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Feasibility Study for Augmentation of the Lusikisiki Regional Water Supply Scheme (WP 10317)

ZALU DAM FEASIBILITY DESIGN

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* *BKS (Pty) Ltd was acquired by AECOM Technology Corporation on 1 November 2012*

LIST OF STUDY REPORTS

This report forms part of the series of reports, prepared for the Feasibility Study for Augmentation of the Lusikisiki Regional Water Supply Scheme. All reports for the Study are listed below.

Report Name	DWA Report Number
Water Resources Assessment	P WMA 12/T60/00/3711
Assessment of Augmentation from Groundwater	P WMA 12/T60/00/3811
Intermediate Reserve Determination	P WMA 12/T60/00/3911
Legal, Institutional and Financial Arrangements	P WMA 12/T60/00/4011
Domestic Water Requirements	P WMA 12/T60/00/4111
Irrigation Potential Assessment	P WMA 12/T60/00/4211
Water Distribution Infrastructure	P WMA 12/T60/00/4311
Materials and Geotechnical Investigations	P WMA 12/T60/00/4411
Zalu Dam Feasibility Design	***P WMA 12/T60/00/4511***
Regional Economics	P WMA 12/T60/00/4611
Environmental Screening	P WMA 12/T60/00/4711
Record of Implementation Decisions	P WMA 12/T60/00/4811
Main Study Report	P WMA 12/T60/00/4911

This report is to be referred to in bibliographies as:

Department of Water Affairs, 2014. FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME: ZALU DAM FEASIBILITY DESIGN, P WMA 12/T60/00/4511

Prepared by:

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Executive summary

INTRODUCTION

The Department of Water Affairs (DWA) appointed BKS (Pty) Ltd[1] in association with four sub-consultants (Africa Geo-Environmental Services, KARIWA Project Engineers & Associates, Scherman Colloty & Associates and Urban-Econ) with effect from 1 September 2010 to undertake the Feasibility Study for Augmentation of the Lusikisiki Regional Water Supply Scheme.

This Zalu Dam Feasibility Design Report is the deliverable for Module 7 of the Feasibility Study for Augmentation of the Lusikisiki Regional Water Supply Scheme.

This report compares different dam sizes and dam types, based on the results from the Water Resources Assessment and Materials and Geotechnical Investigation (which form part of this study) and includes conceptual design for two dam sizes – a 0.6 times the mean annual runoff (MAR) dam as well as a 1.5 MAR dam.

MATERIAL AND GEOTECHNICAL INVESTIGATIONS

The results from the study show that sufficient construction materials are available for a rockfill or concrete dam and good foundations were found on the proposed dam centre line. Residual dolerite clay is available in the borrow area downstream of the dam centre line on the right bank of the river. This material is sufficient for a central earthfill core for a rockfill dam. No natural sand was identified on site during the geotechnical investigation, and must thus be imported from a commercial source.

Two rockfill quarries with unweathered dolerite, one on the right bank and one on the left bank, 1 km upstream of the centre line of the proposed dam, were identified. These sources are located below the full supply level of the dam. Both sources are covered with moderately to completely weathered shales. The moderately weathered shales can be used in the shells of a rockfill dam.

[1] *BKS (Pty) Ltd was acquired by AECOM Technology Corporation on 1 November 2012*

At the centre line of the dam on the right bank a horizontal layer of unweathered dolerite was encountered at a level of approximately 611 masl. This can be used for an approach channel floor for a side channel spillway.

YIELD ANALYSES

The water requirements for 2040 were determined as 6.85 million m^3. Initially, cost estimates were carried out for three proposed Zalu dam sizes, with full supply levels of 615 masl, 619 masl and 622 masl. Optimisation studies indicated that the domestic water requirements and in-stream flow requirements can be met simultaneously with a 0.6 MAR dam for the Lusikisiki Regional Water Supply Scheme (LRWSS) supply area. The 0.6 MAR dam will have a full supply level of 612 masl and the 1.5 MAR dam a full supply level of 622.6 masl.

SEDIMENTATION

The expected sediment volume at the dam was estimated to be 2.52 million m^3 over a 50-year period. This volume was used as horizontal spread dead storage in the yield analysis. However, most of the sediment should be deposited in the upper reaches of the reservoir and not at the dam wall.

DAM TYPE SELECTION

Two dam types and three dam sizes were investigated and cost estimates were determined for each in order to select the dam type to carry through to the feasibility design stage.

A spreadsheet-based cost model was developed using the principles of the Vaal Augmentation Planning Study to determine the quantities and cost for the two proposed dam types and three dam sizes.

*The cost estimates are listed in **Table i**.*

Table i: Summary of cost estimates for various dam types and sizes

Type of Dam	Cost per size of dam (R) (excl VAT)* (2012)		
	FSL = 615 masl	FSL = 619 masl	FSL = 622 masl
Roller Compacted Concrete	600 641 134	720 492 184	827 958 639
Earth Core Rockfill	365 477 607	434 856 268	495 349 034

** Costs include Preliminary and General (P&Gs), Preliminary works (access roads, electricity and water supply to the site), Contingencies, Planning, Design and Supervision.*

An Earth Core Rockfill Dam type was selected for the feasibility design.

DAM LAYOUT

The 0.6 MAR Earth Core Rockfill dam with a full supply level at 612 masl and NOC at 620 masl (35 m high), comprises a side channel spillway on the right bank and an intake tower with a bottom outlet next to the river on the left bank. The layout is shown in ***Figure M1.1*** *(****Appendix M****).*

The 1.5 MAR Earth Core Rockfill dam with a full supply level at 622.6 masl and NOC at 629 masl (44 m high), comprises a side channel spillway on the right bank and an intake tower with a bottom outlet next to the river on the left bank. The layout is shown in ***Figure M2.1*** *(****Appendix M****).*

RIVER DIVERSION

River diversion for construction of the dam is planned in three stages:

- *Stage 1: No coffer dam is required for the period when the outlet conduit is constructed.*
- *Stage 2: Diversion of the river flow through the outlet conduit which will be made possible with a coffer dam.*
- *Stage 3: Plug the opening to the conduit with concrete.*

The upstream coffer dam level is designed for a 5-year flood level and will be used while the upstream section of the embankment in the river is constructed to the required water head to divert the 20-year flood through the conduit.

OUTLET WORKS

The outlet works consists of a twin or dual pipe system comprising multi-level intakes with butterfly valves to enable the selection of the level at which water can be drawn off, and sleeve valves at the downstream end of the pipe system for controlling the releases. The outlet pipes will each have a diameter of 900 mm with 900 mm and 300 mm sleeve valves at each outlet pipe. The 300 mm sleeve valves are for the release of the domestic requirements. The outlet levels should be confirmed during the Environmental Impact Assessment.

FINAL LAYOUT AND COST ESTIMATE

*The layout drawings of the two considered dams are provided in **Appendix M** and **Table ii** summarises the cost estimate.*

Table ii: Cost estimate for the 0.6 MAR and 1.5 MAR dams layout

Activity	***0.6 MAR dam (FSL = 612 masl) Amount (R)***	***1.5 MAR dam (FSL = 622.6 masl) Amount (R)***
Section		
Main Embankment	*78 404 670*	*118 366 320*
Spillway	*58 201 200*	*111 236 500*
Outlet works	*65 596 500*	*70 797 200*
Subtotal A	***202 202 370***	***300 400 020***
Landscaping (5% of Sub-Total A)	*10 110 119*	*15 020 001*
Miscellaneous (15% of Sub-Total A)	*30 330 356*	*45 060 003*
Subtotal B	***242 642 844***	***360 480 024***
Preliminary & General (40 % of sub-total B)	*97 057 138*	*114 192 010*
Preliminary works	*4 500 000*	*4 500 000*
Accommodation	*8 640 000*	*8 640 000*
Subtotal C	***352 839 982***	***517 812 034***
Contingencies (20% of subtotal C)	*70 567 996*	*103 562 407*
Subtotal D	***423 407 978***	***621 374 440***
Design and supervision (15% of subtotal D)	*63 511 197*	*93 206 166*
Subtotal E	***486 919 175***	***714 580 606***
VAT (14% of subtotal E)	*68 168 684*	*100 041 285*
Total Dam Cost	***555 087 859***	***814 621 891***

IMPLEMENTATION PROGRAMME

*Implementation programmes for the 0.6 MAR and 1.5 MAR dams are included in **Appendix Q**. The implementation programmes show that construction can commence in the second half of 2017, with impoundment in August 2020 and April 2021 for the 0.6 MAR and 1.5 MAR dams respectively. The implementation programmes are based on the feasibility design and conceptual design of the 0.6 MAR and 1.5 MAR dams respectively and need to be refined.*

RECOMMENDATIONS

The following is recommended for the 0.6 MAR and 1.5 MAR dams during the tender design phase:

- *The necessity of the designed concrete liner on the dolerite rock must be reconsidered. However, this may only be finally considered after the excavation and rock exposure of the full channel.*
- *It is recommended that the Minimum Operating Level (MOL) of the dam is confirmed. At the design stage the Environmental Impact Assessment (EIA) should be completed and the required minimum water level in the dam will be known.*
- *Testing of the hydraulic conditions in a physical hydraulic model study of the side channel spillway is recommended to assist with the height of the retaining wall next to the return channel as well as the energy dissipation of the discharged water.*
- *The freeboard height and spillway width must be optimised.*
- *The risk of the river diversion must be optimised during the detailed design phase.*
- *The development of hydropower should be reconsidered and included in the design.*

The following is recommended for the 0.6 MAR dam during the tender design phase:

- *The dam must be designed to include the option of future raising.*

The following is recommended for the 1.5 MAR dam during the tender design phase:

- *The conceptual design of the dam must be optimised.*

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List of abbreviations

ACRD	Asphalt Core Rockfill Dam
BoQ	Bill of Quantities
BKS	BKS (Pty) Ltd
CFRD	Concrete Faced Rockfill Dam
DWA	Department of Water Affairs
D: NWRP	Directorate: National Water Resource Planning
ECRD	Earth Core Rockfill Dam
EPBS	Eastern Pondoland Basin Study
EWR	Ecological Water Requirements
EWR1	EWR at site 1
EWR2	EWR at site 2
FSL	Full Supply Level
HFY	Historic Firm Yield
ICOLD	International committee on Large Dams
LRWSS	Lusikisiki Regional Water Supply Scheme
MAR	Mean Annual Runoff
nMAR	Natural MAR
NOC	Non Overspill Crest
P&G	Preliminary and General Cost
PES	Present Ecological State
RDF	Recommended Design Flood
RSA	Republic of South Africa
SANCOLD	South African National Commission on Large Dams
SEF	Safety Evaluation Flood
USBR	United States Department of the Interior, Bureau of Reclamation
URV	Unit Reference Value
VAT	Value added tax (14%)
VAPS	Vaal Augmentation Planning Study
WES	Waterways Experiment Station
Zalu Dam	Proposed dam at the Zalu site

List of units

a	annum
ha	hectare
hrs	hours
km	kilometre
km^2	square kilometre
ℓ	litre
ℓ/cap/day	litres per capita per day
m	metre
m/s	metre per second
m^3/s	cubic metre per second
masl	metres above sea level
million m^3	million cubic metres
million m^3/a	million cubic metres per annum
Mℓ/day	megaliter per day
mm	millimetre
MW	megawatt
Ø	diameter in millimetres
s	second

1 INTRODUCTION

The Department of Water Affairs (DWA) appointed **BKS (Pty) Ltd** in association with four sub-consultants (**Africa Geo-Environmental Services, KARIWA Project Engineers & Associates, Scherman Colloty & Associates and Urban-Econ**) with effect from 1 September 2010 to undertake the **Feasibility Study for Augmentation of the Lusikisiki Regional Water Supply Scheme**.

On 1 November 2012, BKS (Pty) Ltd was acquired by **AECOM Technology Corporation**. The new entity is a fully-fledged going concern with the same company registration number as that for BKS. As a result of the change in name and ownership of the company during the study period, all the final study reports will be published under the AECOM name.

1.1 BACKGROUND TO THE PROJECT

In the 1970s Consultants O'Connell Manthé and Partners and Hill Kaplan Scott recommended that a regional water supply scheme, based on a dam on the Xura River and a main bulk supply reservoir close to the town of Lusikisiki (located within the then defined "administration area" of the Zalu Dam), be developed to provide a potable water supply for the entire region between Lusikisiki and the coast, extending from the Mzimvubu River in the south west to the Msikaba River in the north east. Some areas up to 15 km inland of Lusikisiki would also be supplied. A **White Paper** describing the scheme was tabled by the Transkei Government in 1979. It was envisaged that the scheme would be constructed in phases as described in the report *Lusikisiki Regional Water Supply: Preliminary Report* (Hill Kaplan Scott, 1986).

After the reincorporation of the Transkei Homeland into the Republic of South Africa (RSA) in 1994, the DWA took over responsibility for further development of the scheme. The Directorate: Water Resources Planning commissioned the *Eastern Pondoland Basin Study* (EPBS) in 1999 to further investigate the water supply situation in the area, with the intention of developing a Lusikisiki Regional Water Supply Scheme (LRWSS) in the area. This detailed investigation of surface and groundwater sources confirmed that the Zalu Dam in the Xura River was the preferred source of surface water and recommended further investigation of groundwater sources to augment water supply to the entire area.

In 2007, SRK Consulting undertook the *Lusikisiki Groundwater Feasibility Study* to investigate the groundwater potential in the area. This study reported that there is a relatively strong possibility of high yielding boreholes being developed and that a combination of surface water (from Zalu Dam) and groundwater would be the most attractive combination of sources for the LRWSS.

1.2 STUDY AREA

The Study Area comprises the region between Lusikisiki (up to about 15 km inland) and the coast, extending from the Mzimvubu River in the south-west to the Msikaba River in the north-east, as shown in **Figure 1.1**. This area includes the Zalu Dam site and its catchment in the Xura River, conveyance routes between the dam and control reservoirs, as well as borehole sites that could be developed for augmentation of water supplies from groundwater and the routes of the main pipelines from the boreholes to the control reservoirs.

In the south-western part of the study area the preferred option is to develop local water supplies from groundwater for supplying smaller communities. The broken topography, deep river valleys and the distance from reservoirs in the bulk regional scheme, render supplies to these areas from Zalu Dam very costly.

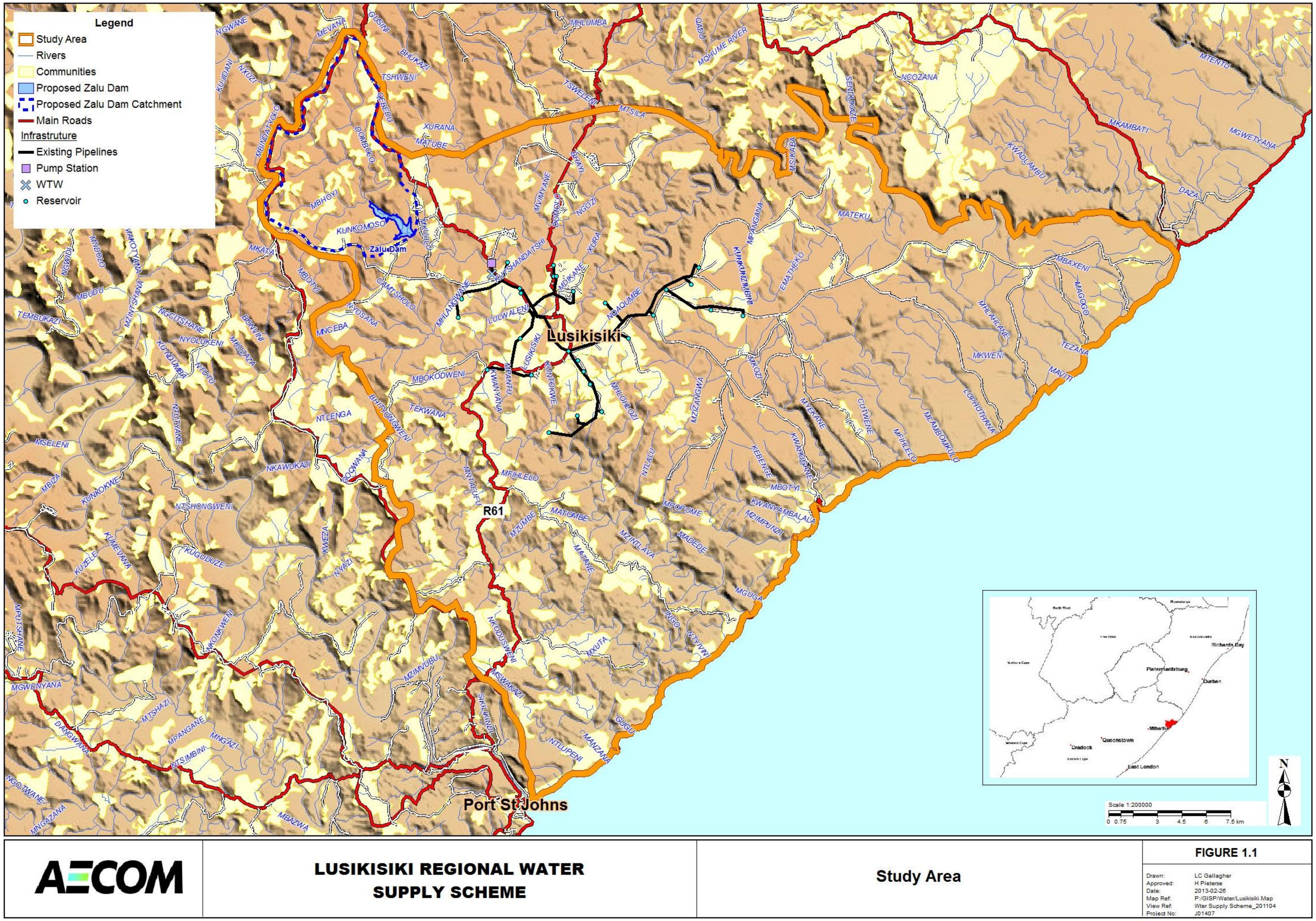

Figure 1.1 Study area

1.3 OBJECTIVE, SCOPE AND ORGANISATION OF THE STUDY

The objective of this study is to undertake a comprehensive engineering investigation at feasibility level of the proposed LRWSS, with the proposed Zalu Dam in the Xura River being the main element, and to recommend the most attractive bulk water supply infrastructure for augmenting water supplies to the whole supply area. The development proposals include the development of local groundwater resources for domestic supplies for smaller communities where this provides the most cost-effective option.

Development of a major dam in the Xura River offers a unique opportunity to provide a stimulus for socio-economic development in this economically depressed region of the Eastern Cape. Poverty is rife in this region, unemployment rates are high and the level of socio-economic activity with a prospect of generating more work opportunities is very low.

This Feasibility Study includes the assessment of all aspects that impact on the viability of utilising a combination of surface water from the Zalu Dam on the Xura River and groundwater for augmentation of the existing domestic water supplies to all water users in the study area. Sufficient water supplies of good quality and reliability must be accessible to all, at an appropriate level of service and affordable cost to the users. It is therefore necessary to:

- Identify all of the technical issues likely to affect implementation, and to define and evaluate all of the actions required to address these issues;
- Provide an estimate of cost with sufficient accuracy and reliability to ensure that management decisions can be made with confidence;
- Decide whether to irrigate or not, and how much; and
- Provide sufficient information to enable design and implementation to proceed without much further investigation.

The required activities for this project have been divided into 14 modules, as detailed in the table below.

Table 1.1: Study structure

Modules	Deliverable
1. PROJECT MANAGEMENT 1.1 Study initiation and inception 1.2 Project management and administration	**Inception Report**
2. WATER RESOURCES	**Water Resources Report**
2.1 Hydrology	♦ Hydrology chapter
2.2 Yield analysis	♦ Yield Analysis chapter
2.3 Reservoir sedimentation	♦ Sedimentation chapter
3. GROUNDWATER AUGMENTATION	**Assessment of Augmentation from Groundwater Report**
4. RESERVE - ECOLOGICAL WATER REQUIREMENTS	**Reserve Determination Report** ♦ Reserve Template
5. WATER REQUIREMENTS	
5.1 Domestic water requirements	**Domestic Water Requirements Report**
5.2 Agriculture / Irrigation potential	**Irrigation Development Report**
6. WATER SERVICE INFRASTRUCTURE	**Water Distribution Infrastructure Report**
6.1 Distribution infrastructure	♦ Chapter in Water Distribution Infrastructure Report
6.2 Water quality	♦ Chapter in Water Distribution Infrastructure Report
7. PROPOSED ZALU DAM	
7.1 Site investigations	**Materials & Geotechnical Investigations Report**
7.2 Dam technical details	**Zalu Dam Feasibility Design Report**, including design criteria, dam type selection, dam sizing
8. COST ESTIMATE AND COMPARISON	♦ Included in relevant reports
9. REGIONAL ECONOMICS	**Regional Economics Report**
10. ENVIRONMENTAL SCREENING	**Environmental Screening Report** ♦ Scope of work for EIA
11. PUBLIC PARTICIPATION	♦ Included in Environmental Screening Report
12. LEGAL, INSTITUTIONAL AND FINANCIAL ARRANGEMENTS	**Legal, Institutional and Financial Arrangements Report**
13. RECORD OF IMPLEMENTATION OF DECISIONS	**Record of Implementation Decisions Report**
14. MAIN REPORT AND REVIEWS	**Main Study Report**

1.4 SCOPE OF THIS REPORT

This **Zalu Dam Feasibility Design Report** is the deliverable for **Module 7** of the *Feasibility Study for Augmentation of the Lusikisiki Regional Water Supply Scheme*.

This report compares different dam sizes and dam types, based on the results from the **Water Resources Assessment** and **Materials and Geotechnical Investigation** (which form part of this study). The selected dam size and type were designed at feasibility level.

2 AVAILABLE INFORMATION

2.1 TOPOGRAPHICAL MAPS

A topographical survey with 1 m contours was carried out by the Department of Water Affairs (date unknown) covering the dam reservoir up to contour 620 masl, with the first approximately 2 km upstream of the proposed dam site surveyed up to contour 625 masl. The survey was carried out in the LO29 coordinate system and was converted by AECOM to the latest WGS84 coordinate system.

This survey is adequate for the feasibility design of the dam, but does not extend far enough to cover the access road. The contours were however extended using the 1:50 000 maps.

A copy of the topographical survey is included in **Appendix A**.

2.2 FLOOD HYDROLOGY

Flood peak estimates were determined in detail by the Department of Water Affairs' Flood Studies Division in 2001 and revised in the *Lusikisiki Groundwater Feasibility Study Phase 2 (LRWSS)* by SRK (May 2009), and were used in this report.

The recommended flood peaks for the proposed Zalu dam are shown in **Table 2.1**.

Table 2.1: Recommended flood peaks (m^3/s) for the proposed Zalu Dam

Return period (years)	2	5	10	20	50	100	200	RMF	SEF
Flood peak (m^3/s)	81	132	182	246	386	548	625	1090	1405

2.3 STAGE-STORAGE VOLUME AND SURFACE AREA RELATIONSHIP

The stage-storage volume and surface area relationships from the available contour map are shown in **Table 2.2** and **Figure 2.1**. The surface areas and volumes for contour levels higher than 620 masl were extrapolated for the dam basin due to unavailable higher contours.

Table 2.2: Stage-Storage volume and surface area for Zalu Dam

Contour (masl)	Surface Area (km^2)	Volume (million m^3)
585	0.0000	0.000
590	0.0306	0.048
595	0.1410	0.427
600	0.3004	1.493
605	0.4839	3.427
610	0.6982	6.357
615	1.0281	10.633
619	1.3380	15.493
620	1.4155	16.704
622	1.5705	19.135
625	1.8029	22.778

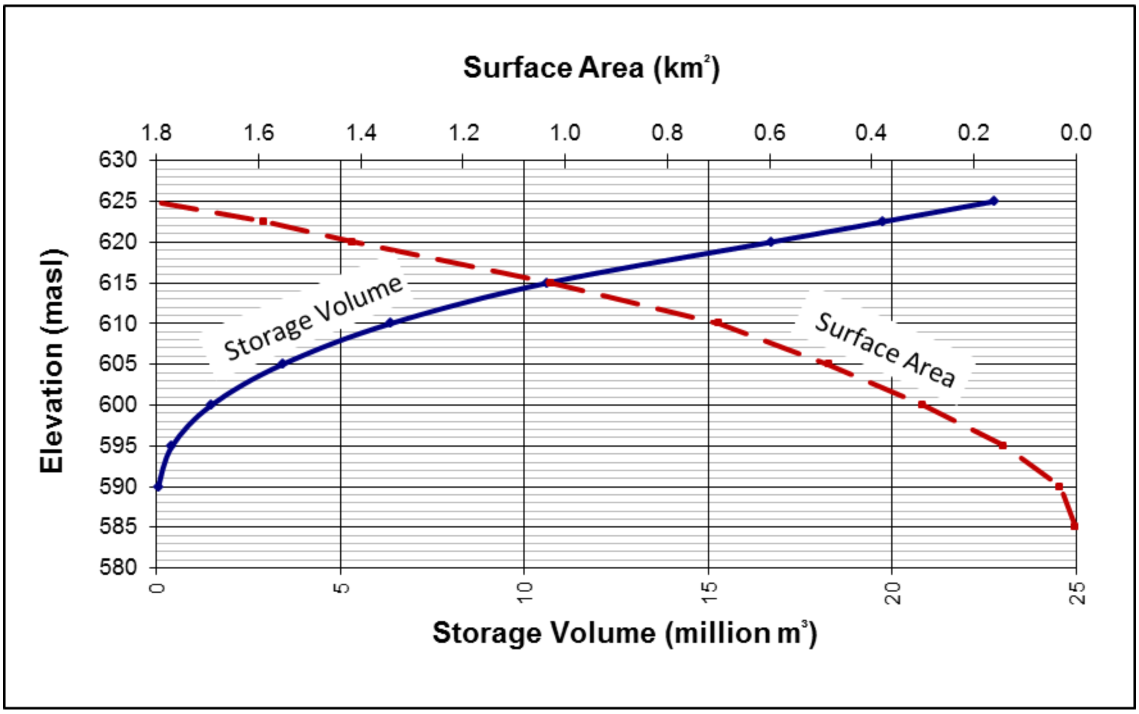

Figure 2.1: Storage volume and surface area curves for the proposed Zalu Dam

2.4 Water Requirements and Dam Yield Characteristics

2.4.1 General

The detailed yield analyses are discussed in the *Water Resources Assessment Report, and* only yield analyses relevant to the dam sizing are discussed in this section.

Various yield analyses using the WRYM computer model were carried out to establish the required Zalu Dam size to meet the expected domestic water requirements in the year 2040 as well as possible irrigation development.

2.4.2 Water requirements

a) Domestic water requirements

The estimated domestic requirements for 2040 is estimated to be 5.4 million m^3/a. Refer to the *Domestic Water Requirements Report*, done as part of this study.

b) Irrigation water requirements

The estimated irrigation water requirements for the year 2040 from the Zalu Dam is 1.45 million m^3/a, including a 10% conveyance loss. Refer to the *Irrigation Potential Report*, done as part of this study.

c) Ecological water requirements

The results for an Ecological Category A/B for the Ecological Water Requirements (EWR) at site 1 (EWR1 at the downstream road bridge) from the Intermediate Reserve Study, done as part of this study, were used in the yield analyses (refer to the *Intermediate Reserve Determination Report*). The results for EWR1 are presented in **Table 2.3**.

Table 2.3: Summary of results as a percentage of the natural MAR

EWR site	Ecological Category	Maintenance low flows		Drought low flows		High flows		Long term mean	
		%MAR	million m³	%MAR	million m³	%MAR	million m³	% MAR	million m³
EWR 1	PES: A/B*	22.49	3.186	5.70	0.807	20.21	2.863	36.79	5.212

**PES: A/B: Present Ecological State: Near ecological state*

The maximum required ecological water release is determined from the 1:1 year freshet for a period of three (3) days, which is 8 m^3/s, and should be released in November.

2.4.3 Water requirement scenarios

To optimise the augmentation of the system from groundwater and to assess different scenarios of domestic and irrigation water requirements, different dam sizes were analysed, as described in the *Water Resources Assessment Report*.

2.4.4 Yield analyses results

The initial yield analyses were done with the domestic water abstracted from Zalu Dam directly. Further analyses acknowledge the benefits in yield of abstracting the domestic water at the downstream weir (T6H004) as the 2040 domestic requirements exceeded the low flow reserve requirement and separate releases for the EWR does not impact the yield of the proposed Zalu Dam.

The dead storage of the proposed Zalu Dam of 2.52 million m^3 is the equivalent 50-year sediment volume retained with an 80% confidence and was used in all analyses.

From the *Water Resources Assessment Report* it was recommended that a 60% MAR Zalu Dam (FSL of 611.915 masl) with a historic firm yield (HFY) and 1:100 year yield of 6.0 million m^3/a and 6.8 million m^3/a respectively, would be sufficient to supply the maximum future water requirements in 2040, i.e. 6.85 million m^3/a. Yield results for Zalu Dam if water is abstracted at the weir (T6H004) are shown in **Table 2.4**.

Table 2.4: Yield of proposed Zalu Dam if water is abstracted at T6H004

Contour (masl)	Area (km^2)	Gross Capacity (million m^3)	%MAR (%)	Net Cap (million m^3)	HFY no EWR1* (million m^3/a)	HFY with low flow EWR (AB)1 (million m^3/a)	Stochastic yield with low flow AB EWR (million m^3/a)			
							1:20	1:50	1:100	1:200
612.0	0.824	7.6	0.6	5.1	6.00	6.00	7.9	7.2	6.8	6.5
622.6	1.617	19.8	1.5	17.3	9.80	9.80	12.1	10.9	10.3	9.8

** EWR1: Ecological Water Requirements at site 1, downstream of Zalu Dam*

2.4.5 Conclusions

Initially, three dam sizes were proposed for costing with full supply levels 615 masl, 619 masl and 622 masl to be used in the Dam Type Selection, refer to **Section 5**.

The final recommended dam size, optimised in this report, is a 0.6 MAR dam with a full supply level of 612 masl to comply with the water requirements for 2040 and water abstractions at the weir T6H004.

To cater for a larger population than was considered in this study, a 1.5 MAR dam corresponding to a full supply level of 622 masl was also investigated.

3 MATERIALS AND GEOTECHNICAL INVESTIGATION

3.1 INTRODUCTION

A materials and geotechnical investigation was conducted during July and August 2012, for a full supply level of 622 masl (1.5 MAR), identifying the required foundations and available construction materials for the proposed Zalu dam. The *Materials and Geotechnical Investigation Report* was compiled and the findings are summarised in this section. **Figure B1** in **Appendix B** shows the geology and positions of the proposed borrow areas.

3.2 GEOLOGY

The proposed dam site and quarries are located in an area where the Xura River had incised its course through a substantial thickness of Ecca shale into a thick dolerite sill. The upper parts of the valley at the proposed centre line of the dam (upper left and right flanks) are therefore underlain by shale, while the lower parts of the centre line and river section are underlain by dolerite.

No dolerite dykes or faults have been observed close to the dam site, and the only major structural feature is a NW-SE trending lineament that runs from the Mzimvubu River in the north to the coast; this can be seen in **Figure B1** (**Appendix B**). This lineament might intersect the dam centre line or run past the site on the left or right flank. No displacement (faulting) along this feature was evident.

Bedrock along the dam centre line is covered by transported materials comprising a thin layer of organic topsoil (hillwash), that is underlain by alluvial sand and boulders in the river section. Bedrock is exposed next to the river stream.

3.3 SEISMIC HAZARD

A Probabilistic Seismic Hazard Analysis (PSHA) was conducted and showed earthquake accelerations of 0.012 g, 0.021 g and 0.114 g for the Operating Basis Earthquake, Maximum Design Earthquake and Maximum Credible Earthquake, respectively.

3.4 CONSTRUCTION MATERIALS

Borrow areas within the dam basin cannot provide sufficient impervious earthfill material for a zoned earth embankment dam. However, sufficient impervious earthfill material is available for an earth core rockfill dam from the two borrow areas that are located downstream of the dam.

The volume of semi-pervious earthfill material available within the one borrow area in the dam basin is not sufficient for a zoned earthfill embankment, and it is expected that the properties of this material across the borrow area might be highly variable. Even by adding the semi-pervious material available from the other two borrow areas inside the dam basin, the total volume is not sufficient if the margin of safety is taken into account.

Sufficient volumes of durable rock for rockfill, concrete aggregate and filters for a rockfill embankment dam with a concrete spillway section can be obtained from two proposed quarry sites within the dam basin.

Since the durable rock in the quarries is covered by considerable quantities of (i) moderately weathered shale, (ii) highly weathered shale and dolerite and (iii) residual and completely weathered shale and dolerite these materials might be considered for use as (i) “soft rockfill”, (ii) semi-pervious fill and (iii) impervious fill respectively in a zoned rockfill embankment comprising of hard rock outer shells with soft rock inner zones.

Considerable quantities of impervious and semi-pervious soil occur as overburden in the proposed rock quarries and might be incorporated in an earth core rockfill dam.

Good quality concrete aggregate can be obtained from the bottom parts of the rockfill quarries. The dolerite quarry can be used to produce crusher sand but natural sand must be obtained from commercial sources. The available volumes of construction materials are summarised in **Table 3.1** and the geology and positions are indicated on **Figure B1**.

Table 3.1: Estimated volumes of materials available from proposed borrow areas, quarries and spillway excavations

Type of material	Estimated volume excluding Bulking Factor (m³)					
	Borrow areas		Left Flank Quarry	Right Flank Quarry	Spillway approach	Total
	Inside Dam basin: BA 1, BA 9, BA 10	Outside/ downstream of Dam basin: BA 3, BA 5				
Overburden (organic topsoil)	73 100	96 800	20 000	14 000	5 000	208 900
Impervious earthfill: Residual and completely weathered shale and dolerite)	0	1 290 000	56 000	35 000	9 000	1 390 000
Semi-pervious earthfill: Highly weathered shale and dolerite)	411 000	0	26 000	35 000	12 000	484 000
Soft rockfill: (Moderately weathered shale)	0	0	90 000	130 000	10 000	230 000
Hard rockfill: (slightly weathered and unweathered dolerite)	0	0	780 000	390 000	5 000	1 175 000

3.5 Foundation Excavations

3.5.1 Dam

For the shells of an **earth embankment** a 0.5 m – 1.0 m thick layer of topsoil has to be removed along the centre line and founding will take place on weak completely weathered shale, weak residual dolerite along the lower left flank, medium dense alluvial soil near the river, strong dolerite along the lower right flank and weak highly weathered shale along the upper right flank.

For the shells of a **rockfill embankment** (below 610 masl), a 5.0 – 6.0 m (at the river section and left flank) and a 0.5 – 2.0 m (at the right flank) layer of topsoil, residual, completely, and highly weathered dolerite have to be removed and founding will take place mainly on slightly weathered and locally on moderately weathered dolerite. Above 610 masl, where the loads are less, founding can take place on highly weathered shale at depths of between 6 m (left flank) and 2 m (right flank).

The **plinth** of a concrete faced rockfill (CFR) dam will be founded at the same depths as the rockfill shells. Extensive grouting will have to be done in the shale above an elevation of 610 masl.

The **clay core** of an earthfill or rockfill dam can be founded at the same depth as the plinth or shells of a rockfill dam.

A **concrete gravity** dam can be founded at a depth of about 6 m along the lower flanks and the river section. Along the upper flanks, the weathered shale has to be removed to depths of up to 12 m to found on slightly weathered dolerite.

Along the lower flanks and in the river section, a nominal single grout curtain to a depth of 20 m to 30 m below founding level is recommended. Along the upper flanks (above 610 masl) a double row of closely spaced grout holes to a depth of 25 m below founding level will be required. This curtain will have to be extended (fanned) some distance into the flanks.

It must be noted that the above recommendations apply to the dam centre line that roughly corresponds with the alignment of a central earth core. However, the plinth for an upstream concrete faced rockfill dam will be located a considerable distance upstream of the dam centre line, and for the design of this type of dam, additional geotechnical investigations will have to be conducted to determine the founding levels and grouting requirements.

3.5.2 Spillway

The founding material for the spillway overspill structure is unweathered dolerite with the following rock mass properties:

- E-modulus = 46 GPa
- Cohesion = 23 MPa
- Friction angle = 42 degrees

About 30 m downstream of the proposed spillway toe, the unweathered rock surface drops suddenly by about 12 m and then continues to drop gradually to about 7 m above river bed level. The weathered rock above the bedrock surface will have to be excavated and might be used as impervious and semi-pervious fill in an embankment. The underlying unweathered dolerite is very strong and widely jointed, having a Kirsten N-value in excess of 10 000. This rock will withstand erosion under flow conditions of over 1 000 kW/m^2 for a period exceeding the lifetime of the dam.

3.6 RESERVOIR SLOPE STABILITY

The risk for damage to the dam wall or surrounding areas due to slope failures within the dam basin is negligible.

3.7 SUMMARY

The materials and geotechnical investigation can be summarised as follows:

- Residual dolerite clay was identified in a borrow area downstream of the dam centre line on the right bank of the river. This material is sufficient for a central core for a rockfill embankment dam.
- Unweathered dolerite was identified on the right bank, 1 to 2 km upstream of the centre line of the proposed dam. The upstream sources are located below the full supply level of the dam.
- Both of the identified borrow areas are covered with moderately to completely weathered shales.
- At the right bank centre line of the dam the unweathered dolerite is encountered at an approximate level 611 masl.
- No natural sand was identified on site during the geotechnical investigation, and will thus have to be **imported from a commercial source**.
- The dolerite quarry can be used to produce crusher sand and aggregates for a concrete dam.
- The layout of the quarries and borrow areas of these materials is shown on **Figure B1** included in **Appendix B**.

4 DAM TYPE AND LAYOUT

4.1 INTRODUCTION

The following principles were followed in identifying different dam types and layouts:

- Using materials available on site, from borrow areas and excavation for the side channel spillway, for construction materials and the balancing thereof;
- Identification of the lowest cost spillway sized for the attenuated SEF;
- Identification of the lowest cost layout; and
- Applying sound and safe dam engineering practices.

4.2 DAM TYPES

An earth embankment dam was not considered due to the insufficient availability of the semi-pervious earthfill material on site.

Based on the construction material and geotechnical investigations (**Section 3**), the following low cost dam types with associated spillway layouts can be accommodated:

- Roller Compacted Concrete (RCC) Gravity Dam with a central spillway.
- Earth Core Rockfill (ECR) Dam with a spillway excavated in dolerite, located on the right bank.
- Concrete Faced Rockfill (CFR) Dam with a spillway excavated in dolerite located on the right bank.
- Asphalt Core Rockfill (ACR) Dam with a spillway in dolerite located on the right bank.

From experience, the CFR and the ACR dams normally are more expensive than the ECR dam and therefore for comparison purposes it was decided to evaluate a RCC Gravity dam and an ECR dam type. **Appendix C** shows typical cross-sections of these two dams.

4.3 LAYOUT OF DAM

The centre line of the dam was positioned perpendicular to the contours across the valley to obtain the lowest volume of materials required to construct the dam.

4.3.1 Earth Core Rockfill Dam

The layout of the earth core rockfill dam includes a side channel spillway on the right bank, excavated in dolerite, and outlet works on the left bank next to the main river section for the required river releases. Backwater calculations were carried out to determine the influence of the flow velocity in the approach channel upstream of the ogee. The results showed that for the SEF (1 405 m^3/s), the head water level in the dam will be 626.12 masl versus the water level at the ogee structure of 623.8 masl due to the water velocity of 6.4 m/s in the approach channel.

Two side channel spillway configurations were considered and are as follows:

- An excavated approach upstream of a concrete chute with an ogee about 30 m downstream of the dam centre line discharging into a downstream plunge pool. The excavated material from the developed plunge pool is about 160 000 m^3 which can be used for rockfill in the embankment.
- An excavated approach channel with an ogee structure and a return channel excavated in the rock (chute). The chute will have a retaining wall on the side closest to the dam embankment and river.

