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DIRECTORATE: OPTIONS ANALYSIS

FEASIBILITY STUDY FOR THE MZIMVUBU WATER PROJECT

RECORD OF IMPLEMENTATION DECISIONS: LALINI DAM AND HYDROPOWER SCHEME

OCTOBER 2014

FEASIBILITY STUDY FOR THE MZIMVUBU WATER PROJECT

APPROVAL

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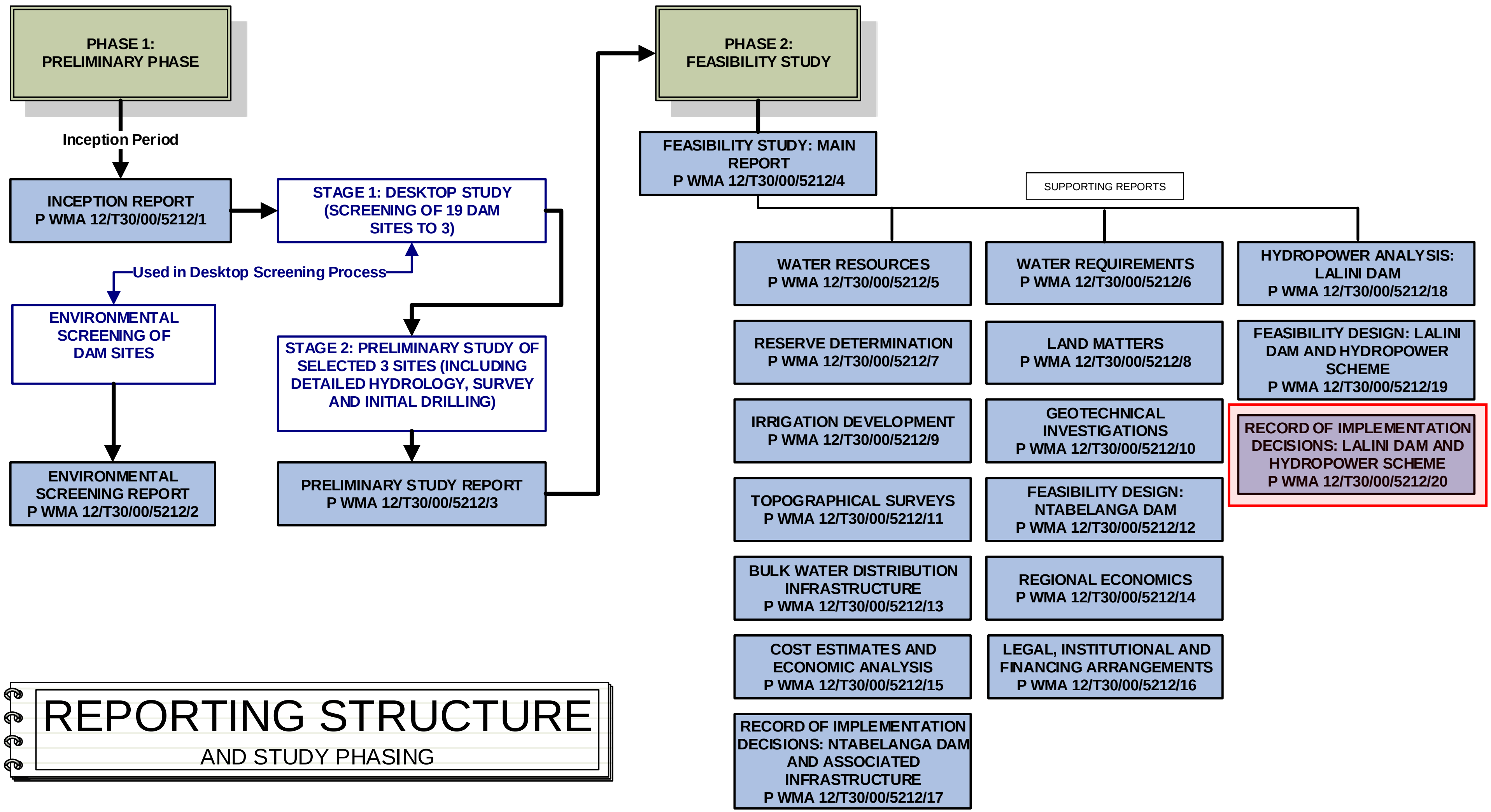
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Note on Departmental Name Change:

In 2014, the Department of Water Affairs changed its name to the Department of Water and Sanitation, which happened during the course of this study. In some cases this was after some of the study reports had been finalized. The reader should therefore kindly note that references to the Department of Water Affairs and the Department of Water and Sanitation herein should be considered to be one and the same.

Note on Spelling of Laleni:

The settlement named Laleni on maps issued by the Surveyor General is locally known as Lalini and both names therefore refer to the same settlement.

