For the southern section from Keerom to Bulshoek Weir, Olifants/Doring River Basin Study (ODRBS) data, as well 278 analytical data sets received from 8 farmers/producers, were used. Previous land-use as well as soil type was seldom indicated.

On average, the pH of soil samples from Keerom to Bulshoek Weir increases from the south to the north. High pH and Ca values could have a serious effect on the solubility and plant availability of phosphorus (P) and trace elements. Crops sensitive to deficient levels of trace elements, especially Fe, could be seriously affected.

In the Keerom to Bulshoek Weir section the soluble salt content in the soils increases from the south to the north. This increase is associated with a decrease in rainfall from south to north, as well as a greater contribution of shale, compared to sandstone, weathering products as parent material.

An evaluation was undertaken to estimate the requirement for chemical ameliorants for soils in the sections Keerom to Bulshoek Weir and for Bulshoek Weir to the coast. Recommendations have been made for phosphorous, potassium, pH and gypsum requirement.

7.5 Leaching requirement

Many soils in the Olifants River Basin are saline and require leaching to decrease the soluble salt content for sustainable crop production under irrigation. Leaching requirement is defined as the fraction of irrigation water that must be leached through the root zone to control soil salinity at any specific level.

For field crops an electrical conductivity of the drainage water (EC_{dw}) of 800 mS/m is generally considered as the upper limit of salt tolerance. For irrigation water with conductivities of 100, 200 and 300 mS/m, the respective leaching requirements will be 13%, 25% and 38%. The quality of the irrigation water used along the Olifants River Basin is extremely good, with conductivity as low as 25 mS/m. This implies a leaching requirement of $\leq$ 3%.

The problem in the lower part of the catchment area is the naturally high soluble salt content in many of the soils that are potentially suitable for irrigated crop production. These soils should therefore be leached to remove soluble salts to a specific soil salinity level. If an EC_{dw} of 800 mS/m is used as the upper limit of salt tolerance, it implies that the average soluble salt content should be lowered to approximately 100 me/l throughout the soil. A more acceptable and sustainable EC_{dw} of 400 mS/m would imply that the salt content should be lowered to 50 me/l.

Soils with a fairly low salinity could be leached in one irrigation season or year. It is, however, impractical for the more saline soils; five years is probably a more realistic time period.

7.6 Irrigation water requirement

The net average annual irrigation water requirement for deciduous fruit, citrus and grapes based on eight crop factor suites, for seven weather stations, from Keerom to the coast, were calculated for the ODRBS (DWAF, 1998). The net average irrigation requirement (excluding leaching requirement) increased from 850 – 1000 mm in the Keerom to Bulshoek Weir section to

1 000 - 1 200 mm in the Bulshoek Weir to the coast section. A leaching component of 10% to 20% was recommended for saline soils in the drier areas.

Net water requirement calculated from class A-pan evaporation values and crop conversion factors only represent water lost through evapotranspiration. The gross "on-land" water requirement can be significantly greater as a function of the type irrigation system, irrigation scheduling and leaching fraction (up to 10% - 20%). Based on the information submitted by farmers/producers the gross water application at Citrusdal for citrus was 8 000 m^3/ha/a and 10 000 m^3/ha/a for drip and micro irrigation respectively, while the net requirement for wine grapes was 7 500 m^3/ha/a and 8 500 m^3/ha/a at Lutzville and Vredendal, respectively.

For the WODRIS, the irrigation water requirement was based on the Irrigation Sub-model of the Water Balance Model (WBM), as modified by the DWAF. Average monthly rainfall for two fairly homogeneous climate zones was used to estimate effective annual rainfall (mm/a) according to the method recommended by the Soil Conservation Services in the USA and used in the "ETCrop" computer programme. The net irrigation requirement (NIR) is the monthly depth of irrigation water required, adjusted for effective rainfall. The annual NIR calculated for wine grapes and vegetables in the cooler region was 805 mm/a and 1 001 mm/a, respectively. In the warmer region the values for wine grapes, table grapes and vegetables were 857 mm/a, 1 037 mm/a and 1 051 mm/a, respectively. An average leaching fraction of 10% was used. Standard irrigation application efficiency factors (drip 95%, micro-jet 80%, sprinkler 75%, centre pivot 85% and flood 65%) were used to convert crop water use to irrigation water requirement. These efficiency factors were decreased by 5% for emerging farmers.

To verify the results of the two previous studies the SAPWAT computer program was used in the present study. Four stations with reliable climate data were used. This program was used to calculate the total irrigation water requirement for a variety of crops and different irrigation systems. The crop water requirement for citrus obtained during the Agricultural Workshops was approximately 300 – 400 mm lower than the SAPWAT estimates. For wine grapes the difference was 130 mm lower, and for vegetables 100 - 200 mm lower. The water requirement for potatoes under centre pivot was approximately the same.

7.7 Crop adaptability

Climate and soil suitability are the most critical factors that will determine the potential expansion of sustainable, economically viable irrigation in the Olifants River Basin. Due to the advanced farming technology and management skills that exist in the intensely developed sections of the catchment, most of the inherent soil limitations do not pose any serious constraints on irrigation development.

Climate information was used to conduct an extensive search for potential crops according to the Ehlers screening system that groups useful plants according to their temperature requirements. This screening process was based primarily on temperature.

According to comments received from workshop attendants climatically adapted crops currently grown in the study area include the following:

- Maize (especially sweet corn) is widely planted from Keerom to the coast.
- Most vegetable crops (e.g. onions, potatoes, tomatoes, sweet potatoes, watermelons, cantaloupes and butternuts) are climatically well adapted and extensively planted.

Planting date is determined by climate. Cabbage, cauliflower, chillies, lettuce, pumpkin, squash and green beans are planted on a small scale for the open market.

- Bitter Seville, citron, lemons, clementine, navel, valencia, satsuma and mandarin are mainly planted in the Clanwilliam-Citrusdal region.
- Grapes are adapted to the climatic conditions along the Olifants River and have a variety of marketing possibilities (e.g. wine, table grapes, raisins, preserving, and "gasohol"). Specific climate sub-zones in the Olifants River Basin have specific advantages in terms of grape production.

Other climatically adapted crops that can be recommended are the following:

- Vegetable crops such as garlic, beetroot, rhubarb and eggplant.
- Subtropical fruit such as avocado, mango (see **Figure 7.1**), papaya, persimmon, granadilla, figs and guavas.
- Nuts such as macadamias, almonds and pecan.

Figure 7.1 Newly-planted mango orchard

7.8 Agricultural workshops

To increase the reliability of qualitative soil suitability evaluations based on soil survey and chemical information, as well as the effect of climate, two round-table agricultural workshops were held. Various farmers/producers in the study area, technical advisors and experts in the citrus, grape and vegetable industries were invited to these round-table discussions with the consultant team.

Each of the compiler groups had to choose at least three soil types that are typical/dominant of their respective farms. The participants completed a questionnaire that covered various aspects pertaining to the soils in the study areas. The questionnaire results were summarised on a soil type basis for the Keerom to Bulshoek Weir and Bulshoek Weir to the coast sections of the study area, and were compared with the results of the soil and crop water requirement study. In most cases the two data sets compared well and confirmed the qualitative soil suitability evaluations based on soil survey and chemical information. There were however certain anomalies regarding deep soil tillage cost and the necessity for drainage.

8. AGRICULTURAL WATER DEMAND MANAGEMENT

8.1 Water Management Plan

The aim of the water demand management investigation was to highlight options available for improved water demand management and to make recommendations on how to improve efficiency and save water, in addition to yield becoming available from a raised Dam. The objective of the Water Management Plan (WMP), as the deliverable, is to improve agricultural water management by stimulating self-analysis and forward thinking on the part of farmers, WUA officials, CMA officials, consultants and advisors.

Developing a WMP, and reviewing it regularly, is a major stimulus to effectively promote co-ordinated action and facilitate negotiations between the CMA, WUAs and other stakeholders. The process does not require expensive data gathering, but uses existing data for its initial implementation and then aims to improve the Plan from year to year.

A first version WMP for the Olifants/Doorn CMA was therefore developed as part of this study. Further information and inputs are needed to develop this WMP into a workable plan for the CMA. One of the major goals of the WMP is to set clear guidelines for communication and water distribution between the WUAs and other stakeholders. After approval, comments should be invited from the WUAs and stakeholders. It is important for the WUAs to develop their own individual WMPs using the Olifants/Doorn CMA WMP as a guideline.

The CMA WMP concentrates on the Olifants and Doring Rivers, and in particular, the Clanwilliam Dam and Bulshoek Weir, the Lower Olifants River Canal and Clanwilliam Canal. These form the main elements in the development of the Olifants River and would be influenced by the raising of the Clanwilliam Dam.

8.2 The Olifants/Doorn CMA

The Olifants-Doorn Catchment Management Agency (ODCMA) will manage the Olifants/Doorn WMA, one of nineteen WMAs in the country, and derives its name from the main rivers draining it, namely the Olifants and Doring rivers. The *Proposal for the Establishment of the ODCMA* was submitted to the DWAF during August 2005 and, after amendments, was approved in August 2006.

Once the ODCMA has been established, the CMA Reference Group will transform into the Catchment Management Committee. The CMA Reference Group will continue to meet after the submission of the proposal for the following reasons:

- To interact with an Advisory Committee on the representation of the CMA Governing Board.
- To discuss any relevant water resource management issues, such as water use charges and water resource development.

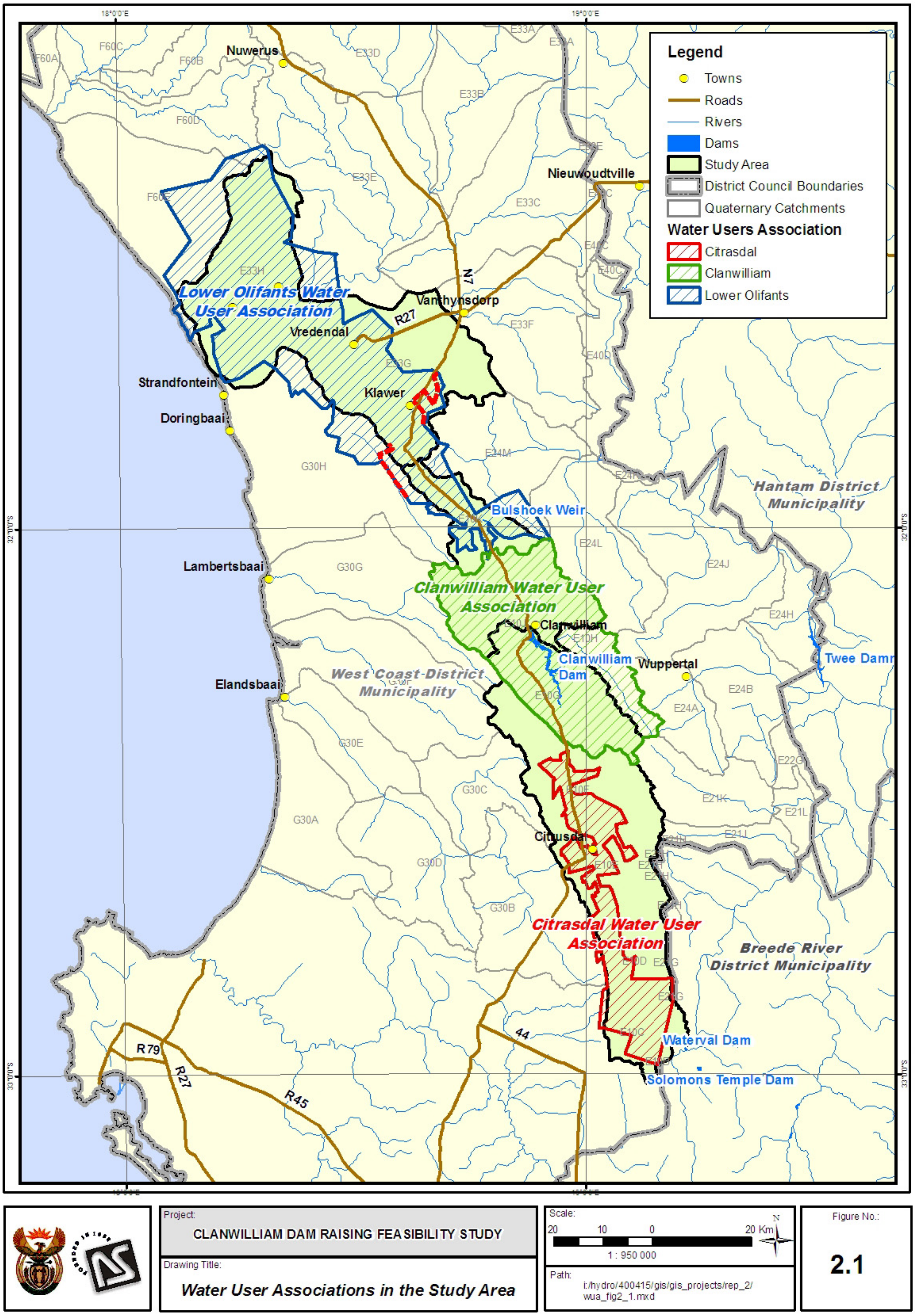

Figure 8.1 Water user associations in the study area

All the rules and regulations applicable to the ODCMA will be in accordance with, and subject to the NWA and the Constitution of the ODCMA, when established. Because the ODCMA has not yet been established no operational capability exists.

8.3 Implementation of the Water Management Plan

Water demand management measures have been identified and discussed as implemented by farmers, irrigation forums/boards of WUAs. Little information is available regarding the irrigation management above the Citrusdal WUA area. The implementation of WMPs in those areas will improve the information and the demand management in that area and can be incorporated in the following WMPs.

The first-order WMPs contain information regarding all the WUAs in the Olifants River catchment area and can be used as discussion points between WUAs. The problems and expectations of the WUAs can be discussed and solutions found. The WUAs in the study area are shown in **Figure 8.1**.

Each type of irrigation system has its own advantages and disadvantages. For flood irrigation one of the main disadvantages is its lower efficiency. An advantage is however that it is cheaper to develop and can easily be left unused for a year if no water is available. An advantage for drip irrigation is its high efficiency, but a disadvantage is the higher capital cost, that needs to be paid back.

Action Plans were developed at desktop level, using the key water resource issues in the "*Proposal for the Establishment of the Olifants-Doorn Catchment Management Agency*", as basis and grouping them under the applicable National Objectives. The Action Plans do not form a complete list of possible activities that the ODCMA has to perform, and it is expected that the CMA would identify further actions, which would be essential to achieve the National Objectives.

The *National Water Resource Strategy* and the *National Water Conservation and Demand Management Strategy* are both cast in a strong strategic management framework. In keeping with this, the WMP is also strongly strategic in its approach to water management.

The overall objective of the Water Conservation and Demand Management Strategy for the agricultural sector is to ensure that water conservation and demand management principals are applied by the agricultural sector, in order to release some water for use within the sector, to open up irrigation opportunities for emerging farmers, to release more water to cater for the needs of competing water users, and to protect the environment. If such water becomes available in a WUA, that WUA will try to sell the water in order to increase its income base. The CMA needs to draw up clear guidelines of how water will be distributed between the different WUAs.

Trying to put equal emphasis on all of the National Objectives at the same time will dissipate and dilute effort, resulting in none of the outputs being achieved. Annual prioritisation, budgeting, assigning of responsible person/s, and a completion date, is essential during the annual review of the WMP.

The CMA must enforce the development of WMPs for the WUAs and then help them each year to evaluate and review their report in order to achieve water conservation and demand management.

9. DAM DESIGN AND COST ESTIMATE

9.1 Dam safety evaluation

Dam safety evaluations of the structure (the most recent in 2005) revealed three aspects that have a detrimental effect on the integrity of the structure:

- The quartzitic sandstone foundation is highly fractured and has a low modulus of elasticity;
- There is doubt about the effectiveness of the pre-stressed cables used in the 1969 raising;
- Alkali-siliceous reaction (ASR) and/or sulphate attack was identified in the concrete.

Analyses incorporating these factors indicated that the stability of the structure under extreme floods is not adequate. It was concluded that remedial works should be done to ensure the safety of the dam, which would entail major construction works.

9.2 Feasibility level design

The remedial work to be undertaken provides an opportunity to also raise the dam more cost-effectively and thereby increase its yield. Implementation of the recently determined Reserve also means that water needs to be released from Clanwilliam Dam/Bulshoek Weir for the ecology. This would require an alternative outlet works arrangement.

A feasibility level design was conducted by DWAF Civil Design: Dam Safety Surveillance to determine feasible raising options for the dam and to determine costs and flood levels. Four raising options, namely no raising, and 5 m, 10 m and 15 m raisings were considered. A number of spillway configurations were investigated and an outlet works configuration is proposed.

9.2.1 Design philosophy

The design philosophy expresses the strategic functional and performance objectives that the designers addressed during the conceptual phase of the design process. The projected milieu in which the structure is expected to function should be matched with the outcomes expected by the stakeholders. The design philosophy developed for the remedial works and/or proposed raising of Clanwilliam Dam was strongly influenced by experience gained through recent design projects and evaluation of existing South African dams. The following aspects were identified as important considerations:

- *Long-term structural reliability*: This implies the elimination of any structural components that deteriorate significantly or unpredictably with time. The use of (unreliable) stressed cables to ensure the stability of the raised concrete gravity section was therefore not considered;
- *Minimal operational requirements/predictable operation*: This implies that the "*operational intelligence"* should be "*built in*" and that the structure should deal safely and predictably with normal and extreme events without the intervention of an operator being required;
- *Minimal maintenance requirements*: This implies that the spillway and non-overspill crest (NOC) should have no regular or "built in" maintenance requirements. Only the inlet/ outlet works can be expected to require regular maintenance;

- *The budget of the sponsor*: In the event of a raising of more than the minimum required for dam safety and environmental purposes, the additional cost will be financed by the water users. The total cost of the raising should be acceptable to the sponsor, given the sponsor's need to keep risk to a practical minimum.

9.2.2 Flood hydrology

The Directorate Hydrological Services of the DWAF conducted a flood frequency analysis for Clanwilliam Dam, in 2005. The analysis was undertaken for the five-yearly dam safety evaluation and was assumed to be adequate for the present design. The 1:200 year flood of 1 705 m^3/s was used as the recommended design flood (RDF). The safety evaluation flood (SEF) is 4 500 m^3/s.

9.2.3 Geotechnical aspects

Alkali-aggregate Reaction (AAR) was identified on the surface of the original structure. For the purpose of this design it was assumed that AAR does not lower the engineering properties of the concrete significantly.