The two side channel spillway configurations are shown in **Figures D1** and **D2**, included in **Appendix D**. The deep plunge pool was not considered for use due to its possible negative visual impact and providing unsafe conditions. The geotechnical investigations also do not favour the excavation of the plunge pool in a further downstream direction.

Moderately weathered rock (shale) material on top of unweathered dolerites (611 masl) at the position of the side channel spillway (on the right bank) can be used for a zoned rockfill dam in the rockfill zones closer to the centre of the embankment dam. Refer to **Figure C1** for a cross section of the recommended ECR Dam's embankment. Rockfill will also be quarried from the identified upstream borrow areas. Clay for the central core can be obtained from the identified downstream borrow areas and aggregates and crushed sand for the concrete works can be processed from the rockfill borrow areas.

The outlet works will be on the left bank next to the river which is closest to the access road. The outlet works will consist of a dual outlet system. The dual outlet system will comprise of the following:

- An intake structure with multi-level intakes with butterfly valves for selecting the level from which water is to be drawn off;
- A conduit through the embankment; and
- Downstream sleeve valves for controlling the river releases.

4.3.2 Concrete Gravity Dam

A Roller Compacted Concrete (RCC) gravity dam consists of a spillway and an outlet works. The spillway is positioned across the river, and the outlet works left of the spillway structure and close to the access road.

The spillway consists of an ogee gravity structure with an energy dissipating structure at the toe of the spillway to prevent undermining of the ogee gravity structure.

Aggregates and crushed sand for the RCC can be processed from the identified quarries upstream of the dam site.

The outlet works consists of a dual outlet system comprising of the following:

- An intake structure with multi-level intakes with butterfly valves for selecting the level at which water is to be drawn off, and
- Sleeve valves in a downstream valve house for controlling the required river releases.

5 COMPARISON OF DAM TYPES AND SIZES

5.1 DAM TYPES AND SIZES

Two dam types and three dam sizes are compared in this section.

The two dam types considered are:

- Earth Core Rockfill (ECR) dam with a side channel spillway on the right bank (refer to **Figure D2** for typical layout), and
- Roller Compacted Concrete (RCC) gravity dam with central spillway (refer to **Figure D3** for typical layout).

In optimising the dam size, the full supply levels of the three dam sizes considered were:

- 615 masl,
- 619 masl, and
- 622 masl.

5.2 SPILLWAY

5.2.1 Foundation level

The geotechnical investigation results indicate the following foundation levels (level of dolerite) for the concrete structures of the two spillway options:

- ECR Dam: 611 masl (also the level of the approach channel)
- RCC Dam: 4.5 m below the natural ground level (refer to the *Materials and Geotechnical Investigations Report* (P WMA 12/T60/00/4411) for the level that varies).

5.2.2 Overflow structure

An ogee type spillway was selected for both types of dam. The discharge table was determined with the formula for ogee shape structures from *Design of Small Dams (USBR, 1987)*. The side channel spillways' upstream approach channel influences the discharge table. The excavation level of the upstream approach channel was selected on the foundation level for the spillway structure (611 masl) and the pool depth determined according to the difference between the approach channel level and the ogee overspill structure level.

5.2.3 Flood attenuation

Detailed flood absorption analyses for a Safety Evaluation Flood (SEF) (1405 m^3/s) were carried out using the FLOOD2 computer programme to determine the flood absorption for different full supply levels and hence the non-overspill crest level (NOC) could be determined.

The parameters used in the flood attenuation are:

- The FSL;
- The stage-storage table for the dam basin;
- A triangular flood hydrograph (with t_c = 3.5 hours); and
- The discharge table for the ogee spillway.

The analyses was carried out for the three full supply levels (FSL) identified with the first assessment in the *Water Resource Assessment Report* and two spillway lengths for each of the two identified dam types. Spillway lengths of 25 m and 35 m were selected for the ECR Dam side spillway and 60 m and 70 m for the RCC Dam.

The results from the flood attenuation are summarised in **Table 5.1**.

Table 5.1: Attenuated safety evaluation flood level versus full supply level for considered dams

Full supply level (masl)	Attenuated safety evaluation flood level (masl)			
	Earth core rockfill dam		Roller compacted concrete dam	
	Spillway length L = 25 m	Spillway length L = 35 m	Spillway length L = 60 m	Spillway length L = 70 m
615	621.95	620.82	619.28	618.90
619	625.59	624.59	623.13	622.78
622	628.31	627.35	626.04	625.71

Table 5.1 shows that the difference between the two spillway lengths for each dam type is not significant and therefore the 25 m and 60 m spillway lengths for the ECR and RCC

dams, respectively, were used in the comparison. The higher NOC levels for the two selected spillway lengths resulted in conservative first round costing.

The graphs developed from the flood attenuation for the two dam types and three dam sizes are included in **Appendix E**.

5.3 Available Material Quantities versus Required Material Quantities

The materials investigation estimated the volume of available materials from the identified quarries below the 622 masl level. The required materials for the two dams, namely ECR and RCC Dams, as determined on the centre line of the dams were compared with the estimated available materials and are summarised in **Table 5.2**.

Table 5.2: Estimated required volumes versus available material

<table>
<tr><th rowspan="2">Type of Material</th><th rowspan="2">Estimated available volume excluding bulking factor (m³)</th><th colspan="3">Required volume of construction material (m³)</th></tr>
<tr><th>FSL = 615 masl</th><th>FSL = 619 masl</th><th>FSL = 622 masl</th></tr>
<tr><td colspan="5">Earth Core Rockfill dam</td></tr>
<tr><td>Impervious earthfill: (clay core)</td><td>1 390 000</td><td>65 000</td><td>80 700</td><td>94 100</td></tr>
<tr><td>Soft and hard rockfill: (shells)</td><td rowspan="3">1 405 000</td><td>397 400</td><td>510 600</td><td>605 700</td></tr>
<tr><td>Gravel layer</td><td>36 200</td><td>41 800</td><td>45 000</td></tr>
<tr><td>Aggregate for spillway concrete</td><td>7 500</td><td>12 000</td><td>16 100</td></tr>
<tr><td colspan="5">Roller Compacted Concrete dam</td></tr>
<tr><td>Aggregate for concrete</td><td>1 405 000</td><td>94 300</td><td>124 900</td><td>152 200</td></tr>
</table>

From **Table 5.2** it is clear that the materials investigation can prove sufficient volumes of impervious earthfill and rockfill material from the quarries and excavations from the side channel spillway.

Large quantities of weathered shale that occur above the hard rock dolerite in the quarries can be considered for use as “soft rockfill” in the central parts of a rockfill dam.

The materials investigation identified that river sand needs to be obtained from a commercial source. The closest known source is Ifafa, which is about 140 km by road from the site.

5.4 Preliminary Cost Estimate

A preliminary cost estimate for the two dam types and three dam sizes were carried out and the quantities for each activity of the dam construction and site specific rates were estimated.

The bill of quantities (BoQ) of the Vaal Augmentation Planning Study (VAPS) was used as a guideline to determine the total cost of each dam.

The estimation of total costs was based on the following:

- 2012 rates
- 5% of the cost of activities for landscaping
- 15% of the cost of activities for miscellaneous items
- 40% of the cost of activities for preliminary and general items
- 10% of total cost of activities for contingencies
- 15 % of total cost including above items for planning, design and supervision.

The cost estimate (BoQ) for each dam and size are included in **Appendix F** and summarised in **Table 5.3**.

Table 5.3: Preliminary cost estimate

Type of Dam	Cost per Size of Dam (R) (Excl VAT)		
	FSL = 615 masl	FSL = 619 masl	FSL = 622 masl
Roller Compacted Concrete	600 641 134	720 492 184	827 958 639
Earth Core Rockfill	365 477 607	434 856 268	495 349 034

The summary of the preliminary cost estimate in **Table 5.3** shows that the Earth Core Rockfill dam type is the most cost effective option for all selected dam sizes.

5.5 Optimum Dam Size

The preliminary cost estimates were used in the calculation of the URV's to determine the optimum dam size.

Optimisation indicated that the domestic water requirements and in stream flow requirements can be met simultaneously and a smaller dam was identified, and the result is a dam with a lower full supply level (FSL). The water requirements were improved after the comparison of the above mentioned dam types and sizes. The above cost estimates were extrapolated for the smaller dam sizes and the URV calculated. The results of the URV are shown in **Table 5.4.**

Table 5.4: URV calculations

Dam size (masl)	Scenario	URV (R/m^3)
614.8	Zalu dam; domestic and irrigation supply	7.90
611.5	Zalu dam augmented with groundwater; domestic and irrigation supply	**6.44**
610.2	Zalu dam; domestic supply	8.39
607.5	Zalu dam augmented with groundwater; domestic supply only	6.62

From the table it is clear that the optimum dam size, for the combination of domestic and irrigation water requirements, has a FSL of 612 masl, also refer to **Section 2.4.4**.

5.6 Conclusion

An **Earth Core Rockfill Dam** with **FSL of 612 masl** is selected as the optimised dam.

In addition, a 1.5 MAR Earth Core Rockfill Dam with a FSL of 622.6 masl was also considered to accommodate a supply area (population) larger than that investigated by this study.

6 FEASIBILITY DESIGN

6.1 0.6 MAR DAM

The feasibility design of a 0.6 MAR Earth Core Rockfill dam is described in this section. The dam has a FSL of 612 masl and an ogee shaped side channel spillway with an overflow width of 25 m.

6.1.1 Spillway

a) General

The spillway consists of an excavated approach channel for smooth streamlines, a concrete gravity ogee structure with a length of 25 m and a return channel excavated in the dolerite.

b) Foundation

The foundation level for the spillway structure on the right bank is 611 masl as obtained from the *Materials and Geotechnical Investigation Report*. Material lower than a level of 611 masl consists of durable coarse dolerite and is suitable for the construction of a rockfill dam.

c) Approach channel

The approach channel must be excavated in rock to increase the upstream pool depth which increases the discharge coefficient. A better discharge coefficient results in a lower headwater level, subsequently the NOC of the embankment is lower and the volume of the required material for the construction of the dam decreases.

Various levels of excavation were considered to determine the optimal excavation depth for the approach channel. The computer programme HECRAS was used to determine the discharge table, and hence the discharge coefficient, for the ogee structure for each considered excavation level. The discharge coefficient was solved from the capacity of the ogee spillway which is expressed as:

$$Q = C\,L_{eff}\,H_e^{1.5}$$

Where:

- Q is the discharge (m^3/s)
- C is the discharge coefficient
- L_{eff} is the effective length of the spillway (m)
- H_e is the upstream head, including the velocity head (m)

The effective length of the spillway (L_{eff}), considering that it is only affected by the two end abutments, is determined as:

$$L_{eff} = L - 2K_a\,H_e = 25 - 0.2\,H_e$$

Where:

- L is the nett length of the spillway (25 m)
- K_a is the abutment contraction coefficient (0.10)

The discharge table and curve for the three excavation levels are included in **Appendix G**.

The routed safety evaluation flood (SEF) and hence the non-overspill crest level for each selected excavation level were determined by routing the SEF through the dam basin, using the FLOOD2 computer programme. The flood routing results for the three options are included in **Appendix H**.

The results of the above hydraulic calculations of the spillway's approach and overspill structure are summarised in **Table 6.1**.

Table 6.1: Summary of the flood absorption results for the overspill structure

Considered Excavation level (masl)	Discharge coefficient for unrouted RDF (625 m^3/s)	Routed SEF (1405 m^3/s)	Discharge coefficient for routed SEF	Non-overspill level (masl)
611	1.10	830.78	1.19	621.73
607	1.80	996.39	1.91	619.91
602	1.96	1030.76	2.13	619.51

From the above results it is clear that the excavation level of 611 masl for the approach is not a feasible solution due to the low discharge coefficient and the high NOC level. There is not a large difference between the routed SEFs and NOC levels for the excavation levels of 607 masl and 602 masl.

More rockfill material will be available for use in the construction of the dam with the excavation at 602 masl, but the retaining walls constructed on the excavated rock level will be higher with more reinforced concrete than for the excavation of 607 masl. The cost difference for the two options, one with the spillway approach bed level at 602 masl and the other at 607 masl, is summarised in **Table 6.2**.

Table 6.2: Comparison of the incremental cost between the two spillway approach levels

Activity	Rate (R)	Quantity	Total (R)
Extra Rockfill excavation from 607 masl to 602 masl for use in dam embankment	0*	40 000 m^3	**0**
Extra Reinforced concrete for construction of higher reinforced retaining walls at 602 masl			
• Concrete	2 000	2 200 m^3	**4 400 000**
• Reinforcement	15 000	220 ton	**3 300 000**
TOTAL			**7 700 000**

** No cost due to use in dam embankment*

From **Table 6.2** it is clear that the spillway with the approach channel bed level at 607 masl is cheaper than the spillway approach level at 602 masl. The spillway with the approach channel bed level at 607 masl could be constructed quicker with a lower reinforced concrete wall. The visual impact of the excavated area will also be less for the 607 masl than for the 602 masl alternative.

The approach channel excavation level selected for this feasibility design is 607 masl.

d) Overspill structure

The overspill structure will have an ogee shape and will be founded at level 607 masl as with the approach channel. The SANCOLD guidelines require that for a Category III dam the ogee must be designed for a recommended design flood (RDF) of 1:200 year (625 m^3/s). The discharge table for the selected approach channel was used to determine the headwater height for the RDF and hence used to define the shape of the ogee structure.

The calculations for the ogee shape are based on the Waterways Experiment Station (WES) standard spillway shapes (*Ven te Chow, 1959*). The formulae which apply are shown graphically in **Figure 6.1** and the determined values in **Table 6.3**.

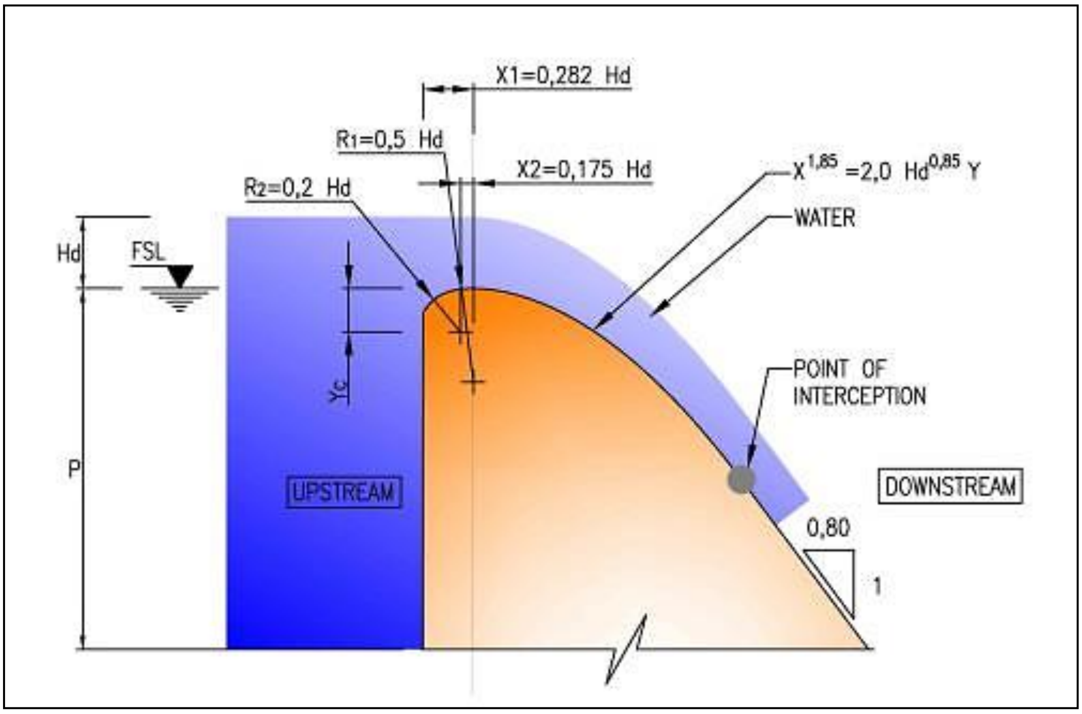

Figure 6.1: Graphical presentation of ogee shape

Table 6.3: Ogee shape characteristics

Parameter	Value/formula
H_d	6 m
R_1	3 m
R_2	1.2 m
X_1	1.692 m
X_2	1.05 m
Curve shape	$Y = 0.1559\ X^{1.85}$
Point of Intersection	X = 5.615; Y = 3.794

e) Return channel

The return channel will be excavated in rock and will have a retaining wall on the embankment/river side to protect the downstream slope of the embankment. The other side of the return channel will be excavated to a slope of 1V:1H below the dolerite level and 1V:1.5H above the dolerite level to the natural ground level. The return channel was positioned to ensure that the water discharging back into the river is at a suitable distance downstream from the toe of the embankment to prevent undermining.

The HECRAS computer programme was used to determine the water depth for the routed SEF in the return channel for different bottom levels. Due to the steep slope of the valley, the waterside of the return channel has much less excavation than the other side. The depth of the channel was selected to ensure that the water flow inside the return channel conforms to the channel flow criteria.

The *Materials and Geotechnical Investigation Report* states that the underlying unweathered dolerite is very strong and widely jointed, having a Kirsten N-value in excess of 10 000. This rock will withstand erosion under flow conditions of over 1 000 kW/m^2 for a period exceeding the lifetime of the dam.

The results of the HECRAS analyses and the graphical presentation of the selected return channel are included in **Appendix J**.

f) Freeboard

The required freeboard based on the RDF was determined according to the *Interim Guidelines on Freeboard for Dams*.

Interim Guidelines on Freeboard for Dams indicates that the following combinations should be considered for a large dam with a high hazard rating:

- **Combination 2:** Sum of the levels for the Recommended Design Flood (RDF) (1:200 year), the wind wave run-up for a 1:25 year event, the wind set-up and the flood surges and seiches.
- **Combination 3:** Sum of the levels for the 1:20 year flood, the wind wave run-up for a 1:100 year event, the wind set-up and flood surges and seiches.

- **Combination 4:** Wave height due to an earthquake, alone, was not investigated due to the low seismic horizontal acceleration for Zalu dam site.
- **Combination 5:** Sum of the levels for RDF and wave height due to a landslide.
- **Combination 6:** As no flood outlets are foreseen, this combination was not investigated.

The graphical presentation for determining the wind setup used in determining the minimum freeboard is included in **Appendix K**.

The results of the above mentioned combinations are summarised in **Table 6.4**.

Table 6.4: Freeboard (m) - Summary of combinations

Combination	RDF	20-year flood	Wind wave and Run-up		Wind set-up	Flood surges and seiches	Land-slide wave	TOTAL (m)
			25-year event	100 year event				
2	6.0	-	0.614	-	0.015	0.5	-	**7.129**
3	-	3.142	-	0.670	0.015	0.5	-	**4.327**
5	6.0	-	-	-	-	-	0.1*	**6.100**

** Obtained from the geotechnical and material investigation*

Combination 2 (7.129 m) requires the largest freeboard; however, this freeboard is not sufficient to pass the attenuated SEF with a wet freeboard of 7.91 m. Therefore, the latter was used to set the NOC level of the embankment as the required freeboard and a **NOC level of 620.0 masl** was adopted.

g) Optimisation of dam freeboard and spillway width

A total cost optimisation of the dam freeboard and spillway width should be carried out during the tender design phase of the project.

6.1.2 Classification of the dam

The dam is 35 m high (classified as large) and has a significant (less than 10 losses of life) hazard potential and is thus classified in accordance with the dam safety legislation as a **Category III dam**.

6.1.3 Embankment

a) Zoning

The principle of using available materials at lowest cost where possible was used for the zoning of the dam.

The material investigation at the quarry and position where the side channel spillway will be excavated showed two types of rockfill. The "softer" rockfill (moderately weathered shale) is layered on top of the coarse rockfill (slightly weathered to unweathered dolerite). The soft rockfill (3D material) can be used in the inner zones of the shells, adjacent to the central core of the dam, and the coarse rockfill (3C material) used in the outer shells of the dam embankment.

Although enough coarse rockfill is available to construct the embankment with only coarse rockfill, the "soft" rockfill needs to be excavated first before the coarse rockfill can be excavated.

The available volume of "soft" rockfill is about 110 000 m^3. This material can be used for zoning in the dam. A line in the cross section between the inner and outer shells downstream of the core at a slope of 1V:0.5H for a dam with a FSL of 612 masl was introduced. No zoning will be designed upstream of the clay core. Refer to **Figure M1.3** in **Appendix M**.

The ratio of "soft" and hard rockfill in the proposed rockfill quarries may not be exactly as predicted from the borehole results, and might result in the production of slightly smaller or larger volumes of "soft" rock. However, the total volume of rockfill is the important value and will not change significantly.

The estimated volume of available "soft" and coarse rockfill material at a level lower than the FSL (612 masl) versus the required material are summarised in **Table 6.5**.

Table 6.5: Available materials versus required material (FSL = 612 masl)

Type of material	Available Material (m^3) (Excluding Bulking Factor)				Material Required
	Left Flank Quarry	Right Flank Quarry	Spillway approach	Total	
Soft rockfill (3D material): (Moderately weathered shale)	10 000	0	110 000	150 000	47 500
Hard rockfill (3C material): (slightly weathered and unweathered dolerite)	280 000	40 000	40 000	360 000	256 500

From **Table 6.5** it is clear that the use of the right flank quarry is not feasible and that enough material is available on site, even without the use of the right flank quarry, to construct the dam.

Table 6.6 shows the selected zones of the embankment and the proposed compaction and grading specifications.

Table 6.6: Compaction and grading specifications of selected zones of the embankment

Component	Zone	
	3D (soft material)	3C (coarse material)
Classification	Quarry run rockfill (moderately weathered shale)	Quarry run rockfill (slightly weathered and unweathered dolerite)
Gradation	0.075 mm: maximum 10% <25 mm: maximum 50%	1 m maximum size
Lift Height (m)	1.0	1.0
Type of roller	10 tonne vibratory roller	10 tonne vibratory roller
Passes	Min. 6	Min. 6

The layout of the main embankment is shown on **Figure M1.2** (**Appendix M**) and the maximum cross-section and details on **Figure M1.3**.

b) Crest width

A crest width is selected to allow vehicle access and limiting the size of the embankment.

A 5 m section between the guardrails is sufficient for vehicles to access the crest. The recommended crest width is thus 6 m to allow for the positioning of the guardrails.

c) Slope stability

The stability of the upstream and downstream slopes of the rockfill embankment at maximum cross-section, as shown in **Figure M1.3** (**Appendix M**), was analysed. The Slope/W software package, using the Bishop method of slices, was used to determine the minimum factor of safety of failure.

The material properties used in the stability analysis are shown in **Table 6.7**.

Table 6.7: Assumptions for slope stability parameters

Material	Parameters		
	Unit weight (kg/m^3)	Phi (°)	Cohesion (kPa)
Rockfill 3D (moderately weathered shale)	2 050	35	13
Rockfill 3C (slightly weathered and unweathered dolerite)	2 200	45	0
Clay core	1 300	26	23
Bedrock level	2 200	45	0
Phreatic line	No water pressure		

Initially upstream and downstream slopes of 1V:2H were used to determine the factor of safety against slope failure. The results showed that for this assumption the factor of safety is marginally above the criteria and the slopes were adjusted until the minimum slope for the upstream and downstream was obtained.

The safety factors against failure for the different options of upstream and downstream slopes are summarised in **Table 6.8**.

Table 6.8: Results of slope stability analysis

Scenario	Factor of Safety						
	Option 1		Option 2		Option 3		Criteria
	U/S SLOPE: 1V:2H	D/S SLOPE: 1V:2H	U/S SLOPE: 1V:1.6H	D/S SLOPE: 1V:1.6H	U/S SLOPE: 1V:1.6H	D/S SLOPE: 1V:1.7H	
Full Dam – steady state flow 3C and 3D material	2.004	1.960	1.603	1.470	1.568	1.533	>1.5
Full Dam – steady state flow Only 3C material	2.004	2.004	1.603	1.603	1.568	1.654	>1.5
Full Dam – seismic 3C and 3D material	1.619	1.620	1.320	1.218	1.293	1.260	>1.0
Full Dam – seismic Only 3C material	1.619	1.580	1.320	1.321	1.293	1.360	>1.0
Rapid Draw down from full supply level (FSL)	2.004	N/A	1.603	N/A	1.568	N/A	>1.2

The figures showing the location of the slip circles for each scenario and option determined with the Bishop Method are included in **Appendix L**.

Table 6.8 shows that the determined safety factors meet the safety criteria, except for the option when the downstream slope is 1V:1.6H. The minimum upstream and downstream slopes which meet the safety criteria for the various scenarios are 1V:6H and 1V:1.7H, respectively.

Optimisation of slope stability can be done during the tender design phase.

d) Foundation seepage control

Seepage through the foundation will be controlled with a cement grout curtain drilled in the core trench. The small amount of seepage passing through the core is picked up in filters immediately downstream of it and prevents the seepage from carrying core material away.

The geotechnical investigation recommends that a nominal single grout curtain, to a depth of 20 m to 30 m below founding level, along the lower flanks and in the river section, should be implemented. Along the upper flanks (above 610 masl) a double row of closely spaced grout holes to a depth of 25 m below founding level will be required. This curtain will have to be extended (fanned) some distance into the flanks.

6.1.4 Outlet works

a) General arrangement

The outlet works is positioned with the intake and outlet near the river, which will also assist with the river diversion during construction. The layout is shown on the general layout drawing and the arrangement of the outlet works is shown in **Figure M1.4** and **Figure M1.5**, included in **Appendix M**. The outlet works consists of an intake tower, conduit through the embankment and the outlet valve house.

The pipe work in the intake structure consists of a twin or dual system comprising multi-level intakes at different levels with butterfly valves in the intake structure for selecting the level at which water is to be drawn off and sleeve valves in the outlet valve house at the downstream end of the conduit for controlling the releases. For this study the levels of the intakes were assumed, and should be confirmed during the Environmental Impact Assessment study.

The intakes are protected with precast concrete trash racks and fine screens to prevent blockage by floating debris. An emergency gate is required for closure for maintenance purposes at the bellmouth entrances.

Access to the outlet works is from the embankment via the access bridge and from downstream along the conduit for inspection purposes.

b) Minimum operating level

The yield analysis assumed a 2.52 million m^3 dead storage due to sediment; however, most of the sediment will be deposited in the upper reaches of the reservoir where the velocity of the water discharging into the reservoir reduces. The assumption was made that only 10% of the sediment will deposit at the dam wall due to the velocity of the water in the reservoir significantly decreasing at the confluence of the two upstream rivers where the sediment will most likely deposit. This corresponds to a sediment level of 592.7 masl at the dam wall. The bottom outlet was selected at 593 masl and the minimum operating level (MOL) must be at least 2 m above this outlet to ensure that surface vortices are not created at the intakes. The MOL is set at 595 masl.

6.1.5 Required outlet capacity

The outlet works is designed to meet the following criteria:

- Fulfil Environmental Water Requirements (EWR);
- Enable releases for domestic use; and
- Empty the dam quickly during emergency drawdown conditions.

- **Environmental requirements**

  The requirements of ecological water release are determined from the 1:1 year freshet which is 8 m^3/s for a period of three (3) days. Refer to the *Intermediate Reserve Determination Report*. This flow is the maximum flow which the outlet needs to be designed for and much larger than the domestic requirements. Therefore the size of the pipe is determined for the situation where both the outlet pipes are fully open to release the ecological water requirements and assumed that maintenance is not carried out during these three (3) days. This will optimise the size of the pipe and provide lower capital and maintenance cost than when the ecological requirements are supplied by one outlet pipe system.

The maximum flow velocity in the pipes is limited to 7 m/s, as recommended by the manufacturers of butterfly valves to avoid excessive noise, vibration and valve wear or failure. The minimum diameter required to release 8 m^3/s, at a minimum required water level of 606 masl using both outlet pipes, is 835 mm. The outlet pipe selected from standard pipe sizes is 900 mm diameter.

- **Domestic releases**

The average required domestic release rate is 0.171 m^3/s. However, the releases will vary to accommodate the environmental requirements. Refer to the *Domestic Water Requirements Report*.

- **Emergency draw down**

In general, the water level should be lowered from FSL to MOL within 120 days and to half depth between FSL and MOL within 60 days.

Without inflow, the dam can be drawn down in 26.8 days, from FSL (612 masl) to MOL through one 900 mm diameter outlet pipe, and to half depth between the FSL and MOL within 13.32 days, both of which meet the requirements. The draw down table and curve are shown in **Appendix N**.

a) Multi-level intakes

Optimal quality of raw water can be obtained by staggering the intakes. Four staggered intakes were selected to ensure that good quality water is released at different dam water levels.

The MOL (595 masl) represents a storage volume of 0.425 million m^3 (± 5.3% of total storage). The design provides for drawing down to this level only.

The selected intake levels are shown in **Table 6.9**.

Table 6.9: Intake levels (masl) (FSL = 612 masl)

Intake Position	Left Pipe Level (masl)	Right Pipe Level (masl)
Bottom intake	593.0	593.0
First Service intake	599.0	-
Second Service intake	-	603.5
Third (top) service intake	607.5	-

b) *Inspection and maintenance*

The vertical sections of the outlet pipes are extended to the deck for aeration and to provide access, particularly to the seals of the butterfly valves, for inspection and maintenance purposes. A cage sized for the 900 mm diameter vertical pipes is lowered with the aid of the overhead gantry on the deck. The outlet pipes can be inspected individually without affecting the required discharge through the other outlet pipe.

Access is provided at the intake and outlet structure for pipeline inspection and maintenance purposes.

c) *Hydro-mechanical equipment*

- **Fine screens**

  The fine screen panels are lowered into guides embedded in the concrete piers. These removable fine screen panels are each fitted with a tray at the upstream bottom to collect trash or debris when the screens are hoisted for cleaning purposes.

  A grappling beam for handling the screens will be provided with storage in a rack on the deck.

- **Emergency gate**

  An emergency gate, interchangeable between the two intake bays, is provided for closing off the bellmouth intakes during emergencies and for maintenance purposes. Built-in parts and guides are provided for handling the gate and for sealing around any of the intake bellmouths.

A grappling beam for handling the screens will be provided with storage in a rack on the deck.

- **Intake level selector valves**

  The four intake selector valves are 900 mm diameter butterfly valves, which are only used to select the level at which water is to be drawn off. They will thus be either fully open or fully closed. (The butterfly valves can be operated locally.)

- **Outlet control valves**

  The control vales for releases down the river are situated downstream at the end of the outlet conduit.

  Sleeve valves with a 900 mm diameter are used to release the environmental water requirements. The 900 mm pipe branches into a 300 mm pipe with a 300 mm sleeve valve before the 900 mm sleeve valve to release the required domestic requirements at MOL. To contain the spray, hoods are provided with diameters of twice the size of the sleeve valves.

- **Overhead crane**

  An overhead gantry crane is required on the deck of the intake structure to handle the fine screens and emergency gate, to install the butterfly valves and to remove them for refurbishment, when required.

  The sleeve valves at the outlet structure can be handled by a mobile crane, when required.

6.1.6 River diversion

a) General

Flood peak attenuation is negligible for the storage created by the coffer dam and was not considered in the design of the coffer dam.

The following stages of river diversion were developed:

- Stage 1: No coffer dam is required for the period when the outlet conduit is constructed.

- Stage 2: Diversion of the river flow through the outlet conduit which will be made possible with a coffer dam.
- Stage 3: Plug the opening to the conduit with concrete.

The following scenarios of coffer dam sizes for one outlet conduit (bottom width of 6 m, vertical side walls of 2.7 m high and part of a 3.5 m radius circle as the roof) for various flood peaks were investigated:

(i) Coffer dam at 5-year flood (132 m^3/s) level during lower flow months while the upstream part of the embankment in the river section is constructed up to the 20-year flood level.

(ii) Coffer dam at 5-year flood (132 m^3/s) level during lower flow months while the upstream part of the embankment in the river section is constructed up to the 50-year flood level.

(iii) Coffer dam at 10-year flood (182 m^3/s) level during lower flow months while the upstream part of the embankment in the river section is constructed up to the 20-year flood peak level.

(iv) Coffer dam at 10-year flood (182 m^3/s) level during lower flow months while the upstream part of the embankment in the river section is constructed up to the 50-year flood peak level.

(v) Coffer dam at 20-year flood (246 m^3/s) level while the upstream part of the embankment in the river section is constructed up to 50-year flood level.

(vi) Coffer dam at 50-year flood (386 m^3/s) level.

Figure 6.2 indicates the construction of the upstream section of the embankment to serve as a coffer dam. The grouting of the foundation will be carried out after the partial construction of the embankment through the clay core.

The size of the conduit must be optimised during the design phase. The river diversion sequence is described below.

b) *Stage 1 River diversion*

Stage 1 river diversion must be during the low flow months and does not require a coffer dam. The level of the river flow for a 10-year flood is 587.6 masl and the outlet works is founded at level 588 masl. During this time the conduit can be constructed for the stage 2 river diversion.

c) *Stage 2 River diversion*

Stage 2 river diversion comprises a coffer dam upstream of the conduit perpendicular to the river and river flow diverted through the outlet conduit. Using the water head and inlet control at the entrance of the culvert the required height of the coffer dam for the various scenarios could be determined.

d) *Stage 3 River diversion*

Once the construction of the embankment is completed up to 606 masl, the outlet conduit, serving as the diversion tunnel, may be closed with a gate immediately upstream of the intake to the conduit. A 2.5 m long concrete plug will be constructed downstream behind the gate and impoundment can commence during Stage 3 river diversion.

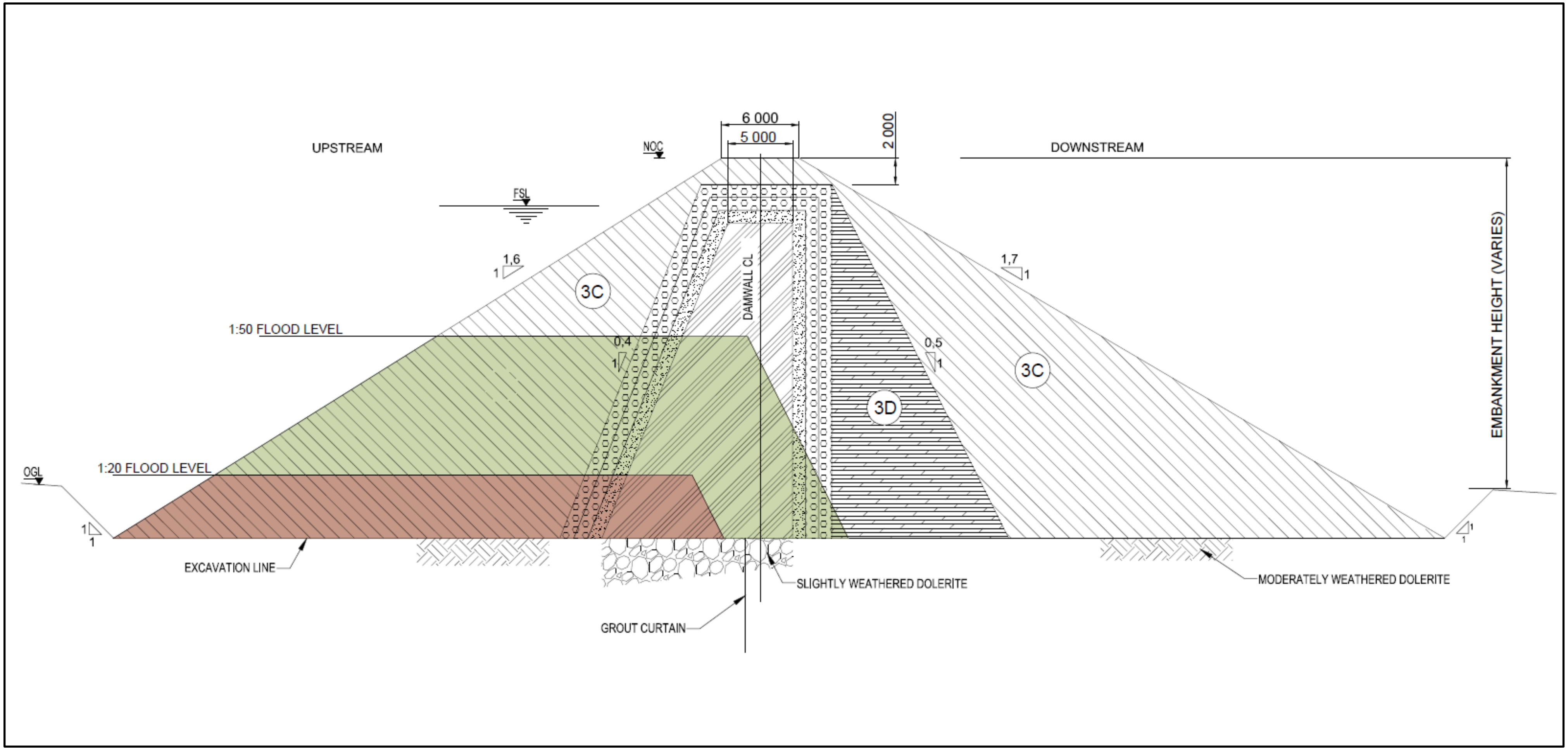

Figure 6.2: Construction of coffer dam as part of embankment

e) Comparison of flood scenarios

The comparison of flood scenarios is summarised in **Table 6.10** for the one culvert size.

Table 6.10: Comparison of river diversion scenarios

Scenario	Upstream Coffer dam				Part of embankment in river section		
	Flood (year)	Crest level (masl)	Cost (R)	Time to construct (months)	Excavation time (months)	Construction of embankment fill (months)	Total construction time with one month lead to excavation (months)
(a)	5	591	250 000	0.4	2.1	4.2	5.3
(b)	5	591	250 000	0.4	3.3	6.7	7.7
(c)	10	593	500 000	0.7	2.1	4.2	5.3
(d)	10	593	500 000	0.7	3.3	6.7	7.7
(e)	20	596	1 200 000	1.9	3.3	6.7	7.7
(f)	50	606	9 180 000	12	N/P*	N/P*	N/P*

**N/P – not possible*

From **Table 6.10** the following can be concluded. Option (a) and (c) are the two options where the coffer dam and the upstream part of the embankment can be constructed in the six months low flow season, with reduced risk. Option (a) is more cost effective than option (c), however, and is thus the preferred option.

f) Recommendation

The recommended option is option (a) which must be implemented during the lower rainfall season.

The upstream coffer dam level is designed for a 5-year flood level and will be used while the upstream section of the embankment in the river is constructed to the required water head to divert the 20-year flood through the conduit. The diversion of the 20-year flood level is acceptable for the construction of an embankment dam and is being used in the Department of Water Affairs. (example: Woodstock dam). The grout curtain will be installed before the downstream part of the embankment is constructed.

It is recommended that the size and layout of the coffer dam and culvert are optimised in terms of risk in the detail design phase.

6.1.7 Design for raising

The 0.6 MAR Zalu Dam has been sized and optimised regarding dam type and layout to meet the lowest cost requirement for the 2040 water requirements. However, due to the uncertainties with future water requirements or the possibility that the requirements may increase in future (such as proclaimed in the guidelines for levels of service published in the National Water Policy Review, 2013), the cost of raising the dam may be more if the dam was not originally designed for raising.

An assessment of the aspects that will be affected by the raising of the dam was done; these aspects are listed below:

- The Intake Tower has to be designed for pressures associated with the raised dam, in this case 621 masl.
- The Bottom Outlet has to be designed to accommodate higher Environmental Water Requirements which will be required for a higher dam due to fewer spills (freshets from the dam). The bellmouth through the concrete and the screen may have to be made larger.
- The top of the core in the embankment has to be positioned towards downstream to facilitate connection to a raised core.
- The Chute of the spillway has to be located towards the right bank to facilitate economic connection of the embankment to the concrete spillway structure.

