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Ncwabeni Off-Channel Storage Dam Feasibility Study: Module 1: Technical Study

MAIN REPORT

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NCWABENI OFF-CHANNEL STORAGE DAM FEASIBILITY STUDY: MODULE 1: TECHNICAL STUDY

Main Report

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FINAL

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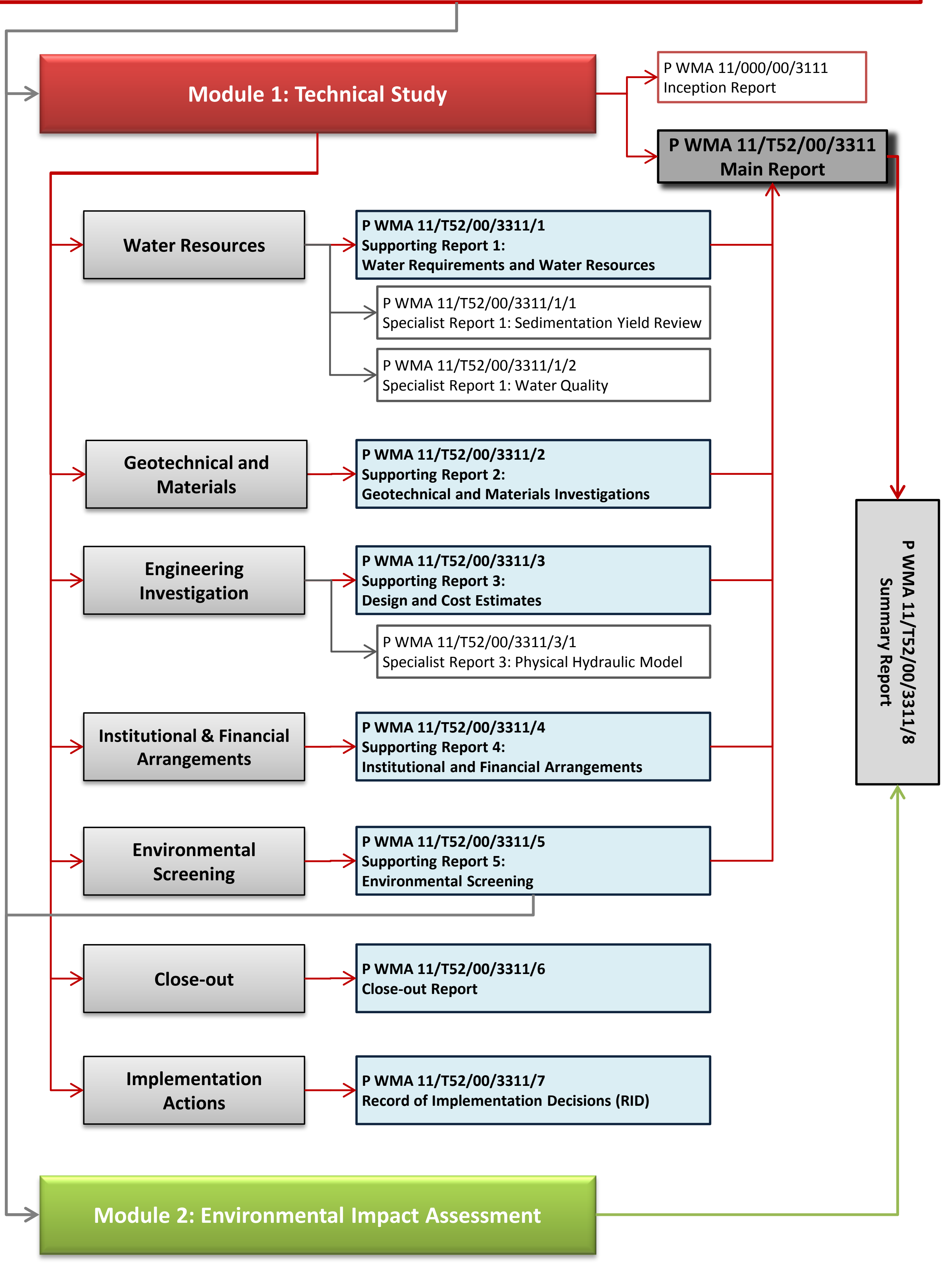
Ncwabeni Off-Channel Storage Dam Feasibility Study – List of Study Reports



EXECUTIVE SUMMARY

Background

The Umzimkhulu Regional Water Supply Scheme (RWSS), which forms part of the KwaZulu Natal's Lower South Coast System, supplies water to the coastal region from Hiberdeen to Margate, including Port Shepstone. The water is presently sourced from non-regulated river flows in the Umzimkhulu River. Abstraction is at the St. Helen's Rock abstraction works which feeds water to the Umzimkhulu/Bhobhoyi Water Treatment Works (WTW) near Port Shepstone.

A study by the Department of Water Affairs (DWA) in 2002 identified the problem of insufficient river flow in the Umzimkhulu to meet the near future projected water requirements. The study recommended that, in order to provide for the water supply to all user sectors, including the Reserve, the construction of an off-channel storage (OCS) dam in one of the tributaries to the Umzimkhulu River should be considered. The reservoir can be filled from its incremental catchment, supplemented by pumping from the Umzimkhulu River during times of high river flows. During times of low flows water can be released back into the Umzimkhulu River for abstraction downstream at the existing St. Helen's Rock abstraction works.

Subsequent studies investigated various OCS dam options and suggested that the two most favourable sites on the Ncwabeni and Gugamela tributary rivers be investigated at a feasibility level. Subsequently the Ncwabeni Off-channel Storage Dam Feasibility Study: Module 1: Technical Study (this study) was initiated by the DWA to conduct a comprehensive engineering investigation at the feasibility level.

Introduction

*The project site lies about 30 km inland of Port Shepstone on the Southern Coast of Kwa-Zulu Natal. The location is shown in **Figure A.1** in **Appendix A**. The location of St Helen's Rock Abstraction is about 25 km downstream of the proposed OCS dam. In recent years, the volume of water being abstracted at St Helen's Rock has exceeded the lowest flows in the dry months resulting in salt water from the estuary and being pumped at St Helen's Rock.*

The purpose of the study was to conduct an environmental screening of the two site options, update the water requirements and water requirement projections, conduct geotechnical and materials investigations to a preliminary design level, conduct the feasibility design on the selected best scheme and determine associated costs, and propose financial and institutional arrangements for the project.

Environmental Screening

The environmental screening task was conducted to provide preliminary information for the EIA study, as well as to guide the engineering tasks where possible on environmental issues. The environmental screening task found the Ncwabeni site to be ecologically more sensitive, but the Gugamela site to be socially more sensitive with people currently living in the dam basin. The preliminary accumulation of impacts found the two sites very similar with the Gugamela site having a slightly higher overall impact. This information was provided to Module 2: the EIA.

Water requirements

Recent water supply records from the Umzimkhulu/Bhobhoyi WTW were obtained and the 2010 water supply volume was approximately 18 million m^3/a. Based on the recent growth in water supply volumes as well as other studies, water demands were projected up until 2040 with the impact of water conservation and water demand management measures included. The projected water demand for the Umzimkhulu RWSS in 2040 is 28.5 million m^3/a. Augmentation of water supply to the Umzumbe area outside of the existing Umzimkhulu RWSS was also provided for. A volume of approximately 1.5 million m^3/a is required to augment the supply from the Mlhabatshane scheme into Umzumbe in the future. The total water requirement to be met by the Umzimkhulu River with an OCS dam included is thus 30 million m^3/a.

Water yields

Using the latest available hydrology and Water Resources Yield Model (WRYM) configuration, the yields of the Umzimkhulu River at St Helen's Rock were determined, with and without different sizes of OCS dams. The current firm yield of the system without the dam is approximately equal to the 2010 water requirement. This is before accounting for ecological water requirements which significantly reduce the available yield. Augmentation of the system is thus urgently required if growth in water requirements are to be met, and the ecology of the lower Umzimkhulu River is to be improved.

Yields were calculated for the Ncwabeni and Gugamela dam site options, for a range of dam sizes and off-channel pumping rates to fill the dams. Based on the calculated yields, a dam size of about 16 million m^3 or greater and an off-channel pumping rate of 0.75 m^3/s or greater is required to meet the future requirement of 30 million m^3/a. This includes taking account of the ecological reserve. The OCS dam will not make direct releases for the ecological reserve, but will improve the situation by allowing the ecological reserve to be met first from available flows in the river, and the dam then supplying the balance required for domestic needs.

Long-term stochastic yields were calculated to confirm the volume of water that could be yielded at required assurance levels. Based on the yield analyses, a refined range of dam sizes and pumping rates were recommended for optimisation and selection of the best scheme.

Geotechnical investigations

A comprehensive geotechnical and material investigation was conducted to establish available founding conditions and available materials for construction. These investigations were conducted in phases with the dam-type selection and cost being updated after each phase thereby directing the next phase. The phases of geotechnical and material investigation included test pitting, seismic refraction surveying, and a number of boreholes for core drilling and testing. The focus of the geotechnical investigations was the Ncwabeni Site. If a fatal flaw was found, the investigation would shift to the Gugamela Site. No fatal flaw was found at the Ncwabeni Site.

It was not possible to locate sufficient quantities of impervious core material within the dam basins or elsewhere in the area for construction of a zoned embankment dam. The lowest cost alternative type of embankment is a concrete-faced rockfill dam. Such a dam comprising of "soft" and "hard" *rockfill zones can be constructed from material that can be obtained from a proposed quarry in the Ncwabeni dam basin.*

A wide fault zone and generally deep weathering on the left flank of site D2 will require very deep excavation for a concrete gravity (RCC) dam indicating that its cost will far exceed those for embankment or composite dams.

A composite dam with a concrete overspill section in the river and along the right flank might be considered, but the left embankment will have to be supported by a long flank wall, the founding levels of which have not been investigated, but are expected to be about 10 m deep.

Investigations along the dam centre line show that founding conditions for a rock-fill dam are favourable with excavation depths not exceeding about 5 m and grouting to depths of between 20 m and 40 m. However, the plinth for an upstream faced rockfill dam will be located a considerable distance upstream of the dam reference line, and for the design purposed, additional geotechnical investigations will have to be conducted.

Sedimentation

Sedimentation of the OCS dam was calculated taking into account the sediment from the Ncwabeni River (incremental catchment) as well as the volume of sediment that is likely to be pumped from the Umzimkhulu River. A total 50 year sediment volume of 2.3 million m^3 has been determined.

Dam Type Selection

Six dam types were investigated and cost estimates were done for each in order to select the preferred dam type to carry through to the feasibility design stage. The cost estimates after the third phase of geotechnical investigations (drilling, sampling of cores and testing) are listed in ***Table i****. Costs were determined using a detailed spreadsheet-based cost model which was developed for this study, and builds on the principles of the Vaal Augmentation Planning Study.*

Table i: Summary of Cost Estimates for Various Dam Types at 167.5 masl (FSL)

Dam Type	*Comparable Cost (R million)**
Roller Compacted Concrete (RCC) Dam	*861.1*
Earthfill Dam	*337.1*
Concrete Face Rockfill Dam (CFRD)	*412.3*
Earth Core Rockfill Dam (ECRD)	*364.3*
Asphalt Core Rockfill Dam (ACRD)	*1,009.9*
Bentonite Core Rockfill Dam (BCRD)	*362.3*

** Costs include Preliminary and General, Preliminary works, Contingencies, Planning, Design, Supervision and VAT*

Sufficient earthfill materials and sandy materials for the Bentonite Core or Earth Core Rockfill dams were not found during the material investigation; however, a rockfill and concrete material quarry was identified and tested inside the dam reservoir and was deemed to be good to use.

The Concrete Faced Rockfill Dam was thus selected for the feasibility design.

Layout of Selected Dam

*The Concrete Faced Rockfill dam with a Full Supply Level at 167.5 masl (47 m high) was selected as the best scheme, and comprises a side channel spillway on the left bank and an intake tower with a bottom outlet next to the river. The layout is shown in **Figure C.1** (**Appendix C**).*

The side channel spillway is 50 m long and it has a chute and a flip bucket.

The outlet works consists of a twin or dual system of 600mm diameter pipes and multi-level intakes to manage the quality of water released back into the Umzimkhulu River.

Abstraction Works

*The layouts of the diversion weir and abstraction works are provided in **Figure D.2** (**Appendix D**). The diversion weir has a dual purpose - it diverts water to the abstraction works for pumping to fill the OCS dam, and gauges flow in the Umzimkhulu River for operation of the system. A fishway is included for the migration of fish and invertebrate species. The abstraction works consists of a gravel trap, sand trap and a hopper to reduce the volume of sediment pumped into the OCS dam:*

A pipeline from the pump station to the dam reservoir will discharge water to the off-channel storage dam. The pipeline is 1000 mm in diameter and 670 m long. The pumping head is 55 m.

The site selection was based on cost comparisons for three positions as well as the best hydraulic conditions, which were tested using a physical hydraulic model. The selected abstraction works configuration was developed and tested in detail using a hydraulic model.

Operation Rule for the Dam and Pumping from Umzimkhulu River

The abstraction of water to fill the dam is to occur in the summer months when flows are greater than the sum of the requirements of the Umzimkhulu Regional Water Supply Scheme, lawful downstream users and the ecological reserve. Releases of water back into the Umzimkhulu River in the winter months will need to be made if the flows are less than the requirements of the Umzimkhulu Regional Water Supply Scheme after providing for the ecological reserve and lawful downstream users. Detailed volumes need to be determined once the reserve has been finalised through the classification process.

Scheme Optimisation

*Scheme optimisation was carried out for various sizes of the selected concrete face rockfill dam. The unit reference values of the various dam sizes are given in **Table ii**:*

Table ii: URV for Selected Ncwabeni Dam Sizes

Unit Reference Value (URV)				Capital Cost (R thousand)	Demand satisfied until	Yield (million m^3/a)
Dam size (FSL)	Discount Rate 6%	8%	10%			
167.50	*1.44*	*1.85*	*2.29*	*371,811*	*2,041*	*30.50*
170.00	*1.52*	*1.96*	*2.45*	*404,539*	*2,047*	*33.00*
172.50	*1.63*	*2.12*	*2.66*	*447,734*	*2,051*	*35.00*
175.00	*1.73*	*2.26*	*2.83*	*481,938*	*2,054*	*36.30*

The study planned for meeting the water demand for a 25-year horizon after construction, before the next scheme is required (e.g. Gugamela etc.).

Final Layout and Cost Estimate

*The conceptual design of the dam and abstraction works layout drawings are provided in **Appendix B** and **Table iii** summarises the cost estimate for the dam and abstraction weir.*

Table iii: Cost Estimate for Selected Scheme

Component	*Cost (R)*
Sum of activities	*284,273,834*
Preliminary & General	*113,709,533*
Preliminary works	*15,904,000*
Accommodation	*6,000,000*
Contingencies	*83,977,474*
Planning, design & supervision	*75,579,726*
Subtotal A	***579,444,567***
VAT (14 % of subtotal A)	*81,122,239*
Total Project Cost (Including VAT)	***660,566,806***

Implementation Programme

*The Implementation Programme for the scheme, which shows that construction should commence in May 2014 with impoundment in 2017 is included in **Appendix E**. Some refinement to the implementation program may be required based on how long it takes to finalise institutional and funding arrangements. The program is very tight and any delays in decision making will most likely cause delays in the program and completion date of the project. This is important as from a water resources perspective the project is already needed.*

Further design work needed

This feasibility study of the Ncwabeni off-channel storage dam was carried out at an advanced phase in terms of the water resources analysis and the materials and geotechnical investigations.

Before the detail design of the project commences, the following should be done:

- *Drilling of the plinth on the plinth line of the CFRD, the trough spillway and position of the intake structure to confirm the foundation levels.*
- *Geotechnical investigation at the right bank of the diversion weir.*
- *A hydraulic model study of the side channel spillway.*

Institutional and Funding arrangements

The capital funding requirement for the Ncwabeni OCS Dam is in the order of R580 million (excl VAT) in 2012 Rands. The cost of the Ncwabeni OCS Dam Project excludes upgrading water treatment works and distribution pipelines.

If the cost is escalated and accumulated interest charges is included the dam will cost in the order of R900 million by 2017.

50% of the households to be supplied from Ncwabeni Dam are classified as poor and will be unable to pay for water.

It is accordingly recommended that at least 50% of the cost of constructing the dam should be funded out of the Regional Bulk Infrastructure Grant (RBIG).

The remaining 50% could be funded out of the Ugu DM's MIG allocation or by Umgeni Water using commercial sources.

It is however unlikely that Ugu DM will be able to contribute substantial MIG funding to the project given their water and sanitation backlog of approximately R2 Billion. It is also unlikely that Ugu DM will be able to raise substantial commercial loan funding at this time.

Two funding options have been proposed:

- *Either Ugu DM could raise funds for the project itself using a combination of RBIG funding, MIG and other grant funding, and limited commercial funding; or*
- *Ugu DM could appoint Umgeni Water as bulk water services provider for the Umzimkhulu RWSS and other areas supplied out of the dam, and Umgeni Water could fund the dam and the upgrading of the downstream water treatment works with a mix of RBIG funding, other grant funding if available, and commercial loans.*

Conclusions

The following conclusions are drawn from the work conducted as part of the Technical module of the Feasibility Study:

- *The water requirements exceed the water availability in the Umzimkhulu River during dry months and an augmentation of the water resource is needed urgently if growing water requirements are to be met, and the ecology of the Estuary is to be improved.*
- *The Ncwabeni OCS Dam Project is to comprise of an off-channel, concrete faced rockfill dam of 47m water height and 15.5 million m^3/a gross storage capacity on the Ncwabeni River, together with an abstraction weir and works on the Umzimkhulu River.*
- *The costs of the Ncwabeni OCS Dam Project is R580 million in 2012 Rand values.*
- *Institutional and financial arrangement options have been identified, and discussions with the relevant roles players commenced. A preferred option has also been recommended, but needs to be accepted by the role players involved.*

Recommendations

The following recommendations are made for finalising the Feasibility Phase and handover for implementation:

- *This main report should be read together with the technical supporting reports for a full understanding of the work that has been conducted.*
- *The RID be finalised once environmental authorisation be approved*
- *The Institutional and Financial arrangements be finalised as this activity is on the critical path of the implementation program. This starts with a formal response from Ugu DM on their preferred funding and institutional arrangement option.*
- *Some additional work Geotechnical work needs to be conducted during the detailed design phase to accompany the drilling investigations conducted during the feasibility phase.*
- *The possibility of water supply directly from the dam needs further investigation by the Water Services authority.*

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LIST OF ABBREVIATIONS

ACR	Asphalt core rockfill
BoQ	Bill of Quantities
BSR	Bentonite sand rockfill
CBA	Cost benefit analysis
CFR	Concrete faced rockfill
DWA	Department of Water Affairs
ECR	earth core rockfill
EIA	Environmental impact assessment
ESI	Environmental Screening Investigation
EWR	Ecological water requirements
FSL	full supply level
HFY	Historic firm yield
IDP	Integrated development plan
mamsl	meters above mean sea level
MRCWRS	Mzinkhulu River catchment water resources study
NGL	natural ground level
NOC	Non overspill crest
OCS	off-channel storage
P&G	preliminary & general
RCC	roller compacted concrete
RDF	Recommended design flood
RID	Record of implementation decisions
RWSS	Regional Water supply scheme
SEF	Safety evaluation flood
SHR	St. Helen's Rock
SKZNFS	Southern KwaZulu-Natal Water Resources Pre-feasibility Study
UFW	Unaccounted for water
URV	Unit reference value
VAPS	Vaal Augmentation Planning Study
WC/WDM	Water conservation and water demand management
WSA	Water services authority
WSS	Water supply system
WR 90	Water resources 1990 (a hydrological study by the WRC)
WR2005	Water resources 2005 (a hydrological study by the WRC)
WRYM	Water resources yield model
WTW	Water treatment works

1 INTRODUCTION

1.1 BACKGROUND TO THE PROJECT

The Umzimkhulu Regional Water Supply Scheme, which forms part of the KwaZulu Natal's Lower South Coast System, supplies water to the coastal region from Hiberdeen to Margate, including Port Shepstone. The water is presently sourced from non-regulated river flows in the Umzimkhulu River. Abstraction is at the St. Helen's Rock abstraction works near Port Shepstone where water is treated and from where it is distributed to various users.

The *Southern KwaZulu-Natal Water Resources Pre-feasibility Study Phase 1* (DWAF, 2002), concluded that during dry periods, the river flow is insufficient to meet the water requirements, even without provision for the release of the ecological Reserve. The study recommended that, in order to provide for the water supply to all user sectors, including the Reserve, the construction of an off-channel storage (OCS) dam in one of the tributaries to the Umzimkhulu River should be considered. The reservoir can be filled from its incremental catchment, supplemented by pumping from the Umzimkhulu River during times of high river flows. During times of low flows water can be released back into the Umzimkhulu River for abstraction downstream at the existing St. Helen's Rock abstraction works.

The 2nd phase of the *Southern KwaZulu-Natal Water Resources Pre-feasibility Study* (DWAF, 2005), as well as the *Mzimkhulu River Off-Channel Storage Pre-feasibility Study* (DWAF, 2007), investigated various sites for an OCS dam along the Lower Umzimkhulu River. The most favourable two sites were found on the Ncwabeni and Gugamela Rivers, which join the main river about 25 km upstream of the St Helen's Rock Abstraction. It also appeared that the social impacts of the Ncwabeni site area lower than the Gugamela site, as people are currently resident in the Gugamela Dam basin.

Subsequently the *Ncwabeni Off-channel Storage Dam Feasibility Study: Module 1: Technical Study* (this study) was initiated by the DWA to conduct a comprehensive engineering investigation at the feasibility level for the proposed Ncwabeni Off-Channel Storage Scheme. The possible dam on the Ncwabeni River was to be considered first and if a fatal flaw is found, the site on the Gugamela River should then be considered.

1.2 SCOPE AND ORGANISATION OF THE STUDY

The technical work was conducted was part of the Ncwabeni OCS dam Feasibility Study: Module 1: Technical Study. The EIA has been conducted under Module 2 of the Feasibility Study.

The **key objectives** of Module 1: Technical study are to:

- Recommend the optimum scheme configuration;
- Undertake feasibility level dam foundation and construction material investigations including quarries;
- Undertake the necessary supporting investigations and studies to support the feasibility study required for the implementation of the scheme;
- Do sufficient design of infrastructure to obtain cost estimates;
- Collaboration with the appointed PSP that will be responsible for the EIA process;
- Optimise the engineering and economic parameters and determine cost estimates for the following components of the scheme; the dam, pipeline, pump station, abstraction works, diversion weir and access roads; and
- Provide institutional arrangements for the smooth implementation of the scheme.

The **sequence of activities** in order from beginning to end followed in this feasibility study included the following:

- Conduct an environmental screening to assess the environmental risks which inform the design team as well as provide starting information for Module 2: the EIA study.
- Water resources assessment including yield analysis for both the Gugamela and Ncwabeni Dam sites;
- Foundation and construction materials investigation;
- Cost comparison of dam types for both Gugamela and Ncwabeni Dams for the yield associated with the most likely water requirements;
- Selection of site and dam type;
- Cost comparison of scheme for incremental yield to the highest water requirement;
- Hydraulic model study of Umzimkhulu River to identify three possible sites for abstraction works;
- Selection of the best layout for abstraction works and diversion weir;
- Selection and cost comparison of abstraction work, diversion weir, pump station, pipeline and access road layouts for the three identified sites;
- Hydraulic model study of selected abstraction work, diversion weir and pump station for optimisation;
- Optimization and cost comparison analysis of selected scheme;
- Conceptual design of selected scheme; and
- Determination of URV of water supplied.
- Identify and recommend institutional and financial arrangements for the project
- Prepare a draft Record of Implementation Decisions (RID) document for hand-over of the project.

1.3 PURPOSE OF THE REPORT

The purpose of the report is to present and integrate the key methodology, assumptions made and results of the various tasks and reports of the Feasibility Study.

1.4 LAYOUT OF THE REPORT

Section 1 of the report presents the background information on the proposed project and the region.

Section 2 covers the Environmental Screening task. More detail is available in ***Supporting Report 5: Environmental Screening.***

Section 3 presents the water requirements and **Section 4** presents the Water Resources and yield analyses. More detail on **Sections 3 and 4** is available in ***Supporting Report 1: Water Requirements and Water Resources***.

Section 5 covers the Geological and materials investigation task. More detail is available in ***Supporting Report 2: Geotechnical and Materials Investigation.***

Section 6 covers the Engineering investigations which includes the feasibility design and cost estimates. More detail is available in ***Supporting Report 3: Design and Cost Estimates.***

Section 7 includes the institutional and financial arrangement options and recommendations. More detail is available in ***Supporting Report 4: Instituional and Financial Arrangements.***

Sections 8 and **9** present the conclusions and recommendations respectively.

1.5 THE PROPOSED PROJECT

Before the results of the various tasks of the Feasibility Study are presented the basic layout and functioning of the proposed OCS dam, must be explained. The layout of the two possible OCS dam options, namely the Ncwabeni and Gugamela OCS dams are shown in **Figure A1** in **Appendix A**.

The OCS dam will provide releases of water back into the Umzimkhulu River to augment the low flows often experienced in the Umzimkhulu River during the winter months. The water is then abstracted at the existing St Helen's Rock works about 25 km downstream of the proposed OCS dam sites. St Helen's Rock itself is about 8 km from the estuary mouth. Although there may be some direct abstraction for communities surrounding the dam site, the majority of the water will be for abstraction at St Helen's Rock. As such the yield from the dam itself is of less importance than how it increases the yield of the system at St Helen's Rock. The focus of the yield assessment will thus be at St Helen's Rock.

The increased yield of the system with the addition of the OCS dam will be derived from:

- Primarily the abstraction, pumping and storage of water from a weir on the Umzimkhulu River into the OCS dam during the summer months when there is surplus water in the river; and
- Incremental runoff directly into the dam from the tributary on which the dam is positioned.

The incremental catchments of the two possible OCS dam site options are very similar in size and runoff. The storage required at either site will therefore be very similar. The preferred OCS dam site from a technical perspective will thus be a function of the cost of dam for which the required yield can be generated (dam height, and type) and the operational costs (pumping height and distance).

2 ENVIRONMENTAL SCREENING

An Environmental Screening Investigation (ESI) for the two site options of the proposed Off-Channel Storage (OCS) Dam was one of the first tasks to be initiated as part of the Feasibility Study. The two alternative OCS dam sites that were investigated are in the Ncwabeni River (a.k.a site D2) and the Gugamela River (site D3A). The ESI provides a platform of information for Module 2 of the Feasibility Study: The EIA, and also guides the technical engineering tasks towards solutions that will be in line with the EIA.

The ESI investigated potential risks associated with the proposed OCS dam in terms of the biophysical, social and economic environment as well as risks in terms of environmental legislation. The purpose of the ESI is to inform the Environmental Impact Assessment Study, module 2 of the Feasibility Study, of what risks need to be investigated. The ESI also assists the engineering team with information of the environment on site. The ESI was conducted in February – April 2011 using available information and by collecting data during a site visit. During the site visit, a tribal council meeting was attended to discuss the proposed OCSS with the local Indunas.

During the screening investigation it was noted that Dam site D2 was in a pristine condition, with a high diversity of species. Species of conservational concern with a potential to occur on both dam sites include two plants, two millipedes, two otters and two catadromous species (species that live in freshwater and breed in the ocean). The two plants are *Diaphananthe millarii* (tree orchid) and *Ceropegia rudatisii*. The two millipedes are *Doratogonus montanus* and *D. infragilis*. The two otters are *Lutra maculicollis* and *Aonyx capensis.* The two catadromous fish species are Mottled Eel and Freshwater Mullet. No human settlements are found within Dam site D2, while several households occur with Dam site D3A. The presence of households within Dam site D3A have had marked impacts on its terrestrial and riparian ecosystems. Although the majority of Dam site D3A is mostly degraded, the headwaters of this dam site are still in a pristine condition.

Health and safety risks associated with the project will include the spreading of HIV/Aids and potential water hazards. Local people use the access road to both dam sites and there are many houses close to this road. Possible accidents between construction vehicles and children or pedestrians on the existing access road will therefore be a significant risk associated with the construction phase. The construction of new roads involves the risks in terms of erosion and ecological impacts.

The farm Gibraltar 8258 is located on the southern banks of the Umzimkhulu River and will potentially be affected by the proposed development. Visual impacts are possible, as the dam wall at both dam sites will possibly be visible from this farm. A hydropower scheme was identified on this farm that utilised the difference in elevation upstream and downstream of the Umzimkhulu River. The operation of the OCS dam can also have an impact on the hydropower scheme.

Potential conflicts could occur between the Mhlabatshana Dam projects, which is approximately 20km north of the Ncwabeni OCS dam. Water from the Umzimkhulu River will possibly be abstracted to augment the water stored in the Mhlabashana Dam. There is also an existing small diameter pipeline in Dam site D3A used for water abstraction, which could be impacted on by the proposed OCS dam.

A loss of income for the local communities are possible, as the areas in both dam sites to be inundated will destroy plants with various medicinal and commercial uses. Although the agricultural potential of both dam sites are considered to be low, there are some households and small-scale farms in Dam site D3A within the area to be inundated. Dam site D2 will not require any displacement of households or farms. Despite the potential losses of income, the construction of the dam will provide short-term employment, if local people are used for construction activities. This will also give local people the opportunity to be trained.

Due to a lack of information, there are some uncertainties regarding the following issues:

- Confirmation of the presence of species of conservational concern.
- The possible occurrence of heritage resources.
- The number of people to be displaced should be confirmed.
- The environmental impacts of access roads and road re-alignments.
- The impacts of the proposed weir on the farm Gibraltar 8258, specifically regarding the hydropower scheme and flood levels of the Mzimkhulu River.

The screening assessment has been undertaken using a rating approach. Every possible risk associated with each environmental issue was rated using the following rating system:

- Favourable (rated at 4 points)
- Uncertain (rated at 3 points) – There is uncertainty on the nature and extent of the impact primarily due to a lack of information on site-specific conditions.
- Not Favourable (rated at 2 point)
- Fatal flaw (rated at 1 point) – where there could be an impact which cannot be mitigated.

Table I is a summary of the risk assessments made in this report. The numbers in **Table I** are the sums of the rates given to all risks associated with each environmental issue. The outcomes of the study indicate that the Dam site D2 is more sensitive in terms of its ecology, while Dam site D3A is more sensitive in terms of social aspects.

Table I: Risk assessment summary

Environmental issue	Site D2	Site D3A
Biophysical		
Geology	7	7
Soil	3	4
Fauna/Flora	6	8
Riverine ecosystem	14	15
Water quality	13	13
Hydrology	8	8
Social		
Agricultural	10	10
Heritage	3	3
Displacement of persons	10	6
Health & safety	8	8
Access route	10	9
Visual	4	4
Infrastructural development	16	16
Economic		
Loss of local income due to project	9	7
Employment creation	8	8
Enviro-legal		
Enviro-legal	3	3
Public Participation	6	6
Total	**139**	**135**

3 WATER REQUIREMENTS

3.1 THE UMZIMKHULU REGIONAL WATER SUPPLY SCHEME

The orientation and layout of the existing Umzimkhulu Regional Water Supply Scheme (RWSS) is shown in **Figure A2** of **Appendix A**.

The Umzimkhulu RWSS supply area (Bhobhoyi Supply Zone) for the requirement projection encompasses the following urban centres:

- Hibberdene
- Port Shepstone
- Louisiana
- Margate
- Shelly Beach
- Southbroom
- Gamalakhe
- Ramsgate

This system also supplies Nsimbini Tribal Authority, the KwaMdlala Tribal Authority, the Murchison-Bhobhoyi rural and peri-urban area as well as the Kwandwalane tribal authority.

Currently, the only source of water for the Umzimkhulu RWSS is un-regulated run-of-river abstractions from the Umzimkhulu River at the St Helen's Rock abstraction, which is positioned 9 km upstream from the River Mouth. The abstracted water is then pumped to the Umzimkhulu Water Treatment Works (WTW), which includes a recently constructed dam for operational/balancing purposes, known as the Umzimkhulu off-channel storage dam. Due to the studies and construction associated with the operations/balancing dam, the DWA have changed the name of the proposed off-channel storage dam which is being investigated in this Feasibility Study, to the Ncwabeni OCS dam to avoid confusion. Any further references to off-channel storage (OCS) dams during this study will pertain to the proposed Ncwabeni OCS dam to augment the water resource, unless otherwise stated.

During low flow periods the shallow water depths and a meandering flow in the sandy river bed make abstraction at St Helen's Rock difficult. To improve the abstraction efficiency during low flow periods, a weir has been proposed at the St Helen's Rock abstraction point. This weir is a necessary part of the overall plans for upgrading water supply system, and needs to be developed in parallel to the proposed OCS dam. The weir at St Helen's Rock will be investigated by the Ugu District Municipality, the Water Services Authority, and will not be focused on further during this study. This proposed weir at St Helen's Rock must also not be confused with the abstraction weir which will be required for off-channel pumping to the Ncwabeni OCS dam higher upstream.

3.2 HISTORICAL WATER SUPPLY

Historical water supply records from the Umzimkhulu Water Treatment Works (WTW) were obtained for fifteen years for the period from 1995 until 2010. Historical supply records from 1995 until 2005 were sourced from the *Bulk Water Services Master Plan* (SSI (Pty) Ltd, 2006). Historical water production and consumption based on meter readings was also provided by Ugu for the past six years from July 2004 until June 2010. The production and consumption figures are presented in **Figure 3-1**.

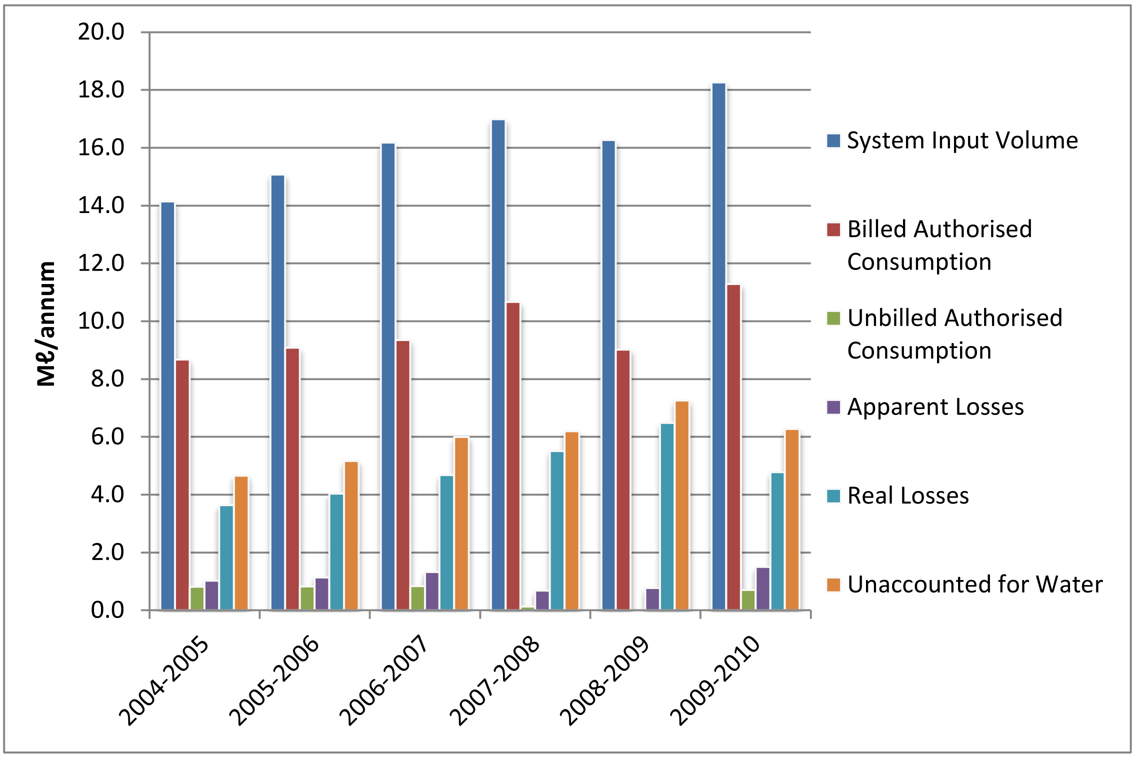

Figure 3-1: Umzimkhulu Regional Supply Scheme water production volumes, consumption volumes and losses

Over the past six years the unaccounted for water (UFW) has averaged about 35% and real losses in the order of about 30%. According to Ugu, water conservation and water demand management (WC/WDM) measures have been introduced to reduce losses and unaccounted for water in the system.

Before a significant and costly new scheme is implemented to augment the water resource, it is necessary to use the existing resource wisely and efficiently. As such WC/WDM measures and savings have been included as part of the water requirement projections.

After consulting with role players (DWA, UGU, BKS), and considering the current UFW figures, it was established that UGU can achieve a UFW target of 24% (of water requirement) to be attained between 2010 to 2015, which would be about a 2.0% annual decrease in UFW.

3.3 WATER REQUIREMENT PROJECTIONS

The current water supply and requirements have been established and provide a reliable base from which to project water requirements into the future.

3.3.1 Population within the Umzimkhulu Regional Water Supply Scheme

Population dynamics is a key driver of water requirement growth as well as the funding arrangements of water supply schemes. Various sources of data on the population and demographics of the region exist. Ugu District Municipality's IDP estimates that there are 50 650 households in the Hibiscus Coast area and a population of 222 281 giving 4.7 persons per household on average.

A household count of the Umzimkhulu Regional Water supply Scheme supply area was conducted for the Feasibility Study based on 2010 aerial photography. Using estimated persons per household obtained from recent studies in the area the population for the Umzimkhulu RWSS was estimated based on the results of the household count. The estimated population is shown in **Table 3.1**.

Table 3.1: Estimated population of the Umzimkhulu Regional Water Supply Scheme based on household count

Household type	Households			Population		
	Urban	Rural	Total	Urban	Rural	Total
Houses	16 944	7 472	24 416	79 637	49 315	128 952
Dwellings/huts		22 546	22 546		68 991	68 991
Total	**16 944**	**30 018**	**46 962**	**79 637**	**118 306**	**197 943**
Schools	16	52	68			
Hospitals	6	1	7			
Clinics	0	21	21			

Another source of information for is the recent Sector Wide Infrastructure Audit (Hibiscus Coast Municipality, 2011). This report showed that approximately 50% of the households in the Municipality are urban and 50% rural.

Based on the three different sources of data, the current population within the Umzimkhulu RWSS supply area is between 153 000 and 197 000. The household population demographics are approximately half rural, and half urban and peri-urban.