The upper right flank contains a potentially unfavourable siltstone band which could contribute to a failure surface. The siltstone band might require some foundation improvements, but it is not expected to have a major influence on the design of the structure.

Only one leak, approximately 200 m downstream on the left flank, is currently visible. Initial drilling results from the current investigations suggest that the foundation is sound. Foundation grouting should be done to provide for the additional pressure head behind the dam and to ensure adequate shear resistance of the foundation. Dowling might also be required.

A form of apron is recommended. It will serve as both an energy dissipating structure for the spillway and additional shear resistance for the structure on the foundation.

Figure 9.1 Existing quarry to the west of the Dam

For the purpose of stability analyses, 0,075 g, 0,15 g and 0,30 g were accepted as seismic loads for the service, abnormal and extreme loads, respectively.

Results from geotechnical investigations indicate that adequate aggregate is available from an extension of the existing hard rock quarry (see **Figure 9.1**) for the proposed raising by roller compacted concrete (RCC). RCC is the preferred material mainly due to the rapid tempo at which it can be placed, resulting in shorter construction periods and its relatively low heat of hydration. For the purposes of this report the design was based on the use of RCC. The eventual choice of spillway type and construction programme may dictate the use of mass concrete.

9.2.4 Structural stability

The stability of the structure was evaluated for the different raising options based on the traditional thin beam theory.

The water levels used in the calculations were obtained from the results of the spillway hydraulics calculations. Only the water levels from the existing length ogee spillway were used. These values were the highest and thus provided the most conservative results.

The most important value required from the stability analysis was the downstream slope required to provide adequate factors of safety against shear and over-turning. The extreme values of compression and tension in the concrete also had to be within the prescribed limits. The downstream slope governs the volume of material required to raise the dam and therefore has a major influence on the cost of the project. It was calculated that a downstream slope of 0,8:1 horizontal : vertical will ensure a stable structure. All volume calculations were based on this value.

9.2.5 Spillway

At each FSL an ogee and a labyrinth spillway option (see **Figure 9.2**) were investigated. For the three raisings above 105,25 m the option of lengthening the spillway by 21,35 m was also considered.

Figure 9.2 Example of a labyrinth spillway at Maguga Dam

9.2.6 Non-overspill crests

For the purpose of this report the NOCs were raised vertically and waterproof concrete balustrades or parapet walls were added, thus adding to the storage height of the structure. Both the left and right NOCs were assumed to be 4,5 m wide. The crest levels of the NOCs were assumed to be at the maximum water levels. This means that a 0 m freeboard is accepted during the SEF.

9.3 Outlet works

9.3.1 Flow requirements

The new outlet works for releases to the Olifants River were initially designed for a release of up to 36 m^3/s, which is just less than that of an average daily peak flow for a Class 3 flood for the EWR at EWR Site 2 on the Olifants River. It was concluded that a 'Class 3' (and less) outlet requirement is considered achievable at reasonable cost.

Following the operationalisation of the Reserve, it was however concluded that, provided that the Doring River continues to provide the flood flows at the estuary, as required by the approved Preliminary Reserve for EWR Site 2, it is unnecessary to create large outlet capacity for a raised Clanwilliam Dam, for this scenario. The outlet capacity required of the Clanwilliam Dam could be limited to the required flow peak required by the river reach between Clanwilliam Dam and Bulshoek Weir, of about 20 m^3/s, to meet the EWR between Clanwilliam Dam and Bulshoek Weir.

It has been assumed that the outlet capacity for the Clanwilliam Canal and hydro-electric turbine would remain unchanged.

9.3.2 Design and costing

A proposed outlet works configuration was designed and costed, as shown in **Figure 9.3**.

The existing outlet works comprise two ϕ 1 219 mm pipes (RL 79,55) and two ϕ 914 mm pipes (RL 81,99). Both 1 219 mm pipes are located within the spillway section, the one being just left of the existing outlet chamber and the other towards the middle of the spillway. These (ϕ 1 219 mm) pipes are used for releases to the river. Water is discharged to the river by means of two 914 mm sleeve valves, with a combined maximum capacity of 22 m^3/s.

The ϕ 914 mm pipes exit the dam wall in the outlet chamber, where flow through these pipes is controlled. One pipe is blanked off but a branch just before the end of the pipe supplies water to the Clanwilliam WUA via the Clanwilliam Canal, at a maximum flow of 1.75 m^3/s. The other supplies water to a privately owned hydro-electric turbine at a maximum flow rate of 7.5 m^3/s.

The new outlet works would comprise a combination of ϕ 1 200 mm pipes and ϕ 900 mm pipes. The ϕ 900 mm pipes would be used to extend the existing ϕ 914 mm pipes. All other pipes would have a diameter of 1 200 mm. Discharge would be by means of 900 mm sleeve valves (for the ϕ 1 200 mm pipes) and 600 mm sleeve valves (for the ϕ 900 mm pipes). The combination and quantity of valves would be refined during the design phase, depending on the required discharge capacity and operational requirements of the outlet works.

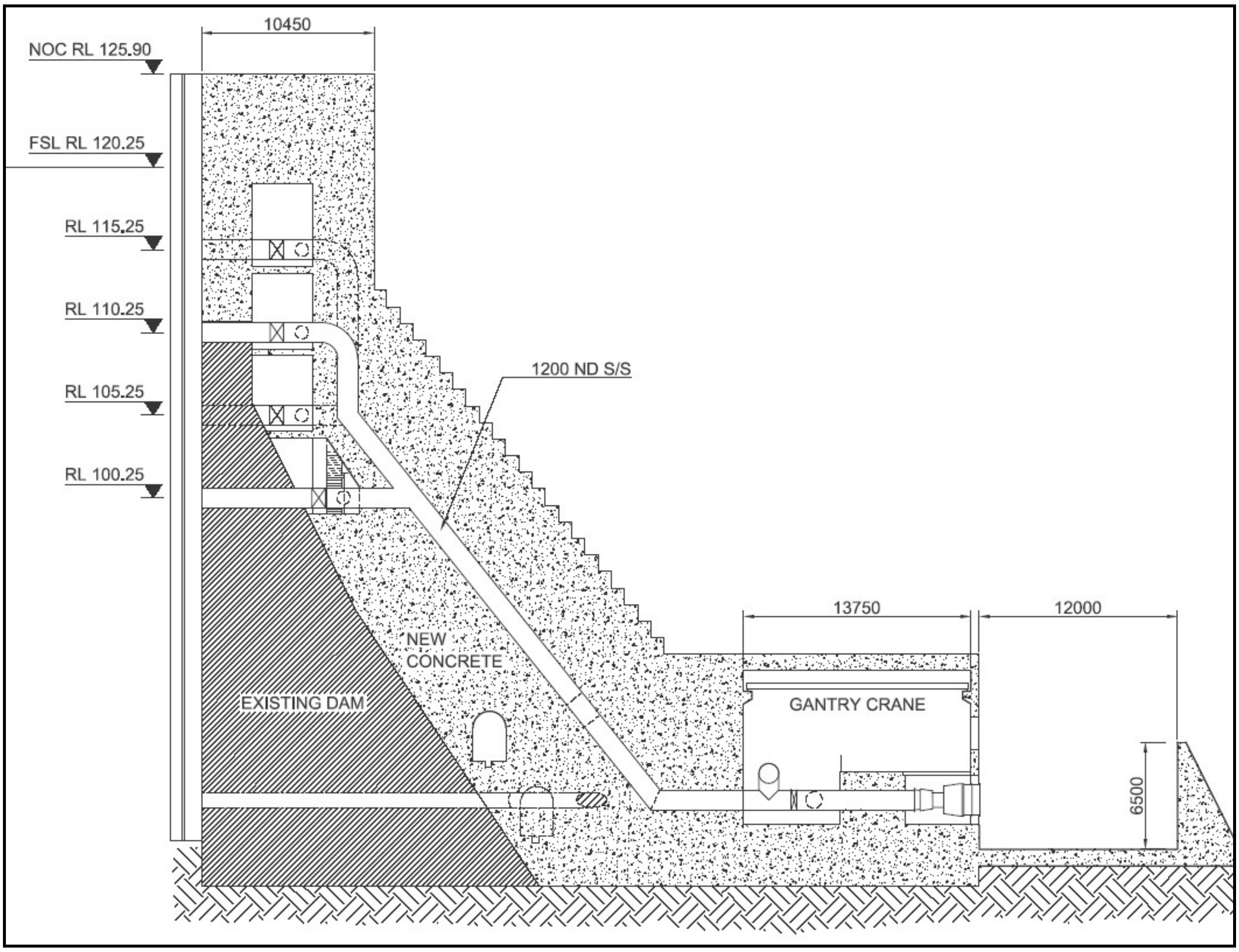

Figure 9.3 Preliminary design of outlet works

Clanwilliam Dam currently releases up to 8 m^3/s in summer to irrigators, which is expected to increase to about 11 m^3/s, should the dam be raised.

Smaller sleeve valves (than the pipe diameter) are chosen for better control of flow through these valves and to have a "throttle" effect on flow so as to limit velocities through the butterfly valves. High flow velocities through the butterfly valves may lead to cavitation and for preliminary design purposes the flow velocities through the butterfly valves have been limited to 5 m/s.

For a required discharge capacity greater than 12 m^3/s, it would be preferable to retain and extend the existing pipes in the spillway section.

The cost of the outlet works will be determined by the required outlet capacity and by the need for a multi-level inlet system. For a discharge capacity of 30 m^3/s for instance, the cost of a 0 m raising and a 15 m raising varies between R16,6 million and R17,9 million (includes cutting through the existing wall, but excludes other civil works).

The hydro-power plant at Clanwilliam Dam was upgraded by the private operator during 2006/07 and is currently running at full capacity. The new plant has been designed taking the possible dam raising into account. The plant provides base load and helps to stabilise the current variations. Turbines of 1.7 mW capacity have been installed, but only 1.1 mW is currently generated. There is therefore capacity for expansion, as well as significant demand for additional power generation (cost of power generation is lower than Eskom's). It should be considered to increase the flow to the plant, as well as the linking of the future multi-level outlet to the intake of the hydro-power plant.

9.4 Dam wall costs

A number of options were analysed and preliminary designs were prepared to an acceptable level of detail for the purposes of this feasibility study. Volumes and quantities were calculated to estimate costs of the various raising options. The calculated costs include estimates for the professional fees, access roads, instrumentation and mechanical components. A graphical presentation of the costs is given in **Figure 9.4**. For the purposes of a feasibility design, a probable error of 25 to 40% in calculated costs can be accepted.

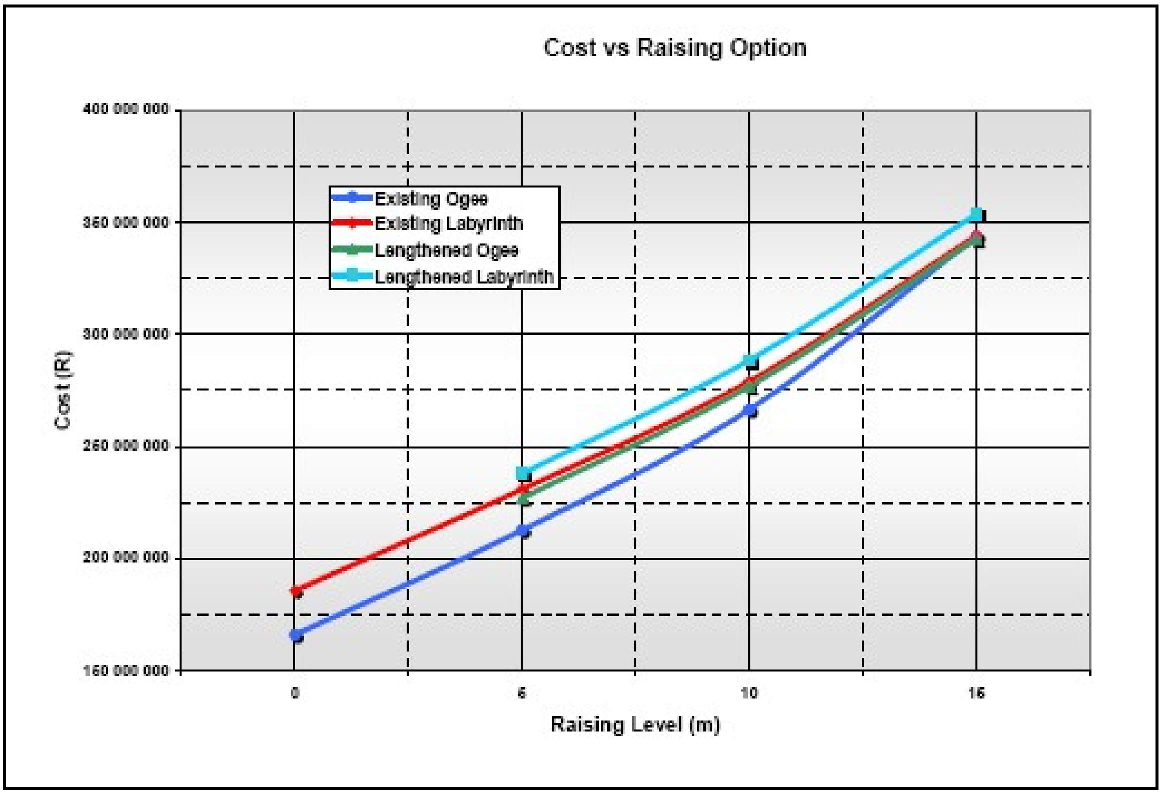

Figure 9.4 Cost per raising option

As expected, the costs of the labyrinth spillway options are higher than those for the ogee spillway options. This is due to the larger volumes of reinforcing steel to be used. A labyrinth spillway, on the other hand, reduces the area inundated by a flood of a particular frequency. This has not been taken into account in this evaluation.

The cost calculations indicate that for all raising options the lowest construction costs will be achieved by constructing an ogee spillway of the same 117,5 m length as the existing spillway. At the 15 m raising all the options would cost more or less the same except for the lengthened labyrinth option that would be significantly more expensive.

It is also interesting to note that, for the 15 m raising, the costs of the existing length ogee and labyrinth and of the lengthened ogee variations are very similar because the volume of concrete required for the NOCs of the existing length ogee would be very large due to the high discharge head over the spillway. This causes a more rapid increase in cost than for the other options.

10. AFFECTED ROADS AND OTHER INFRASTRUCTURE

The purpose of this investigation was to assess the impacts on the existing roads and other infrastructure surrounding the dam that would result from the raising of the Clanwilliam Dam wall. The extent of this impact depends on the raising option selected.

10.1 Infrastructural issues investigated

The following infrastructural issues, arising from the proposed raising of the dam wall, were investigated:

- The re-alignment of Trunk Road 11 Section 4 (hereafter referred to as the N7) to the west of the Clanwilliam Dam (see **Figure 10.1**).
- The continued provision of access to residences, farmsteads and cultivated land along Divisional Roads 2183 and 1487 and Main Road 539 to the east of the dam. The viability of the farms in terms of the impacts on usable agricultural land is briefly addressed.
- The continued functioning of Divisional Road 2183 as part of an alternative route in the event that the N7 between Clanwilliam and Citrusdal is temporarily closed.
- The maintenance of access to the Cederberg Wilderness Area, Algeria and other communities in the Cederberg area from the N7 via the causeway across the Olifants River (Main Road 539) and Divisional Road 1487.
- The maintenance of access to farms and residential developments on the western side of the dam via minor road 16/2, the so-called Renbaan Road.
- The replacement of other infrastructural elements in the area around the dam such as built structures, pumping systems and boreholes.
- The loss of land.

Figure 10.1 The N7 to the west of the Dam

Figure 10.2 Divisional Road 2183 to the east of the Dam

10.2 Trunk road 11, Section 4 (N7)

The predicted 1:50 year flood levels for each dam raising option were adopted as the minimum elevation criteria for the N7. The two affected portions of the N7 are from km 89.32 to 95.92 and km 68.77 to 70.22, respectively (Section 4 of the N7 begins at Piketberg). The affected lengths vary from 1.6 to 3.7 km for the various raising options.

Affected roads are shown in **Figure 10.3**.

Three new road re-alignments were evaluated for affected portions of the N7 closest to the dam wall (see **Figure 10.4**). The currently envisaged extent of the quarry, from which material for the dam wall is to be obtained, does not impinge directly on any of these re-alignments. The centre-line of Alignment 3, at approximately 41 metres distance, is closest to the edge of the quarry. Alignment 1 does not require any bridge construction but requires the longest deviation from the current alignment. Alignment 2 is closer to the dam and requires less earthworks but the construction of a bridge. The preferred alignment, Alignment 3, is the least costly and also deviates least from the existing alignment, although it requires the construction of a bridge.

The affected portions of the N7 further south would not be re-aligned but the road would have to be raised above its present level in places, to reduce the risk of flooding.