It is recommended that these aspects are taken into consideration during the tender and detailed design phases.

6.2 1.5 MAR Dam

To accommodate a larger population than was investigated in the feasibility study, a 1.5 MAR dam was also considered. This dam option was considered at a conceptual design level and will need to be optimised during the detailed design phase.

The aspects that differ from the 0.6 MAR dam described above will be explained is this section.

The layout of the 1.5 MAR dam is shown in **Figure M2.1** (**Appendix M**).

6.2.1 Spillway

The approach channel excavation bed level for the 1.5 MAR dam option was taken as the top of the dolerite level at 611 masl.

The required freeboard was based on the results of the initial flood attenuation carried out during the comparison of dam types and sizes. The freeboard passing the attenuated SEF is 6.4 m. A NOC level of the embankment of **629 masl** was adopted.

A total cost optimisation of the dam freeboard and spillway width should be carried out during the tender design phase of the project.

Figure M2.6 and **Figure M2.7** (**Appendix M**) show the layout and details of the spillway.

6.2.2 Classification of the dam

The dam is 44 m high (classified as large) and has a significant (less than 10 losses of life) hazard potential and is thus classified in accordance with the dam safety legislation as a **Category III dam**.

6.2.3 Embankment

a) Zoning

The dam is designed to accommodate two types of rockfill ("soft" and coarse). The approach channel's excavation level is at 611 masl, which is the dolerite level. From the approach channel only "soft" rockfill and no coarse rockfill will be obtained.

The ratio of "soft" and hard rockfill in the proposed rockfill quarries may not be exactly as predicted from the borehole results, and might result in the production of slightly smaller or larger volumes of "soft" rock. However, the total volume of rockfill is the important value and will not change significantly.

The estimated volume of available "soft" and coarse rockfill material within the FSL (622.6 masl) versus the required material are summarised in **Table 6.11**.

Table 6.11: Available materials versus required material (FSL = 622.6 masl)

Type of material	Available Material (m^3) (Excluding Bulking Factor)				MATERIAL REQUIRED
	Left Flank Quarry	Right Flank Quarry	Spillway approach	Total	
Soft rockfill (3D material): (Moderately weathered shale)	90 000	130 000	91 980	311 980	87 571
Hard rockfill (3C material): (slightly weathered and unweathered dolerite)	780 000	390 000	-	1 170 000	441 030

From **Table 6.11** it is clear that enough material is available on site for the dam.

The selected zones of the embankment, proposed compaction and grading specifications as for the 0.6 MAR dam are applicable.

The layout of the main embankment is shown in **Figure M2.2** (**Appendix M**) and the maximum cross-section and details in **Figure M2.3**.

b) Slope stability

The results for the upstream and downstream slopes determined from the slope stability for the 0.6 MAR dam was adopted for the 1.5 MAR dam. Thus, the minimum upstream and downstream slopes are 1V:6H and 1V:1.7H, respectively.

Optimisation of slope stability can be done during the tender design phase.

6.2.4 Outlet works

a) General arrangement

The outlet works is positioned at the same position as for the 0.6 MAR dam, and will also assist with the river diversion during construction.

The layout is shown on the general layout drawing and the arrangement of the outlet works is shown on **Figure M2.4** and **Figure M2.5**, included in **Appendix M**.

The levels of the intakes were assumed, and should be confirmed during or after the Environmental Impact Assessment study.

Access to the outlet works is from the embankment via the access bridge and from downstream along the conduit for inspection purposes.

b) Minimum operating level

The minimum operating level (MOL) of 595 masl was adopted with the bottom outlet at 593 masl. This level needs to be confirmed from the Environmental Impact Assessment.

6.2.5 Required outlet capacity

The outlet works is designed to meet the same criteria as for the 0.6 MAR dam:

- Fulfil Environmental Water Requirements (EWR);
- Enable releases for domestic use; and
- Empty the dam during emergency draw down conditions.

The minimum size for the outlet pipe for inspection and maintenance is the standard pipe size of 900 mm diameter.

In general, the water level should be lowered from FSL to MOL within 120 days and to half the depth between FSL and MOL within 60 days.

Without inflow, the dam can be drawn down in 50 days from FSL (622.6 masl) to MOL through one (1) 900 mm diameter outlet pipe, and to half the depth between the FSL and MOL within 32.7 days, both of which meet the requirements. The draw down table and curve are shown in **Appendix N**.

Optimal quality of raw water can be obtained by staggering the intakes. Four staggered intakes were selected to ensure that good quality water is released at different dam water levels. The MOL (595 masl) represents a storage volume of 0.425 million m^3.

The selected intake levels are shown in **Table 6.12**.

Table 6.12: Intake levels (masl) (FSL = 622.6 masl)

Intake Position	Left Pipe Level (masl)	Right Pipe Level (masl)
Bottom intake	593.0	593.0
First Service intake	604.0	-
Second Service intake	-	610.0
Third (top) service intake	616.0	-

6.3 HYDROPOWER POTENTIAL

6.3.1 0.6 MAR dam (FSL = 612 masl)

The terms of reference for this study do not include the consideration of hydropower development. As all water supply and instream flow supplies will be released from the dam, it was decided to include an assessment of hydropower development potential for this dam.

The maximum hydropower potential was determined as follows:

- Based on
  - Constant releases from the dam for domestic use, of about 5.4 million m^3 per year = $0.171 m^3/s$;
  - Available average head of 13.34 m;
  - The equation to calculate the hydropower potential:

$$P = \rho \times g \times \eta \times Q \times H$$

Where:

- P = Power in Watt
- ρ = Density of water = 1000 kg/m^3
- g = Gravitational acceleration = 9.8 m^2/s
- η = Total entrance and mechanical efficiency = 0.85 (assumed)
- Q = Flow rate = 0.171 m^3/s
- H = Head = 13.34 m

The base load hydropower potential is **19 kW**.

6.3.2 1.5 MAR dam (FSL = 622.6 masl)

The available average head for the 1.5 MAR dam is 20.7 m, resulting in a base load hydropower potential of **29.5 kW.**

6.3.3 Recommendations

Although provision has been made for a hydropower plant at the dam, it is recommended that this aspect be investigated further in the tender and detailed design phases of the project.

7 COST ESTIMATE OF FEASIBILITY DESIGN

7.1 INTRODUCTION

The construction cost was estimated for the quantity of each construction activity as per the layout drawings included in **Appendix M**.

The estimation of total costs was based on the following:

- 2012 rates
- 5% of the cost of all activities for landscaping
- 15% of the cost of all activities for miscellaneous items
- 40% of the cost of all activities for preliminary and general items
- 10% of total cost of all activities for contingencies
- 15% of total cost including above items for planning, design and supervision.

7.2 0.6 MAR DAM

The cost estimate (BoQ) for the feasibility design of the 0.6 MAR dam is included in **Appendix P** and summarised in **Table 7.1**.

Table 7.1: Cost estimate for the 0.6 MAR dam (FSL = 612 masl)

Activity	Amount (R)
Section	
Main Embankment	78 404 670
Spillway	58 201 200
Outlet works	65 596 500
Subtotal A	**202 202 370**
Landscaping (5% of Sub-Total A)	10 110 119
Miscellaneous (15% of Sub-Total A)	30 330 356
Subtotal B	**242 642 844**
Preliminary & General (40 % of sub-total B)	97 057 138
Preliminary works	
(a) Access road for main dam	2 000 000
(b) Electrical supply to site	2 000 000
(c) Construction water to site	500 000
Accommodation	8 640 000
Subtotal C	**352 839 982**
Contingencies (20% of subtotal C)	70 567 996
Subtotal D	**423 407 978**
Design and supervision (15% of subtotal D)	63 511 197
Subtotal E	**486 919 175**
VAT (14% of subtotal E)	68 168 684
Total Dam Cost	**555 087 859**

7.3 1.5 MAR DAM

The cost estimate (BoQ) for the 1.5 MAR dam is summarised in **Table 7.2** from the detail included in **Appendix P**. This option is described in slightly less detail as compared to the description of the 0.6 MAR dam.

Table 7.2: Cost estimate for the 1.5 MAR dam (FSL = 622.6 masl)

Activity	Amount (R)
Section	
Main Embankment	118 366 320
Spillway	111 236 500
Outlet works	70 797 200
Subtotal A	**300 400 020**
Landscaping (5% of Sub-Total A)	15 020 001
Miscellaneous (15% of Sub-Total A)	45 060 003
Subtotal B	**360 480 024**
Preliminary & General (40 % of sub-total B)	114 192 010
Preliminary works	
(a) Access road for main dam	2 000 000
(b) Electrical supply to site	2 000 000
(c) Construction water to site	500 000
Accommodation	8 640 000
Subtotal C	**517 812 034**
Contingencies (20% of subtotal C)	103 562 407
Subtotal D	**621 374 440**
Design and supervision (15% of subtotal D)	93 206 166
Subtotal E	**714 580 606**
VAT (14% of subtotal E)	100 041 285
Total Dam Cost	**814 621 891**

8 IMPLEMENTATION PROGRAMME

Feasibility implementation programmes for the 0.6 MAR and 1.5 MAR dams, including the construction of the scheme, are provided in **Appendix Q**. The philosophy followed was:

- Finance to be secured before commencement of the project.
- No large access roads are required prior to construction.
- A local quarry must be developed and required plant must be erected.
- The construction of the intake tower is on the critical path.
- Construction placement rates in **Appendix Q** are applicable.
- River diversion is carried out in three stages.

This is a realistic feasibility implementation programme and can be fast-tracked during the detailed design phase.

9 CONCLUSIONS AND RECOMMENDATIONS

Two dam types and three dam sizes were investigated to find the optimum scheme and dam size in relation to groundwater use and the Reserve Requirements in this study. The 0.6 MAR earth core rockfill (ECR) dam with a Full Supply Level (FSL) of 612 masl was selected as optimum dam option based on the lowest capital cost and available construction materials for the water requirements of the LRWSS supply area.

The cost comparison between the different dam types and sizes was used to guide the selection of the dam type and the full supply level.

The dam at a full supply level of 612 masl will yield 6.8 million m^3/a at 1:100 year assurance of supply. The domestic requirement is 5.4 million m^3/a in 2040, the irrigation requirements 1.45 million m^3/a (including 10% losses) and the 1:1 year ecological freshet requirement is 8 m^3/s for a period of three days per year. The release for domestic use will be sufficient for the maintenance ecological requirements.

The cost estimate for the 0.6 MAR (FSL = 612 masl) ECR dam is R 555 087 859 (including VAT) and a summary of the cost estimate of the selected scheme is shown in **Table 7.1**.

The cost estimate for the 1.5 MAR (FSL = 622.6 masl) ECR dam is R 814 621 891 (including VAT) and a summary of the cost estimate of the selected scheme is shown in **Table 7.2**.

The cost estimate includes a concrete lining in the return channel. The evaluation at this feasibility stage indicates that no lining is required and needs to be re-evaluated during the tender design phase.

The total scheme cost can be used to determine the final unit reference value and tariff estimates.

The following is recommended for the 0.6 MAR and 1.5 MAR dams during the tender design phase:

- The necessity of the designed concrete liner on the dolerite rock must be reconsidered. However, this may only be finally considered after the excavation and rock exposure of the full channel.
- The Minimum Operating Level (MOL) of the dam is to be confirmed. At that stage the Environmental Impact Assessment (EIA) should have been completed and the required minimum water level in the dam should be known.
- The selection levels on the intake tower are to be confirmed from the Environmental Impact Assessment.
- Hydropower development is to be taken into consideration – see **Section 6.3**.
- Testing of the hydraulic conditions in a physical hydraulic model of the side channel spillway to determine the height of the retaining wall next to the return channel.
- The freeboard height and spillway width are to be optimised.
- The risk of the river diversion must be optimised during the detailed design phase.
- The 0.6 MAR dam (FSL 612) is designed for future raising as discussed in **Section 6.1.7**.
- The conceptual design of the 1.5 MAR dam must be optimised during the detailed design phase if this is the option chosen for implementation.

10 REFERENCES

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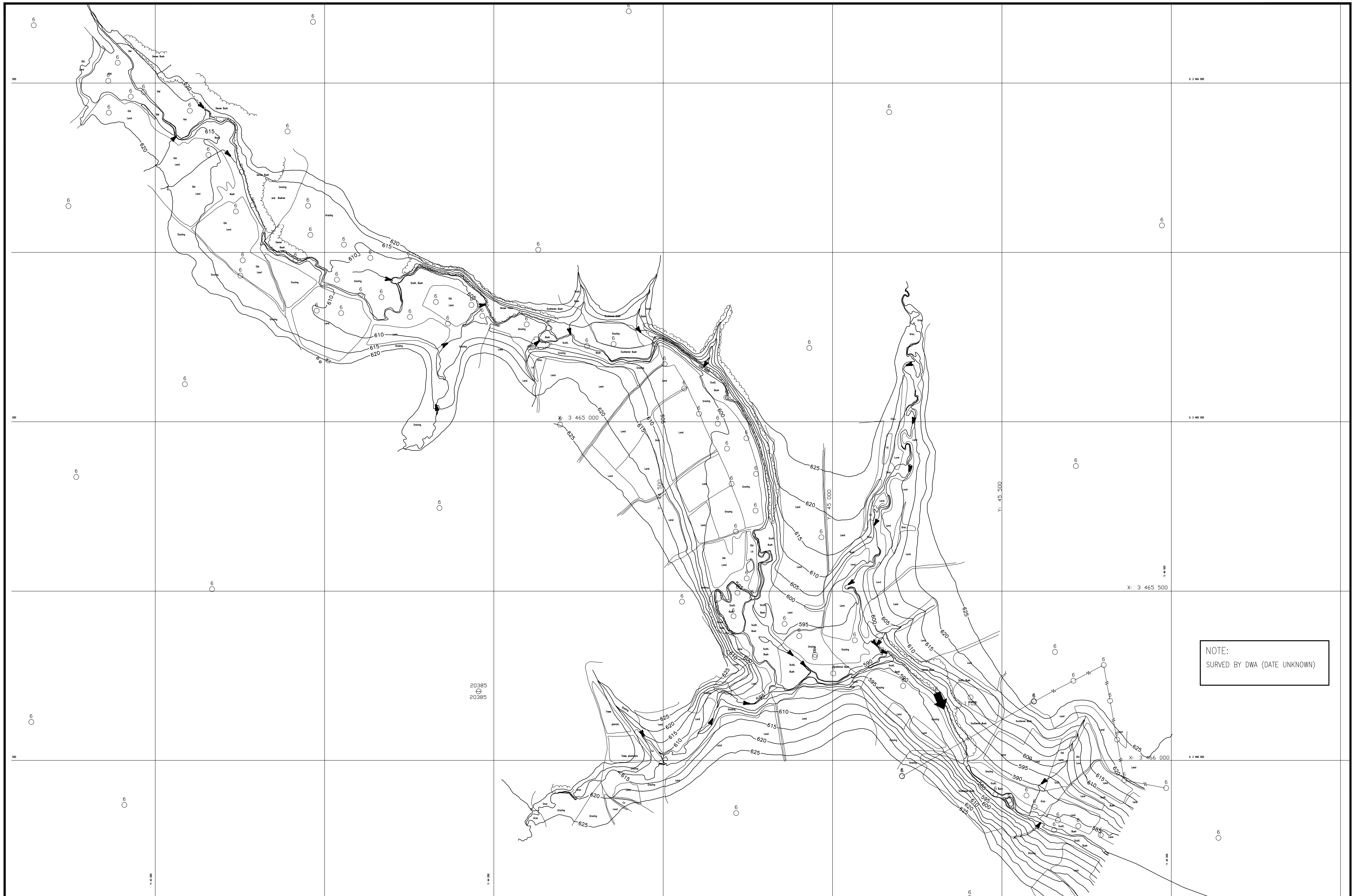
Appendix A

Topographical Survey



AECOM

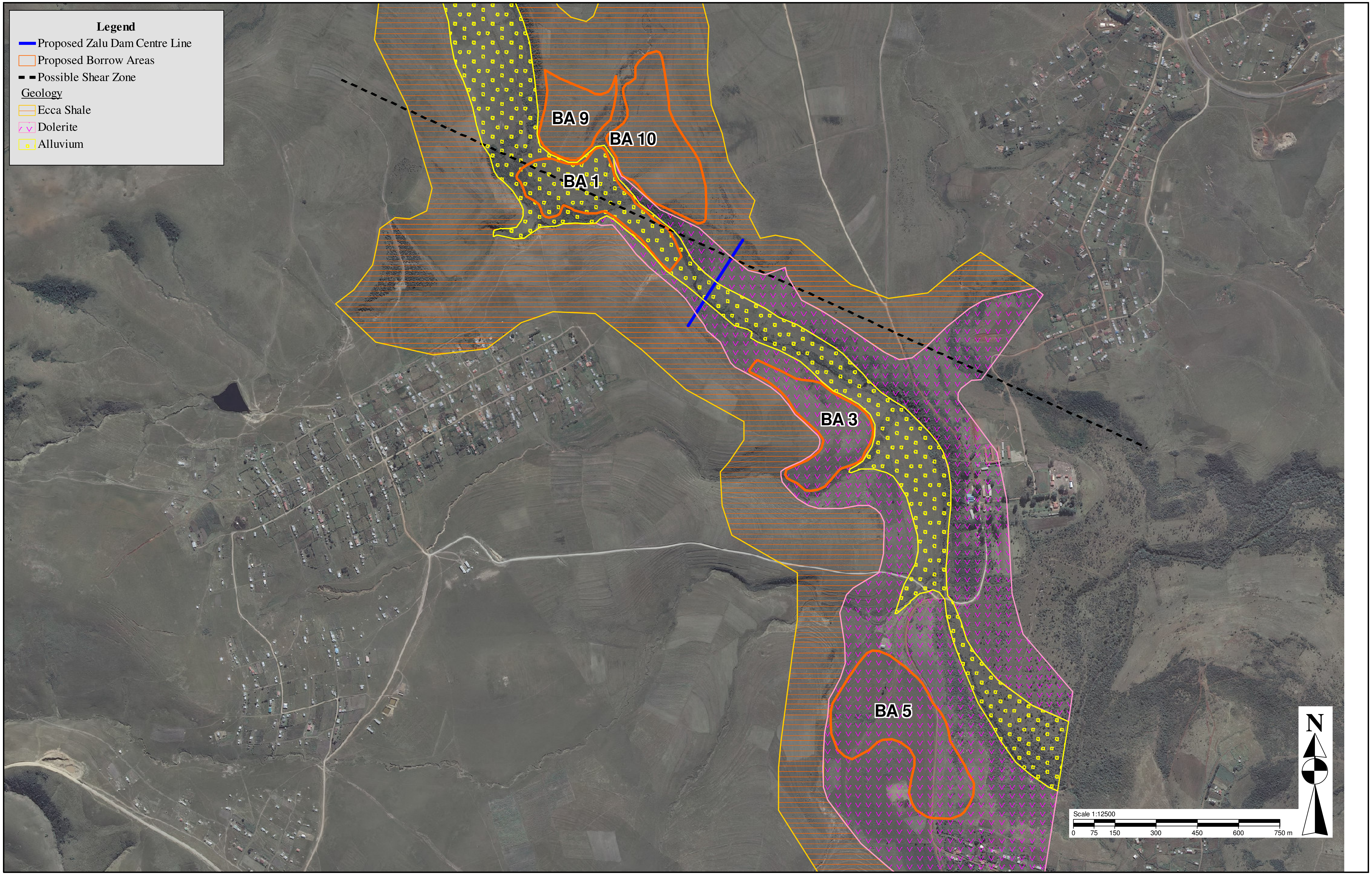
FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME
FEASIBILITY DESIGN: PROPOSED ZALU DAM - TOPOGRAPHICAL SURVEY

AECOM DETAIL/FIGURE No.

FIG. A1

Appendix B

Map of Materials and Geotechnical Investigation



AECOM

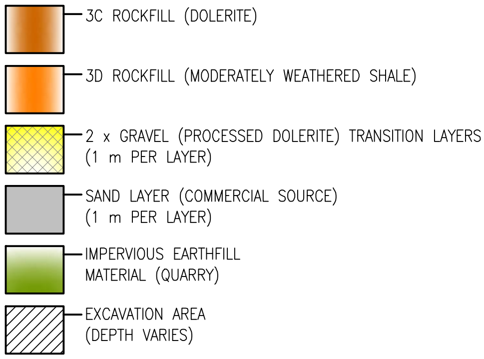
Feasibility Study for Augmentation of the Lusikisiki Regional Water Supply Scheme:
Proposed Zalu Dam
Geology and Locations of Borrow Areas

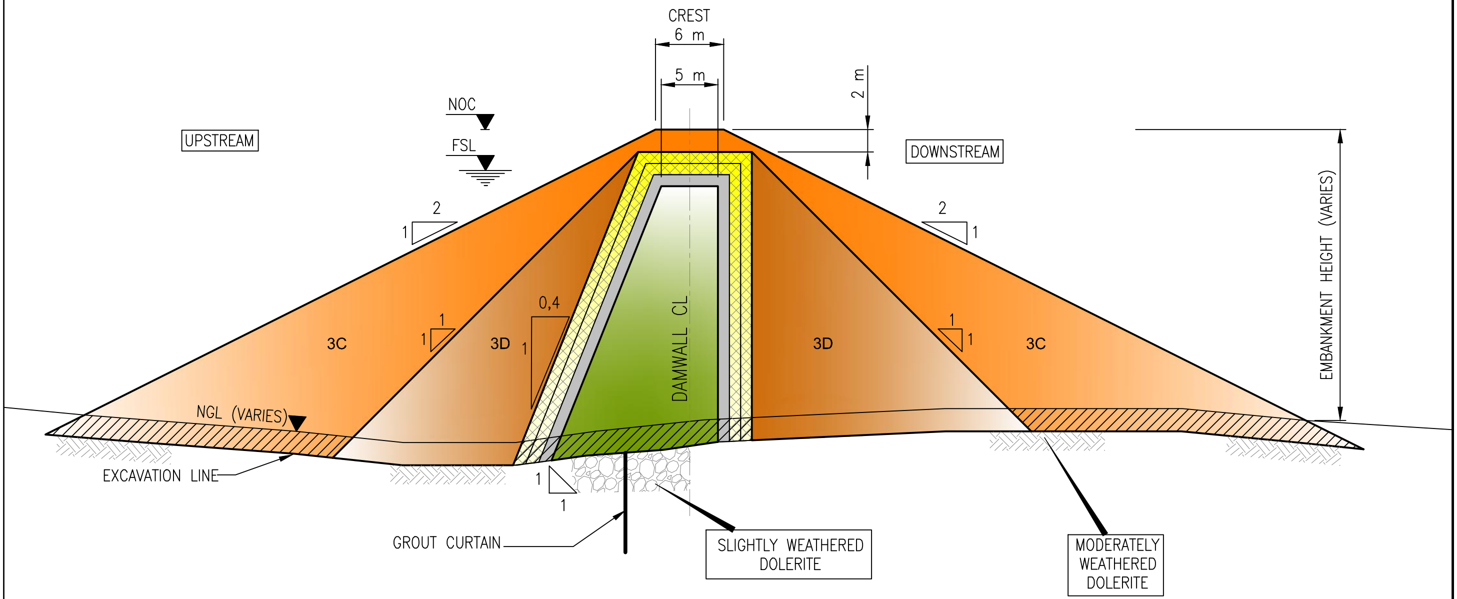
FIGURE B1

Drawn:	LC Gallagher
Checked:	J Ehlers
Date:	2014-01-07
Map Ref:	Lusikisiki_WGS29.Map
View Ref:	Geology and Borrow Areas

Appendix C

Typical Cross Section of Investigated Dam Types



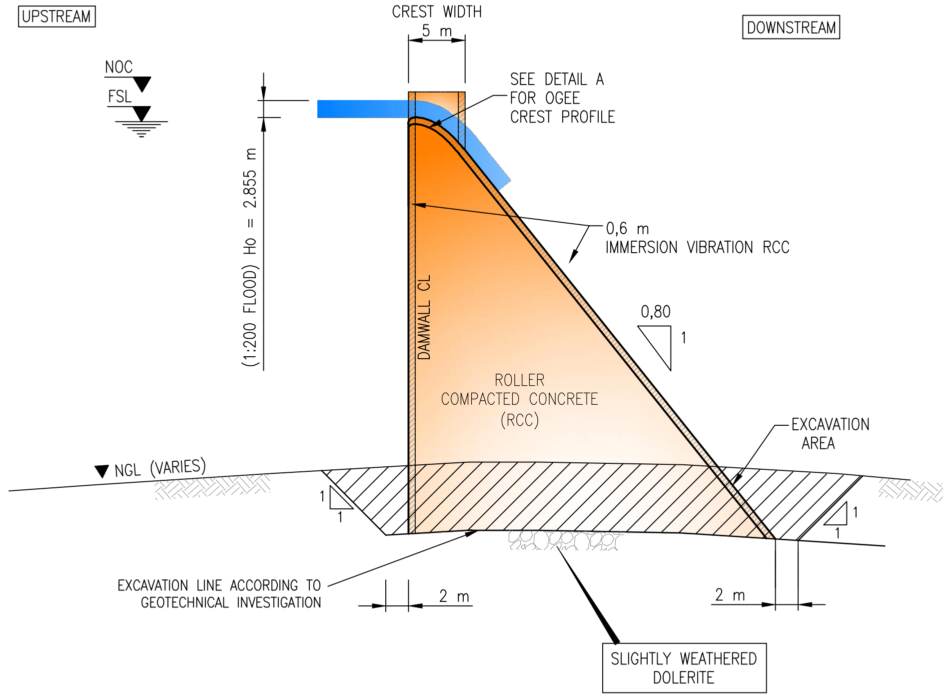


SECTION A–A
TYPICAL SECTION
NTS

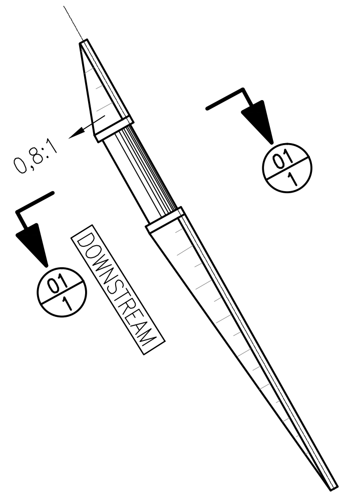
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME
FEASIBILITY DESIGN: PROPOSED ZALU DAM - EARTH CORE ROCFILL DAM SLOPE 2/1 m U/S AND 2/1 m D/S

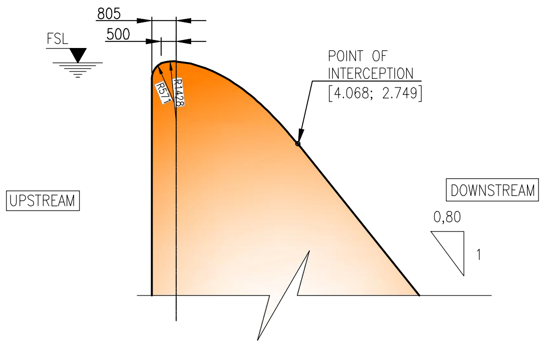
AECOM DETAIL/FIGURE No.
FIG. C1



SECTIONAL VIEW 01–01
TYPICAL SECTION
NTS



PLAN VIEW OF EMBANKMENT
(CREST TO NGL)
NTS



DETAIL A
OGEE CREST PROFILE
NTS

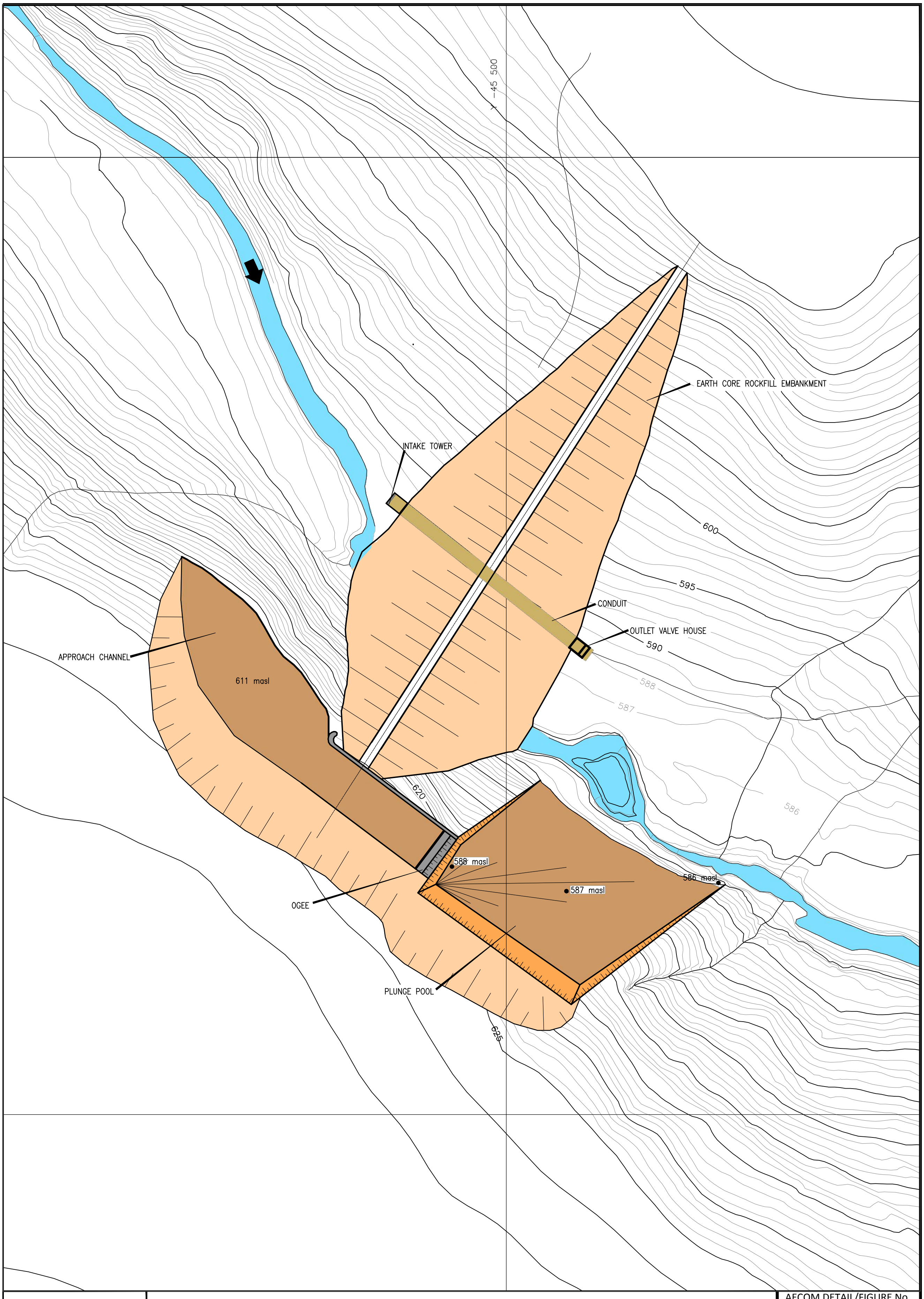
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF LUSIKISIKI REGIONAL WATER SUPPLY SCHEME
FEASIBILITY DESIGN: PROPOSED ZALU DAM - ROLLER COMPACTED CONCRETE (RCC) GRAVITY DAM

AECOM DETAIL/FIGURE No.
FIG. C2

Appendix D

Layout of Investigated Dam Options

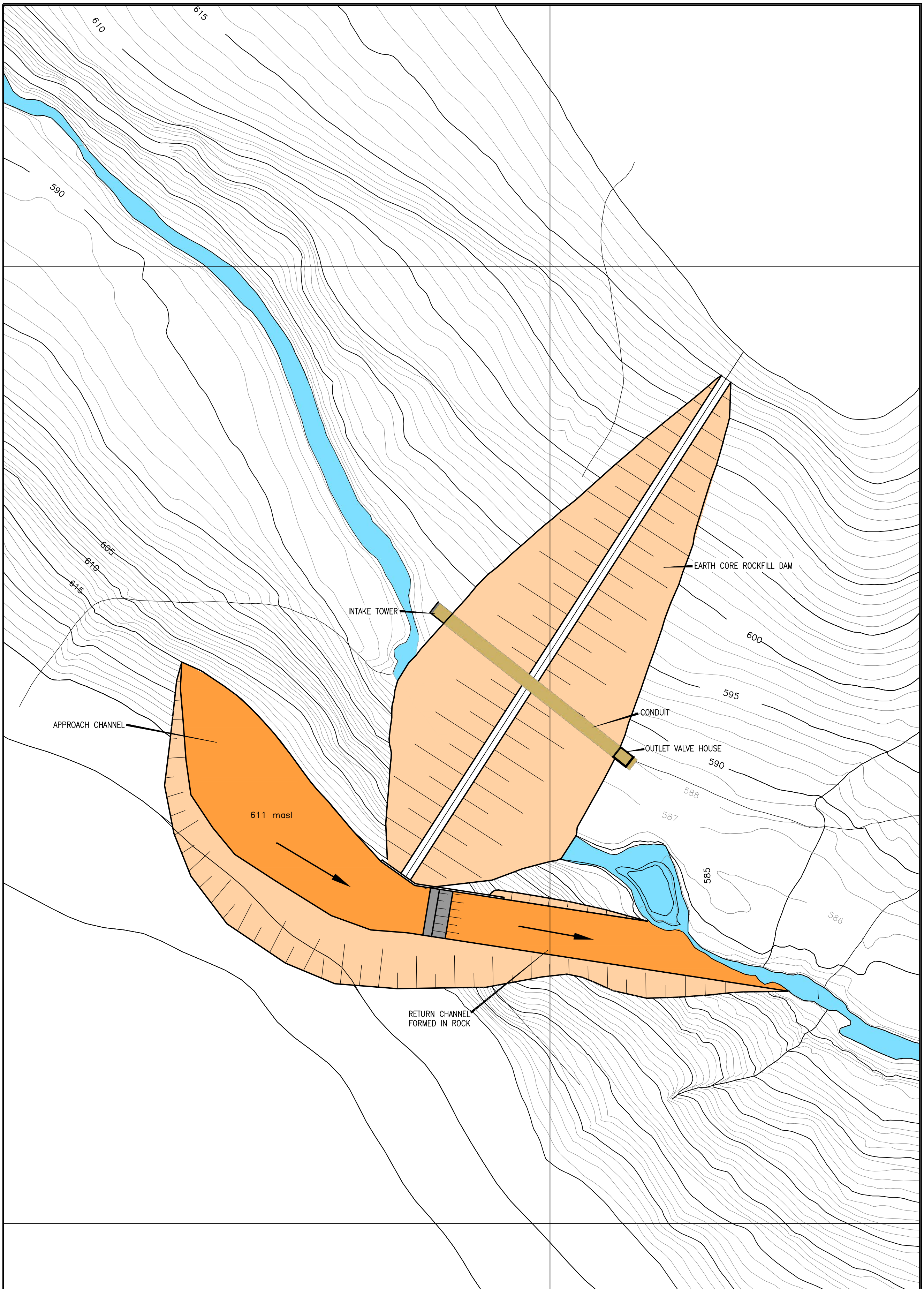


AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME
FEASIBILITY DESIGN: PROPOSED ZALU DAM - LAYOUT OF EARTH CORE ROCKFILL DAM
- SPILLWAY CONFIGURATION - OPTION 1

AECOM DETAIL/FIGURE No.

FIG. D1



AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME
FEASIBILITY DESIGN: PROPOSED ZALU DAM - LAYOUT OF EARTH CORE ROCKFILL DAM
- SPILLWAY CONFIGURATION - OPTION 2

AECOM DETAIL/FIGURE No.

FIG. D2

AECOM

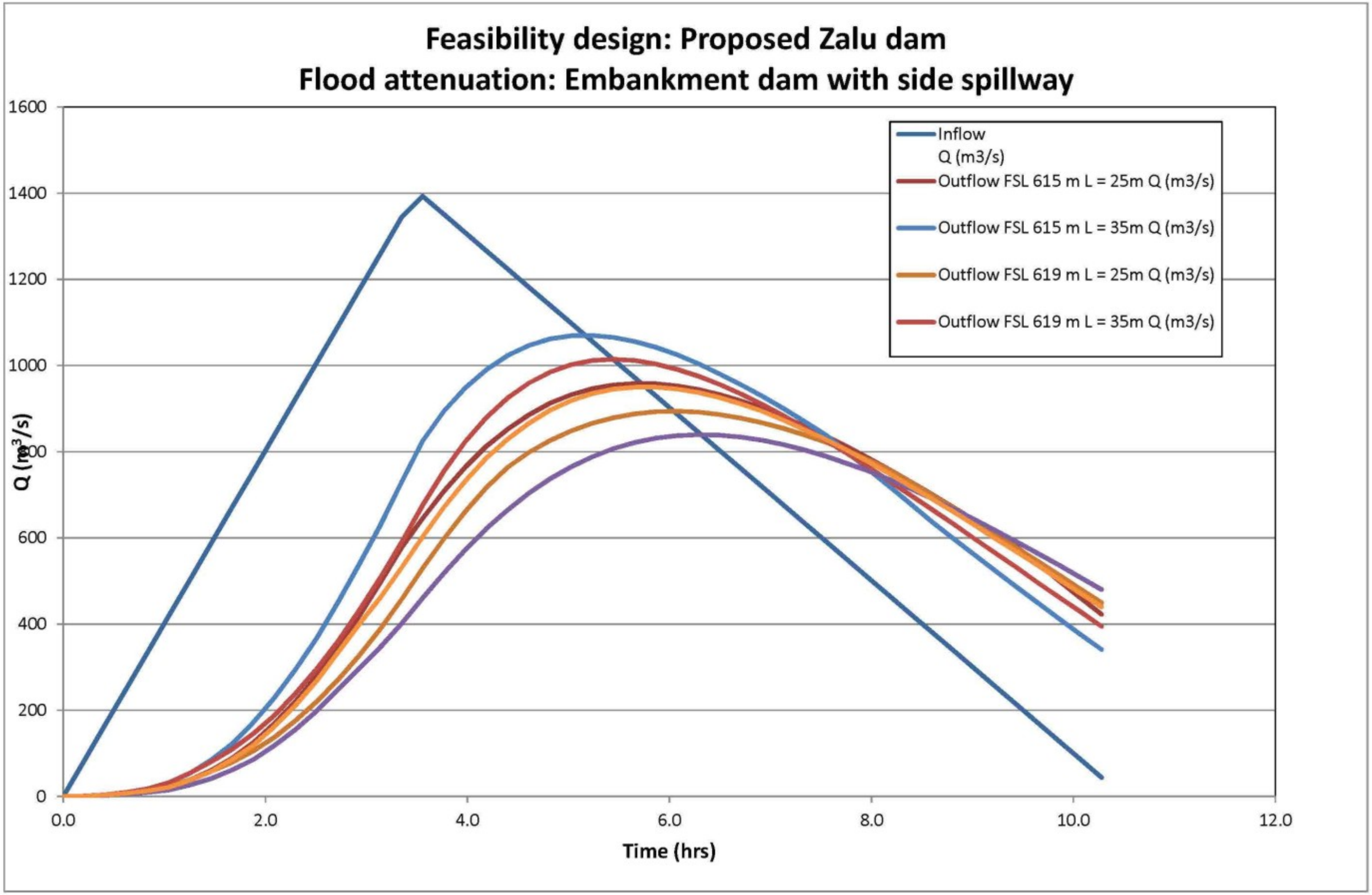
FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME
FEASIBILITY DESIGN: PROPOSED ZALU DAM - LAYOUT OF ROLLER COMPACTED CONCRETE DAM

AECOM DETAIL/FIGURE No.