3.3.2 Water requirement projections for the Umzimkhulu RWSS

3.3.2.1 Water requirement projections of the pre-feasibility study

The water requirement projections as determined by the *Mzimkhulu Off-channel Storage Dam Pre-feasibility Study* (DWA, 2007) are now dated and need to be updated based on actual recorded supply figures, as well as most likely current situation. The planning water requirement projection scenario from the pre-feasibility study has been plotted together with the actual historical supply information obtained for 1995 up until 2010 in **Figure 3-2**. As can be seen the trend of actual water supply volumes have grown at a similar rate to the water requirements estimated by the Pre-feasibility planning scenario. The water requirements of the pre-feasibility study are however slightly lower than actual supply for the five year period between 2005 and 2010.

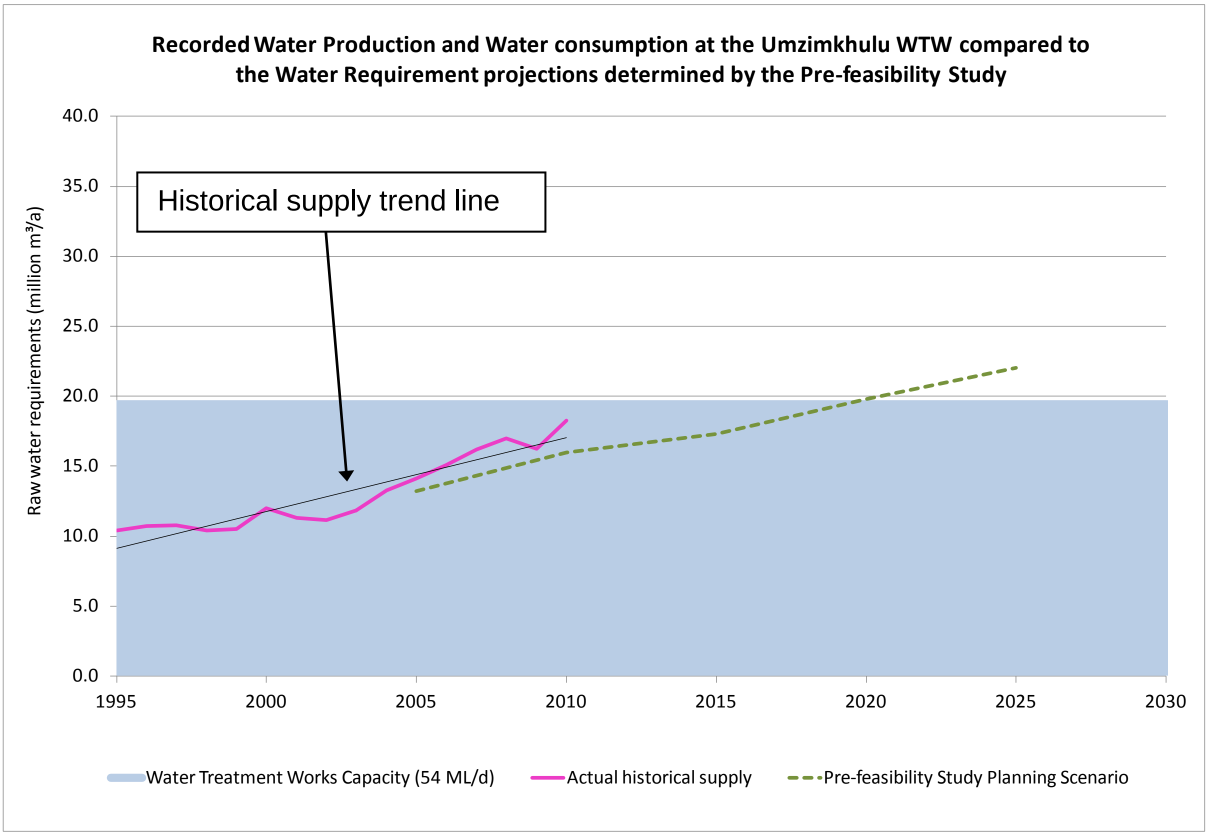

Figure 3-2: Comparison of water supply record with projected water requirements from the pre-feasibility study

Considering other recent studies conducted in the area such as the *Water Resources Planning Study* (Ugu, 2004), and the *Development of a reconciliation strategy for All Towns in the Eastern Region* (DWA, 2011), future water requirement scenarios were formulated for planning purposes.

High, medium and low growth rates of 3.3%, 2.3% and 1.3% applied in a linear manner where thus adopted by this feasibility to cover the range of likely water requirement growth expected for the Umzimkhulu RWSS. Furthermore the medium growth scenario was selected as the planning scenario, and the high and low growth scenarios selected as the upper and lower bounds of the water requirement projection envelope. These water requirement projection scenarios where discussed and accepted by the key role players (DWA, UGU, and BKS). The three scenarios of water requirement projections presented in **Figure 3-3** .

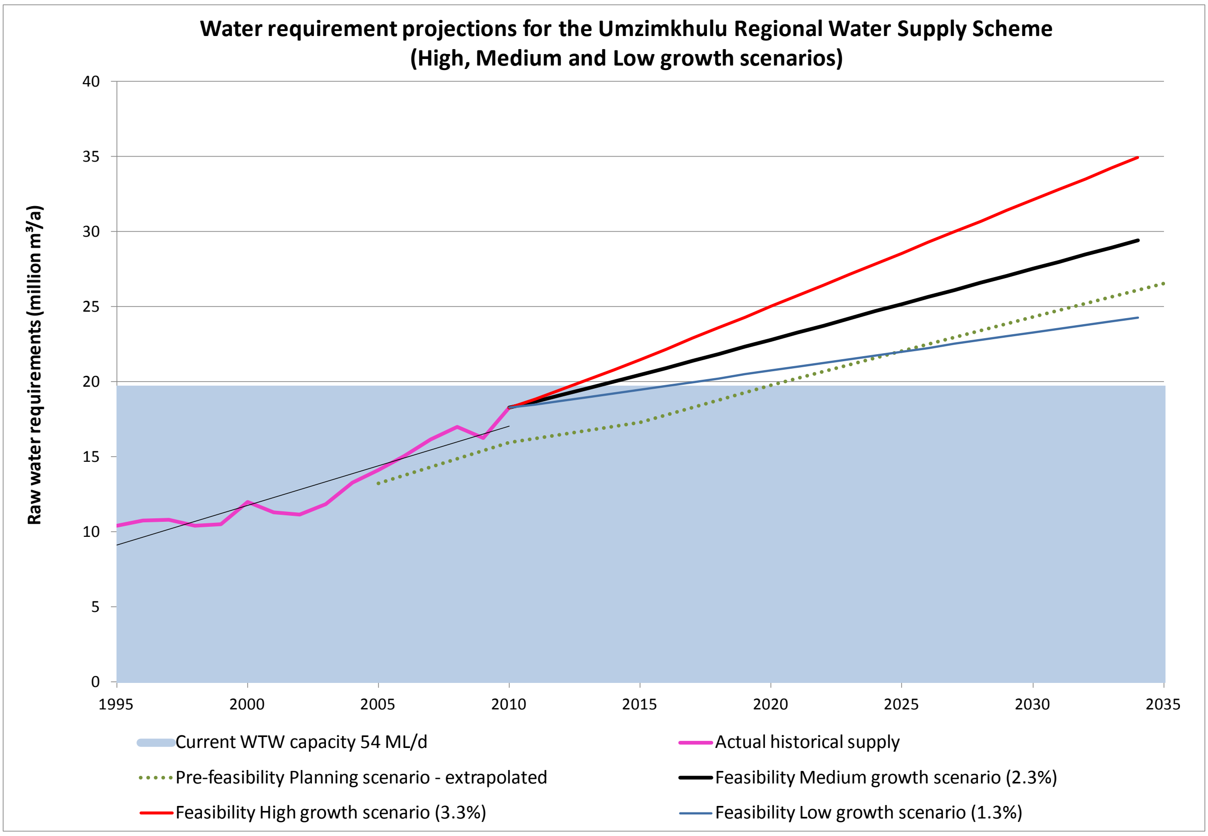

Figure 3-3: Water requirement projections scenarios adopted for the feasibility study

Due to the current high level of water losses included within the water consumption figures, the water loss reduction through WC/WDM measures should be added to the water requirement projection scenarios to account for more efficient use of existing and future water resources. The impact of water loss reduction (2010 to 2015) on the water requirement projection of the planning scenario is presented in **Figure 3-4**. Apart from more efficient and sustainable use of the water resource, the successful reduction of water losses through WC/WDM measures will also have the very important impact of delaying the need for upgrading the Umzimkhulu WTW's capacity by about four years.

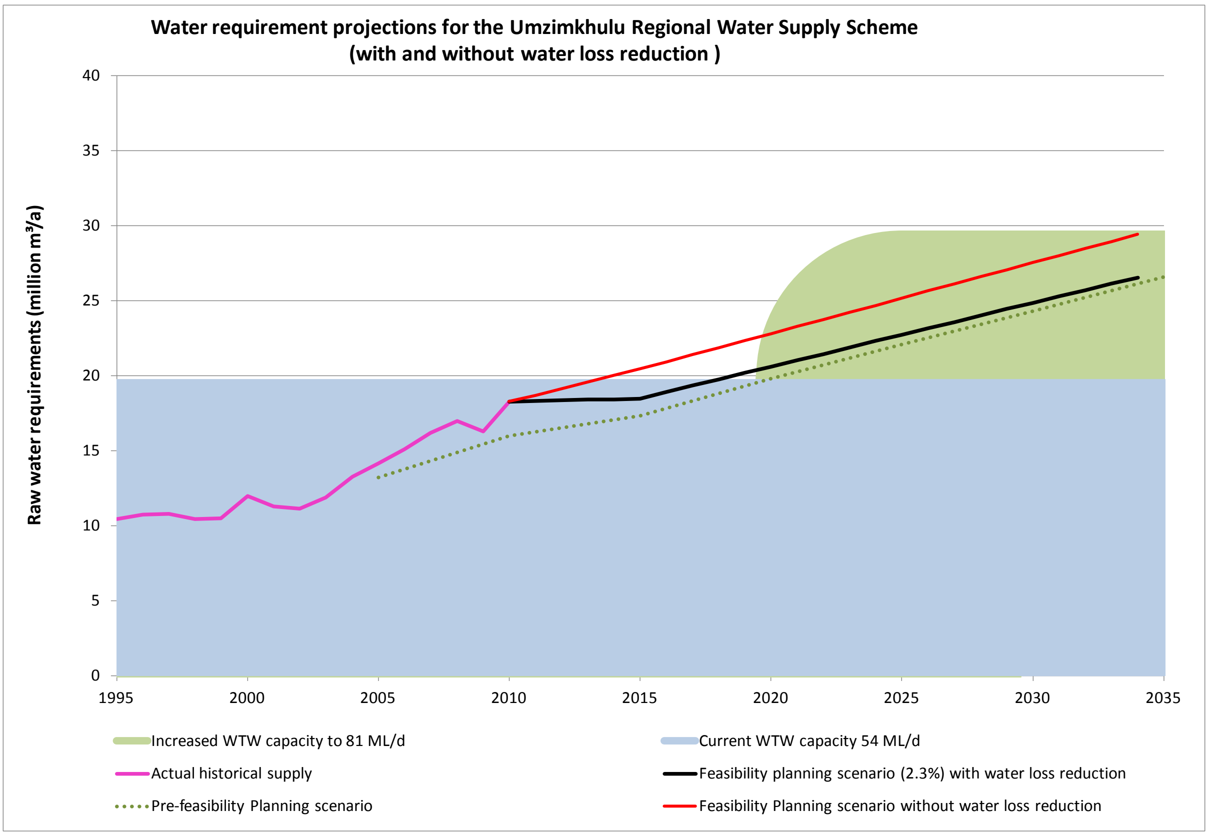

Figure 3-4: Water requirement projection planning scenario adopted for the feasibility study, with and without WC/WDM

Population and water requirements have been determined for the existing Umzimkhulu RWSS supply area. There are however, areas outside of the existing supply area need of water services delivery and could be supplied water from the proposed OCS dam through an expansion of the Umzimkhulu RWSS supply area.

3.4 UMZUMBE SUPPLY AREA

3.4.1 Mlhabatshane Regional Water Supply Scheme

Currently there are smaller stand-alone schemes within the Umzumbe rural area that draw water from the Umzumbe River, namely the Phungashe, the Ndwebu and Assissi schemes. Some of these stand-alone schemes are planned to be incorporated in phases into a larger Mlhabatshane Regional Water Supply Scheme (RWSS). Currently Umgeni Water is busy implementing the Mlhabatshane Dam and first phase of the bulk water scheme which will incorporate the existing Phungashe scheme. Ultimately the Mhlabatshane water supply scheme is planned to supply the full area between the Umzimkhulu and Mzumbe rivers, from Phungashe in the North-west to Frankland in the South-east. Initial plans were for the Mlhabatshane RWSS to supply the full supply area with a level of service of 32.5 ℓ/c/d. Subsequent to the

Mlhabatshane Pre-feasibility Study, the Ugu DM requested that various options be investigated to bring this level of water service up to the desired 60 ℓ/c/d. This was conducted as a follow up study namely the *Mlhabatshane Regional Water Supply Scheme Report – Bulk Supply Options* (Ugu, 2009). The study concluded that the yield of a practical sized Mlhabatshane Dam of 1.56 million m^3/a, will not have sufficient water to supply the planned area in its entirety with the desired level of service of 60 ℓ/c/d. With abstractions of water from the Umzimkhulu River adjacent to Phungashe in summer to augment the dam, sufficient water to meet a water requirement of 2.79 million m^3/a could be yielded.

3.4.1.1 Umzumbe-Mhlabatshane supply area population

Based on a household count for the Umzumbe-Mhlabatshane supply area using 2010 aerial photography, the population of the Mhlabatshane supply area was estimated at about 97 000 people (**Table 3.2**). This is slightly more than that determined by the *Mlhabatshane Regional Water Supply Scheme Report – Bulk Supply Options* (Ugu, 2009) of approximately 90 500 using predominantly 2001 census data.

Table 3.2: Population determined from household count (2010)

Area	Houses	Dwellings	Population	Schools	Clinics	Hospitals
Mlabatshane supply area (*excl. KwaMdlala*)	957	29 653	97 054	46	7	0
Assisi supply area	198	3 177	11 028	2	1	0

3.4.1.2 Umzumbe-Mhlabatshane supply area population

Although a number of studies on rural areas have show very little or even negative growth, the increase in population based on the revised population count for 2010 suggests that the population may well be growing albeit slowly. This is particularly likely for the areas closer to Port Shepstone and the coast, which are becoming denser through migrations from deeper rural areas to be closer to the urban centre.

Three growth rates, namely low, medium and high, with annual growth rates of 0.0%, 1.0% and 1.3% respectively were adopted for the water requirement projections. These growth rates accommodate both a small increase in population as well as possible increases in future level of service above the current 60 ℓ/c/d target. The medium growth scenario was assumed as the most likely growth rate for the area, as it is more in line with the estimated growth between 2001 and 2010 of about 0.9% based on the two different household counts.

3.4.1.3 Umzumbe – Mhlabatshane supply area water requirements

For the current population of 97 000 and a level of water service of 60 ℓ/c/d (with reasonable bulk conveyance losses of 25%) the 2010 requirement for the Mhlabatshane Supply area in Umzumbe is in the order of 2.85 million m^3/a.

Based on the medium growth scenario of 1.1% per annum, the water requirements are expected to increase to 3.64 million m^3/a by 2035. This is greater than the yield that the Mlhabatshane scheme with abstraction from the Umzimkhulu River in summer (phase 1 and 2) can yield of 2.79 million m^3/a. The projected water balance for the Umzumbe-Mhlabatshane Supply Area with only the Mhlabatshane Scheme is shown in **Figure 3-5**.

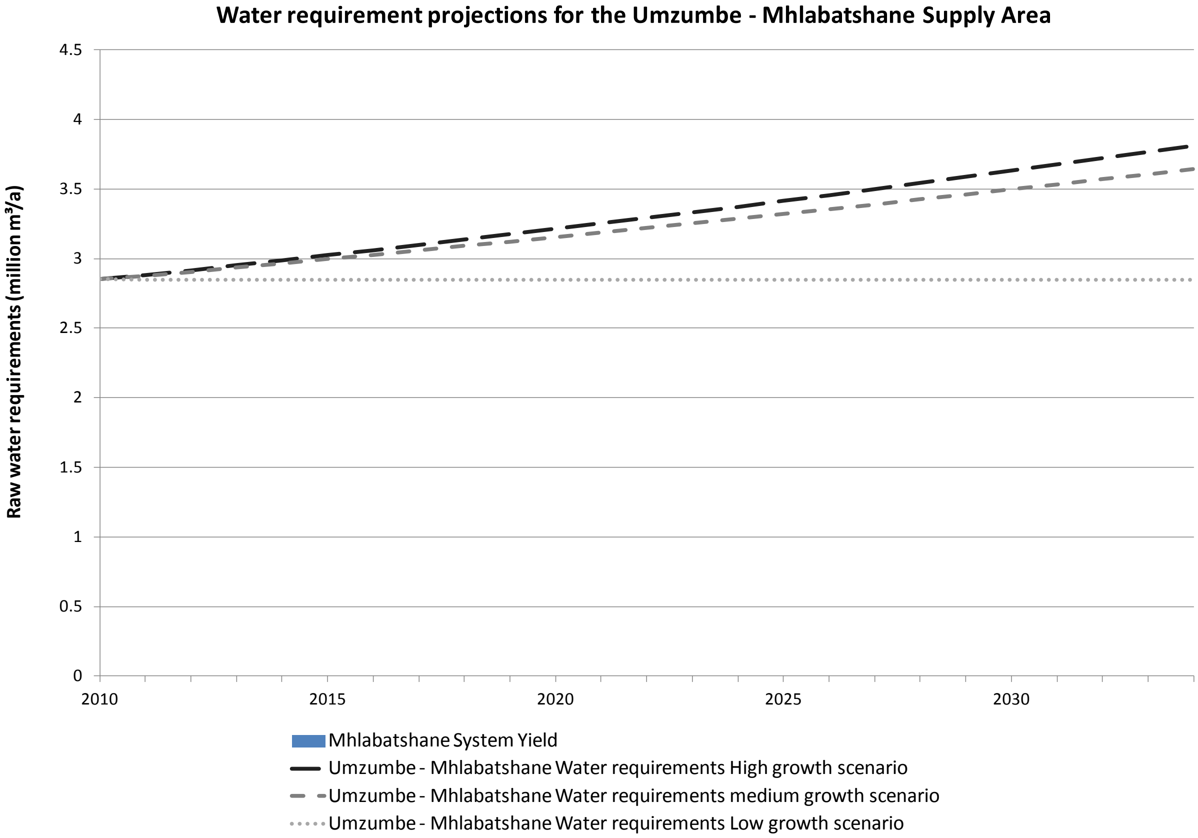

Figure 3-5: Mhlabatshane Water Supply Scheme projected water balance

As such, through discussions with the Ugu DM, it is proposed that the water supply to the Umzumbe area is augmented by the proposed OCS dam, so that the full desired level of service of 60 ℓ/c/d can be achieved. The lower lying areas furthest from the Mhlabatshane Dam could be supplied by the proposed OCS dam, leaving the higher lying areas closer to the Mlhabatshane Dam to be supplied by the Mhlabatshane WSS. The suggested split in supply as presented in **Figure A3** of **Appendix A.** The proposed supply to each of these areas is thus linked to a specific population/portion of Umzumbe. This is shown in **Figure 3-6**.

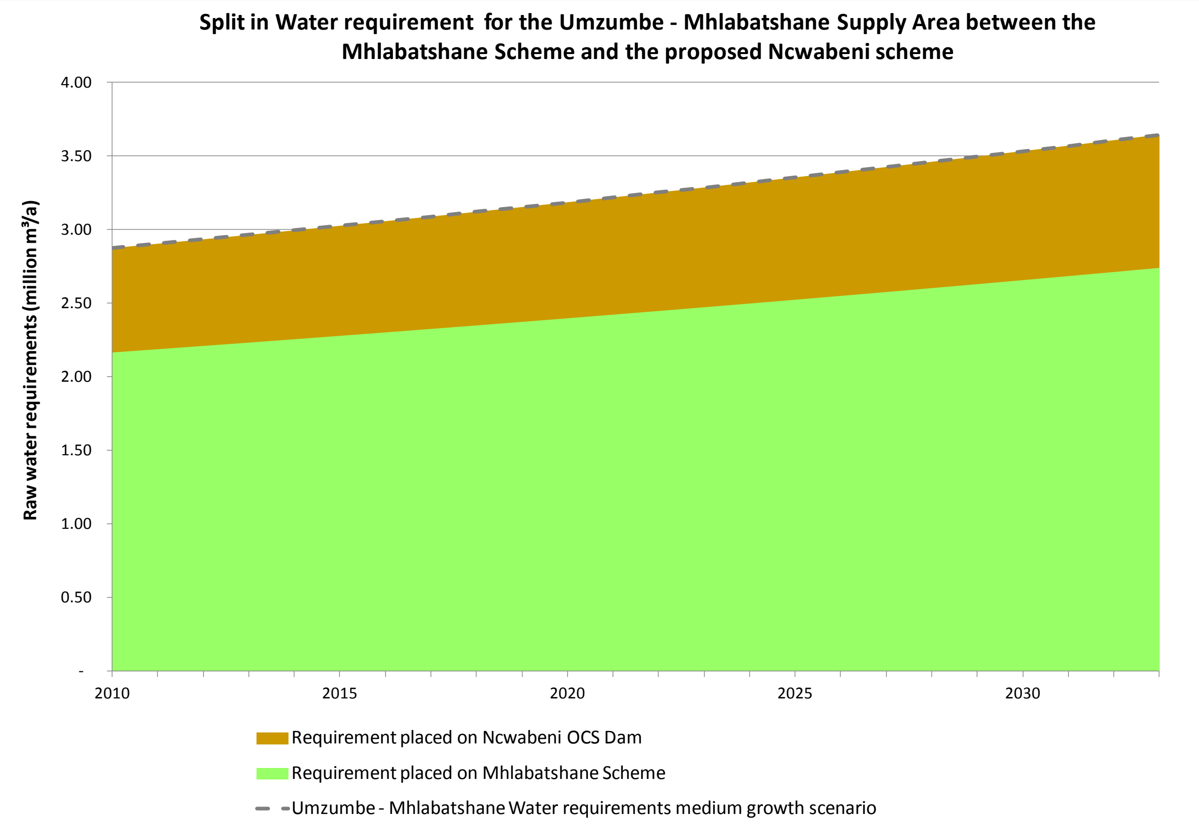

Figure 3-6: Mhlabasthane Water Supply Scheme projected water balance

In addition to the Mhlabatshane supply area, the Assisi supply scheme water requirements has been added to the Umzimkhulu RWSS as the Assisi scheme cannot deliver sufficient water to meet the full demand, and the water of the Umzumbe River currently being used to supply the Assisi scheme can be better utilised north of the Umzumbe River where there is a water resources shortage. The addition of the Assisi Supply Area Water requirements to the Umzimkhulu RWSS as well as the portion of the Mhlabatshane supply area water requirements also being assigned to the Umzimkhulu RWSS is shown in **Figure 3-7**.

Note: The same colours have been used in **Figure 3-6** and **Figure 3-7** for the different supply area as in as **Figure A3** of **Appendix A.**

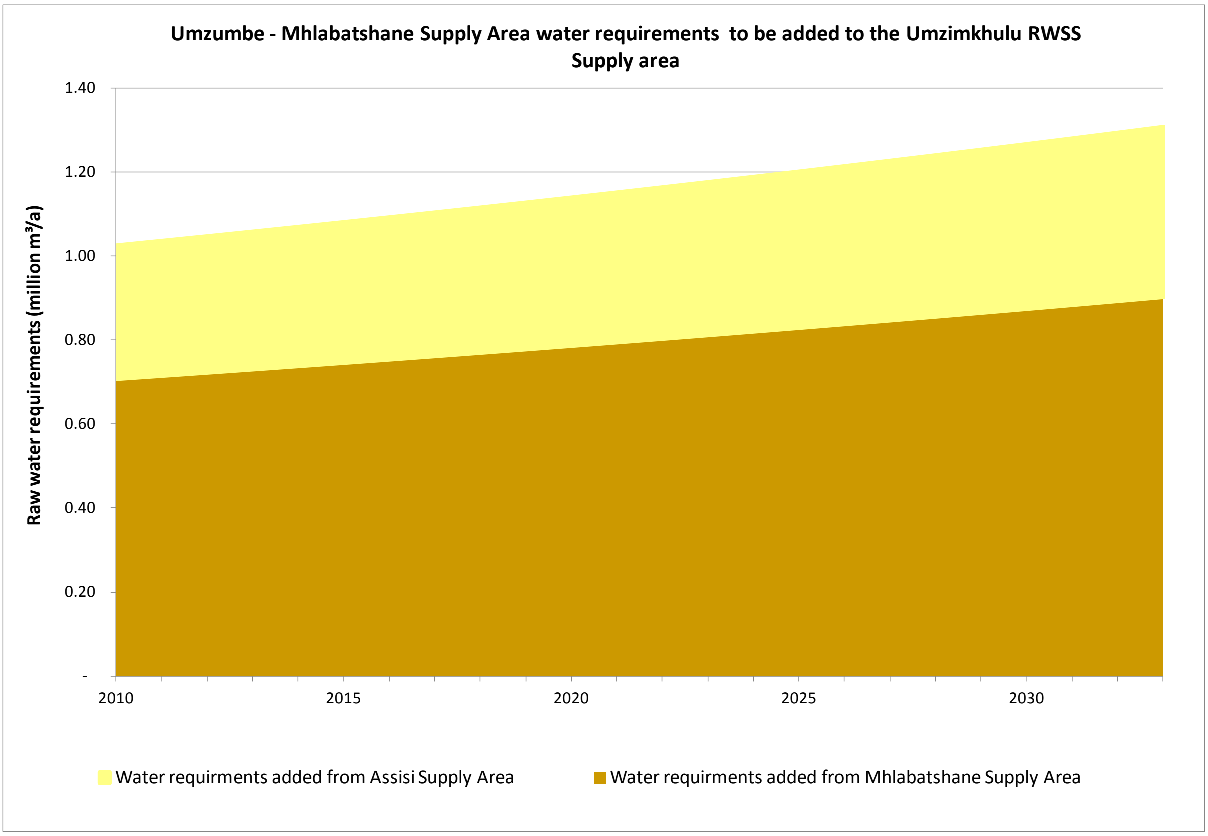

Figure 3-7: Umzumbe water requirements to be added to the Umzimkhulu RWSS

3.5 TOTAL WATER REQUIREMENT PROJECTIONS FOR THE UMZIMKHULU RWSS

The total water requirements for the Umzimkhulu RWSS are the combination of the water requirement projections for the Existing supply area and the water requirements identified in the new Umzumbe supply area. These water requirements are presented in **Figure 3-8**. Based on this planning horizon, the OCS dam will thus be sized to yield about 30 million m^3/a, to be able to meet the planning horizon water requirements.

The water availability of the Umzimkhulu RWSS will now be assessed, both without and then with the OCS dam to determine both the timing and size of the dam required.

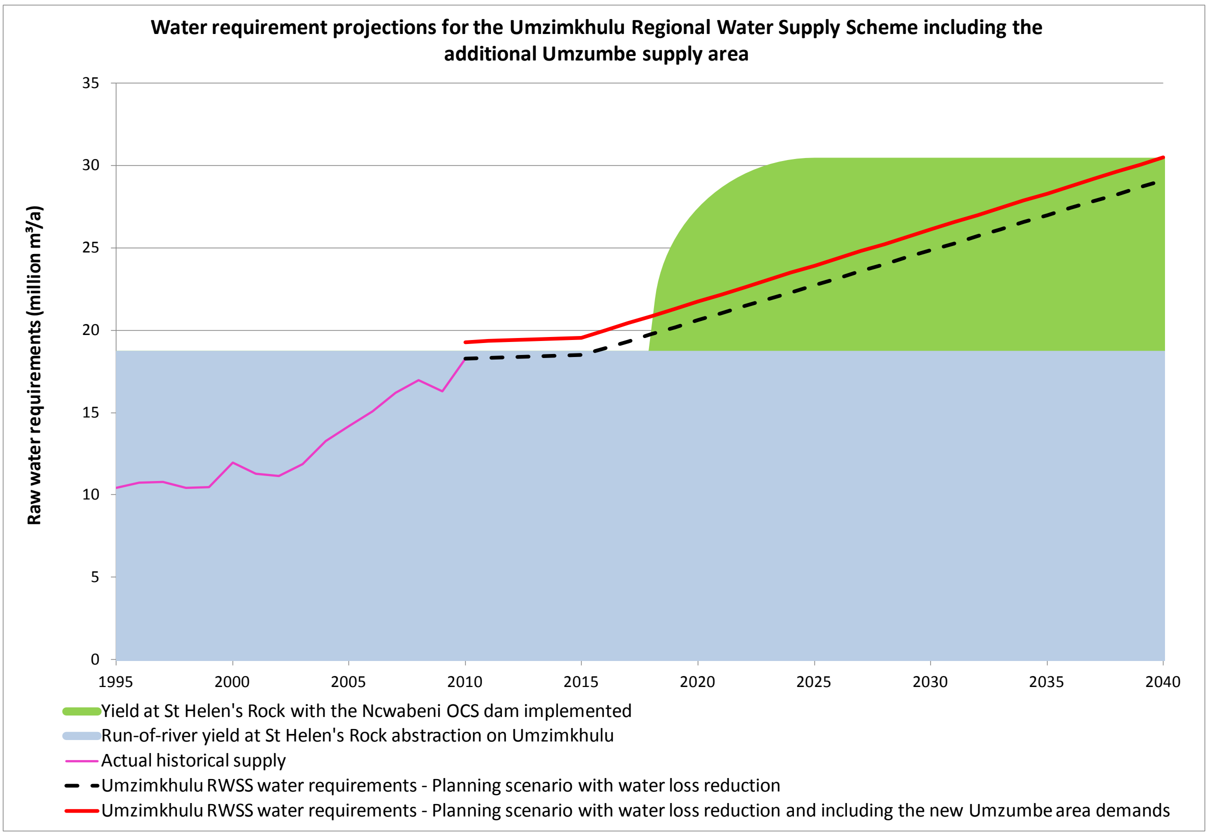

Figure 3-8: Planning scenario Water requirement projection to be used for sizing the off-channel storage dam

4 WATER AVAILABILITY

4.1 ASSESSMENT OF THE HYDROLOGY

Before conducting yield analyses the most recent hydrology determined by the *Mzimkhulu River Catchment Water Resource Study* (DWA, 2011), was reviewed. Based on the hydrology review, it appears that there are no fatal flaws in the hydrology as determined by the *MRCWRS*. Initial concerns about afforestation water use have subsequently been resolved. The study was done on a detailed basis focused on the Umzimkhulu River catchment, and is more detailed than previous studies such as the WR90 and WR2005, which most likely explains the differences in the hydrology from the previous studies.

The naturalised hydrology with the revised user-defined afforestation water use, excluding the SAMI-groundwater module, up to the end September 2008 will be used for the water availability analyses.

4.2 SEDIMENTATION

Reduced sedimentation is an advantage of an off-channel storage dam compared to a dam on the main river channel. Some sedimentation of the off-channel storage dams is still expected from the incremental catchment of the tributary on which the dam lies, as well as some finer particle of sediment being pumped from the abstraction weir and works. When determining the yields, the anticipated long term sedimentation of the off-channel storage dams needs to be taken into account.

Using the information emanating from the Sedimentation yield Review and the Physical Hydraulic Model Study, the calculations of sedimentation of the OCS dams was refined and the 50 year sediment volume was determined to be 2.6 million m^3. This is slightly higher than the sediment volume determined by the Pre-feasibility Study of 2.1 million m^3.

4.3 YIELD ANALYSIS

Various yield analyses were performed to determine the water availability of Umzimkhulu Regional Supply Scheme with the addition of OCS dam options. The yields analyses consisted of three phases, namely:

1. Set-up and testing of the Water Resources Yield Model (WRYM)
2. Historic firm yield analyses to determine yields for various sizes of OCS dams and abstraction rates, for the purposes of selecting the best scheme; and
3. Stochastic yields of the final selected scheme to confirm the assurance of supply.

4.3.1 WRYM setup and testing

To simulate the water resources of the Umzimkhulu River and determine the yields of the potential off-channel storage dam options, the Water Resources Yield Model (WRYM) was utilised. This study built on the existing WRYM system configuration developed for the *Mzimkhulu River Catchment Water Resource Study* (MCWRS) conducted by the DWA in 2010/2011. Some enhancements were made to the configuration of the *MCWRS* particularly in the Lower Umzimkhulu River which was the focus of this Feasibility Study.

The ecological water requirements (EWR) were reviewed by the study team to confirm their appropriate inclusion and application in the WRYM.

The EWR information was obtained from the MRCWRS and comparing this against the information as included in the WRYM configuration of the MRCWRS. Discussions were also held with the Reserve team of the MRCWRS.

The full EWR review is included in **Annexure C** of **Supporting Report 1 – Water Requirements and water Resources**. The key outcomes of the review are:

- The EWR's are generally correctly implemented in the WRYM (one small amendment was needed for an EWR site which lies on a tributary of the main river).
- The EWR for the Gibraltar site should be adopted for just below the abstraction weir on the Umzimkhulu River.
- The inclusion of an off-channel storage dam and off-channel pumping in the summer months, together with releases of water for St Helen's Rock in the winter months, does not negatively impact the EWR below the proposed project. EWR compliance actually improves compared to that of the Gibraltar site just upstream.

4.3.2 Present day yield

The present day yields were determined for the Umzimkhulu RWSS with the unregulated run-of-river abstraction at St Helen's Rock as per the current situation. The yields were compared to those stated in the pre-feasibility study and are summarised in **Table 4.1**.

Table 4.1: Present day firm yields at St Helen's Rock (million m³/a)

	Feasibility study	Pre-feasibility study
Yield with EWR	3.3	0.0
Yield without EWR	18.3	49.0

The present day firm yields determined by this feasibility study are approximately the same in magnitude as the 2010 water requirement. This is to be expected as the water resource is being fully utilised, as was highlighted by salt water being pumped at the St Helen's Abstraction in recent very dry winter months.

If the Reserve is to be implemented the yield drops significantly as all the water in the river during the dry months needs to be reserved for ecological purposes. It must be noted that the EWRs utilised are preliminary and still need to refined through the classification process, but provide a good initial indication of the significant impact that implementation of the Reserve will have on the current run-of-river abstraction yield.

4.4 FUTURE PLANNING SCENARIOS

Three future catchment development levels, were considered when determining the yield of the system with an off-channel storage dam included. These future scenarios included various levels of expansion in afforestation and different possible infrastructure developments. All future scenarios included domestic water requirements at an estimated 2030 level. No expansion in irrigation was considered. The first two future scenarios were adopted from the *MRCWRS*, and the future scenario 5 was added for the purposes of this study.

Scenarios 1: All small growers - Future Scenario 1 (FS1) has increased forestry areas of 29 400 ha for small growers throughout the catchment. A mitigation dam on the Ngwangwane River, to mitigate the impacts of the afforestation development on low flows was considered.

Scenarios 2: Small growers in the Bisi catchment - Future Scenario 2 (FS2) is similar to FS1, but only has increased forestry areas of 21 050 ha for small growers in the Bisi and Middle Umzimkhulu river catchments.

Similarly the inclusion of a mitigation dam on the Bisi River, to mitigate the impacts of the afforestation development on low flows was considered.

Scenario 5: No afforestation growth – Future scenario 5 assumes no further growth in afforestation from current levels. Only growth in domestic water requirements are accounted for.

4.5 HISTORIC FIRM YIELD ANALYSES

Historic firm yields (HFY) were determined for various OCS dam sizes and pumping rates. As the OCS dam will fit into a greater scheme, the focus of the HFY analyses was the available yield at the St Helen's Rock abstraction point.

4.5.1 Conveyance losses

Conveyance losses of 20 % were included to account for the possible loss of water in the river stretch between the dam and the St Helen's Rock abstraction 25 km downstream.

4.5.2 Historic firm yields with no pumping

Yields were determined for the system with an OCS dam, with no pumping from the Umzimkhulu River to fill the dam in the wet season. Ecological Water Requirements (EWR) were included. The yield of the system for a dam sizes as proposed by the Pre-feasibility Study, without off-channel pumping is only in the order of 11 to 15 million m^3/a. This is an increase of about 10 million m^3/a, from the yield of 3.3 million m^3/a for the system without an off-channel storage dam (**Table 4.1**). However, taking into consideration the implementation of the reserve and EWR's in the catchment, an off-channel storage dam without pumping will not yield sufficient water to supply the current or future water requirements. As such, off-channel pumping must be considered.

4.5.3 Historic firm yields with off-channel pumping

The historic firm yield at St Helen's Rock for Ncwabeni and Gugamela OCS dam options were determined for a range of dam sizes and pumping rates. This was done for future Scenarios 1, 2 and 5. A wide range of pumping and dam sizes were considered. Little difference in yield was found between future scenarios and FS2 was chosen to be used as indicative of future development levels in the catchment while being sufficiently conservative for planning purposes. The historic firm yields for the Ncwabeni and Gugamela options are shown in **Figure 4-1** and **Figure 4-2** respectively.

Based on the initial firm yield curves the optimal pumping rates above which no increase in yield is observed, where plotted against dam size for both Ncwabeni and Gugamela Dam options (see **Figure 4-3**).