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LIST OF ACRONYMS AND ABBREVIATIONS

ASGISA-EC	Accelerated and Shared Growth Initiative for South Africa – Eastern Cape
CAPEX	Capital Expenditure
CFRD	Concrete-faced rockfill dam
CMA	Catchment Management Agency
CTC	Cost to Company
CV	Coefficient of Variability
DAFF	Department of Agriculture, Forestry and Fisheries
DBSA	Development Bank of Southern Africa
DEA	Department of Environment Affairs (National)
Dia.	Diameter
DM	District Municipality
DME	Department of Minerals and Energy
DoE	Department of Energy
DRDAR	Department of Rural Development and Agrarian Reform
DRDLR	Department of Rural Development and Land Reform
DWA	Department of Water and Sanitation
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
EAP	Environmental Assessment Practitioner
EC	Eastern Cape
ECRD	Earth core rockfill dam
EF	Earthfill (dam)
EIA	Environmental Impact Assessment
EIR	Environmental Impact Report
EMP	Environmental Management Plan
EPWP	Expanded Public Works Programme
ESIA	Environmental and Social Impact Assessment
EWR	Environmental Water Requirements
FSL	Full Supply Level
GERCC	Grout enriched RCC
GMA	Gross margin analysis
GN	Government Notices
GW	Gigawatt
GWh/a	Gigawatt hour per annum
IAPs	Invasive Alien Plants
IB	Irrigation Board
IFC	International Finance Corporation
IPP	Independent Power Producer
IRR	Internal Rate of Return
IMRP	Integrated Water Resource Planning (Directorate)
IVRCC	Internally vibrated RCC
ISO	International Standards Organisation
kW	Kilowatt

LM	Local Municipality
ℓ/s	Litres per second
ℓ/c/d	Litres per capita per day
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MEC	Member of the Executive Council
MIG	Municipal Infrastructure Grant
MW	Megawatt
NEMA	National Environmental Management Act
NERSA	National Energy Regulator of South Africa
NHRA	National Heritage Resources Act
NOCL	Non-overspill crest level
NWA	National Water Act
NWPR	National Water Policy Review
NWRMS	National Water Resources Management Strategy
O&M	Operations and Maintenance
OPEX	Operational Expenditure
PES	Present Ecological Status
PICC	Presidential Infrastructure Co-ordinating Committee
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PSC	Project Steering Committee
PSP	Professional Services Provider
RBIG	Regional Bulk Infrastructure Grant
RCC	Roller-compacted concrete
RDF	Recommended Design Flood
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RID	Record of Implementation Decisions
RWI	Regional Water Institution
RWU	Regional Water Utilities
SAWS	South African Weather Service
SEF	Safety Evaluation Flood
SEZ	Special Economic Zone
SIP	Strategic Integrated Project
SMC	Study Management Committee
SPV	Special Purpose Vehicle
TCTA	Trans Caledon Tunnel Authority
TOR	Terms of Reference
UOS	Use of System
URV	Unit Reference Value
V_{50}	Sedimentation over 50 years
WEF	Water Energy Food
WRC	Water Research Commission

WRYM	Water Resources Yield Model
WSA	Water Services Authority
WSP	Water Services Provider
WTE	Water Trade Entity
WTW	Water treatment works
WUA	Water User Association
WWTW	Wastewater treatment works

LIST OF UNITS

Description	Standard unit
Elevation	m a.s.l.
Height	m
Distance	m, km
Dimension	mm, m
Area	m^2, ha or km^2
Volume (storage)	m^3
Yield, Mean Annual Runoff	m^3/a
Rotational speed	rpm
Head of Water	m
Pressure	Pa
Diameter	mm or m
Temperature	^oC

Description	Standard unit
Velocity, speed	m/s, km/hr
Discharge	m^3/s
Mass	kg, tonne
Force, weight	N
Gradient (V:H)	%
Slope (H:V) or (V:H)	1:5 (H:V) or 5:1 (V:H)
Volt	V
Power	W
Energy used	kWh
Acceleration	m/s^2
Density	kg/m^3
Frequency	Hz

1. BACKGROUND AND INTRODUCTION

The Mzimvubu River catchment in the Eastern Cape Province of South Africa is situated in one of the poorest and least developed regions of the country. Development of the area to accelerate the social and economic upliftment of the people was therefore identified as one of the priority initiatives of the Eastern Cape Provincial Government.

Harnessing the water resources of the Mzimvubu River, the only major river in the country which is still largely unutilised, is considered by the Eastern Cape Provincial Government as offering one of the best opportunities in the Province to achieve such development. In 2007, a special-purpose vehicle (SPV) called ASGISA-Eastem Cape (Pty) Ltd (ASGISA-EC) was formed in terms of the Companies Act to initiate planning and to facilitate and drive the Mzimvubu River Water Resources Development.

The five pillars on which the Eastern Cape Provincial Government and ASGISA-EC proposed to model the Mzimvubu River Water Resources Development are:

- Forestry;
- Irrigation;
- Hydropower;
- Water transfer; and
- Tourism.

The Department of Water and Sanitation (DWS) commissioned the Feasibility Study for the Mzimvubu Water Project with the overarching aim of developing water resources schemes (dams) that can be multi-purpose reservoirs in order to provide benefits to the surrounding communities and to provide a stimulus for the regional economy, in terms of irrigation, forestry, domestic water supply and the potential for hydropower generation amongst others.

The objective of the study was to screen and rank previously identified dam development options, and to select the best single option to be implemented first, using appropriate decision-making criteria. The scope of the study required that the selected single multi-purpose scheme be investigated to a feasibility level of detail, ready to be handed over for detailed design and implementation.

The resulting recommended scheme comprises the following:

A new dam at Ntabelanga on the Tsitsa River (a major tributary of the Mzimvubu River), with storage capacity sufficient to reliably supply the raw and potable water requirements to a planning horizon of the year 2050, for:

- some 726 616 people and other water consumers in the region,
- a bulk raw water distribution system to supply irrigation water to some 2 868 ha of high potential land,
- a new water treatment works at the Ntabelanga dam to supply the potable water requirements,
- Primary and secondary bulk water distribution systems to deliver treated water in bulk to the whole supply area. From these bulk systems, tertiary distribution systems to the consumers will be implemented by the District Municipalities, and
- a hydropower plant at Ntabelanga Dam to generate up to 5 MW of power.