FIG. D3

Appendix E

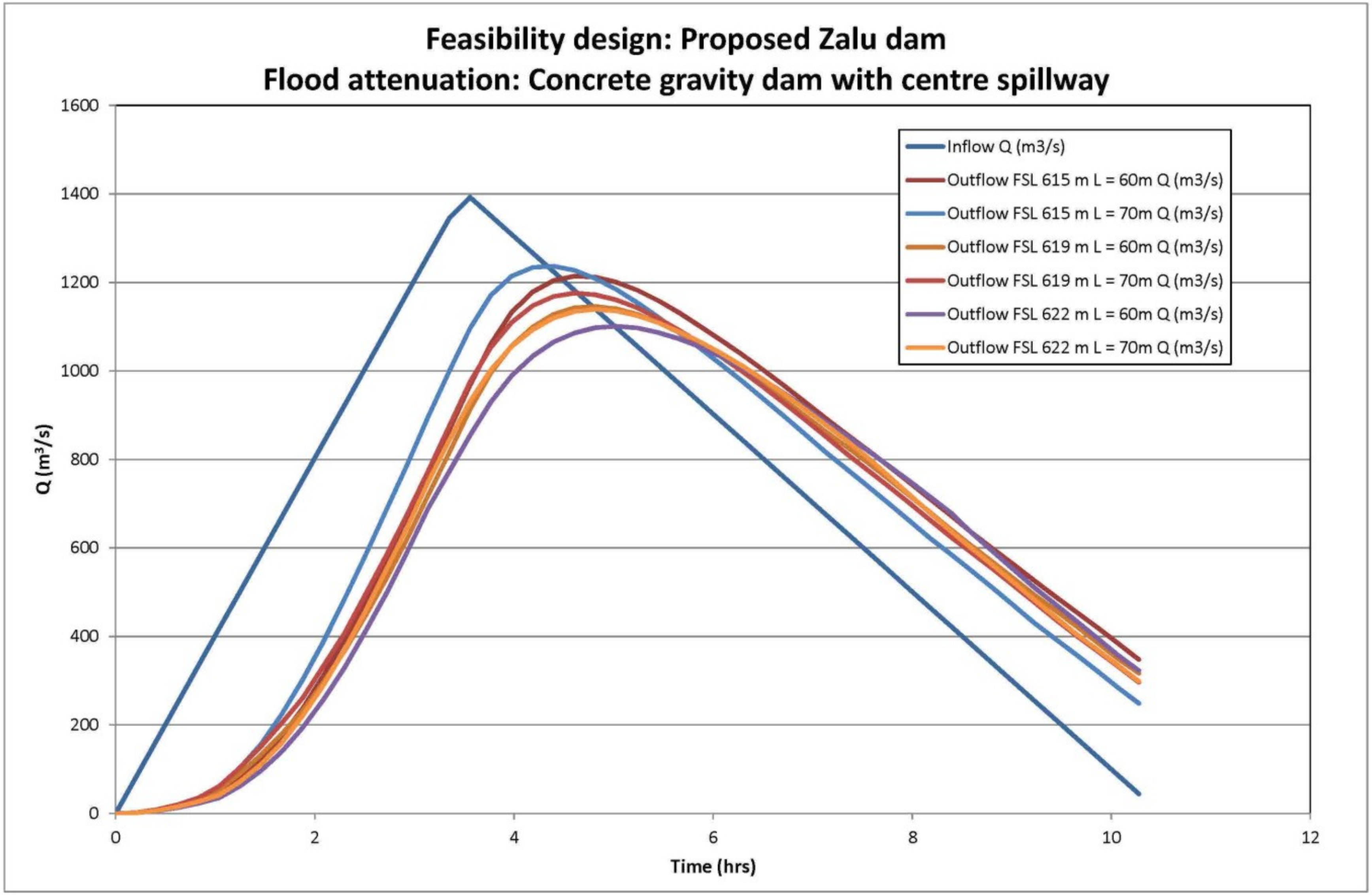
Flood Attenuation for Different Dam Types and Sizes



Feasibility Study for Augmentation of the Lusikisiki Regional Water Supply Scheme: Proposed Zalu Dam
Embankment dam summary attenuation

FIGURE E1

Drawn:	LC Gallagher
Checked:	M Trumpelmann
Date:	2014-01-08
Map Ref:	MT02_2014
Project No:	J01407



AECOM

Feasibility Study for Augmentation of the Lusikisiki Regional Water Supply Scheme: Proposed Zalu Dam
Concrete dam summary attenuation

FIGURE E2

Drawn:	LC Gallagher
Checked:	M Trumpelmann
Date:	2014-01-08
Map Ref:	MT01_2014
Project No:	J01407

Appendix F

Cost Estimates for Different Dam Types and Sizes

Figure F1

EARTHCORE ROCKFILL (ECR) DAM **FSL = 615 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE Rand	QUANTITY	AMOUNT Rand
1	6.1	**Clearing**				
	6.1.1	(a) sparse	ha			
	6.1.2	(b) bush	ha	25 000	4.00	100 000.00
	6.1.3	(c) trees	ha			
2	6.2	**River diversion**	Sum			250 000.00
3	6.3	**Excavation**				
		(a) Bulk				
	6.3.1	(i) all materials	m3	40	153 958	6 158 312.37
	6.3.2	(ii) extra over for rock	m3	90	107 770	9 699 341.99
		(b) Confined				
	6.3.3	(i) all materials	m3			
	6.3.4	(ii) extra over for rock	m3			
		(c) Preparation of solum				
	6.3.5	(i) all materials	m2	15	26 173	392 600.78
	6.3.6	(II) extra over for rock (Core)	m2	175	5 235	916 068.48
4	6.4	**Drilling & Grouting**				
	6.4.1	(a) Curtain grouting	m drill	1 200	6 353	7 623 315.57
	6.4.2	(b) Consolidation grouting	m drill	1 500	1 000	1 500 000.00
5	6.5	**Embankment**				
	6.5.1	(a) Earthfill	m3			
	6.5.2	(b) Impervious material (Clay core)	m3	50	68 863	3 443 135.54
	6.5.3	(c) Rockfill				
		(i) 3C	m3	80	327 119	26 169 552.30
		(ii) 3D	m3	80	110 672	8 853 776.42
	6.5.4	(d) Filters (Gravel and sand layers)				
		(i) Gravel	m3	180	36 190	6 514 119.64
		(ii) Sand (commercial source)	m3	380	17 532	6 662 237.79
	6.5.5	(e) Overhaul beyond 3km	m3km	5	100 000	1 500 000.00
6		**Concrete Works**				
	6.6	(a) Formwork				
	6.6.1	(i) gang formed	m2			
	6.6.2	(ii) intricate	m2			
	6.7	(b) Concrete				
	6.7.1	(i) mass	m3			
	6.7.2	(ii) structural	m3			
	6.8	(c) Reinforcing	t			
7	6.9	**Outlet works**				40 000 000.00
9	6.11	Additional Items				
	6.11.1	(a) Spillway (including slope protection)	Sum			51 002 614.00
		SUB-TOTAL				**170 785 074.88**

EARTHCORE ROCKFILL (ECR) DAM **FSL = 615 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE RAND	QUANTITY	AMOUNT
10	6.12	**Landscaping** (% of 1-9)	%	5	170 785 075	8 539 253.74
11	6.13	**Miscellaneous** (% of 1-9)	%	15	170 785 075	25 617 761.23
		SUB TOTAL A				204 942 089.86
12	6.14	**Preliminary & General** (% of sub-total A)	%	40	204 942 090	81 976 835.94
13	6.15	**Preliminary works**				
	6.15.1	(a) Access road	m	450 000	3	1 350 000.00
	6.15.2	(b) Electrical supply to site	Sum			1 200 000.00
	6.15.3	(c) Construction water to site	Sum			350 000.00
	6.15.4	(d) Railhead & materials handling	Sum			
14	6.16	**Accommodation**	Sum			350 000.00
		SUB TOTAL B				290 168 925.80
15	6.17	**Contingencies** (% of sub total B)	%	10	290 168 926	29 016 892.58
		SUB TOTAL C				319 185 818.38
16	6.18	**Planning design & supervision** (% of sub total C)	%	15	319 185 818	47 877 872.76
		SUB TOTAL D				**367 063 691.14**
17	6.19	**VAT** (% of sub total D)	%	14	367 063 691	51 388 916.76
		NETT PROJECT COST				418 452 607.89
18	6.2	**Cost of relocations**	Sum			
19	6.21	**Cost of land acquisition**	Sum			
		TOTAL PROJECT COST				**418 452 607.89**

Figure F2

EARTHCORE ROCKFILL (ECR) DAM **FSL =** **619 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE Rand	QUANTITY	AMOUNT Rand
1	6.1	**Clearing**				
	6.1.1	(a) sparse	ha			
	6.1.2	(b) bush	ha	25 000	5.00	125 000.00
	6.1.3	(c) trees	ha			
2	6.2	**River diversion**	Sum			250 000.00
3	6.3	**Excavation**				
		(a) Bulk				
	6.3.1	(i) all materials	m3	40	177 569	7 102 749.46
	6.3.2	(ii) extra over for rock	m3	90	124 298	11 186 830.41
		(b) Confined				
	6.3.3	(i) all materials	m3			
	6.3.4	(ii) extra over for rock	m3			
		(c) Preparation of solum				
	6.3.5	(i) all materials	m2	15	30 437	456 553.57
	6.3.6	(II) extra over for rock (Core)	m2	175	6 087	1 065 291.67
4	6.4	**Drilling & Grouting**				
	6.4.1	(a) Curtain grouting	m drill	1 200	7 181	8 617 304.37
	6.4.2	(b) Consolidation grouting	m drill	1 500	1 000	1 500 000.00
5	6.5	**Embankment**				
	6.5.1	(a) Earthfill	m3			
	6.5.2	(b) Impervious material (Clay core)	m3	50	85 215	4 260 740.82
	6.5.3	(c) Rockfill				
		(i) 3C	m3	80	411 945	32 955 579.92
		(ii) 3D	m3	80	141 502	11 320 175.60
	6.5.4	(d) Filters (Gravel and sand layers)				
		(i) Gravel	m3	180	41 795	7 523 100.81
		(ii) Sand (commercial source)	m3	380	20 308	7 716 984.65
	6.5.5	(e) Overhaul beyond 3km	m3km	5	100 000	1 500 000.00
6		**Concrete Works**				
	6.6	(a) Formwork				
	6.6.1	(i) gang formed	m2			
	6.6.2	(ii) intricate	m2			
	6.7	(b) Concrete				
	6.7.1	(i) mass	m3			
	6.7.2	(ii) structural	m3			
	6.8	(c) Reinforcing	t			
7	6.9	**Outlet works**				40 000 000.00
9	6.11	Additional Items				
	6.11.1	(a) Spillway (including slope protection)	Sum			67 965 317.00
		SUB-TOTAL				**203 545 628.28**

EARTHCORE ROCKFILL (ECR) DAM **FSL = 619 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE RAND	QUANTITY	AMOUNT
10	6.12	**Landscaping** (% of 1-9)	%	5	203 545 628	10 177 281.41
11	6.13	**Miscellaneous** (% of 1-9)	%	15	203 545 628	30 531 844.24
		SUB TOTAL A				244 254 753.93
12	6.14	**Preliminary & General** (% of sub-total A)	%	40	244 254 754	97 701 901.57
13	6.15	**Preliminary works**				
	6.15.1	(a) Access road	m	450 000	3	1 350 000.00
	6.15.2	(b) Electrical supply to site	Sum			1 200 000.00
	6.15.3	(c) Construction water to site	Sum			350 000.00
	6.15.4	(d) Railhead & materials handling	Sum			
14	6.16	**Accommodation**	Sum			350 000.00
		SUB TOTAL B				345 206 655.50
15	6.17	**Contingencies** (% of sub total B)	%	10	345 206 656	34 520 665.55
		SUB TOTAL C				379 727 321.05
16	6.18	**Planning design & supervision** (% of sub total C)	%	15	379 727 321	56 959 098.16
		SUB TOTAL D				**436 686 419.21**
17	6.19	**VAT** (% of sub total D)	%	14	436 686 419	61 136 098.69
		NETT PROJECT COST				497 822 517.90
18	6.2	**Cost of relocations**	Sum			
19	6.21	**Cost of land acquisition**	Sum			
		TOTAL PROJECT COST				**497 822 517.90**

Figure F3

EARTHCORE ROCKFILL (ECR) DAM **FSL = 622 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE Rand	QUANTITY	AMOUNT Rand
1	6.1	**Clearing**				
	6.1.1	(a) sparse	ha			
	6.1.2	(b) bush	ha	25 000	6.00	150 000.00
	6.1.3	(c) trees	ha			
2	6.2	**River diversion**	Sum			250 000.00
3	6.3	**Excavation**				
		(a) Bulk				
	6.3.1	(i) all materials	m3	40	196 754	7 870 150.24
	6.3.2	(ii) extra over for rock	m3	90	137 728	12 395 486.63
		(b) Confined				
	6.3.3	(i) all materials	m3			
	6.3.4	(ii) extra over for rock	m3			
		(c) Preparation of solum				
	6.3.5	(i) all materials	m2	15	33 950	509 254.54
	6.3.6	(II) extra over for rock (Core)	m2	175	6 790	1 188 260.59
4	6.4	**Drilling & Grouting**				
	6.4.1	(a) Curtain grouting	m drill	1 200	7 948	9 538 007.97
	6.4.2	(b) Consolidation grouting	m drill	1 500	1 000	1 500 000.00
5	6.5	**Embankment**				
	6.5.1	(a) Earthfill	m3			
	6.5.2	(b) Impervious material (Clay core)	m3	50	98 831	4 941 560.22
	6.5.3	(c) Rockfill				
		(i) 3C	m3	80	484 051	38 724 071.80
		(ii) 3D	m3	80	167 943	13 435 427.31
	6.5.4	(d) Filters (Gravel and sand layers)				
		(i) Gravel	m3	180	46 260	8 326 765.77
		(ii) Sand (commercial source)	m3	380	22 516	8 556 096.70
	6.5.5	(e) Overhaul beyond 3km	m3km	5	100 000	1 500 000.00
6		**Concrete Works**				
	6.6	(a) Formwork				
	6.6.1	(i) gang formed	m2			
	6.6.2	(ii) intricate	m2			
	6.7	(b) Concrete				
	6.7.1	(i) mass	m3			
	6.7.2	(ii) structural	m3			
	6.8	(c) Reinforcing	t			
7	6.9	**Outlet works**				40 000 000.00
9	6.11	Additional Items				
	6.11.1	(a) Spillway (including slope protection)	Sum			83 216 492.00
		SUB-TOTAL				**232 101 573.78**

EARTHCORE ROCKFILL (ECR) DAM **FSL = 622 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE RAND	QUANTITY	AMOUNT
10	6.12	**Landscaping** (% of 1-9)	%	5	232 101 574	11 605 078.69
11	6.13	**Miscellaneous** (% of 1-9)	%	15	232 101 574	34 815 236.07
		SUB TOTAL A				278 521 888.53
12	6.14	**Preliminary & General** (% of sub-total A)	%	40	278 521 889	111 408 755.41
13	6.15	**Preliminary works**				
	6.15.1	(a) Access road	m	450 000	3	1 350 000.00
	6.15.2	(b) Electrical supply to site	Sum			1 200 000.00
	6.15.3	(c) Construction water to site	Sum			350 000.00
	6.15.4	(d) Railhead & materials handling	Sum			
14	6.16	**Accommodation**	Sum			350 000.00
		SUB TOTAL B				393 180 643.95
15	6.17	**Contingencies** (% of sub total B)	%	10	393 180 644	39 318 064.39
		SUB TOTAL C				432 498 708.34
16	6.18	**Planning design & supervision** (% of sub total C)	%	15	432 498 708	64 874 806.25
		SUB TOTAL D				**497 373 514.59**
17	6.19	**VAT** (% of sub total D)	%	14	497 373 515	69 632 292.04
		NETT PROJECT COST				567 005 806.64
18	6.2	**Cost of relocations**	Sum			
19	6.21	**Cost of land acquisition**	Sum			
		TOTAL PROJECT COST				**567 005 806.64**

Figure F5

ROLLER COMPACTED CONCRETE DAM (RCC) **FSL = 619 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE Rand	QUANTITY	AMOUNT Rand
1	6.1	**Clearing**				
	6.1.1	(a) sparse	ha			
	6.1.2	(b) bush	ha	25 000	2	50 000
	6.1.3	(c) trees	ha			
2	6.2	**River diversion**	Sum	1 800 000	1	1 800 000
3	6.3	**Excavation**				
		(a) Bulk				
	6.3.1	(i) all materials	m3	40	62 183	2 487 310
	6.3.3	(ii) extra over for rock	m3	90	55 964	5 036 803
		(b) Confined				
	6.3.2	(i) all materials	m3			
	6.3.3	(ii) extra over for rock	m3			
	6.3.4	(c) Final foundation preparation	m2	170	7 239	1 230 662
4	6.4	**Drilling & Grouting**				
		(a) Curtain grouting	m drill	1 200	6 001	7 201 270
		(b) Consolidation grouting	m drill	1 500	1 500	2 250 000
5	6.5	**Formwork**				
	6.5.1	(a) Gang formed	m2	400	266 776	106 710 387
	6.5.2	(b) Intricate	m2	500	1 974	986 892
6	6.6	**Concrete**				
	6.6.1	(a) RCC	m3	1 100	114 116	125 527 400
	6.6.2	(b) IVRCC including waterstop	m3	1 800	9 842	17 716 090
	6.6.3	(c) Structural	m3	2 200	11 412	25 105 480
7	6.7	**Reinforcing**	t	15 000	1 141	17 117 373
8	6.8	**Outlet works**				25 000 000
10	6.10	**Additional Items**				
		SUB-TOTAL				**338 219 666**

ROLLER COMPACTED CONCRETE DAM (RCC) **FSL = 619 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE RAND	QUANTITY	AMOUNT
11	6.11	**Landscaping** (% of 1-9)	%	5	338 219 666	16 910 983
12	6.12	**Miscellaneous** (% of 1-9)	%	15	338 219 666	50 732 950
		SUB TOTAL A				405 863 599
13	6.13	**Preliminary & General** (% of sub-total A)	%	40	405 863 599	162 345 440
14	6.14	**Preliminary works**				
	6.14.1	(a) Access road	km	450 000	3.0	1 350 000.00
	6.14.2	(b) Electrical supply to site	Sum			1 200 000
	6.14.3	(c) Construction water to site	Sum			350 000
	6.14.4	(d) Railhead & materials handling	Sum			
15	6.15	**Accommodation**	Sum			350 000
		SUB TOTAL B				569 559 039
16	6.16	**Contingencies** (% of sub total B)	%	10	569 559 039	56 955 904
		SUB TOTAL C				626 514 943
17	6.17	**Planning design & supervision** (% of sub total C)	%	15	626 514 943	93 977 241
		SUB TOTAL D				**720 492 184**
18	6.18	**VAT** (% of sub total D)	%	14	720 492 184	100 868 906
		NETT PROJECT COST				821 361 090
19	6.19	**Cost of relocations**	Sum			
20	6.20	**Cost of land acquisition**	Sum			
		TOTAL PROJECT COST				**821 361 090**

Figure F6

ROLLER COMPACTED CONCRETE DAM (RCC) **FSL = 622 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE Rand	QUANTITY	AMOUNT Rand
1	6.1	**Clearing**				
	6.1.1	(a) sparse	ha			
	6.1.2	(b) bush	ha	25 000	2	50 000
	6.1.3	(c) trees	ha			
2	6.2	**River diversion**	Sum	1 800 000	1	1 800 000
3	6.3	**Excavation**				
		(a) Bulk				
	6.3.1	(i) all materials	m3	40	73 953	2 958 103
	6.3.3	(ii) extra over for rock	m3	90	66 557	5 990 158
		(b) Confined				
	6.3.2	(i) all materials	m3			
	6.3.3	(ii) extra over for rock	m3			
	6.3.4	(c) Final foundation preparation	m2	170	8 286	1 408 662
4	6.4	**Drilling & Grouting**				
		(a) Curtain grouting	m drill	1 200	6 864	8 236 526
		(b) Consolidation grouting	m drill	1 500	1 500	2 250 000
5	6.5	**Formwork**				
	6.5.1	(a) Gang formed	m2	400	284 489	113 795 585
	6.5.2	(b) Intricate	m2	500	2 142	1 070 804
6	6.6	**Concrete**				
	6.6.1	(a) RCC	m3	1 100	139 877	153 864 419
	6.6.2	(b) IVRCC including waterstop	m3	1 800	11 449	20 608 703
	6.6.3	(c) Structural	m3	2 200	13 988	30 772 884
7	6.7	**Reinforcing**	t	15 000	1 399	20 981 512
8	6.8	**Outlet works**				25 000 000
10	6.10	**Additional Items**				
		SUB-TOTAL				**388 787 356**

ROLLER COMPACTED CONCRETE DAM (RCC) **FSL =** **622 masl**

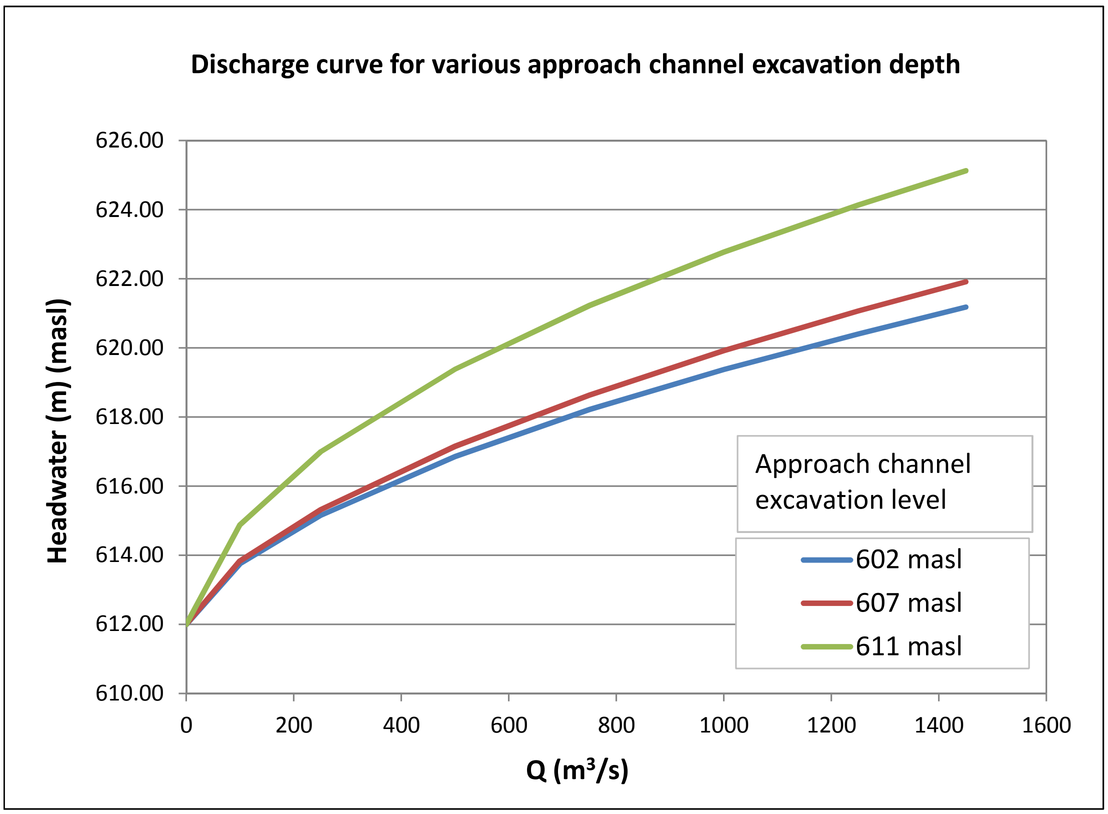
No	PAY REF	DESCRIPTION	UNIT	RATE RAND	QUANTITY	AMOUNT
11	6.11	**Landscaping** (% of 1-9)	%	5	388 787 356	19 439 368
12	6.12	**Miscellaneous** (% of 1-9)	%	15	388 787 356	58 318 103
		SUB TOTAL A				466 544 827
13	6.13	**Preliminary & General** (% of sub-total A)	%	40	466 544 827	186 617 931
14	6.14	**Preliminary works**				
	6.14.1	(a) Access road	km	450 000	3.0	1 350 000.00
	6.14.2	(b) Electrical supply to site	Sum			1 200 000
	6.14.3	(c) Construction water to site	Sum			350 000
	6.14.4	(d) Railhead & materials handling	Sum			
15	6.15	**Accommodation**	Sum			350 000
		SUB TOTAL B				654 512 758
16	6.16	**Contingencies** (% of sub total B)	%	10	654 512 758	65 451 276
		SUB TOTAL C				719 964 034
17	6.17	**Planning design & supervision** (% of sub total C)	%	15	719 964 034	107 994 605
		SUB TOTAL D				**827 958 639**
18	6.18	**VAT** (% of sub total D)	%	14	827 958 639	115 914 209
		NETT PROJECT COST				943 872 848
19	6.19	**Cost of relocations**	Sum			
20	6.20	**Cost of land acquisition**	Sum			
		TOTAL PROJECT COST				**943 872 848**

Appendix G

Discharge Tables and Curves for Different Approach Channel Excavation Levels

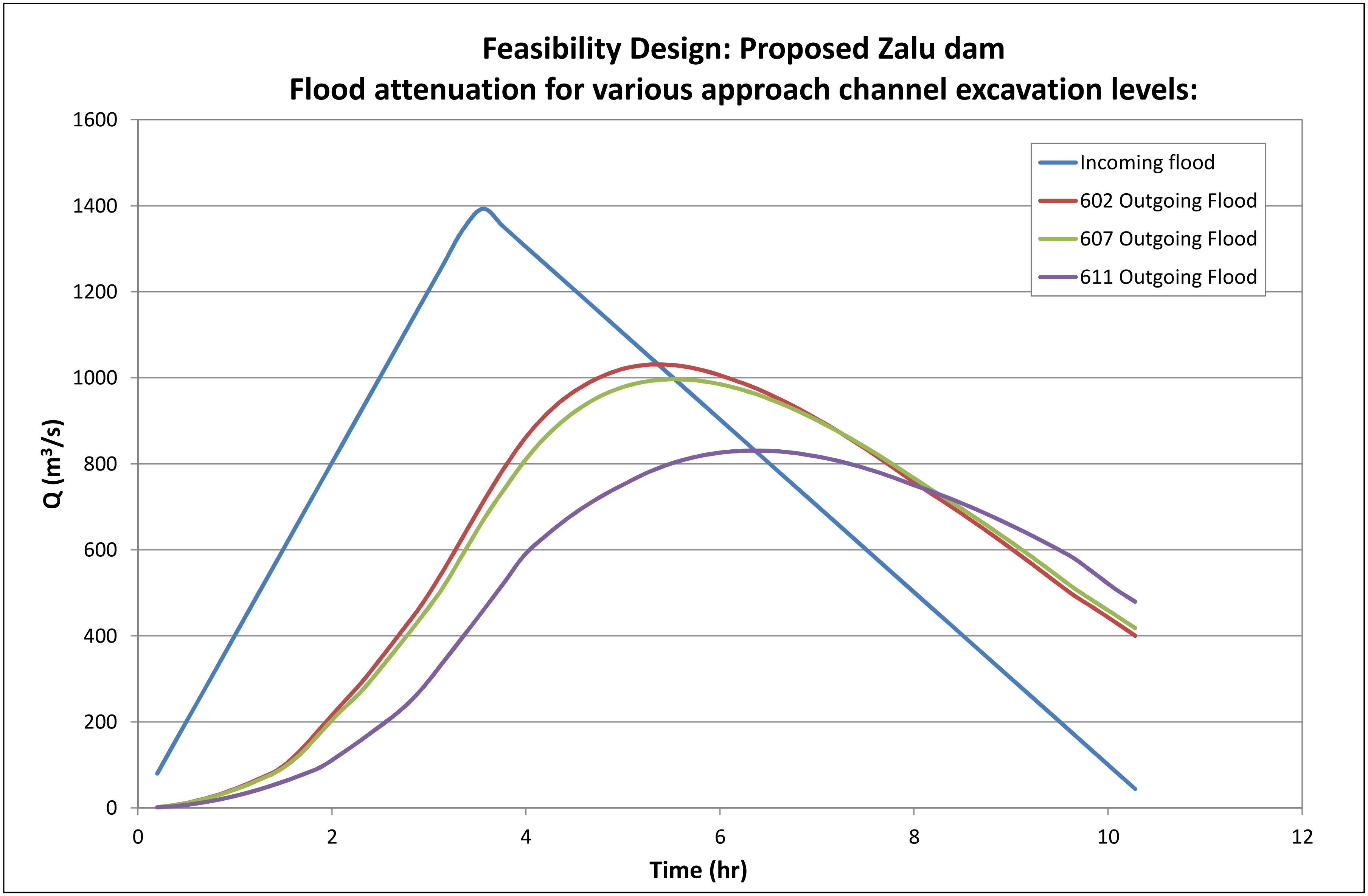
Feasiblity Design: Proposed Zalu dam
Discharge table for various approach channel excavation levels

Q (m^3/s)	Head (masl)		
	602 masl	**607 masl**	**611 masl**
0	612.00	612.00	612.00
100	613.76	613.84	614.89
250	615.16	615.32	617.00
500	616.86	617.16	619.39
750	618.22	618.64	621.23
1000	619.38	619.93	622.78
1250	620.41	621.08	624.14
1450	621.19	621.92	625.13



Appendix H

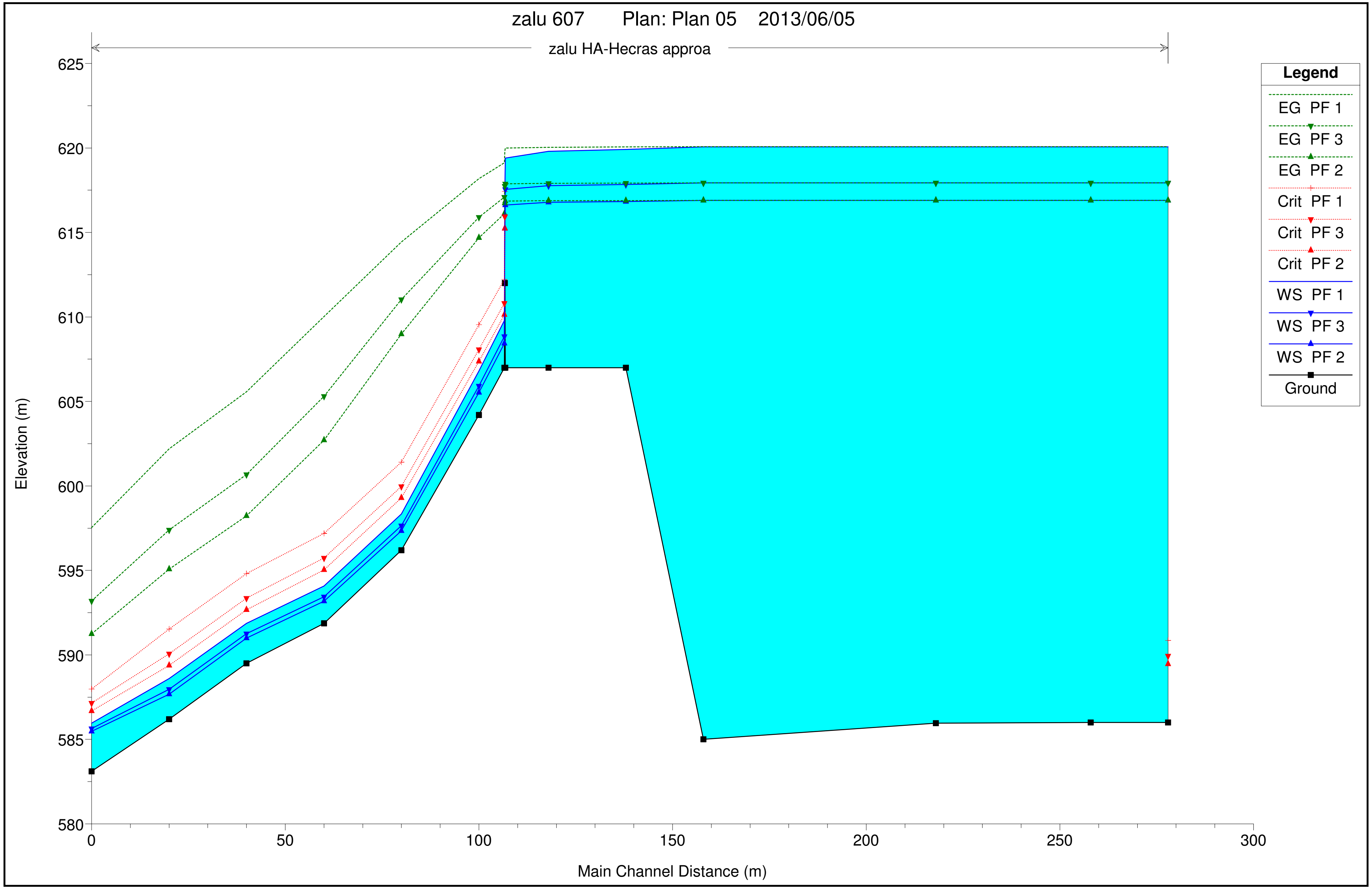
Flood Attenuation for Different Approach Channel Excavation Levels



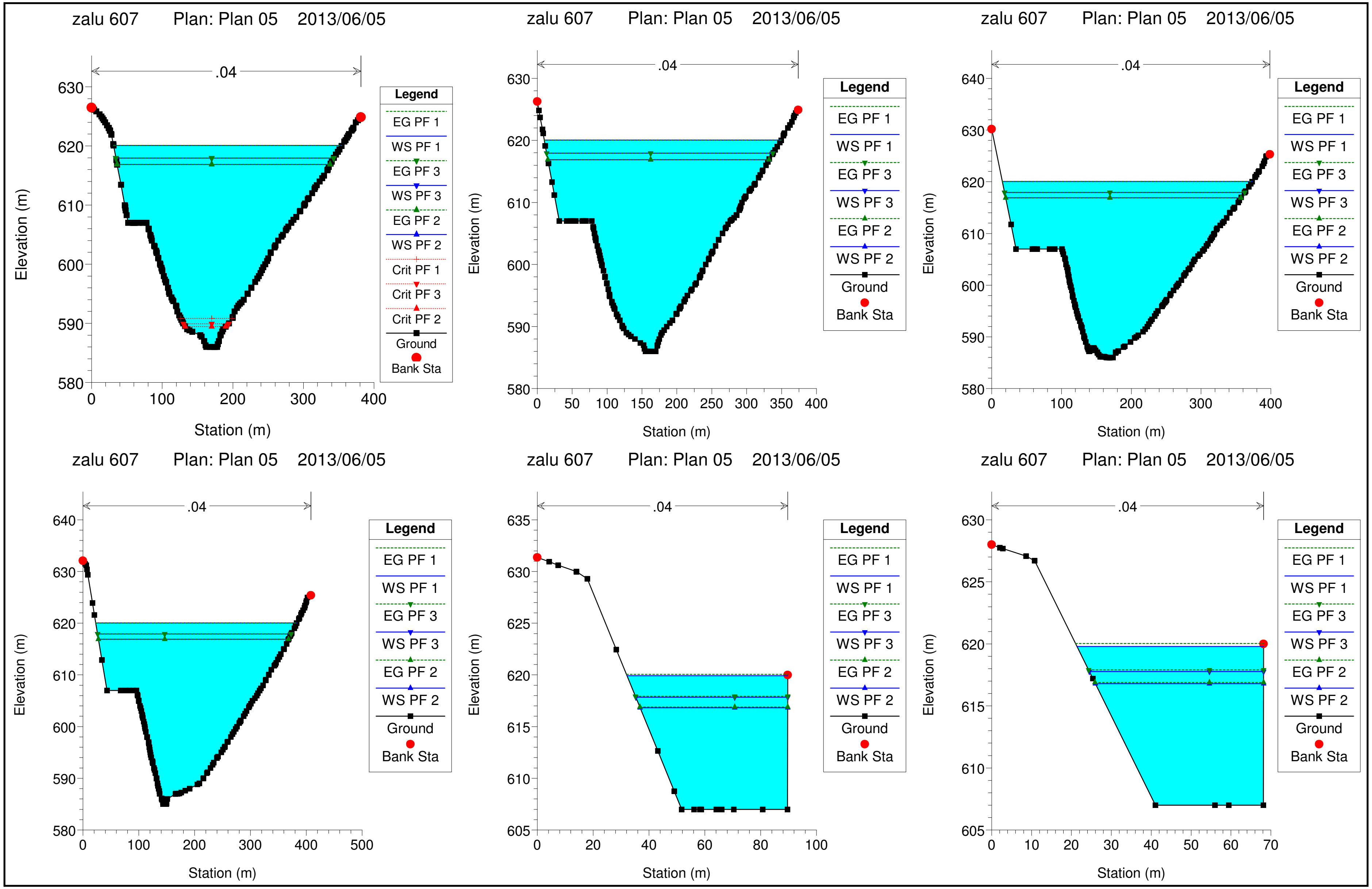
Feasibility Design: Proposed Zalu dam
Flood attenuation for various approach channel excavation levels:
Incoming flood
602 Outgoing Flood
607 Outgoing Flood
611 Outgoing Flood
Q (m³/s)
Time (hr)
0
200
400
600
800
1000
1200
1400
1600
0
2
4
6
8
10
12