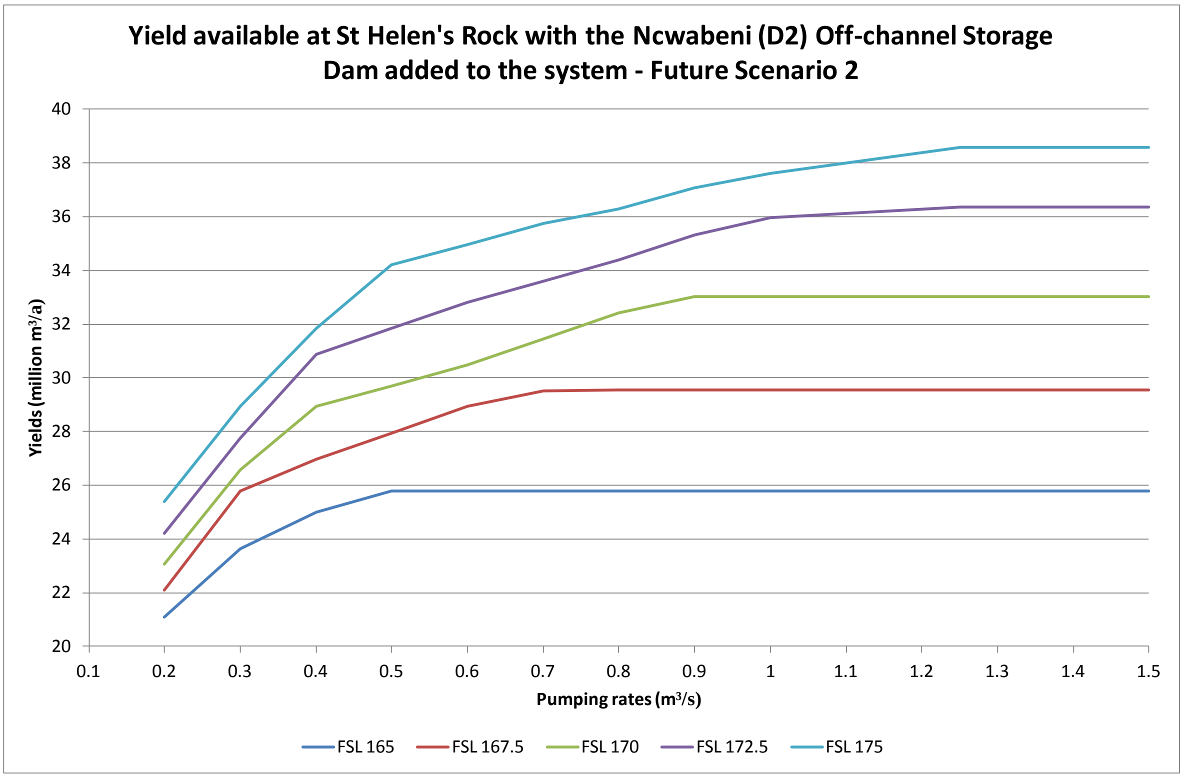

Figure 4-1: Firm yields at St Helen's Rock for various Ncwabeni dam sizes and different pumping rates and Future Scenario 2

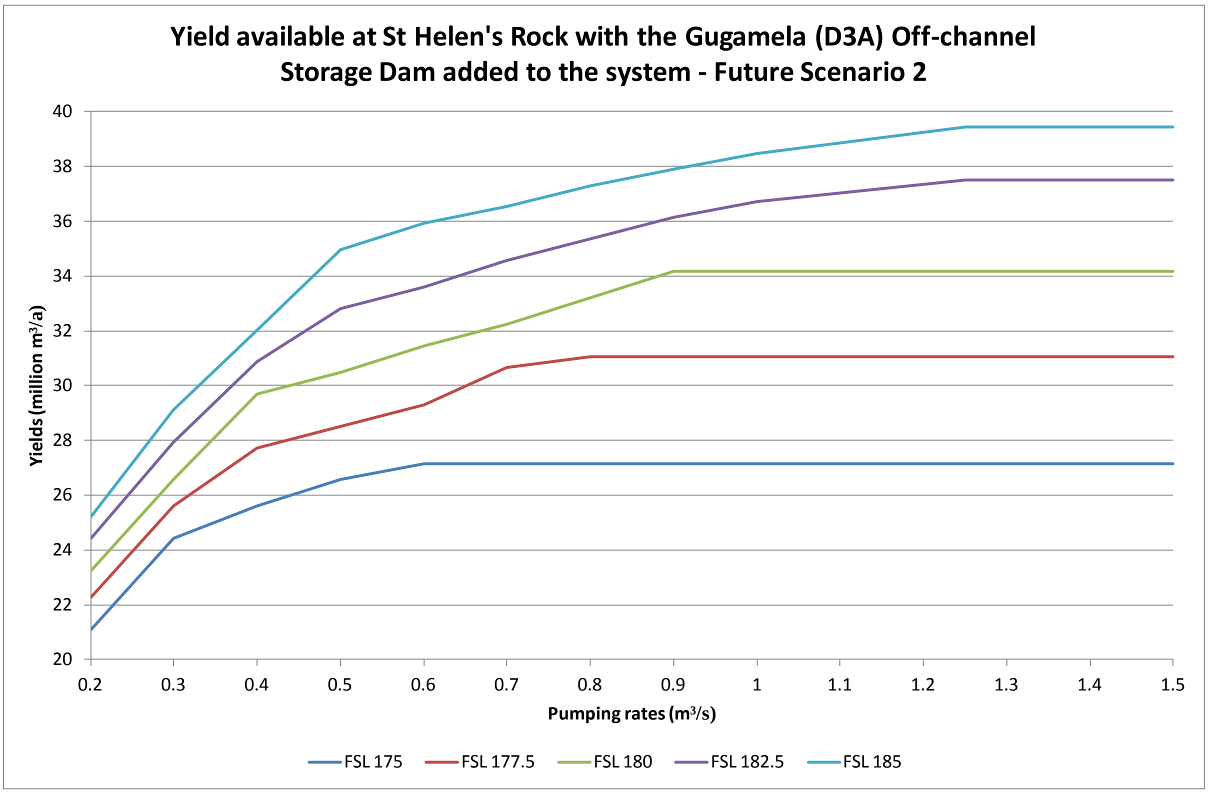

Figure 4-2: Firm yield curves for the Umzimkhulu RWSS for different configurations of the Gugamela OCS Dam

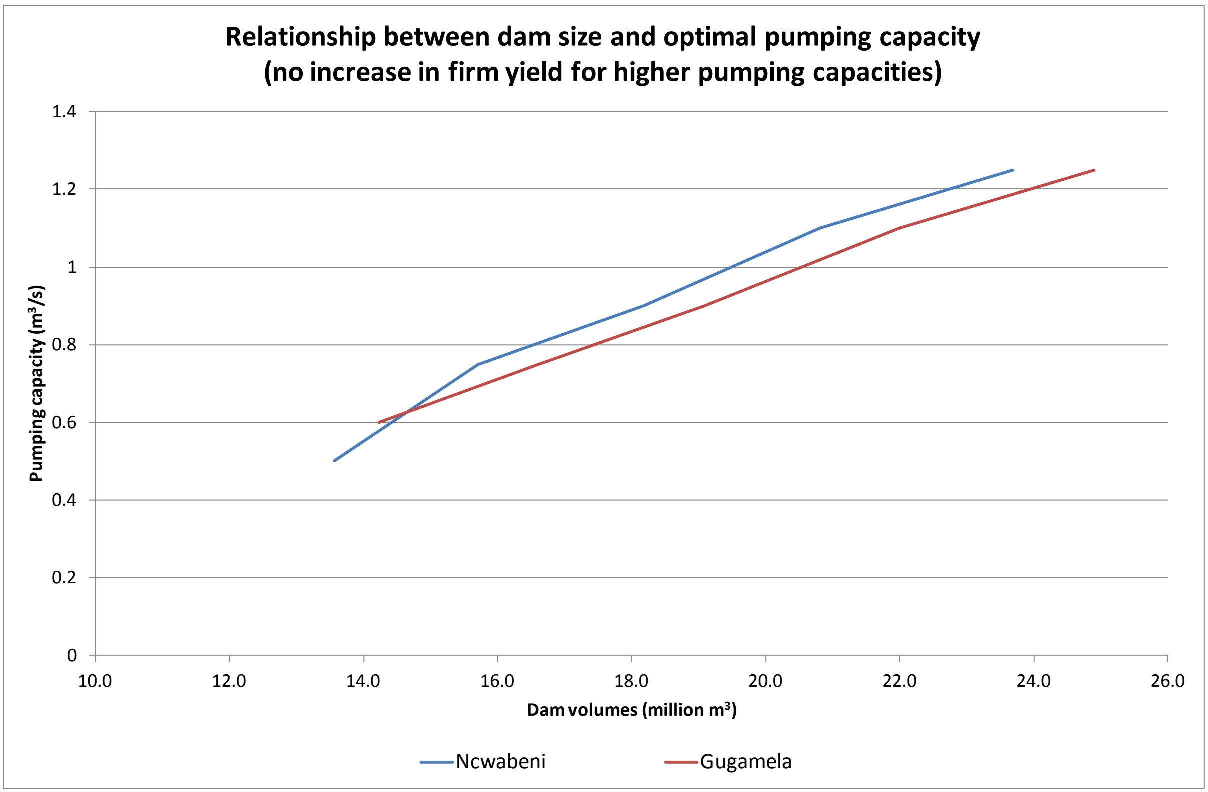

Figure 4-3: Relationship between dam size and pumping capacity

Pumping rates of approximately 0.7 to 0.9 m^3/s are required to achieve sufficient yield to satisfy the projected water requirement of 30 million m^3/a for the planning horizon.

4.6 CAMERO ESTATES HYDROPOWER

During a site visit to the landowners with the study team of Module 2: The Environmental Impact Assessment Study, it was confirmed that a hydropower plant existed at Camero Estates and had been in operation for some years. The hydropower plant diverts water through a tunnel across the narrow part of the peninsula on which the estate is positioned. The head difference of the natural drop in the river as it flows around the peninsula is used to generate power. The layout of the hydropower plant is shown in **Figure 4-4**.

Figure 4-4: Existing hydropower plant at Camero Estates and relation to the off channel storage dam project site

Currently Camero Estates operates the hydropower plant to drive their irrigation pumps. The land owner has indicated that he is interested in operating the hydropower to its full potential in the future and sell electricity. This could be a potential energy source for the pumping water to the OCS dam. This possibility is explored further in **Supporting Report 3: Engineering design and cost estimates**.

The water diverted through the tunnel of the hydropower plant will not pass the abstraction weir for off-channel pumping, and as such this should be taken into account when determining yields of the system.

The characteristics of the hydropower plant were obtained from the land owner. Fully developed the hydropower plant can reportedly develop in the order of 600 kW of power with a flow of 15 m^3/s through the plant, and a static head of 10 m.

The yields of the system with the Ncwabeni OCS dam included were thus recalculated taking into account a flow of 15 m^3/s bypassing the off-channel pumping abstraction point. The impact of the full 15 m^3/s diversion is a reduction in yield of between 1.8 and 0.6 million m^3/a depending on the pumping rate. These results can also be viewed as a bigger pumping rate is required to achieve the same yield once the hydropower diversion is taken into account.

In assessing and discussing these results, it became apparent that the hydropower plant will not divert all the water in the river up to 15 m^3/s. There is no diversion weir, and therefore the diversion efficiency will not be 100% of the flows. It will also be in the interest of the ecology of the river section around the peninsula to maintain some level of flows.

The off-channel pumping will also be conducted during the summer months when flows in the river are higher. Diversion of lower flows in the winter months by the hydropower plant will have little impact on the off-channel pumping to the OCS dam, but will need to be factored into the releases from the OCS dam.

As such the impact of the existing hydropower plant, even if developed to its full potential, should have little impact on the yield of the system.

4.7 LONG-TERM STOCHASTIC YIELDS

Long-term stochastic yields were calculated to determine the assurance of supply for the Umzimkhulu RWSS with the inclusion of an OCS dam. Long-term stochastic yield curves were generated for Ncwabeni OCS dam for FS2 and for four dam sizes with Full Storage Levels from 167.5 masl to 175.0 masl. The results of the long-term stochastic yield analyses are presented in **Table 4.2**, for key assurance levels.

Table 4.2: Long-term stochastic yields for the Umzimkhulu RWSS with an off-channel storage dam included

Long-term stochastic yield (million m^3/a)					
Dam size		Assurance of supply			
FSL	Volume	95%	98%	99%	99.5%
(masl)	*(million m^3)*	*1:20 years*	*1:50 years*	*1:100 years*	*1:200 years*
167.5	15.7	31.5	30.5	29.0	27.5
170.0	18.2	34.0	32.7	31.2	29.5
172.5	20.8	36.5	35.0	33.5	32.0
175.0	23.7	37.0	36.3	35.0	33.5

The long-term stochastic yield curves are very flat and as such the 95% or 98% assurance of supply volume is likely to be critical. The single assurance of supply level often used for domestic supply is an average of 98%, or 1:50 year failure. This shows that all dams with a full storage level of 167.5 masl or greater can yield sufficient water at an acceptable assurance of supply to meet the water requirements for the planning horizon of 2040.

4.8 SIZING OF SCHEME

For the calculation of URVs and the optimisation of the best scheme, the following summary of information was provided:

- Four dam sizes to be considered, namely a dam with a FSL of 167.5 masl which meets the planning horizon future water requirements, as well as three larger dams with FSL of 170.0, 172.5 and 175.0 masl. These dams were considered to derive the unit cost curve, as the minimal unit cost may occur for a larger dam
- A pumping rate of 0.75 m^3/s or greater should be considered for off-channel pumping. Pumping rates greater than 0.75 m^3/s, however, are not likely to provide any benefits within the 2040 planning horizon. A larger pumping rate may also be considered for off-peak hours pumping.

The capacity of the pumping infrastructure should also be sized to be upgraded should the Gugamela scheme be built in the future.

4.9 OPERATION OF THE SCHEME

It is important to determine how the scheme should be operated so that the operational, and in particular the pumping costs of the different scheme sizes, can be factored into the URVs and selection of the best scheme.

The operation of the off-channel abstraction and release of water from the off-channel storage dam is as follows:

Off-channel pumping:

- Off channel pumping occurs during the summer months when the river flows are higher. This is typically November to March.
- Pumping into the dam can only commence once the flows in the Umzimkhulu River are greater than required abstraction at St Helen's Rock or the ecological water requirements for the stretch of the Umzimkhulu River below the dam and weir, whichever is larger.
- Abstraction should not occur when the river is in flood and carries a large sediment load.
- If the dam levels are sufficiently high pumping can be confined to off-peak hours to reduce energy costs (if power supply is from Eskom). If hydropower from the Camero Estates is to be used this may not be a factor.

Releases of water from the Dam:

- Water is released from the off-channel dam back into the Umzimkhulu River to augment low flows in the winter months.
- The volume of water that needs to be released is the difference between the total water requirements of the Umzimkhulu Regional Water Supply Scheme and the

flows in the river after allocating water to the Reserve and lawful downstream users.

- In this way water in the dam will not directly supply the Reserve, but will supply the shortfall to domestic users after flows in the river are used to meet the Reserve. If the Reserve has not been set through the classification process then a compensation flow for the estuary could be maintained in the river below St Helen's Rock until such time as the reserve flows are finalised.
- It is recommended that required releases be determined on a weekly or daily basis.

As can be seen from the operation of the dam, measuring of flows in the Umzimkhulu River will be an integral part of both off-channel pumping and releases from the dam. As such the weir for off-channel pumping has been identified to also be a gauging weir, and is being designed accordingly by the engineering investigation task team. Flows that enter the Umzimkhulu River from the Umzinkhulwana River just up-stream of St Helen's Rock will also needed to be gauaged.

The gauged and measured flows at the abstraction weir on the Umzimkhulu River and the outflow of the Umzimkhulwana River will need to be input into an operating system that calculates water releases based on current water requirements and ecological flow requirements. The operating system and release calculation will also need to take into account Camero Estates Hydropower flows, and water users between the dam and St Helen's Rock. A framework for the operating system and release calculation has been included in **Appendix G**. A real-time system will most likely be needed with the appropriate telemetry to convey flow measurements.

The average monthly off-channel pumping was determined based on the 88 year historical flow sequence and is shown in **Figure 4-5** as a percentage of time pumped with a 0.75 m^3/s pumping rate. The average monthly releases at a 2040 development level are shown in **Figure 4-6**. Actual abstraction and pumping will vary from year to year and greater abstractions from the Umzimkhulu River will be needed to refill the OCS dam during dry years, and only a few months of pumping will be required during wet years.

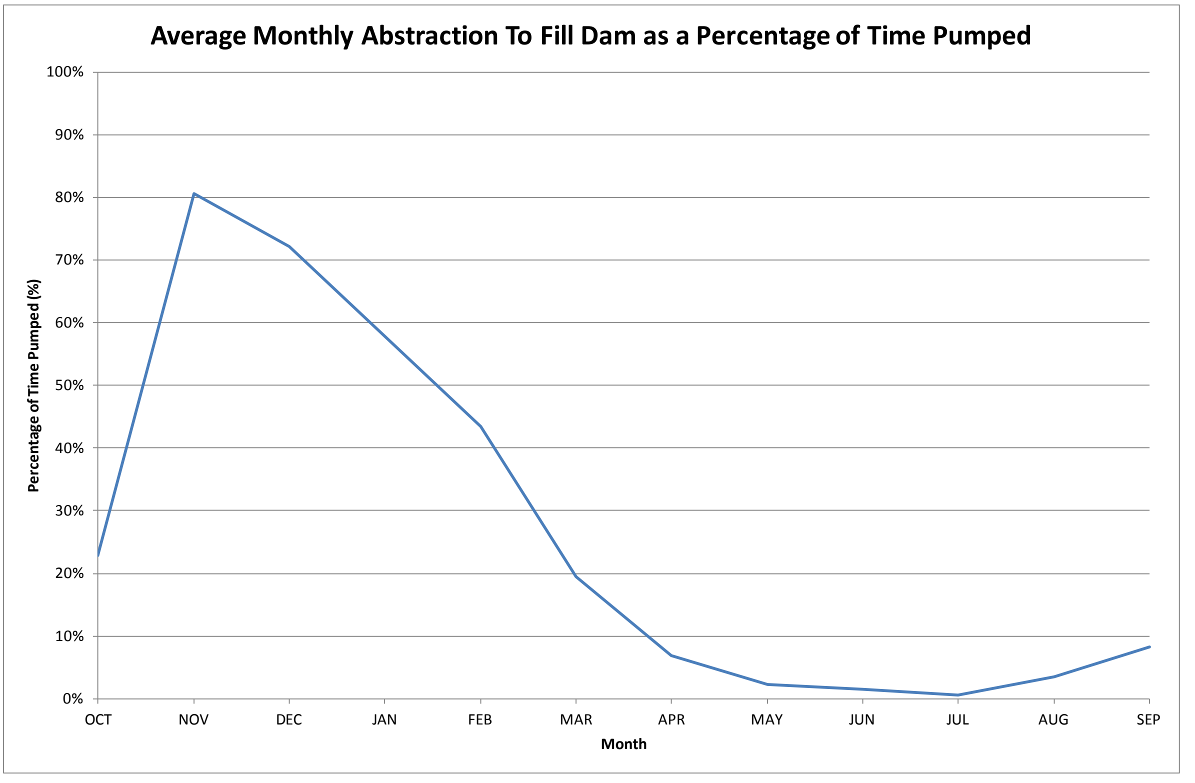

Figure 4-5: Average monthly pumping to fill OCS dam in summer months

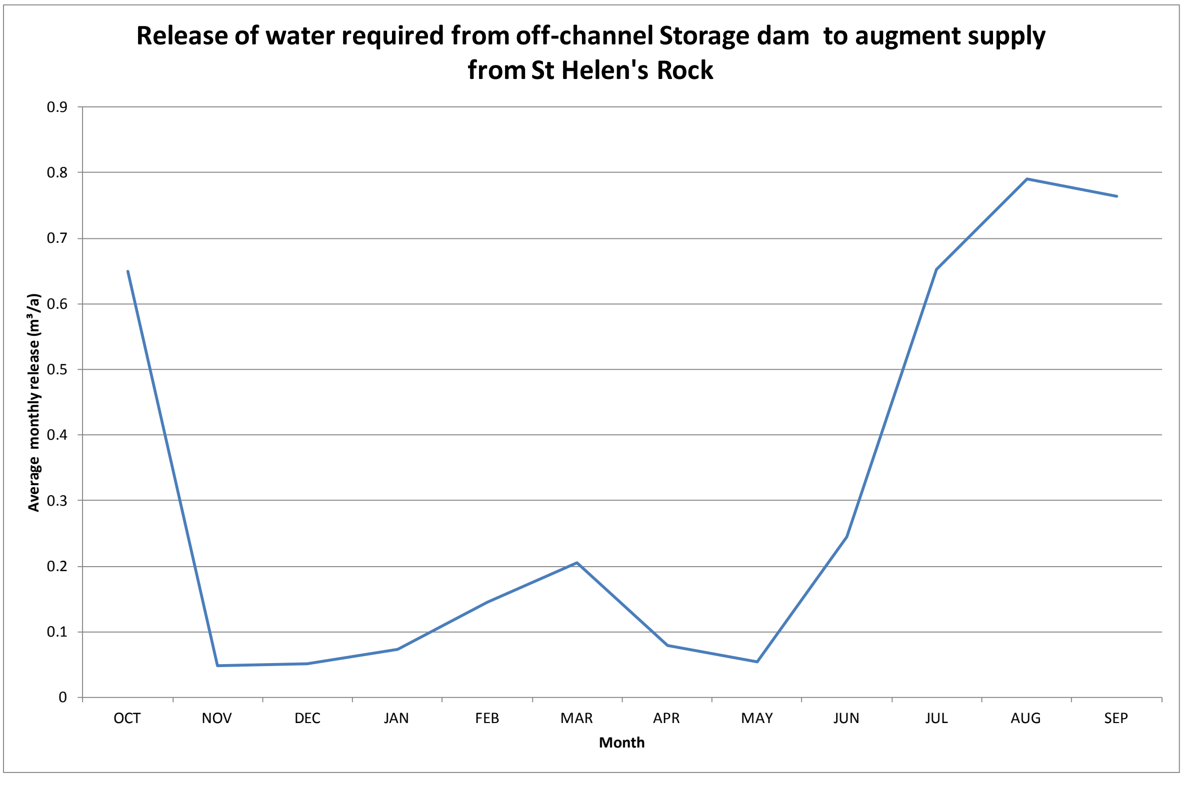

Figure 4-6: Average monthly releases from the OCS dam to augment supply of the Umzimkhulu Regional Water supply Scheme

For the purposes of URV calculations, the average pumping in the summer months was consolidated into the number of months continuous pumping, to better capture how the system will be operated, i.e. pump continuously until the dam is full. This information is included in **Table 4.3**.

Table 4.3: Average number of months continuous pumping required to fill OCS dams of different sizes with a pumping rate of 0.75 m^3/s

Dam size	Number of months pumping continuous	Dam yield
167.5	3.25	30.5
170.0	3.76	32.7
172.5	4.38	35.0
175.0	5.06	36.3

4.10 Dam alternatives higher up in the Umzimkhulu River catchment

As mentioned in **Section 6.2**, the *MRCWRS* identified possible afforestation development in the catchment as well as possible infrastructure developments such as dams on the main channel of the Umzimkhulu River and its major tributaries.

Various dam sizes were considered for different water uses. The most likely development was for dams to mitigate low flow reduction caused by afforestation developments. The possibility of adding domestic water use was raised, thereby effecting a multi-purpose dam development.

At a reconnaissance level, the supply from a multi-purpose dam to Port Shepstone was investigated as an alternative to the proposed OCS dam. A multi-purpose dam would need to be close enough to the afforestation to effectively mitigate the reduction in flows without losing significant stretches of river. A dam in the Bisi River catchment, a major tributary of the Umzimkhulu, was considered, as it is lower than other dam sites identified by the *MRCWRS*, which is advantageous for releases down to St Helen’s Rock. This dam is still more than 80 km upstream of St Helen’s Rock. The position of this dam is shown in **Figure 4-7**.

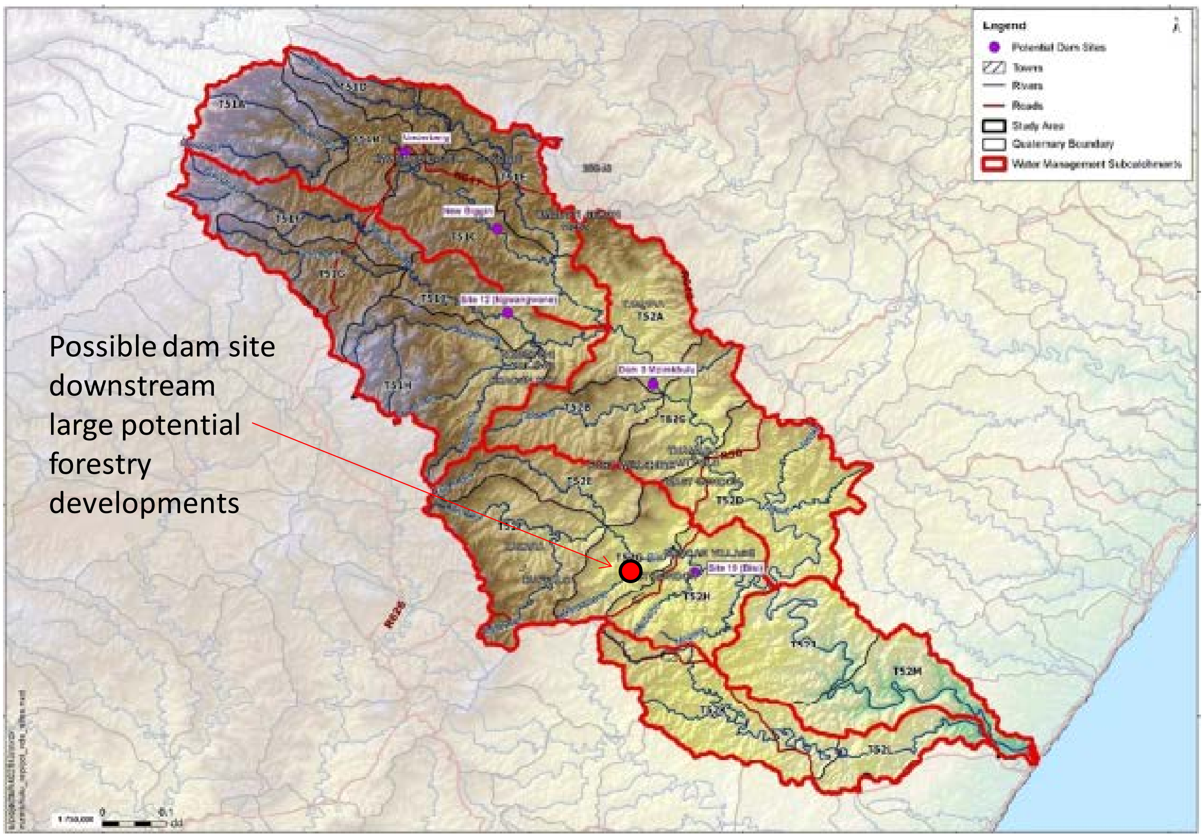

Figure 4-7: Dam site in the Bisi River

The dam on the Bisi River was sized to supply the EWR and mitigate low flows, as well as yield an additional 30 million m^3/a for St Helen's Rock. Conveyance losses of 20% where included. The findings of this exercise were:

- A dam on the Bisi River of approximately 45 million m^3 storage would be required. Of this volume approximately 17 million m^3 will be lost to sedimentation.
- This is significantly more storage than is needed for the OCS dam.
- Practical operation of a dam much higher upstream needs to be questioned, as well as the possible losses between the release and abstraction point.
- The multi-purpose component of the dam is only about 18% for afforestation (i.e. the afforestation could build a smaller 9 million m^3 "large farm dam" upstream for their purposes of mitigation).
- A multi-purpose scheme, which is still in the early stages of the project planning life-cycle, would take longer to study further and implement, delaying water delivery and increasing the risk of water shortages and associated economic impacts.

As such a multi-purpose dam upstream on the main channel is a less favorable solution to resolve the water resource shortages experienced by the Umzimkhulu RWSS.

4.11 SUMMARY AND CONCLUSIONS OF WATER RESOURCES TASK

The water resources task conducted a detailed water requirements assessment for Port Shepstone and surrounds, and determined water availability of the Umzimkhulu River with various options of off-channel storage dams included. The following conclusions have been drawn from the work conducted:

Water Requirements:

- The current (2010) demand for water in the Umzimkhulu Regional Water Supply Scheme area is in the order of 18.5 million m^3/a.
- Future water requirements have been projected up until 2040 of approximately 30 million m^3/a, which includes the successful implementation of WC/WDM and reduction of water losses and more efficient use of water.
- WC/WDM is an essential part of ensuring the efficient use of the current water resource before the dam can be built, as well as the augmented water resource including the dam.
- The Umzumbe area that is planned to be supplied from the Mhlabatshane Scheme needs to be augmented with 1.4 million m^3/a water from the Umzimkhulu River and the Ncwabeni dam, if the full desired level of water services of 60 L/c/d is to be achieved by 2030.
- The Umzimkhulu RWSS area was thus expanded for planning purposes to include the lower portion of Umzumbe.
- The total water requirement which needs to be supplied from the lower Umzimkhulu River system with an off-channel storage dam included is in the order of 30 million m^3/a.

Water Availability:

- The WRYM system configuration from the *Mzimkhulu River Catchment Water Resources Study* conducted by the DWA in 2011, was updated and refined to determine yields for this Feasibility Study.
- The hydrology and the ecological water requirements included in the WRYM were reviewed by the Feasibility Study team.
- Firm yields were conducted to determine water available at St Helen’s Rock abstraction. The current yield without taking into account ecological water requirements is in the order of 18.3 million m^3/a. This is already lower than the 2010 water requirement.
- The water resource of the Umzimkhulu River needs urgent augmentation if the growing water requirements of the Umzimkhulu RWSS are to be met and the improvement of the ecological reserve is to be possible.
- The yields at St Helen’s Rock with various sizes of both the Ncwabeni and Gugamela dams included were calculated. This was done for a range of off-channel pumping rates to fill the dams between 0.2 m^3/s and 1.5 m^3/s.
- For each dam size an optimal pumping rate was found above which no increase in firm yield is achieved. The optimal pumping rate for dam sizes that can meet the 2040 water requirement is in the order of 0.7 to 0.8 m^3/s.

- An optimisation exercise was conducted to determine the best size of dam to be taken further into feasibility design. A dam size for the Ncwabeni site with a full supply level of 167.5 masl or greater was proposed, or a dam on the Gugamela of 177 msal. This equates to dams with capacities of approximately 16 million m^3.
- A desktop assessment was made of supply to the Umzumbe area directly from the dam or by extending the pipelines of the Umzimkhulu RWSS.
- An off-channel storage dam in the Lower Umzimkhulu River is the preferred solution to the water resources problem experienced in winter. A larger dam on the main channel was investigated at a desktop level of detail and was found to be a less favourable, even if developed as a multi-purpose dam.

System operation:

- The proposed dam will be filled in the summer months and will require on average 3.5 months of continuous pumping at a rate of 0.75 m^3/s to be filled.
- Water shall be released in the winter months to supply the shortfall in water available in the Umzimkhulu River.
- Releases from the dam are not made directly for the reserve but, allow the reserve to be supplied first by available flows in the Umzimkhulu River.
- Flows at the weir for off-channel abstraction and pumping should be gauged for the purposes of operation of the proposed scheme.
- An operational releases calculation framework was developed. This includes the measurement of flows passing through the hydropower plant at Camero Estates as well as the flows from the Umzimkhuluwana River entering the Umzimkhulu River just above St Helen's Rock abstraction.

RECOMMENDATIONS

The following recommendations are made based on the water requirements and water resources availability assessments:

1. A dam on the Ncwabeni of 167.5 masl or greater, or a dam on the Gugamela of 177 masl or greater be considered when selecting the best scheme.
2. The abstraction weir should be used to gauge flows if possible for operation of the scheme.
3. The project needs to implemented as soon as possible as the water requirement already exceeds the water resource without allowing for the implementation of the ecological reserve.
4. A validation and verification exercise needs to be conducted in the catchment to confirm legal water users both above the project site as well as between the dam and the water abstraction point.
5. The possibility of using water directly from the dam should be investigated further by the water services authority.
6. WC/WDM measures need to be implemented by the WSA.
7. An additional study is needed to investigate mitigation dams for afforestation developments in the catchment.

5 GEOTECHNICAL AND MATERIALS INVESTIGATION

5.1 TERMS OF REFERENCE AND SCOPE OF WORK

The pre-feasibility study by DWA identified two alternative dam sites namely the D2 site on the Ncwabeni River and the D3A site on the Gugamela River which should be investigated in the feasibility study. Capital costs and the URVs associated with the two alternatives were found to be almost identical but Site D2 was preferred from social perspectives due to the communities in the D3A basin that would need to be relocated. Selection of the preferred option would therefore largely depend on costs associated with geotechnical conditions at the dam sites and the availability of construction materials and slope stability.

During 2011, the feasibility stage geotechnical and materials investigations where conducted to assist with the site selection and other studies which will allow accurate costing and commencement of construction works. The approach was to first focus on the D2 site on the Ncwabeni River due to it's lower social impacts. If any fatal flaw was found, the focus would then shift to the D3A site on the Gugamela River.

The purpose and scope of the geotechnical investigations were to:

- Review the available geotechnical information.
- Describe the general geology of the area and prepare a geological map.
- Investigate any potential flaws for construction of a dam at Site D2.
- Investigate sources for dam construction materials.
- Undertake geotechnical investigations for the dam foundations, spillway structure, diversion weir in the Umzimkhulu River, pump station and the rising main.
- Assess the stability of slopes around the reservoir rim.

This section describes the site conditions, based on a desktop study and field investigations conducted from 21 February 2011 to 3 March 2011 and from 25 July 2011 to 7 October 2011. Laboratory testing was completed in December 2011. Further detail is available in ***Supporting Report 2 – Geotechnical and Materials Investigation.***

5.2 GEOLOGY

The project area including the dam centre line, the spillway line, weir sites, pump station site, quarry site and most of the borrow areas are underlain by granitic bedrock of the Oribi Gorge Suite. This rock is weathered to various degrees and depths across the area, with slightly weathered to unweathered rock on surface or at shallow depth near the rivers and deeper weathering in the higher lying areas.

The bedrock is generally covered by layers of colluvial clayey silty sand in the higher lying areas, while there are well-developed layers of alluvial silt, sand and gravel closer to the rivers.

5.3 Fatal flaw

During the initial stages of the investigation, attention was given to the possible occurrence of a fatal flaw at Site D2. However nothing that would rule out the construction of a dam or would result in excessive cost was identified.

5.4 Construction materials

It was not possible to locate sufficient quantities of impervious core material for construction of a zoned embankment dam within the dam basins or elsewhere in the area. The only alternative type of embankment is a concrete-faced rockfill dam. Such a dam comprising of "soft" and "hard" rockfill zones can be constructed from completely and highly weathered granite (soft rockfill) and moderately weathered to unweathered granite (hard rockfill) that can be obtained from a proposed quarry in the D2 dam basin. Good quality concrete aggregate for construction of the concrete face can be obtained from rock in the bottom part of the quarry.

5.5 Dam foundations

A wide fault zone and generally deep weathering on the left flank of site D2 will require very deep excavation for a concrete gravity (RCC) dam indicating that its cost will far exceed those for embankment or composite dams.

A composite dam with a concrete overspill section in the river and along the right flank might be considered, but the left embankment will have to be supported by a long flank wall, the founding levels of which have not been investigated, but are expected to be about 10 m deep.

Investigations along the dam centre line show that founding conditions for a rock-fill dam are favourable with excavation depths not exceeding about 5 m and grouting to depths of between 20 m and 40 m. However, the plinth for an upstream faced rockfill dam will be located a considerable distance upstream of the dam reference line, and for the design purposed, additional geotechnical investigations will have to be conducted.

5.6 Spillway and rising main

The proposed spillway control structure on the upper left flank may have to be relocated because of deep weathering in that area. The proposed return channel will need to be concrete-lined and will be founded on highly weathered (soft rock) granite with local zones of completely weathered granite (very soft rock).

It is recommended that additional investigations be conducted during the design stage to select the most favourable position for the spillway control structure and to determine the required founding levels.

5.7 WEIR FOUNDATIONS

The lower weir site has good founding conditions on the left flank and in the river section. However, the flat-lying right flank is underlain by thick alluvium.

5.8 PUMP STATION

Alluvium of variable thickness is underlain by good quality founding rock. Founding levels will depend on the position selected for the pump station.

5.9 RESERVOIR SLOPE STABILITY

In the unlikely event of a slope failure along the rim of the reservoir, the volume of mobilised material will be very small (less than 0.3% of the reservoir volume) and the effect on the dam level will be minimal.

6 DESIGN AND COST ESTIMATES

This section describes the methodology applied for the selection of the dam, diversion weir and abstraction works sites, the selection of the dam type and size as well as costing thereof. The phases followed during the design are summarised below and described in the following paragraphs.

- Confirmation of the results from the Pre-feasibility study (DWA, 2007) for the comparison between the Ncwabeni D2 and Gugamela D3A sites, and the selection of the dam site.
- Comparison of two alternative centre lines for the preferred, Ncwabeni D2 dam site by means of costing various dam types on the alternative centre lines and select the preferred site.
- Carry out geotechnical investigation (foundation and construction materials) in three phases, with guidance from the cost comparison of selected dam types and sizes for each phase.
- Determine the best layout and site for the diversion weir and abstraction works.
- Selection of the best scheme in regard with size of dam.
- Carry out the design of the selected best scheme on feasibility level.

6.1 COMPARISON OF NCWABENI D2 AND GUGAMELA D3A DAMS

In the Umzimkhulu River Off-Channel Storage Pre-feasibility Study (DWA, 2007)[3] the capital costs and unit reference values (URV) associated with the development of the two possible dam options identified, Ncwabeni D2 and Gugamela D3A, were found to be almost identical.

The possible dam at the Ncwabeni D2 site was the preferred option from a social perspective, due to the people living in the D3A basin. The Terms of Reference (TOR) of the Ncwabeni Off-channel Storage Dam Feasibility Study: Module 1: Technical Study specified that this dam site was to be considered first and that a dam at the Gugamela D3A site should only be considered if a fatal flaw was identified at the Ncwabeni D2 site. The cost comparison between the two possible dams identified at the Gugamela D3A site and the Ncwabeni D2 site with full supply levels (FSL) at 175 masl and 167.5 masl respectively, was determined. The FSL was selected from the yield associated with the most likely water demand.

The cost comparison of the dams at the Gugamela D3A and Ncwabeni D2 sites was based on the same parameters and layouts specified for the two selected schemes in the Pre-feasibility Study[3]*.* The costs were estimated in accordance with the *Guidelines for Preliminary Sizing, Costing and Engineering Economic Evaluation of Planning Options (DWAF, 1996)*[5] established from the Vaal Augmentation Planning study (VAPS).

From the cost comparison it was clear that the capital costs calculated during the Pre-feasibility Study (DWAF, 2007) and this study are almost identical for the two dam options.

From a cost perspective, the Ncwabeni D2 site was taken further in the next phases of this study (detailed geotechnical and materials investigations), and the Gugamela D3A option would only be considered if a fatal flaw is identified later on.

6.2 COMPARISON OF ALTERNATIVE CENTRE LINES

The objective of this task was to identify alternative centre lines for the selected Ncwabeni D2 dam site and compare the cost estimate of three dam types at the alternative sites based on available information.

The following three alternative dam types were investigated for the Ncwabeni D2 and Ncwabeni D2 Alternative dam sites:

- Roller compacted concrete (RCC) gravity dam
- Zoned earthfill embankment dam
- Concrete faced rockfill (CFR) dam

Sizing of the Ncwabeni D2 dam (165 masl full supply level with capacity of 13.6 x 10^6 m^3) was guided by the full supply level according to the yield associated to the most likely water demand, found in the Pre-feasibility Study[(3)], and a similar dam size was subsequently selected for the Ncwabeni D2 Alternative dam (185 masl full supply level with capacity of 13.7 x 10^6 m^3).