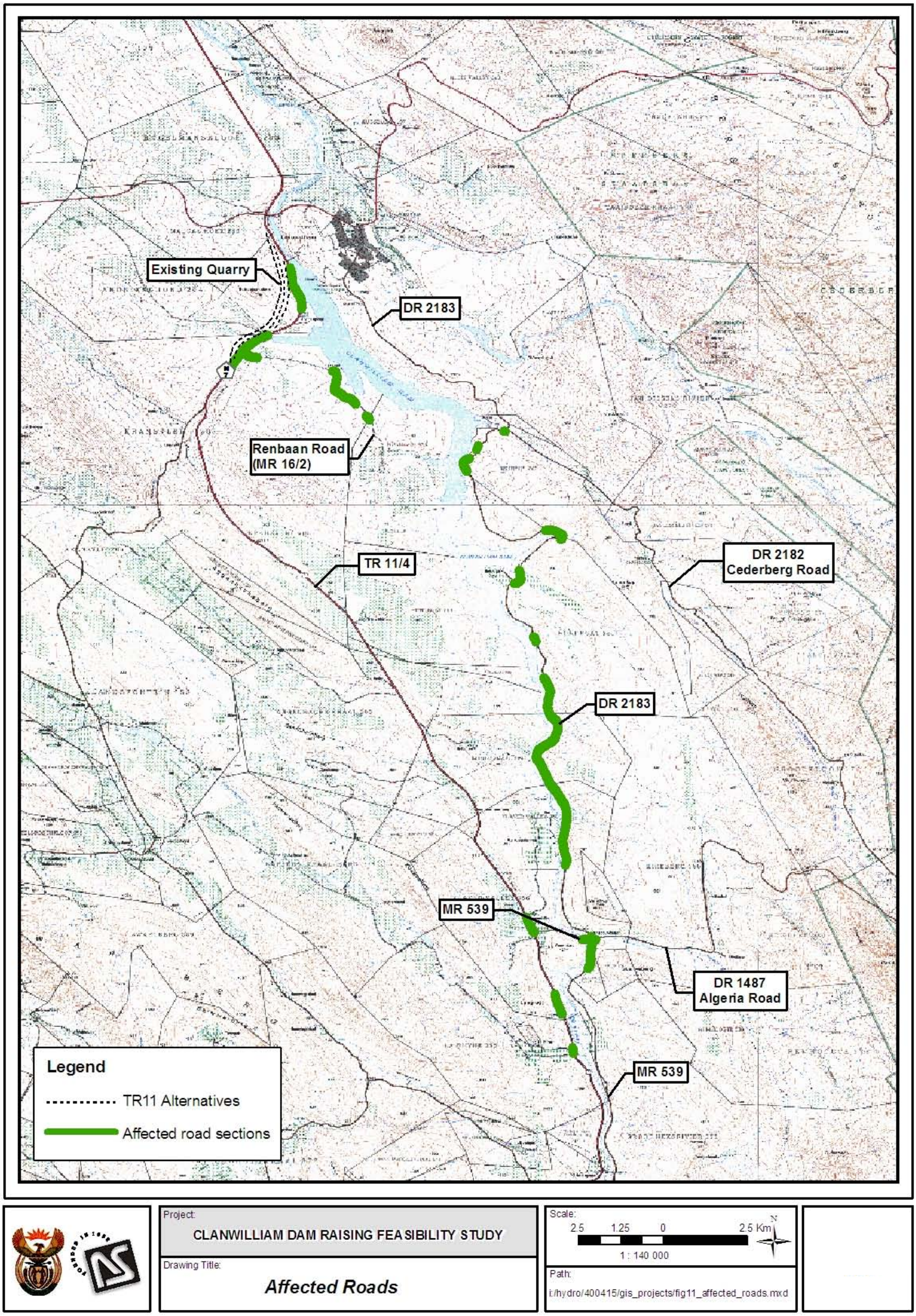

Figure 10.3 Affected roads

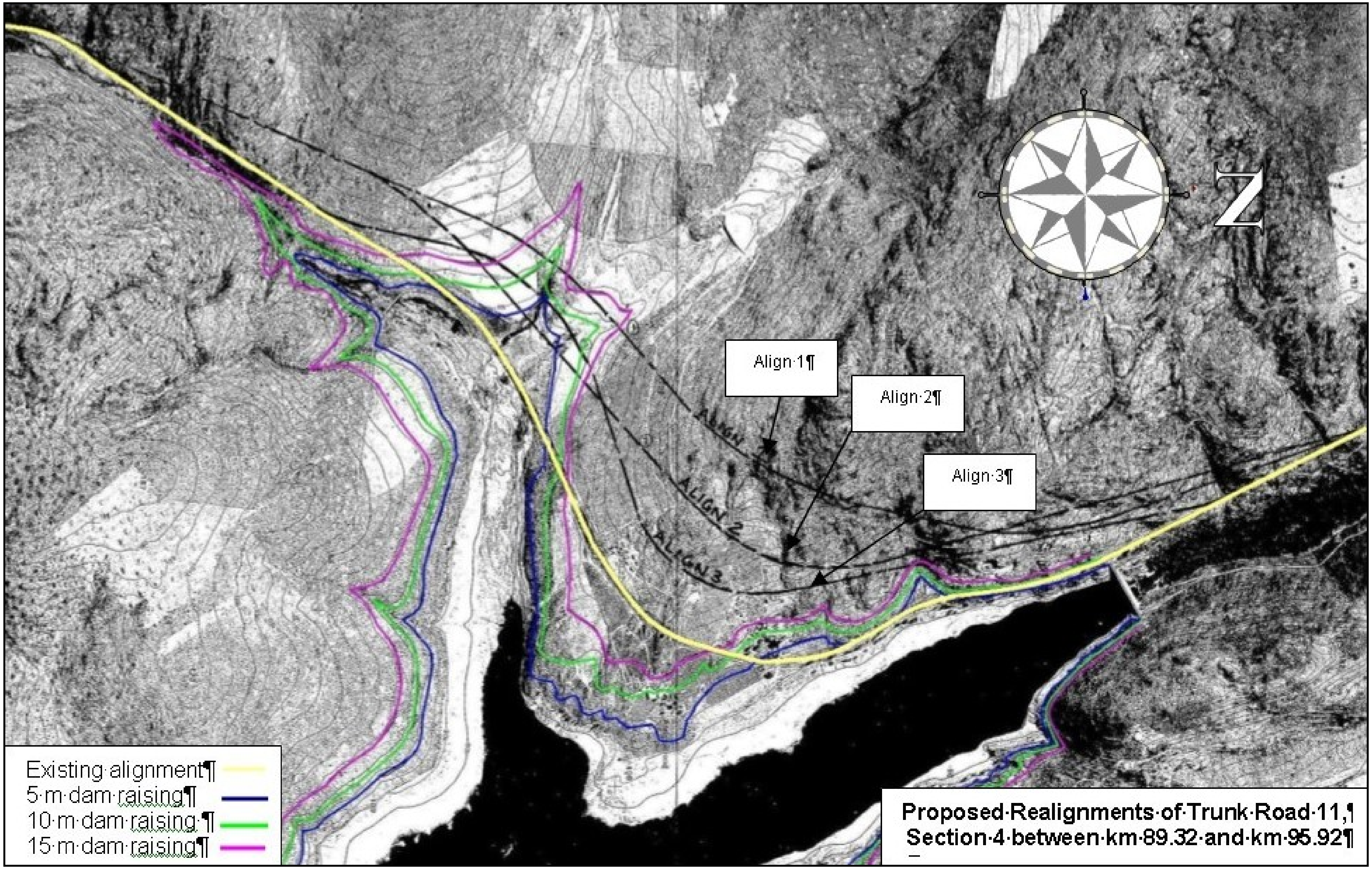

Figure 10.4 Alternative re-alignments of the N7

10.3 Divisional and minor roads

Divisional Road 2183 (see **Figure 10.5** and **Figure 10.6**) is an existing gravel road on the eastern side of the dam, running in a southerly direction from Clanwilliam, virtually on the banks of the dam along its southern part. It terminates at the intersection with Divisional Road 1487 and Main Road 539. It provides both local access to the farms and residences on the eastern shore of the dam and operates as part of an alternate route between Clanwilliam and Citrusdal.

Figure 10.5 Road DR 2183 at the Rondegat River

Figure 10.6 The bridge over the Rondegat River, road DR 2183

Divisional Road 1487 leads in an easterly direction to the Cederberg Wilderness Area. Main Road 539 carries traffic from the "T" junction with the N7 via a causeway across the Olifants River to this intersection and then continues south to Citrusdal. This route, comprising a portion of Main Road 539 and Divisional Road 1487, links Algeria and other communities in the Cederberg to each other and to the N7.

Minor Road 16/2 (Renbaan Road) is a minor gravel road that provides the only access to three farms and three residential developments on the western side of the Clanwilliam Dam.

The predicted 1: 10 year flood levels for each dam raising option have been adopted as the minimum elevation criteria for these roads.

Affected sections along Divisional Road 2183 vary from 4.3 to 8.1 km, for the various raising options. To the north of the farm Kriedoukrantz' "Beeswerf" orchard, it appears not feasible to re-align this section of Divisional Road 2183 and thus to retain its function as a through-road. Affected sections along Divisional Road 1487 (Algeria Road) and Main Road 539 vary between 0 and 0.3 km, for the various raising options. Affected sections along Main Road 539 (to Citrusdal) vary between 0 and 1.0 km, for the various raising options. Affected sections along Minor Road 16/2 vary from 0.1 to 1.9 km, for the various raising options.

10.4 Impacts on other infrastructure

Other land and infrastructure between the purchase line for the current dam and the purchase lines for the three raising options that would be affected are tourist facilities, residential development, agricultural developments and municipal infrastructure.

The Clanwilliam Municipality Dam Resort (see **Figure 10.9**), Clanwilliam Aquatic Club, and the motel adjacent to the N7 Total Garage Complex on the western side of the dam (known as the "Cedar Inn") would be affected.

Three established major residential developments in the study area, namely Caleta Cove (see **Figure 10.7**), Nooitgedacht Nature Resort and Sederview Farm cc. would be affected, as well as the proposed Kransvlei Golf Estate.

Figure 10.7 Caleta Cove

Agricultural development that would be affected comprises farm houses (from 1 to 10 houses), labourers' cottages (from none to 11 affected) (see **Figure 10.8**) and irrigation infrastructure. Affected irrigation infrastructure is composed of farm dams (3 to 5), boreholes (4), pump houses (7 to 10) and pipelines connecting the irrigated fields to their respective water sources.

The extent of agricultural land to be expropriated was determined, classed under orchards, other cultivated lands and uncultivated lands.

A section of the pipeline route from the Cederberg Municipality pump station to their reservoirs may be marginally affected by the raising of the dam.

Figure 10.8 Farm worker's house

Figure 10.9 Municipal caravan park

10.5 Cost estimate

The consolidated cost estimate for mitigating the impacts on both the roads and other infrastructure are shown in **Table 10.1**, based on 2006 rates for earthworks operations and road construction. The costs include provisions for preliminary and general items, contingencies and VAT.

Table 10.1 Consolidated mitigation cost estimates for roads and other infrastructure in R million

Description	Dam raising option		
	5 m	**10 m**	**15 m**
Sub-total for the N7	87.5	91.8	97.2
Sub-total for minor roads	13.7	40.8	56.4
SUB-TOTAL FOR ROADS	**101.2**	**132.6**	**153.6**
Tourist facilities (land costs not included)	2.2	8.2	8.8
Residential developments (land costs included)	7.6	20.4	35.9
Municipal infrastructure	0.3	0.3	0.3
Agricultural developments (land costs not included)	10.3	22.7	32.4
Expropriation of agricultural land	4.6	8.6	12.9
SUB-TOTAL FOR OTHER INFRASTRUCTURE	**25.0**	**60.2**	**90.3**
CONSOLIDATED TOTALS	**126.2**	**192.8**	**243.9**

10.6 Findings

Technically feasible re-alignments can be achieved for those sections of the N7 affected by the raising of the dam wall. Of the three re-alignment alternatives investigated for the section of the N7 between km 89.32 and km 95.92, Alignment 3 is preferred, as it deviates least from the existing alignment and appears to be the cheapest to construct. The position of the quarry will not impinge directly on the three alignments, but the phasing of the construction of the road and of the dam will have to be carefully planned so that access for traffic on the N7 is maintained, and conflicts between construction traffic hauling material between the quarry and the dam wall and the traffic on the N7 are minimised. Ideally, the road should be constructed before dam construction commences.

It appears not feasible to re-align Divisional Road 2183 all the way along the eastern bank of the Dam up to the intersection with the road to Algeria (DR 1487) to the south so as to maintain through access. Access to the following two farms would be from the north only (or alternatively via a new road, that links to road DR 2182):

- Rondegat 269 (Portion1) and
- Lebanon Citrus Farm (Portion of Rondegat 269).

Kriedouwkrans (Portions of Klawervlei 350, Krieberg 360 and others) will retain access from the south only, up to their "Beeswerf" orchard (see **Figure 10.7**).

Road DR 2182 and a section of the Algeria road (MR 539/DR 1487) would serve as the alternate through-road to the section of the N7, between the Algeria turnoff and the Clanwilliam turnoff, and would need to be well-maintained.

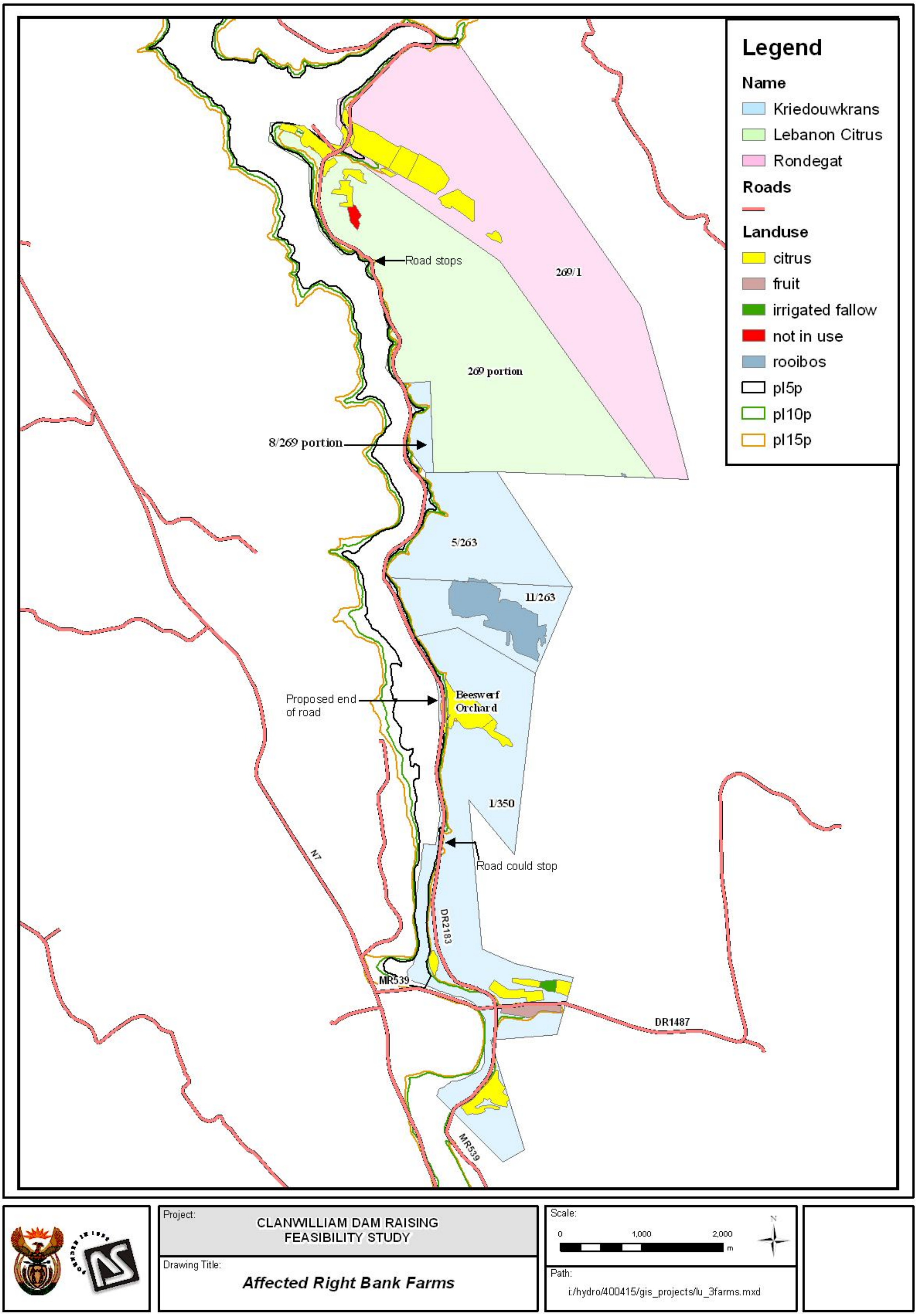

Figure 10.10 Affected right bank farms

Affected portions of the Algeria Road (MR 539/DR 1487) should be re-aligned and a structure that can pass a 1:10 year flood should be constructed, to provide access across the Olifants River.

Expropriation of any affected farms in their entirety does not seem necessary. It needs to be considered whether the optimum course is to expropriate parts of these farms, and to compensate their owners. This specifically applies to sections of Lebanon Citrus Farm and Kriedoukrantz that may no longer be accessible.

Affected portions of the Renbaan Road (MR 16/2) should be re-aligned.

The road to Citrusdal from the Algeria Road (MR 539) is needed in order to provide an alternative route in the event of the N7 being temporarily closed. The affected portions of the road should therefore be re-aligned.

The level of detail adopted in this study is sufficient for assisting to indicate the preferred raising option. However, once the preferred raising option has been identified, the impacts on the infrastructure should be investigated in greater detail and confirmed with a detailed survey of the affected areas adjacent to the dam. Only such an investigation can yield sufficiently accurate information for determining the compensation payable to affected owners adjacent to the dam.

11. FINANCIAL VIABILITY OF IRRIGATION FARMING

This investigation dealt with the evaluation of the financial viability of existing irrigation farming as well as the envisaged expansion of irrigation farming in relevant regions of the Olifants River system that may utilise additional irrigation water, following the potential raising of the Clanwilliam Dam. The envisaged expansion of irrigation farming addresses the option of the expansion of existing irrigation farms as well as the development of new irrigation farms.

11.1 Methodology

Typical farming situations were modeled for each of the identified regions of the study area, with the assistance of leading farmers and other industry experts, using information becoming available from the study. The evaluated regions are:

- Citrusdal;
- Clanwilliam;
- Melkboom/Trawal; and
- Klawer/Vredendal.

It is assumed that the financial results that are associated with the typical farming models of each region will also apply to the total irrigated area of that region. It is further assumed that the managerial inputs on each of the typical farms in the different regions of the study area will be optimal. The financial analyses were done at constant 2005/06 price levels.

The financial viability of irrigation farming was evaluated with the aid of a computer model and by applying the following decision-making criteria, namely:

a. Profitability: internal rate of return (IRR) on capital employed in real terms;

b. Affordability: expected cash-flow and break-even year at different own-to-loaned capital ratios

c. Relative "efficiency" of the utilisation of irrigation water
   - Annuity of the net financial benefits per m^3 irrigation water applied
   - Number of jobs created per 1 000 m^3 of irrigation water applied

The results of the financial viability analysis for existing irrigation farming and the envisaged irrigation developments in the different regions of the study area are presented in **Tables 11.1**, **11.2** and **11.3**.

Table 11.1 Financial viability of existing irrigation farming in the study area

Scenario/Region	Water Need	Evaluation Criteria						
		IRR *	NPV/ha **	Annuity/m^3 Water ***	Break-even Year****			Jobs/1000 m^3 Water
					Equity at: 80%	Equity at: 60%	Equity at: 40%	
	(m^3/ha)	(%)	(R)	(R)				(number)
Citrusdal Citrus farm	11,380	4.55%	(19,684)	0.05	05/06	05/06	05/06	0.05
Clanwilliam Citrus farm	9,177	7.54%	20,575	0.33	05/06	05/06	05/06	0.06
Melkboom/Trawal Mixed farm	9,495	1.99%	(54,416)	(0.20)	05/06	05/06	05/06	0.03
Melkboom/Trawal table grape farm	13,580	34.44%	607,371	3.31	05/06	05/06	05/06	0.10
Klawer/Vredendal Mixed farm	9,197	10.34%	46,490	0.51	05/06	05/06	05/06	0.03
Klawer/Vredendal table grape farm	13,580	9.57%	107,643	0.86	05/06	05/06	05/06	0.10

* Internal rate of return (in real terms) on capital investment.