1.1 Additional Detailed Investigations for Lalini Dam and Hydropower Scheme

Following the completion of the above feasibility study stages it was agreed that the sizing and modus operandi of the Ntabelanga Dam and its associated works would also take into account further multi-purpose roles, namely:

i) to provide sufficient flow of water downstream of the Ntabelanga Dam to meet environmental water requirements (EWR) for an ecological Class C; and
ii) to provide additional balancing storage volume and consistent downstream flow releases to enable a second, smaller dam at Lalini (located on the Tsitsa River some 3.5 km above the Tsitsa Falls) to generate significant hydropower for supply into the national grid.

Whereas the role described in i) is a statutory requirement for all large dams, the role given in item ii) was based upon the proposal that the generation and sale of hydropower-based energy could be used to cross-subsidize the significant energy costs required for pumping water for the irrigation and domestic water supply schemes proposed to be supplied from the Ntabelanga Dam.

The agricultural water requirements for the Tsolo area would require lifting the water more than 150 m, which would normally render such a scheme non-viable in terms of the pumping cost component of water supplied, unless hydropower is developed to generate revenue to reduce the net unit cost of water.

The purpose of this second dam and hydropower scheme at Lalini would thus be to generate significant revenue by selling energy into the ESKOM grid, thus generating a net positive income stream which would be used to subsidise the energy and operating costs of the main Ntabelanga water supply and irrigation scheme, thus providing self-sustainability and, potentially, surplus revenue which could be used to redeem capital costs or to finance other regional development projects.

A more detailed hydropower analysis and feasibility design study was therefore undertaken to assess the output potential of the Lalini Dam hydropower scheme when used conjunctively with the Ntabelanga Dam. This analysis used the detailed hydrology developed for the catchment and the naturalised and historical flow series that was developed therefrom.

The conjunctive hydropower scheme for the Ntabelanga and Lalini Dams is described in the Hydropower Analysis: Lalini Dam Report No. P WMA 12/T30/00/5212/18 and the Feasibility Design: Lalini Dam and Hydropower Scheme Report No. P WMA 12/T30/00/5212/19.

A separate Record of Implementation Decisions was issued for the Ntabelanga Dam and Associated Infrastructure, as Report No. P WMA 12/T30/00/5212/17.

1.2 Scope of the Record of Implementation Decisions

A Memorandum of Agreement between the Chief Directorates of Integrated Water Resource Planning (CD: IWRP) and Infrastructure Development (CD: ID) dated March 2005, clarifies "the division and/or sharing of roles, responsibilities and accountability of the Chief Directorates through the various project phases from planning to the commissioning of a project".

The Memorandum furthermore states that once the detail planning of the Project has been concluded and the scheme configuration and other related requirements for implementation have been approved by the Minister, the project shall be formally handed over by the CD: IWRP to the CD: ID for implementation. This formal handover of the project is concluded through an official document called the Record of Implementation Decisions (RID), and is signed off by responsible officials from both the CD: IWRP and the CD: ID.

The RID describes the scope of the project, the specific configuration of the scheme to be implemented, the required implementation timelines, the finalisation of required institutional arrangements and the required environmental mitigation measures as described in the Environmental Impact Report (EIR) as well as any further requirements that may be prescribed by the National Department of Environmental Affairs (DEA) in the Environmental Authorisation (EA).

Any work carried out outside of the scope of the RID is considered unauthorised work unless official approval for such work has been obtained from the CD: IWRP prior to such work being carried out. The powers of the CD: IWRP to authorise the extent of development is vested in the approval by the Minister. Anything beyond what was originally approved by the Minister then becomes unauthorised developments.

This document serves as the RID for the implementation of the Mzimvubu Water Project: Lalini Dam and Hydropower Scheme and therefore concludes the formal handover of the project from CD: IWRP to CD: ID.

The purpose of the RID is to enable the Department of Water and Sanitation (DWS) to implement the decisions taken on the basis of the recommendations of the Feasibility Study. In this regard the other Feasibility Study reports serve to support this document. The Feasibility Study reports are as listed above.

The RID should be read in conjunction with the original Feasibility Study reports as well as the Environmental Impact Report (EIR), the EA as issued by DEA, and the reserve determination study report, amongst others.

The Ministerial Approval is included as Appendix A.

The RID does not only deal with the construction of the physical infrastructure but also touches on other aspects that are required for the successful implementation of the project.

2. OVERVIEW OF THE PROJECT

2.1 Mzimvubu Feasibility Study

The Mzimvubu Feasibility Study commenced in January 2012 and was completed in October 2014 in three stages as follows:

- Inception;
- Phase 1 – Preliminary Study; and
- Phase 2 – Feasibility Study.

The purpose of the study was not to repeat or restate the research and analyses undertaken on the several key previous studies, but to make use of that information previously collected, to update and add to this information. The purpose was also to undertake more focussed and detailed investigations and feasibility level analyses for the dam site options identified as being the most promising and cost beneficial.

2.1.1 Inception Stage

The aim of the Inception stage was to finalise the Terms of Reference (TOR) as well as to include, inter alia, the following:

- A detailed review of all the data and information sources available for the assignment;
- A revised study methodology and scope of work;
- A detailed review of the proposed study schedule, work plan and work breakdown structure indicating major milestones;
- Provision of an updated organogram and human resources schedule, and
- Provision of an updated project budget and monthly cash flow projections.