Flood absorption analyses were undertaken for the sizing of spillways and freeboard for the three dam types. The required freeboard above the full supply level (FSL) of the various dam types was determined in accordance with the publication, *Interim Guidelines on Freeboard for Dams* (SANCOLD, 1990)[(6)]. Spillway lengths of 50 m and 100 m were selected and the maximum water level in the dams for the safety evaluation flood (985 m^3/s) was obtained by routing various storm duration hydrographs through each respective reservoir.

The costs of the roller compacted concrete (RCC) gravity dam was based on a 100 m long straight ogee spillway and the ogee crest profile was based on the 200-year flood peak discharge of 415 m^3/s. The costs of the zoned earthfill embankment and concrete faced rockfill (CFR) dams were based on a 50 m broad crest side channel spillway with an 11 m wide spillway chute (based on similar design floods and the design of the spillway at Woodstock Dam).

The results from the geotechnical investigations were not available at the time of this phase and estimated excavation depths were used. Costs for the river diversion and outlet works for all dam types of the Ncwabeni D2 and D2 Alternative dams were based on private contractors unit rate costs for Spring Grove Dam [(7)], which is currently under construction near Rosetta in KwaZulu-Natal. The costs were however scaled in accordance with site conditions e.g. a quarry close to the dam with site specific cost for the transport of aggregates.

The required material quantities with estimated costs (excluding VAT) for each dam type for the Ncwabeni D2 and Ncwabeni D2 Alternative dams were determined on the natural ground level (NGL) of the centre line and are shown in **Table 6.1**.

The result of the first order cost comparisons of the Ncwabeni D2 and D2 Alternative dams revealed that the cost of an RCC dam is much higher than the earthfill and rockfill dams. The RCC dam was thus not considered in the selection of the best site between the two alternative centre lines.

Table 6.1: Required material quantities and cost estimates for dam types for Ncwabeni D2 (FSL 165 masl) and Dam D2 Alternative (FSL 185 masl)

Dam Type	Required Total Quantity (m^3)					Cost (excl. VAT)
	Concrete	Coarse Rockfill	Earthfill (core) Impervious Material	Earthfill (shell) Semi-pervious Material	Slope Pro-tection / Filters	
Dam D2						
RCC Dam	265,912	-	-	-	-	R610,935,058
Earthfill Dam	-	-	137,718	810,390	65,005	R204,042,136
CFR Dam	8,115	549,335	-	-	-	R222,143,553
Dam D2 Alternative						
RCC Dam	270,982	-	-	-	-	R597,842,510
Earthfill Dam	-	-	154,967	1,115,178	61,344	R226,406,231
CFR Dam	-	-	-	-	-	-

The Ncwabeni Dam D2 site is the most attractive from a cost perspective and an embankment type with a small side spillway is the lowest in cost. The D2 dam also has a larger catchment area, and the yield of D2 dam should then also be more than that of Dam D2 Alternative. Ncwabeni Dam D2 was selected as the preferred site and the further investigations were based on this site.

6.3 FLOOD HYDROLOGY

Flood frequency analyses were conducted for the Ncwabeni Dam site as part of the Pre-feasibility Study[3] and were used for the sizing of the spillway, chute and stilling basin. Flood peaks for the RDF/1:200-year and SEF floods for the Ncwabeni Dam site are summarised in **Table 6.2.**

Table 6.2: Flood peaks for the Ncwabeni Dam Site

Flood	Flood Description	Flood Peaks (m^3/s)
Q200 / RDF	200-year flood peak discharge / Recommended design flood	415
SEF($RDF_{+\Delta}$)	Safety evaluation flood	985

Apart from the inflow volume and the hydrograph shape, the degree of flood peak attenuation is affected by the spillway discharge characteristics and the stage-storage characteristics. The ogee profile was shaped for the RDF outflow peak with a design discharge coefficient of 2.18. The flood attenuation for the RDF and SEF are shown in **Table 6.3**.

Table 6.3: Flood peak attenuation results

Flood Event	RDF	SEF
Inflow Peak (m^3/s)	415	985
Outflow peak (m^3/s)	243.3	636.7

6.4 Phased Approach for Managing Geotechnical Investigations and Dam Type Selection

The geotechnical and material investigation was managed using a phased approach for the optimisation of the dam type, as shown in **Figure 6-1**.

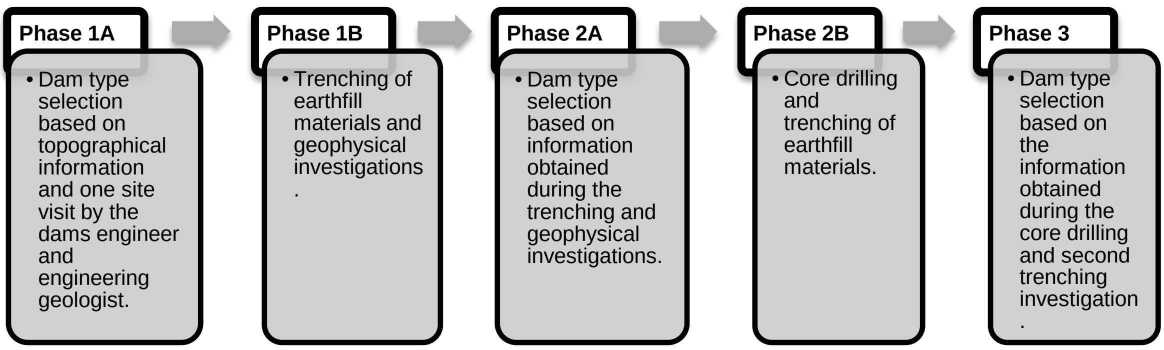

Figure 6-1: Phased approach used for the optimisation of the dam type

For ease of reference and for the remainder of this report, the selected dam site will be referred to as the Ncwabeni Off-channel Storage (OCS) Dam site.

Six alternative dam types for a range of Full Supply Levels (between 163 masl and 177.5 masl) were investigated through the various phases of the foundations and construction materials investigations. At each phase the material quantities and cost for the alternative dam type at various Full Supply Levels were determined. The cost comparisons were based on the VAPS cost model framework and were conducted with the cost model that was specifically developed for this study.

The following six alternative dam types (typical cross-sections are provided in **Appendix B**) were investigated:

- Roller compacted concrete (RCC) gravity dam (Fig. B1)
- Zoned earthfill embankment dam (Fig. B2)
- Concrete faced rockfill (CFR) dam (Fig. B3)
- Earth core rockfill (ECR) dam (Fig B4)
- Asphalt core rockfill (ACR) dam (Fig B5)
- Bentonite sand rockfill (BSR) dam (Fig B6)

A composite dam could be selected by combining above-mentioned types of dams.

The analyses for the RCC gravity dams were based on a 100 m long straight ogee spillway, whereas the costs of the zoned earthfill embankment and CFR dams were based on a 50m broad crest side channel spillway with an 11 m wide spillway chute sufficient for a discharge of 500 m^3/s (attenuated SEF) were determined for the different full supply levels.

Capital costs for the river diversion and outlet works of the (i) roller compacted concrete (RCC) gravity dam, (ii) earthfill embankment dam, and (iii) rockfill embankment dams respectively, were calculated and included in the cost model developed for this study. A cost model was developed early in the study and was thus used throughout the geotechnical investigation (foundations and construction materials) phases and advanced as and when new information became available.

These phases of the geotechnical investigation are as follows:

Phase 1A: Dam type selection based on topographical information and a site visit by the dams engineer and engineering geologist.

Phase 1A focused on the following three dam types, (i) roller compacted concrete (RCC), (ii) zoned earthfill and (iii) concrete face rockfill dams. No detailed information on the foundation and materials as well as excavation depths were available and these were based on estimated information. **Table 6.4** summarises the results of this first-phase cost comparison for the three types of dams. As a dam with an FSL of 167.5 masl corresponds to the yield that satisfies the most likely growth scenario, this dam size was selected for comparison purposes.

Table 6.4: Phase 1A – Total cost estimates (R millions)

Cost (FSL at 167.5 masl)	RCC Dam	Earthfill Dam	CFR Dam
Total cost (including VAT))	R674	R310	R443

The results showed that the zoned earthfill embankment dam is the most favourable from a cost perspective and the geotechnical investigation was recommended to focus on the identifying of potential borrow areas for construction materials (semi-pervious earthfill, clay, and aggregates/rockfill) as well as founding levels in the following phases.

Phase 2A: Dam type selection based on the information obtained during the trenching and geophysical investigations.

Phase 2A focused on four dam types, (i) zoned earthfill, (ii) concrete faced rockfill, (iii) earth core rockfill and (iv) asphalt core rockfill dam. The cost comparison for this phase was based on the excavation depths from the trenching and geophysical investigation. **Table 6.5** summarises the results of the second phase of cost comparisons.

Table 6.5: Phase 2A – Total cost estimate (R millions)

Cost (FSL at 167.5 masl)	Earthfill Embankment Dam	CFR Dam	ECR Dam	ACR Dam
Total cost (including VAT)	R316	R437	R339	R875

The results showed that the earthfill embankment dam has the lowest cost, followed by the earth core rockfill dam. Further geotechnical investigations was recommended to focus on semi-pervious and impervious earthfill resources, as well as quarries for aggregates, sand and rockfill because of the identified risk that earthfill materials might not be found in sufficient quantities.

Phase 3: Dam type selection based on the information obtained during the core drilling and second trenching investigation.

The cost comparison for this phase focused on the following three dam types, (i) concrete faced rockfill, (iii) asphalt core rockfill and (iii) bentonite sand rockfill dam. Excavation depths for this phase were based on the information from the drilling and trenching investigation. **Table 6.6** summarises the results of the cost comparison.

Table 6.6: Phase 3A –Total costs (R millions)

Cost	CFR Dam	ACR Dam	BSR Dam
Total cost (incl. VAT)	R412	R1,010 *	R362

* The higher costs shown in this table, are due to deeper foundation levels for the asphalt core.

The bentonite/sand/rockfill dam is the most attractive dam in terms of cost, closely followed by the CFR dam. Materials laboratory results received after these cost estimates were prepared showed that sufficient earthfill materials could not be found and sufficient sandy materials for a bentonite/sand could not be motivated. A quarry for rockfill, aggregates and sand was identified close to the dam site.

Based on the above results, the best possible dam type at the lowest cost most available material is a concrete faced rockfill (CFR) dam, which was recommended for further investigation.

6.5 DIVERSION WEIR, ABSTRACTION WORKS, PIPELINE AND ACCESS ROAD

The diversion weir, abstraction works, pipeline and access road to the abstraction works are part of the Ncwabeni off-channel storage dam scheme. The abstraction works consists of an inlet weir to the gravel trap canal, sand trap canal, fishway, hopper and jet pump to remove sediment and a pump station. The design is based on a low-maintenance design with a high assurance of supply.

The approach followed to select the preferred site was to prepare layouts of the abstraction works at each of the three identified site options (**Appendix D**). The layouts included the pipelines and access roads associated with each site. Cost were then calculated and compared.

The rates and costs are based on the following:

- 2011 tariffs
- 5% of the cost of activities for landscaping
- 15% of the cost of activities for miscellaneous
- 40% of the cost of activities for preliminary and general
- 10% of total cost of activities for contingencies
- Present values determined for life span of 30 years and an 8% discount rate

The total cost estimates for three weir site options are summarised in **Table 6.7**:

Table 6.7: Summary of cost estimates

Item	Amount (R) (excluding VAT)		
	Option 1	Option 2	Option 3
Sum of activities	26,615,178	27,024,260	21,675,644
Landscaping (5% of sum of activities)	1,330,759	1,351,213	1,083,782
Miscellaneous (15% of sum of activities)	3,992,277	4,053,639	3,251,347
Subtotal A	**31,938,214**	**32,429,112**	**26,010,773**
Preliminary and General (40% Subtotal A)	12,775,285	12,971,645	10,404,309
Subtotal B	**44,713,499**	**45,400,757**	**36,415,082**
Present value operational cost for pumps	9,823,169	9,203,238	9,241,401
Present value for maintenance	3,059,683	3,079,025	2,826,128
Subtotal C	**57,596,301**	**57,683,020**	**38,482,611**
Contingencies (10% of Subtotal C)	5,759,630	5,768,302	3,848,261
Total Present Value Cost	**63,355,931**	**63,451,322**	**53,330,872**

The cost estimates for the three options in **Table 6.7** indicate that Option 3 is the most cost effective, and that the sensitivity regarding operational and maintenance cost does not play a significant role.

Option 3 (the lower weir site) was recommended for further detailed investigations with the physical hydraulic model study.

6.6 SELECTION OF BEST SCHEME

The final aspect to selection of the best scheme is to optimally size the dam. The selection of the best scheme size was based on water delivery over the planned supply horizon of the scheme, capital, and operation and maintenance costs, and other factors into account. For this purpose, unit reference values of water were conducted for the size of dam that meets the water requirement projections, as well as incrementally larger schemes. This was done to determine if the optimal scheme from a URV perspective is larger than the required scheme from a yield perspective. Dam sizes from 167.5 to 175 m FSL were considered. The resulting URVs for these dam sizes are provided in **Table 6.8**. The URVs are based on the following:

- 2012 costs
- Standard maintenance costs and intervals for civil and mechanical equipment
- A cost for new powerlines to bring electricity to the site of R15 million based on discussions with Eskom
- Pumping 24 hours a day when the flow is available in the river

Table 6.8: **Unit Reference Values for selected Ncwabeni Dam sizes**

Dam size	Discount Rate			Capital Cost	Demand satisfied until	Yield
(FSL)	**6%**	**8%**	**10%**	**R'000**		**million m^3/a**
URV (R/m^3)						
167.50	1.44	1.85	2.29	371 811	2041	30.50
170.00	1.52	1.96	2.45	404 539	2047	33.00
172.50	1.63	2.12	2.66	447 734	2051	35.00
175.00	1.73	2.26	2.83	481 938	2054	36.30

Table 6.8 shows that the unit reference values of the smallest dam size meeting the projected water requirements is the lowest. Thus a dam with a 167.5 masl FSL is proposed for Ncwabeni D2 site as the best size of scheme for the feasibility design.

6.7 FEASIBILITY DESIGN OF SELECTED SCHEME

The optimum scheme selected to be taken further on feasibility design-level was thus a Concrete Faced Rockfill Dam with a FSL of 167.5 masl, a broad crested side channel spillway and a diversion weir, abstraction works, pipeline and access road at the most downstream site (option three). Operational and maintenance costs are not sensitive for this scheme configuration.

Layout drawings of the selected scheme are included in **Appendix C (Figures C.1).**

6.7.1 Summary of Findings on Materials and Geotechnical Investigation

The main findings from the Materials and Geotechnical Investigations (**section 5**) are:

- The in-situ granites are weathered to a certain degree above riverbed level and slightly weathered to unweathered below the riverbed.
- The plinth of a CFR Dam can be located on moderately weathered granites.
- The spillway side-channel weir can be founded on moderately weathered granites.
- The bottom outlet will be founded on slightly weathered granites.
- The quarry has soft rockfill above riverbed level and coarse rockfill below riverbed level.

6.7.2 Embankment

The principle of using available materials at lowest cost where possible was used for the decision on the zoning of the dam. The quarry investigation showed two types of rockfill, soft rockfill (3B material) and coarse rockfill (3C material). Thus, a decision was made to use the soft rockfill for the core of the dam, with a shell that comprises coarse rockfill. **Figure C.2** shows the layout of the main embankment and **Figure C.3** and **Figure C.4** the maximum cross-section and detail.

The embankment crest width was recommended to be 6 m wide, which will provide 5 m between the guardrails on either side. This width meets stability requirements and is sufficient for providing access for vehicles from the left bank. Provision is also made for turning vehicles by means of a turning circle on the right bank of the dam wall.

The stability of the upstream and downstream slopes of the rockfill embankment (excluding the parapet wall) at maximum cross-section, was analysed. Only rockfill 3B and rockfill 3C covering the complete cross-sectional area were modelled. The Bishop method of slices was used to determine the minimum safety factors of failure and the cross section with outer slopes for the embankment of 1V:1.4H was used. The results from the slope stability are shown in **Table 6.9**.

Table 6.9: Slope stability safety factors

Case	Minimum Safety Factor Against Failure of Slip Circles			
	Upstream Slope (No Water in Dam)		Downstream Slope	
	Determined	Criteria*	Determined	Criteria*
Empty dam	1,303	>1.2	1,377	>1.3
Empty dam, seismic load of 0.1 g horizontal acceleration	1,114	>1.1	1,133	>1.1

*Acceptable criteria for rockfill dams.

Table 6.9 shows that the determined safety factors meet the safety criteria.

The required freeboard to accommodate waves without overtopping of the embankment was assessed. It was found that the embankment NOC should be at 170.8 masl, resulting in a freeboard of 3.3 m.

Seepage was encountered during water tests of boreholes, 15-25 m below the surface on the left flank of the foundation of the embankment. Seepage through the foundation will be controlled with a cement grout curtain, which is to be constructed from the plinth of the CFR Dam. Consolidation grouting will also be specified below the plinth on each side of the grout curtain to ensure the rock below the plinth is sealed and that there is good contact between the rock and the plinth.

In terms of the shell of the CFR Dam, the concrete plinth at the upstream toe of the embankment would be located on highly weathered granites. However, if inconsistent (weathered) material is found on site, this plinth will have to be founded deeper. The interface of the slab and the foundation will need to be grouted to prevent leakage along this contact.

At moderately to highly weather rock, the plinth can have minimum width of 4 m and thickness of 400 mm. In the river section the width of the plinth was designed to have a minimum width of 6 m. Plinth vertical joints are provided at 5 m spacing, which would be suitable for the Contractor’s placing techniques.

The perimeter joint and vertical construction joints of the face slab will be provided with copper waterstops. A second rubber waterstop is included in the perimeter joint for extra protection.

After compaction, the upstream face must temporarily be sealed with an intruder kerb of low quality concrete to protect the Zone 2B material from erosion caused by rainfall runoff. The concrete of the face slab will then be placed on this protected surface.

6.8 SPILLWAY, CHUTE AND STILLING BASIN

The decision on the type of spillway to be used is linked to numerous factors and it was decided to propose a side channel spillway with an FSL at 167.5 masl.

Parameters used in the design are listed in **Table 6.10**.

The wall heights of the chute were determined using the Principle of conservation of energy. Bernoulli’s theorem utilises this principle and was designed for the routed SEF water level plus a freeboard allowance of 2 m.

Table 6.10: Spillway design parameters

Parameter	Unit	Quantity
P	m	3
Ho	m	2.44
Co	n/a	2.18
L (Spillway length)	m	50
Length of sides (each)	m	25
Start of trough invert width	m	9
Level of trough invert (at start)	masl	157.5
End of trough invert width	m	11
Level of spillway invert (at end)	masl	159.5
Spillway side slopes	n/a	1V:0,7H

The energy dissipating structure, a flip bucket, at the outlet of the chute is designed for the routed RDF. In the event of an SEF, damage would occur at the stilling basin but the safety of the dam would not be jeopardised. This is in line with SANCOLD's requirements. The dimensions of the flip bucket will be 15 m (l) x 3.6 m (d) x 11 m (w) which is sufficient to resist the shear force in the horizontal direction. In the vertical direction, the bearing capacity of the soil underneath the flip bucket with this size is also sufficient to carry the pressure on this energy dissipating structure.

In **Appendix C**, **Figure C.7** shows a layout and longitudinal section of the spillway and **Figure C.8** shows details on the spillway trough. A model study will be required to confirm the design.

6.9 OUTLET WORKS

The outlet works is positioned with the intake and outlet near the river, which will also assist with the river diversion. The outlet works consists of a twin or dual system comprising multi-level intakes at different levels with butterfly valves for selecting the level at which water is to be drawn off, and sleeve valves at the downstream end for controlling the releases. An emergency gate is required for closure for maintenance purposes at the bellmouth entrances. The intakes are protected with precast concrete trash racks and fine screens to prevent blockage by floating debris. Access to the outlet works will be from the right bank via the access bridge and from downstream along the conduit for inspection purposes.

There is no requirement of ecological water release for the area between the dam and the Umzimkhulu River, although recommendations for the abstraction levels were made in the Water Quality Report [(14)].

The required domestic release rate is 1.5 m^3/s. The minimum diameter required for the outlet pipe is 523 mm and the outlet pipe selected has a 600 mm diameter to enable access during maintenance.

The level of the bottom intake, as based on the level of sediment after 50 years, will be at 145 masl and the MOL at 147 masl, to ensure that surface vortices are not created at the intakes. Without inflow, the dam can be drawn down in 97.4 days from FSL (167.5 masl) to MOL (less than the required 120 days) through the 600 mm diameter outlet pipe, and to half depth between the FSL and MOL within 41.5 days (less than the required 60 days).

The staggered intake levels produce optimal quality of raw water for release back into the Umzimkhulu River and/or direct use of water from the dam. Four staggered intakes were selected using the recommendations in the Water Quality Report, combined with the assumption for the sediment level next to the dam wall.

The selected intake levels are shown in **Table 6.11**.

Table 6.11: Intake levels (masl)

Intake	Left	Right
Bottom Intake (masl)	-	145,0
First Service Intake (masl)	149,5	-
Second Service Intake (masl)	-	157,5
Third Service (Top) Intake (masl)	161,5	-

The outlet pipes can be inspected individually without affecting the required discharge through the other outlet pipe. The pipelines along the conduit are 800 mm diameter pipes. Access is provided at the intake and outlet structure for pipeline inspection and maintenance purposes.

The layout of the outlet tower is shown in **Figures C.5** and **C.6** in **Appendix C**.

6.10 River Diversion

The river diversion is designed for the 20-year flood and the flood peak attenuation will be negligible with the storage created by the cofferdam. Based on the hydrology, the risk of flooding from October to April is higher than during the other months. The size of the different river diversion stages will largely be dictated by the construction programme. The following stages of river diversion are applicable:

- Stage 1: Water runs in the river and the natural slope left of the river serves the same purpose as a cofferdam, while the intake tower and conduit is constructed. A cofferdam is required downstream of the embankment.
- Stage 2: Diversion through the outlet conduit with a cofferdam upstream and downstream of the outlet conduit.
- Stage 3: Plug the opening to the conduit with cement.

6.11 PRINCIPAL DETAILS OF THE PROPOSED NCWABENI DAM

Table 6.12 summarises the main details of the selected Ncwabeni OCS Dam Project.

Table 6.12: Principal details of the proposed Ncwabeni Dam

Classification		
Size	Large	
Hazard potential	High	
Classification	III	
Site		
Location (dam wall)	30° 36' 27.04" S 30° 14' 22.12" E	
Catchment area	39.91	km^2
Mean annual runoff (MAR)	4 000 000	m^3
Estimated average annual sediment load	65 000	m^3
Full supply level (FSL)	167.5	masl
Gross storage capacity at FSL	15.53	m^3
Surface area of water at FSL	0.93	km^2
Firm yield	30	m^3/a
Recommended Design Flood (RDF) = 1:200 year RI routed flood peak	415	m^3/s
Safety Evaluation Flood (SEF) = Unrouted RMF+Δ	985	m^3/s
Dam Embankment		
Type of embankment	Concrete faced rockfill	
Maximum height of embankment (above river bed level at downstream toe)	44.5	m
Embankment crest length (including spillway)	541	m
Base width of embankment at maximum cross section	150	m
Crest width of embankment	6	m
Non Overspill Crest elevation (excluding settlement allowance)	170.8	masl
Upstream slope	1 (V): 1.4 (H)	m^3/m
Downstream slope	1 (V): 1.4 (H)	m/m
Total embankment volume above excavation level	795,983	m^3
Freeboard height	3.27	m
River Diversion		
Discharge capacity	155	m^3/s

6.12 DIVERSION WEIR AND ABSTRACTION WORKS

The selected layout of the diversion weir and abstraction works were mainly optimised done by means of a hydraulic model study.

The methodology for the physical hydraulic model study involved the following:

- Optimisation of the layout was done by visual inspection for a range of flows.
- The final test for the optimised layout was carried out for a range of flow conditions, including sediment transport tests in the laboratory.

After the range of flows was discharged, the following was observed and the conclusions made:

- The training wall next to the low notch will help entrain the sediment upstream, but it is a risk in terms of the debris that can stick on top of this wall, which can also obstruct the gravel trap's outlet and closure of the radial gate.
- A dividing wall is required between the low and higher notch to improve the accuracy of the flow measurement.
- A right-bank training wall is required where the weir reaches the surveyed bed level.
- The gravel trap works well to scour the coarse material naturally with the aid of the secondary currents against the high intake wall or by using the radial gate during smaller floods to flush the sediment from the gravel trap.
- The sand trap has a steep bed slope and flushing was effective, but some deposition occurred on the inside of the bend upstream of the radial gate.

The following modifications were made to the design after discussions regarding these observations with the DWA:

- The diversion weir was moved downstream so that the training wall left of the weir is the extension of the right side wall of the gravel trap. The height of the training wall is made 1.2 m higher than the low notch, which is lower than the wall at the radial gate of the gravel trap, thereby solving the problem of debris on the wall.
- A dividing wall was added between the two notches of the weir and on the right bank where the weir reaches the natural bed level.
- The hopper and sand trap were rotated in plan towards the left bank to make space for the new weir location. The downstream end of the sand trap adjacent to the hopper was thus straightened, which would also limit sediment deposition upstream of the radial gate during flushing.

The model was modified as required and more tests were conducted of which the main findings are:

- The impact of the weir on the river for the 1:100 year flood is damming of 2.28 m. (This is acceptable as the DWA's requirement is about 2 m)
- The minimum required level for the top of the left bank structures is 125.08 masl (determined from the hydraulic model study).
- The 1:2 year flood only partially scoured the area in front of the intakes at the upstream end of the gravel trap when the gravel trap is full and without opening the radial gate.

- The 1:5 year and larger floods scoured all the gravel (sand in model) from the intakes by the secondary currents. Flushing of the gravel trap through the radial gate starting with a filled trap with gravel (sand in the model) was effective under all flow conditions. The sand trap canal could be flushed effectively by opening the radial gate under all flow conditions.

The design head of the diversion weir is 1.3 m. The discharge table and curve was determined for the diversion weir, with the lower notch at 115.94 masl (25 m length) and the higher notch at 116.24 masl (67 m length). The lower notch length of 25 m was selected to measure low flows of 10 m^3/s or less, accurately.

The diversion weir is positioned at a rock outcrop in the river. During the detail design stage, geotechnical information is required at the position where the weir connects the right bank.

The migration of fish and invertebrate species in the Umzimkhulu River will not be impeded if a fishway is added. The fishway consists of two components in order to accommodate different species. One component is a vertical slot fishway structure between the gravel trap canal and the sand trap canal to accommodate the migration of fish species. The other component is a sloped wall on the right side of the diversion weir that forms part of the diversion wall to accommodate the passage of invertebrate species. Fish and invertebrate species must be able to migrate for a flow range of 10-120 m^3/s and a maximum velocity in the fishway of 1.4 m^3/s.

Flows at the weir will be measured and gauged for operational purposes. The feasibility of this was tested with the physical hydraulic model and the lower weir site is suitable for gauging purposes.

6.13 ACCESS ROADS AND RELOCATION OF ROADS

The following criteria were used for the layout of the access and relocated roads to the Ncwabeni Dam and abstraction works sites:

- Slope of road not steeper than 1V:10H (10%)
- Road width of 6 m, including a stormwater drain

6.14 CONSTRUCTION COST ESTIMATES

A user friendly interactive cost model spreadsheet was developed for the construction cost estimates. The main objective of the cost model was to determine cost estimates with interlinked facilities for each component of the structure to compare construction cost estimates for different dam types, range of full supply levels and three abstraction works positions. A user manual for the Cost Model was included in the *Report 3: Design and Cost estimates*.

The construction cost estimate for the selected scheme is summarised in **Table 6.13**. Cost estimations were based on:

- 2011 costs
- 40% for preliminary and general
- 20% for contingencies
- 15% for planning, design and supervision

Table 6.13: Summary of cost estimate

Component	Cost (R)
Section	
Main Embankment	197,782,342
Spillway	18,083,846
Outlet works	37,730,244
Diversion weir and abstraction works (including roads to site)	30,677,400
Subtotal A	**284,273,833**
Preliminary & General (40 % of sub-total A)	113,709,533
Preliminary works	
(a) Access road for main dam	604,000
(b) Electrical supply to site	15,000,000
(c) Construction water to site	300,000
(d) Railhead and materials handling	
Accommodation	6,000,000
Subtotal B	**419,887,367**
Contingencies (20% of subtotal B)	83,977,473
Subtotal C	**503,864,840**
Planning, design and supervision (15% of subtotal C)	75,579,726
Subtotal D	**579,444,566**
VAT (14% of subtotal D)	81,122,239
Total Project Cost	**660,566,805**

6.15 Implementation Programme

A draft implementation programme including the construction of the scheme is provided in **Appendix E**. The philosophy followed was:

- Finance to be secured before commencement of the project, as existing roads are adequate
- No large access roads are required prior to construction.
- A local quarry must be developed and plant must be erected for crushing aggregate and sand materials and for mixing concrete.
- The erection of the intake tower is on the critical path.
- Practical construction placement rates are applicable.
- River diversion is carried out in three stages.
- Phasing of placement of rockfill.

The final implementation program will be determined once the RID and financial and institutional arrangements have been finalised.

6.16 Climate data for Construction

As part of the feasibility investigation, climate data was gathered for the purposes of construction planning. The analysis is Included in **Appendix F**. In summary, collection and analyses of the daily rainfall data for the project site showed that on average 21 days with rainfall greater than 10 mm is expected per year.

6.17 Conclusion and Recommendations from Feasibility Design

The position of the dam was confirmed from the pre-feasibility study as the Ncwabeni dam site. Six dam types were investigated and the concrete faced rockfill dam was selected based on the lowest capital cost and available construction material.

Several configurations of the abstraction works were investigated as well as three site positions. The selected configuration comprises a diversion weir that also serves as a gauging measuring structure, a fishway, a gravel and sand trap, a hopper and a pump station. The lower site was selected as the best site because of its favourable hydraulic and foundation conditions and because it presented the best cost estimate.

A cost model was used to guide the material and geotechnical investigation, the selection of the dam type, the full supply level and the selection of the best scheme.

The conceptual design of the selected scheme comprises the following components:

- Concrete Faced Rockfill Dam (lowest cost for type of dam for the available construction materials)
- Diversion and gauging weir (crump weir to monitor flow in Umzimkhulu River)
- Abstraction works (including a jet pump in the hopper for the abstraction of fine sediments, and two gate controls at the end of the canals to remove sand and gravel).
- A pump station and pipeline to fill the off-channel storage dam.

The following recommendations are required to carry out the detail design:

- Additional geotechnical investigations must be conducted during the design stage to select the most favourable position for the spillway control structure and to determine the required founding levels.
- A hydraulic model study of the side channel spillway.
- Further geotechnical investigations to confirm foundation levels at the plinth line of the CFR dam and the position of the outlet structure, and the right bank of the diversion weir.
- A larger scale hydraulic model study of the abstraction works and fishways
- More detail on the final ecological flow requirements in the Umzimkhulu River below the weir to finalise detailed operating rules.

7 FINANCIAL AND INSTITUTIONAL ARRANGEMENTS

A more comprehensive analysis of the financial and institutional arrangements is included as a separate volume namely ***Supporting Report 4 – Financial and Institutional Arrangements***. What follows is a summary of that analysis.

7.1 DAM SERVES UGU DM

The Ugu District Municipality is the Water Services Authority and comprises six Local Municipalities, namely Hibiscus Coast, Ezinqoleni, Umuziwabantu, Vulamehlo, Umzumbe and Umdoni.

The Ncwabeni OCS Dam will only supply water to areas within the Ugu DM, namely it will be the primarily supply of water to the Hibiscus Coast LM and will supplement the supply of other schemes to the Umzumbe LM rural areas.

7.2 TOTAL NUMBER OF BENEFICIARIES AND PROJECTED DEMAND

The total water requirements and number of households that needs to be supplied in future by the planned Ncwabeni OCS dam is the sum of the households in the current Umzimkhulu RWSS supply area and those households in the Umzumbe area that cannot be supplied out of the new Mhlabatshane Scheme and existing Assissi WTP, that is 58 000 households with an estimated population of 258 000 people.

The current urban/rural split of the Umzimkhulu RWSS is about 70% urban and commercial and about 30% rural. The addition of rural areas outside of the existing Umzimkhulu RWSS will increase the supply of water to poorer rural areas.

7.3 POVERTY

Poverty in the Ugu District is unevenly distributed with Umzumbe municipality being the worst affected followed by Hibiscus Coast. In 2008 it was estimated that 394 623 people, then 55% of the population, were living in Poverty in Ugu District [source Global Insight 2010 and Ugu DM IDP].

Based on these studies it is estimated that approximately **50% of the population** being supplied out of Ncwabeni OCS Dam **will not be able to pay for water**.

7.4 EVALUATION OF FUNDING OPTIONS

An important component of the feasibility study is to recommend institutional arrangements for funding and operating the dam. Consultations have been held with Ugu DM officials and water portfolio committee, Umgeni Water at a technical/official level, COGTA, National Treasury and within DWA in this regard. A formal presentation will not be made to the board of Umgeni Water until feedback has been received from the Ugu DM water portfolio committee.

When evaluating the funding options it must be born in mind that the capital funding requirement for the Ncwabeni Dam is in the order of R580 million in 2012 Rands. The cost of the dam excludes upgrading water treatment works and distribution pipelines. If escalation and accumulated interest charges is included then the dam will cost in the order of **R900 million by 2017**.

The following sources of funding have been considered, either as stand-alone sources, but more likely as partial solutions in combination with others:

- Ugu allocates a portion of its MIG grant funding to the project;
- Ugu raises loan funding from commercial sources (bank loans or softer loans from DBSA);
- National Government funds the scheme on-budget as a Government Water Works;
- National Government provides a special/dedicated grant using the Regional Bulk Infrastructure Grant (RBIG) mechanism;
- Umgeni Water funds the works as a bulk water services provider;
- Umgeni Water provides bridging finance as implementing agent.

It is evident that the institutional arrangements and the funding arrangements are interdependent. National Treasury has also confirmed that ownership of infrastructure and responsibility for funding are generally inseparable.

A commercial funder will expect the institution that raises the loan to reflect the asset on the other side of the balance sheet. Likewise RBIG adjudication committee would expect the application for grant funding to be lodged by the owner of the proposed infrastructure.

These funding options, which can be used in certain combinations, are now evaluated:-

7.4.1 Funding Option 1: Ugu allocates a portion of its MIG grant funding to the project

It appears that the Ugu DM MIG grant funding is already over allocated to the +- R2 billion services backlog and it is unlikely, given their social responsibility, that Ugu DM will be in a position to allocate significant MIG funding to the Ncwabeni OCS Dam (+- R900 million by 2017).

Ugu DM Portfolio Committee has yet to confirm that they will not be in a position to allocate significant MIG funding to finance the Ncwabeni OCS Dam but it is anticipated that this will be the case.

7.4.2 Option 2: Ugu raises loan funding from commercial sources

Given the level of poverty in Ugu DM it is clear that Ugu DM is already charging a reasonable tariff and simply raising tariffs will not provide a simple solution to addressing its financial challenges.

Ugu DM Portfolio Committee has yet to confirm that they will not be in a position to raise significant loan funding to finance the Ncwabeni OCS Dam but it is anticipated that this will be the case.

7.4.3 Option 3: 4.3 National overnment funds the works on budget as a government water work

Chapter 11 of the National Water Act gives the Minister the power to establish and operate government waterworks in the public interest out of funds allocated by Parliament or from other sources.

Examples of such waterworks include water storage dams, water transfer schemes and flood attenuation works.

There is not a strong motivation to declare the Ncwabeni OCS dam as a government water work in that it is a local dam serving only one district municipality and is not interlinked into a system of waterworks, nor is it of national strategic importance.

The Minister is of course not prohibited from declaring the dam a Government Water Works if it is in the national interest. Note that the Minister is unlikely to declare the water treatment works and other bulk works as Government Water Works.

Water from a government waterwork may be made available for allocation to water users and charges may be fixed for this water.

If the dam is funded on budget by Government then the tariff will be determined in accordance with DWA’s National Water Pricing Strategy as published in Government Gazette No 29697 of 16 March 2007. The tariff would include a depreciation charge, a return on assets charge of 4% p.a. as well as operations and maintenance costs.

7.4.4 Option 4: National Government provides grant funding through RBIG

In light of the recognition given to water projects as mechanisms to create employment in the latest Presidential State of the Nation Address, the relative poverty of the population residing in the Ugu DM area, and the social benefits of this project, there is a strong motivation for government to favourably consider making a grant available to this project. In this context it should be noted that some 50% of the water supplied out of the dam will be provided to people who cannot pay for water.

The Ncwabeni OCS Dam is a bulk regional dam, as opposed to a national dam, as the full supply area falls within the Ugu DM. The National DWA Coordinator of the RBIG has confirmed that in principle RBIG can be used for the funding of the social component of the dam (approximately 50%) as well as for upgrading the water treatment works and the bulk distribution pipelines.

According to National Treasury the institution that raises funding for the dam should be the owner of the dam. The owner of the proposed dam should accordingly lead the RBIG application process. Support in preparing the application can be given by DWA.

DWAs Director General is the transferring national officer responsible for the implementation of the Grant. The Grant provides funding for feasibility studies and other studies required to prepare an application for funding.

7.4.5 Option 5: Umgeni Water appointed as bulk potable water service provider to own and to operate Ncwabeni OCS dam and the Umzimkhulu Regional Water Supply Scheme

DWA is currently, through its Institutional Realignment (IR) Project, re-assessing the role of water boards with the intention of restructuring the current water boards to be Regional Water Utilities.

Umgeni Water is already providing services within parts of the Ugu DM under a bulk water services provider agreement and Umgeni Water (at official level and not yet at board level) has indicated that it would favourably consider providing bulk potable water services in the areas supplied by the Ncwabeni Dam.

A quid quo pro arrangement could be agreed whereby Umgeni Water takes ownership of and operations responsibility for the treatment works and upgrades them; and raises private sector capital to partly fund the Ncwabeni OCS Dam and abstraction works.

Umgeni Water could apply to utilise Regional Bulk Infrastructure Grant (RBIG) funding to partially offset the costs of upgrading the treatment plants and the construction of the dam.

The current WSP agreement between Ugu DM and Umgeni Water would be varied in terms of which Umgeni Water would own and operate the dam and treatment works as part of the Umgeni Water system and would charge Ugu DM its uniform systems tariff (the same tariff Umgeni Water charges eThekwini and its other bulk users) to recover costs.

The involvement of Umgeni Water as owner should have the additional advantage of facilitating an improvement in the maintenance of the dam and treatment works.

National Treasury has indicated that they would need to confirm to what extent Umgeni Water could absorb the Ncwabeni OCS Dam on their balance sheet.