** Net present value at a real discounting rate of 4% per year, (i.e. 10% nominal interest per year at a yearly inflation rate of, say, 6%).

*** Annuity of the net benefits per m^3 irrigation water applied at a real discounting rate of 4% per year.

**** At a real loan interest rate of 4% per year, i.e. 10% nominal interest per year. The break-even year remains constant, indicating that all existing irrigation consists of viable entities that will surpass the break-even point within one year. Current irrigation is also insensitive to the own-to-loaned capital ratios for the range evaluated.

Table 11.2 Financial viability of the proposed expansion of existing irrigation farms in the study area

Scenario/Region	Water Need	Evaluation Criteria						
		IRR *	NPV/ha **	Annuity/m³ Water ***	Break-even Year****			Jobs/1000 m³ Water
					Equity at: 80%	Equity at: 60%	Equity at: 40%	
	(m³/ha)	(%)	(R)	(R)				(number)
Citrusdal citrus farm expansion	11,380	3.19%	(65,846)	(0.11)	06/07	06/07	> 40 Years	0.05
Clanwilliam citrus farm expansion	8,870	6.38%	6,118	0.28	13/14	15/16	17/18	0.06
Melkboom/Trawal mixed farm expansion	9,378	5.42%	(8,594)	0.15	12/13	19/20	22/23	0.04
Melkboom/Trawal table grape expansion	13,580	28.76%	685,269	3.79	05/06	05/06	05/06	0.09
Klawer/Vredendal mixed farm expansion	9,106	10.26%	48,479	0.53	05/06	05/06	05/06	0.03
Klawer/Vredendal table grape expansion	13,037	11.24%	189,645	1.38	11/12	12/13	12/13	0.10

* Internal rate of return (in real terms) on capital investment.
** Net present value at a real discounting rate of 4% per year, i.e. 10% nominal interest per year at a yearly inflation rate of, say, 6%.
*** Annuity of the net benefits per m^3 irrigation water applied at a real discounting rate of 4% per year.
**** At a real loan interest rate of 4% per year, i.e. 10% nominal interest per year.

Table 11.3 Financial viability of the envisaged new irrigation farms in the study area

Scenario/Region	Water Need (m^3/ha)	Evaluation Criteria						
		IRR * (%)	NPV/ha ** (R)	Annuity/m^3 Water *** (R)	Break-even Year****			Jobs/1000 m^3 Water (number)
					Equity at: 80%	Equity at: 60%	Equity at: 40%	
Citrusdal new Citrus farm	11,380	1.42%	(240,432)	(0.80)	> 40 Years	> 40 Years	> 40 Years	0.05
Clanwilliam new Citrus farm	8,870	4.19%	(58,010)	0.05	32/33	36/37	39/40	0.05
Melkboom/Trawal new mixed farm	9,378	Negative	(113,563)	(0.53)	> 40 Years	> 40 Years	> 40 Years	0.04
Melkboom/Trawal new table grape farm	13,580	11.05%	338,574	2.38	15/16	15/16	16/17	0.09
Klawer/Vredendal new mixed farm	9,106	4.93%	(22,452)	0.15	>40 years	>40 years	>40 years	0.03
Klawer/Vredendal new table grape farm	13,580	5.24%	(44,479)	0.37	19/20	21/22	23/24	0.09

* Internal rate of return (in real terms) on capital investment.

** Net present value at a real discounting rate of 4% per year, (i.e. 10% nominal interest per year at a yearly inflation rate of, say, 6%).

*** Annuity of the net benefits per m^3 irrigation water applied at a real discounting rate of 4% per year.

**** At a real loan interest rate of 4% per year, i.e. 10% nominal interest per year.

As far as the profitability criterion is concerned, an IRR of at least 4% per year in real terms (i.e. an IRR of 10% per year in nominal terms at an inflation rate of, say, 6% per year) can be seen as a benchmark. At a benchmark IRR of 10% per year in nominal terms (i.e. an IRR of 4% per year in real terms at an inflation rate of, say, 6% per year) the following irrigation farming situations that were analysed, seem to be financially viable:

11.2.1 Existing irrigation farming

Klawer/Vredendal region:

- Mixed farming, i.e. wine grapes and tomatoes (real IRR of 10.34 % per year)
- Table grape farming (real IRR of 9.57 % per year)

Melkboom/Trawal region:

- Table grape farming (real IRR of 34.44 % per year)

Clanwilliam region:

- Citrus farming with potatoes (real IRR of 7.54 % per year)

Citrusdal region:

- Citrus farming (real IRR of 4.55 % per year)

11.2.2 Expansion of existing irrigation farming

Klawer/Vredendal region:

- Mixed farming, i.e. wine grapes and tomatoes (real IRR of 10.26 % per year)
- Table grape farming (real IRR of 11.24 % per year)

Melkboom/Trawal region:

- Mixed farming, i.e. wine grapes and tomatoes (real IRR of 5.42 % per year)
- Table grape farming (real IRR of 28.76 % per year)

Clanwilliam region:

- Citrus farming with potatoes (real IRR of 6.38 % per year)

11.2.3 New irrigation farms

Melkboom/Trawal region:

- Table grape farming (real IRR of 11.05 % per year)

Clanwilliam region:

- Citrus farming with potatoes (real IRR of 4.19 % per year)

Klawer/Vredendal region:

- New mixed farm, i.e. wine grapes and tomatoes (real IRR of 4.93 % per year)
- New table grape farm (real IRR of 5.24 % per year)

It is clear from the financial analysis that, given the assumptions made, existing irrigation farming is quite profitable in the relevant regions of the study area. The main contributing factors in this regard are, *inter alia*:

- Well developed and well managed farms;
- Sound supporting marketing structures for produce;
- Sound profitability levels for the major farming branches due to efficient farming practices and favourable price levels for produce;
- The availability of affordable irrigation water (at R2 046 per annum per listed hectare under irrigation in the LORWUA area).

11.2 Financial viability findings

Farming practices in the relevant regions of the study area are relatively capital intensive. It seems that it will be more viable to expand existing farms than to develop new irrigation farms. The typical mixed farming situation in the Melkboom/Trawal region is at present under financial stress (i.e. a real IRR of 1.99% per year). Possible contributing factors to this finding are, *inter alia:*

- Relatively small farms (i.e. 35 ha relative to 60 ha in Klawer/Vredendal) and thus the negative impact of higher unit overhead costs;
- A decline in prices as far as the main enterprise, (i.e. wine grapes) is concerned.

The analysis shows further that an expansion of the mixed farming situation in Melkboom/Trawal to 50 ha should lead to increased profitability (i.e. a real IRR of 5.42% per year).

The expansion of table grape farming in the Melkboom/Trawal region seems to be the most viable option from a financial point of view. It also seems to be a viable option to expand existing citrus farms in the Clanwilliam region in combination with potato production. Year cropping (i.e. potato production in this case) can have a considerable positive effect on the cash flow of farms. Farmers in the Clanwilliam area have sound experience and thus know how as far as the production and marketing strategies of the potato branch is concerned.

The expansion of citrus farming upstream of the Clanwilliam Dam (i.e. irrigation development on individual farms in Citrusdal) is not envisaged to be profitable, mainly due to the expected relatively high cost of irrigation infrastructure. The irrigators could also be expected to pay twice, first for the Clanwilliam Dam development and then for their own irrigation infrastructure.

Several possibilities exist as far as the raising of the Clanwilliam Dam wall is concerned, each having a unique cost and yield level. This leads to different water unit cost levels. The sensitivity of farm profitability for different water unit cost levels was therefore also analysed.

The increment between the expected highest unit water cost (i.e. R0.81/m^3) and the lowest (i.e. R0.37/m^3) is relatively small. The sensitivity analysis thus showed that, given the small variation in the unit cost of irrigation water that is associated with alternative dam raising possibilities, the water cost *per se* would only have a minor impact on the profitability level of individual farms. When stated in another way it means that the expected cost of the additional irrigation water is a relatively small component of the total cost structure of the mainly capital intensive farming developments that are envisaged.

Irrigation farming activities in the investigation area are relatively capital intensive and risky. Top-grade managerial and labour skills are preconditions for financial success and any shortcomings in this regard will have a negative impact on the financial results from farming.

The trend that the market value of land exceeds the production value thereof implies that a farmer should be able to supply a considerable portion of the farm's capital need from own financial sources. New entrants from previously disadvantaged groups will therefore be faced with the mentioned realities and in order for them to be successful, special measures should be considered, *inter alia*:

- Training facilities to further managerial skills;
- Appropriate financial support systems via Government schemes;
- Appropriate farming ownership models and financial support systems to accommodate and further "partnerships" between existing commercial farmers and new entrants to farming.

The finding that the expansion of existing farms should be more profitable than the development of new farms led to an investigation of the financial viability of a "partnership" between the farmer and his labourers, as far as the expansion of farming activities is concerned. Several possibilities exist as far as partnership agreements are concerned. A business trust, with the farmer and his labourers as beneficiaries, served as an example of a "joint venture" to counter the mentioned barriers to entry to farming. The financial analysis in this regard indicated that, given the assumptions made, the proposed "joint venture" should be viable, in general, in the different regions of the investigation area. Particulars in this regard should, however, be investigated comprehensively for each individual case.

Figure 11.1 Orange tree

12. ECONOMIC IMPLICATIONS

12.1 Introduction

A socio-economic impact assessment of the various Clanwilliam Dam raising options was conducted. There are a number of complexities involved, as some individuals and activities will benefit from the dam raising, while others will be either temporarily disrupted or permanently affected in a negative way. A socio-economic impact assessment was needed to analyse and weigh these effects against one another.

There are numerous alternatives for the project, all of which have been explained and assessed. Alternatives deal with the raising height (5 m, 10 m and 15 m raising options) and outlet works configuration, as well as how to manage and allocate the additional yield.

The characteristics of the catchment area have been described as a baseline against which impacts are assessed. The impacts on aquaculture, agriculture, tourism and the local municipalities have been addressed. In addition, some ethical and sustainability issues were considered and recommendations were made regarding the raising of the Clanwilliam Dam wall.

This investigation focussed on the Cederberg and Matzikama Local Municipalities' areas, in the West Coast District, Western Cape.

12.2 Methodology

Due to the complexities of the alternatives being assessed, a combined qualitative-quantitative approach was used. Baseline information was gathered regarding the socio-economic profile of the study area. This entailed analysis of census and other socio-economic data in order to gain understanding of the economic structure and population demographics of the study area. Numerous existing reports on the proposed raisings were reviewed and incorporated as inputs into the study.

Due to the complexity of the project, development issues and sectors affected were assessed and reported on.

Recognised input-output modelling techniques were utilised to determine the direct and indirect impacts of the various alternatives in terms of employment, economic growth and economic opportunities created and lost by each alternative. As not all of the impacts could be quantified, qualitative discussions supplemented the results of this modelling process.

Finally, the results of this work were framed within a national and regional policy context, as well as various international trends regarding sustainable and ethical development.

Figure 12.1 View across Clanwilliam Dam - housing development

12.3 Socio-economic profile

Both the Cederberg and Matzikama Municipalities are characterised by vast, rural agricultural and conservation land, with small urban centres. The chief economic activity is agriculture, contributing 29% of the Cederberg GGP and 19% of the Matzikama GGP and employing 58% and 49% of the employed populations of Cederberg and Matzikama, respectively. Other economic sectors are largely centred on serving the agricultural sector and/or processing agri-products. Economic growth is positive, but slow at an average of 2.35% per annum over the past 11 years.

The combined populations for the study area was approximately 112 152 in 2006. This is largely dispersed over the rural areas. Unemployment for the area is comparatively low, at below 9%, but many of those classified as "employed" are working in elementary jobs, often seasonal or part-time work. Household incomes are, as a result, low, with more than $^3/_4$ earning less than R3 200/month. Education levels are low, with the area having a higher rate of no-schooling than the West Coast District. The implications are:

- Opportunities for semi-skilled work are essential to the livelihood of, particularly, the rural population;
- Access to education opportunities and awareness of the importance of education must be enhanced.

Access to services is also low (for example, only about 30% have access to a telephone in their dwelling), but is characteristic of rural South Africa. Many families reside on farms and are dependent on farms for employment, housing and access to transport.

Poverty is particularly high in the rural areas, where access to services is lower that the averages for the study area and vulnerability to economic changes are high. The Ebenhaeser community is an example of this, with approximately 3 500 people almost solely dependent on subsistence activities.

12.4 Development issues

The Olifants-Doorn WMA is a dry area, yet has a strong agricultural sector on which the economy is centred. The Clanwilliam Dam is an important component of the WMA. Due to the strong relationships with water between tourism, agriculture, fishing and other sectors, the need for increased water availability has been identified.

Various alternatives for the raising of the Dam have been analysed. These include three height options (5 m, 10 m and 15 m raising); four design options (ogee and labyrinth shapes, existing or extended lengths) and two water use options for the additional yield. The latter includes a full-use option, in which all additional yield is utilised for irrigation and a Reserve implementation option, in which ecological requirements are met and water is released to maintain the downstream-ecosystems and its dependents.

Impacts of these alternatives are both positive and negative. Negative effects include temporary and permanent losses of facilities, land and infrastructure as well as livelihoods for the Ebenhaeser community.

12.5 Socio-economic impact

Recognised Input-Output modelling techniques were utilised to determine the economic impact of the raising alternatives in terms of new business sales, Gross Geographic Product (GGP) and employment created and lost. It was determined that positive impacts far exceed the negative ones. It was further determined that the 15 m raising option had the best outcomes relative to costs.

Assuming that the Reserve will be implemented, the findings in terms of capital expenditure (CAPEX) for the construction period are summarised as follows:

Table 12.1 Summary of impacts : CAPEX : Implementation Option 1

Type of Impact	Safety Work	Alternatives		
		5 m	10 m	15 m
Total NBS[1] (R'000)	552,000	1,371,000	1,976,000	2,525,000
Total GGP (R'000)	102,000	294,000	432,000	564,000
Total jobs	270	2,680	4,260	6,930

1) New business sales

This includes the construction work on the dam wall, the re-alignment of roads, the mitigation of impacts on surrounding properties as well as the initial start-up of new agricultural land, in terms of irrigation infrastructure and first crops.

In terms of operation, both losses and gains are evident. This operational expenditure (OPEX) is summarised as follows:

Table 12.2 Summary of Impacts: OPEX: Implementation Option 2

Type of Impact	Alternatives		
	5 m	10 m	15 m
Total NBS gains (R'000)	325,000	556,000	779,000
Total NBS losses (R'000)	26,000	51,000	56,000
Total GGP gains (R'000)	102,000	177,000	243,000
Total GGP losses (R'000)	8,000	16,000	17,000
Total job gains	2,000	3,000	3,720
Total job losses	110	260	270
Rates and taxes (R'000)	29,000	51,000	70,000

As can be seen, the permanent benefits far exceed the temporary losses.

12.6 Other considerations

It was found that for the raising of Clanwilliam Dam, the benefits are wide and far stronger than the negative impacts. Thus, the displacement of some can be justified for the benefit of more. Further, sustainability issues were addressed.

Social benefits of the Clanwilliam Dam raising are important for the poverty alleviation strategies of the study area. Jobs, new sources of income and opportunities for economic advancement are all created. With adequate support in terms of access to transport, training and funding, the project could result in significant improvements in the overall standard of living of the populations of the Cederberg and Matzikama Local Municipalities.

12.7 Socio-economic findings

On the basis of the findings, the 15 m raising option, together with the implementation of the Reserve were recommended, from a macro-economic perspective. Some specific recommendations to maximise the benefits and minimise the negative impacts were provided as follows:

- Enhance sustainability practices of all water users in the WMA through awareness campaigns, as well as other programmes or subsidies to advocate the use of water-efficient technologies (particularly irrigation systems);
- Train and assist farm managers to cope with expansion, especially where new partnerships and trusts have been formed;
- Include the Ebenhaeser and other disadvantaged and disenfranchised communities in participatory processes;

- Match the skills-levels of those that are temporarily and permanently negatively affected by the Dam raising with the new opportunities created;
- Monitor the impact felt by the Ebenhaeser community and assist their management of livelihoods (agriculture and fishing activities) through appropriate programmes;
- Identify those families who will lose their homes and access to transport as a result of lost jobs. Prioritise these individuals for new agricultural land, trusts and BEE ventures;
- Develop a strong marketing campaign to bring old visitors back and attract new visitors to the Clanwilliam Dam Resort and other tourist facilities (assuming that these facilities could be replaced) once the dam raising construction is completed.

13. IRRIGATION DEVELOPMENT AND WATER DISTRIBUTION OPTIONS

13.1 Objective

This investigation focused on the distribution options of additional yield that is made available through the raising of Clanwilliam Dam. It investigates the range of available options to productively and cost-effectively use and distribute the additional water, and describes the analysis, conceptual design and costing thereof. The advantages and disadvantages of these distribution options are compared to assess their viability.

13.2 Availability of land for irrigation

It can be deduced that the availability of land with suitable soil for irrigated agriculture is not a limiting factor to the expansion of irrigation in the study area. Due to the advanced farming technology and management skills that exist in the intensely developed sections of the basin, most of the inherent soil limitations do not pose any serious constraints on irrigation development.

13.3 Increased assurance of supply of the ORGWS

Farmers currently receive water at an unacceptably low assurance of supply. The yield analysis undertaken for this study estimates current assurance of supply at around the 1:10 year level, although it is likely even lower. LORWUA has expressed the need to increase the overall assurance of supply for the ORGWS. This would benefit current and future irrigators during periods of drought and provide for more assured agricultural planning, so that they can be certain of obtaining their full quota in most years, and an increased percentage of their quota in very dry years. This could have a significant socio-economic benefit to the area.

13.4 Region 1: Area upstream of Clanwilliam Dam

13.4.1 Expansion of existing farms or new farms (from river and off-channel dams)

The expansion of citrus farming upstream of the Clanwilliam Dam (i.e. irrigation development on individual farms – see **Figure 13.1**), or the development of new farms is not envisaged to be profitable based on the use of surface water, mainly due to the expected relatively high cost of new irrigation infrastructure, in addition to paying for the raising of the Clanwilliam Dam to compensate for the loss of yield. There may though be opportunities for some farmers who wish to fully utilise existing infrastructure. The further development of the groundwater potential is considered to be a more attractive option for future development.