The Inception Phase culminated in the production of an Inception Report (DWS Report Number P WMA 12/T30/00/5212/1) which also constituted the final TOR for the study.

2.2 Screening of Alternative Development Options

2.2.1 Preliminary Study Phase

The Preliminary Report describes the activities undertaken during the preliminary study phase, summarizes the findings and conclusions, and provides recommendations for the way forward and scope of work to be undertaken during the Feasibility Study phase.

The Preliminary Study Phase was divided into two stages:

i. Desktop Study, and
ii. Preliminary Study.

The aim of the desktop study was, through a process of desktop review, analyses of existing reports and data, and screening, to determine the three best development options from the pre-identified 19 development options (from the previous investigation).

The aim of the preliminary study was to gather more information with regard to the three selected development options as well as to involve the Eastern Cape Provincial Government and key stakeholders in the process of selecting the single best development option to be taken forward into Phase 2 of the study.

The main activities undertaken during the second stage of Phase 1 were as follows:

- Stakeholder involvement;
- Environmental screening;
- Water requirements assessment;
- Hydrological investigations;
- Geotechnical investigations;
- Topographical survey investigations; and
- Selection process.

The three development options that were investigated were multi-purpose dams and associated infrastructure at the following dam sites:

- Ntabelanga on the Tsitsa River (a tributary of the Mzimvubu River)
- Thabeng on the Kinira River (a tributary of the Mzimvubu River)
- Somabadi on the Kinira River (a tributary of the Mzimvubu River)

The multi-purpose usage of all three dam options included regional bulk potable water supplies, irrigated agriculture, and hydropower.

An extensive investigation of the water requirements, cost-benefits, social upliftment and impacts was undertaken as well as a multi-criteria decision-making process and the resulting choice of preferred option was that at Ntabelanga Dam site.

The findings and recommendations from the screening of Alternative Development Options are described in the Preliminary Study Report No. P WMA 12/T30/00/5212/3.

Preliminary Environmental Screening was also carried out at this stage, and a Scope of Work for the full Environmental Impact Assessment Study was prepared. This is described in the Environmental Screening Report No. P WMA 12/T30/00/5212/2.

The Preliminary Study recommended Ntabelanga as the preferred dam site and scheme development to be taken forward to Feasibility Study level.

3. DETAILED PLANNING STAGE

3.1 Planning Processes

The key activities undertaken during the feasibility study initially focussed on the Ntabelanga Dam and were as follows:

- Detailed hydrology (over and above that undertaken during the Preliminary Study);
- Reserve determination;
- Water requirements investigation (including agricultural and domestic water supply investigations);
- Topographical survey (over and above that undertaken during the Preliminary Study);
- Geotechnical investigation (more detailed investigations than during the Preliminary Study);
- Dam feasibility design;
- Irrigation Development;
- Bulk Potable and Irrigation Water Distribution feasibility design;
- Hydropower analysis;
- Land matters;
- Public participation;
- Regional economics;
- Cost Estimates and Economic Analysis, and
- Legal, institutional and financial arrangements.

An Environmental Impact Assessment was undertaken in a separate study that was undertaken in parallel to the technical feasibility study.

The above activities are described in more detail in the Main Report No. P WMA 12/T30/00/5212/4 and are summarised herein.

The multi-purpose usages and requirements for the Ntabelanga Dam are described in the Water Requirements Report No. P WMA 12/T30/00/5212/6, and the Irrigation Development Report No. P WMA 12/T30/00/5212/9.

3.2 Conjunctive Use of Ntabelanga Dam with Lalini Dam

Detailed investigations were undertaken for the Lalini Dam (as described in Section 1.1) once it had been established that the Ntabelanga-Lalini Dams conjunctive scheme was deemed worthy of being included in the feasibility study.

It was confirmed and agreed that the sizing and modus operandi of the Lalini Dam and its associated works would take into account its main role, namely:

- to generate hydropower both locally at the dam wall and at a hydroelectric plant (HEP) located in the Tsitsa River gorge downstream of the Tsitsa Falls; and
- to provide sufficient flow of water downstream of the Lalini Dam and these hydroelectric plants (HEPs) to meet environmental water requirements for an ecological Class B/C.

In order to facilitate this analysis detailed investigations were undertaken of the Lalini Dam components of the scheme, inter alia:

- Detailed topographical survey and positioning of the proposed Lalini Dam;
- Geotechnical investigations of the dam site, sources of construction materials, and tunnel alignments;
- Investigation of various Lalini hydropower scheme configuration options; and
- Hydropower modelling simulations of the Lalini hydropower plant and two mini-hydropower plants at Ntabelanga and Lalini dams for the conjunctive scheme.

3.3 Lalini Dam Site Selection

The location of a dam site at Lalini had been investigated in previous studies, including the 2004 ESKOM study of “Hydropower Potential in the Eastern Cape”.

This was further investigated during this feasibility study and confirmed following a site reconnaissance mission. The preferred site is at a narrowing neck of the Tsitsa River approximately 3.5 km upstream of the Tsitsa Falls, co-ordinates: 31°15'44.76"S and 28°55'15.87"E.

It was concluded that there were no better upstream dam wall locations available with regard to river valley shape (which affects dam wall length), geology/founding conditions, close proximity to construction materials, and the depth versus volume characteristics of the impoundment.