This option should only be discussed with the board of Umgeni Water once Ugu DM has confirmed their view on this option.

7.4.6 Option 6: Umgeni Water is appointed as implementing agent for the water resource works and Umgeni Water partly funds those works

Should DWA decide not to manage the construction of the dam in-house, and if it is agreed that Ugu DM should not be tasked with constructing the dam, then DWA/Ugu DM could appoint Umgeni Water as an implementing agent to manage the construction on its behalf.

As Implementing Agent, Umgeni Water would construct the works for a fee and would recover the full cost of the works as a stand-alone or ring fenced project. In other words there would be a requirement for either grant funding from national government and/or a firm repayment agreement with Ugu DM which would together cover the full cost of the works. Such agreements would be independent of the ability of Ugu DM to recover the cost of the works from consumer tariffs as that would not be a matter within Umgeni Water's control.

The financial risk would not be passed onto Umgeni Water and there would accordingly be no funding/financial advantage in this option.

[The possibility of Umgeni Water owning and funding the dam is discussed as Option 5 below].

A note on the current operations of the Umzimkhulu RWSS

Ugu DM is currently operating the Umzimkhulu RWSS.

It is evident from the Blue and Green Drop reports that Ugu DM is performing satisfactorily.

The main concern is Ugu DM's current operating budget shortfall and the stretched operating and capital budget going forward. Non-revenue water in Ugu District is also relatively high at about 34%.

7.5 IMPACT OF DAM ON WATER TARIFFS

It is difficult to do a comparison of the impact on the retail price of water for the two alternatives until the exact funding mix is known.

As a benchmark, the average charge obtained by dividing all of Ugu DM's budgeted water service charges (monthly charges and variable charges) by Ugu DM's budgeted water consumption gives an average unit retail charge of R14.27 per kl. Note that this is not Ugu DM's per unit variable charge. Ugu DM's variable charges are set out in sub-paragraph 4.2 above.

If, as is envisaged in Option 1 above, the dam is funded by Ugu DM with a mix of 50% RBIG and 50% commercial funding (which is perhaps not achievable by Ugu DM at this time) then the price of water from that dam will be in the order of R98 c/kl (2012 Rands). If this additional cost of water is allocated only to those users who receive water from the dam then the average unit retail charge will rise from approximately R14.27 per kl to R15.25 per kl. The higher the percentage of grant funding that Ugu DM can raise and the large user group over which the cost of water from the dam is allocated, the less the cost impact of the dam on the average retail price of water.

If the dam is funded by Umgeni Water and incorporated into their bulk water system as envisaged in Option 2 above then the dam will have an effect on the Umgeni Water universal bulk water charge (ie the tariff charged to all bulk water users) but will not be a specific charge levied on Ugu DM. Ugu DM would pay the universal Umgeni Water bulk water charge of approximately R3.56 per kl. The cost of abstracting and treating bulk water is not differentiated in the Ugu DM budget from other water related costs. If it is assumed for example that 30% of Ugu DM's water costs are attributable to abstracting raw water and producing bulk potable water then the average unit retail charge will drop from approximately R14.27 per kl to R13.07 per kl [R3.56 +70% of R14.27] if Umgeni provides the bulk water and Ugu DM only manages the retail water.

This last calculation is merely a realistic example and it will be necessary for the Ugu DM's budgeting team, perhaps with the assistance of National Treasury, to determine the real budgetary impact of entering into a bulk WSP agreement with Umgeni Water.

7.6 MACRO ECONOMIC CONTRIBUTION OF DAM

The macro economic contribution of the dam is summarised in **Table 7.1**. A comprehensive report on the analysis supporting this table is included as **Annexure C** of ***Supporting Report 4 – Financial and Institutional Arrangements***.

Table 7.1: Nationial macro economic impact of Ncwabeni OCS Dam

	Construction phase	Operations Phase	Total Impact of Dam
Impact on Gross Domestic Product (GDP)	**R 730 mil.**	**R 7.59 mil.**	**R 737 mil.**
Impact on capital formation	**R 1,471 mil.**	**R 18.25 mil.**	**R 1,489 mil.**
Impact on employment [person years]	**3,900**	**67**	**3,967**
Skilled impact on employment [person years]	**795**	**13**	**808**
Semi-skilled impact on employment [person years]	**2,319**	**27**	**29**
Unskilled impact on employment [person years]	**787**	**27**	**814**
Impact on Households	**R 480 mil.**	**R 4.90 mil.**	**R 485 mil.**
Low Income Households	R 77 mil.	R 0.80 mil	R 78 mil.
Medium Income Households	R 90 mil.	R 0.99 mil.	R 91 mil.
High Income Households	R 312 mil.	R 3.11 mil.	R 315 mil.

7.7 ASSESSMENT AND MITIGATION OF RISKS

The major risk is the time that it will take to obtain the various authorisations, to conclude agreements, and to obtain funding. These include:-

- Prepare the application and obtain approval for RBIG funding;
- Prepare the application and obtain approval for water storage and abstraction licences;
- Complete an environmental impact assessment including public consultation and obtain environmental authorisation;
- Obtain council and board resolutions for Ugu DM and Umgeni Water to enter into a WSP agreement and for Umgeni Water to partially fund the project, and to negotiate the details of such an agreement.

A mitigating action would be for the three parties (Ugu DM, Umgeni Water and DWA) to take a number of binding decisions/resolutions very early in the process.

7.8 RECOMMENDATIONS FROM FINANCIAL AND INSTITUTIONAL ASSESSMENT

While a number of sources of funding have been discussed, the most feasible funding and related institutional options can be summarised as follows:

Option 1: Ugu DM as funder, implementer and operator

- Ugu DM provides evidence that they can, together with a say 50% RBIG contribution, fund the dam and treatment works.
- UGU DM makes an application for RBIG funding, with DWA assistance, to fund the social component of the dam, say 50% of the R900 million cost (excluding VAT but including escalation and interest), as well as the phased (multi-year) upgrading of the water treatment works and the bulk distribution pipelines.
- The viability of this option will need to be confirmed by Ugu DM Water in cooperation with National Treasury.
- Ugu DM as the owner of the dam operates and maintains the dam and meets dam safety requirements and water use license requirements.
- Ugu DM could appoint Umgeni Water as implementing agent at an agreed fee to supervise the Dam design and construction. Alternatively DWA could provide support to Ugu DM who procures the dam design and construction.

Option 2: Umgeni Water as bulk water services provider, funder and operator

- Ugu DM and Umgeni Water enter into a bulk water services provider agreement in terms of which Umgeni Water is obliged to fund the dam and in a phased manner upgrade the water treatment works and recover their disbursements through bulk water tariffs.

- Umgeni Water makes an application for RBIG funding, with Ugu DM and DWA assistance, to fund the social component of the dam, say 50% of the cost of the dam, as well as the phased (multi-year) upgrading of the water treatment works and the bulk distribution pipelines.
- The viability of this option together with Umgeni Water's other large planned investments will need to be confirmed by Umgeni Water in cooperation with National Treasury.
- Umgeni Water, as owner of the dam, applies for a water use licence and for environmental authorisation with formalised (written agreement) DWA assistance;
- Umgeni Water as owner of the dam supervises the Dam design and construction.
- Umgeni Water as owner of the dam operates and maintains the dam and meets dam safety requirements.

8 CONCLUSIONS

Based on the results of the work conducted for technical tasks presented in **Section 2** to **Section 6** the following consolidated conclusions are made with regards to the Ncwabeni off-channel storage Dam project:

Water Resources:

- The current run-of-river supply of water from the Umzimkhulu River is insufficient to supply water requirements greater than the 2010 level, without taking into account the ecological reserve.
- The off-channel storage dam is needed to augment water resources.
- A total future planning horizon water requirement of 30 million m^3/a is projected for the supply area for 2040.
- The supply area includes both the Umzimkhulu Regional water supply scheme, and the lower South West portion of Umzumbe local Municipality (to augment the Mhlabatshane supply area).
- An off-channel dam of 16 million m^3 storage or greater, and an off-channel pumping rate of 0.75 m^3/s can yield sufficient water to meet the future water requirement in 2040.

Geotechnical and Materials:

- The geotechnical and materials investigation found no fatal flaw in the founding conditions at the Ncwabeni site.
- Not enough impervious material was found for an earthfill embankment dam.

Feasibility design and selection of the best scheme:

- Comparison of costs between the Ncwabeni and Gugamela sites was updated from the Pre-feasibility study, and found the costs of the two preferred sites to be similar. The operation costs for the Ncwabeni will be lower.
- Based on the cost comparison, the lack of a fatal flaw at the Ncwabeni site, and the social impacts identified at the Gugamela site, the Ncwabeni site was chosen for the feasibility design.
- The selection of the best scheme was conducted in phases based on the phased geotechnical and materials investigation which included test pitting, a seismic refraction survey and drilling a number of boreholes.
- A Concrete Faced Rockfill Dam was selected for the dam type (lowest cost dam type for the available construction materials), with a side-channel spillway and chute.
- A low level diversion weir on the Umzimkhulu River which includes a crump weir to monitor flow in Umzimkhulu River for operation purposes.
- Abstraction works including a jet pump in the hopper for the abstraction of fine sediments, two gate controls at the end of the canals to remove sand and

gravel, and a fishway to allow the migration of species identified during the fish specialist study of the EIA.

- A pump station on the left hand bank of the weir and pipeline (670 m in length and 1000 mm in diameter) to fill the off-channel storage dam.
- The sizing of the Ncwabeni dam was based on unit reference values (URV), and supply windows. The dam size required to meet the demand, as well as larger dam sizes were considered.
- Based on URVs and water supply windows, a dam with a Full Supply Level (FSL) of 167.5 masl and storage of 16 million m^3 was selected.

Cost of Selected Scheme:

- The cost of the selected scheme was calculated to be R660 million including VAT and 20% contingencies.

Institutional and Financial Arrangements:

- Five different funding options were identified for the proposed Ncwabeni OCS Dam project
- Two of the five funding options were recommended for further discussion between Ugu DM, the DWA and Umgeni Water.
- The tariff impacts of the different funding and institutional arrangement options were calculated.
- A cost Benefit analysis was conducted which showed the dam will have a benefit of in the order of R190 million.
- The preferred funding option if for Ugu DM and Umgeni Water enter into a bulk water services provider agreement in terms of which Umgeni Water is obliged to fund and construct the dam. Umgeni water also to apply for grant funding such as RBIG for the social component of the dam of about 50%.
- The Alternative funding option is for Ugu to show that they can together with the 50% social funding from say RBIG, pay for the dam.

Project Hand over

- A Record of Implementation Decisions (RID) will be finalised once the EIA study is completed and financial and institutional arrangements are made.
- The implementation program shows that with decisions being taken timeously the construction of the dam can begin in 2014 and the earliest delivery date of water is 2017. The program is very tight however, and any delays will most likely result in water being delivered in 2018.
- Some key activities as identified on the program once the final design begins is Phase 2 of the Cultural Resources Management (implementation of the plan identified in the EIA) that will be key due to the presence of graves in the dam basin.

9 RECOMMENDATIONS

The following recommendations are made for completion of the planning phase of the Ncwabeni OCS Dam project:

- The financial and Institutional arrangements for the project are finalised and funding secured.
- The RID be finalized once the environmental authorization approval is received in early 2013.
- Additional investigations must be conducted during the design stage to select the most favourable position for the spillway control structure and to determine the required founding levels.
- Further geotechnical investigations to confirm foundation levels at the plinth line of the CFR dam and the position of the outlet structure and the right bank of the diversion weir.
- A hydraulic model study of the side channel spillway.
- A larger scale hydraulic model study of the abstraction works and fishway.
- More detail on the final ecological flow requirements in the Umzimkhulu River below the weir to determine detailed operating rules.
- The operating rule calculation framework be expanded on to develop the detailed pumping and release rules for the off-channel storage dam.
- The Ugu DM as the Water services authority implement WC/WDM measures to extend the currently available water resource until the Ncwabeni OCS Dam can be augment the scheme in 2017/2018.
- Ugu DM investigates the possibility of supplying water directly from the dam, and updates their Bulk Water Master Plan to include the Ncwabeni Dam.
- An additional study is conducted by the DWA to investigate mitigation dams for afforestation development in the catchment in more detail.

10 REFERENCES

(1) **DWA, South Africa, 2002.** *KwaZulu-Natal Water Resources Pre-Feasibility Study: Phase 1*. DWA Report No P U000/00/0201.

(2) **DWA, South Africa, 2005.** *KwaZulu-Natal Water Resources Pre-Feasibility Study: Phase 2*. DWA Report No P WMA 11/000/00/0505.

(3) **DWA, South Africa, 2007.** *Mzimkhulu River Off-channel Storage Pre-feasibility Study: Pre-feasibility Main Report*. Prepared by UWP Consulting (Pty) Ltd, DWA Report No P WMA 11/000/00/1307.

(4) **DWA, South Africa, 2006.** *Mzimkhulu River Off-channel Storage Pre-feasibility Study: Flood Frequency Analysis*. DWA Report No T500/001/2006/01.

(5) **DWA, South Africa, 2012.** *Ncwabeni Off-Channel Storage Dam: Feasibility Study: Module 1: Technical Study, - Specialist Report 1: Sediment Yield Report.* DWA Report no. P WMA 11/T52/00/3311/1/1. Conducted by ASP Technology (Pty) Ltd on behalf of the DWA.

(6) **DWA, South Africa, 2012**. Ncwabeni Off-Channel Storage Dam: Feasibility Study: Module 1: Technical Study – Specialist Report 2: Water Quality Report. DWA report no. P WMA 11/T52/00/3311/1/2. Conducted by BKS (Pty) Ltd on behalf of the DWA**.**

(7) **DWA, South Africa, 1996.** *Guidelines for Preliminary Sizing, Costing and Engineering Economic Evaluation of Planning Options.*

(8) **SANCOLD, South Africa, 1990.** *Interim Guidelines on Freeboard for Dams.* Report No.3. The South African National Committee on Large Dams, PO Box 3404, Pretoria 0001, RSA.

(9) **SANCOLD, South Africa.** 1991. *Guidelines on Safety in Relation to Floods of SANCOLD.* Safety Evaluation of Dams, Report No.4. The South African National Committee on Large Dams, PO Box 3404, Pretoria 0001, RSA.

(10) **United States Department of the Interior Bureau of Reclamation.** 1987. *Design of Small Dams.* US Government Printing Office, Denver, Colorado.

(11) **United States Department of the Interior Bureau of Reclamation.** 1976. *Design of Gravity Dams.* US Government Printing Office, Denver, Colorado.

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Appendix A

Maps

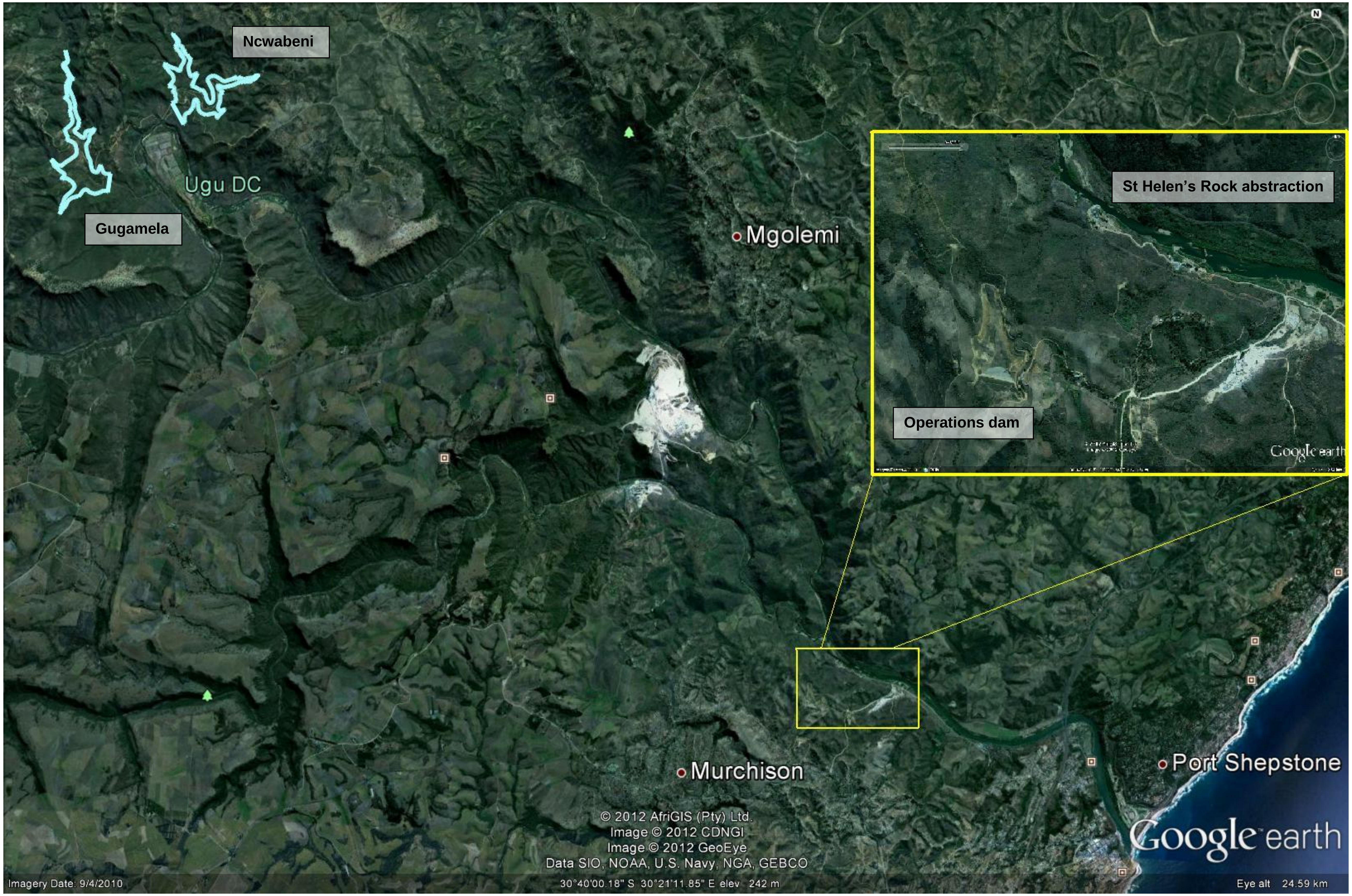


Figure A1: Location of Ncwabeni and Gugamela off-channel storage dam sites and the St Helen's Rock abstraction

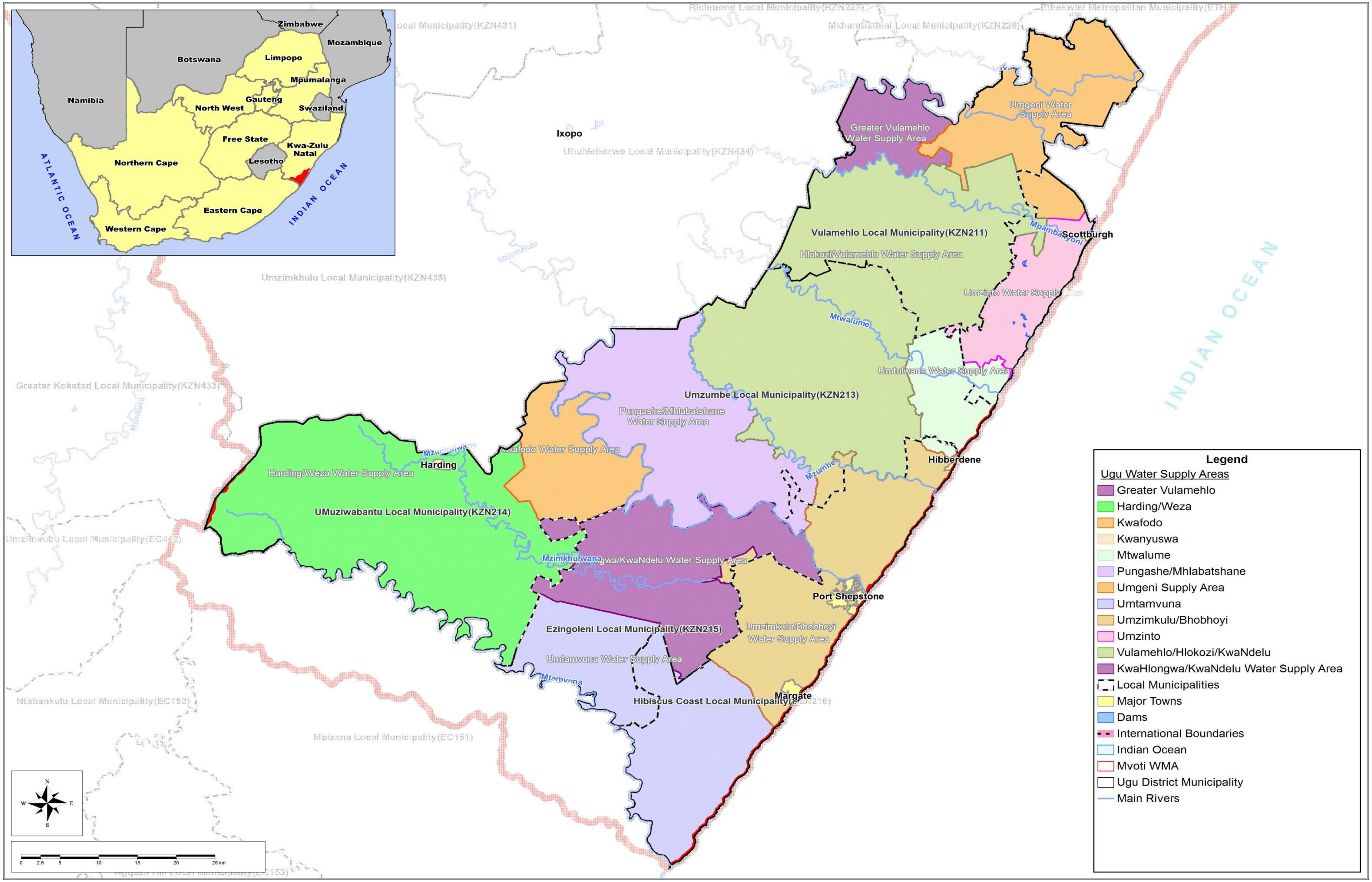


Figure A2: Water supply areas and local government boundaries of the Lower South Coast (adopted from All Towns Study - DWA, 2011)

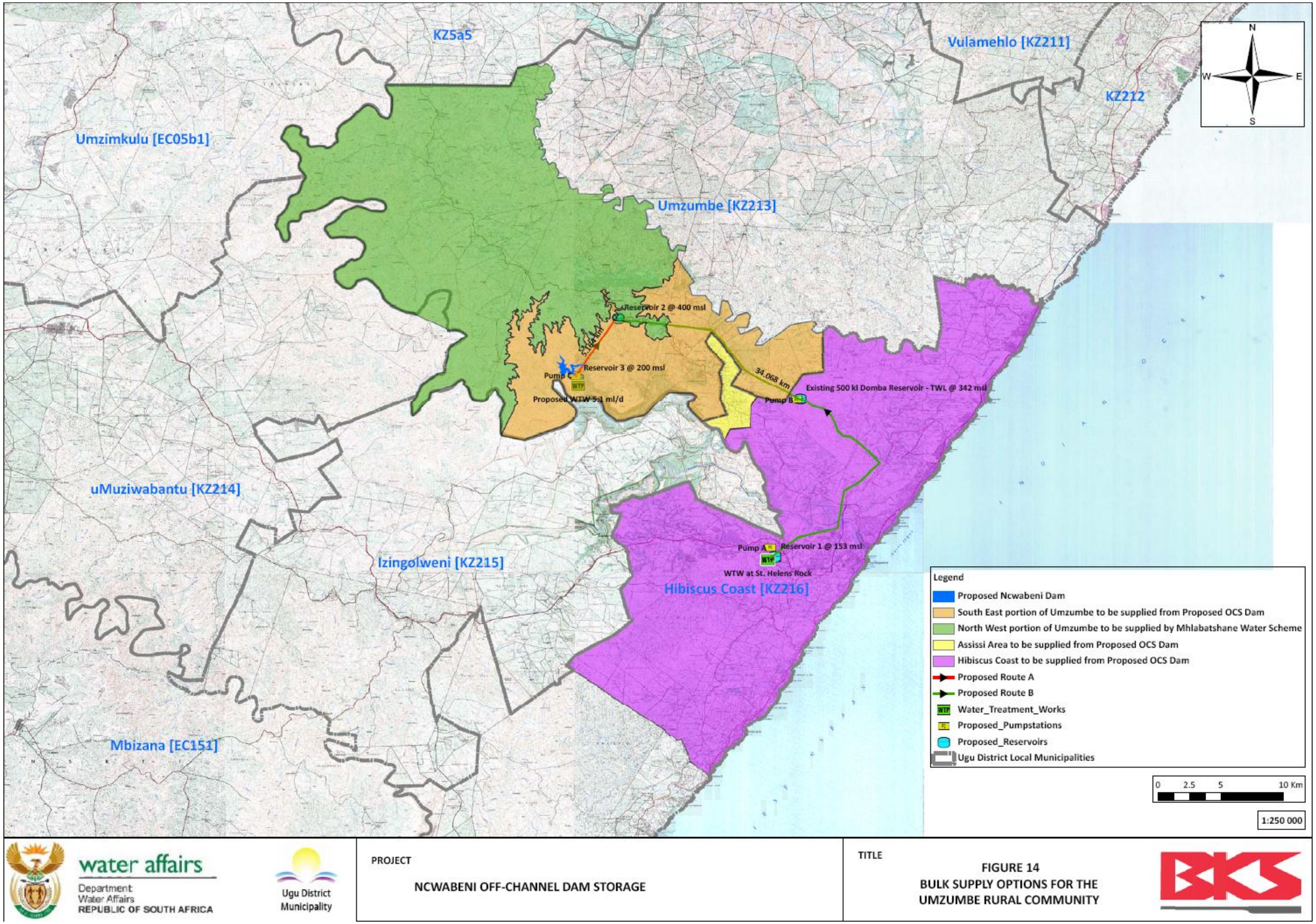
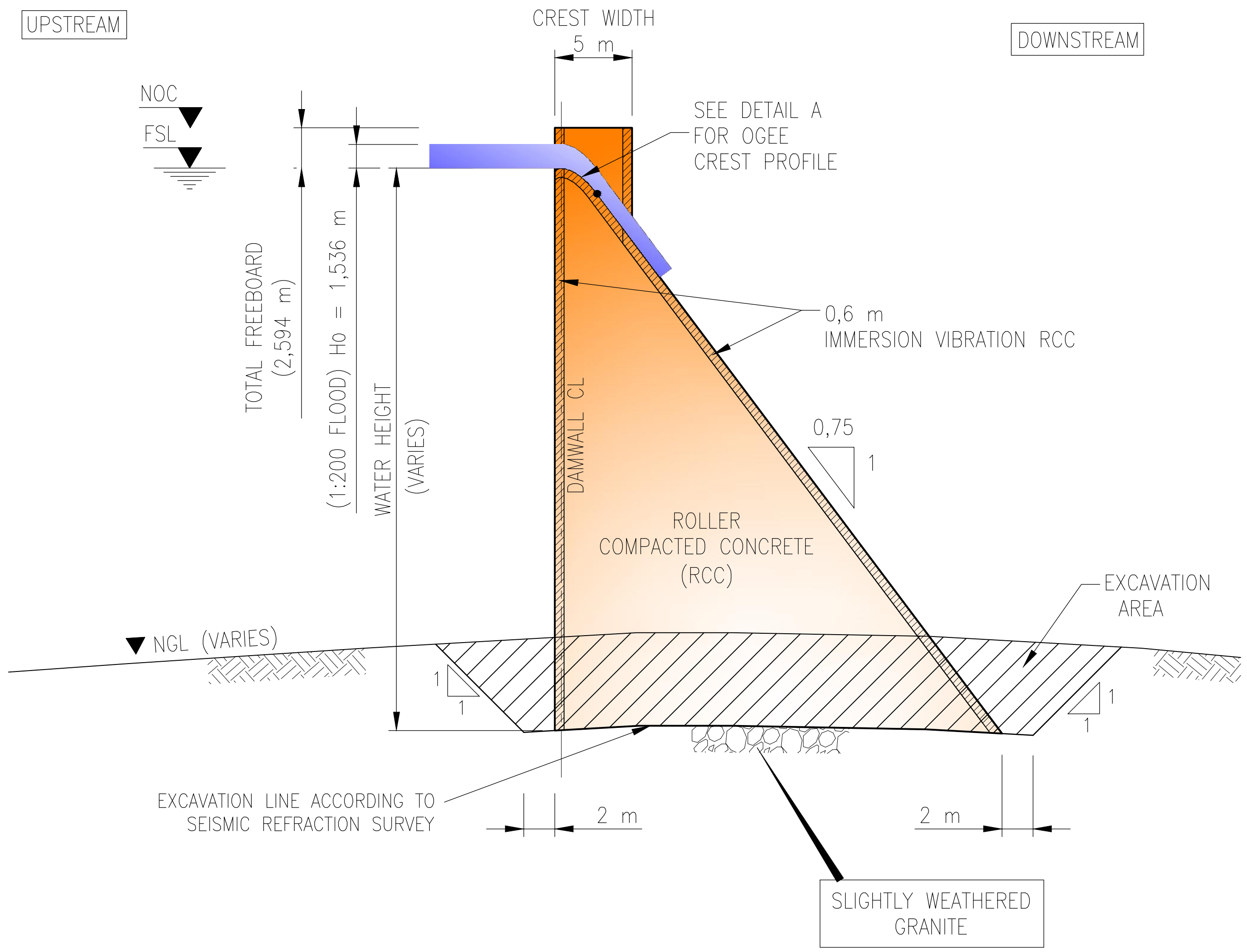


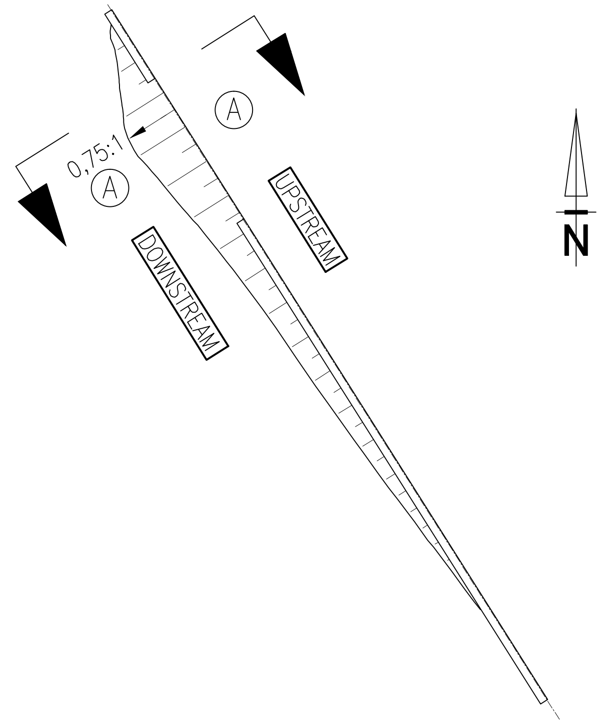
Figure A3: Proposed split in water supply to Umzumbe from Mhlabatshane WSS and the Umzimkhulu RWSS, and bulk supply options to Umzumbe

Appendix B

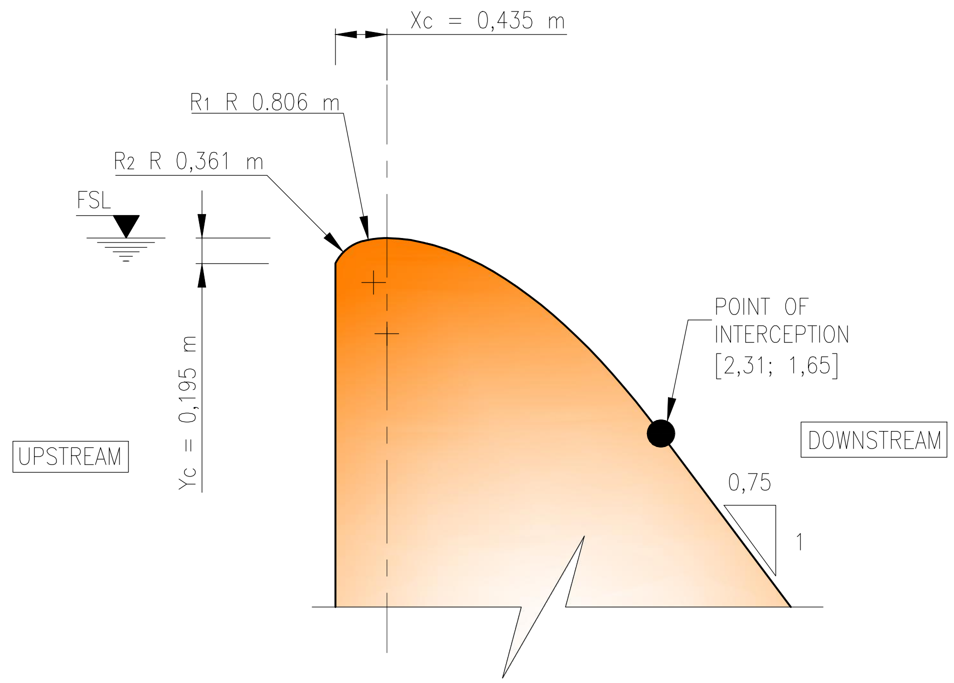
Drawings of Alternative dam types and cross sections



SECTIONAL VIEW A–A
TYPICAL SECTION
NTS



PLAN VIEW OF EMBANKMENT
(CREST TO NGL)
NTS



DETAIL A
OGEE CREST PROFILE
NTS

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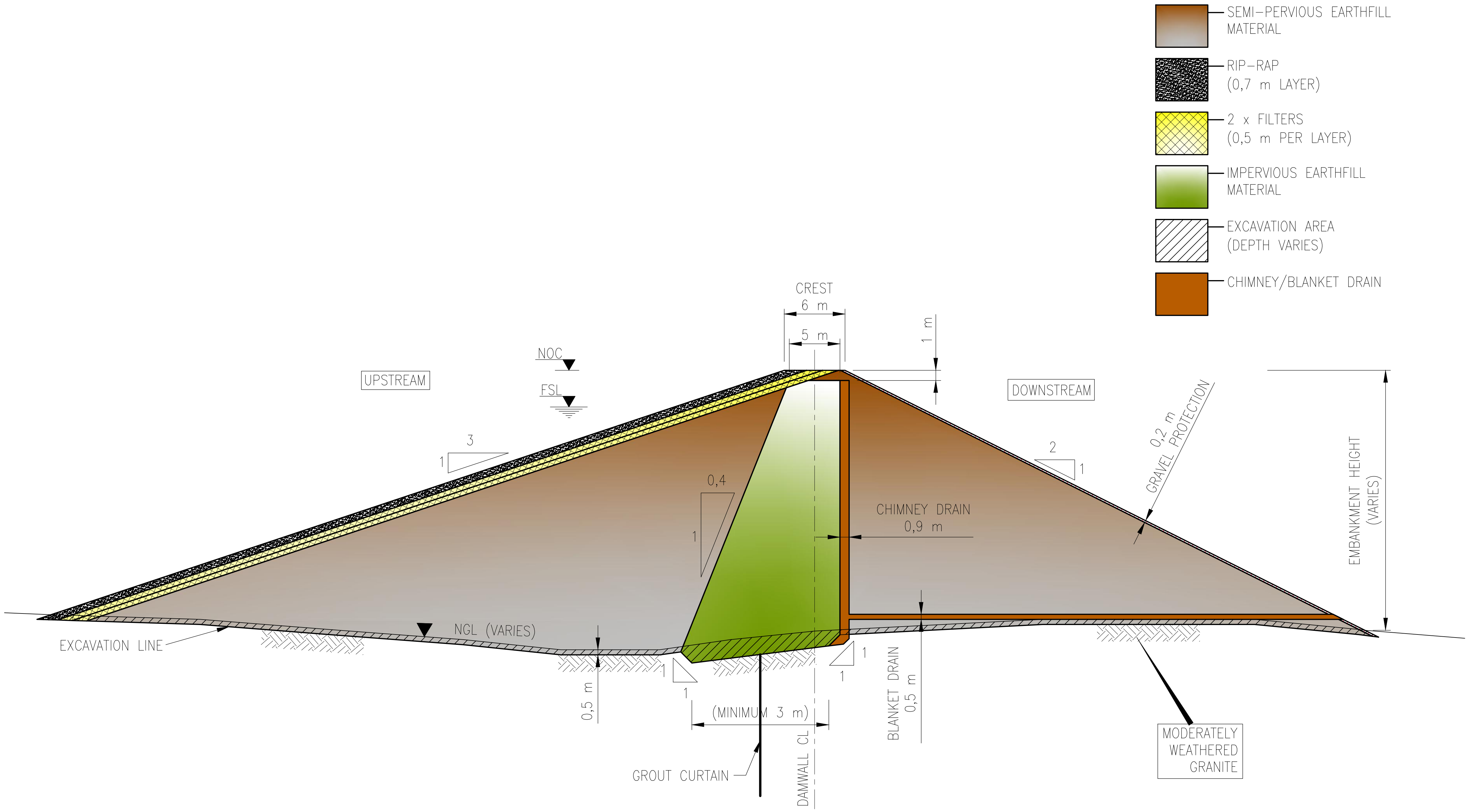
Water Affairs
REPUBLIC OF SOUTH AFRICA