Appendix J

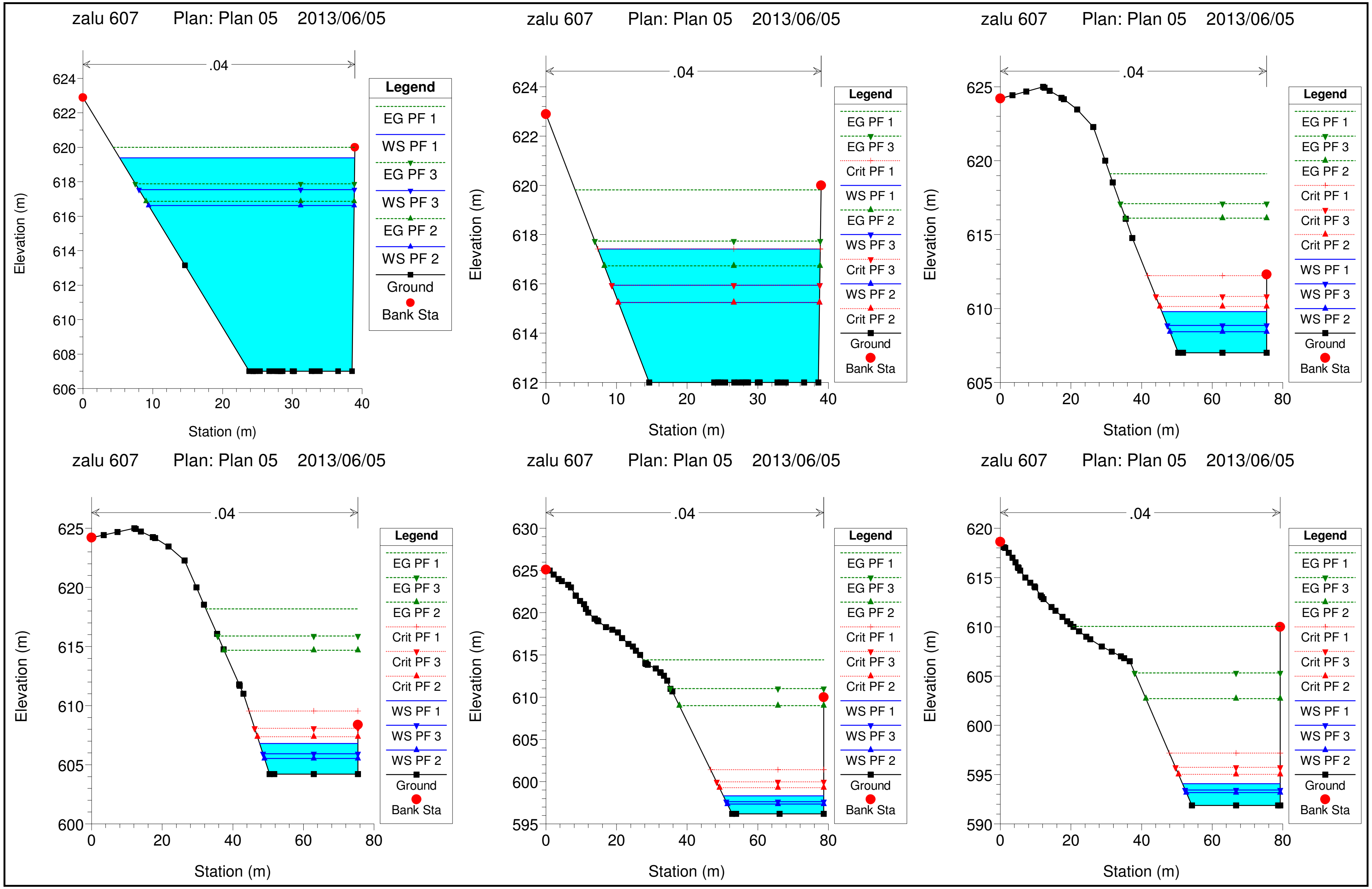
HECRAS Results for Return Channel



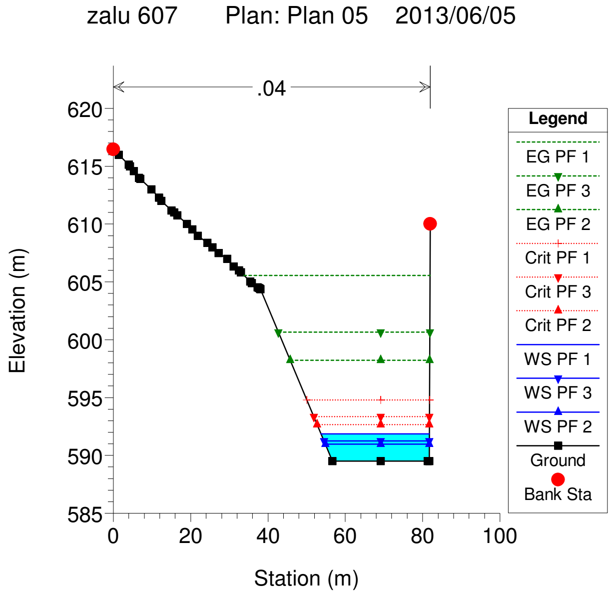
zalu 607 Plan: Plan 05 2013/06/05
zalu HA-Hecras approa
Legend
EG PF 1
EG PF 3
EG PF 2
Crit PF 1
Crit PF 3
Crit PF 2
WS PF 1
WS PF 3
WS PF 2
Ground
Elevation (m)
Main Channel Distance (m)
625
620
615
610
605
600
595
590
585
580
0
50
100
150
200
250
300

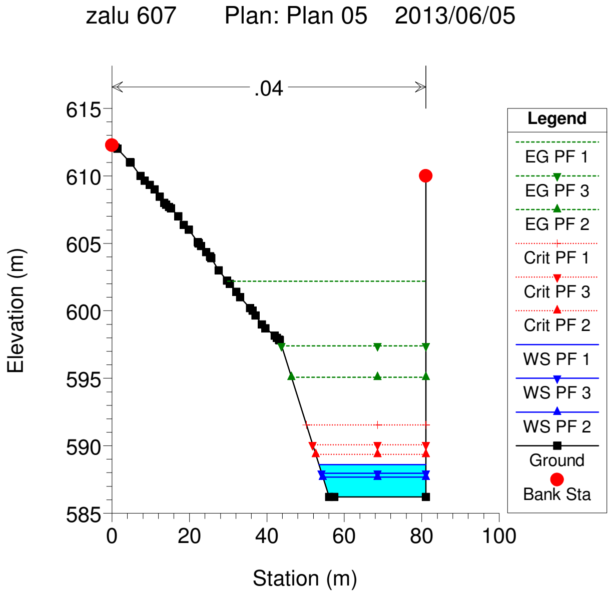


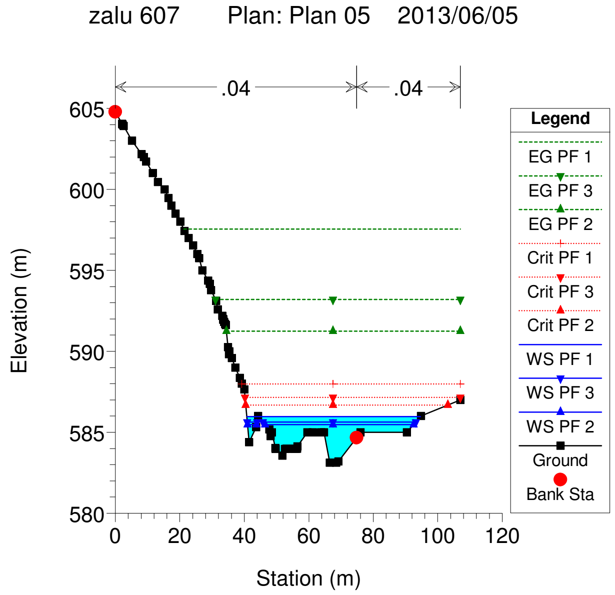
zalu 607 Plan: Plan 05 2013/06/05
.04
Elevation (m)
Station (m)
Legend
EG PF 1
WS PF 1
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Crit PF 1
Crit PF 3
Crit PF 2
Ground
Bank Sta
580
590
600
610
620
630
0
100
200
300
400
zalu 607 Plan: Plan 05 2013/06/05
.04
Elevation (m)
Station (m)
Legend
EG PF 1
WS PF 1
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Ground
Bank Sta
580
590
600
610
620
630
0
50
100
150
200
250
300
350
400
zalu 607 Plan: Plan 05 2013/06/05
.04
Elevation (m)
Station (m)
Legend
EG PF 1
WS PF 1
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Ground
Bank Sta
580
590
600
610
620
630
640
0
100
200
300
400
zalu 607 Plan: Plan 05 2013/06/05
.04
Elevation (m)
Station (m)
Legend
EG PF 1
WS PF 1
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Ground
Bank Sta
580
590
600
610
620
630
640
0
100
200
300
400
500
zalu 607 Plan: Plan 05 2013/06/05
.04
Elevation (m)
Station (m)
Legend
EG PF 1
WS PF 1
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Ground
Bank Sta
605
610
615
620
625
630
635
0
20
40
60
80
100
zalu 607 Plan: Plan 05 2013/06/05
.04
Elevation (m)
Station (m)
Legend
EG PF 1
WS PF 1
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Ground
Bank Sta
605
610
615
620
625
630
0
10
20
30
40
50
60
70



zalu 607 Plan: Plan 05 2013/06/05
.04
Legend
EG PF 1
WS PF 1
EG PF 3
WS PF 3
EG PF 2
WS PF 2
Ground
Bank Sta
Elevation (m)
Station (m)
zalu 607 Plan: Plan 05 2013/06/05
.04
Legend
EG PF 1
EG PF 3
Crit PF 1
WS PF 1
EG PF 2
WS PF 3
Crit PF 3
WS PF 2
Crit PF 2
Ground
Bank Sta
Elevation (m)
Station (m)
zalu 607 Plan: Plan 05 2013/06/05
.04
Legend
EG PF 1
EG PF 3
EG PF 2
Crit PF 1
Crit PF 3
Crit PF 2
WS PF 1
WS PF 3
WS PF 2
Ground
Bank Sta
Elevation (m)
Station (m)
zalu 607 Plan: Plan 05 2013/06/05
.04
Legend
EG PF 1
EG PF 3
EG PF 2
Crit PF 1
Crit PF 3
Crit PF 2
WS PF 1
WS PF 3
WS PF 2
Ground
Bank Sta
Elevation (m)
Station (m)
zalu 607 Plan: Plan 05 2013/06/05
.04
Legend
EG PF 1
EG PF 3
EG PF 2
Crit PF 1
Crit PF 3
Crit PF 2
WS PF 1
WS PF 3
WS PF 2
Ground
Bank Sta
Elevation (m)
Station (m)
zalu 607 Plan: Plan 05 2013/06/05
.04
Legend
EG PF 1
EG PF 3
EG PF 2
Crit PF 1
Crit PF 3
Crit PF 2
WS PF 1
WS PF 3
WS PF 2
Ground
Bank Sta
Elevation (m)
Station (m)


zalu 607 Plan: Plan 05 2013/06/05
.04
Elevation (m)
Station (m)
Legend
EG PF 1
EG PF 3
EG PF 2
Crit PF 1
Crit PF 3
Crit PF 2
WS PF 1
WS PF 3
WS PF 2
Ground
Bank Sta


zalu 607 Plan: Plan 05 2013/06/05
.04
Elevation (m)
Station (m)
Legend
EG PF 1
EG PF 3
EG PF 2
Crit PF 1
Crit PF 3
Crit PF 2
WS PF 1
WS PF 3
WS PF 2
Ground
Bank Sta


zalu 607 Plan: Plan 05 2013/06/05
.04
.04
Elevation (m)
Station (m)
Legend
EG PF 1
EG PF 3
EG PF 2
Crit PF 1
Crit PF 3
Crit PF 2
WS PF 1
WS PF 3
WS PF 2
Ground
Bank Sta

Appendix K

Freeboard: Wind Set-up

AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME
FEASIBILITY DESIGN: PROPOSED ZALU DAM - WIND SET-UP

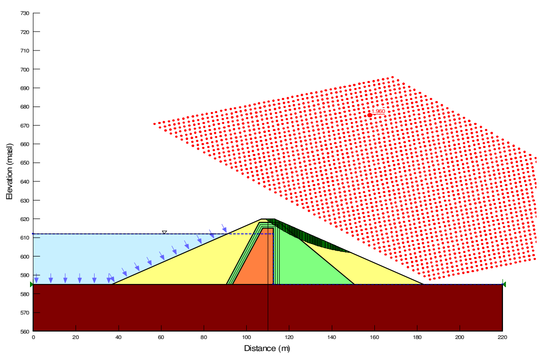
AECOM DETAIL/FIGURE No.
FIG. K1

Appendix L

Stability Analysis

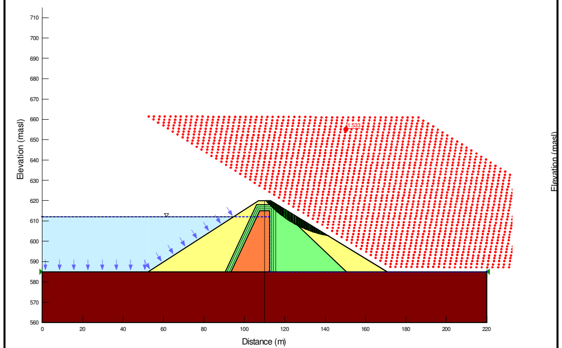
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis - **Figure L1**				
Downstream - Dam full with steady state flow				
Upstream slope:	1:2	V:H		Notes:
Downstream slope:	1:2	V:H		**Downstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.960 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



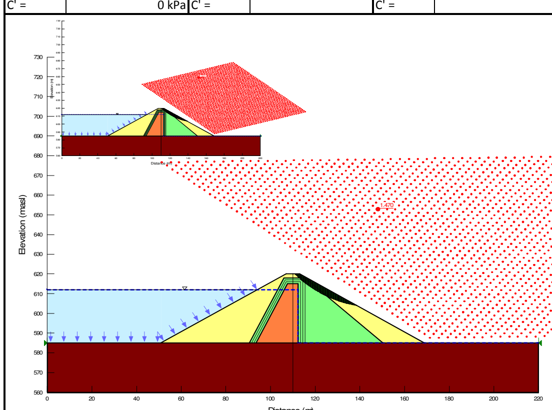
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L3**				
Downstream - Dam full with steady state flow				
Upstream slope:	1:1.55	V:H		Notes:
Downstream slope:	1:1.65	V:H		**Downstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		
Height:	35	m		**FOS = 1.533 >1.5**
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



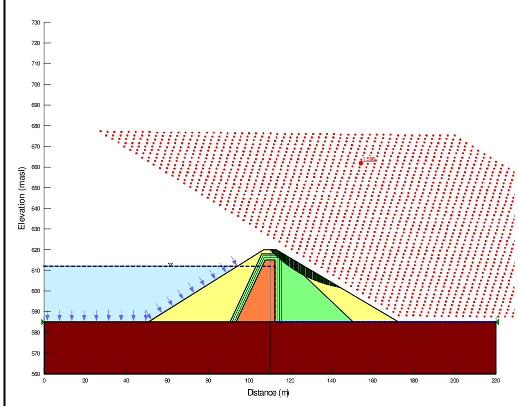
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L2**				
Downstream - Dam full with steady state flow				
Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.6	V:H		**Downstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		
Height:	35	m		**FOS = 1.470 < 1.5**
Seismic (Horizontal):	0	k	(k*g)	**NOT SUITABLE**
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L4**				
Downstream - Dam full with steady state flow				
Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.7	V:H		**Downstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		
Height:	35	m		**FOS = 1.596 > 1.5**
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



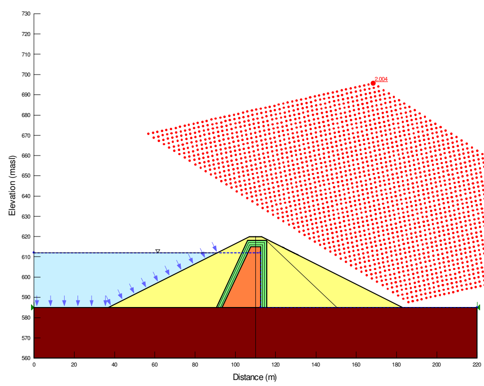
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis - **Figure L5**

Downstream - Dam full with steady state flow

Upstream slope:	1:2	V:H		Notes:
Downstream slope:	1:2	V:H		**Downstream slope** analysis with only 3C material in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 2.004 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials

3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



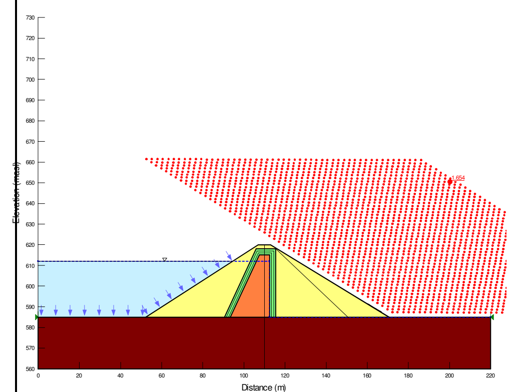
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L7**

Downstream - Dam full with steady state flow

Upstream slope:	1:1.55	V:H		Notes:
Downstream slope:	1:1.65	V:H		**Downstream slope** analysis with only 3C material in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.654 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials

3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



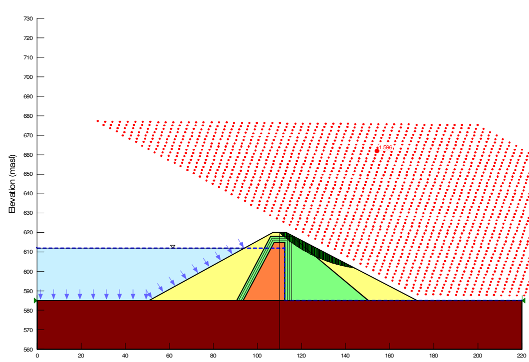
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L6**

Downstream - Dam full with steady state flow

Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.6	V:H		**Downstream slope** analysis with only 3C material in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.603 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials

3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



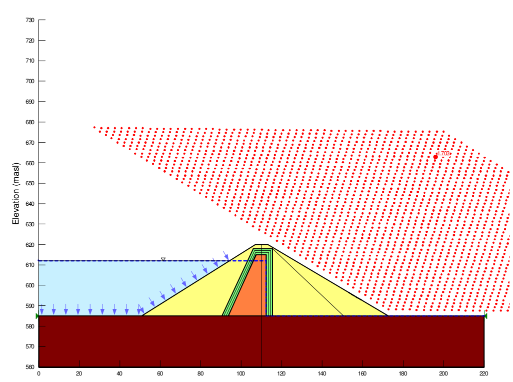
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L8**

Downstream - Dam full with steady state flow

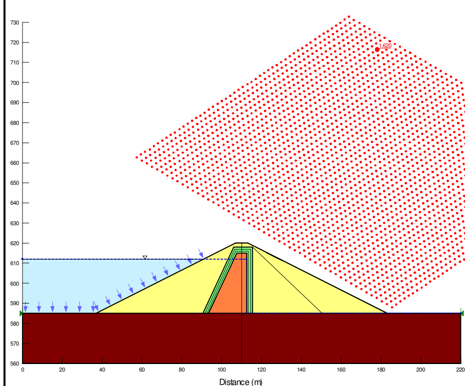
Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.7	V:H		**Downstream slope** analysis with only 3C material in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.703 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials

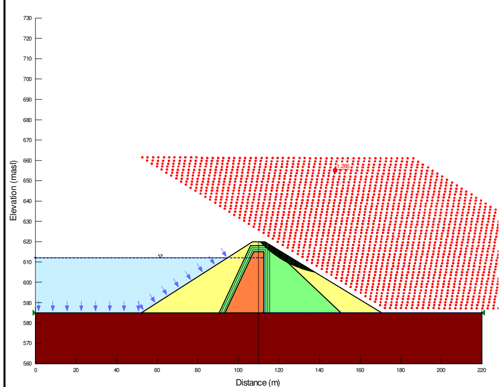
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



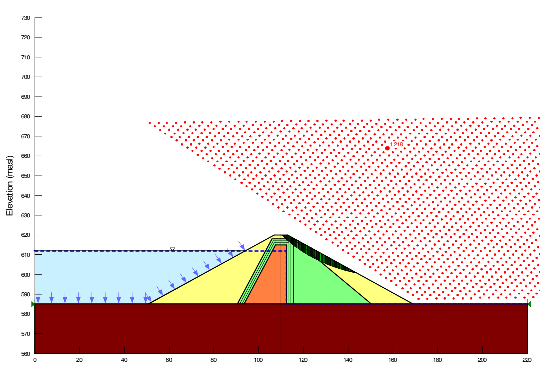
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L9**					
Downstream - Dam full with seismic action					
Upstream slope:	1:2	V:H		Notes:	
Downstream slope:	1:2	V:H		**Downstream slope Seismic Analysis** analysis with 3C and 3D materials in the shell **FOS = 1.620 > 1.0**	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl			
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



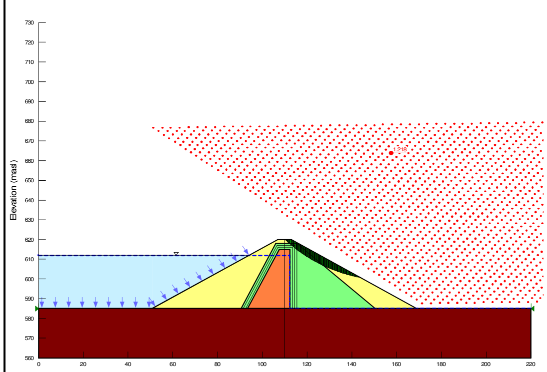
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L11**					
Downstream - Dam full with seismic action					
Upstream slope:	1:1.55	V:H		Notes:	
Downstream slope:	1:1.65	V:H		**Downstream slope Seismic Analysis** analysis with 3C and 3D materials in the shell **FOS = 1.266 > 1.0**	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl			
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



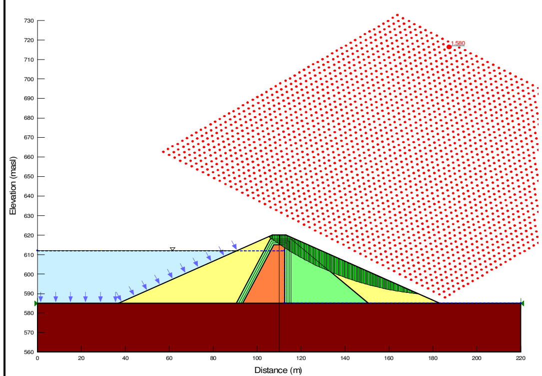
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis - **Figure 10**					
Downstream - Dam full with seismic action					
Upstream slope:	1:1.6	V:H		Notes:	
Downstream slope:	1:1.6	V:H		**Downstream slope Seismic Analysis** analysis with 3C and 3D materials in the shell **FOS = 1.218 > 1.0**	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl			
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



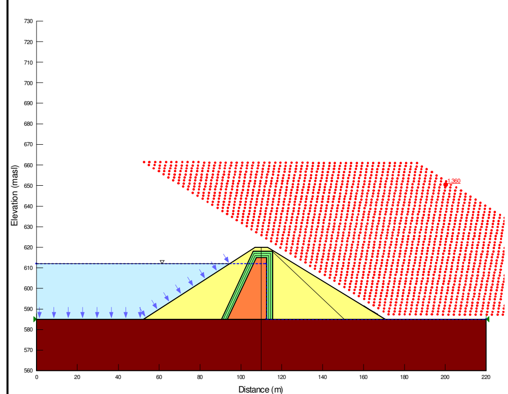
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L12**					
Downstream - Dam full with seismic action					
Upstream slope:	1:1.6	V:H		Notes:	
Downstream slope:	1:1.7	V:H		**Downstream slope Seismic Analysis** analysis with 3C and 3D materials in the shell **FOS = 1.314 > 1.0**	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl			
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



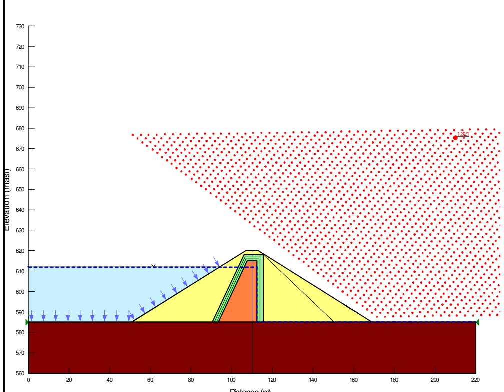
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L13**					
Downstream - Dam full with seismic action					
Upstream slope:	1:2	V:H		Notes:	
Downstream slope:	1:2	V:H		**Downstream slope** analysis with only 3C material in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl		**FOS = 1.580 > 1.0**	
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



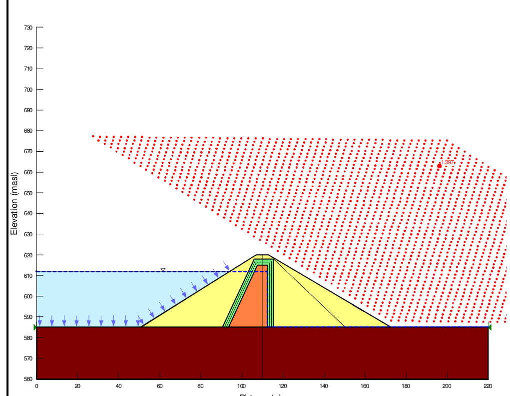
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L15**					
Downstream - Dam full with seismic action					
Upstream slope:	1:1.55	V:H		Notes:	
Downstream slope:	1:1.65	V:H		**Downstream slope** analysis with only 3C material in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl		**FOS = 1.360 > 1.0**	
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L14**					
Downstream - Dam full with seismic action					
Upstream slope:	1:1.6	V:H		Notes:	
Downstream slope:	1:1.6	V:H		**Downstream slope** analysis with only 3C material in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl		**FOS = 1.321 > 1.0**	
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	

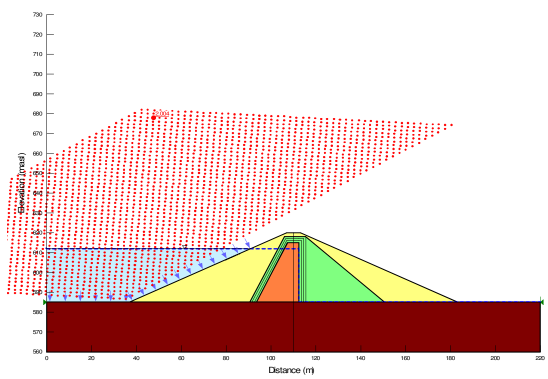


Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L16**					
Downstream - Dam full with seismic action					
Upstream slope:	1:1.6	V:H		Notes:	
Downstream slope:	1:1.7	V:H		**Downstream slope** analysis with only 3C material in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl		**FOS = 1.397 > 1.0**	
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



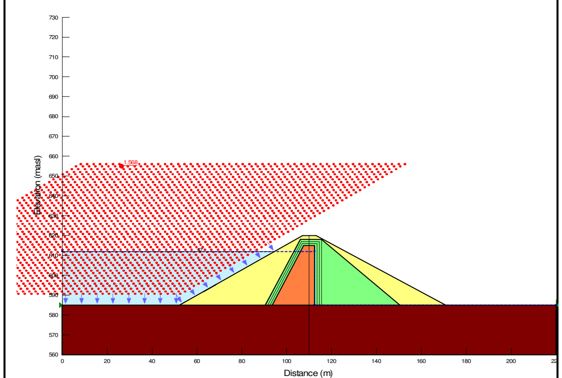
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L17**				
Upstream - Dam full with steady state flow				
Upstream slope:	1:2	V:H		Notes:
Downstream slope:	1:2	V:H		**Upstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 2.004 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



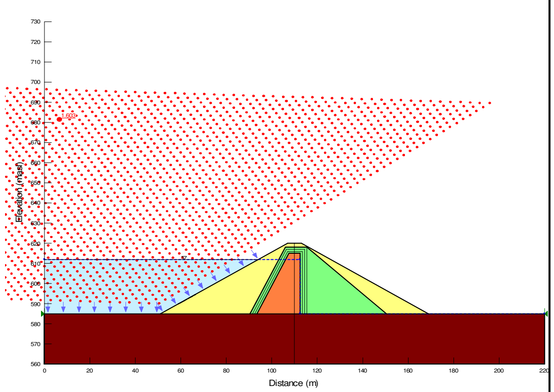
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L19**				
Upstream - Dam full with steady state flow				
Upstream slope:	1:1.55	V:H		Notes:
Downstream slope:	1:1.65	V:H		**Upstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.568 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



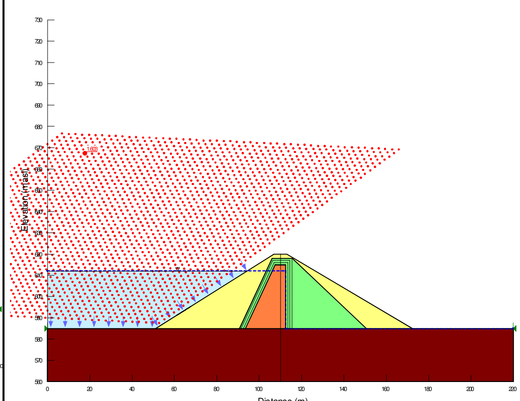
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L18**				
Upstream - Dam full with steady state flow				
Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.6	V:H		**Upstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		
Height:	35	m		**FOS = 1.603 > 1.5**
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L20**				
Upstream - Dam full with steady state flow				
Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.7	V:H		**Upstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.603 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



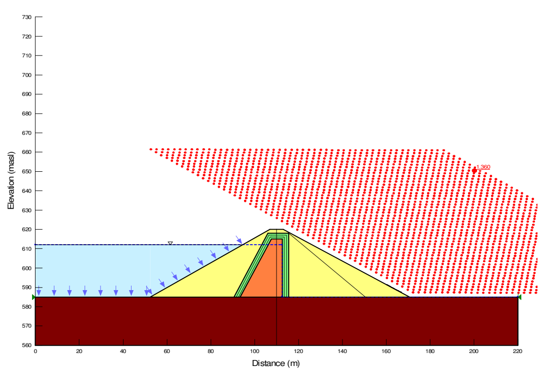
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L21**

Upstream - Dam full with steady state flow

Upstream slope:	1:1.55	V:H		Notes:
Downstream slope:	1:1.65	V:H		**Upstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.568 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials

3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



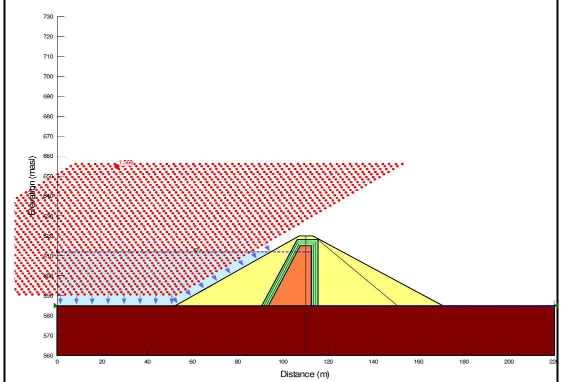
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L23**

Upstream - Dam full with steady state flow

Upstream slope:	1:1.55	V:H		Notes:
Downstream slope:	1:1.65	V:H		**Upstream slope** analysis with only 3C material in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.568 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials

3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



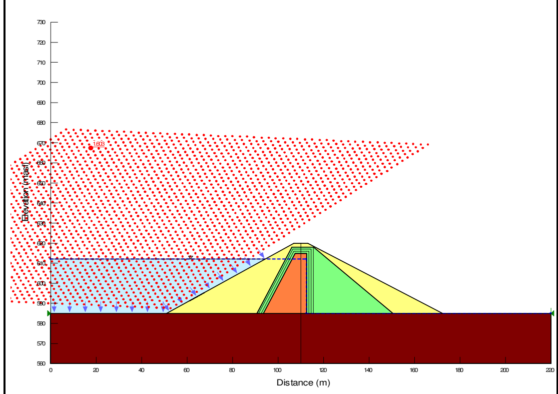
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L22**

Upstream - Dam full with steady state flow

Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.7	V:H		**Upstream slope** analysis with 3C and 3D materials in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.603 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials

3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



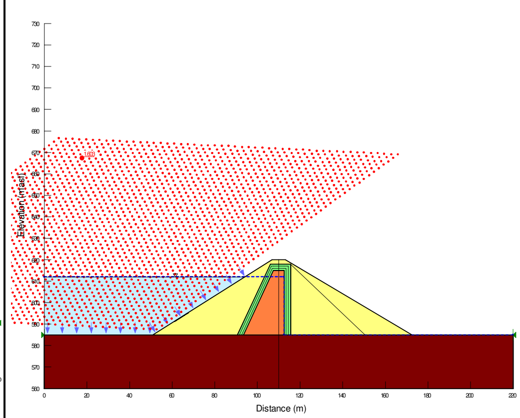
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L24**

Upstream - Dam full with steady state flow

Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.7	V:H		**Upstream slope** analysis with only 3C material in the shell
Water level (FSL):	612	masl		
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.603 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

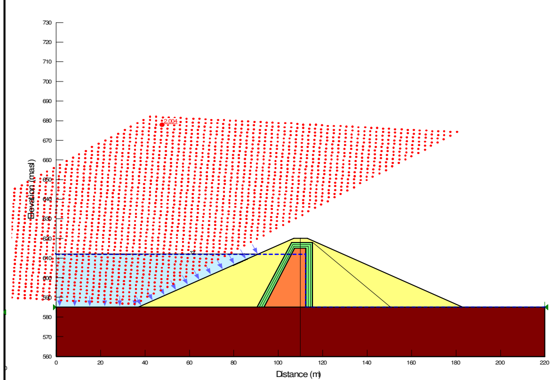
Materials

3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



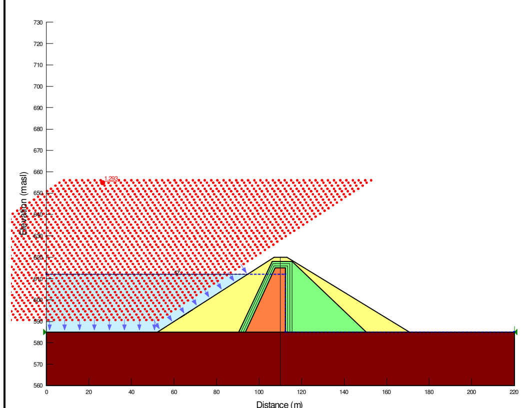
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L25**				
Upstream - Dam full with steady state flow				
Upstream slope:	1:2	V:H		Notes:
Downstream slope:	1:2	V:H		**Upstream slope** analysis
Water level (FSL):	612	masl		with only 3C material in the shell
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 2.004 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



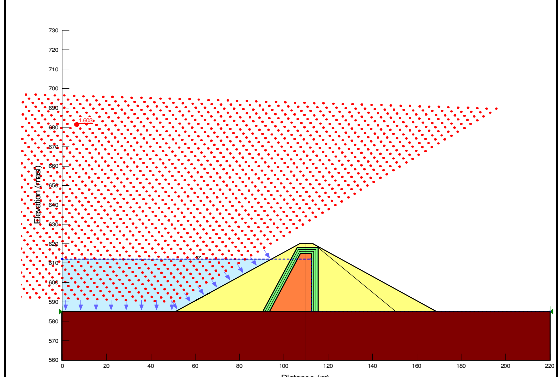
u Dam - Slope Stability Analysis- **Figure L27**				
m full with seismic action				
Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.6	V:H		**Upstream slope Seismic Analysis**
Water level (FSL):	612	masl		analysis with 3C and 3D materials
Crest level (NOC):	620	masl		in the shell
NGL:	585	masl		
Height:	35	m		**FOS = 1.293 > 1.0**
Seismic (Horizontal):	0.1	k	(k*g)	
Seismic (Vertical):	0.1	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



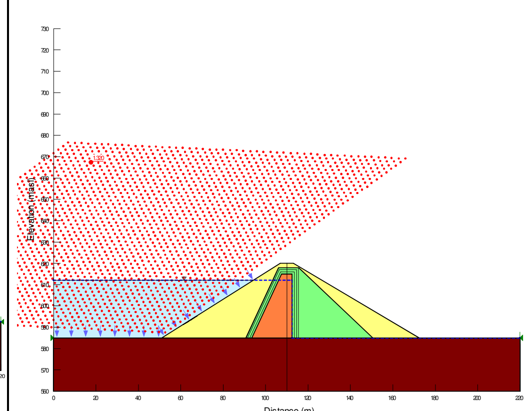
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L26**				
Upstream - Dam full with steady state flow				
Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.6	V:H		**Upstream slope** analysis
Water level (FSL):	612	masl		with only 3C material in the shell
Crest level (NOC):	620	masl		
NGL:	585	masl		**FOS = 1.603 > 1.5**
Height:	35	m		
Seismic (Horizontal):	0	k	(k*g)	
Seismic (Vertical):	0	k	(k*g)	

Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	

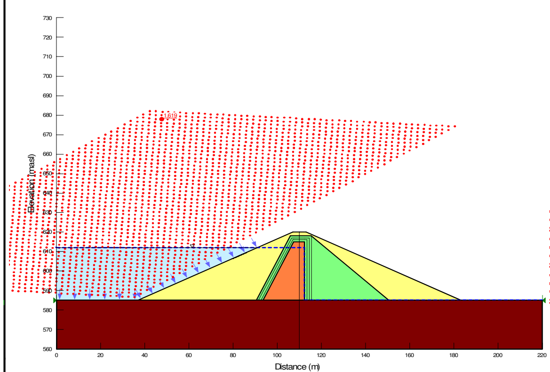


Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L28**				
Upstream - Dam full with seismic action				
Upstream slope:	1:1.6	V:H		Notes:
Downstream slope:	1:1.7	V:H		**Upstream slope Seismic Analysis**
Water level (FSL):	612	masl		analysis with 3C and 3D materials
Crest level (NOC):	620	masl		in the shell
NGL:	585	masl		
Height:	35	m		**FOS = 1.320 > 1.0**
Seismic (Horizontal):	0.1	k	(k*g)	
Seismic (Vertical):	0.1	k	(k*g)	

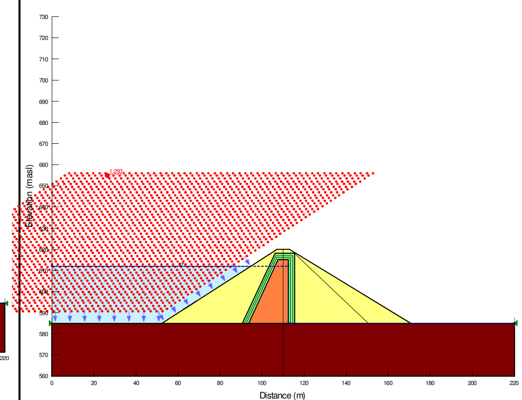
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



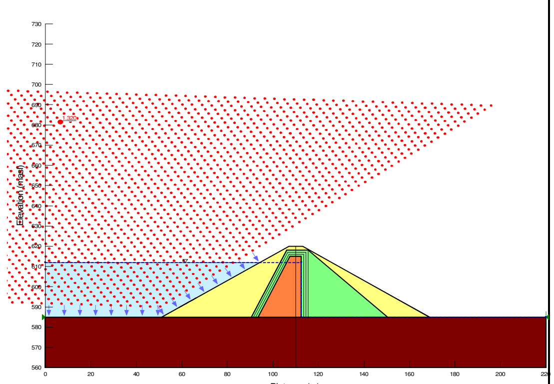
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L29**					
Upstream - Dam full with seismic action					
Upstream slope:	1:2	V:H		Notes:	
Downstream slope:	1:2	V:H		**Upstream slope Seismic Analysis** analysis with 3C and 3D materials in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl			
Height:	35	m		**FOS = 1.619 > 1.0**	
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



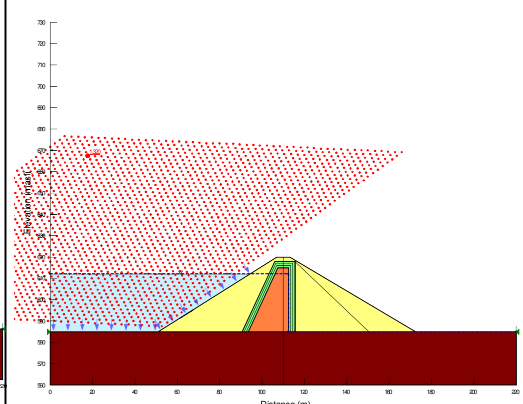
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L31**					
Upstream - Dam full with seismic action					
Upstream slope:	1:1.55	V:H		Notes:	
Downstream slope:	1:1.65	V:H		**Upstream slope Seismic Analysis** with only 3C material in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl		**FOS = 1.293>1.0**	
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



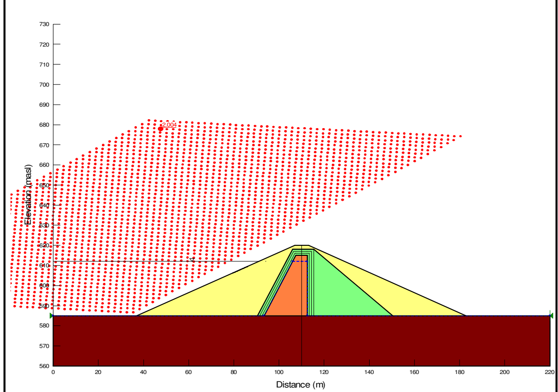
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L30**					
Upstream - Dam full with seismic action					
Upstream slope:	1:1.6	V:H		Notes:	
Downstream slope:	1:1.6	V:H		**Upstream slope Seismic Analysis** analysis with 3C and 3D materials in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl			
Height:	35	m		**FOS = 1.320 > 1.0**	
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