Figure 13.1 Irrigation upstream of Clanwilliam Dam

13.4.2 Rosendaal Dam, as alternative combined balancing dam

If built, the previously investigated Rosendaal Dam above the Visgat gorge would provide storage for winter water, to be released for use in summer. Existing infrastructure could be utilised by the Citrusdal WUA, although similar infrastructure would need to be provided for new users. The farmers downstream of this potential dam, but upstream of the Clanwilliam Dam, would benefit from the additional storage provided by the proposed dam, as an alternative to building many small additional farm dams. The Dam would have to make provision for the Reserve, which would have to be more accurately determined, to be able to refine the cost estimate and available yield. If Clanwilliam Dam would be raised, the viability of building another dam on the Olifants River would also diminish.

The dam could potentially increase the yield to upper-Olifants irrigators, as well as increasing their assurance of supply. Release of irrigation water from Rosendaal Dam would increase the summer base flows in the Olifants River, potentially threatening indigenous fish species. Furthermore, the introduction of alien fish into the dam could affect the survival of indigenous fish species.

13.5 Region 2: Area between Clanwilliam Dam and Bulshoek Weir

13.5.1 Expansion of existing farms, or development of new farms (pumping from river)

This area has the advantage that users are not reliant on bulk distribution infrastructure. Water can be pumped directly from the river for irrigation, because their water is stored in the Dam upstream. Farmers in this area have sound experience and know-how as far as the production and marketing strategies of the potato branch is concerned. It seems to be a viable option to expand existing citrus farms in this region, in combination with potato production (real IRR of 6.4% per year). Year cropping (i.e. potato production in this case) can have a considerable positive effect on the cash flow of farms. The establishment of new farms is marginally profitable (real IRR of 4.2% per year).

13.6 Region 3: Area downstream of Bulshoek Weir to the estuary

13.6.1 Expansion of existing farms, or development of new farms in the Melkboom/ Trawal area (pumping from canal)

The typical mixed farming situation in the Melkboom/Trawal region is at present under financial stress (see **Figure 13.2**). The analysis shows that an expansion of the mixed farming situation in Melkboom/Trawal to 50 ha should lead to increased profitability (i.e. a real IRR of 5.4% per year). The expansion of table grape farming in the Melkboom/Trawal region seems to be the most viable option in the study area, from a financial point of view, and should be pursued (real IRR of 28.8% per year).

13.6.2 Expansion of existing farms, or development of new farms in the Klawer/ Vredendal area (pumping from canal)

The expansion of existing irrigation farming in the Klawer/Vredendal region would be profitable for:

- Mixed farming, i.e. wine grapes and tomatoes (real IRR of 10.3% per year); and
- Table grape farming (real IRR of 11.2% per year).

New irrigation farms in the Klawer/Vredendal region would be marginally profitable but is not recommended, as it would not be affordable, for:

- A new mixed farm, i.e. wine grapes and tomatoes (real IRR of 4.9% per year);
- A new table grape farm (real IRR of 5.2% per year).

13.6.3 Additional water supplied through the current main canal

There is very little scope to release more water through the Trawal canal section during the peak demand month of January. As a result this option of releasing additional water down the canal for direct use is not particularly viable. One way of using more water would be to introduce alternative crop types that have a different water requirement, with peak demands at different times to those currently grown. This option is however not popular with farmers, because of the high risk involved in ensuring that there is a reliable market available for the alternative crops at the right time.

13.6.4 Increasing the capacity of the canal system by raising the canal

If the canal had a larger carrying capacity, more water could be made available for irrigation downstream of Bulshoek Weir. The new sections would otherwise have to be joined to and supported by the existing badly degraded concrete lining, which is not advisable. Therefore, it is not recommended that the canal profile should be increased in order to increase its capacity.

Figure 13.2 Olifants River, canal and irrigation (photo taken by B. Dyason)

13.6.5 Replacement of the canal system

The cost estimate for lining the entire canal (pre-cast concrete lining or cast concrete) is extremely high and certainly does not seem feasible, however, it may be worthwhile investigating the costs of replacing certain portions of the canal on an annual basis. The option of a steel pipe as alternative implies a pipe with a very large diameter which would be very expensive. It may also be impractical to implement this option, as it would mean closing down the scheme, possibly for years.

13.6.6 Reducing losses in the canal / refurbishment of the canal system

Undertaking of short-term and medium-term repairs are regarded as essential, as not doing so would impinge on the functionality of the scheme. This would increase operational costs, but there is likely no alternative. This option would also have the benefit of limiting losses from the canal.

13.6.7 Provision of an additional balancing dam/s along the canal

Should a large balancing dam be built somewhere along the canal system, it would increase the yield of the system, or the assurance of supply. A significant benefit may be realised during a drought. Having to pump water from the dam into the canal system would however add to the cost. Although no specific site has yet been identified for this option, it is at face value believed to be a costly option. The Provincial Department of Agriculture is in support of further investigation of this option.

13.6.8 Additional farm dams along canal

This option could increase the yield from the system, although it is not considered to have much potential, mainly as a result of limited land availability due to the small farm sizes.

13.6.9 Releasing water downriver from Bulshoek Weir and pumping into canal sections to use spare capacity in identified canal sections

This option could utilise the spare capacity in various canal sections, as indicated in **Figure 4.4**, for additional irrigation, either to expand current irrigation or potentially for new irrigation. A disadvantage is the poorer water quality, as a result of mixing in the river with irrigation return flows and Doring River water in early and late summer, compared to current water quality. This would not be a problem for the Karoovlakte option, where the quality would be acceptable, but the water quality for the Vredendal option would potentially not be acceptable to farmers. The Vredendal option would also necessitate a higher leaching %. The additional infrastructure and need to pump would lead to increased input costs. As a result, the establishment of new farms may become unprofitable, while the expansion of existing irrigation may be marginal. Further investigation into the financial viability of this option, as a result of the increased input cost, would be needed.

Further variations of this water distribution option that has not been explored in this study, such as e.g. supplying the entire right bank canal by pumping from the Olifants River. This would free up capacity in the first reaches of the left bank canal for further expansion. Alternatively, water could be pumped from the Olifants River into the left bank canal at mid-point. This would also free up capacity in the upper left bank canal. Available suitable land for specific crops, affordability and water quality (which may be inhibitive, depending on where water is pumped out of the river) would significantly influence the viability of these options.

13.6.10 Zypherfontein Irrigation Scheme

The Zypherfontein Scheme, downstream of Klawer on the right bank, provides an option for a large new development downstream of Bulshoek Weir, but above the confluence with the Doring River, to avoid poorer water quality. While schemes that include resource-poor farmers may be phased in over time, this provides an opportunity for much faster uptake of the water. The LORWUA has indicated that they would strongly support such a scheme. The specific crops to be planted could be critical and need to be carefully assessed. Because it is a large scheme, with much of the irrigation scheme located further away from the river, costs are expected to be somewhat higher than for small schemes located closer to the river. There may, however, be other, smaller, benefits in the scale of the project. Depending on crop type, such a scheme would likely be viable, but a further, more detailed investigation into financial viability is needed.

13.6.11 Ebenhaeser community supply

Suitable land is available and bulk water supply for irrigation is for now adequate. The current water supply is under-utilised. Internal distribution of irrigation water, through unlined canals that are not properly maintained, is deemed unacceptable, and requires attention. There is a need to investigate the potential to supply each of the plots with a reliable supply of water, and better agricultural and community management is needed.

13.7 Provision of water to non-agricultural users

The total allocations from the LORGWS for all non-agricultural use are 8.4 million m^3/a. Current use is only about 60% of allocations. It is recommended that predicted future growth over a reasonable time horizon be accommodated.

14. RESOURCE-POOR FARMERS

The Olifants River Valley, like much of South Africa, is characterised by significant income and social disparities and fluctuating seasonal unemployment. The potential raising of Clanwilliam Dam offers a unique opportunity to make water available to address some of these issues by supporting water allocation reform. The objective of this investigation was to identify ways in which the additional yield made available through the dam raising can be used to meet these objectives and to ensure that the available natural resources of the area are used to the greatest benefit to society.

14.1 Approach

The investigation comprised a review of existing literature on resource-poor farmer (RPF) initiatives around the country as well as in the particular study area. A small workshop of stakeholders was held to consolidate ideas and this was followed by interviews with selected stakeholders. A conscious decision was made not to engage in a large-scale public consultation process, as there were a number of other studies that have already been conducted in the area. The most recent of these was a survey of existing RPF schemes conducted by the West Coast District Municipality. Instead, the results from these studies were analysed and used to make recommendations on appropriate models for using the additional yield to support RPFs and other Historically Disadvantaged Individuals (HDIs) in the area.

Figure 14.1 The Olifants River at Trawal

14.2 Resource-poor farmer options

This suite of options that should be considered includes:

- **Ensuring the protection of the Reserve.** This will provide socio-economic benefits as a result of a healthy aquatic ecosystem. Benefits could come through tourism ventures, such as the Vleiland Project, or through direct dependence such as the Ebenhaeser fishermen and other communities, both inside and outside of the study area, that are dependent on the fish that use the estuary for breeding. Water for the Reserve therefore has an important equity component.

- **Allocation of additional water to the municipalities.** This will support the growing domestic demand and the increase in industrial demands, particularly in the Matzikama Municipality. Most of this water would be used to directly support equity needs through provision of domestic needs, employment and support for broad-based black economic empowerment (BBBEE) industrial projects.

- **Allocation of water to ensure availability for municipal commonage schemes.** There are currently a number of successful commonage schemes in both municipalities. These schemes should be focused on providing basic livelihood support and food security, while those farmers who have proved to be successful at this scale, such as the Vredendal Samewerk Boerdery (VSB) or the Rastafarian Community Scheme near Citrusdal, should be given the opportunity to expand into fully commercial agriculture.

- **Establishment of a development company (DEVCO) to co-ordinate the development of a sustainable broad based black economic empowerment agricultural project.** The development of a sustainable BBBEE agricultural project will require cooperation from a number of role players. This could be achieved through the establishment of a DEVCO that would be responsible for ensuring support from all the necessary parties and administering the benefits. It is proposed that such a development should include downstream industries such as a canning factory to provide additional market opportunities so as not to compete directly with existing commercial farmers. This would encourage support from these farmers who should be encouraged to become shareholders in the venture. A number of potential sites for such a development were identified in WODRIS, but these may be difficult to service with water, given the limited capacity of the existing canal. Another possible location for such a development would be on land located on the right bank of the river just downstream of Bulshoek Weir. This would require additional infrastructure to supply the water as the existing canal is located on the left bank, but is more feasible than areas identified lower down. The opportunity to approach the national government to assist in the funding of such a development should be considered, as it could become a flagship development project in support of the Accelerated and Shared Growth Initiative of South Africa (ASGISA) and other government initiatives.

- **Support for Joint ventures (JVs) between existing commercial farmers and RPFs.** A number of JVs have already been established in the area and appear to be working well. In this case, however, it is important to recognise the power dynamics between the two parties. For example, it is recommended that the DWAF assign the value of the water to the RPFs and that this is recognised in any agreement as the contribution of the RPFs to the resultant JV trust. This will also impact on the assessment of the contribution made by the commercial farmer, as any land contributed by him must now be valued as dry land. DWAF should also ensure that the RPFs have adequate representation when negotiating the conditions of the JV and that this be monitored closely to ensure that the benefits are being shared fairly. The benefit of JVs between existing commercial farmers and their workers is that workers have an income, during the initial years, until the JV-venture shows a profit.

- **Encourage black commercial farmers and investors.** Sole ownership was highlighted as the most desirable business model for commercial farmers. In the effort to support resource-poor or emerging farmers, the DWAF must not ignore any opportunities to support private black commercial farmers or investors. These could either be individuals or groups of individuals who have proved themselves by successfully farming on commonage land, such as the VSB, or new farmers and investors looking for commercial opportunities in the area. The DWAF could support these farmers by providing water allocations and grants for developing infrastructure.

- **Encourage existing commercial farmers to provide sufficient land and water to existing farm workers**. This would enable them to provide for their own food and livelihood security. This could be considered as one of the conditions for an increased allocation of water to improve the current assurance of supply.

- **Use allocation of additional water as an incentive to make land available for land reform**. There are a number of existing farmers who have purchased additional land in order to improve their water allocation. The possibility of releasing this land at dry land rates to support the objectives of land reform in exchange for increasing the assurance of supply on other parts of their farm should be explored.

- **Retain water "in trust" for future allocation.** It is also proposed that the DWAF retain a certain amount of water “in trust” for the future development of HDI farmers, or for other development opportunities that may arise in the future. The argument here is that the DWAF should not seek to allocate all available water immediately unless there is a sufficient equity demand to take up this water. If some surplus remains it should be held over until equity users come to the fore. Where appropriate this water could be temporarily allocated to existing commercial farmers until such future development opportunities are established, or left in the river to improve the environmental integrity of the resource.

14.3 Discussion of conclusions

The main conclusion from this study was that there is potential to use water to support the development of HDIs in the area, but that the solution is not a single large-scale RPF-scheme. Instead, a suite of development options is proposed. The proposed development options recognise the dual objectives of using water to support poverty alleviation and sustainable livelihoods on the one hand, and the transformation of commercial agriculture on the other. The proposed development options will require significant engagement by the DWAF and close co-operation with other spheres of government to ensure the success of any initiative.

Large-scale black irrigation schemes, common in our history, serve to entrench the process of separate development, whereas the range of options suggested and required here will result in more integrated development and with that a normalisation of society. There are some opportunities to establish black farmers on new areas, but these would need to be complemented by a range of other options for using the water. These options may also prove to have a higher chance of success and greater benefits than the development of new schemes.

The potential raising of Clanwilliam Dam provides a unique opportunity for water to be used successfully to promote water reform and the development of HDIs in the area. This will, however, not be an easy process as it is important to consider a range of opportunities. It will require a substantial commitment from the DWAF and other spheres of Government. At the same time it is also important to consider the negative impacts that raising of the dam wall may have. These impacts may well be particularly significant for the very group of people that the possible raising of the dam wall is intended to help.

14.4 Development agency

In order to ensure the equitable distribution of the benefits from the raising of the dam, it is recommended that consideration be given to establishing a multi-stakeholder planning and development committee, the Olifants/Doring River Development Agency (ODDA). This committee would be responsible for developing a vision for the catchment, identifying possible opportunities and partnerships and preparing a business plan for the equitable allocation of water. The ODDA would be responsible for co-ordinating the development of the proposed initiatives, ensuring the equitable distribution of benefits and monitoring progress so that changes can be made when necessary or in response to new opportunities that arise.

15. ENVIRONMENTAL AUTHORISATION

Environmental authorisation is undertaken through the regulatory Environmental Impact Assessment (EIA) process, which comprises two phases, namely the Scoping Phase and the Environmental Impact Report (EIR) Phase. The process ensures investigation, description and assessment of the potential environmental impacts of the proposed project and provides recommendations regarding the potential for mitigation of impacts, and how the positive impacts can be enhanced. The reports produced in this process provide the basis for informed decision-making by the DWAF with respect to which option to pursue, and by the Provincial Department of Environmental Affairs and Development Planning (D:EA&DP) regarding whether or not to authorise the activity and if so, under what conditions.

15.1 Activities for authorisation

The proposed project, *inter-alia,* entails the following activities for which environmental authorisation is being sought:

- The raising of the Clanwilliam Dam by up to 15 m;
- Re-alignment of a portion of the N7 national road between km 89.32 and km 95.92, totalling 2 700 m in length;
- Raising of a portion of the N7 national road between km 68.77 and km 70.22, totalling 1 km in length; and
- Re-alignment of the gravel access road on the eastern side of the dam, to retain maintenance access to the top of the dam wall.

15.2 The environmental impact assessment (EIA) process

The process was undertaken in terms of Regulation 1182 of the Environment Conservation Act (No. 73 of 1989) which identifies certain activities which "could have a substantial detrimental effect on the environment". These scheduled activities require authorisation from the competent environmental authority. D:EA&DP was granted delegation by the national Department of Environmental Affairs and Tourism (DEAT) to act as the competent environmental authority for this project. It should be noted that the application was submitted under the ECA regulations and despite the fact that these have been superseded by the National Environmental Management Act EIA regulations of 2006 the application is allowed under the transitional arrangements to be completed under the ECA process.

The DWAF is applying for authorisation to undertake the following scheduled activities in the process of raising the Clanwilliam Dam and re-aligning portions of the N7:

- upgrading of a dam and associated infrastructure affecting the flow of a river,
- re-alignment of roads and associated structures,
- storage of hazardous substances on the construction site, during the construction period, such as diesel fuel;
- the change of land-use from agricultural or zoned undetermined use or an equivalent zoning to any other land-use, and

- The cultivation or any other use of virgin ground.

The proposed project therefore requires authorisation from D:EA&DP, following the prescribed EIA process as detailed in Regulation 1183. The Scoping Report Phase identified those aspects that required specialist investigation and assessment during the EIR Phase and was submitted in December 2005. The EIR describes and assesses the potential environmental impacts of the feasible alternatives, as identified during Scoping, and was submitted to D:EA& DP in October 2007.

This provides the basis for informed decision-making by the DWAF with respect to which option to pursue, and by D:EA&DP regarding whether or not to authorise the activity and if so, under what conditions.

15.3 Public participation

Public participation forms an integral component of the EIA process. The nature of the public consultation during the Scoping and EIR Phase was comprehensive and was undertaken in accordance with the requirements of Regulation 1183. It included advertising in regional and local newspapers, distribution of background information and draft reports, holding of several public meetings and focus group meetings, and capturing issues in issues trails, which are included in the reports.

15.4 Alternatives considered

Refer to **Figure 10.3**, which shows the location of the Dam and the portions of the N7, divisional and minor roads, which would potentially be affected by the various dam raising options.

Several alternatives were assessed in the EIR, namely:

- For the raising of the dam, these include four dam raising options (no raising, 5 m, 10 m and 15 m raising), and two outlet works options.
- For re-alignment/raising of sections of the N7, these include three alternative re-alignments between km 89.32 and km 95.92, and raising of the N7 between km 68.77 and km 70.22.
- For re-alignment/raising of divisional or minor roads, these include raising and/or re-alignment of portions of roads DR 1487, MR 539, DR 2183 and MR 16/2.
- For construction site layout alternatives, these include two alternative sites and re-alignment of the service road to the east of the dam wall.