THE NCWABENI OFF CHANNEL STORAGE DAM
FEASIBILITY STUDY:
MODULE 1: TECHNICAL STUDY

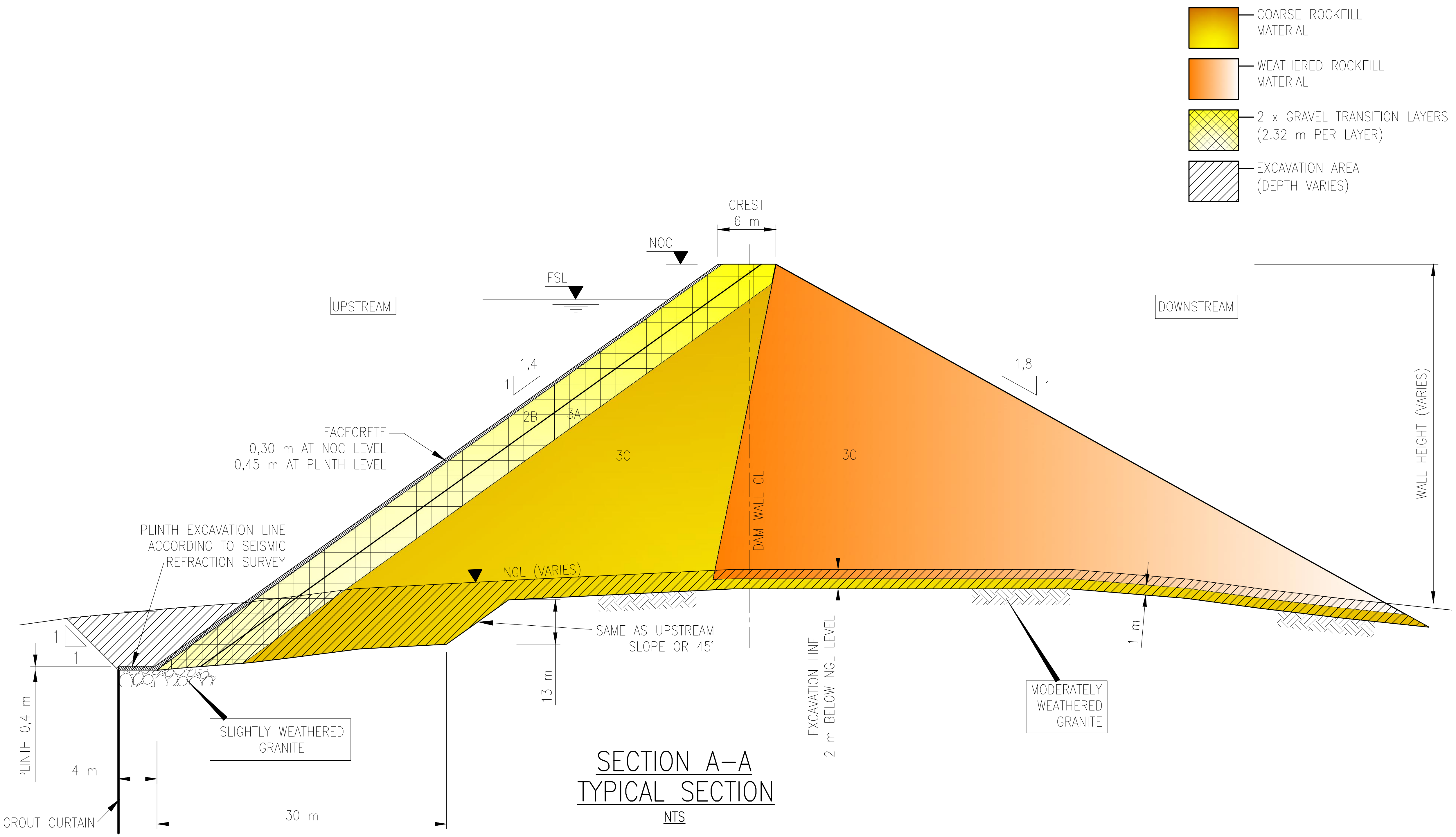
ROLLER COMPACTED CONCRETE (RCC) GRAVITY DAM
SLOPE: 0,75/1 m D/S

BKS DETAIL/FIGURE No.
FIG. B1



SECTION A–A
TYPICAL SECTION
NTS

THE NCWABENI OFF CHANNEL STORAGE DAM FEASIBILITY STUDY: MODULE 1: TECHNICAL STUDY	EARTHFILL DAM SLOPE: 3/1 m U/S AND 2/1 m D/S	BKS DETAIL/FIGURE No. FIG. B2



SECTION A–A
TYPICAL SECTION
NTS

THE NCWABENI OFF CHANNEL STORAGE DAM
FEASIBILITY STUDY:
MODULE 1: TECHNICAL STUDY

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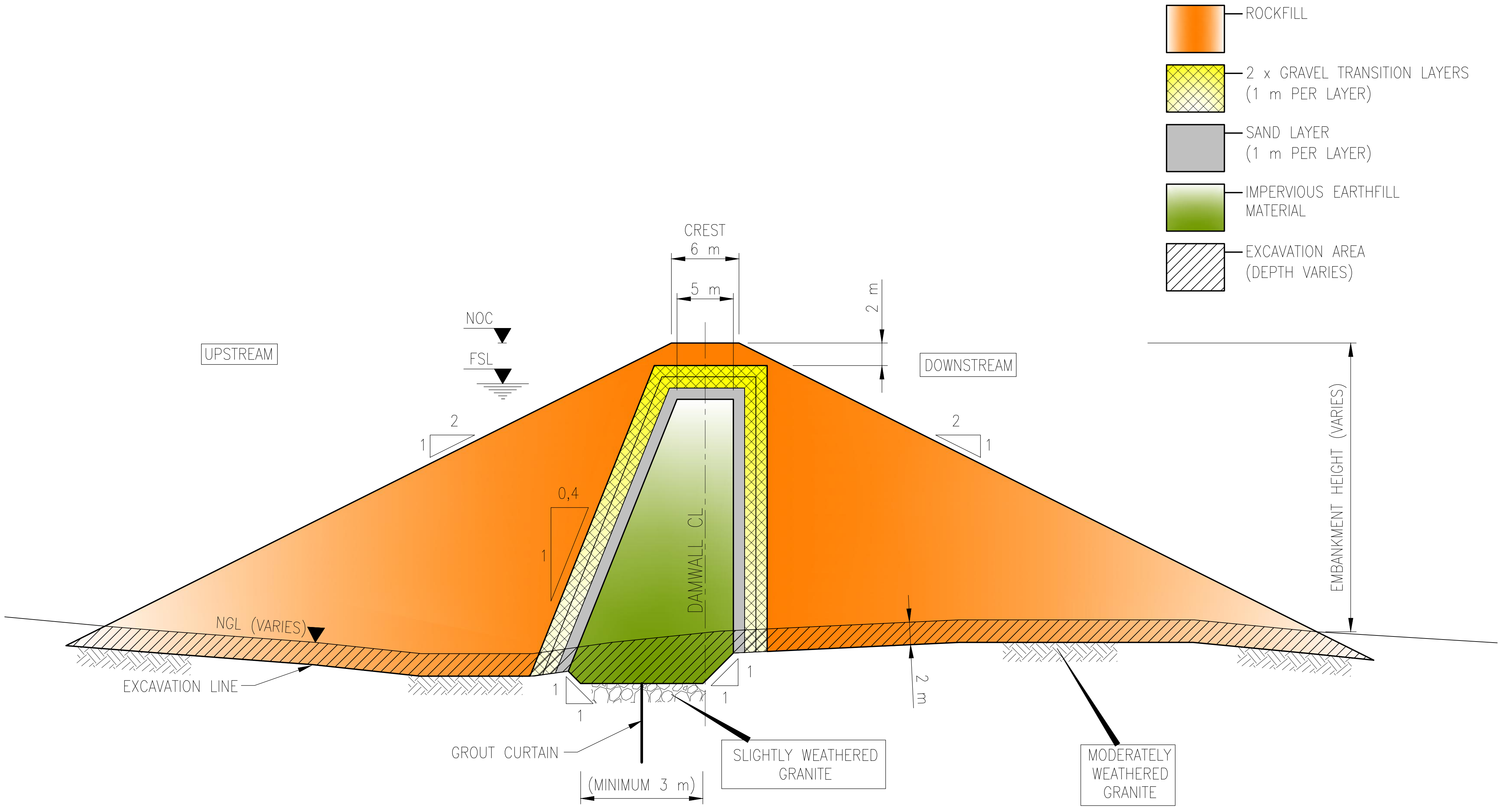
CONCRETE FACED ROCKFILL DAM (CFR)
SLOPE: 1,4/1 m U/S AND 1,8/1 m D/S

BKS DETAIL/FIGURE No.
FIG. B3



SECTION A–A
TYPICAL SECTION

NTS

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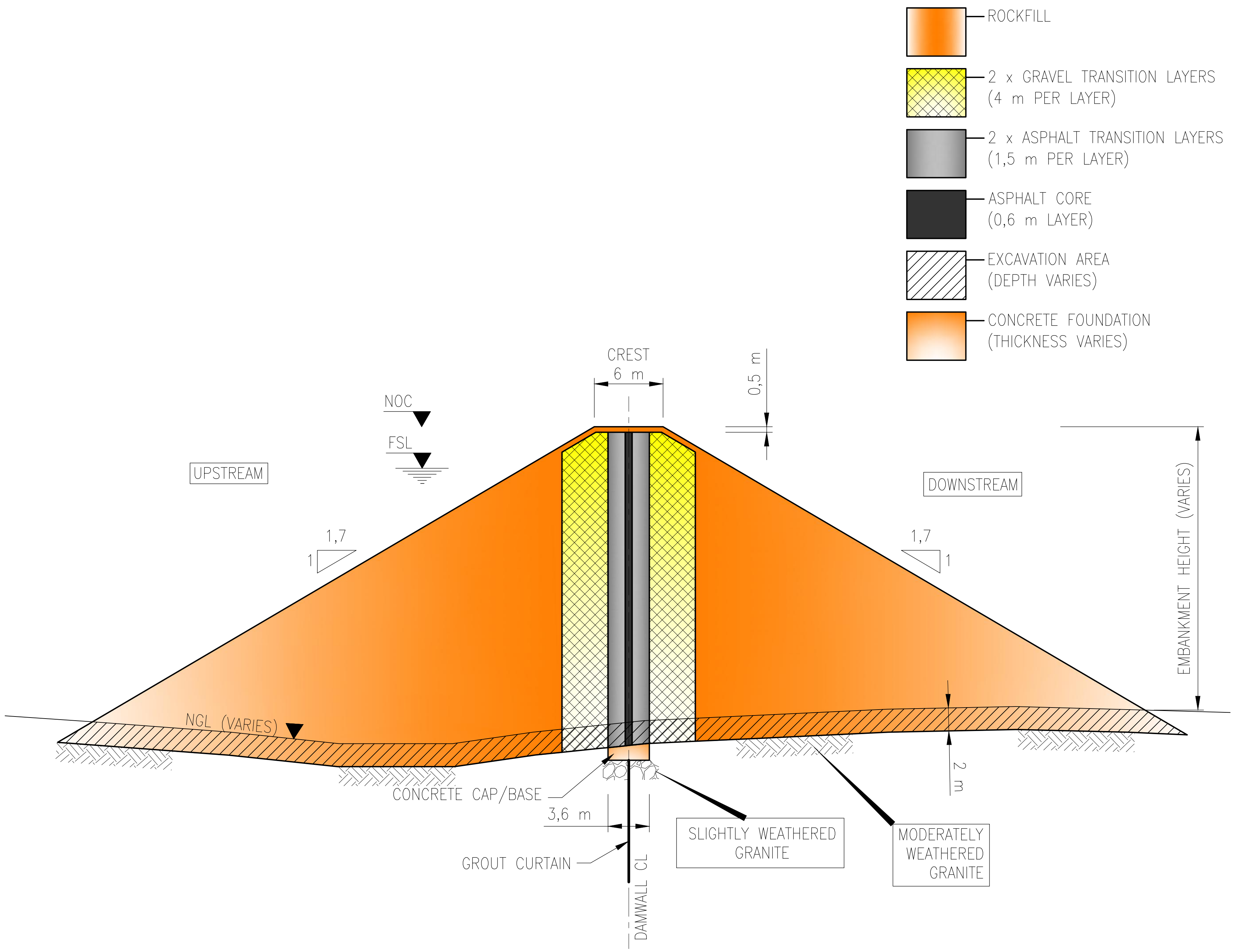
THE NCWABENI OFF CHANNEL STORAGE DAM
FEASIBILITY STUDY:
MODULE 1: TECHNICAL STUDY

EARTH CORE ROCKFILL DAM
SLOPE: 2/1 m U/S AND 2/1 m D/S

BKS DETAIL/FIGURE No.
FIG. B4



SECTION A–A
TYPICAL SECTION
NTS

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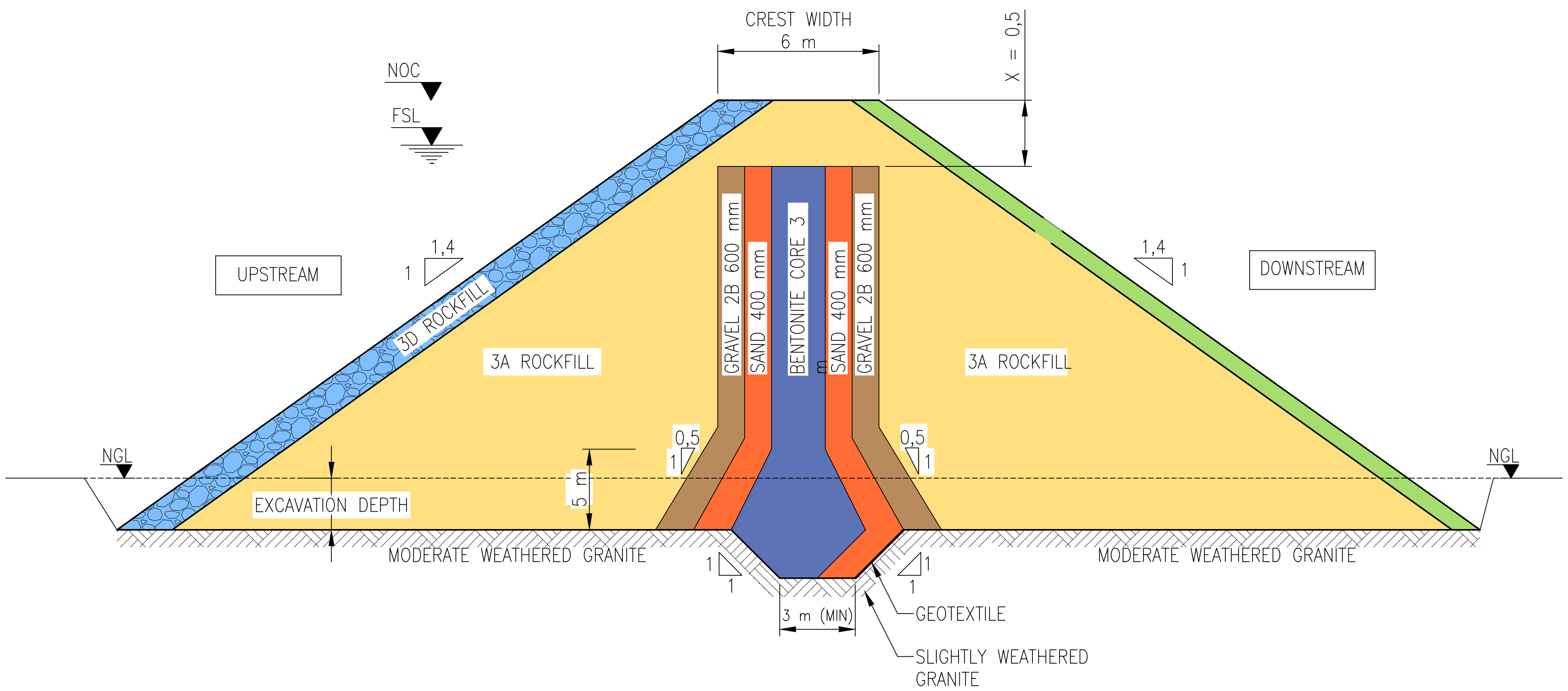
THE NCWABENI OFF CHANNEL STORAGE DAM
FEASIBILITY STUDY:
MODULE 1: TECHNICAL STUDY

ASPHALT CORE ROCKFILL DAM
SLOPE: 1,7/1 m U/S AND 1,7/1 m D/S

BKS DETAIL/FIGURE No.
FIG. B5



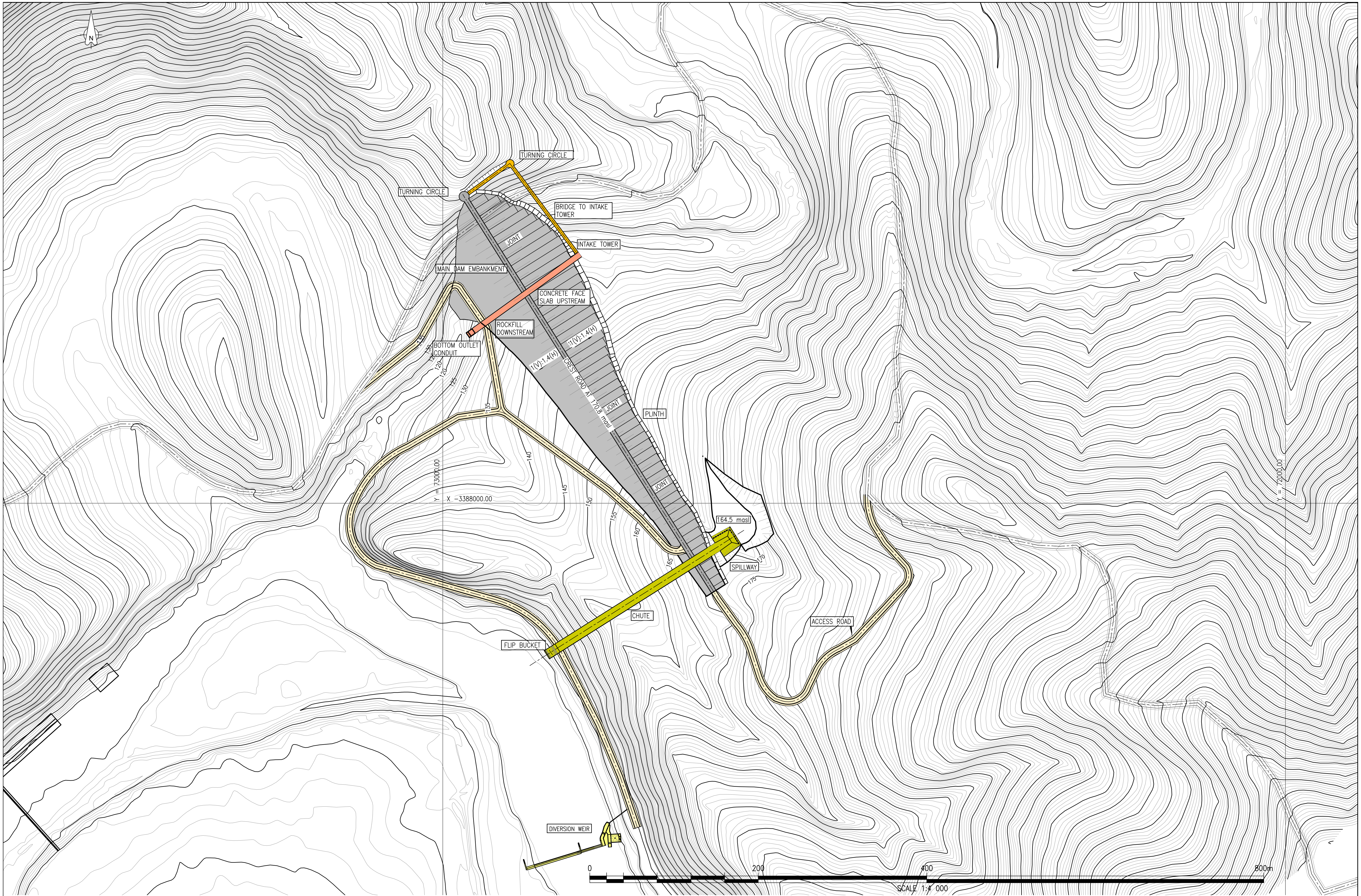
BENTONITE SAND ROCKFILL DAM
TYPICAL SECTION

NTS

BKS / water affairs, Department: Water Affairs, REPUBLIC OF SOUTH AFRICA	THE NCWABENI OFF CHANNEL STORAGE DAM FEASIBILITY STUDY: MODULE 1: TECHNICAL STUDY	BENTONITE SAND ROCKFILL DAM SLOPE: 1/1,4 m U/S AND 1/1,4 m D/S	BKS DETAIL/FIGURE No. FIG. B6

Appendix C

Selected Scheme layouts



NCWABENI OFF CHANNEL STORAGE DAM FEASIBILITY STUDY:
MODULE 1: TECHNICAL STUDY

GENERAL LAYOUT FOR THE RECOMMENDED CFR DAM AT NCWABENI DAM SITE

FIG. C.1

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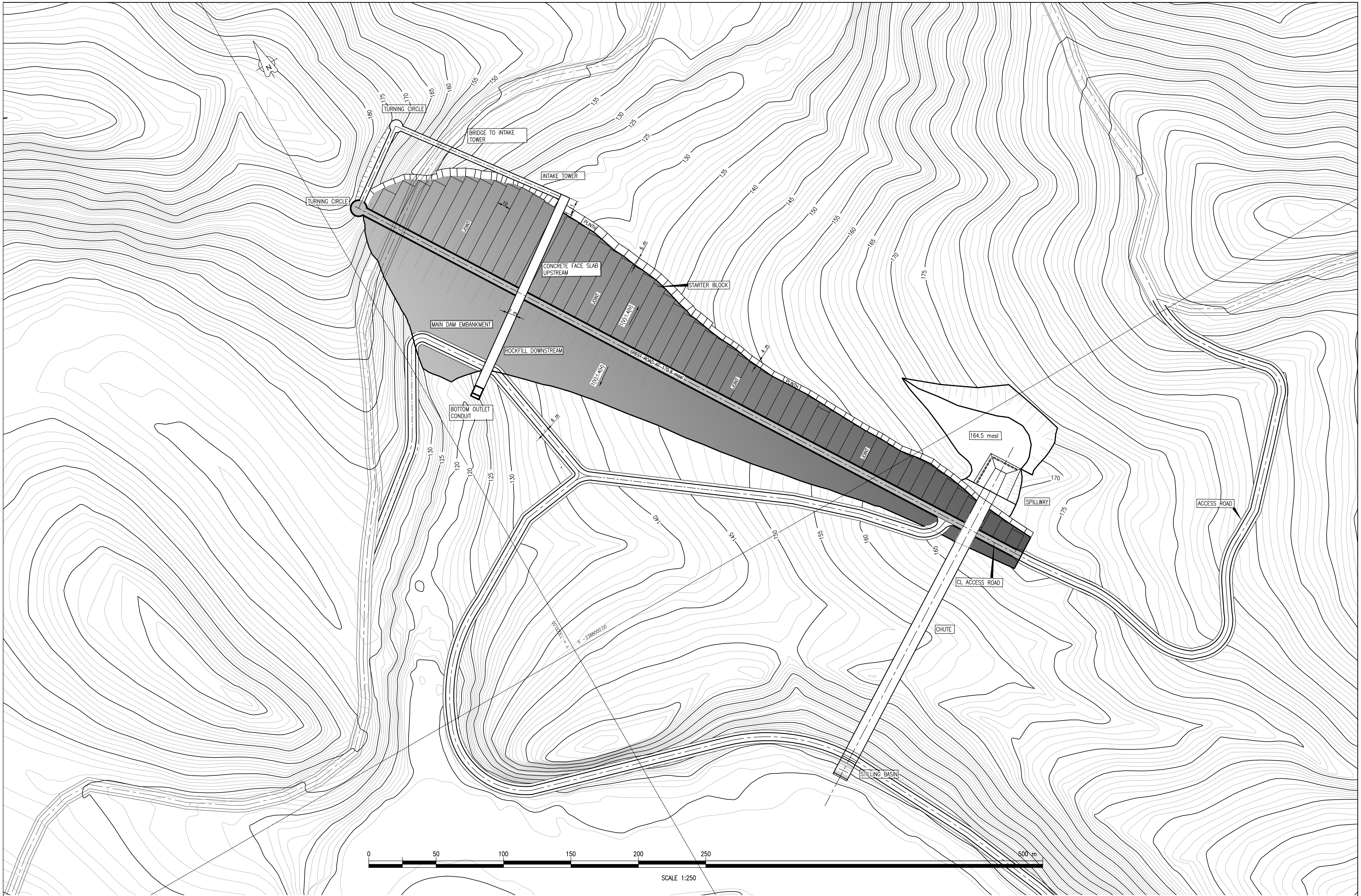

NCWABENI OFF CHANNEL STORAGE DAM FEASIBILITY STUDY:
MODULE 1: TECHNICAL STUDY

MAIN EMBANKMENT: LAYOUT

FIG. C.2

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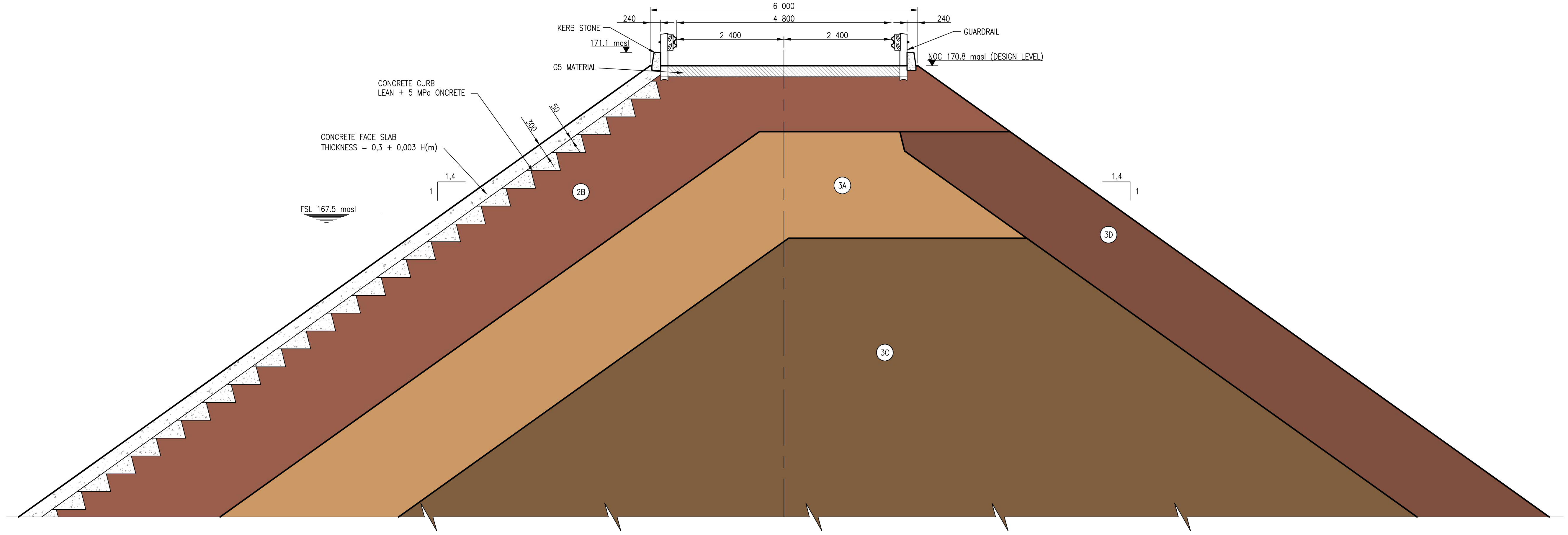
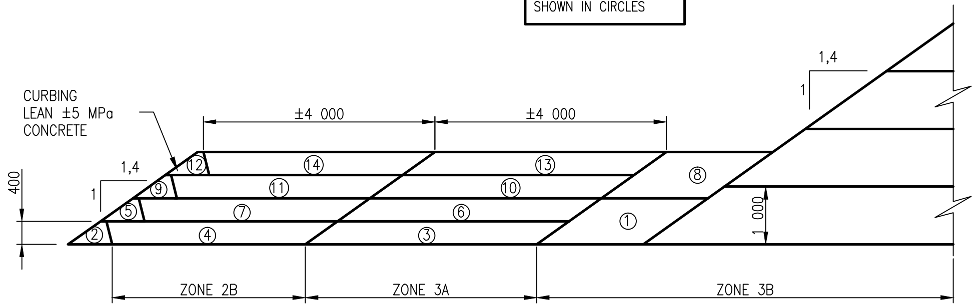
Water Affairs
REPUBLIC OF SOUTH AFRICA



DETAIL A (CREST)

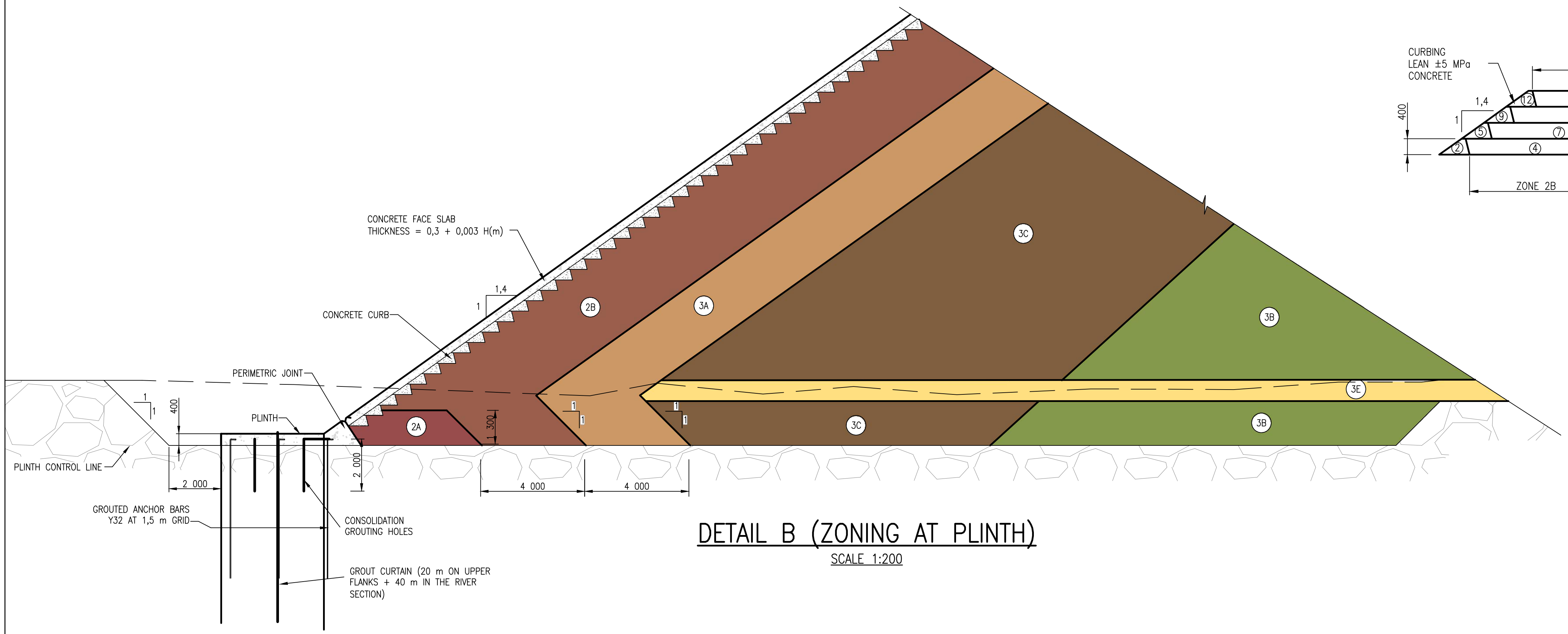
SCALE 1:100

NOTE:
PLACEMENT SEQUENCE SHOWN IN CIRCLES



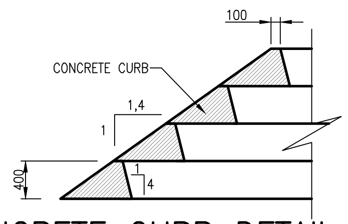
TYPICAL CURB PLACING PROCEDURES

NOT TO SCALE



DETAIL B (ZONING AT PLINTH)

SCALE 1:200



CONCRETE CURB DETAIL

NOT TO SCALE

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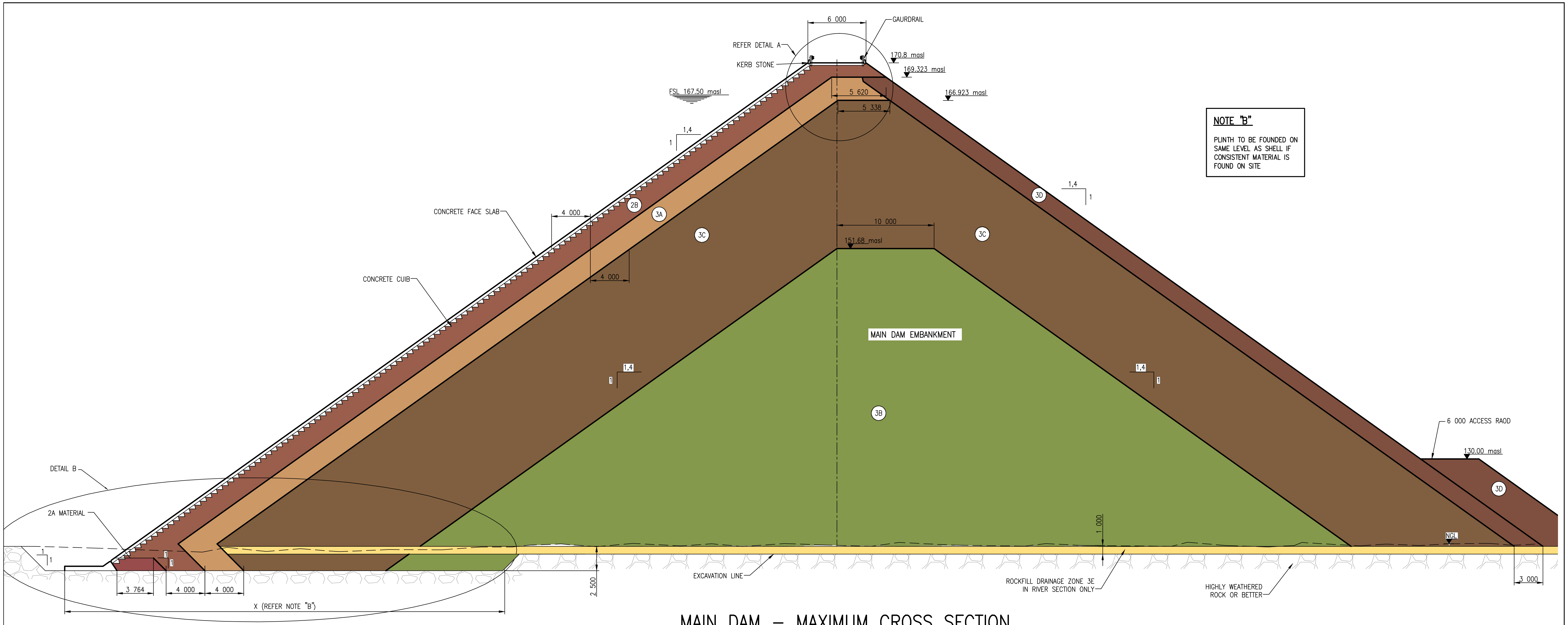
Water Affairs
REPUBLIC OF SOUTH AFRICA

NCWABENI OFF CHANNEL STORAGE DAM FEASIBILITY STUDY:
MODULE 1: TECHNICAL STUDY

MAIN EMBANKMENT: MAXIMUM CROSS SECTION AND DETAILS

FIG.C.4



NOTE "B"

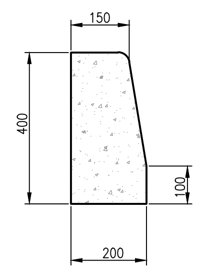
PLINTH TO BE FOUNDED ON SAME LEVEL AS SHELL IF CONSISTENT MATERIAL IS FOUND ON SITE

MAIN DAM – MAXIMUM CROSS SECTION

SCALE 1:400

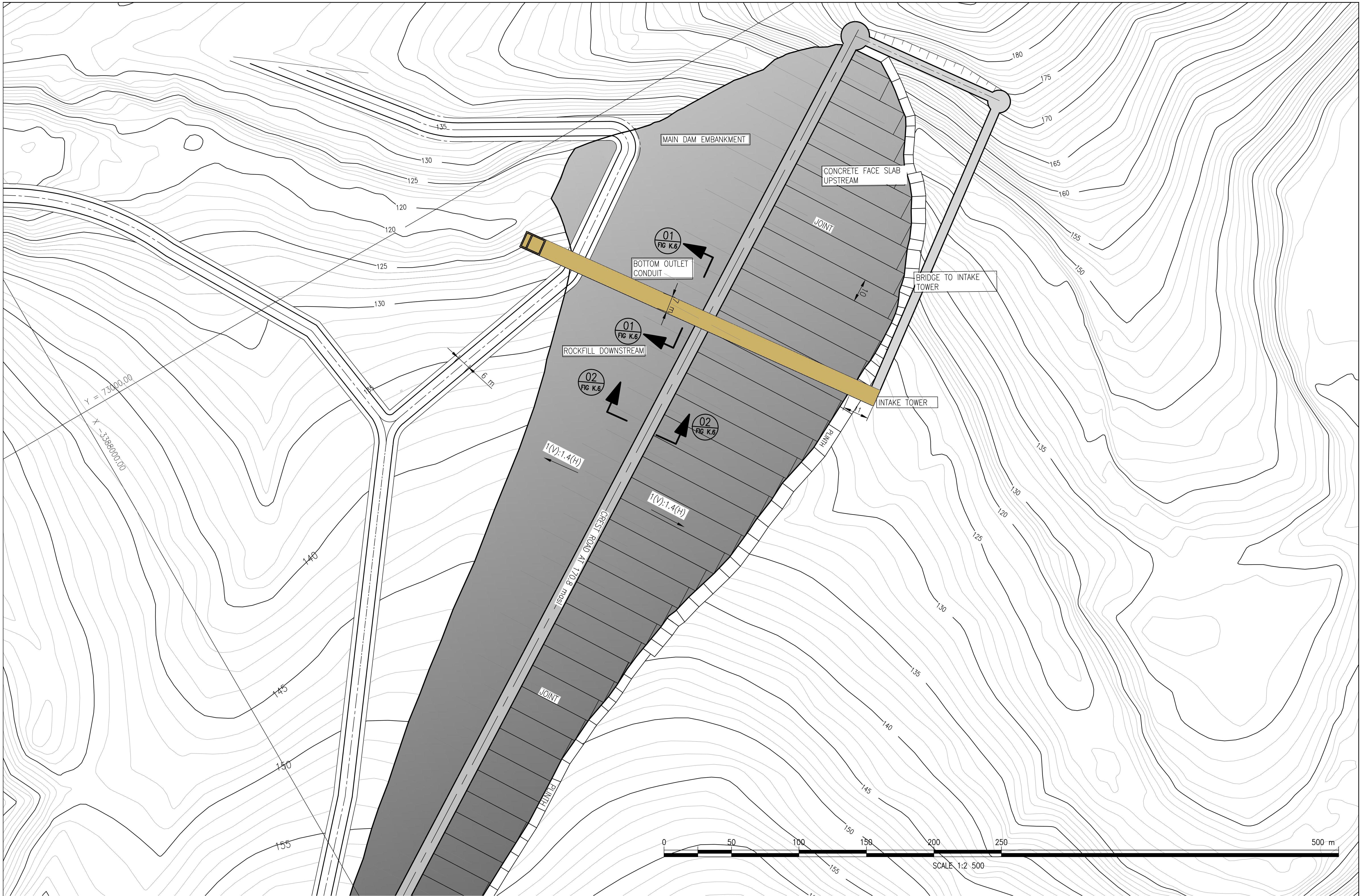
MATERIALS TABLE

ZONE	CLASSIFICATION	GRADATION	LIFT HEIGHT (m) *	TYPE OF ROLLER	PASSES (NUMBER)
2A	DURABLE CRUSHED ROCK	D15 = 0,3 TO 0,7 mm	0,2	50 kN VIBRATOR	4 ***
2B	DURABLE CRUSHED ROCK	MAX. PARTICLE SIZE 76 mm	0,4	≤ 10 TONNE VIBRATORY ROLLER	4 MIN. + SURFACE COMPACTION **
3A	SELECTED SMALL QUARRY RUN ROCK	MAX. PARTICLE SIZE 400 mm	0,4	≥ 10 TONNE VIBRATORY ROLLER	6 MIN.
3B	QUARRY RUN ROCKFILL (SOFT GRANITES)	0,075 mm: MAX. 10% < 25 mm: MAX. 50%	1,0	10 TONNE VIBRATORY ROLLER	6 MIN. ****
3C	QUARRY RUN ROCKFILL (COARSE GRANITES)	1 m MAX SIZE	1,0	10 TONNE VIBRATORY ROLLER	6 MIN. ***
3D	SELECTED DURABLE GRANITES	60 % > 0,6 m	NA	–	PLACED BY BACHOE, OR OTHER APPROVED MEANS
3E	QUARRY RUN DURABLE ROCK	0,075 mm: MAX. 5% < 25 mm: MAX. 40%	0,5/0,2	10 TONNE VIBRATORY ROLLER	6 MIN.