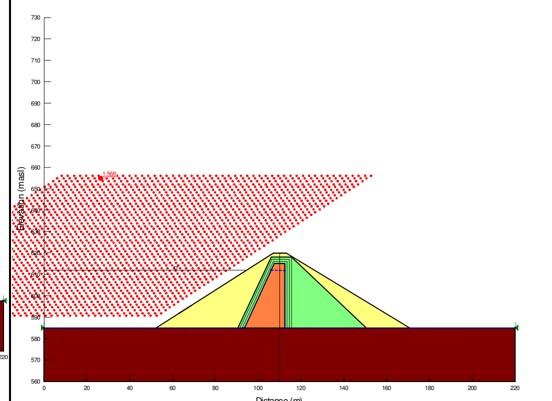
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L32**					
Upstream - Dam full with seismic action					
Upstream slope:	1:1.6	V:H		Notes:	
Downstream slope:	1:1.7	V:H		**Upstream slope Seismic Analysis** with only 3C material in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl		**FOS = 1.320>1.0**	
Height:	35	m			
Seismic (Horizontal):	0.1	k	(k*g)		
Seismic (Vertical):	0.1	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



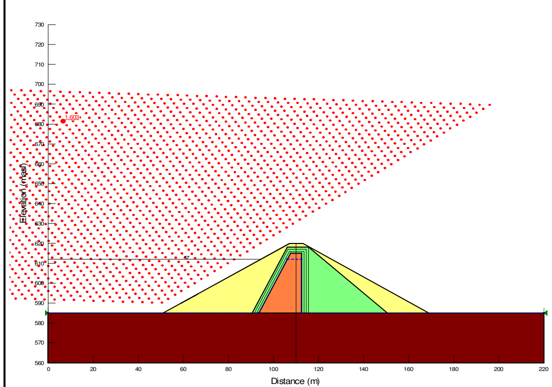
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L33**					
Upstream - Rapid draw down from full supply level					
Upstream slope:	1:2	V:H		Notes:	
Downstream slope:	1:2	V:H		**Downstream slope** analysis with 3C and 3D materials in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl		**FOS = 2.004 > 1.2**	
Height:	35	m			
Seismic (Horizontal):	0	k	(k*g)		
Seismic (Vertical):	0	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



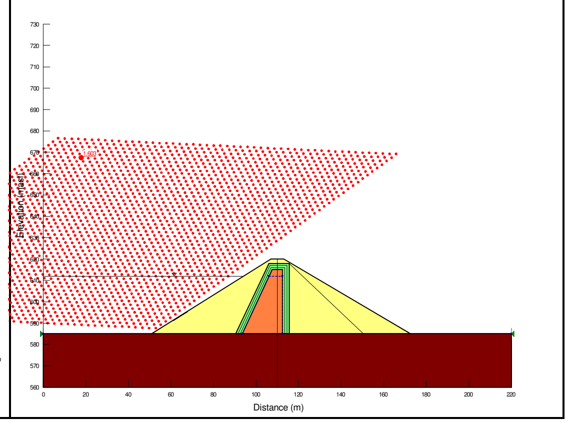
Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L35**					
Upstream - Rapid draw down from full supply level					
Upstream slope:	1:1.55	V:H		Notes:	
Downstream slope:	1:1.65	V:H		**Downstream slope** analysis with 3C and 3D materials in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl			
Height:	35	m		**FOS = 1.568 >1.2**	
Seismic (Horizontal):	0	k	(k*g)		
Seismic (Vertical):	0	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately Weathered Shale)		Clay (Impervious Earthfill Material)	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L34**					
Upstream - Rapid draw down from full supply level					
Upstream slope:	1:1.6	V:H		Notes:	
Downstream slope:	1:1.6	V:H		**Downstream slope** analysis with 3C and 3D materials in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl			
Height:	35	m		**FOS = 1.603 > 1.2**	
Seismic (Horizontal):	0	k	(k*g)		
Seismic (Vertical):	0	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	

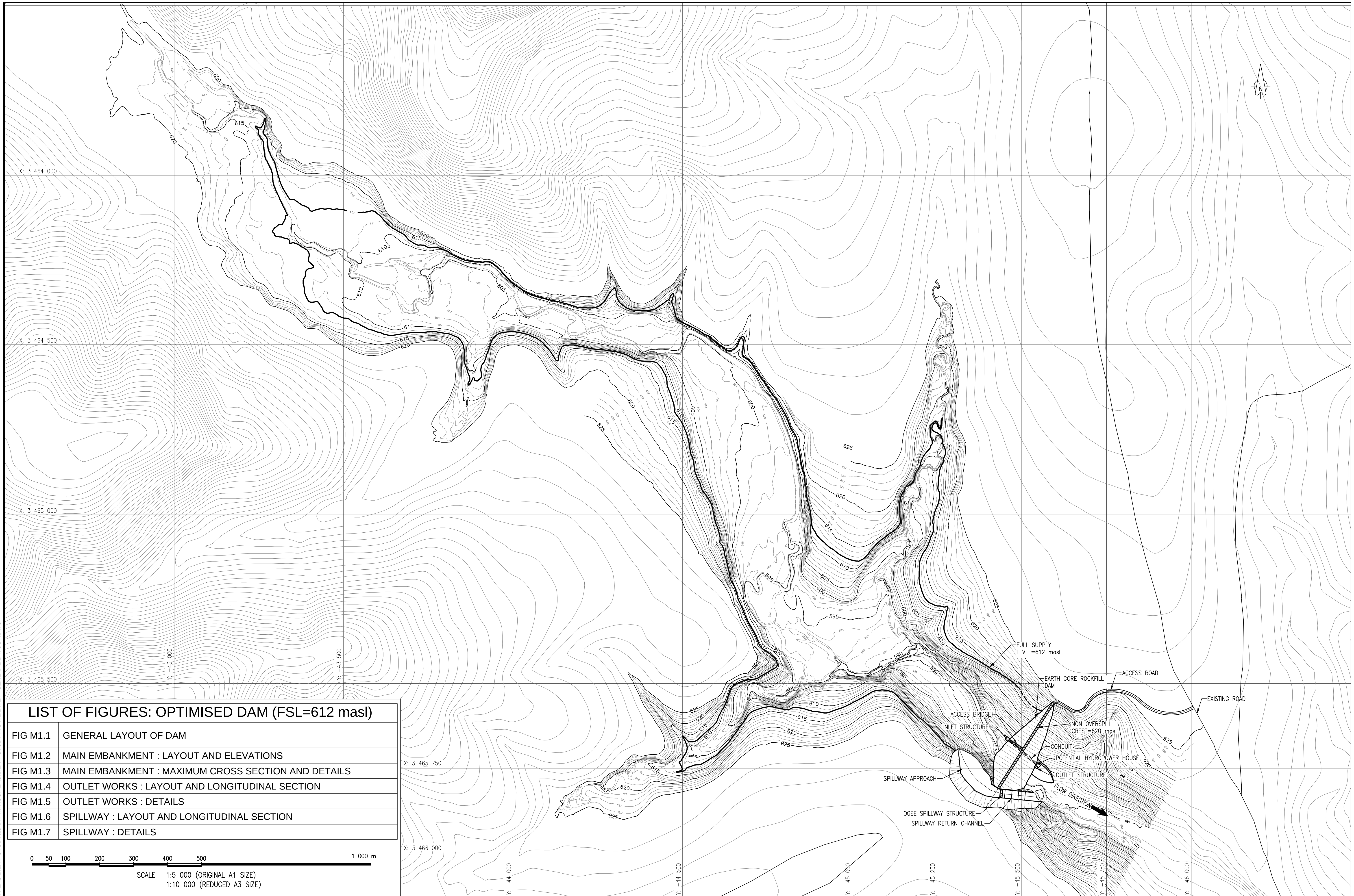


Feasibility Design: Proposed Zalu Dam - Slope Stability Analysis- **Figure L36**					
Upstream - Rapid draw down from full supply level					
Upstream slope:	1:1.6	V:H		Notes:	
Downstream slope:	1:1.7	V:H		**Downstream slope** analysis with 3C and 3D materials in the shell	
Water level (FSL):	612	masl			
Crest level (NOC):	620	masl			
NGL:	585	masl			
Height:	35	m		**FOS = 1.603 >1.2**	
Seismic (Horizontal):	0	k	(k*g)		
Seismic (Vertical):	0	k	(k*g)		
Materials					
3C Rockfill (Dolerite)		3D Rockfill (Moderately		Clay (Impervious	
Yellow		Green		Orange	
Density:	2200 kg/m^3	Density:	2050 kg/m^3	Density:	1300 kg/m^3
ϕ' =	45°	ϕ' =	35°	ϕ' =	26°
C' =	0 kPa	C' =	13 kPa	C' =	23 kPa
Rock (Dolerite)					
Brown					
Density:	2200 kg/m^3	Density:		Density:	
ϕ' =	45°	ϕ' =		ϕ' =	
C' =	0 kPa	C' =		C' =	



Appendix M

Feasibility Design Drawings



LIST OF FIGURES: OPTIMISED DAM (FSL=612 masl)

AECOM

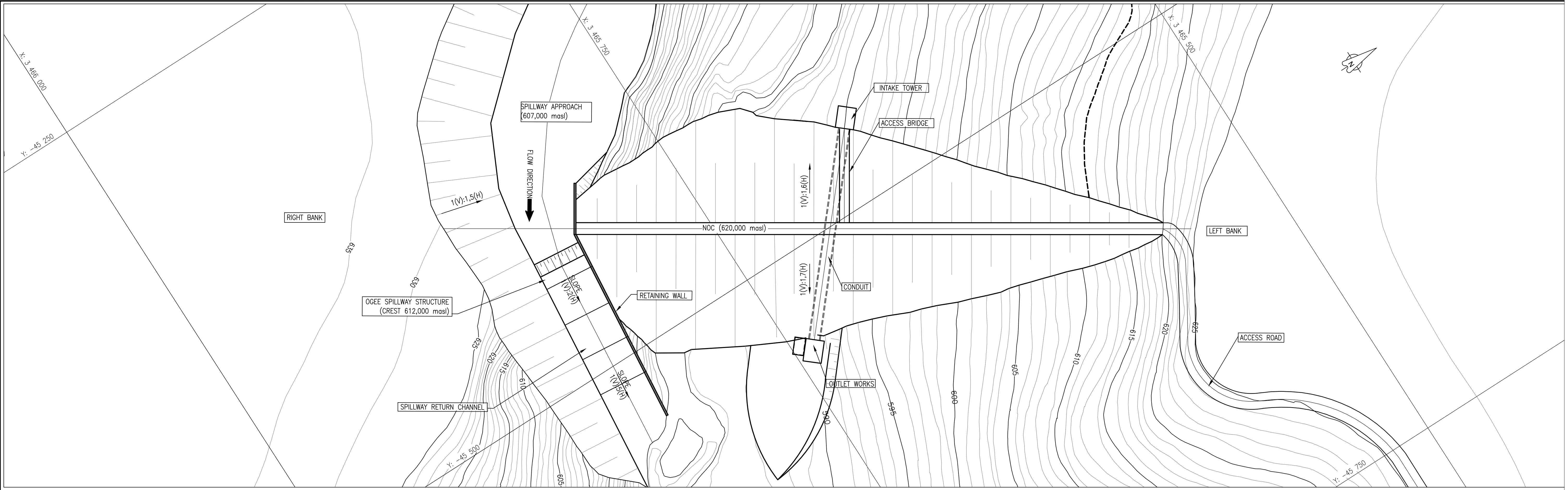
FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED OPTIMISED ZALU DAM GENERAL LAYOUT

AECOM DETAIL/FIGURE No.

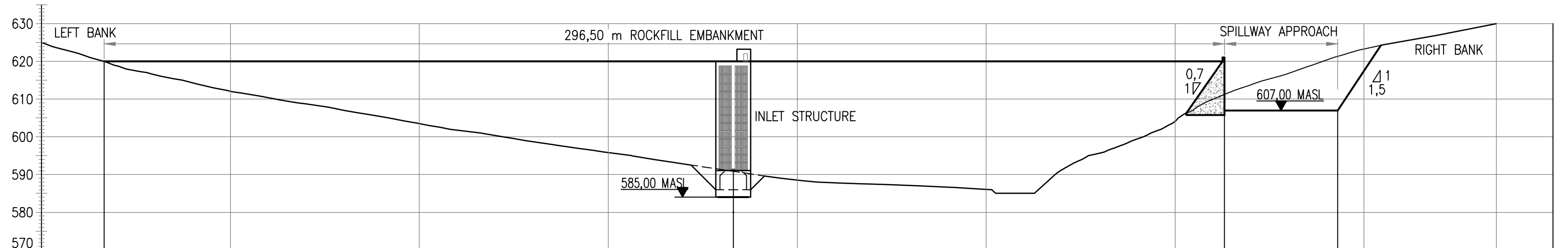
FIG. M1.1

N:\301407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M1.1-M1.7- GENERAL LAYOUT.DWG - 2013 07 04



PLAN OF EMBANKMENT

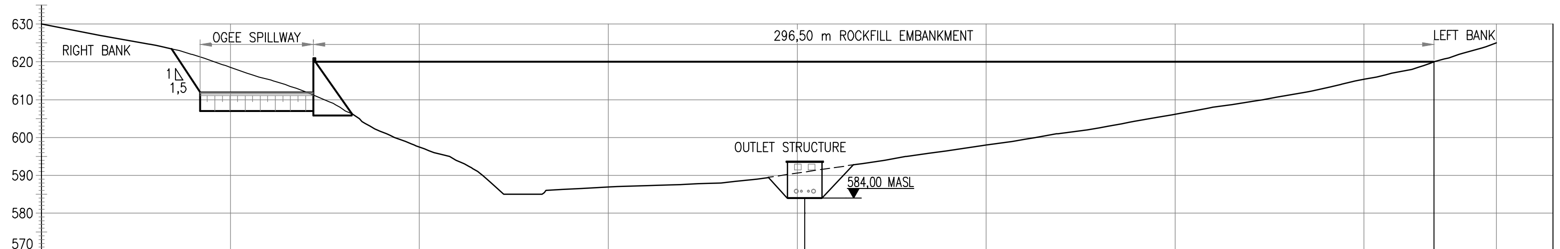
SCALE 1 : 2 000



CHAINAGE (m)	0,00	16,57	50,00	100,00	150,00	183,07	200,00	250,00	300,00	313,07	343,07	350,00	385,05
NATURAL GROUND LEVEL (m)	625,00	620,00	612,85	603,47	595,82	590,90	588,55	586,09	603,97	611,22	621,33	623,31	630,00

UPSTREAM ELEVATION

SCALE 1 : 2 000



CHAINAGE (m)	0,00	50,00	100,00	150,00	200,00	201,38	250,00	300,00	350,00	378,50	385,05
NATURAL GROUND LEVEL (m)	630,00	6108,60	597,49	586,88	590,62	590,90	598,00	606,14	615,40	620,00	625,00

0 10 20 30 40 50 100 200 m

SCALE 1:1 000 (ORIGINAL A1 SIZE)
1:2 000 (REDUCED A3 SIZE)

DOWNSTREAM ELEVATION

SCALE 1 : 2 000

N:\301407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M1.1-M1.7- GENERAL LAYOUT.DWG - 2013/07/04

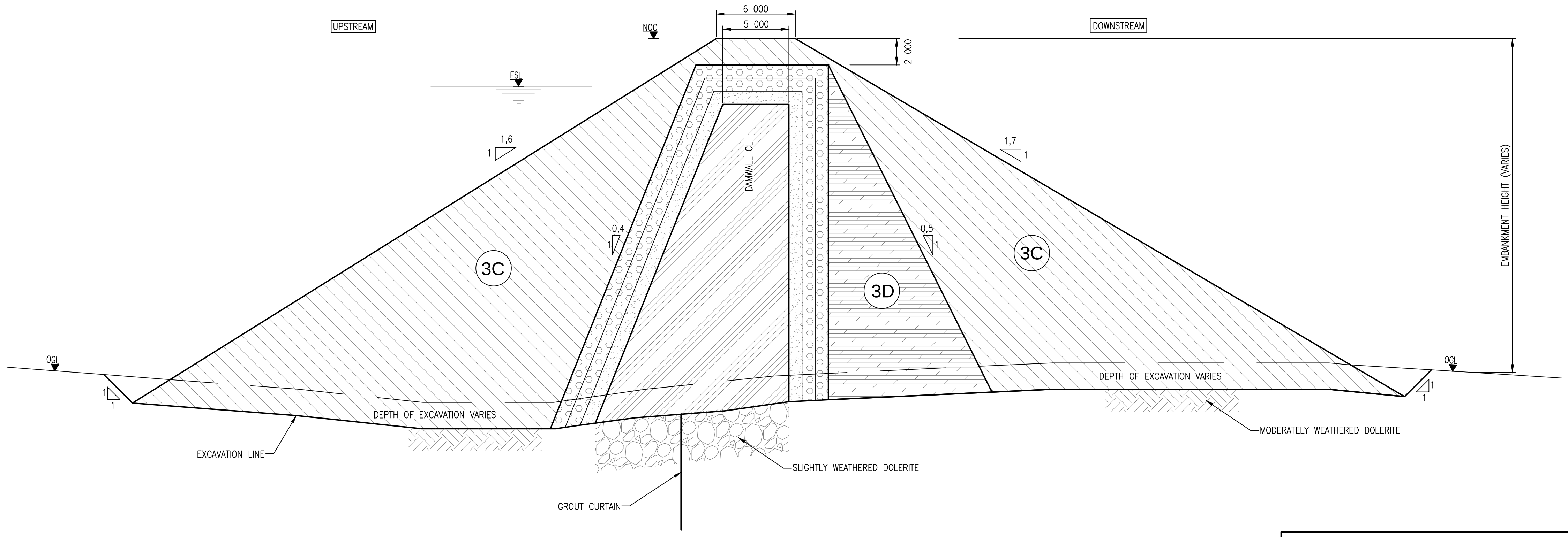
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED OPTIMISED ZALU DAM
MAIN EMBANKMENT - LAYOUT AND ELEVATIONS

AECOM DETAIL/FIGURE No.

FIG. M1.2



TYPICAL CROSS SECTION THROUGH EMBANKMENT

SCALE 1 : 500

0 5 10 20 30 40 50 100 m

SCALE 1 : 500 (ORIGINAL A1 SIZE)
1 : 1 000 (REDUCED A3 SIZE)

LEGEND:

- 3C ROCKFILL (DOLERITE)
- 3D ROCKFILL (MODERATELY WEATHERED SHALE)
- 2 x GRAVEL (PROCESSED DOLERITE) TRANSITION LAYERS (1 m PER LAYER)
- SAND LAYER (COMMERCIAL SOURCE) (1 m PER LAYER)
- IMPERVIOUS EARTHFILL MATERIAL (QUARRY)

N:\J01407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M1.1-M1.7- GENERAL LAYOUT.DWG - 2015-07-04

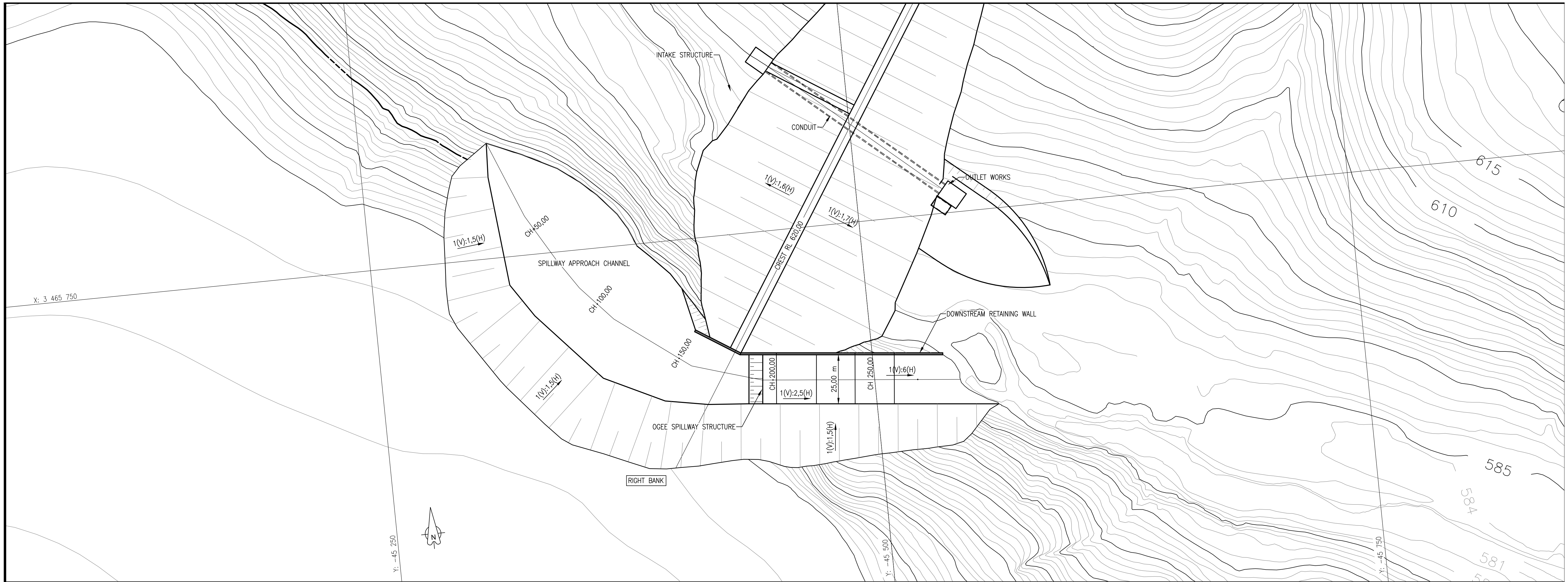
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED OPTIMISED ZALU DAM
MAIN EMBANKMENT - MAXIMUM CROSS SECTION

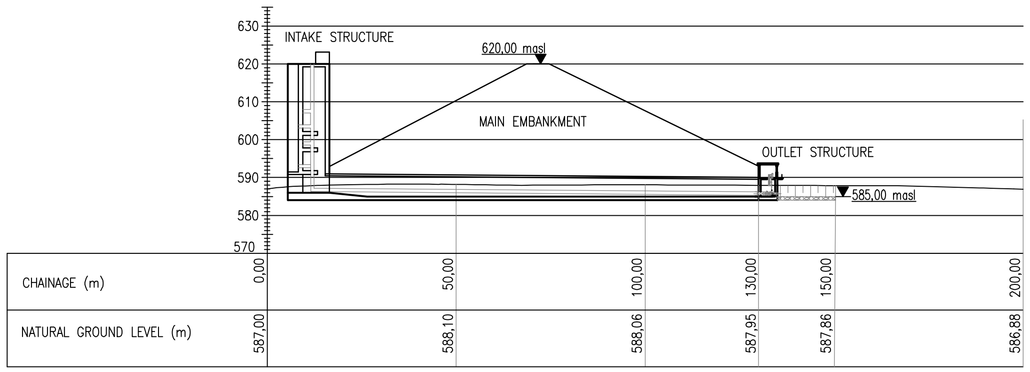
AECOM DETAIL/FIGURE No.

FIG. M1.3



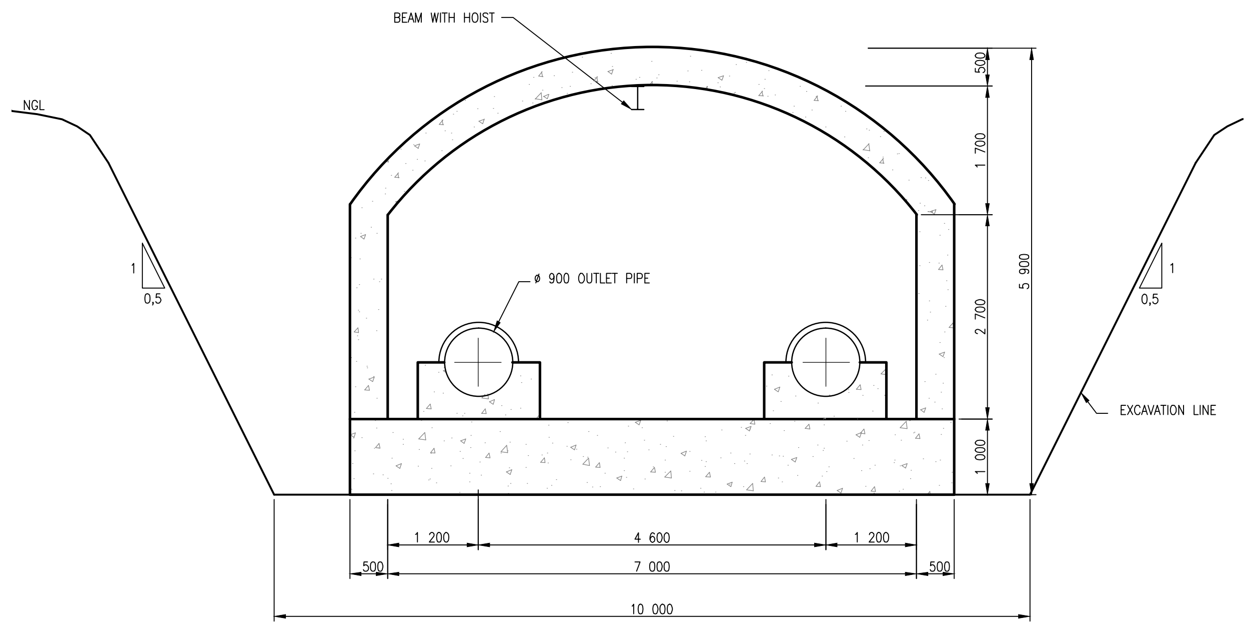
OUTLET WORKS : LAYOUT PLAN

SCALE 1 : 1 000



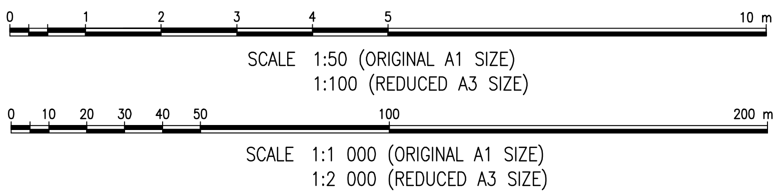
LONGITUDINAL SECTION THROUGH OUTLET WORKS

SCALE 1 : 1 000



CONDUIT TYPICAL CROSS SECTION

SCALE 1 : 50



AECOM

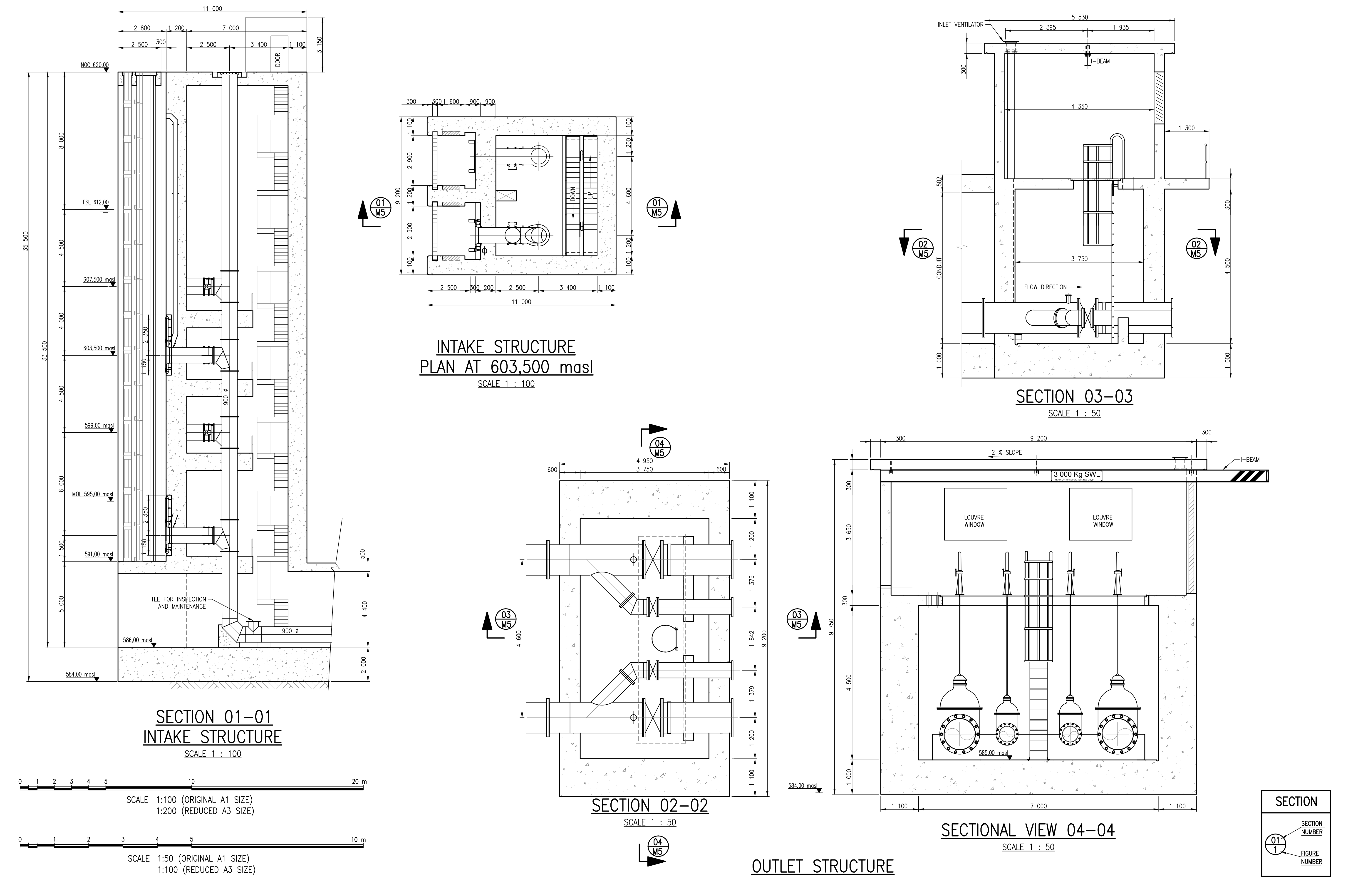
FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED OPTIMISED ZALU DAM
OUTLET WORKS - LAYOUT AND SECTION

AECOM DETAIL/FIGURE No.

FIG. M1.4

N:\J01407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M1.1-M1.7- GENERAL LAYOUT.DWG - 2015.07.04



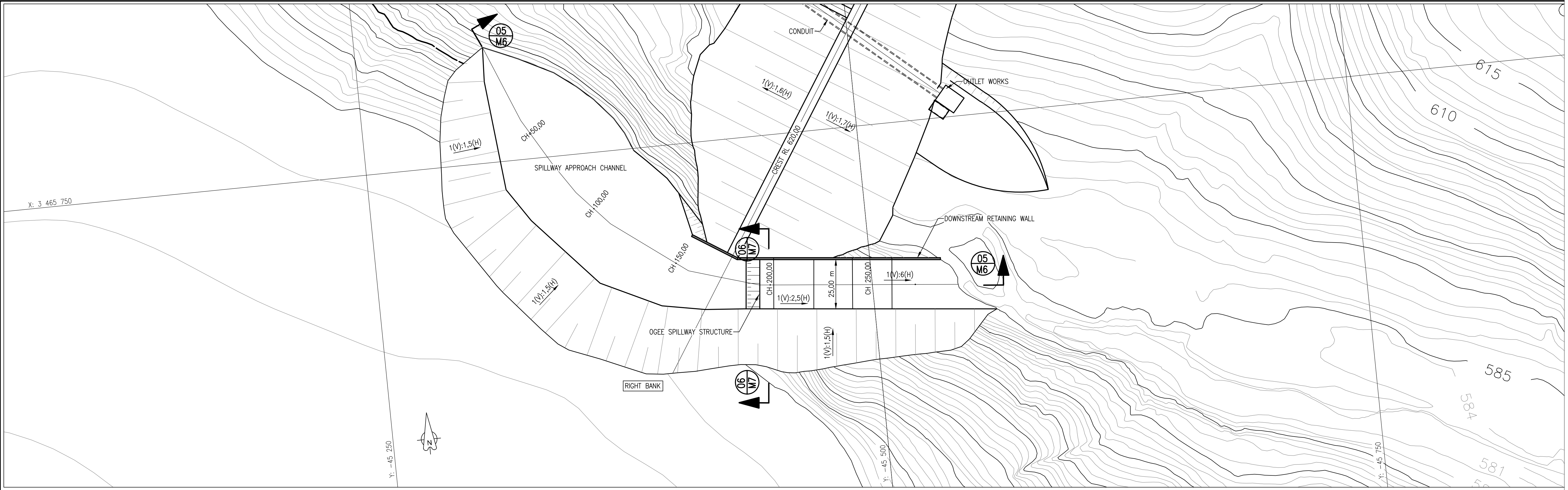
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED OPTIMISED ZALU DAM OUTLET WORKS - DETAILS

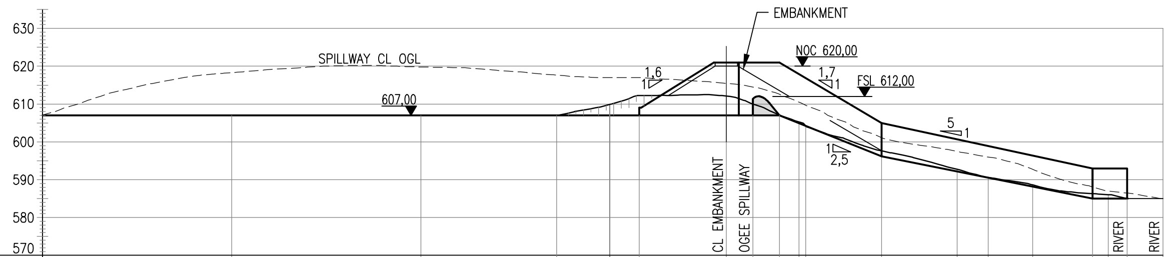
AECOM DETAIL/FIGURE No.

FIG.M1.5



PLAN OF SPILLWAY

SCALE 1 : 1 000



CHAINAGE (m)	0,00	50,00	100,00	135,90	150,00	157,77	180,77	187,80	194,80	200,00	201,80	221,80	241,80	250,00	261,80	277,62	281,80	281,80	296,25
SPILLWAY CENTRE LINE NATURAL GROUND LEVEL (m)	607,00	618,30	619,78	617,07	616,98	616,98	609,55	614,53	612,60	610,05	609,58	601,10	597,46	596,05	598,64	588,00	586,97	586,97	585,00
SPILLWAY LEFT FLANK NATURAL GROUND LEVEL (m)				607,00	610,00	612,27	604,35	610,00	607,10	605,29	604,52	597,61	592,74	590,59	592,78	586,32	586,05	586,05	
SPILLWAY FLOOR LEVEL (m)	607,00								607,00		604,20	596,20	592,19		588,17	585,00	585,00	585,00	585,00
SPILLWAY RETAINING WALL TOP (m)						609,00	621,00		621,00			605,00				593,00		593,00	
HECRAS SECTIONS										HR 100		HR 80	HR 60		HR 40	HR 20			

LONGITUDINAL SECTION 05–05

SCALE 1 : 1 000

0 10 20 30 40 50 100 200m

SCALE 1:1 000 (ORIGINAL A1 SIZE)
SCALE 1:2 000 (REDUCED A3 SIZE)

SECTION

01 / 1 — SECTION NUMBER / FIGURE NUMBER

N:\J01407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M1.1-M1.7- GENERAL LAYOUT.DWG - 2013-07-04

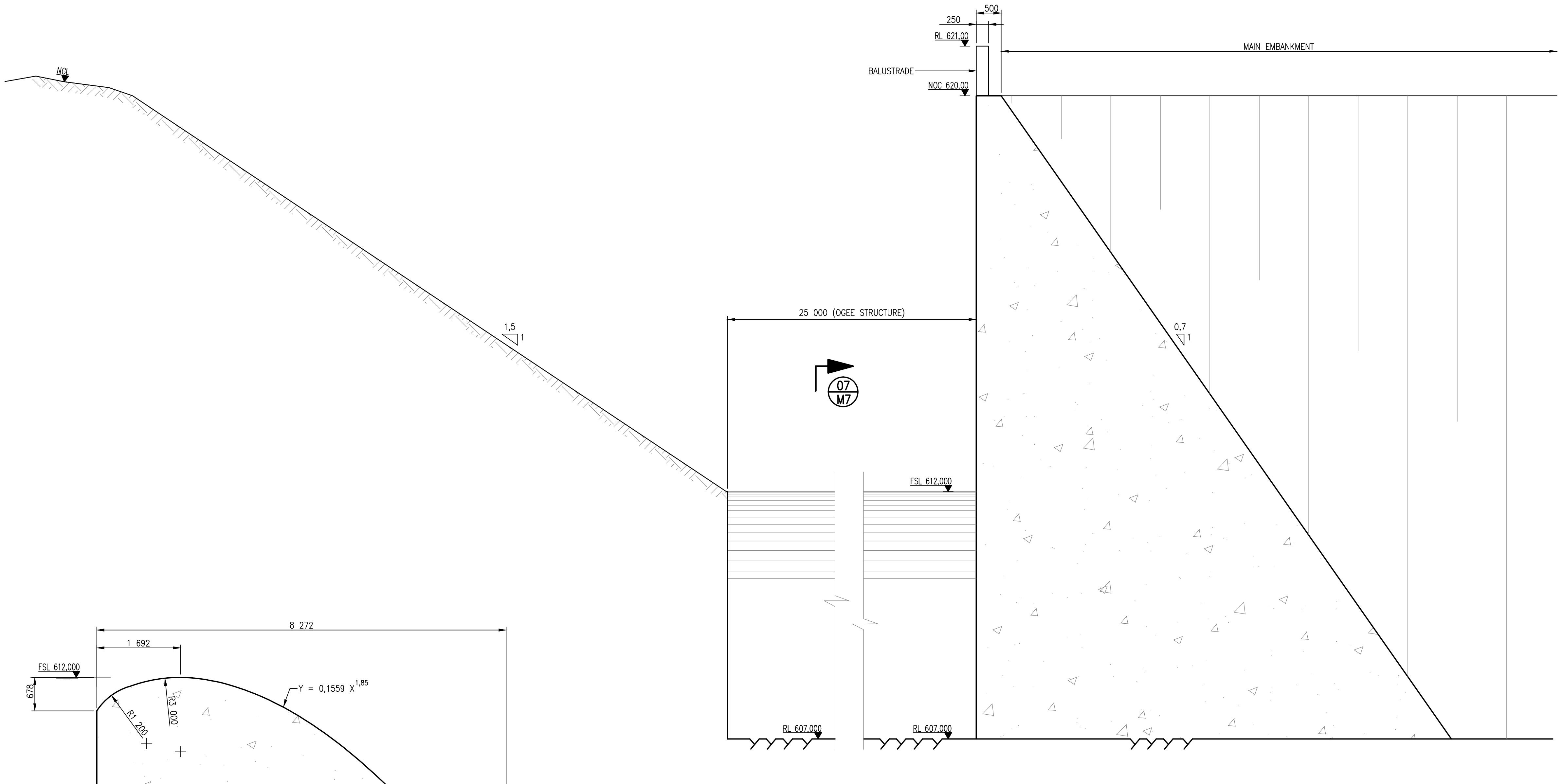
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED OPTIMISED ZALU DAM SPILLWAY - LAYOUT AND SECTION

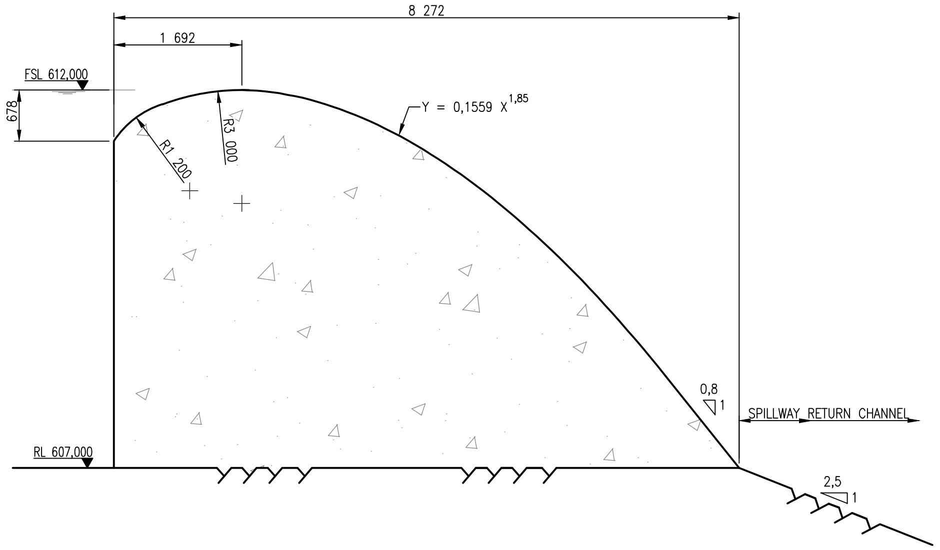
AECOM DETAIL/FIGURE No.