This location also offered several different options for hydropower configurations which are described in detail in the Feasibility Design: Lalini Dam and Hydropower Scheme Report No. P WMA 12/T30/00/5212/19. Localities of the Ntabelanga and Lalini Dams are given on Figures 3-2 and 3-3.

Figures 3-1, 3-4 and 3-5 are photographs that were taken during the site reconnaissance mission which was undertaken to inspect the surface morphology and implied geology, and to thus determine a preferred dam alignment.

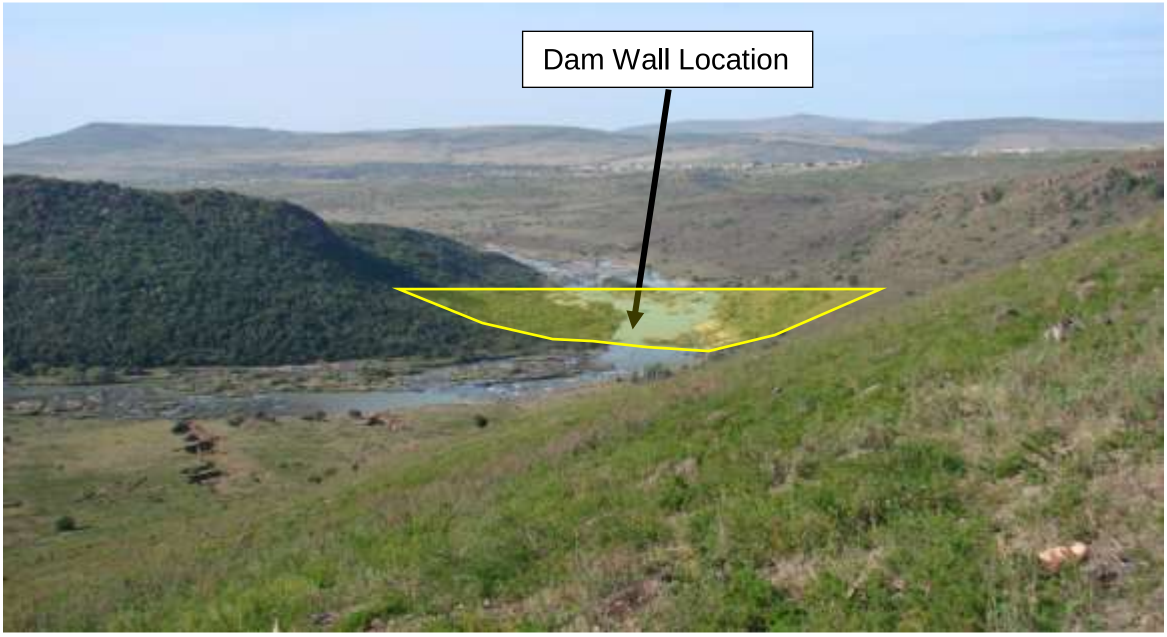

Figure 3-1: Proposed Lalini Dam Site Looking Downstream

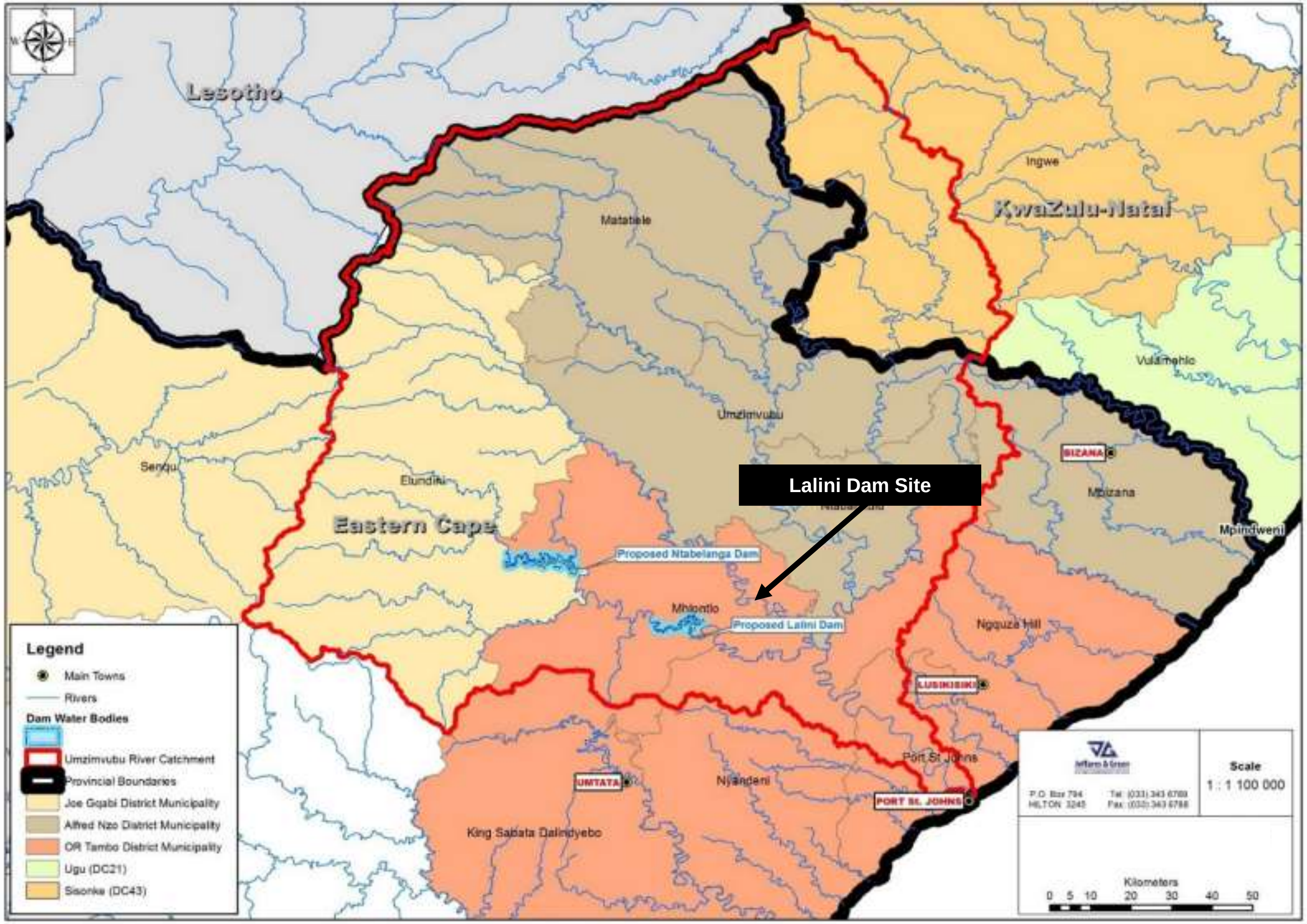

Figure 3-2: Localities of Ntabelanga and Lalini Dams Relative to Overall Mzimvubu Catchment Area