15.5 Identified potential impacts

Potential impacts were identified for:

- Raising of the Dam (construction impacts);
- Raising of the Dam (Operational Phase);
- Re-alignment/raising of affected portions of the N7 (Construction Phase); and

- Re-alignment/raising of affected portions of the N7 (Operational Phase).

The impacts of the Dam raising on the Crassula natans-Cotula coronopifolia Wetland (see **Figure 15.1**), which would fall within the FSL of the raised dam, and on the route of the N7 re-alignment, was a significant consideration.

Figure 15.1 The Crassula natans-Cotula coronopifolia Wetland

15.6 Methodology and assessment

The methodology applied to this EIA process is broadly consistent with that described in the DEAT *Guideline Document on the EIA Regulations* (1998). This methodology was outlined in the *Plan of Study for EIA* and approved by D:EA&DP. Using a tabulated system, each impact is described according to its extent (spatial scale), magnitude (size or degree scale) and duration (time scale). Mitigation measures are described for each impact to minimise the negative impacts and enhance the positive impacts. The criteria above are used to ascertain the significance of the impact, firstly in the case of no mitigation and then with the most effective mitigation measures in place. Once significance of an impact has been determined, the probability of this impact occurring, as well as the confidence in the assessment of the impact, is determined and documented. Lastly, the reversibility of the impact is estimated.

Challenges faced during the application of the methodology, as described, relate to the subjectivity in assigning significance to an impact, the consideration of cumulative impacts and the need for integration with other development in the area. The EIR has identified and provided a comparative assessment of the potential environmental impacts that are likely to occur as a result of the proposed activities. The outcome of the assessment, namely the significance of the impact and the probability of it occurring, is summarised in two colour-coded matrices (refer to **Tables 15.1** and **15.2**).

15.7 Assessment of potential impacts

15.7.1 Construction phase impacts of the Dam raising

The most significant identified negative impacts on the bio-physical and social environment during the construction phase (Refer to **Table 14.1**) include the following:

- Deterioration of water quality;
- Sedimentation and erosion;
- Impact on aquatic ecology;
- Storage and utilisation of hazardous substances for all proposed height increases;
- Noise pollution.

Nevertheless the negative impacts, in terms of their significance, are likely to be reduced by the relatively short duration of the impact and can be mitigated by the development and implementation of an appropriate Environmental Management Plan (EMP). Creation of employment opportunities is a significant positive impact of the construction phase.

15.7.2 Operational phase impacts associated with the Dam raising

The most significant negative operational phase impacts of the raising of Clanwilliam Dam (refer to **Table 15.1**) on the biophysical and social environment without mitigation, include the following:

- Impact on achieving the recommended scenario for ecological water requirements for all options which increase the height of the wall;
- Impact on riverine fish for all proposed height increases;
- Impact on reservoir induced seismicity for all proposed height increases;
- Impact on heritage resources for all proposed height increases;
- Impact of inundation of roads and access with height increases of 10 m and 15 m;
- Impact of inundation on existing infrastructure other than roads with height increases of 10 m and 15 m;
- Impact on local livelihood security with height increases of 10 m and 15 m;
- Impact on flora with a height increase of 15 m.

Even though the mitigation measures mentioned in the EIR would not eliminate these above-mentioned impacts, their significance would be considerably reduced. The probability of these impacts would be marginally reduced.

In addition to the aforementioned negative impacts, there would be several positive impacts arising without mitigation, namely:

- The impact on assurance of supply to farmers progressively increases as the proposed heights of the dam wall increase;
- The impact of increased water yield on resource-poor farmers steadily improves as the proposed heights of the dam wall increases;
- Impact on the local economy gradually improves with an increase in the proposed height of the dam wall;
- Impact on the macro-economy gradually improves with an increase in the proposed height of the dam wall.

If mitigation measures are implemented these impacts are enhanced and become even more significant positive impacts.

For the impact on the ecological flow requirements and riverine fish the introduction of a multi-level outlet structure, which is the recommended mitigation measure for all options which raise the dam wall, improves the current water quality situation and provides a medium positive impact as it improves on the existing situation.

15.7.3 Operational Phase Impacts associated with the re-alignment of the N7

The operational phase impacts of highest significance without mitigation associated with the re-alignment of the N7 (refer to **Table 14.2**), is as follows:

- Impact on the local livelihood security, using alignment 1, 2 or 3;
- The impact on heritage resources, using alignment 1, 2 or 3;
- The visual impact, using alignment 1 or 2.

The impact on traffic flow is considered to be a high positive impact as it ensures that the existing level of service is maintained.

With the implementation of mitigation measures outlined in the EIR, the significance of the negative impacts would be considerably reduced. The probability of these impacts would be marginally reduced.

15.8 EIA conclusions

15.8.1 Potential raising of the Clanwilliam Dam

The impacts associated with the development of infrastructure such as a dam take place on two distinct levels. There are a series of local impacts that include the biophysical and socio-economic impacts of the increased inundation area, and the regional impacts, which result from additional water being made available for use. The recipients of the operational phase project benefits are generally located in the broader Olifants River Valley region, whereas those who are most directly affected by the consequences of the potential dam raising are located in the immediate vicinity of the dam and its lake area.

There are two critical elements of the project with respect to ecological health of the river system. Firstly, the multilevel outlet structure is required for all the dam raising options which entail raising the height of the wall, as it is critical to ensuring that the impacts on the aquatic environment due to the increased storage, and water use, are mitigated in the immediate downstream vicinity of the wall. Secondly, the estuary must receive sufficient baseflow during dry months to stabilise its ecological status and halt deterioration of its condition. The operation of the Clanwilliam Dam/Bulshoek Weir system must therefore be optimised, to allow the appropriate releases to be made, whilst minimising the effect of these releases on the yield.

It is important to highlight the findings of the Olifants/Doring Comprehensive Reserve Determination which recommended that water resource infrastructure development on the Olifants River be maximised through the raising of Clanwilliam Dam and that the Doring River remain unimpounded and free of large dams. This option was documented in that study to be the best compromise between potential economic development and agricultural expansion in the catchment and the ecological requirements of the aquatic ecosystem.

It is clear from the assessment (summarised in Table 15.1 and 15.2) that all raising options, namely 5, 10 and 15 m, provide significantly greater positive impacts than the dam safety work (0 m raising) alone. In order to access the potential socio-economic benefits, increased water availability is needed for use in the region. The difference between the 5, 10 and 15 m impacts are not sufficient to motivate one raising option strongly over another for environmental reasons.

There are no impacts that, with mitigation, are so significant that they would rule out a raising up to the 15 m option.

15.8.2 Construction of the Dam

The construction phase is likely to result in a number of impacts on the biophysical and social environment. The duration of the construction period is anticipated to be 24 months (0 m raising), 30 months (5 m raising), 36 months (10 m raising) or 42 months (15 m raising). Although the construction phase impacts have a high nuisance value to local residents and visitors, the impacts are limited in duration and are mostly reversible. They are therefore of limited significance in the context of an EIA. All reasonable steps should be taken to minimise disturbance to the local population throughout the construction period. The construction phase potential impact, which is likely to have the most significant impact, is damage to the river downstream of the dam.

The significance of the construction phase impacts are likely to be curtailed by strict control of compliance with the construction phase EMP, by an appropriately qualified Environmental Control Officer (ECO) and the relatively short duration. A detailed riverine monitoring programme will also need to be developed and implemented.

15.8.3 Proposed Re-alignments of the N7 between Km 89.32 and Km 95.92

If the dam is raised the N7 needs to be re-aligned to maintain the level of services. Three alignment options were assessed. Alignment 3 is the preferred alternative in terms of technical criteria, and it has the lowest botanical and visual impacts. Alignment 3 has the lowest overall environmental impact and therefore the technical recommendation to pursue Alignment 3 is supported.

15.8.4 Re-alignment and/or Raising of Secondary Roads

Authorisation for secondary activities, *viz.* the raising/re-alignment of divisional or minor roads affected by the raising of the dam, was applied for. These secondary activities and their alternatives were however considered at a Scoping level, to ensure holistic consideration of the possible impacts associated with the raising of the dam. This was undertaken to determine whether there are any fatal flaws associated with these secondary activities and their potential alternatives. This includes re-alignment and raising of affected sections. The DWAF should purchase sections of properties where no access can be provided. A bridge should be constructed where DR1487 crosses the Olifants River on the Algeria road.

The conceptual and detailed design for viable alternatives would only be undertaken during the Detailed Design Phase of the Dam raising. Once detailed design of the activities has been done, those activities that require environmental approval in terms of the National Environmental Management Act (108 of 1998) would be subjected to the necessary processes. It should be noted, however, that the DWAF would not necessarily be the proponent, as the relevant roads authority may wish to undertake the activities.

15.9 The way forward

The Final EIR has been submitted to D:EA&DP for their review and decision. Once D:EA&DP have reviewed the document and are satisfied that it contains sufficient information to make an informed decision, D:EA&DP will use the information contained within the EIR to determine the environmental acceptability of the proponents' preferred options. Thereafter, D:EA&DP will issue a Record of Decision outlining the nature of their decision and the Conditions of Approval attached to any authorisation, should the proposed activity be approved.

Following the issuing of the Record of Decision, interested and affected parties (I&APs) will be notified of D:EA&DP's decision by means of letters to all registered I&APs. There will be a 30-day appeal period during which I&APs will have an opportunity to appeal against D:EA&DP's decision to the Minister of Environmental Affairs and Tourism in terms of the Environment Conservation Act.

There are several outstanding processes which need to be undertaken once the environmental authorisation is resolved. If a positive Record of Decision is received and not overturned by appeal the following processes will be required:

Prior to commencement of any works:

- Development of the detailed Project Environmental Management and Monitoring Plan, once the detailed Dam design has been undertaken.
- Mining Plan and Environmental Management Programme Report authorisation from the Department of Minerals and Energy for use of the Quarry and, where necessary, borrow pits for sand and gravel sources outside of the dam basin.

Prior to any impacts being experienced:

- The design for the secondary roads and the Algeria bridge will need to be undertaken and, where necessary, environmental authorisation sought under the National Environmental Management Act
- Heritage mitigation measures to be undertaken as per EIA, documentation of resources, removal of rock paintings, heritage permits for the removal and destruction of artefacts and the removal of graves processes will need to be followed.
- Land acquisition process and landowner engagement
- Road de-proclamation and where appropriate re-proclamation and associated public process (N7 and secondary roads).

Table 15.1 Matrix of impacts for the Clanwilliam Dam raising indicating significance and probability

Impact	0 m		5 m		10 m		15 m	
	Without mitigation	With mitigation	Without mitigation	With mitigation	Without mitigation	With mitigation	Without mitigation	With mitigation
OPERATIONAL PHASE IMPACTS (DAM RAISING)								
Impact on flora	VERY LOW (-) Highly Prob.	VERY LOW(-) Highly Prob.	MED(-) Highly Prob.	MED-LOW (-) Probable	MED-HIGH (-) Highly Prob.	MED(-) Probable	HIGH(-) Highly Prob.	MED-HIGH (-) Probable
Impact on fauna	NEUTRAL Definite	N/A	VERY LOW (-) Highly Prob.	VERY LOW (-) Probable	LOW (-) Highly Prob.	VERY LOW (-) Probable	LOW (-) Highly Prob.	VERY LOW (-) Probable
Impact of reservoir associated seismicity	MEDIUM (-) Unlikely	N/A	HIGH (-) Unlikely	N/A	HIGH (-) Unlikely	N/A	HIGH (-) Unlikely	N/A
Impact on achieving the Ecological Water Requirements	LOW (-) Highly Prob	LOW (+) Probable	HIGH (-) Highly Prob	MED (+) Probable	HIGH (-) Highly Prob	MED (+) Probable	HIGH (-) Highly Prob	MED (+) Probable
Impact on riverine fish	LOW (-) Highly Prob	LOW (+) Probable	HIGH (-) Highly Prob	MED (+) Probable	HIGH (-) Highly Prob	MED (+) Probable	HIGH (-) Highly Prob	MED (+) Probable
Impact on groundwater resources	NEUTRAL Definite	N/A N/a	LOW (-) Probable	VERY LOW Possible	LOW – MED(-) Probable	LOW (-) Possible	MED (-) Probable	LOW-MED (-) Possible
Visual impacts	VERY LOW (-) Definite	VERY LOW (-) Definite	LOW (-) Definite	VERY LOW (-) Highly Prob.	LOW – MED(-) Definite	LOW – MED(-) Highly Prob.	MED (-) Definite	MED (-) Highly Prob.
Impact on heritage resources	VERY LOW (-) Definite	VERY LOW (-) Definite	HIGH (-) Definite	MED – LOW(-) Definite	HIGH (-) Definite	MED – LOW(-) Definite	HIGH (-) Definite	MED – LOW(-) Definite
Impact of inundation of roads and access	NEUTRAL Definite	N/A	MED (-) Definite	VERY LOW (-) Unlikely	HIGH (-) Definite	VERY LOW (-) Unlikely	HIGH (-) Definite	VERY LOW (-) Unlikely
Impact of inundation on existing infrastructure, other than roads	NEUTRAL Definite	N/A	LOW (-) Highly Prob.	VERY LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable	HIGH (-) Highly Prob.	LOW (-) Probable
Impact on local livelihood security	NEUTRAL Definite	N/A	LOW (-) Highly Prob.	VERY LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable	HIGH (-) Highly Prob.	LOW (-) Probable
Impact on estuarine livelihoods	MED - HIGH(-) Definite	MED (-) Probable	MED - HIGH(-) Highly Prob.	MED (-) Probable	MED (-) Highly Prob.	LOW (-) Probable	LOW (-) Highly Prob.	VERY LOW (-) Probable
Impact on assurance of supply to farmers	HIGH (-) Highly Prob.	N/A	LOW (+) Possible	N/A	MED (+) Possible	N/A	HIGH (+) Possible	N/A
Impact of increased water yield on Resource Poor Farmers	NEUTRAL Probable	N/A	LOW (+) Possible	MED (+) Highly Prob.	MED – HIGH (+) Possible	HIGH (+) Highly Prob.	HIGH (+) Possible	HIGH (+) Highly Prob.
Impact on the local economy	NEUTRAL Definite	NEUTRAL Definite	LOW (-) Probable	VERY LOW(+) Probable	MED–LOW(-) Probable	LOW (+) Probable	MED (-) Probable	MED–LOW(+) Probable
Macro-economic impacts	NEUTRAL Definite	NEUTRAL Definite	LOW (+) Probable	MED (+) Probable	MED (+) Probable	HIGH (+) Probable	HIGH (+) Probable	HIGH (+) Probable

Table 15.1 continued

Impact	0 m		5 m		10 m		15 m	
	Without mitigation	With mitigation	Without mitigation	With mitigation	Without mitigation	With mitigation	Without mitigation	With mitigation
CONSTRUCTION PHASE IMPACTS (DAM RAISING)								
Disturbance of flora	LOW (-) Definite	VERY LOW (-) Highly Prob.	LOW (-) Definite	VERY LOW (-) Highly Prob.	LOW (-) Definite	VERY LOW (-) Highly Prob.	LOW (-) Definite	VERY LOW (-) Highly Prob.
Disturbance of terrestrial fauna	LOW (-) Definite	VERY LOW (-) Highly Prob.	LOW (-) Definite	VERY LOW (-) Highly Prob.	LOW (-) Definite	VERY LOW (-) Highly Prob.	LOW (-) Definite	VERY LOW (-) Highly Prob.
Sedimentation and erosion	MED - HIGH(-) Highly Prob	MED – LOW(-) Possible	MED - HIGH(-) Highly Prob	MED – LOW(-) Possible	MED - HIGH(-) Highly Prob	MED – LOW(-) Possible	MED - HIGH(-) Highly Prob	MED – LOW(-) Possible
Deterioration of water quality	MED - HIGH(-) Highly Prob	MED – LOW(-) Possible	MED - HIGH(-) Highly Prob	MED – LOW(-) Possible	MED - HIGH(-) Highly Prob	MED – LOW(-) Possible	MED - HIGH(-) Highly Prob	MED – LOW(-) Possible
Impact on aquatic ecology	MED - HIGH(-) Highly Prob	LOW (-) Probable	MED - HIGH(-) Highly Prob	LOW (-) Probable	MED - HIGH(-) Highly Prob	LOW (-) Probable	MED - HIGH(-) Highly Prob	LOW (-) Probable
Traffic impacts	MED (-) Highly Prob	LOW (-) Highly Prob	MED (-) Highly Prob	LOW (-) Highly Prob	MED (-) Highly Prob	LOW (-) Highly Prob	MED (-) Highly Prob	LOW (-) Highly Prob
Interruption of water releases	MED (-) Probable	LOW (-) Possible	MED (-) Probable	LOW (-) Possible	MED (-) Probable	LOW (-) Possible	MED (-) Probable	LOW (-) Possible
Storage and utilisation of hazardous substances on site	HIGH (-) Possible	VERY LOW (-) Unlikely	HIGH (-) Possible	VERY LOW (-) Unlikely	HIGH (-) Possible	VERY LOW (-) Unlikely	HIGH (-) Possible	VERY LOW (-) Unlikely
Risk of fire	MED (-) Possible	VERY LOW (-) Unlikely	MED (-) Possible	VERY LOW (-) Unlikely	MED (-) Possible	VERY LOW (-) Unlikely	MED (-) Possible	VERY LOW (-) Unlikely
Creation of job opportunities	MED (+) Definite	HIGH (+) Highly Prob	MED (+) Definite	HIGH (+) Highly Prob	MED (+) Definite	HIGH (+) Highly Prob	MED (+) Definite	HIGH (+) Highly Prob
Influx of workers to area (Health and Safety Risks)	MED (-) Possible	LOW (-) Probable	MED (-) Possible	LOW (-) Probable	MED (-) Possible	LOW (-) Probable	MED (-) Possible	LOW (-) Probable
Impact on services - influx of job seekers	MED (-) Highly Prob.	LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable
Disturbance to sense of place/ aesthetics	MED (-) Highly Prob.	LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable
Windblown dust	MED (-) Highly Prob.	LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable	MED (-) Highly Prob.	LOW (-) Probable
Litter/ waste pollution	MED (-) Highly Prob.	VERY LOW (-) Probable	MED (-) Highly Prob.	VERY LOW (-) Probable	MED (-) Highly Prob.	VERY LOW (-) Probable	MED (-) Highly Prob.	VERY LOW(-) Probable
Noise pollution	MED - HIGH(-) Definite	MED-LOW (-) Highly Prob.	MED - HIGH(-) Definite	MED-LOW (-) Highly Prob.	MED - HIGH(-) Definite	MED-LOW (-) Highly Prob.	MED - HIGH(-) Definite	MED-LOW (-) Highly Prob.
Light pollution	MED (-) Definite	LOW (-) Highly Prob.	MED (-) Definite	LOW (-) Highly Prob.	MED (-) Definite	LOW (-) Highly Prob.	MED (-) Definite	LOW (-) Highly Prob.
Impact of sourcing construction material	MED (-) Definite	LOW (-) Highly Prob.	LOW-MED(-) Definite	LOW (-) Highly Prob.	MED (-) Definite	MED-LOW(-) Highly Prob.	MED (-) Definite	MED-LOW(-) Highly Prob.