FIG. M1.6



SECTIONAL VIEW 06–06

SCALE 1 : 50

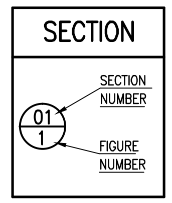


SECTION 07–07

SCALE 1 : 50

0 1 2 3 4 5 10 m

SCALE 1:50 (ORIGINAL A1 SIZE)
1:100 (REDUCED A3 SIZE)



AECOM

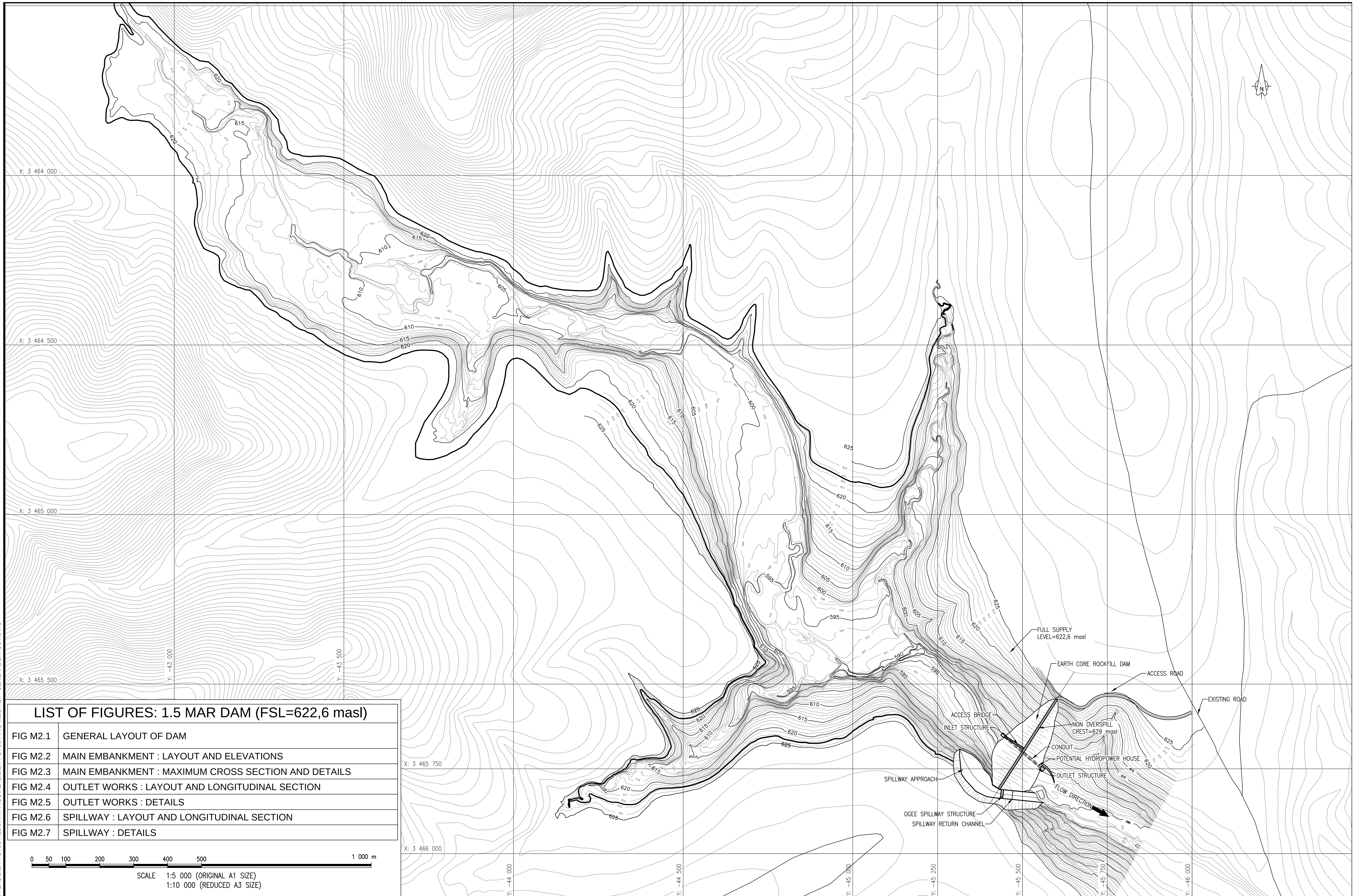
FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED OPTIMISED ZALU DAM SPILLWAY - DETAILS

AECOM DETAIL/FIGURE No.

FIG. M1.7

N:\J01407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M1.1-M1.7- GENERAL LAYOUT.DWG - 2013-07-04



LIST OF FIGURES: 1.5 MAR DAM (FSL=622,6 masl)

0 50 100 200 300 400 500 1 000 m

SCALE 1:5 000 (ORIGINAL A1 SIZE)
1:10 000 (REDUCED A3 SIZE)

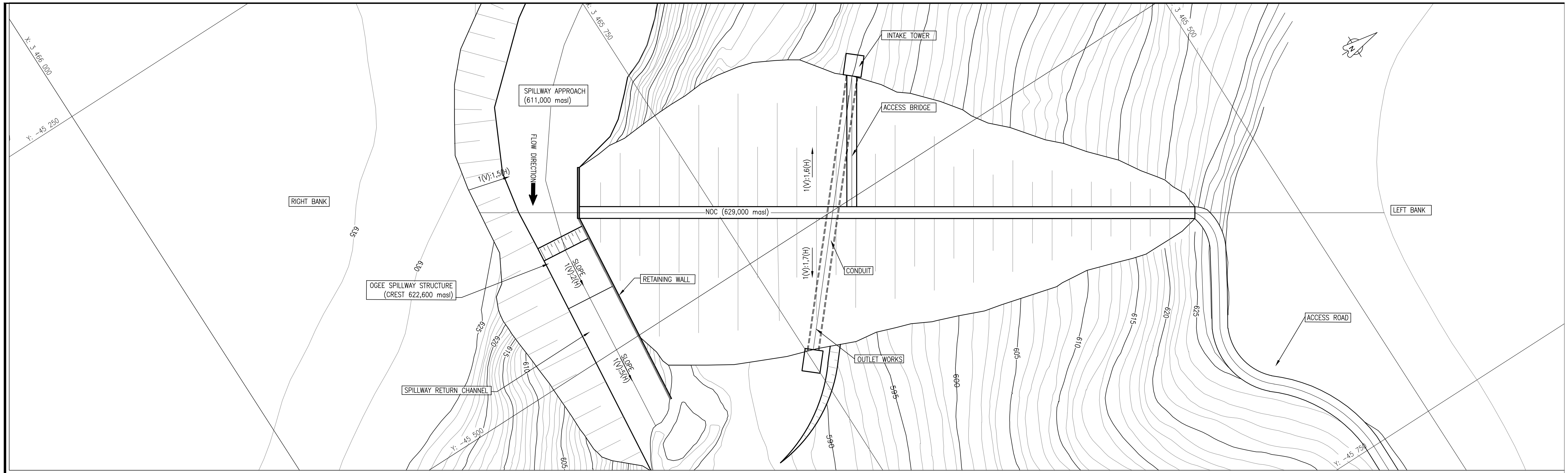
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED 1,5 MAR ZALU DAM GENERAL LAYOUT

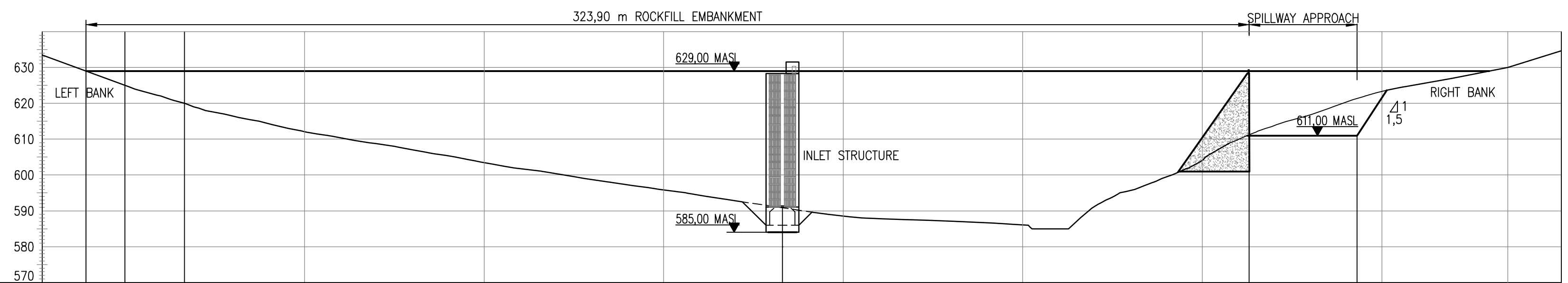
AECOM DETAIL/FIGURE No.

FIG. M2.1



PLAN OF EMBANKMENT

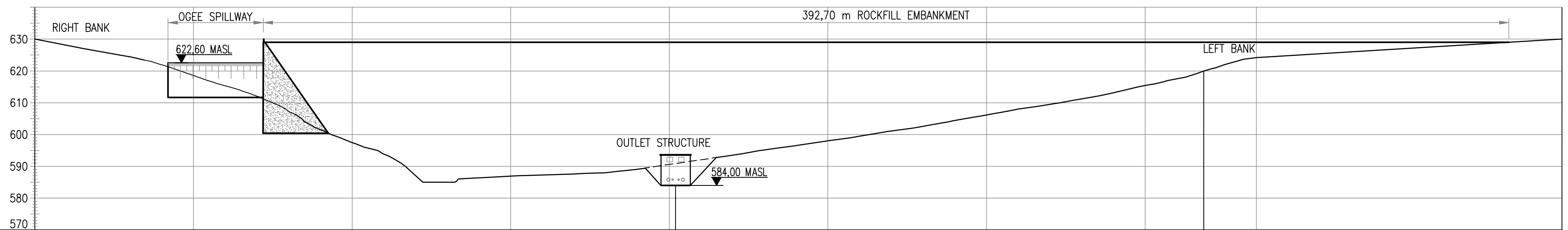
SCALE 1 : 2 000



CHAINAGE (m)	-23,05	-10,28	0,00	16,57	50,00	100,00	150,00	183,07	200,00	250,00	300,00	313,07	343,07	350,00	385,06
NATURAL GROUND LEVEL (m)	625,00	625,00	625,00	620,00	612,85	603,47	595,82	590,90	588,55	586,09	603,97	611,22	621,33	623,31	630,00

UPSTREAM ELEVATION

SCALE 1 : 2 000



CHAINAGE (m)	0,00	50,00	100,00	150,00	200,00	201,98	250,00	300,00	350,00	368,50	385,08	481,04
NATURAL GROUND LEVEL (m)	630,00	6108,60	597,49	586,88	590,62	590,90	598,00	606,14	615,40	620,00	625,00	630,00

0 10 20 30 40 50 100 200 m

SCALE 1:1 000 (ORIGINAL A1 SIZE)
1:2 000 (REDUCED A3 SIZE)

DOWNSTREAM ELEVATION

SCALE 1 : 2 000

N:\301407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M2.1-M2.7- GENERAL LAYOUT.DWG - 2015.07.04

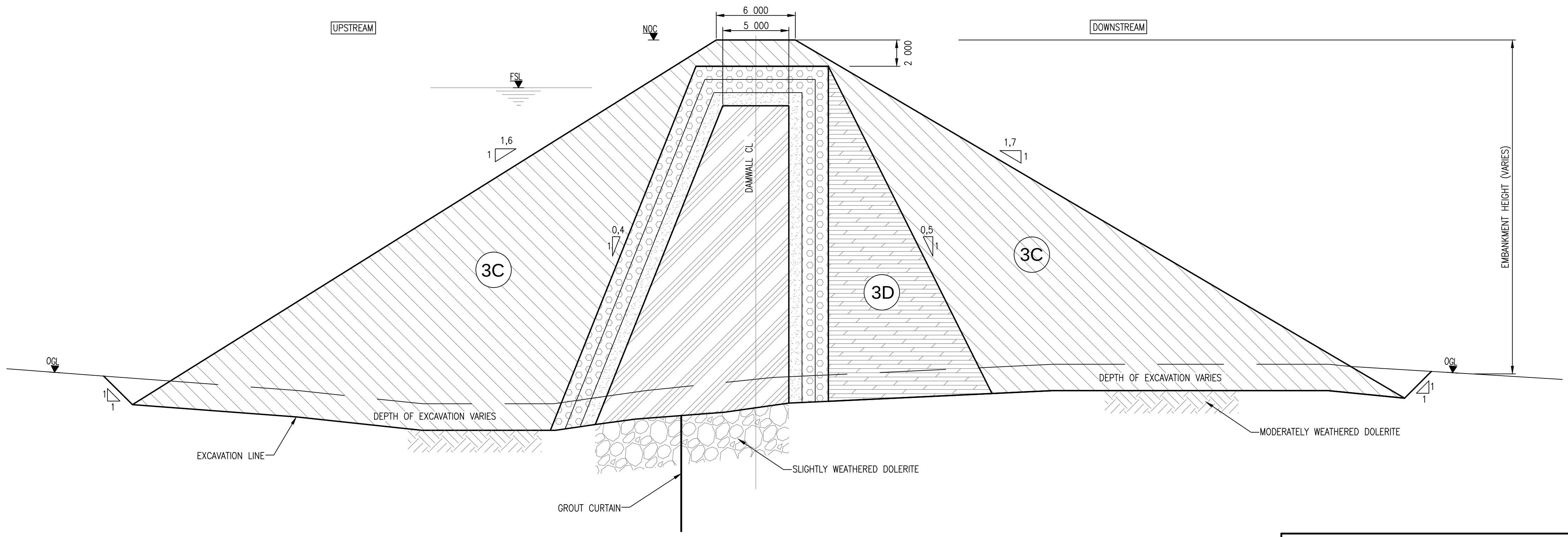
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE
LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED 1,5 MAR ZALU DAM
MAIN EMBANKMENT - LAYOUT AND ELEVATIONS

AECOM DETAIL/FIGURE No.

FIG. M2.2



TYPICAL CROSS SECTION THROUGH EMBANKMENT

SCALE 1 : 500

0 5 10 20 30 40 50 100 m

SCALE 1 : 500 (ORIGINAL A1 SIZE)
1 : 1 000 (REDUCED A3 SIZE)

LEGEND:

- 3C ROCKFILL (DOLERITE)
- 3D ROCKFILL (MODERATELY WEATHERED SHALE)
- 2 x GRAVEL (PROCESSED DOLERITE) TRANSITION LAYERS (1 m PER LAYER)
- SAND LAYER (COMMERCIAL SOURCE) (1 m PER LAYER)
- IMPERVIOUS EARTHFILL MATERIAL (QUARRY)

N:\301407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M2.1-M2.7- GENERAL LAYOUT.DWG - 2015-07-04

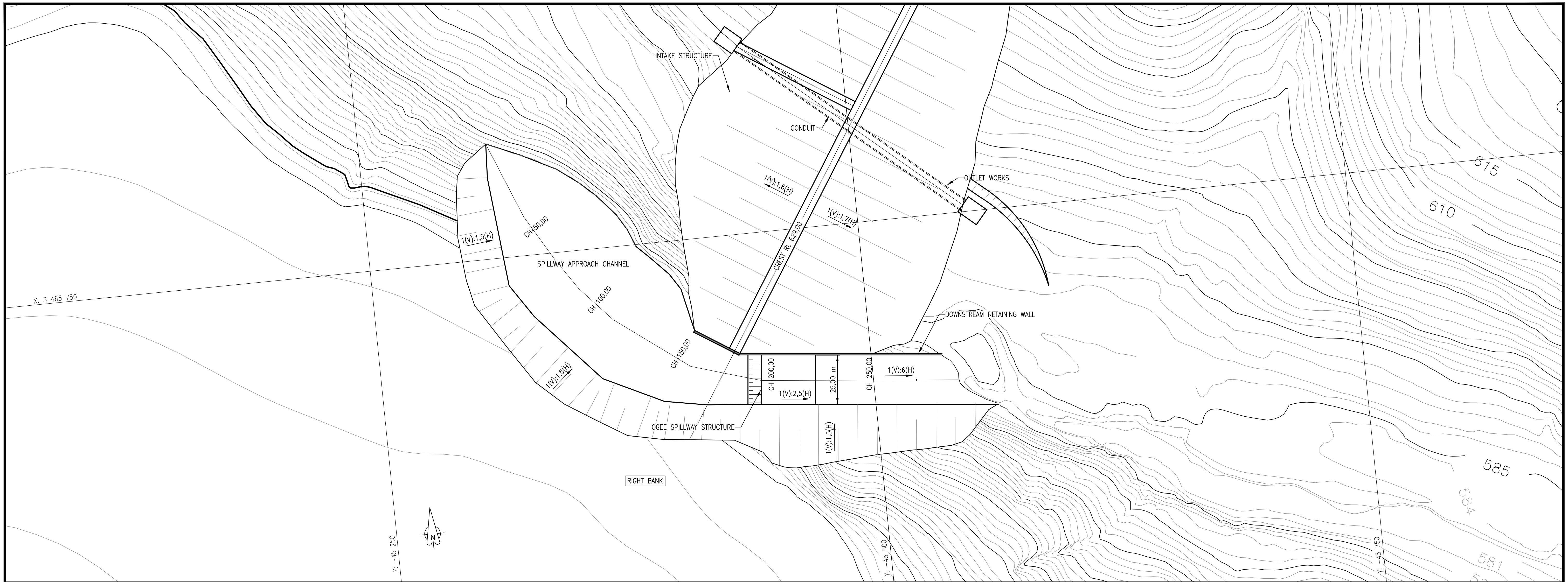
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED 1,5 MAR ZALU DAM
MAIN EMBANKMENT - MAXIMUM CROSS SECTION

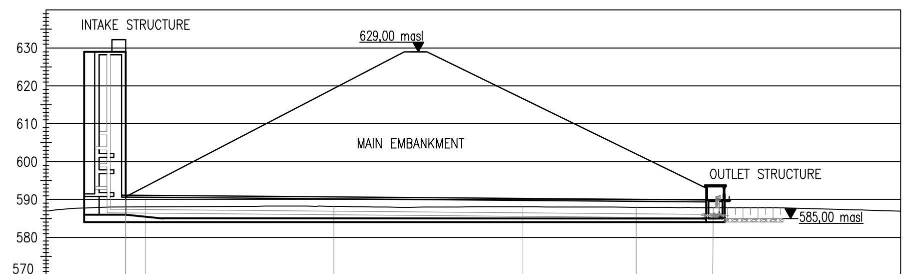
AECOM DETAIL/FIGURE No.

FIG. M2.3



OUTLET WORKS : LAYOUT PLAN

SCALE 1 : 1 000



CHAINAGE (m)	–24,08	0,00	50,00	100,00	130,00	150,00	200,00
NATURAL GROUND LEVEL (m)		587,00	588,10	588,06	587,95	587,86	586,88

LONGITUDINAL SECTION THROUGH OUTLET WORKS

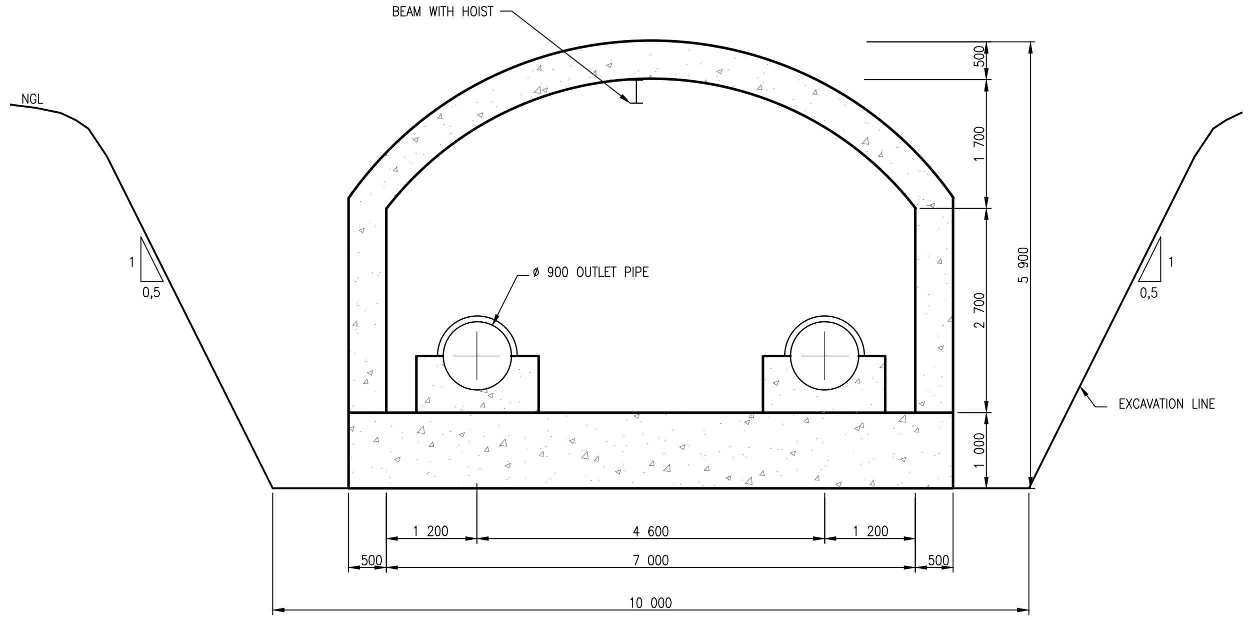
SCALE 1 : 1 000

0 1 2 3 4 5 10 m

SCALE 1:50 (ORIGINAL A1 SIZE)
1:100 (REDUCED A3 SIZE)

0 10 20 30 40 50 100 200 m

SCALE 1:1 000 (ORIGINAL A1 SIZE)
1:2 000 (REDUCED A3 SIZE)



CONDUIT TYPICAL CROSS SECTION

SCALE 1 : 50

AECOM

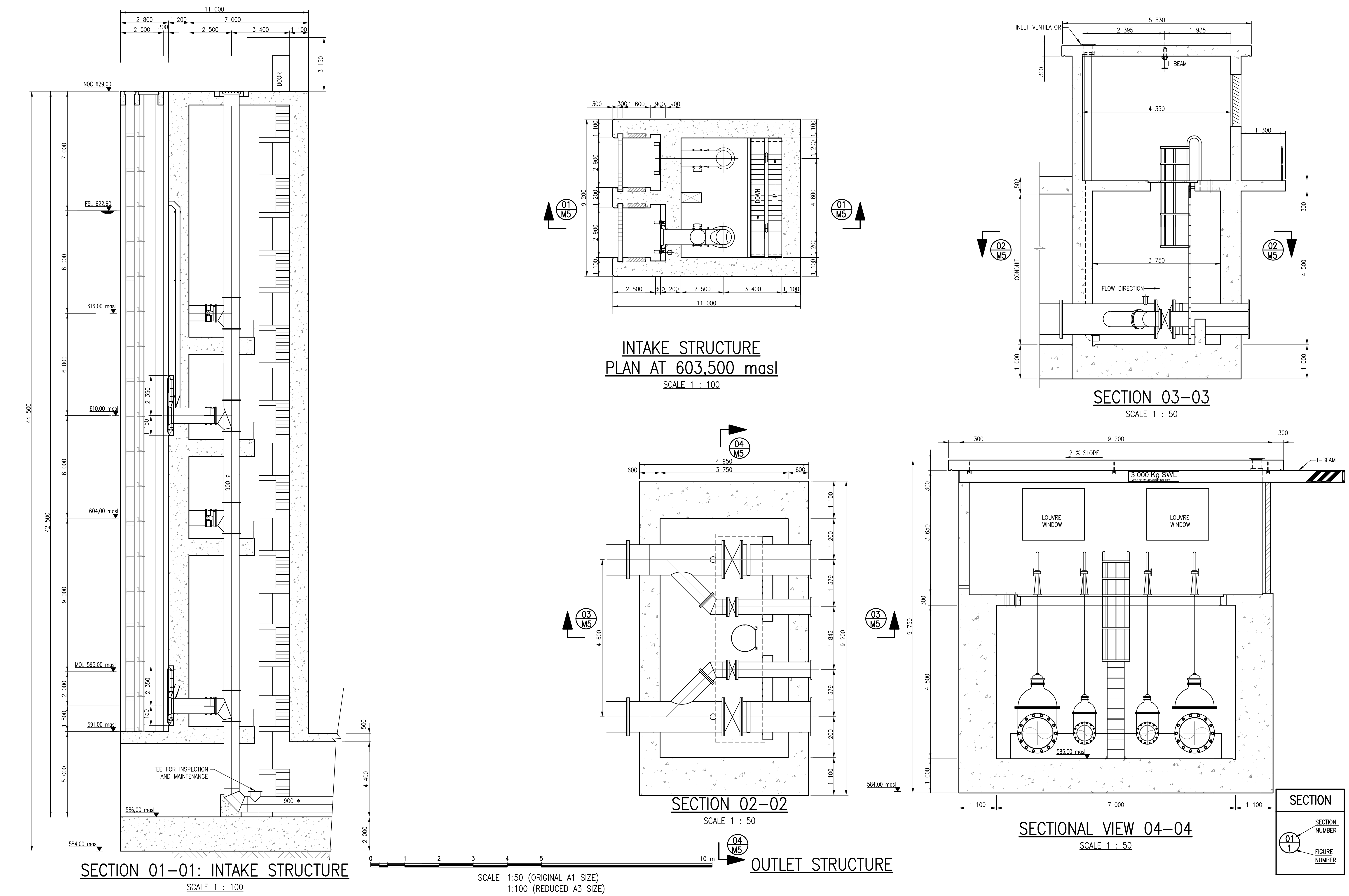
FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED 1,5 MAR ZALU DAM
OUTLET WORKS - LAYOUT AND SECTION

AECOM DETAIL/FIGURE No.

FIG. M2.4

N:\J01407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M2.1-M2.7 - GENERAL LAYOUT.DWG -



AECOM

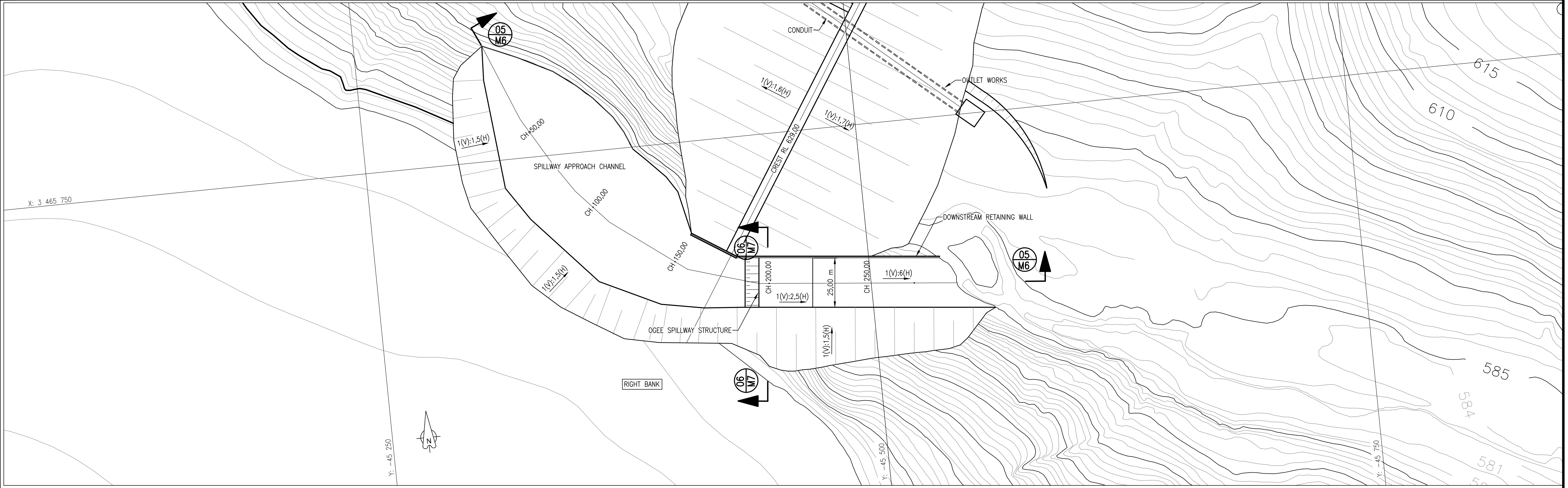
FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED 1,5 MAR ZALU DAM OUTLET WORKS - DETAILS

AECOM DETAIL/FIGURE No.

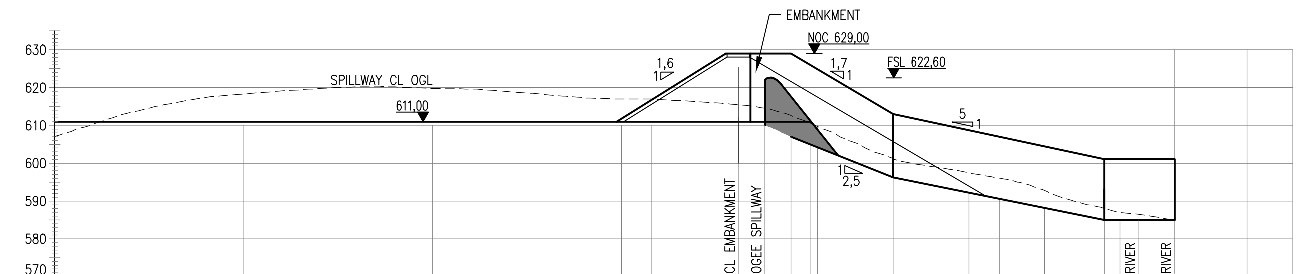
FIG.M2.5

N:\J01407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M2.1-M2.7- GENERAL LAYOUT.DWG -



PLAN OF SPILLWAY

SCALE 1 : 1 000

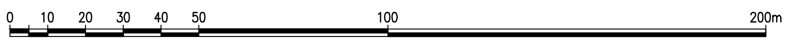


	CL EMBANKMENT	OGEE SPILLWAY	RIVER	RIVER

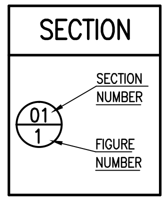
CHAINAGE (m)	SPILLWAY CENTRE LINE NATURAL GROUND LEVEL (m)	SPILLWAY LEFT FLANK NATURAL GROUND LEVEL (m)	SPILLWAY FLOOR LEVEL (m)	SPILLWAY RETAINING WALL TOP (m)	HECRAS SECTIONS
0,00	607,00		607,00		
50,00	618,30				
100,00	619,78				
150,00	616,98	610,00		611,00	
157,77	616,98	612,27			
180,77 (CL EMBANKMENT)	609,55	604,35	611,00	629,00	
187,80 (OGEE SPILLWAY)	614,53	610,00	611,00		
194,80	612,60	607,10		629,00	
200,00	610,05	605,29	607,00		HR 100
201,80	609,58	604,52	604,20		
221,80	601,10	597,61	596,20	613,00	HR 80
241,80	597,46	592,74	592,19		HR 60
250,00	596,05	590,59			
261,80	598,64	592,78	588,17		HR 40
277,62	588,00	586,32	585,00	601,00	
281,80	586,97	586,05	585,00		HR 20
281,80 (RIVER)	586,97	586,05	585,00		
296,25 (RIVER)	585,00		585,00	601,00	

LONGITUDINAL SECTION 05–05

SCALE 1 : 1 000



SCALE 1:1 000 (ORIGINAL A1 SIZE)
SCALE 1:2 000 (REDUCED A3 SIZE)



N:\J01407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M2.1-M2.7- GENERAL LAYOUT.DWG -

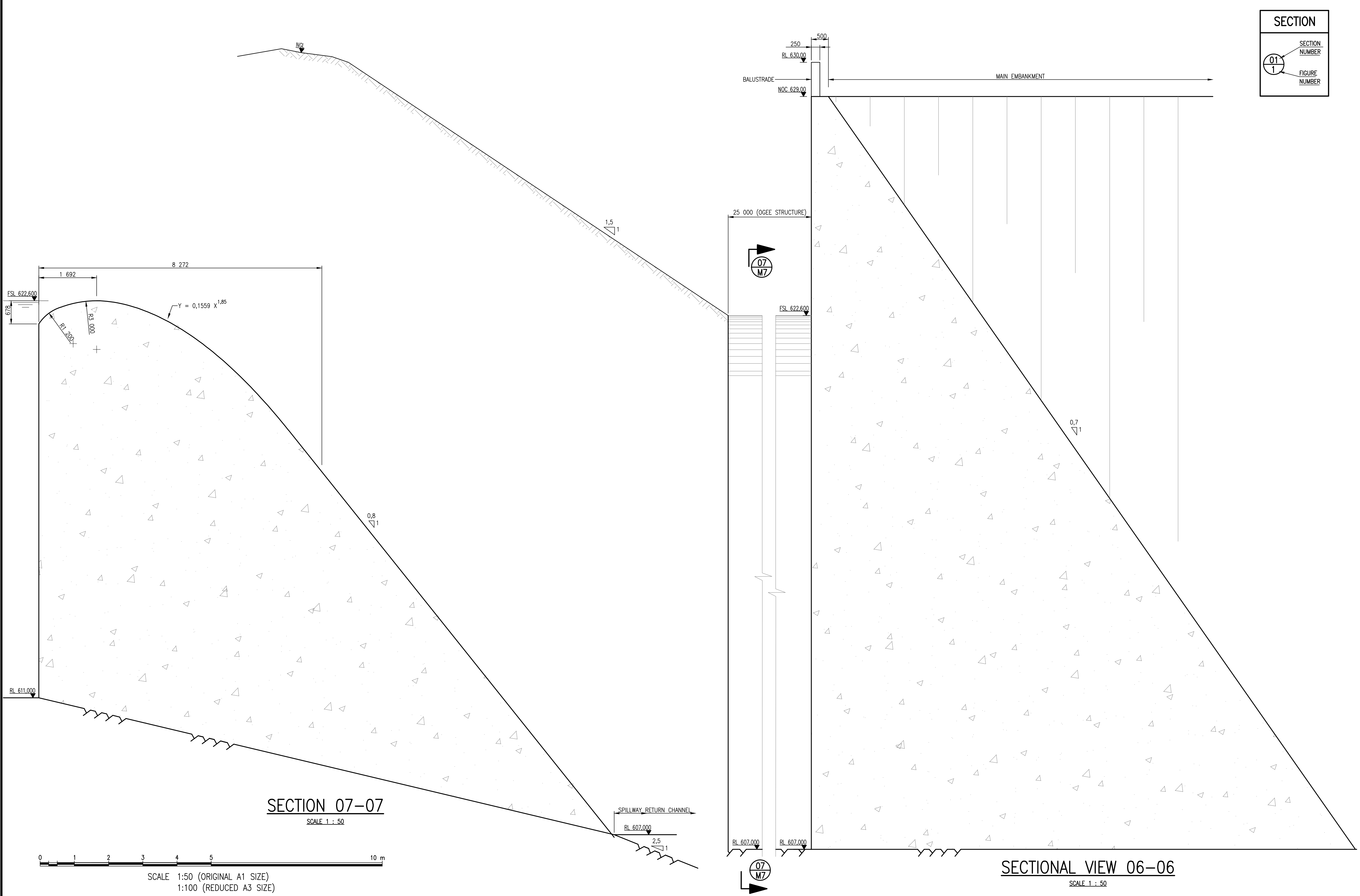
AECOM

FEASIBILITY STUDY FOR AUGMENTATION OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED 1,5 MAR ZALU DAM SPILLWAY - LAYOUT AND SECTION

AECOM DETAIL/FIGURE No.

FIG. M2.6



FEASIBILITY STUDY FOR AUGMENTATION OF THE
LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

FEASIBILITY DESIGN: PROPOSED 1,5 MAR ZALU DAM
SPILLWAY - DETAILS

AECOM DETAIL/FIGURE No.