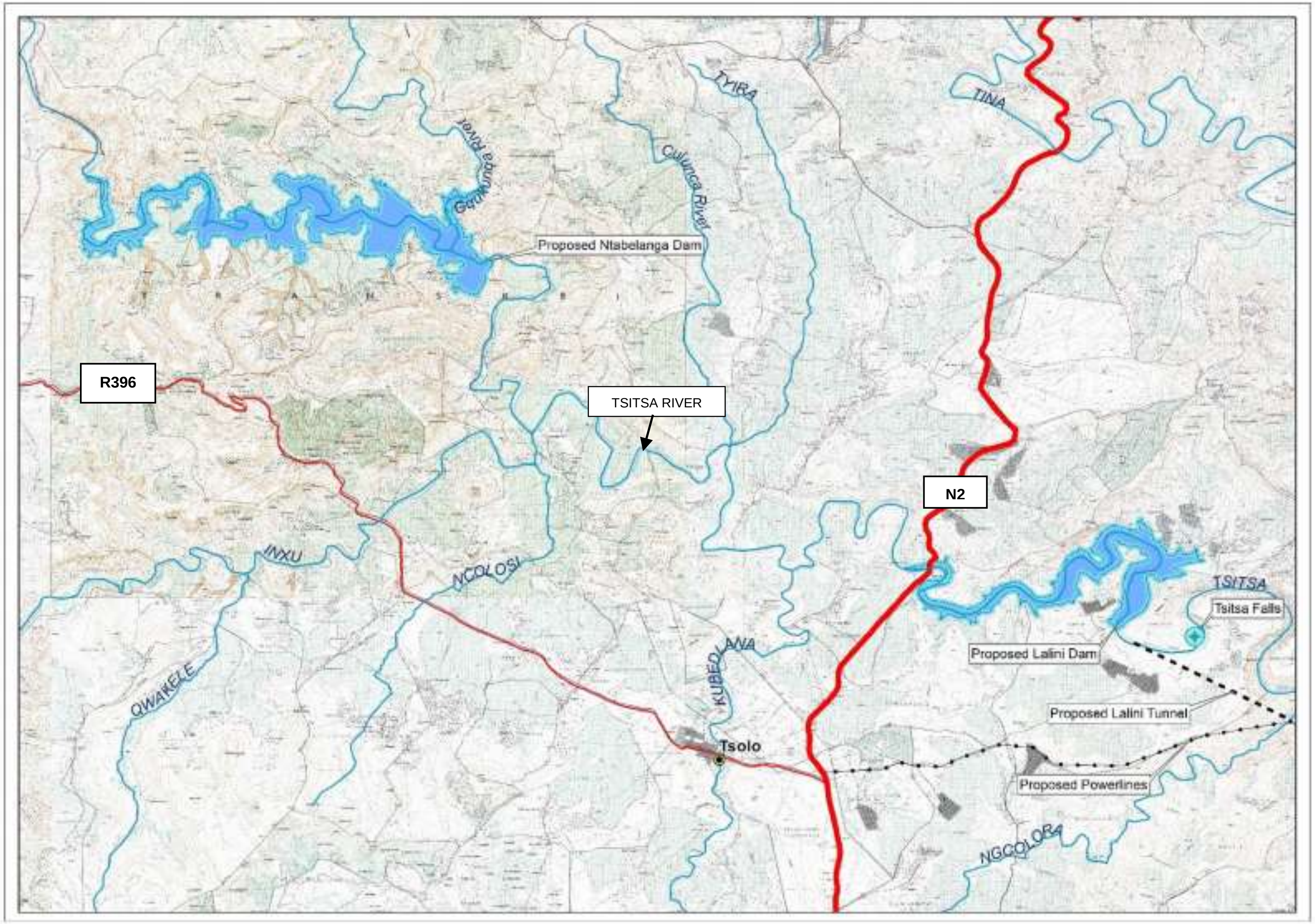

Figure 3-3: Locality of Lalini Dam Relative to the Ntabelanga Dam

Both upstream and downstream of the primary dam site, the valley widens and flattens, and the next suitable dam site location downstream is below Tsitsa Falls. However, this would require a very high dam wall in order to provide sufficient head for hydropower generation. Furthermore, the Tsitsa Falls would be inundated once the dam is constructed. Therefore, the more detailed Lalini Dam wall siting investigations for the feasibility study have been focussed on the narrowest part of the Tsitsa River valley some 3.5 km upstream of the Tsitsa Falls.