KERB STONE DETAIL

SCALE 1:20



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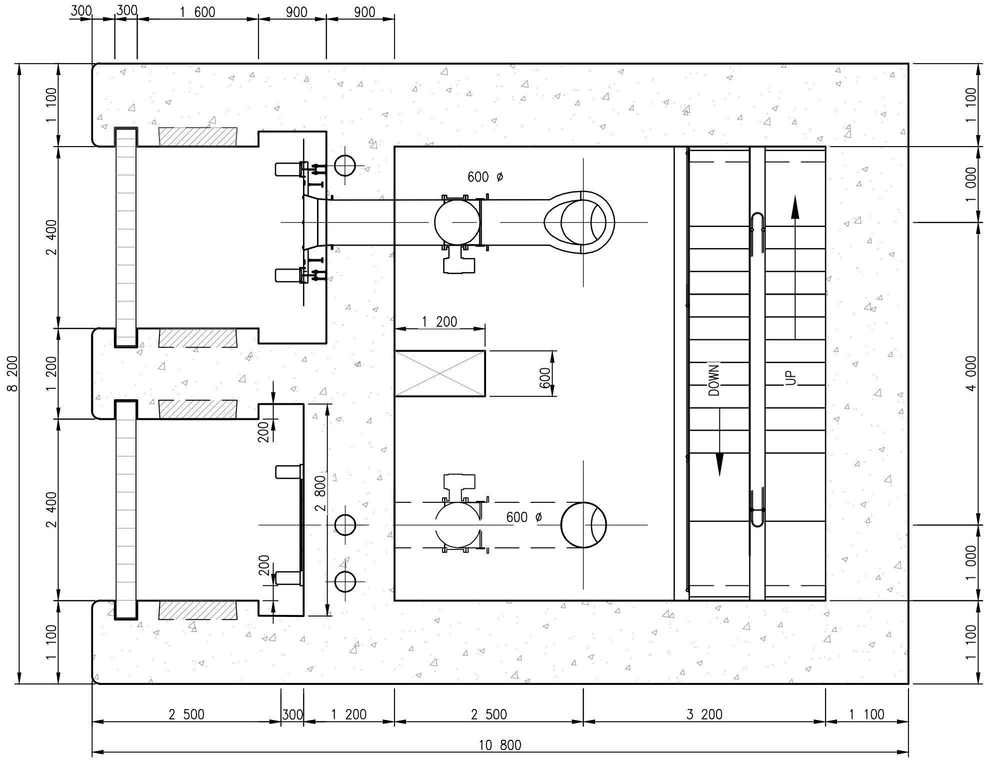
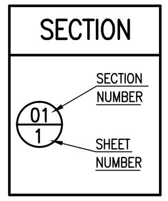
NCWABENI OFF CHANNEL STORAGE DAM FEASIBILITY STUDY:
MODULE 1: TECHNICAL STUDY

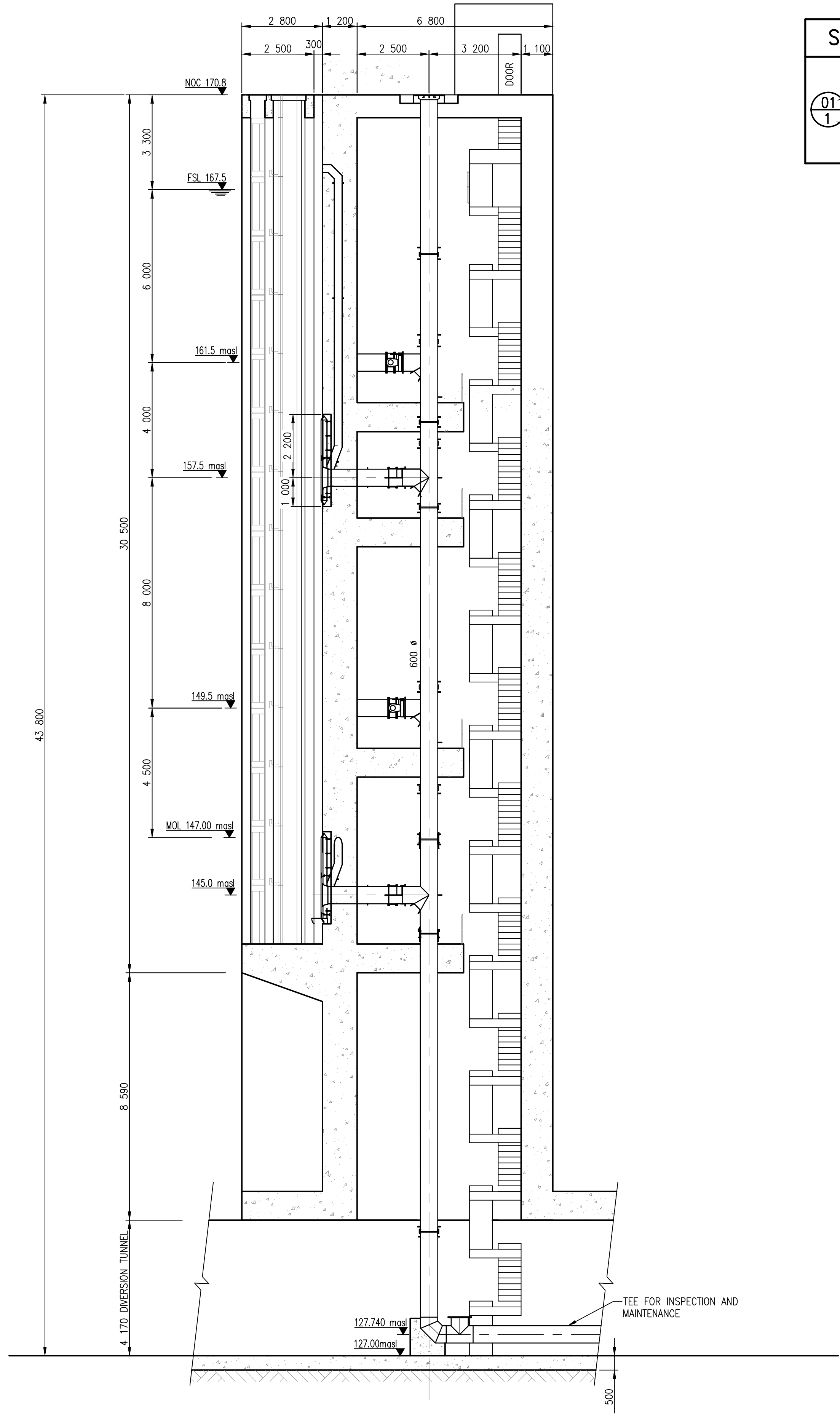
OUTLET WORKS: LAYOUT

FIG.C.5

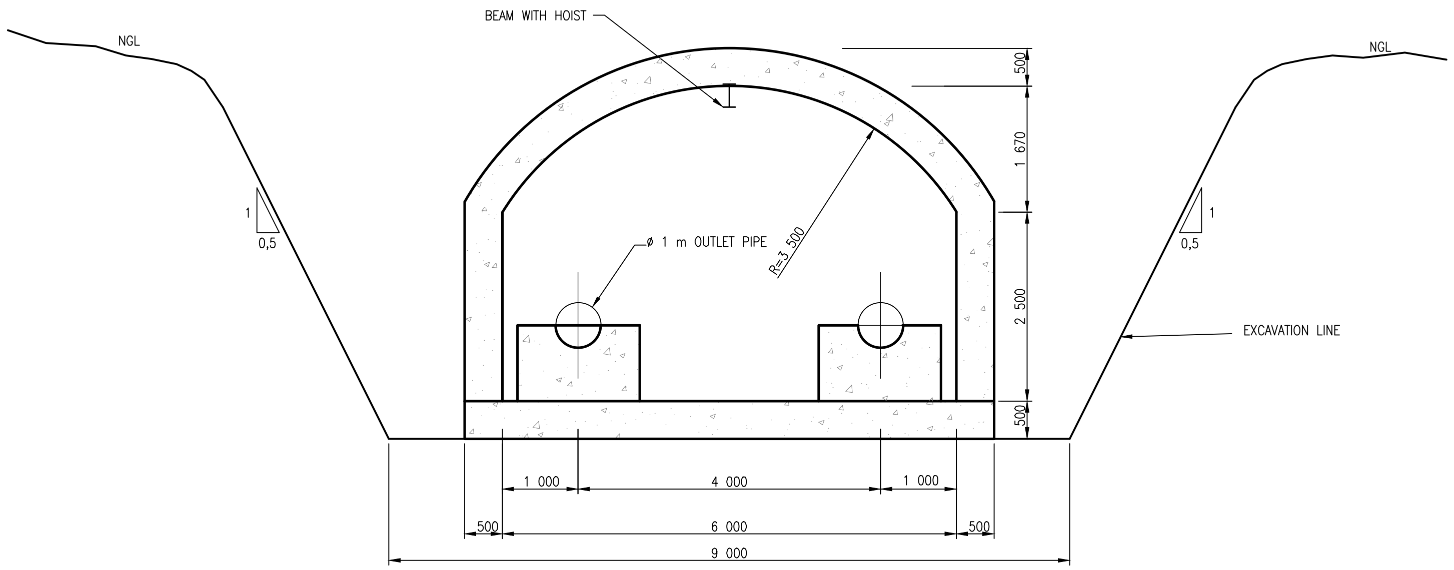


PLAN AT 161,5 masl
SCALE 1:100





SECTION 01–01
SCALE 1:200



SECTION 02–02: CONDUIT
SCALE 1:100

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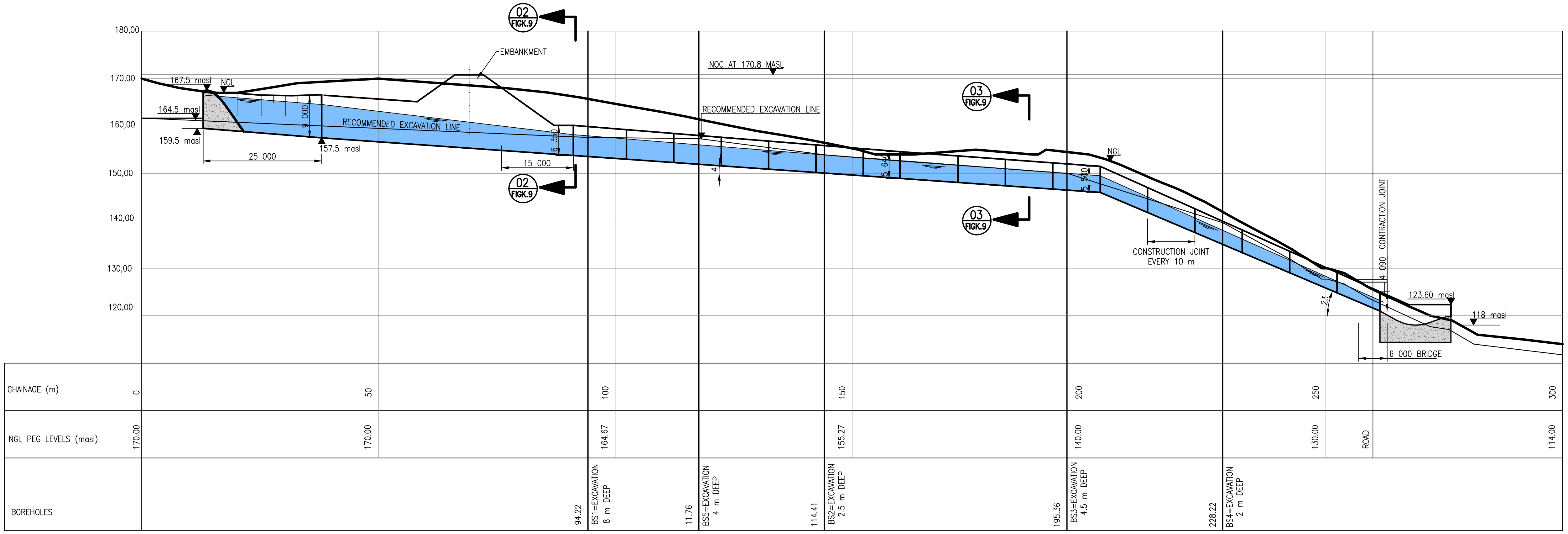
OUTLET WORKS: PLAN LAYOUT, SECTIONS & DETAILS

FIG.C.6

LAYOUT PLAN

SCALE 1:1 000



LONGITUDINAL SECTIONAL VIEW

SCALE 1:1 000 (H)
1:100(V)

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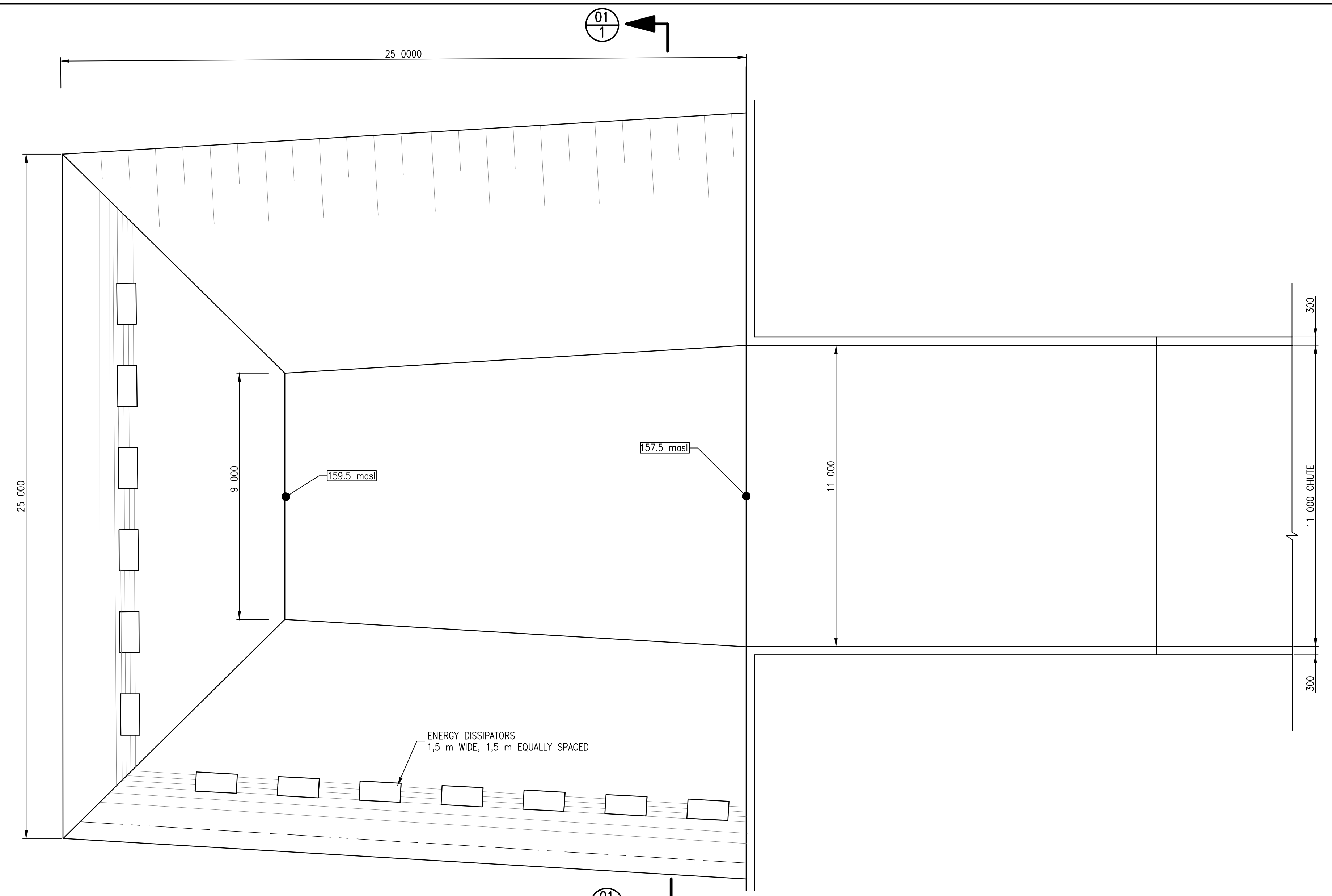
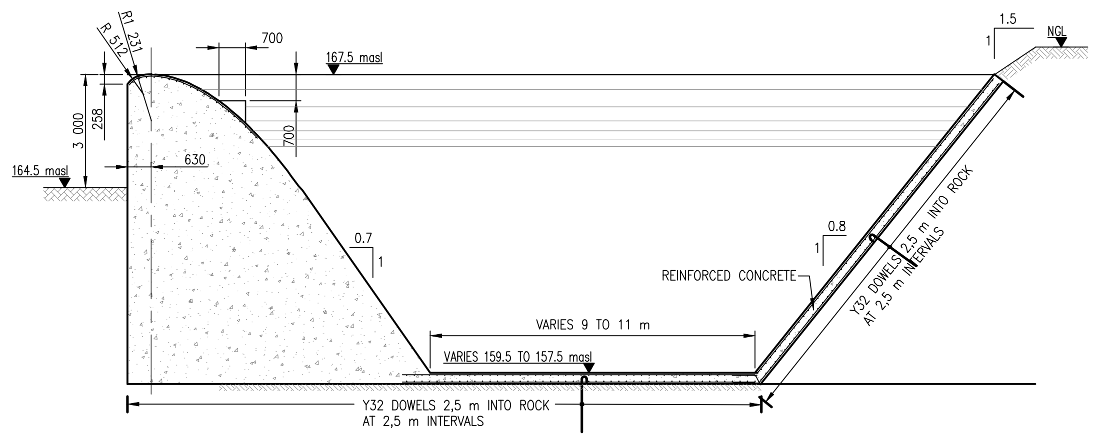
SPILLWAY: LAYOUT AND LONGITUDINAL SECTIONAL VIEW

FIG.C.7



PLAN OF SPILLWAY TROUGH

SCALE 1 : 200



SECTION 01–01

SCALE 1 : 200

SECTION

SECTION NUMBER

SHEET NUMBER

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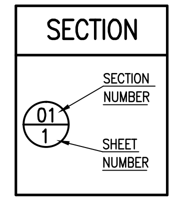
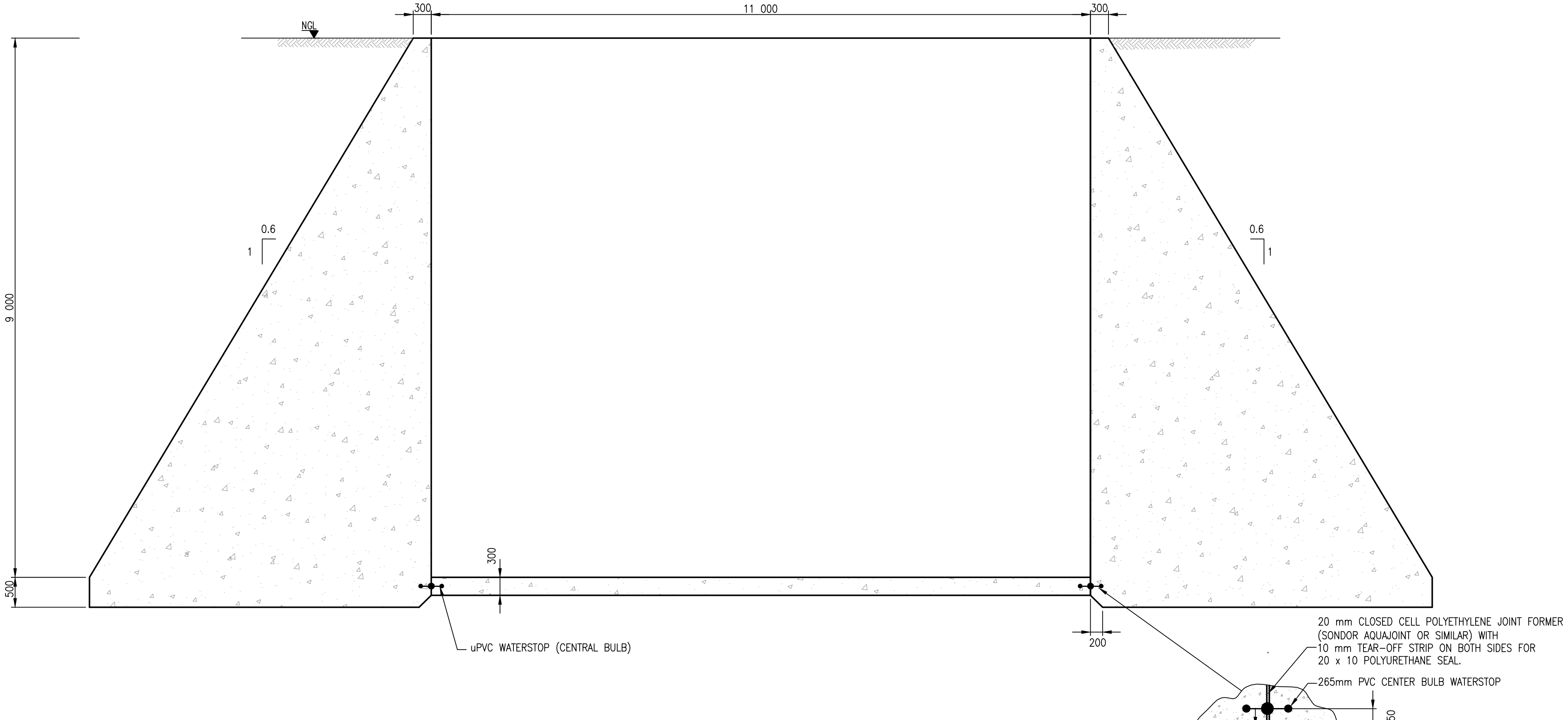
MODULE 1: TECHNICAL STUDY

SPILLWAY: TROUGH PLAN AND SECTION

FIGC.8

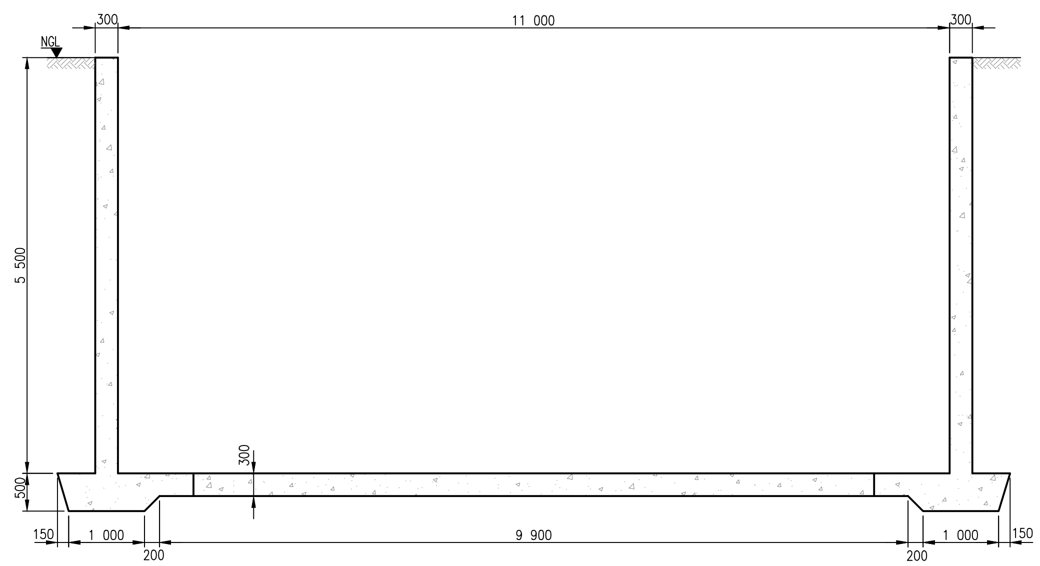




SECTION 02–02
SCALE 1 : 100

NOTE:

CONTRACTION JOINTS AT 10 m INTERVALS (REFER DRG 200)



SECTION 03–03
SCALE 1 : 100

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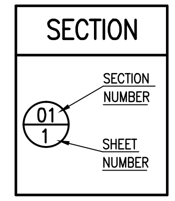
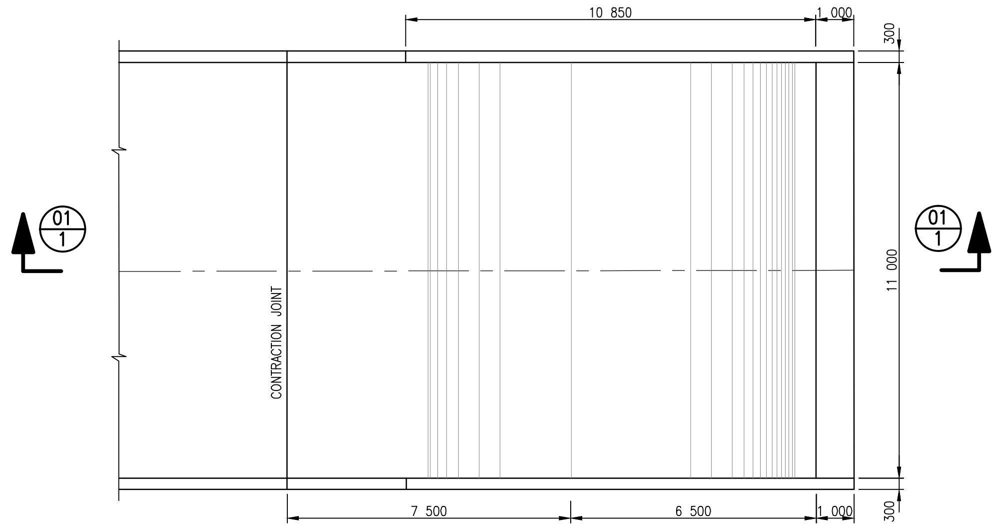
NCWABENI OFF CHANNEL STORAGE DAM FEASIBILITY STUDY:
MODULE 1: TECHNICAL STUDY

SPILLWAY: CHUTE SECTIONS

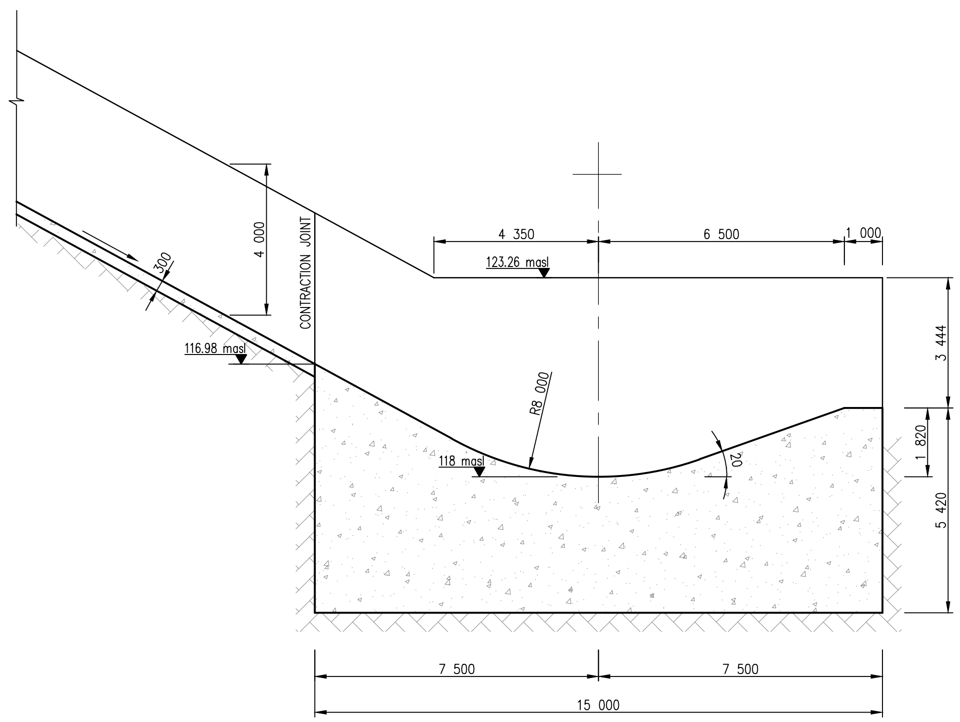
FIGC.9





PLAN OF FLIP BUCKET

SCALE 1 : 200



SECTION 01–01

SCALE 1 : 200

Appendix D

Abstraction Weir Layouts

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BKS

THE NCWABENI OFF-CHANNEL STORAGE DAM
FEASIBILITY STUDY
MODULE 1: TECHNICAL STUDY

Identified Abstraction Works Sites on the Mzimkhulu River

FIGURE D1

Drawn:	LC Gallagher
Checked:	LC Gallagher
Approved:	M Trümpelmann
Date:	2012_08_30
Map Ref:	.../Water/Ncwabeni
View Ref:	Mzimkhulu Weir Sites

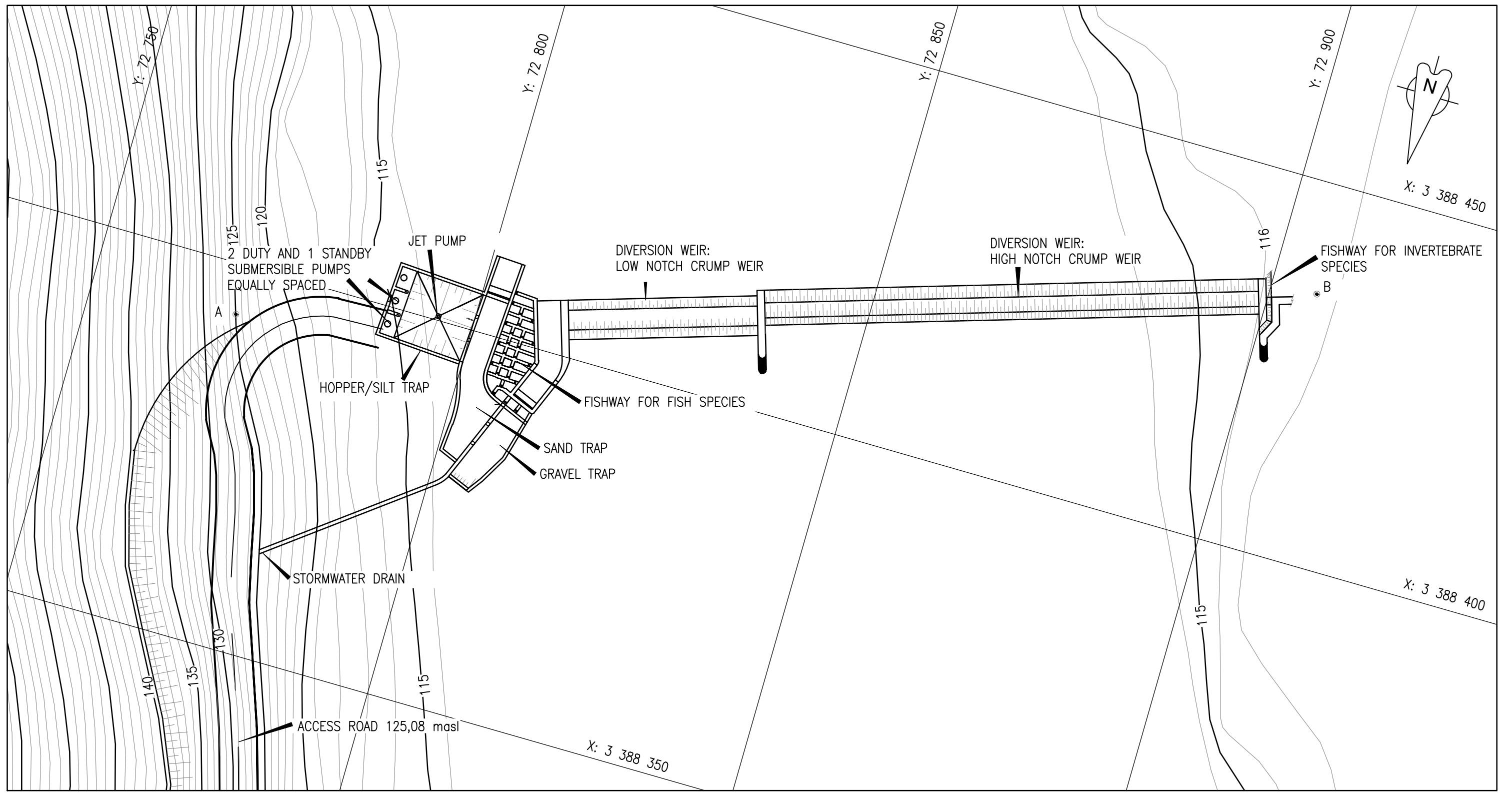
SETTING OUT CO-ORDINATES		
POINT	X	Y
A	3 388 393.417	72 769.452
B	3 388 435.345	72 906.139

NOTES:

1. ROOF SLAB COVERING THE SAND TRAP AND PUMPSTATION NOT SHOWN
2. ROCKFILL NOT SHOWN ON PLAN LAYOUT

NOTES FOR FISHWAY:

1. MINIMUM EFFECTIVE AREA OF POOL: 1,1 LENGTH x 1,0 WIDE
2. ALL VERTICAL SLOTS WITH OPENING OF 150 mm
3. BOTTOM SURFACE OF POOLS TO BE ROUGHENED



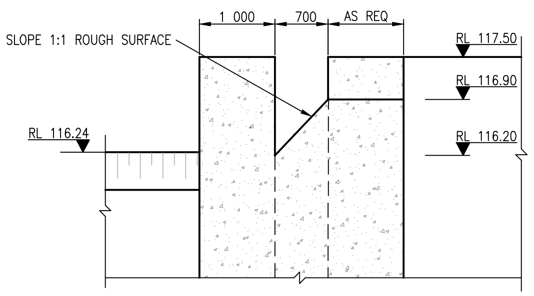
PLAN LAYOUT

SCALE 1: 1000

NOTCH LEVELS OF FISHWAY:

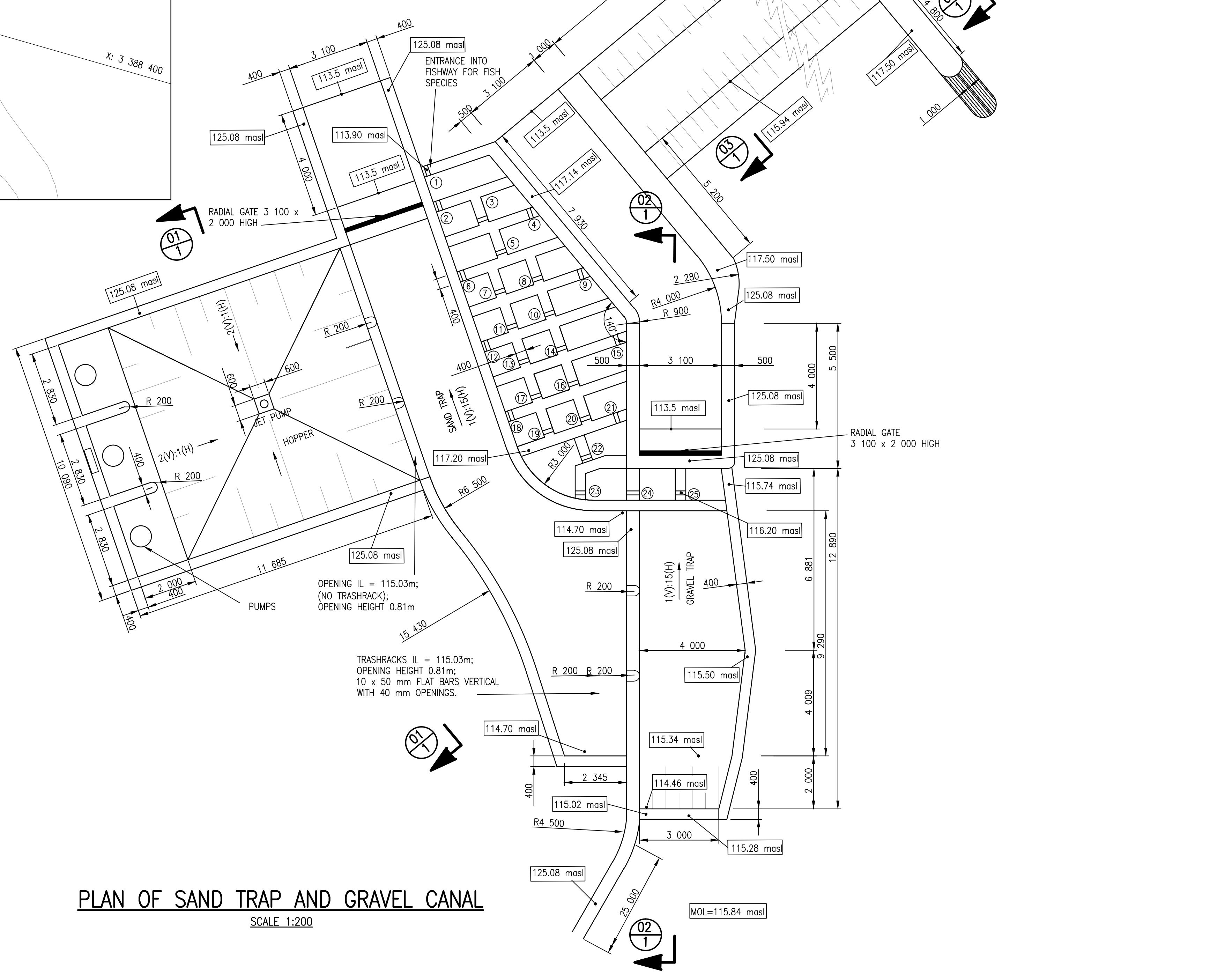
(masl)