Table 15.2 Matrix of impacts for the N7 re-alignment indicating significance and probability

Impact	Alignment 1		Alignment 2		Alignment 3	
	Without mitigation	With mitigation	Without mitigation	With mitigation	Without mitigation	With mitigation
OPERATIONAL PHASE IMPACTS (N7 RE-ALIGNMENT)						
Impact on flora	LOW-MED (-) Definite	LOW (-) Highly Prob.	LOW – MED (-) Definite	LOW (-) Highly Prob.	LOW (-) Definite	VERY LOW (-) Highly Prob.
Impact on fauna	LOW (-) Highly Prob.	VERY LOW (-) Possible	LOW (-) Highly Prob.	VERY LOW (-) Possible	LOW (-) Highly Prob.	VERY LOW (-) Possible
Visual impact	LOW – MED (-) Definite	LOW (-) Highly Prob.	LOW – MED (-) Definite	LOW (-) Highly Prob.	LOW (-) Definite	VERY LOW (-) Highly Prob.
Impact on heritage resources	MED (-) Possible	VERY LOW (-) Unlikely	MED (-) Possible	VERY LOW (-) Unlikely	MED (-) Possible	VERY LOW (-) Unlikely
Impact on local livelihood security	HIGH (-) Definite	LOW (-) Highly Prob.	HIGH (-) Definite	LOW (-) Highly Prob.	HIGH (-) Definite	VERY LOW (-) Highly Probable
Impact on traffic flow on the N7	HIGH (+) Highly Prob.	N/A	HIGH (+) Highly Prob.	N/A	HIGH (+) Highly Prob.	N/A
CONSTRUCTION PHASE IMPACTS (N7 RE-ALIGNMENT)						
Integrated construction phase impacts	LOW – MED (-) Highly Probable	LOW – V. LOW (-) Probable	LOW – MED (-) Highly Probable	LOW – V. LOW (-) Probable	LOW – MED (-) Highly Probable	LOW – V. LOW (-) Probable

16. FINANCIAL EVALUATION

This evaluation focused on the cost of the dam, as well as the cost of water and its affordability. It further evaluated the various options available for the financing of the dam raising scheme, as well as the financing options available to resource-poor farmers. Recommendations are made on the feasibility of raising the dam, and on the preferred height of raising.

16.1 Capital costs

Capital costs have been determined, with a base year of 2006, to make the dam safe for extreme events (0 m for dam safety), as well as for the raising of the dam by 5 m, 10 m and 15 m. At each FSL an ogee and a labyrinth spillway option were investigated and costed. For the three raisings the option of lengthening the spillway by 21,35 m was also considered. At each raising level a capital cost was selected (generally the lowest) and the cost relative to the 0 m raising for an ogee spillway was determined, and was used for the URV calculations. Capital costs for dam safety work is estimated at R165.9 million. The incremental capital costs (relative to that of the dam safety work) for the 5 m, 10 m and 15 m raising options are R172.9, R 293.3 and R422.1 million respectively, for the most likely financial Scenario (discussed under the following section). These costs are shown in **Figure 16.1**.

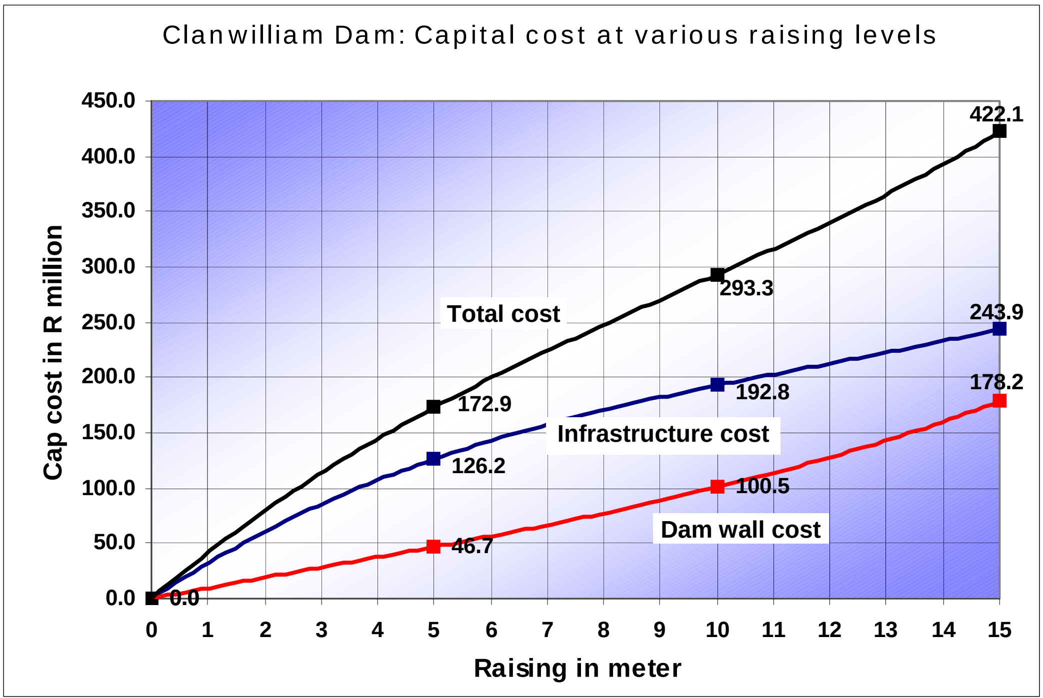

Figure 16.1 Capital costs

16.2 Scenarios for yields and costs determination

Four scenarios were formulated, to present various ways in which the Reserve could potentially be implemented, with respect to the potential curtailment of existing uses or reduced assurance of supply, or even the financing of specific structural alterations. These Scenarios are:

Scenario 1: The Reserve is accommodated by future/new users;
Scenario 2: The Reserve is accommodated by existing users;
Scenario 3: The Reserve is accommodated by existing and future users;
Scenario 4: The DWAF pays for structural alterations to replace lost yield as a result of the implementation of the Reserve.

The implementation of Scenario 1 is not recommended, as water cost would be too high, and it is unacceptable that only additional/new users pay for the implementation of the Reserve. Scenarios 2 or 3 are recommended, with Scenario 3 being preferred to Scenario 2, as it makes sense that all users have to contribute towards the Reserve. The selection of Scenario 4 is fully dependent on the position of the DWAF in terms of responsibility for the Reserve. If the DWAF would decide to fund structural alterations to replace lost yield as a result of the implementation of the Reserve, water costs from the Dam raising scheme would be much lower, and more affordable.

16.3 Unit reference values

Unit reference values (URVs) were determined for three scenarios, based on a range of assumptions, for the various dam raising options, and for discount rates of 4%, 6% and 8%, respectively (see **Figure 16.2**). The lowest URV is approximately at the 9 m raising level. At a discount rate of 6% a 15 m raising would have a URV of R 0.48/m^3.

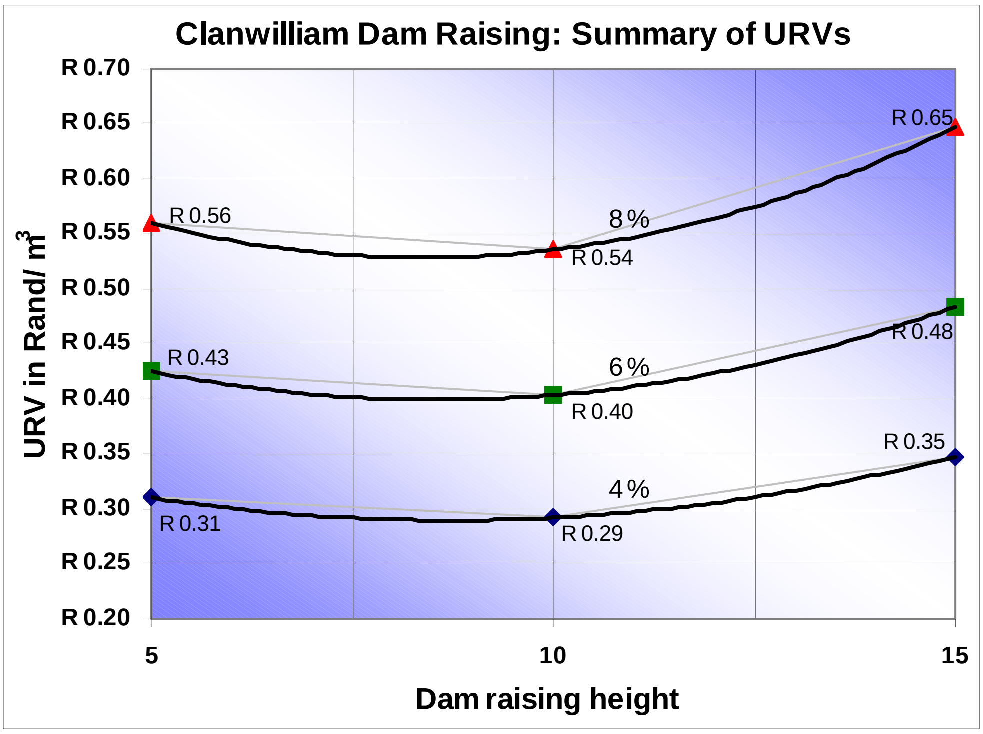

Figure 16.2 URVs for Scenario 2 at various Dam raising levels

Incremental URVs (**Figure 16.3**) have been determined for Scenario 2, which are indicative for the other scenarios as well. Indications are that a raising increment of between the 0-5 m raising and the 5-10 m raising would have the lowest URV, while the 5-15 m incremental raising is on the high side (especially the last 2.5 m incremental raising), and especially so for the higher discount rates. A range of criteria for the selection of the recommended height of raising has been recommended.

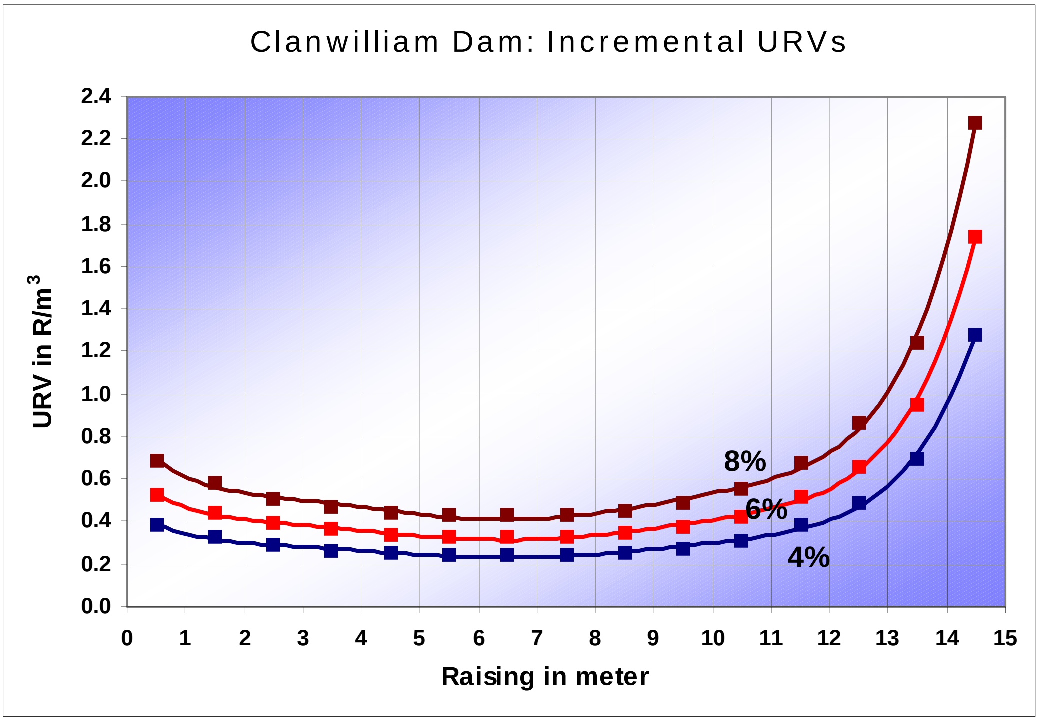

Figure 16.3 Incremental URVs for Scenario 2

16.4 Water cost and affordability

Implications were determined for the potential situation where a reduction in yield, as a result of the implementation of the Reserve, needs to be absorbed by the current Olifants River users, which could vary from a 4% reduction in allocations, for dam safety work only, to a 5.8% reduction in allocation for a 10 m or 15 m raising.

The evaluation on financial viability of irrigation farming indicated that water cost *per se* (i.e. at the envisaged cost levels that are associated with the alternative dam raisings) will have a limited impact on the profitability of farms. Water from the scheme is also very affordable to existing urban water users, without taking the cost of any further downstream infrastructure into account.

URVs determined for groundwater sub-schemes, in the Clanwilliam Trough Scheme and for the Citrusdal Syncline Scheme, as part of the groundwater resources investigation of this study, are of a similar order as that of the Dam raising, at a lower level of confidence.

16.5 Recommended height of raising

The following was concluded:

- Up to a 15 m raising, the maximum potential level of raising, is technically feasible, with a URV of R0.48/m^3, at a 6% discount rate (Scenario 2).
- Incremental URVs for the last 2 m of raising are significantly higher than the average URVs.
- The lowest average URV is at the 9 m raising, which would normally have been the selected level for raising. For this scheme however, the URV is so attractive, relative to the cost of other bulk water schemes, that an increased height of raising is recommended.
- There is adequate demand for water and significant support for the dam raising from LORWUA and in general.
- This scheme offers significant opportunities for water allocation reform and this should be pursued.

A raising level of 13 m seems sensible from a cost perspective, to limit the raising of the last meters of raising that would have significantly high incremental URVs, when compared with the likely cost of other potential bulk water development in the catchment (most likely groundwater).

16.6 Motivation for investing in this scheme

The active encouragement of allocations of water to resource-poor farmers from the Dam raising scheme can address significant income and social disparities, low-income levels, and fluctuating seasonal unemployment in the Olifants River Valley. The commitment to achieving social development and equity through the preferential allocation of water to resource-poor farmers is one of the key poverty eradication strategies for the area. The nature of employment in the area is predominantly in agriculture, with a lack of opportunities for women in this industry. The percentage of the possible population that is not economically active is also high, particularly amongst women. Half of all jobs in the area are in agriculture.

The raising of the Dam provides a significant opportunity for transformation of the commercial agricultural sector in this area. A further potential benefit to society would be the contribution to racial and gender equity in the area, as well as the amount of employment creation.

It is necessary to distinguish between making water available for the enhancement of livelihoods and the eradication of poverty on the one hand, and for the transformation of commercial agriculture on the other.

16.7 Scheme financing options

Because Clanwilliam Dam is owned by the DWAF, all charges, following the dam raising, would be levied in terms of the *Pricing Strategy for Raw Water Use Charges*. In terms of the Pricing Strategy, the raising of the Dam could be described as being built as a betterment, mainly for social purposes. New farmers would only be given access to irrigation, or existing farmers be allowed to expand, on condition that the full financial cost (depreciation plus return on assets plus O&M) be paid for the development.

A number of options for financing of the scheme, as set out in the Pricing Strategy, were briefly addressed. These include:

- Return on assets (ROA);
- Government schemes funded off-budget;
- Schemes owned by CMAs and WUAs;
- Combinations of financing mechanisms;
- Phasing-in of charges.

The Pricing Policy states that: "*There may be instances when the state will develop water infrastructure in the expectation of promoting economic development. In these instances social users will be charged in terms of on-budget governmental funding, while a rate equivalent for off-budget funding will be negotiated with economic users. The classification of a project will be at the sole discretion of the Minister of Water Affairs and Forestry*."

In terms of the Pricing Policy, ROA charges are not applicable to resource-poor farmers. ROA charges would apply for new government schemes constructed for established commercial farmers.

16.8 Financing options for resource-poor farmers

A suite of possible opportunities have been recommended, to be considered for the potential use of water from the Clanwilliam Dam, to support the development of resource-poor farmers in the area.

The lack of financial support has been highlighted as one of the main hindrances to emerging farmers. Funding is required for capital expenses as well as to fund equity acquisition in a joint venture. A wide range of potential sources of funding for resource-poor farmers have therefore been identified and discussed, and includes:

- Department of Land Affairs;
- Department of Water Affairs and Forestry;
- Agricultural organisations;
- Department of Provincial and Local Government;
- Department of Labour; and
- Land Bank.

17. CONCLUSIONS

Based on the findings, conclusions are drawn in terms of the following:

- Dam design and related issues;
- Costs and URVs;
- Other technical and economic considerations;
- Use of water;
- Environmental issues;
- Social upliftment and equity; and
- Scheme financing.

17.1 Dam design and related issues

Following a design philosophy, as adopted by the DWAF, for the remedial works and/or proposed raising of Clanwilliam Dam, of structural reliability, minimal operational requirements/ predictable operation and minimal maintenance requirements the following is concluded:

- The preferred method of dam raising is the construction of an integral mass concrete structure against the downstream face of the existing mass gravity dam, with a downstream slope of 0,8:1 horizontal : vertical (h:v).
- For all raising options the lowest construction costs will be achieved by constructing an ogee spillway of the same 117,5 m length as the existing spillway. For the 15 m raising, the lengthened labyrinth option would be significantly more expensive than the other options, which would all cost more or less the same.
- A multilevel outlet structure is not recommended if the dam is not raised, because the dam is overtopped frequently enough (almost annually) to sustain the spawning of the Clanwilliam Yellow Fish downstream, but is required for the raising options evaluated, to meet downstream water quality requirements/sustain the spawning of downstream Clanwilliam Yellow Fish;
- It is deemed that the required outlet capacity of a raised Clanwilliam Dam could be determined by the recommended EWR peak flow in the Olifants River reach between Clanwilliam Dam and Bulshoek Weir, of about 20 m^3/s, and the maximum required future releases for irrigation (likely about 11 m^3/s)
- The size of the outlet works for the Clanwilliam WUA into the Clanwilliam Canal would remain unchanged.
- It should be considered to increase the flow to the hydro-power plant, as well as the linking of the future multi-level outlet to the intake of the hydro-power plant.
- Results from the geotechnical investigations indicate that adequate course aggregate is available for the proposed raising. The source/availability of sand still needs to be confirmed.