3.3.1 Site Morphology and Geology

The morphology and geology evident from the observations during the reconnaissance mission was that the dam would be founded on competent dolerite which extends well below the likely dam foundation level and into and up the left hand abutment. On the right hand abutment the dolerite is overlain by competent sandstone. The *prima facie* evidence from the site reconnaissance was of a highly suitable dam site.

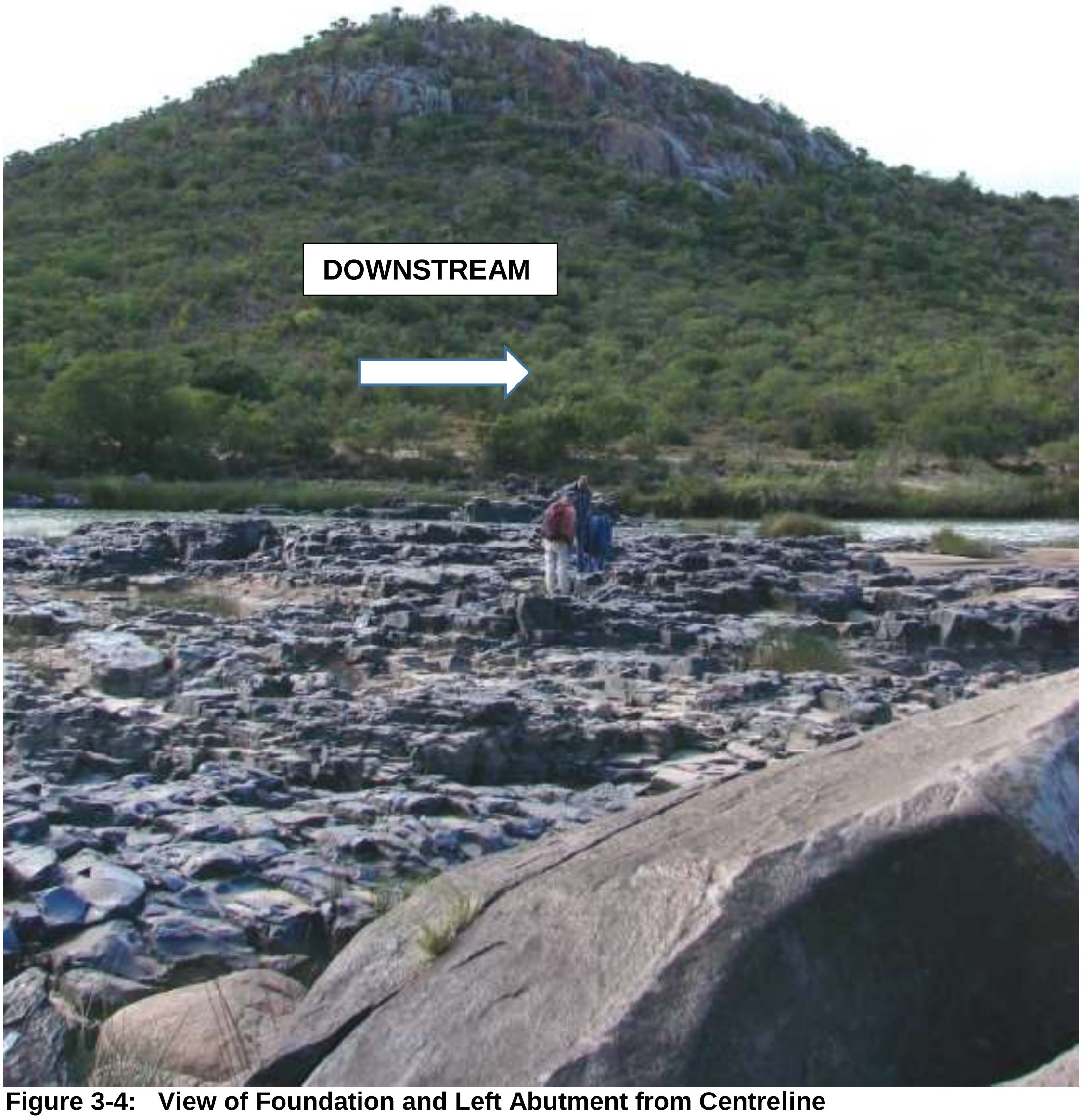

Figure 3-4: View of Foundation and Left Abutment from Centreline

Based upon these findings, geotechnical investigations (core drilling) and materials trial pitting and sampling were carried out on the dam wall alignment and potential spillway locations, as well as potential rock quarries and borrow pits, and are described in detail in Geotechnical Investigations Report No. P WMA 12/T30/00/5212/10.

3.3.2 *Summary of Dam Site and Materials Investigations*

Whilst the above geotechnical investigations report provides full details, results, conclusions and recommendations regarding the dam site investigations, and the investigations to identify suitable dam construction materials, the following is a summary thereof.