FIG. M2.7

N:\J01407 - LUSIKISIKI FEASIBILITY STUDY\15 DRAWINGS\FEASIBILITY STUDY\FIG M2.6 GENERAL LAYOUT.DWG - 2013-07-04

Appendix N

Draw Down Table and Curve

Feasibility Study: Proposed Zalu dam (FSL = 612 masl)
Draw - Down through 1 x 900 mm diameter outlet pipe

Full Supply Level = 612 masl
Minimum Operating Level = 595 masl (MOL)

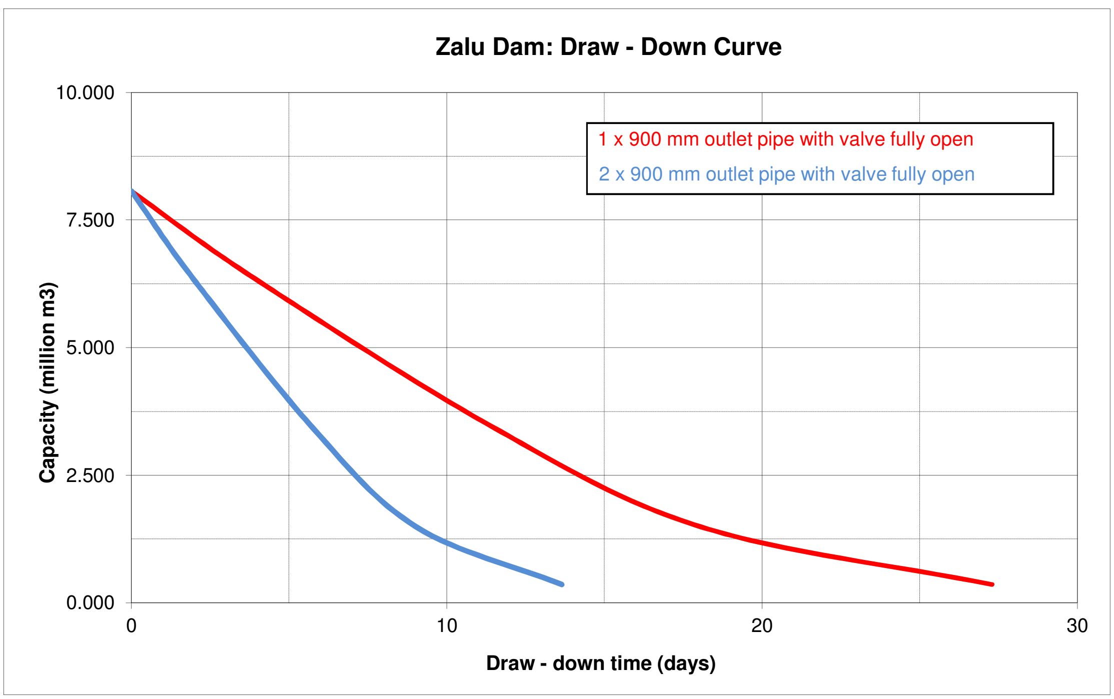
Discharge through 900mm diameter pipe
$Q = CA^*(2gH)^{0,5}$ … C = 0,45
pipe size = 0.9

<u>Draw - Down Table: 1 x 900 mm diameter pipe with valve fully open</u>

Water depth (m)	Capacity (million m3)	Qout (m3/s)	Qout avg (m3/s)	Change in capacity (million m3)	Change in time (days)	Tot time (days)
612.0	8.067	5.228			0	0
610.0	6.357	4.911	5.070	1.710	3.9	3.9
605.0	3.427	4.010	4.461	2.930	7.6	11.5
600.0	1.493	2.835	3.423	1.934	6.5	18.0
595.0	0.361	0.000	1.418	1.132	9.2	27.3

<u>Draw - Down Table: 2 x 900 mm diameter pipe with valve fully open</u>

Water depth (m)	Capacity (million m3)	Qout (m3/s)	Qout avg (m3/s)	Change in capacity (million m3)	Change in time (days)	Tot time (days)
612.0	8.067	10.457			0	0
610.0	6.357	9.822	10.139	1.710	2.0	2.0
605.0	3.427	8.020	8.921	2.930	3.8	5.8
600.0	1.493	5.671	6.845	1.934	3.3	9.0
595.0	0.361	0.000	2.835	1.132	4.6	13.6



Feasibility Study: Proposed 1,5 MAR Zalu dam (FSL = 622.6 masl)
Draw - Down through 1 x 900 mm diameter outlet pipe

Full Supply Level = 622,6 masl
Minimum Operating Level = 595 masl (MOL)

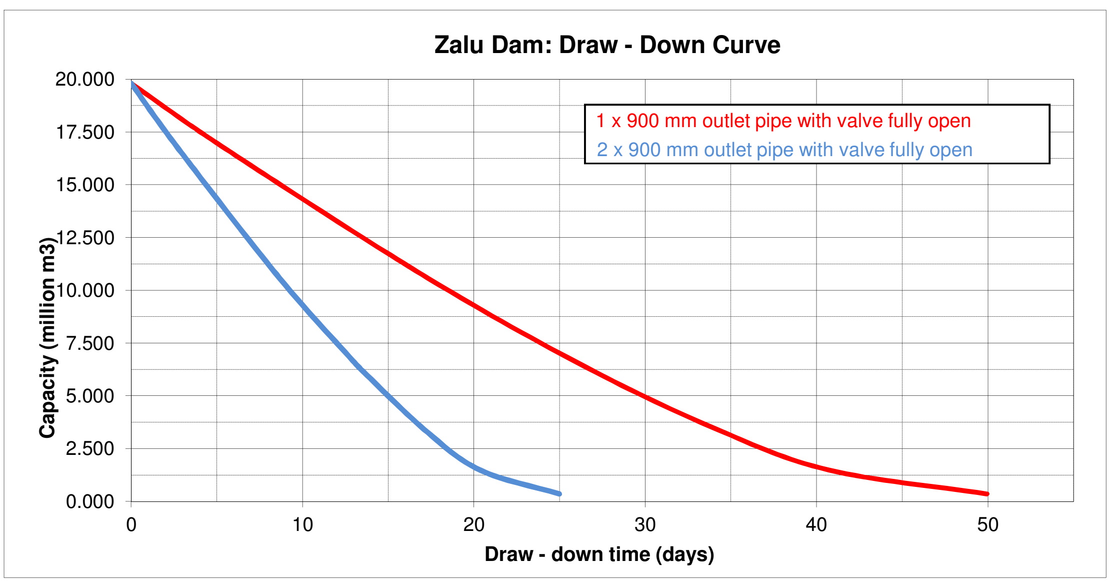
Discharge through 900mm diameter pipe
$Q = CA^*(2gH)^{0,5}$ … C = 0,45
pipe size = 0.9

Draw - Down Table: 1 x 900 mm diameter pipe with valve fully open

Water depth (m)	Capacity (million m3)	Qout (m3/s)	Qout avg (m3/s)	Change in capacity (million m3)	Change in time (days)	Tot time (days)
622.6	19.800	6.662			0	0
620.0	16.700	6.340	6.501	3.100	5.5	5.5
615.0	10.600	5.671	6.006	6.100	11.8	17.3
610.0	6.357	4.911	5.291	4.243	9.3	26.6
605.0	3.427	4.010	4.461	2.930	7.6	34.2
600.0	1.493	2.835	3.423	1.934	6.5	40.7
595.0	0.361	0.000	1.418	1.132	9.2	49.94

Draw - Down Table: 2 x 900 mm diameter pipe with valve fully open

Water depth (m)	Capacity (million m3)	Qout (m3/s)	Qout avg (m3/s)	Change in capacity (million m3)	Change in time (days)	Tot time (days)
622.6	19.800	13.324			0	0
620.0	16.700	12.681	13.002	3.100	2.8	2.8
615.0	10.600	11.342	12.011	6.100	5.9	8.6
610.0	6.357	9.822	10.582	4.243	4.6	13.3
610.0	6.357	9.822	9.822	0.000	0.0	13.3
605.0	3.427	8.020	8.921	2.930	3.8	17.1
600.0	1.493	5.671	6.845	1.934	3.3	20.3
595.0	0.361	0.000	2.835	1.132	4.6	24.97



Appendix P

Final Cost Estimate

EARTHCORE ROCKFILL (ECR) DAM **FSL = 612 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE Rand	QUANTITY	AMOUNT Rand
1	**1**	**Clearing**				
1.1	1.1	(a) sparse	ha			
1.2	1.2	(b) bush	ha	25 000	4.00	100 000
1.3	1.3	(c) trees	ha			
2	**2**	**River diversion**	Sum			250 000
3	**3**	**Excavation**				
		(a) Bulk				
3.1	3.4	(i) all materials	m3	40	186 193	7 447 720
3.2	3.5	(ii) extra over for rock	m3	90	137 802	12 402 180
		(b) Confined				
3.4	3.4	(i) all materials	m3	40	20 000	800 000
3.5	3.5	(ii) extra over for rock	m3	90	15 000	1 350 000
		(c) Preparation of solum				
3.6	3.10	(i) all materials	m2	15	22 931	343 965
3.7	3.5	(II) extra over for rock	m2	175	4 586	802 585
4	**5.0**	**Drilling & Grouting**				
4.1	5.1	(a) Curtain grouting	m drill	1 200	7 820	9 384 000
5	**4.0**	**Embankment**				
	4.5	(a) Rockfill				
5.2		(i) 3C	m3	80	250 265	20 021 200
5.3		(ii) 3D	m3	80	48 392	3 871 360
	4.6	(b) Filters (Gravel and sand layers)				
5.4		(i) Gravel	m3	180	65 112	11 720 160
5.5		(ii) Sand (commercial source)	m3	380	15 075	5 728 500
5.6	4.7	(c) Impervious material (Clay core)	m3	50	53 660	2 683 000
5.7	4.9	(d) Overhaul beyond 3km	m3km	5	100 000	1 500 000
6		**Concrete Works**				
	6.0	(a) Formwork				
6.1	6.1	(i) gang formed (spillway and retaining walls)	m2	450	3 336	1 501 200
6.2	6.2	(ii) intricate (outlet works)	m2	550	5 790	3 184 500
	7.0	(b) Concrete				
6.3	7.1	(i) structural	m3	2 200	11 635	25 597 000
6.4	7.11	(ii) slope protection	m2	3 000	9 000	27 000 000
		(iii) Bridge from crest to intake structure	Sum	2 000 000	1	2 000 000
	8.0	(c) Reinforcing				
6.5		(i) Structural (steel rod)	t	15 000	1 345	20 175 000
7	**10.0**	**Mechanical Items**				
7.1	10.1	Valves and gates	Sum	18600000	1	18 600 000
7.2	10.2	Cranes and hoists	Sum	5500000	1	5 500 000
7.3	10.3	Structural steelwork	Sum	20240000	1	20 240 000
		SUB-TOTAL A				**202 202 370**

No	PAY REF	DESCRIPTION	UNIT	RATE RAND	QUANTITY	AMOUNT
8	11.0	**Landscaping** (% of 1-9)	%	5	202 202 370	10 110 119
9	12.0	**Miscellaneous** (% of 1-9)	%	15	202 202 370	30 330 356
		SUB TOTAL B				242 642 844
10	13.0	**Preliminary & General** (% of sub-total B)	%	40	242 642 844	97 057 138
11	14.0	**Preliminary works**				
	14.1	(a) Access road	km	500 000	4	2 000 000
	14.2	(b) Electrical supply to site	Sum			2 000 000
	14.3	(c) Construction water to site	Sum			500 000
	14.4	(d) Railhead & materials handling	Sum			n/a
12	15.0	**Accommodation**	Sum			8 640 000
		SUB TOTAL C				352 839 982
13	16.0	**Contingencies** (% of sub total C)	%	20	352 839 982	70 567 996
		SUB TOTAL D				423 407 978
14	17.0	**Planning design & supervision** (% of sub total D)	%	15	423 407 978	63 511 197
		SUB TOTAL D				**486 919 175**
15	18.0	**VAT** (% of sub total E)	%	14	486 919 175	68 168 684
		NETT PROJECT COST				555 087 859
	19.0	**Cost of relocations**	Sum			unknown
	20.0	**Cost of land acquisition**	Sum			unknown
		TOTAL PROJECT COST				**555 087 859.05**

EARTHCORE ROCKFILL (ECR) DAM **FSL = 622.6 masl**

No	PAY REF	DESCRIPTION	UNIT	RATE Rand	QUANTITY	AMOUNT Rand
1	**1**	**Clearing**				
1.1	1.1	(a) sparse	ha			
1.2	1.2	(b) bush	ha	25 000	5.00	125 000
1.3	1.3	(c) trees	ha			
2	**2**	**River diversion**	Sum			250 000
3	**3**	**Excavation**				
		(a) Bulk				
3.1	3.4	(i) all materials	m3	40	286 936	11 477 440
3.2	3.5	(ii) extra over for rock	m3	90	199 366	17 942 940
		(b) Confined				
3.4	3.4	(i) all materials	m3	40	20 000	800 000
3.5	3.5	(ii) extra over for rock	m3	90	15 000	1 350 000
		(c) Preparation of solum				
3.6	3.10	(i) all materials	m2	15	31 722	475 830
3.7	3.5	(II) extra over for rock	m2	175	6 344	1 110 270
4	**5.0**	**Drilling & Grouting**				
4.1	5.1	(a) Curtain grouting	m drill	1 200	9 845	11 814 000
5	**4.0**	**Embankment**				
	4.5	(a) Rockfill				
5.2		(i) 3C	m3	80	441 031	35 282 480
5.3		(ii) 3D	m3	80	87 571	7 005 680
	4.6	(b) Filters (Gravel and sand layers)				
5.4		(i) Gravel	m3	180	91 203	16 416 540
5.5		(ii) Sand (commercial source)	m3	380	21 573	8 197 740
5.6	4.7	(c) Impervious material (Clay core)	m3	50	92 368	4 618 400
5.7	4.9	(d) Overhaul beyond 3km	m3km	5	100 000	1 500 000
6		**Concrete Works**				
	6.0	(a) Formwork				
6.1	6.1	(i) gang formed (spillway and retaining walls)	m2	450	5 810	2 614 500
6.2	6.2	(ii) intricate (outlet works)	m2	550	8 380	4 609 000
	7.0	(b) Concrete				
6.3	7.1	(i) structural	m3	2 200	26 291	57 840 200
6.4	7.11	(ii) slope protection	m2	3 000	9 000	27 000 000
		(iii) Bridge from crest to intake structure	Sum	3 000 000	1	3 000 000
	8.0	(c) Reinforcing				
6.5		(i) Structural (steel rod)	t	15 000	2 841	42 615 000
7	**10.0**	**Mechanical Items**				
7.1	10.1	Valves and gates	Sum	18600000	1	18 600 000
7.2	10.2	Cranes and hoists	Sum	5500000	1	5 500 000
7.3	10.3	Structural steelwork	Sum	20255000	1	20 255 000
		SUB-TOTAL A				**300 400 020**

No	PAY REF	DESCRIPTION	UNIT	RATE RAND	QUANTITY	AMOUNT
8	11.0	**Landscaping** (% of 1-9)	%	5	300 400 020	15 020 001
9	12.0	**Miscellaneous** (% of 1-9)	%	15	300 400 020	45 060 003
		SUB TOTAL B				360 480 024
10	13.0	**Preliminary & General** (% of sub-total B)	%	40	360 480 024	144 192 010
11	14.0	**Preliminary works**				
	14.1	(a) Access road	km	500 000	4	2 000 000
	14.2	(b) Electrical supply to site	Sum			2 000 000
	14.3	(c) Construction water to site	Sum			500 000
	14.4	(d) Railhead & materials handling	Sum			n/a
12	15.0	**Accommodation**	Sum			8 640 000
		SUB TOTAL C				517 812 034
13	16.0	**Contingencies** (% of sub total C)	%	20	517 812 034	103 562 407
		SUB TOTAL D				621 374 440
14	17.0	**Planning design & supervision** (% of sub total D)	%	15	621 374 440	93 206 166
		SUB TOTAL D				**714 580 606**
15	18.0	**VAT** (% of sub total E)	%	14	714 580 606	100 041 285
		NETT PROJECT COST				814 621 891
	19.0	**Cost of relocations**	Sum			unknown
	20.0	**Cost of land acquisition**	Sum			unknown
		TOTAL PROJECT COST				**814 621 891.26**

Appendix Q

Implementation Programme

Feasibility Study: Proposed Zalu dam (0.6 MAR dam, FSL 612 masl)
Production Rates for Implementation Programme

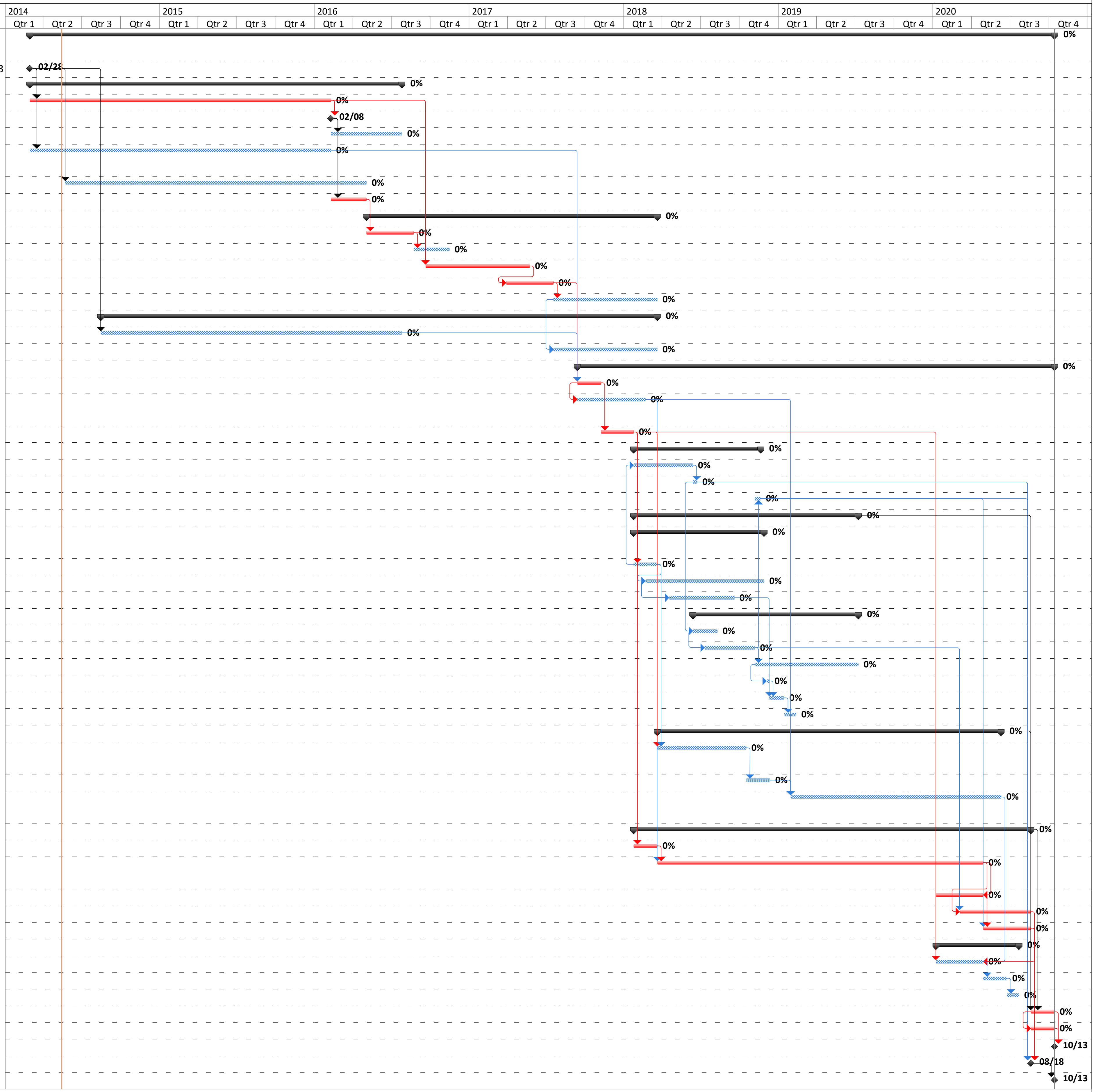
	Production			Time	Time
	Unit	Volume	Rate/day	(Days)	(Months)
River diversion					
Stage 1 (construction of conduit)	m^3	2 500.00	25.00	100.00	5.00
Stage 2 (water through conduit)					-
- Cofferdam 1 (u/s of embankment)	m^3	3 360.00	500.00	6.72	0.34
Main embankment					
Foundation Excavation	m^3				
- Left and right flank from 596masl to NOC (620masl)	m^3	60 000.00	1 500.00	40.00	2.00
- River section up to 596masl	m^3	99 264.00	1 500.00	66.18	3.31
Drilling, consolidation and curtain grouting					
- Left and right flank from 595masl to NOC (620masl)	m	4 000.00	20.00	200.00	10.00
- River section up to 596masl	m	3 100.00	20.00	155.00	7.75
Embankment Rockfill					-
- Left and right flank from 596masl to NOC (620masl)	m^3	160 700.00	1 500.00	107.13	5.36
- U/s part of river section up to contour 596masl serving as coffer dam	m^3	146 810.00	1 500.00	97.87	4.89
- D/s part of river section and from level 596masl to NOC (620 masl)	m^3	125 000.00	1 500.00	83.33	4.17
Spillway					
Spillway excavation (approach and return channel)	m^3	150 000.00	1 000.00	150.00	7.50
Drilling, consolidation and curtain grouting	m	750.00	20.00	37.50	1.88
Formwork, reinforcing and structural concrete placement	m^3	8 500.00	25.00	340.00	17.00
Outlet works					
Excavation and foundation preparation	m^3	7 500.00	75.00	100.00	5.00
Reinforcement, formwork, concrete and unformed surfaces	m^3	3 610.00	7.00	515.71	25.79

Feasibility Study: Proposed Zalu dam (1.5MAR dam, FSL = 622,6 masl)
Production Rates for Implementation Programme

	Production			Time	Time
	Unit	Volume	Rate/day	(Days)	(Months)
River diversion					
Stage 1 (construction of conduit)	m^3	2 500.00	25.00	100.00	5.00
Stage 2 (water through conduit)					-
- Cofferdam 1 (u/s of embankment)	m^3	3 360.00	500.00	6.72	0.34
Main embankment					
Foundation Excavation	m^3				
- Left and right flank from 596masl to NOC (629masl)	m^3	80 444.83	1 500.00	53.63	2.68
- River section up to 596masl	m^3	86 655.17	1 500.00	57.77	2.89
Drilling, consolidation and curtain grouting					
- Left and right flank from 596masl to NOC (629masl)	m	5 577.46	20.00	278.87	13.94
- River section up to 595masl	m	4 322.54	20.00	216.13	10.81
Embankment Rockfill					-
- Left and right flank from 596masl to NOC (620masl)	m^3	272 626.36	1 500.00	181.75	9.09
- U/s part of river section up to contour 596masl serving as coffer dam	m^3	249 062.07	1 501.00	165.93	8.30
- D/s part of river section and from level 596masl to NOC (620 masl)	m^3	212 061.57	1 500.00	141.37	7.07
Spillway					
Spillway excavation (approach and return channel)	m^3	150 000.00	1 000.00	150.00	7.50
Drilling, consolidation and curtain grouting	m	750.00	20.00	37.50	1.88
Formwork, reinforcing and structural concrete placement	m^3	22 600.00	25.00	904.00	45.20
Outlet works					
Excavation and foundation preparation	m^3	7 500.00	75.00	100.00	5.00
Reinforcement, formwork, concrete and unformed surfaces	m^3	4 250.00	7.00	607.14	30.36

Implementation programme Zalu_v3_612masl_new river diversion.mpp

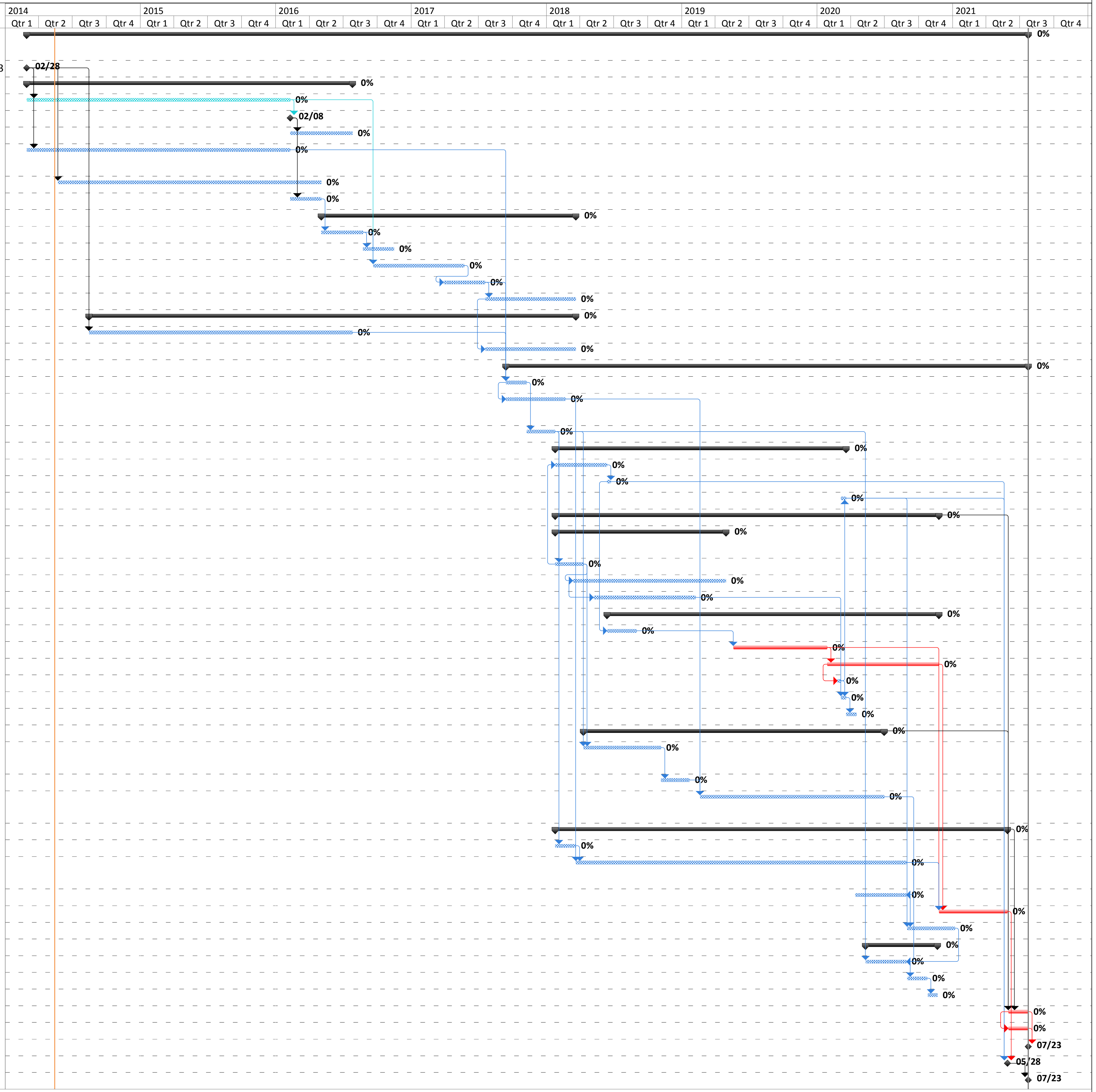
ID	Task Name	Duration	Start	Finish	Predecessors	Successors
1	**Implementation Programme for the Proposed Zalu dam**	**1640 days**	**Fri 14/02/28**	**Tue 20/10/13**		
2	End of current project: Lusikisiki Feasibility Study	0 days	Fri 14/02/28	Fri 14/02/28		17FS+6 mons,7,8FS+3
3	**1. ENVIRONMENTAL AUTHORISATION**	**600 days**	**Fri 14/02/28**	**Mon 16/07/25**		
4	1.1 Environmental Impact Assessment	24 mons	Fri 14/02/28	Mon 16/02/08	2	5,13
5	1.2 Environmental authorisation	0 days	Mon 16/02/08	Mon 16/02/08	4	6,9
6	1.3 Appeal period	6 mons	Tue 16/02/09	Mon 16/07/25	5	
7	2. INSTITUTIONAL AND FINANCIAL ARRANGEMENTS	24 mons	Fri 14/02/28	Mon 16/02/08	2	20
8	3. DECISION SUPPORT STAGE	24 mons	Fri 14/05/23	Mon 16/05/02	2FS+3 mons	
9	4. Ministerial Approval	60 days	Tue 16/02/09	Mon 16/05/02	5	11
10	**5. DETAIL TENDER AND DESIGN PHASE**	**460 days**	**Tue 16/05/03**	**Tue 18/03/20**		
11	5.1 Procurement of Design PSP	4 mons	Tue 16/05/03	Mon 16/08/22	9	13FS+1 mon,12
12	5.2 Additional geotechnical investigations	3 mons	Tue 16/08/23	Mon 16/11/14	11	
13	5.3 Tender design	8 mons	Tue 16/09/20	Tue 17/05/23	11FS+1 mon,4	14FS-2 mons
14	5.4 Tender documents and procurement	4 mons	Wed 17/03/29	Tue 17/07/18	13FS-2 mons	15,20FS+2 mons
15	5.5 Detail design	8 mons	Wed 17/07/19	Tue 18/03/20	14	18SS
16	**6 PRELIMINARY WORKS**	**880 days**	**Fri 14/08/15**	**Tue 18/03/20**		
17	6.1 Electrical supply to site (ESKOM)	24 mons	Fri 14/08/15	Mon 16/07/25	2FS+6 mons	20
18	6.2 Heritage assessment and Land acquisition	8 mons	Wed 17/07/19	Tue 18/03/20	15SS	
19	**7. CONSTRUCTION PHASE**	**760 days**	**Wed 17/09/13**	**Tue 20/10/13**		
20	7.1 Site establishment	8 wks	Wed 17/09/13	Tue 17/11/07	17,14FS+2 mons,7	21SS,22
21	7.2 Mobilisation and erection of crusher and batching plant	5 mons	Wed 17/09/13	Tue 18/02/20	20SS	45,42
22	7.3 Site clearing	2 mons	Wed 17/11/08	Tue 18/01/23	20	44,50,40,29
23	**7.4 River diversion**	**214 days**	**Wed 18/01/24**	**Mon 18/11/19**		
24	7.4.1 Stage 1 (no coffer dam)	5 mons	Wed 18/01/24	Tue 18/06/12	29SS	25
25	7.4.2 Stage 2 (upstream coffer dam)	0.4 mons	Wed 18/06/13	Fri 18/06/22	24	56,33SS
26	7.4.3 Stage 3 (Plug of intake tower)	2 wks	Tue 18/11/06	Mon 18/11/19	34	56,48
27	**7.5 Main embankment**	**364 days**	**Wed 18/01/24**	**Mon 19/07/08**		**53**
28	**7.5.1 Stage 1 (Left and right flank, excl. river section, from 596masl up to NOC)**	**220 days**	**Wed 18/01/24**	**Tue 18/11/27**		
29	7.5.1.1 Excavation	2 mons	Wed 18/01/24	Tue 18/03/20	22	30FS-1 mon,24SS,40
30	7.5.1.2 Curtain grouting	10 mons	Wed 18/02/21	Tue 18/11/27	29FS-1 mon	31SS+2 mons
31	7.5.1.3 Embankment fill	5.5 mons	Wed 18/04/18	Tue 18/09/18	30SS+2 mons	37
32	**7.5.2 Stage 2 (River section up to 596masl))**	**264 days**	**Wed 18/06/13**	**Mon 19/07/08**		
33	7.5.2.1 Excavation	2.1 mons	Wed 18/06/13	Thu 18/08/09	25SS	34SS+1 mon
34	7.5.2.2 U/ S Embankment fill	4.2 mons	Wed 18/07/11	Mon 18/11/05	33SS+1 mon	26,47,35
35	7.5.2.3 Curtain grouting	8 mons	Tue 18/11/06	Mon 19/07/08	34	36SS+1 mon
36	7.5.2.4 D/s Embankment fill	4.9 days	Tue 18/12/04	Mon 18/12/10	35SS+1 mon	37
37	7.5.3 Crest road construction	2 wks	Mon 18/12/10	Mon 19/01/14	31,36	38
38	7.5.4 Finishing (guardrails etc.)	1 mon	Mon 19/01/14	Mon 19/02/11	37	
39	**7.6 Spillway, chute and stilling basin**	**550 days**	**Wed 18/03/21**	**Tue 20/06/09**		**53**
40	7.6.1 Spillway excavation (apporach and return channel)	7.5 mons	Wed 18/03/21	Tue 18/10/16	22,29	41
41	7.6.2 Spillway grouting	2 mons	Wed 18/10/17	Tue 18/12/11	40	42FS+1 mon
42	7.6.3 Formwork, reinforcing and structural concrete placement	17 mons	Wed 19/01/30	Tue 20/06/09	41FS+1 mon,21	50FF-4 mons
43	**7.7 Outlet works (incl conduit)**	**640 days**	**Wed 18/01/24**	**Tue 20/08/18**		**53**
44	7.7.1 Excavation and foundation preparation	2 mons	Wed 18/01/24	Tue 18/03/20	22	45
45	7.7.2 Reinforcement, formwork, concrete and unformed surfaces	26 mons	Wed 18/03/21	Tue 20/04/28	44,21	46FF,47FS-2 mons
46	7.7.3 Hydro-mechanical items (stage 1)	4 mons	Wed 20/01/08	Tue 20/04/28	45FF	48
47	7.7.4 Access bridge to intake tower	6 mons	Wed 20/03/04	Tue 20/08/18	45FS-2 mons,34	56
48	7.7.5 Hydro-mechanical items (stage 2)	4 mons	Wed 20/04/29	Tue 20/08/18	26,46	50FF-4 mons
49	**7.8 Access roads**	**140 days**	**Wed 20/01/08**	**Tue 20/07/21**		
50	7.8.1 Roadbed & mass earthworks	4 mons	Wed 20/01/08	Tue 20/04/28	22,48FF-4 mons,4	51
51	7.8.2 Layerworks	2 mons	Wed 20/04/29	Tue 20/06/23	50	52
52	7.8.3 Surfacing	1 mon	Wed 20/06/24	Tue 20/07/21	51	
53	7.9 Fencing	2 mons	Wed 20/08/19	Tue 20/10/13	27,39,43	54SS,55
54	7.10 Landscaping	2 mons	Wed 20/08/19	Tue 20/10/13	53SS	55
55	7.11 Commissioning and handover	0 days	Tue 20/10/13	Tue 20/10/13	53,54	
56	8. RESERVOIR IMPOUNDMENT	0 days	Tue 20/08/18	Tue 20/08/18	25,47,26	57FS+2 mons
57	9. EARLIEST WATER DELIVERY	0 days	Tue 20/10/13	Tue 20/10/13	56FS+2 mons	



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

Implementation programme Zalu_v3_622.6masl_new river diversion.mpp

ID	Task Name	Duration	Start	Finish	Predecessors	Successors
1	**Implementation Programme for the Proposed Zalu dam (FSL = 622.6 masl)**	**1830 days**	**Fri 14/02/28**	**Fri 21/07/23**		
2	End of current project: Lusikisiki Feasibility Study	0 days	Fri 14/02/28	Fri 14/02/28		17FS+6 mons,7,8FS+3
3	**1. ENVIRONMENTAL AUTHORISATION**	**600 days**	**Fri 14/02/28**	**Mon 16/07/25**		
4	1.1 Environmental Impact Assessment	24 mons	Fri 14/02/28	Mon 16/02/08	2	5,13
5	1.2 Environmental authorisation	0 days	Mon 16/02/08	Mon 16/02/08	4	6,9
6	1.3 Appeal period	6 mons	Tue 16/02/09	Mon 16/07/25	5	
7	2. INSTITUTIONAL AND FINANCIAL ARRANGEMENTS	24 mons	Fri 14/02/28	Mon 16/02/08	2	20
8	3. DECISION SUPPORT STAGE	24 mons	Fri 14/05/23	Mon 16/05/02	2FS+3 mons	
9	4. Ministerial Approval	60 days	Tue 16/02/09	Mon 16/05/02	5	11
10	**5. DETAIL TENDER AND DESIGN PHASE**	**460 days**	**Tue 16/05/03**	**Tue 18/03/20**		
11	5.1 Procurement of Design PSP	4 mons	Tue 16/05/03	Mon 16/08/22	9	13FS+1 mon,12
12	5.2 Additional geotechnical investigations	3 mons	Tue 16/08/23	Mon 16/11/14	11	
13	5.3 Tender design	8 mons	Tue 16/09/20	Tue 17/05/23	11FS+1 mon,4	14FS-2 mons
14	5.4 Tender documents and procurement	4 mons	Wed 17/03/29	Tue 17/07/18	13FS-2 mons	15,20FS+2 mons
15	5.5 Detail design	8 mons	Wed 17/07/19	Tue 18/03/20	14	18SS
16	**6 PRELIMINARY WORKS**	**880 days**	**Fri 14/08/15**	**Tue 18/03/20**		
17	6.1 Electrical supply to site (ESKOM)	24 mons	Fri 14/08/15	Mon 16/07/25	2FS+6 mons	20
18	6.2 Heritage assessment and Land acquisition	8 mons	Wed 17/07/19	Tue 18/03/20	15SS	
19	**7. CONSTRUCTION PHASE**	**950 days**	**Wed 17/09/13**	**Fri 21/07/23**		
20	7.1 Site establishment	8 wks	Wed 17/09/13	Tue 17/11/07	17,14FS+2 mons,7	21SS,22
21	7.2 Mobilisation and erection of crusher and batching plant	5 mons	Wed 17/09/13	Tue 18/02/20	20SS	45,42
22	7.3 Site clearing	2 mons	Wed 17/11/08	Tue 18/01/23	20	44,50,40,29
23	**7.4 River diversion**	**531.1 days**	**Wed 18/01/24**	**Thu 20/03/19**		
24	7.4.1 Stage 1 (no coffer dam)	5 mons	Wed 18/01/24	Tue 18/06/12	29SS	25
25	7.4.2 Stage 2 (upstream coffer dam)	0.4 mons	Wed 18/06/13	Fri 18/06/22	24	56,33SS
26	7.4.3 Stage 3 (Plug of intake tower)	2 wks	Thu 20/03/05	Thu 20/03/19	36	56,48
27	**7.5 Main embankment**	**710 days**	**Wed 18/01/24**	**Tue 20/11/24**		**53**
28	**7.5.1 Stage 1 (Left and right flank, excl. river section, from 596masl up to NOC)**	**314 days**	**Wed 18/01/24**	**Mon 19/04/29**		
29	7.5.1.1 Excavation	2.7 mons	Wed 18/01/24	Mon 18/04/09	22	30FS-1 mon,24SS,40
30	7.5.1.2 Curtain grouting	14 mons	Tue 18/03/13	Mon 19/04/29	29FS-1 mon	31SS+2 mons
31	7.5.1.3 Embankment fill	9.1 mons	Tue 18/05/08	Wed 19/02/06	30SS+2 mons	37
32	**7.5.2 Stage 2 (River section up to 596masl))**	**610 days**	**Wed 18/06/13**	**Tue 20/11/24**		
33	7.5.2.1 Excavation	2.9 mons	Wed 18/06/13	Fri 18/08/31	25SS	34FS+1 mon
34	7.5.2.2 U/s Embankment fill	8.3 mons	Mon 19/05/20	Mon 20/01/27	33FS+1 mon	47,35
35	7.5.2.3 Curtain grouting	10.8 mons	Tue 20/01/28	Tue 20/11/24	34	47,36SS+1 mon
36	7.5.2.4 D/s Embankment fill	7.1 days	Tue 20/02/25	Thu 20/03/05	35SS+1 mon	26,37
37	7.5.3 Crest road construction	2 wks	Thu 20/03/05	Thu 20/03/19	31,36	38
38	7.5.4 Finishing (guardrails etc.)	1 mon	Thu 20/03/19	Thu 20/04/16	37	
39	**7.6 Spillway, chute and stilling basin**	**550 days**	**Tue 18/04/10**	**Mon 20/06/29**		**53**
40	7.6.1 Spillway excavation (apporach and return channel)	7.5 mons	Tue 18/04/10	Mon 18/11/05	22,29	41
41	7.6.2 Spillway grouting	2 mons	Tue 18/11/06	Mon 19/01/21	40	42FS+1 mon
42	7.6.3 Formwork, reinforcing and structural concrete placement	17 mons	Tue 19/02/19	Mon 20/06/29	41FS+1 mon,21	50FF-4 mons
43	**7.7 Outlet works (incl conduit)**	**830 days**	**Wed 18/01/24**	**Fri 21/05/28**		**53**
44	7.7.1 Excavation and foundation preparation	2 mons	Wed 18/01/24	Tue 18/03/20	22	45
45	7.7.2 Reinforcement, formwork, concrete and unformed surfaces	30.4 mons	Wed 18/03/21	Fri 20/08/28	44,21	46FF,47FS-2 mons
46	7.7.3 Hydro-mechanical items (stage 1)	5 mons	Mon 20/04/13	Fri 20/08/28	45FF	48
47	7.7.4 Access bridge to intake tower	6 mons	Wed 20/11/25	Fri 21/05/28	45FS-2 mons,35,3	56
48	7.7.5 Hydro-mechanical items (stage 2)	4 mons	Mon 20/08/31	Wed 21/01/06	26,46	50FF-4 mons
49	**7.8 Access roads**	**140 days**	**Mon 20/05/11**	**Fri 20/11/20**		
50	7.8.1 Roadbed & mass earthworks	4 mons	Mon 20/05/11	Fri 20/08/28	22,48FF-4 mons,4	51
51	7.8.2 Layerworks	2 mons	Mon 20/08/31	Fri 20/10/23	50	52
52	7.8.3 Surfacing	1 mon	Mon 20/10/26	Fri 20/11/20	51	
53	7.9 Fencing	2 mons	Mon 21/05/31	Fri 21/07/23	27,39,43	54SS,55
54	7.10 Landscaping	2 mons	Mon 21/05/31	Fri 21/07/23	53SS	55
55	7.11 Commissioning and handover	0 days	Fri 21/07/23	Fri 21/07/23	53,54	
56	8. RESERVOIR IMPOUNDMENT	0 days	Fri 21/05/28	Fri 21/05/28	25,47,26	57FS+2 mons
57	9. EARLIEST WATER DELIVERY	0 days	Fri 21/07/23	Fri 21/07/23	56FS+2 mons	



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