1	113.9	14	115.1
2	114.0	15	115.2
3	114.1	16	115.3
4	114.1	17	115.4
5	114.2	18	115.5
6	114.3	19	115.6
7	114.4	20	115.7
8	114.5	21	115.8
9	114.6	22	115.9
10	114.7	23	116.0
11	114.8	24	116.1
12	114.9	25	116.2
13	115.0		



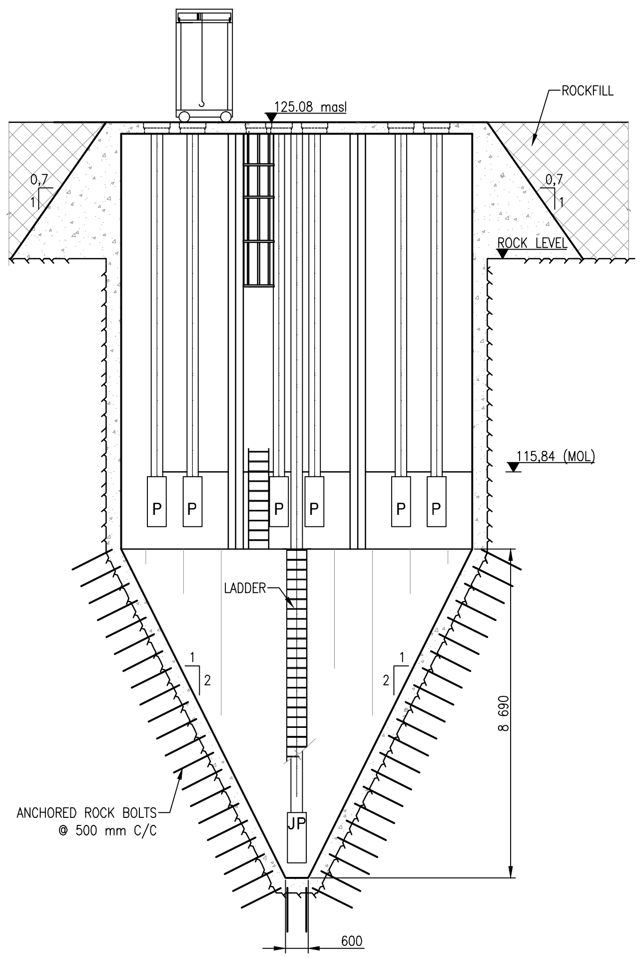
SECTION 05–05

SCALE 1: 100



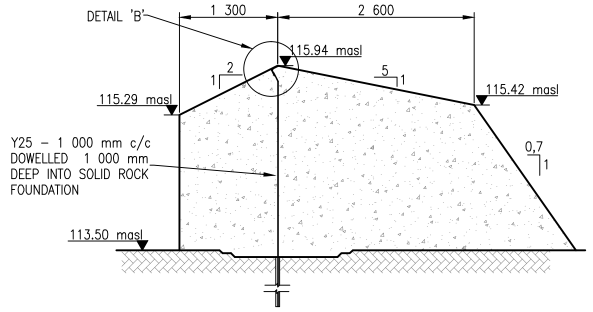
PLAN OF SAND TRAP AND GRAVEL CANAL

SCALE 1:200



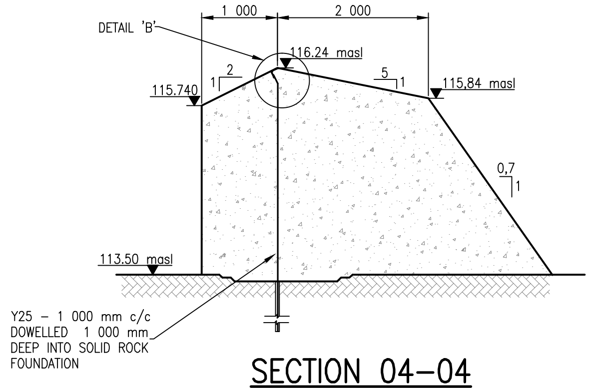
SECTION 01–01

SCALE 1:200



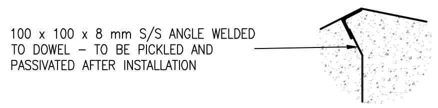
SECTION 03–03

SCALE 1:100

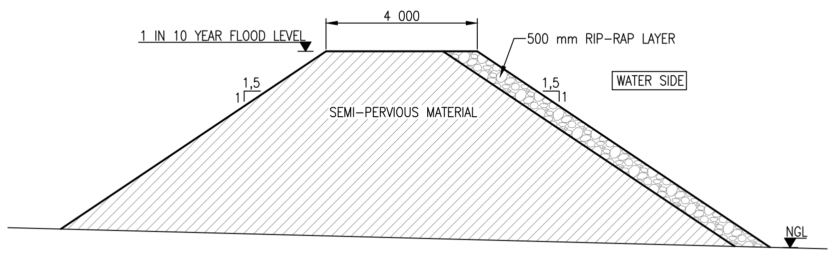


SECTION 04–04

SCALE 1:100

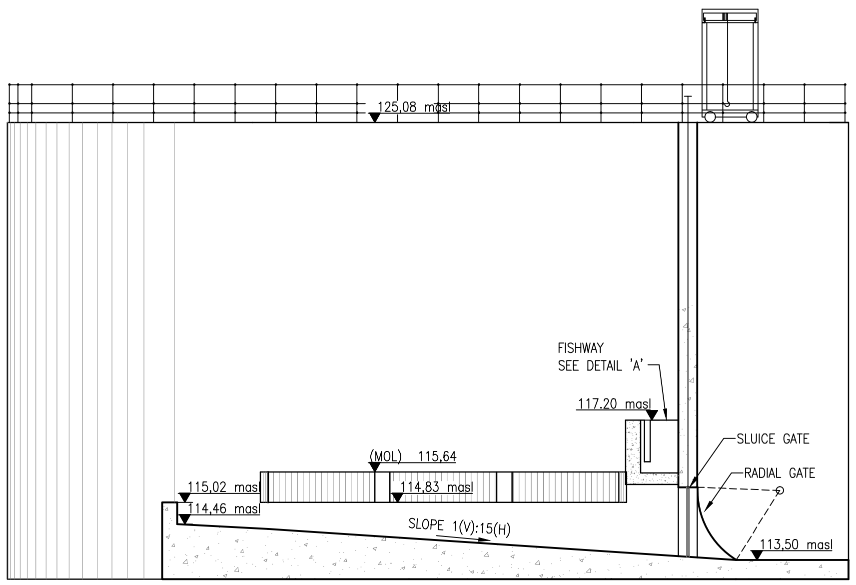


DETAIL 'B'



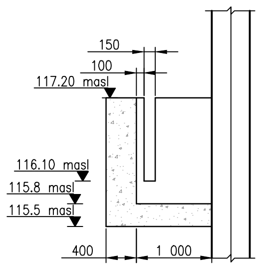
TYPICAL SECTION: COFFER DAM

SCALE 1:200



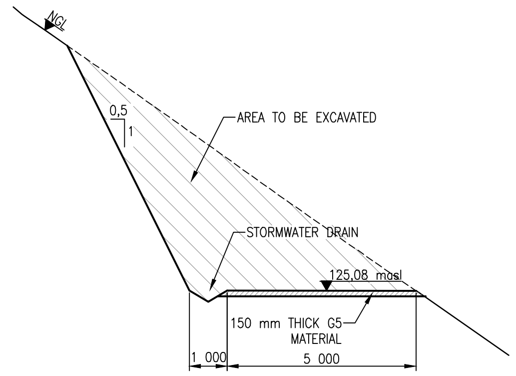
SECTIONAL VIEW 02–02

SCALE 1:200



DETAIL 'A'

SCALE 1:100



TYPICAL SECTION THROUGH ACCESS ROAD

SCALE 1:100

NCWABENI FEASIBILITY STUDY

DIVERSION WEIR AND ABSTRACTION WORKS: SECTIONS

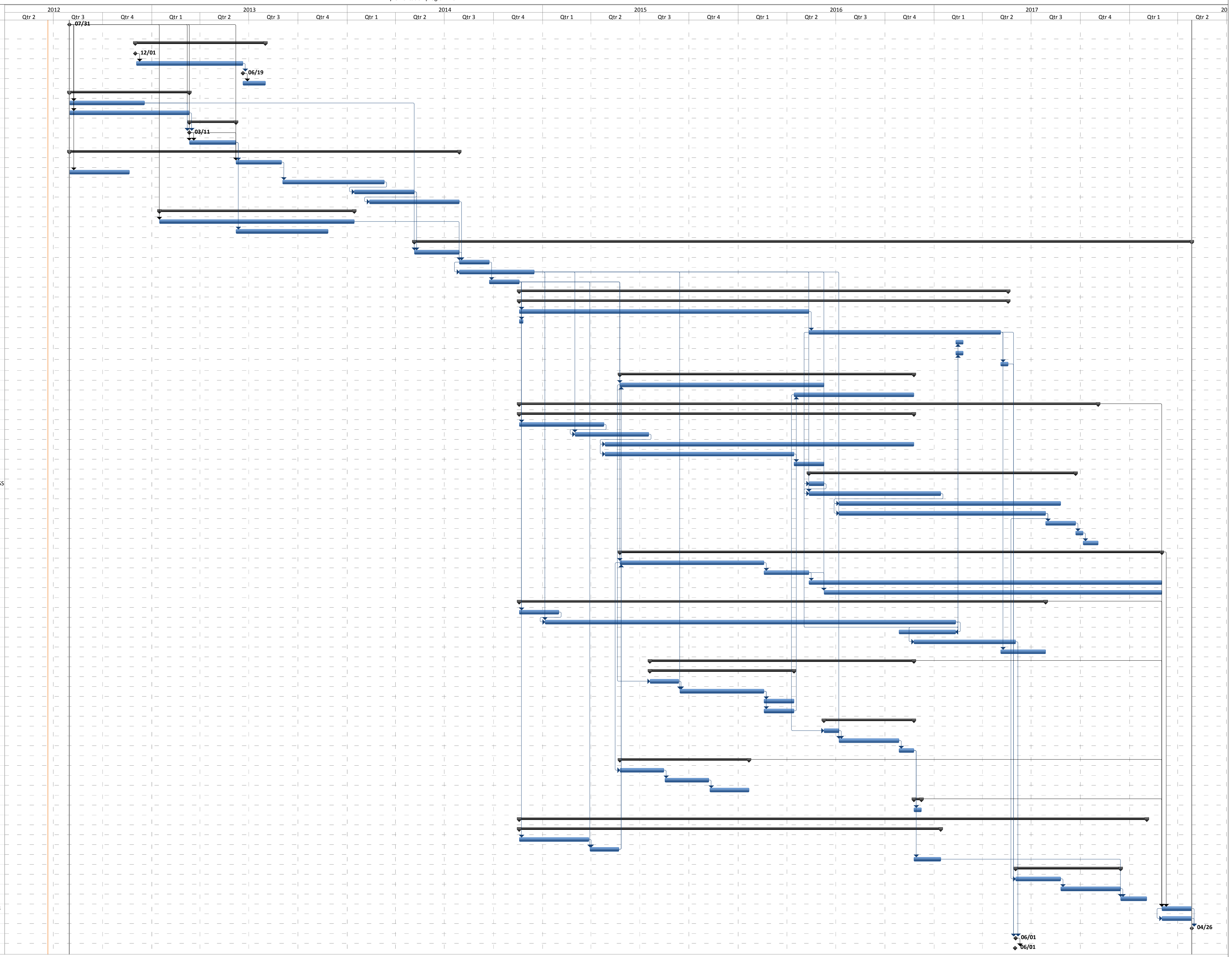
FIG. D.3

Appendix E

Implementation Program

The Ncwabeni Off Channel Storage Dam
Feasibility Study Module 1: Technical Study
Implementation programme

ID	Task Name	Duration	Start	Finish	Predecessors
1	End of current project: Ncwabeni Off channel Storage Dam Feasibility Study: Module 1: Technical Study	0 days	Tue 12/07/31	Tue 12/07/31	
2	**1. ENVIRONMENTAL AUTHORISATION**	**170 days**	**Sat 12/12/01**	**Wed 13/07/31**	
3	1.1 Submission of FEIR to DEA	0 days	Sat 12/12/01	Sat 12/12/01	
4	1.2 DEA review	7 mons	Mon 12/12/03	Wed 13/06/19	3
5	1.3 Environmental authorisation (ROD)	0 days	Wed 13/06/19	Wed 13/06/19	4
6	1.4 Appeal period	6 wks	Thu 13/06/20	Wed 13/07/31	5
7	**2. INSTITUTIONAL AND FINANCIAL ARRANGEMENTS**	**160 days**	**Tue 12/07/31**	**Mon 13/03/11**	
8	2.2 Securing funding for project	5 mons	Tue 12/07/31	Mon 12/12/17	1
9	2.3 Water supply arrangements	8 mons	Tue 12/07/31	Mon 13/03/11	1
10	**3. RID**	**60 days**	**Mon 13/03/11**	**Thu 13/06/06**	
11	3.1 Issuing of RID	0 days	Mon 13/03/11	Mon 13/03/11	1,8,9
12	3.2 Handover of project	3 mons	Tue 13/03/12	Thu 13/06/06	1,11
13	**4. DETAIL AND TENDER DESIGN PHASE**	**500 days**	**Tue 12/07/31**	**Mon 14/07/28**	
14	4.1 Procurement of Design PSP	3 mons	Fri 13/06/07	Fri 13/08/30	1,11,12
15	4.2 Additional geotechnical investigations (drilling)	16 wks	Tue 12/07/31	Mon 12/11/19	1
16	4.3 Tender design	6 mons	Mon 13/09/02	Mon 14/03/10	14
17	4.4 Prepare tender documents	4 mons	Tue 14/01/14	Mon 14/05/05	16FS-2 mons
18	4.5 Detail design	6 mons	Tue 14/02/11	Mon 14/07/28	17FS-3 mons
19	**5. PRELIMINARY WORKS**	**240 days**	**Tue 13/01/15**	**Mon 14/01/13**	
20	5.1 Electrical supply to site (ESKOM)	12 mons	Tue 13/01/15	Mon 14/01/13	1FS+6 mons
21	5.2 Heritage assessment & search and rescue	6 mons	Fri 13/06/07	Mon 13/11/25	12
22	**6. CONSTRUCTION PHASE**	**980 days**	**Tue 14/05/06**	**Thu 18/04/26**	
23	6.1 Procurement of Contractor and award	12 wks	Tue 14/05/06	Mon 14/07/28	17,8
24	6.2 Site establishment	8 wks	Tue 14/07/29	Mon 14/09/22	23,18,20
25	6.3 Mobilisation and erection of crusher and batching plant	5 mons	Tue 14/07/29	Mon 14/12/15	24SS
26	6.4 Site clearing	2 mons	Tue 14/09/23	Mon 14/11/17	24
27	**6.5 River diversion**	**610 days**	**Tue 14/11/18**	**Thu 17/05/18**	
28	**6.5.1 Main embankment**	**610 days**	**Tue 14/11/18**	**Thu 17/05/18**	
29	6.5.1.1 Stage 1	18 mons	Tue 14/11/18	Wed 16/05/11	26
30	(a) Cofferdam 1 (Downstream of embankment)	1 wk	Tue 14/11/18	Mon 14/11/24	26
31	6.5.1.2 Stage 2	12 mons	Thu 16/05/12	Thu 17/05/04	29
32	(a) Cofferdam 2 (Upstream of embankment)	0.5 mons	Fri 17/02/10	Thu 17/02/23	61
33	(b) Cofferdam 3 (Downstream of embankment)	2 wks	Fri 17/02/10	Thu 17/02/23	61
34	6.5.1.3 Stage 3 (Plug of intake tower)	2 wks	Fri 17/05/05	Thu 17/05/18	31
35	**6.5.2 Diversion weir and abstraction works**	**380 days**	**Mon 15/05/25**	**Wed 16/11/23**	
36	6.5.2.1 Stage 1	13 mons	Mon 15/05/25	Wed 16/06/08	26,83
37	6.5.2.2 Stage 2	8 mons	Thu 16/04/14	Wed 16/11/23	69
38	**6.6 Main embankment**	**730 days**	**Tue 14/11/18**	**Thu 17/11/02**	
39	**Stage 1 (Left flank excl. river section up to NOC)**	**500 days**	**Tue 14/11/18**	**Wed 16/11/23**	
40	6.6.1 Fill and plinth excavation	5 mons	Tue 14/11/18	Fri 15/04/24	26
41	6.6.2 Formwork and plinth placement	5 mons	Mon 15/03/02	Fri 15/07/17	40FS-2 mons,25
42	6.6.3 Drilling, consolidation and curtain grouting	20 mons	Mon 15/04/27	Wed 16/11/23	41FS-3 mons
43	6.6.4 Embankment fill	12 mons	Mon 15/04/27	Wed 16/04/13	42SS
44	6.6.5 Formwork and face slab placement	2 mons	Thu 16/04/14	Wed 16/06/08	43
45	**Stage 2 (Right flank and river section up to NOC)**	**340 days**	**Thu 16/05/12**	**Thu 17/09/21**	
46	6.6.1 Fill and plinth excavation	1 mon	Thu 16/05/12	Wed 16/06/08	61FS-18 mons,31SS
47	6.6.2 Formwork and plinth placement	8 mons	Thu 16/05/12	Thu 17/01/12	25,46FS-1 mon
48	6.6.3 Drilling, consolidation and curtain grouting	14 mons	Thu 16/07/07	Thu 17/08/24	47FS-6 mons
49	6.6.4 Embankment fill	13 mons	Thu 16/07/07	Thu 17/07/27	48SS
50	6.6.5 Formwork and face slab placement	2 mons	Fri 17/07/28	Thu 17/09/21	49
51	6.6.6 Crest road construction	2 wks	Fri 17/09/22	Thu 17/10/05	50
52	6.6.7 Finishing (guardrails etc.)	1 mon	Fri 17/10/06	Thu 17/11/02	51
53	**6.7 Spillway, chute and stilling basin**	**680 days**	**Mon 15/05/25**	**Thu 18/03/01**	
54	6.7.1 Spillway excavation (trough, chute and flip bucket)	9 mons	Mon 15/05/25	Wed 16/02/17	26,83
55	6.7.2 Spillway grouting	3 mons	Thu 16/02/18	Wed 16/05/11	54
56	6.7.3 Formwork and reinforcing	22 mons	Thu 16/05/12	Thu 18/03/01	55
57	6.7.4 Structural concrete placement	21 mons	Thu 16/06/09	Thu 18/03/01	25,55FS+1 mon
58	**6.8 Outlet works**	**660 days**	**Tue 14/11/18**	**Thu 17/07/27**	
59	6.8.1 Excavation and foundation preparation	2 mons	Tue 14/11/18	Fri 15/01/30	26
60	6.8.2 Reinforcement, formwork, concrete and unformed surfaces	26 mons	Mon 15/01/05	Thu 17/02/09	59FS-1 mon,25
61	6.8.3 Hydro-mechanical items (stage 1)	3 mons	Thu 16/10/27	Thu 17/02/09	60FF
62	Access bridge to intake tower	6 mons	Thu 16/11/24	Thu 17/06/01	60FS-2 mons
63	6.8.4 Hydro-mechanical items (stage 2)	3 mons	Fri 17/05/05	Thu 17/07/27	31
64	**6.9 Diversion weir and abstraction works**	**340 days**	**Mon 15/07/20**	**Wed 16/11/23**	
65	**6.9.1 Diversion weir on the left hand side section and abstraction works**	**180 days**	**Mon 15/07/20**	**Wed 16/04/13**	
66	(a) Excavation and foundation preparation	2 mons	Mon 15/07/20	Fri 15/09/11	36SS+2 mons
67	(b) Reinforcement, formwork, concrete and unformed surfaces	5 mons	Mon 15/09/14	Wed 16/02/17	66,25
68	(c) Hydro-mechanial equipment	2 mons	Thu 16/02/18	Wed 16/04/13	67
69	(d) Backfill	2 mons	Thu 16/02/18	Wed 16/04/13	67
70	**6.9.2 Diversion weir on the right hand side section**	**120 days**	**Thu 16/06/09**	**Wed 16/11/23**	
71	(a) Excavation and foundation preparation	1 mon	Thu 16/06/09	Wed 16/07/06	37SS+2 mons
72	(b) Formwork, Concrete and unformed surfaces	4 mons	Thu 16/07/07	Wed 16/10/26	71,25
73	(c) Backfill	1 mon	Thu 16/10/27	Wed 16/11/23	72
74	**6.10 Pipeline**	**160 days**	**Mon 15/05/25**	**Wed 16/01/20**	
75	6.10.1 Excavation and foundation preparation	3 mons	Mon 15/05/25	Fri 15/08/14	54SS
76	6.10.2 Laying of pipeline (including encasement)	3 mons	Mon 15/08/17	Fri 15/11/06	75
77	6.10.3 Backfill	2 mons	Mon 15/11/09	Wed 16/01/20	76
78	**6.11 Pump station**	**10 days**	**Thu 16/11/24**	**Wed 16/12/07**	
79	6.11.3 Installation of pumps	2 wks	Thu 16/11/24	Wed 16/12/07	73
80	**6.12 Access roads and relocation of roads**	**780 days**	**Tue 14/11/18**	**Thu 18/02/01**	
81	**Access road to diversion weir and abstraction works**	**520 days**	**Tue 14/11/18**	**Thu 17/01/12**	
82	6.12.1 Roadbed & mass earthworks	4 mons	Tue 14/11/18	Fri 15/03/27	26
83	6.12.3 Layerworks	2 mons	Mon 15/03/30	Fri 15/05/22	82,26
84	6.12.4 Surfacing	1 mon	Thu 16/11/24	Thu 17/01/12	73
85	**Realignment of road**	**140 days**	**Fri 17/06/02**	**Thu 17/12/14**	
86	6.12.1 Roadbed & mass earthworks	3 mons	Fri 17/06/02	Thu 17/08/24	49FS-2 mons
87	6.12.3 Layerworks & surfacing	4 mons	Fri 17/08/25	Thu 17/12/14	86
88	6.12.6 Road marking and finishing	1 mon	Fri 17/12/15	Thu 18/02/01	87,84
89	6.13 Fencing	2 mons	Fri 18/03/02	Thu 18/04/26	38,53,58,64,74,78
90	6.14 Landscaping	2 mons	Fri 18/03/02	Thu 18/04/26	89SS
91	6.15 Commissioning and handover	0 days	Thu 18/04/26	Thu 18/04/26	89,90
92	**7. RESERVOIR IMPOUNDMENT**	**0 days**	**Thu 17/06/01**	**Thu 17/06/01**	**31,62,34**
93	**8. EARLIEST WATER DELIVERY**	0 days	Thu 17/06/01	Thu 17/06/01	92FS+2 mons



Project: Implementation program
Date: Thu 12/06/21

Task | Split | Milestone | Summary | Project Summary | External Tasks | External Milestone | Inactive Task | Inactive Milestone | Inactive Summary | Manual Task | Duration-only | Manual Summary Rollup | Manual Summary | Start-only | Finish-only | Deadline | Progress

Appendix F

Climate Data for Construction

1 CLIMATOLOGY DATA FOR THE NCWABENI CONSTRUCTION SITE

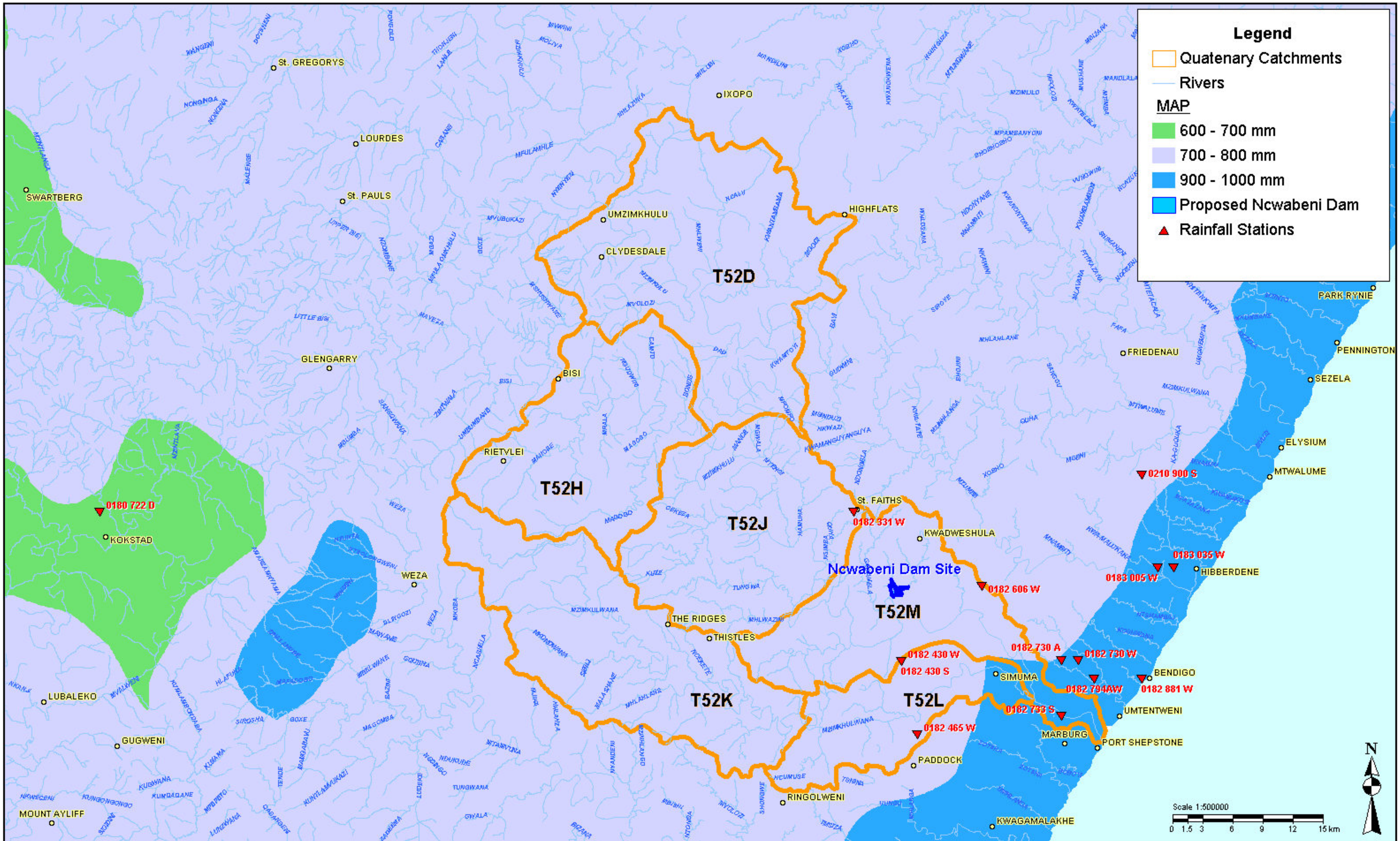
1.1 Rainfall

Information on the rain gauge network in the vicinity of the proposed construction site was obtained from the WRC daily database (2004). All gauges with less than a 15 year record length, and more than 16% gaps in the record were discarded. The details of the selected gauges considered as representative of the rainfall at the proposed Ncwabeni Dam site are shown in **Table 1-1**.

Table 1-1 Information on usable rainfall gauges close to the proposed Ncwabeni Dam site

Station number	Station name	Latitude	Longitude	Begin year	End year	Number of record years	Gaps (%)	MAP (mm)
0180 722 D	T3E002 Kokstad	30°32'	29°25'	1959	1979	21	0	718
0182 331 W	ST FAITHS - POL	30°32'	30°12'	1969	1989	21	6	977
0182 430 S	ORIBI FLATS	30°40'	30°15'	1964	2000	37	9	831
0182 430 W	MINNEHAHA	30°40'	30°15'	1951	2008	58	2	821
0182 465 W	PADDOCK E	30°44'	30°16'	1992	2008	17	7	1064
0182 606 W	MEHLOMNYAMA - POL	30°36'	30°20'	1922	2003	82	7	605
0182 730 A	THE VALLEYS, P SHEPS	30°40'	30°25'	1939	1988	50	16	1047
0182 730 W	THE VALLEYS	30°40'	30°26'	1937	2008	72	2	1100
0182 733 S	UMZIMKULU MILL	30°43'	30°25'	1967	1991	25	8	1129
0182 794 AW	PORT SHEPSTONE - VRT	30°41'	30°27'	1939	1995	57	6	945
0182 881 W	SOUTHPORT - POL	30°41'	30°30'	1971	1991	21	3	1177
0183 005 W	KLOOFEND	30°35'	30°31'	1903	1990	88	5	1009
0183 035 W	RUMPUS RIDGE	30°35'	30°32'	1922	1939	18	7	1059
0210 900 S	HIBBERDENE	30°30'	30°30'	1956	2000	45	3	1008

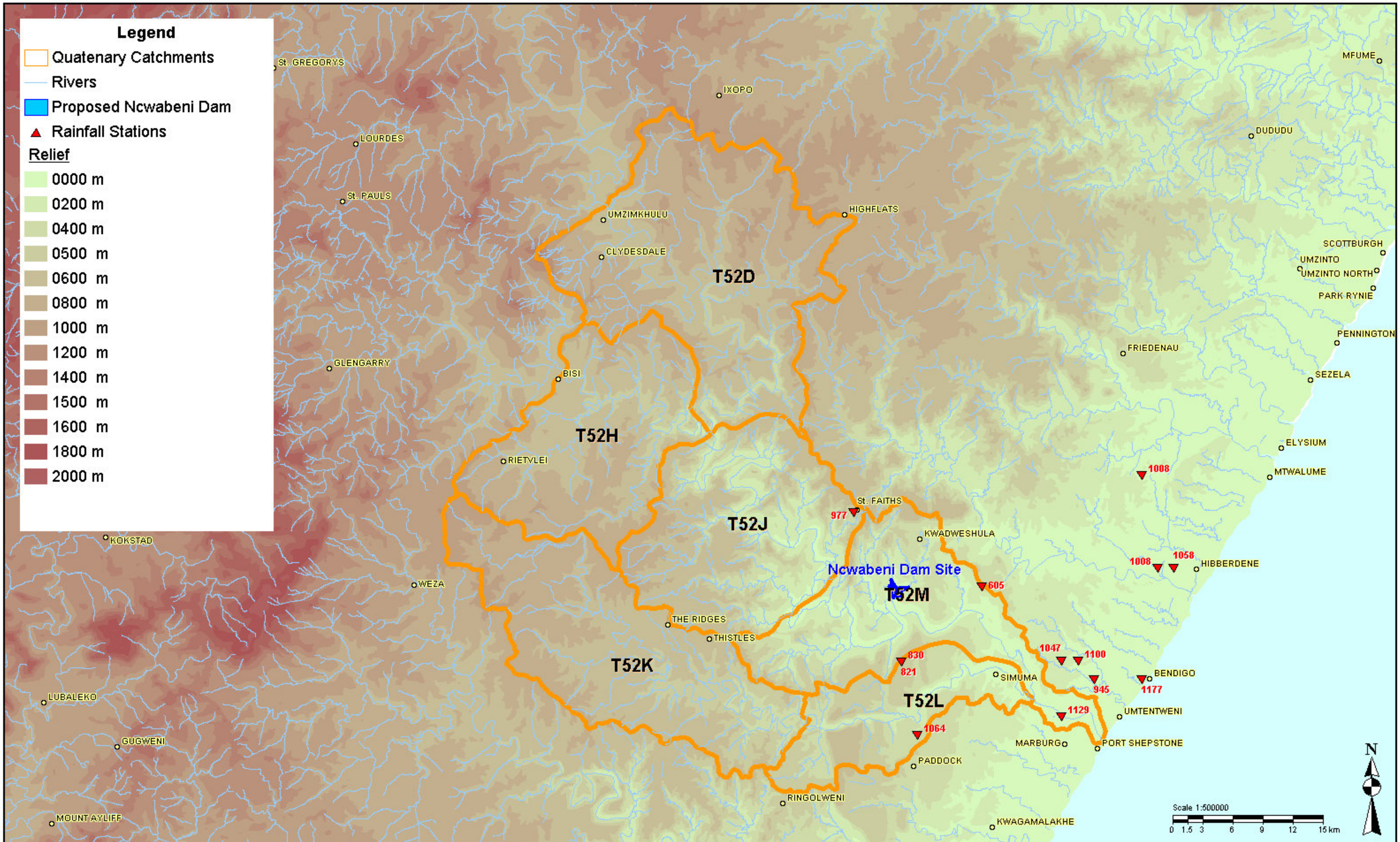
The positions of these gauges together with the rainfall isohyets are given in **Figure 1**. **Figure 2** shows the Mean Annual Precipitation (MAP) of these gauges together with their elevations.



NCWABENI FEASIBILITY STUDY
RAINFALL STATIONS

FIGURE 1

Drawn:	LC Gallagher
Checked:	E van Niekerk
Approved:	E van Niekerk
Date:	2011_11_07
Map Ref:	.../Water/Ncwabeni
View Ref:	Rainfall Stations



NCWABENI FEASIBILITY STUDY
TOPOGRAPHY

FIGURE 2

Drawn:	LC Gallagher
Checked:	E van Niekerk
Approved:	E van Niekerk
Date:	2011_11_07
Map Ref:	.../Water/Ncwabeni
View Ref:	Topography

Table 1-2 compares the number of days in a month with rainfall > 10mm over the common period of 1/1/1970 to 31/12/1989. Many gaps in raingauge 182606 W for this period rendered this station not usable for analyses and results were not included in the statistics.

Table 1-2 Number of days per month with rainfall > 10mm for period: 1/1/1970 - 31/12/1989 (19 years)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOT
182 430 W	2.4	2.1	2.2	1.2	0.7	0.5	0.5	1.0	1.3	2.3	2.5	2.6	19.3
182 430 S	2.4	2.3	2.0	1.3	0.8	0.4	0.3	1.0	1.5	2.5	2.5	2.2	19.2
182 331 W	4.3	3.9	3.2	1.4	0.8	0.4	0.4	1.0	2.3	2.5	2.9	3.2	26.3
182 606 W	3.3	3.5	2.5	1.0	0.9	0.4	0.6	1.0	1.7	2.7	3.2	3.0	23.8
AVERAGE	**3.0**	**2.8**	**2.5**	**1.3**	**0.8**	**0.4**	**0.4**	**1.0**	**1.7**	**2.4**	**2.6**	**2.7**	**21.6**[1]

[1]Average excludes the results obtained from raingauge 182 606 W

Considering all available information available, raingauge 182 430 W was selected as the most representative reliable raingauge that can be used for estimating rainfall for the proposed Ncwabeni Dam. The rainfall statistics for this station is given in **Table 1-3**.

Table 1-3 Rainfall for raingauge 182 430 W with MAP of 832 mm over period January 1952 to December 2000

Month	Number of days with rainfall > 10mm (days)	Average monthly precipitation (mm)
JAN	2.6	94
FEB	2.5	105
MAR	2.5	95
APR	1.6	57
MAY	0.8	38
JUN	0.5	26
JUL	0.5	23
AUG	0.9	31
SEP	1.4	67
OCT	2.5	96
NOV	2.7	97
DEC	2.6	105
TOTAL/AVERAGE	**21.1**	**832**

1.2 Evaporation

Although there are eight evaporation stations currently in the catchment, none of them is currently operational, with four of them without any data. Monthly evaporation data was sourced from the Hydrological Information Publication No. 13 and the DWA HYDSTRA databank. The HYDSTRA mean annual evaporation (MAE) is not considered to be a true representation of the MAE as the annual totals of the updated data seemed to be low (e.g. T5E001), which is a result of the way incomplete monthly data was used in the calculation of the MAE. Since evaporation is fairly constant between years and it is generally accepted that the MAE using more than 10 years of data will be remain fairly constant, the published data was accepted as the most reliable data source. Available evaporation data from the publications are given in **Table 1-4**.

Table 1-4 Observed and evaporation used in previous studies

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOT	MAP
T5E001-A01	123	118	148	156	141	137	102	80	72	74	100	112	1363	665
T5E002-A01	157	153	168	159	141	134	104	92	84	90	125	147	1552	1099
T5E003-A01	143	140	152	154	136	130	107	96	91	103	117	125	1492	1003
T5E004-A01	137	149	159	164	144	135	110	98	95	94	110	115	1510	1112
WR90-A01	175	156	149	122	105	86	91	116	122	134	135	166	1558	665
T5E001-S01[1]	100	101	129	138	120	114	89	73	55	60	63	89	1149	665
WR90-S01[1]	100	101	129	138	120	114	89	73	55	60	83	89	1150	901

[1]The S-pan data are slightly shaded.

2 CONCLUSIONS AND RECOMMENDATIONS

The observed rainfall data for raingauge 182 430 W with a MAP of 832 mm over period January 1952 to December 2000 is considered to be the most appropriate raingauge to be considered for the Ncwabeni Dam analyses. The average number of days in a month with rainfall > than 10 mm, is 21 days. **Table 1-3** provides more details of the monthly distribution of the rainfall.

The WR90 S-pan evaporation data corresponds to the observed data of T5E001 which is the only S-pan gauge in the catchment. However the measured A-pan evaporation at this station is approximately 11% lower than that of T5E004 and T5E003. These two stations are closer to the proposed Ncwabeni Dam site. A small adjustment, to increase the S-pan evaporation by approximately 10% to 1 266 mm per annum, is therefore recommended for yield analyses at the dam.

Appendix G

Framework for operation rules

$Q_{release} = Q_{st\ helen's\ demand} - Q_{surplus\ at\ st\ helen's}$ Equation 1

$Q_{surplus\ at\ st\ helen's} = Q_{surplus\ umzimkhulu} + Q_{umzimkhulwana} - Q_{estuary}$ Equation 2

$Q_{surplus\ umzimkhulu} = Q_{abstraction\ weir} + Q_{hydropower} - Q_{downstream\ users}$ Equation 3

$Q_{pump} = Q_{abstraction\ weir} + Q_{hydropower} - Q_{ewr}$ Equation 4

<u>Note:</u>

- When calculating the release volume required, or the pumping volume possible, two different EWR's are used. This is because the focus is placed on the respective abstraction points to ensure that water is not over-abstracted from the river. When pumping water into the dam, the EWR (Q_{ewr}) is used is it is directly impacted on by the pumping. When releasing water from the dam, the abstraction point of interest is the EWR below St Helen's ($Q_{st\ helen's}$).
- The dam is not to release water specifically for the reserve (Q_{ewr} or $Q_{st\ helen's}$), but is to be operated such that water in the river is first allocated to the reserve and the dam then supplies the balance of the requirement at St Helen's ($Q_{st\ helen's}$).
- As such no negative values will be carried over from Equation 2 to Equation 1. If there is insufficient water in the Umzimkhulu River to meet the estuary EWR the dam will not release water to compensate (users in the catchment must comply).