17.2 Costs and URVs

- The cost of the Dam wall and appurtenant infrastructure is R 165.9 million for remedial work only (zero raising).
- Incremental cost estimates of the dam wall and appurtenant infrastructure for the Dam raising options are R46.7 million, R100.5 million and R178.2 million, for the 5 m, 10 m, and 15 m raising levels, respectively.
- Cost estimates for mitigating the impacts on the roads and other infrastructure for the three dam raising options are R126.2 million, R192.8 million, and R243.9 million, for the 5 m, 10 m, and 15 m raising levels respectively. The study has however
- Total costs for the three dam raising options are R172.9 million, R293.3 million, and R422.1 million, for the 5 m, 10 m, and 15 m raising levels, respectively.
- URVs for the Dam raising vary between R0.40/m^3 and R0.48/m^3 for Financial Scenario 2, at a 6% discount rate.
- The lowest average URV is at the 9 m raising, which would normally have been the selected level for raising. For this scheme however, the URV is so attractive, relative to the cost of other bulk water schemes, that an increased height of raising has been considered.
- Incremental costs of the last one to two meters of raising (more than a 13 m raising) are significantly higher than the average URVs.
- URV estimates for large-scale groundwater development range from R0.49/m^3 to R1.04/m^3, at a lower level of confidence.

17.3 Other technical and economic considerations

- The remedial work to be undertaken to ensure the safety of the dam under extreme circumstances provides the opportunity to simultaneously raise the Dam wall, at a relatively low cost;
- Raising of the Dam, up to 15 m, the maximum potential level of raising, is technically feasible.
- Clanwilliam Dam is in a good trophic state and it was estimated that, provided the phosphorus loads remain unchanged, there would probably not be a major shift in trophic status if the dam wall is raised.
- Two large-scale confined artesian basins are located within the study area, comprising two significant fractured Table Mountain Group rock aquifers. The water quality is good and is suitable for domestic use and irrigation. Two schemes, the Clanwilliam Trough and the Citrusdal Syncline Basin Schemes, have been identified to develop and manage these artesian basins, in an incremental manner in the longer-term. Significant yield could be realised, with URVs estimates ranging from R0.49/m^3 to R1.04/m^3.
- The potential for agricultural water demand management measures have been identified and evaluated, but was hampered by the lack of reliable information. A first-level Water Management Plan was developed for the study area, and Action Plans were developed at desktop level.

- Technically feasible re-alignments can be achieved for those sections of the N7 national road affected by the raising of the dam wall. It is not feasible to re-align Divisional Road 2183 all the way along the eastern bank of the Dam up to the intersection with the road to Algeria (DR 1487) to the south so as to maintain through access. Road DR 2182 and a section of the Algeria road (MR 539/DR 1487) would serve as the alternate through-road. Affected portions of other affected roads can be mitigated.
- Land between the purchase line for the current dam and the purchase lines for the three raising options that would be affected contain tourist facilities, residential development, agricultural developments and municipal infrastructure. Expropriation of any affected farms in their entirety can likely be avoided.
- A macro-economic evaluation found that the permanent benefits of raising Clanwilliam Dam far exceed the temporary and permanent losses.

17.4 Use of the water

- There is adequate demand for water and significant support for the dam raising from LORWUA and in general.
- The availability of land with suitable soil for irrigated agriculture is not a limiting factor to the expansion of irrigation in the study area.
- All irrigation initiatives for uptake of water from the dam raising should be proven to be feasible and beneficial.
- The scheme would provide the possibility to make significant yield available for resource-poor farmers;
- Farming practices in the relevant regions of the study area are relatively capital intensive. Evaluations done for various regions of the study area with similar characteristics has evaluated the viability of "typical farms" in these regions, for the existing situation, expansion of existing farms, and for new farms. It seems that it will be more viable to expand existing farms than to develop new irrigation farms. The Melkboom/Trawal region holds the most potential, but the Klawer/Vredendal and Clanwilliam regions could also be profitably farmed. Irrigators upstream of Clanwilliam Dam would likely find it too costly to take up water from the scheme.
- The financing model would determine the cost of additional water from the scheme, in terms of the Revised Pricing Strategy. New infrastructure development may have a social as well as a commercial component, in which case State funding and related charges will apply on the social component, while loan funding and related charges will apply on the commercial component. The State could alternatively also finance the entire scheme and negotiate a rate equivalent for off-budget funding with economic users. The classification of a project will be at the sole discretion of the Minister of Water Affairs and Forestry.
- Sensitivity analysis showed that, given the small variation in the unit cost of irrigation water that is associated with alternative dam raising possibilities, the water cost *per se* will only have a minor impact on the profitability level of individual farms.
- The scheme is very affordable to existing urban water users, without taking the cost of any further downstream infrastructure into account.

17.5 Environmental issues

- The scheme would have relatively low environmental impacts compared to other surface water development options of the same scale;
- The Environmental Impact Assessment concluded that the difference between the 5, 10 and 15 m impacts are not sufficient to motivate one raising option strongly over another for environmental reasons. There are no impacts that, with mitigation, are so significant that they would rule out a raising up to the 15 m option.
- The scheme would provide the opportunity to meet the ecological Reserve of the Olifants River and Estuary.

17.6 Social upliftment and equity

- There is significant potential to use water to support the development of historically disadvantaged individuals in the area, but the solution is not a single large-scale RPF-scheme. Instead a suite of development options is proposed.
- Social benefits of the Clanwilliam Dam raising are important for the poverty alleviation strategies of the study area and for water allocation reform. Jobs, new sources of income and opportunities for economic advancement could be created. With adequate support in terms of access to transport, training and funding, the project could result in significant improvements in the overall standard of living of the local population.
- The potential raising of Clanwilliam Dam provides a unique opportunity for water to be used successfully to promote water reform, to contribute to racial and gender equity in the area, and the development of previously disadvantaged individuals in the area. This will, however, not be an easy process as it is important to consider a range of opportunities. The raising of the Dam provides a significant opportunity for transformation of the commercial agricultural sector in this area. This will require a substantial commitment from the DWAF and other spheres of government.
- The lack of financial support has been highlighted as one of the main hindrances to emerging farmers. Funding is required for capital expenses as well as to fund equity acquisition in a joint venture. A wide range of potential sources of funding for resource-poor farmers have therefore been identified and discussed.

17.7 Scheme financing

- The DWAF could either cover the infrastructural cost to replace yield lost as a result of the implementation of the Reserve (although this would be a departure from standard Departmental policy), or such cost should be distributed amongst all users, existing and future. The potential waiving of such cost, for new (and possibly existing) farmers should be considered, in order to make the water more affordable to resource-poor farmers.
- Scheme financing options have only been briefly addressed in this study.

- Because the existing Clanwilliam Dam is a Government Water Scheme, Treasury will finance the dam safety work. Although the financing of the raising could be undertaken by another financing agency, the institutions involved would possibly not be willing to make funds available without adequate guarantees from the Government. A more pragmatic approach could possibly be for Government funding to be made available for the raising.

18. RECOMMENDATIONS

Based on the conclusions, the following recommendations are made in terms of the following :

- Dam raising
- Other resources
- Use of water
- Water quality
- Environmental mitigation measures
- LORGWS operation rules
- Operationalisation of the reserve
- Monitoring
- Financing and implementation of the scheme

18.1 Dam raising

i) The DWAF recommends that Clanwilliam Dam be raised by constructing an integral mass concrete structure against the downstream face of the existing mass gravity dam. The method of construction and the type of spillway will be finalised during the detailed design phase. The source/availability of sand still need to be confirmed once environmental authorisation has been received.

ii) A multi-level outlet structure must be built for all dam raising options to ensure that the water quality and temperature requirements of the downstream environment can be satisfied. Since the latest information on the ecological water requirements only became available after the modelling task was completed, it is recommended that a refined release pattern be created for the recommended dam raising height, based on the operating rules of the Dam as well as the ecological requirement and irrigation demands downstream of the Dam.

iii) Further evaluation of the hydropower generation possibilities, and the linking of the future multi-level outlet to the intake of the hydro-power plant is needed.

iv) From a cost perspective, a 13 m raising is recommended. This scheme would have a yield of 69.5 million m^3/a, at a capital cost of R365 million (2006 costs) and a unit reference value of R0.45/m^3, at a 6% discount rate for Financial Scenario 2.

18.2 Other resources

i) Further development of the Water Management Plan is proposed, to improve agricultural water management by stimulating self-analysis and forward thinking. The CMA must enforce the development of this Plan and then help the WUAs each year to evaluate and review it in order to achieve water conservation and demand management.

ii) Groundwater schemes could be developed for direct groundwater use from the Clanwilliam Trough and the Citrusdal Syncline Basin Schemes, or for conjunctive use with surface water. It is recommended that a feasibility study be undertaken under a separate initiative for priority sub-schemes, to be selected on criteria such as strategic location, potential yield, potential benefits, potential impacts and costs. A feasibility study must include drilling of exploration and monitoring boreholes.

18.3 Use of water

i) The DWAF should ensure that as much as practically possible of the water made available from the raising of the Clanwilliam Dam goes towards transformation and poverty alleviation in the area.

ii) The LORWUA should indicate to what extent they wish to take up a portion of the increased yield of the ORGWS, to improve the assurance of supply of the scheme.

iii) Any potential identified opportunities for future irrigation would need to be evaluated in terms of the conditions and costs relating to that specific opportunity. Final cost estimates of specific development options must be obtained, based on the cost of the dam, and the available yield for allocation to new irrigation development.

iv) Consideration should be given to establishing an Olifants/Doring River Development Agency, or other relevant implementation vehicle, which could vary in scale of influence, to:

- Develop a common vision for the catchment/scheme;
- Identify possible development opportunities and partnerships;
- Develop an allocation schedule and business plan for ensuring the support of resource-poor farmers and other broad-based black economic empowerment opportunities;
- Co-ordinate and support the proposed developments;

v) The further identification of suitable farms or projects to potentially take up additional water can to a large extent be left to the implementing agency and the potential users of future water requirements, although potential resource-poor farmers would need specific support.

vi) Monitor the progress of the proposed developments and make changes when necessary or in reaction to new opportunities.

vii) A business plan should be developed for the uptake of additional yield from a raised Clanwilliam Dam which should address:

- Funding and cost-related issues;
- Salient features of the raised dam scheme and a summary of the most relevant other supporting information from this study;
- How to meet the objectives of water allocation reform;
- Recommended models for the allocation of water;
- How to convey the message on opportunities to potential future users;

- Mechanisms of support for potential resource-poor farmers;
- A guideline for potential applicants;
- Clarification of the roles and responsibilities that various Government organisations and other organisations would have;

viii) A study should be undertaken into the potential for one (or more) large new schemes for the uptake of additional yield, such as the identified Zypherfontein Scheme. While such a scheme presents the opportunity to settle a larger number of resource-poor farmers on land simultaneously, there may be many pitfalls and sensitivities that need to be carefully unpacked and evaluated. The opportunity for national government to fund (or assist in funding) such a development should be considered, as it could become a flagship development project in support of ASGISA and other government initiatives.

ix) Evaluate applications from non-agricultural users on merit, and make some allowance for the future uptake of non-agricultural use. The uptake of non-agricultural use that can benefit the poor would need special attention to ensure that it does not fall through the cracks.

18.4 Water quality

Water quality recommendations regarding thermal stratification and the need for a multi-level outlet structure are as follows:

i) Since the latest information on the ecological water requirements only became available after the water quality modelling task was completed it is recommended that a refined release pattern be created for the recommended dam raising height, based on the operating rules of the Dam as well as the ecological requirement and irrigation demands downstream of the Dam. This, in addition to more representative meteorological and inflow data will provide a more realistic representation of the temperature profile most likely to exist in the Dam and the ability to match the required temperature downstream of the Dam.

ii) For the proposed raised dam level, the following approach should be adopted during the dam design phase to determine the level of confidence that can be attached to the results presented in this report:

a. Re-run the Dam trajectories with realistic ecological requirements imposed, to determine the most probable dam levels at the beginning of November for each proposed new dam height;
b. Re-run the hydrodynamic and water quality model using the most probable starting level at the beginning of November to determine the probability of meeting the temperature requirement;
c. Decide, in consultation with an ecologist whether the determined probability for meeting the downstream temperature requirement is acceptable.

iii) The most recent arrangement of the multi-level off-take structure should be investigated in more detail in terms of the approach outlined in the previous recommendation to determine whether an additional outlet is required between 100.25 mamsl and 83.56 mamsl.

18.5 Environmental mitigation measures

The EIR outlined various mitigation measures, which, if implemented, could minimise the negative impacts, and enhance the positive effects associated with the possible projects. The following mitigation measures are required:

i) A multi-level outlet structure must be built for all options that would increase the height of the dam wall, to ensure that the water quality and temperature requirements of the downstream environment can be satisfied.

ii) Operating rules for the Clanwilliam Dam and Bulshoek Weir must be compiled to ensure the achievement of the Reserve requirements.

iii) Undertaking releases from the system to meet the recommended EWRs, to ensure that the Olifants River and estuary receive the required volume and quality of water, at the right times.

iv) Environmental specifications for the construction phase need to be developed in concert with the detailed design of the dam and associated infrastructure. These must include a detailed riverine monitoring programme and vegetation rehabilitation plan.

v) Compensation payment shall be determined in accordance with the standard Government policy.

vi) A biodiversity Conservation offset should be adopted which includes the following provisions:

- No new physical structures or development nodes must be allowed in a 50 m wide buffer area of the FSL.
- A conservation zone (in addition to the 50m buffer) should be established around the dam, which is equivalent to the area lost to inundation. This should include natural uncultivated area and critical habitats. This zone should be established through the most appropriate mechanism, which may include expropriation, contractual conservation areas and/or limited activity zones.

vii) The DWAF must commit to ensuring that as much as possible of the water made available from the raising of the Clanwilliam Dam goes towards transformation and poverty alleviation in the area, in accordance with the Water Allocation Reform policy.

viii) The appropriate heritage permits, for the re-interment of graves and for the removal, preservation and/or recording of heritage artefacts must be obtained.

ix) No lay-bys or picnic areas must be situated within easy walking distance of the Andriesgrond Cave, to minimise the risk of vandalism of the rock art or deposits.

x) Any road construction activities at the present Kransvlei River marsh crossing must avoid changing the Kransvlei River channel itself and its immediate banks.

18.6 LORGWS operational rules

i) Revised operational rules for the LORGWS should be established, including:

- Releases for irrigators Reserve and the hydro-power scheme;
- A refined release pattern from the multi-level outlet works;
- Changing of the operation from using almost all of the available water each summer to allowing for a carry-over from year-to-year for drought years.

18.7 Operationalisation of the Reserve

i) Manage the increased pumping of winter water upstream of Clanwilliam Dam, for storage and use during summer, through revised licence conditions, to significantly limit the pumping from the river during the summer months, and as a result improve the ecological condition of the upper Olifants River.

ii) Consider cancelling concessions granted to riparian irrigators downstream of Bulshoek Weir, as there is a risk that the summer baseflow releases for the estuary may be intercepted and not reach the estuary.

iii) Halt all illegal activity in the river channel, such as bulldozing, which increases the volume of water that needs to be released to rectify the destruction of habitat and increases the rate at which silt accumulates in the dams.

iv) Maintain summer baseflow releases from Bulshoek Weir for the Reserve, to supplement the return flows from irrigators along the Lower Olifants River Canal, to maintain a summer baseflow of about 1.5 m^3/s entering the estuary. To reduce the risk of these releases being intercepted by riparian irrigators further downstream consider releasing these flows as pulses, potentially coinciding with the freshette releases made from Clanwilliam Dam to trigger fish spawning.

18.8 Monitoring

i) Develop and implement a detailed riverine monitoring programme.

ii) On an ongoing basis, monitor the effectiveness of the proposed ecological releases, and implement refinement of the releases if needed.

iii) Institute a monitoring programme for the systematic monitoring of the pertinent data for assessing or modelling water quality in the reservoir. This programme should include:

- Hourly meteorological data (air temperature, dew point temperature, wind speed, wind direction, and percentage sunshine);

- Inflow rates;
- Inflow and in-lake water quality; and
- Release rates.

iv) LORWUA should continue to monitor and control the biomass of filamentous algae by chemical means.

v) Measure all abstractions, from Clanwilliam Dam down to the estuary. The Clanwilliam WUA should monitor the abstractions from pump stations, as the existing measurement system is not functioning. Water use records should be released to other parties, such as LORWUA, at least monthly so that they can determine the losses for the month.

vi) Monitor inflowing nutrient loads to a raised Dam. It is also recommended that monitoring of the inflow water chemistry be restored and that the inflowing nutrient loads are examined on an annual basis.

18.9 Financing and implementation of the scheme

i) It would be most appropriate to implement the scheme using Government funding because:

- Clanwilliam Dam forms part of an existing Government Water Scheme;
- Dam safety work must be paid for by Government and is a substantial proportion of the total cost;
- The raising of the dam would mainly be undertaken for resource-poor farmers;
- It could be appropriate for Government to fund as a form of subsidisation, either writing off the entire capital cost or part of it. This would, however, not be in accordance with the DWAF's pricing policy, but could be motivated in terms of the policy as a deserving cause.
- Other funders may not be forthcoming because of the perceived risk on non-payment;
- The scheme has already been placed on the Department's Capital Budget.

ii) The roles and responsibilities of various Government departments, WUAs, municipalities, NGO, etc. in terms of the implementation of the project must be clarified and such organisations need to commit to allocated responsibilities.

iii) In order to ensure the equitable distribution of the benefits from the raising of the Dam, a multi-stakeholder Olifants/Doring River Development Agency should be established. This proposed Agency should be responsible for developing a vision for the catchment, identifying possible opportunities and partnerships and preparing a business plan for the equitable allocation of water. Their responsibilities should include co-ordinating the development of the proposed initiatives and monitoring the progress so that changes can be made when necessary or in response to new opportunities that arise.

iv) Without a doubt, the raising of the Clanwilliam Dam provides one of the cheapest development possibilities in the Western Cape as far as irrigation for resource-poor farmers is concerned. This, combined with the opportunity to grow high-value crops makes this an opportunity too important to be missed.

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