Figure 3-5: View of Right Abutment from Centreline

The feasibility level geotechnical investigation of the proposed Lalini Dam and conduit pipeline and tunnel sections entailed the following:

i. The drilling of four rotary core boreholes along the proposed alignment of the dam axis, two on the left flank and two on the right flank. Dolerite outcrop occurs across the river section.

ii. The drilling of seven boreholes for the proposed hydro-power scheme, of which four were positioned along or adjacent to the preferred horizontal alignment, one just below the dam to cater for the pipeline section or an alternative tunnel alignment and one to the south west of the preferred tunnel alignment to cater for an alternative longer and deeper tunnel option. Five of the boreholes were inclined 5° off vertical to facilitate the undertaking of core orientation measurements.

iii. The drilling of six boreholes in an identified potential rock quarry site.

iv. A co-ordinated trial pitting investigation of identified potential borrow pits for earth embankment construction.

v. The excavation of trial pits along the proposed pipeline alignment.

vi. Water pressure tests were conducted at representative intervals in all the dam boreholes and in one tunnel borehole.

vii. Rock strength tests were conducted on representative borehole core samples, either by means of laboratory unconfined compressive strength (UCS) tests or point load strength index (PLSI) tests conducted on site.

viii. Representative samples were retrieved of the unconsolidated materials proposed for earthfill dam construction to facilitate testing and analysis.

ix. Water samples were retrieved from selected boreholes and from the Tsitsa River, the former for chemical aggressiveness testing and the latter to assess suitability for use in construction.

x. Associated rock exposure mapping and photography.

Figure 3-6 shows a summary of the core logs in the four boreholes drilled along the dam wall centreline.

Figure 3-7 shows the locality of identified quarries and borrow areas identified that will provide sufficient quantities of materials for each dam type construction.

The extent of the geotechnical investigations undertaken along the proposed dam axis has concluded that the site is suitable for the construction of an earthfill embankment dam, a rockfill dam, or a RCC dam.

Based upon the drilling undertaken the dam foundation invert will vary from between 6 m and 8 m below ground level on the upper flanks to between 3 m and 4 m below ground level on the lower flanks. Dolerite outcrops, visible across the river section, implying that only moderate excavation would be required in this area.

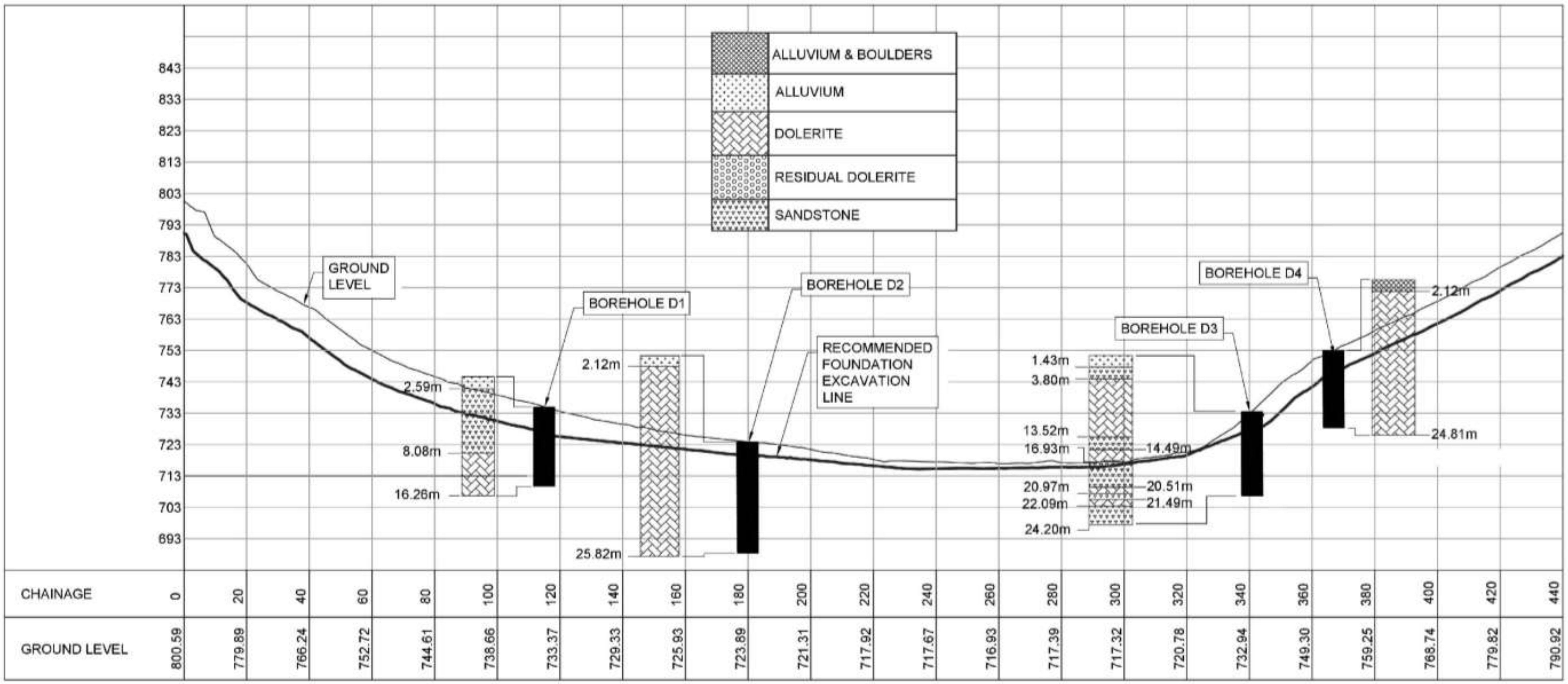

Figure 3-6: Lalini Dam Centreline Borehole Log Summary

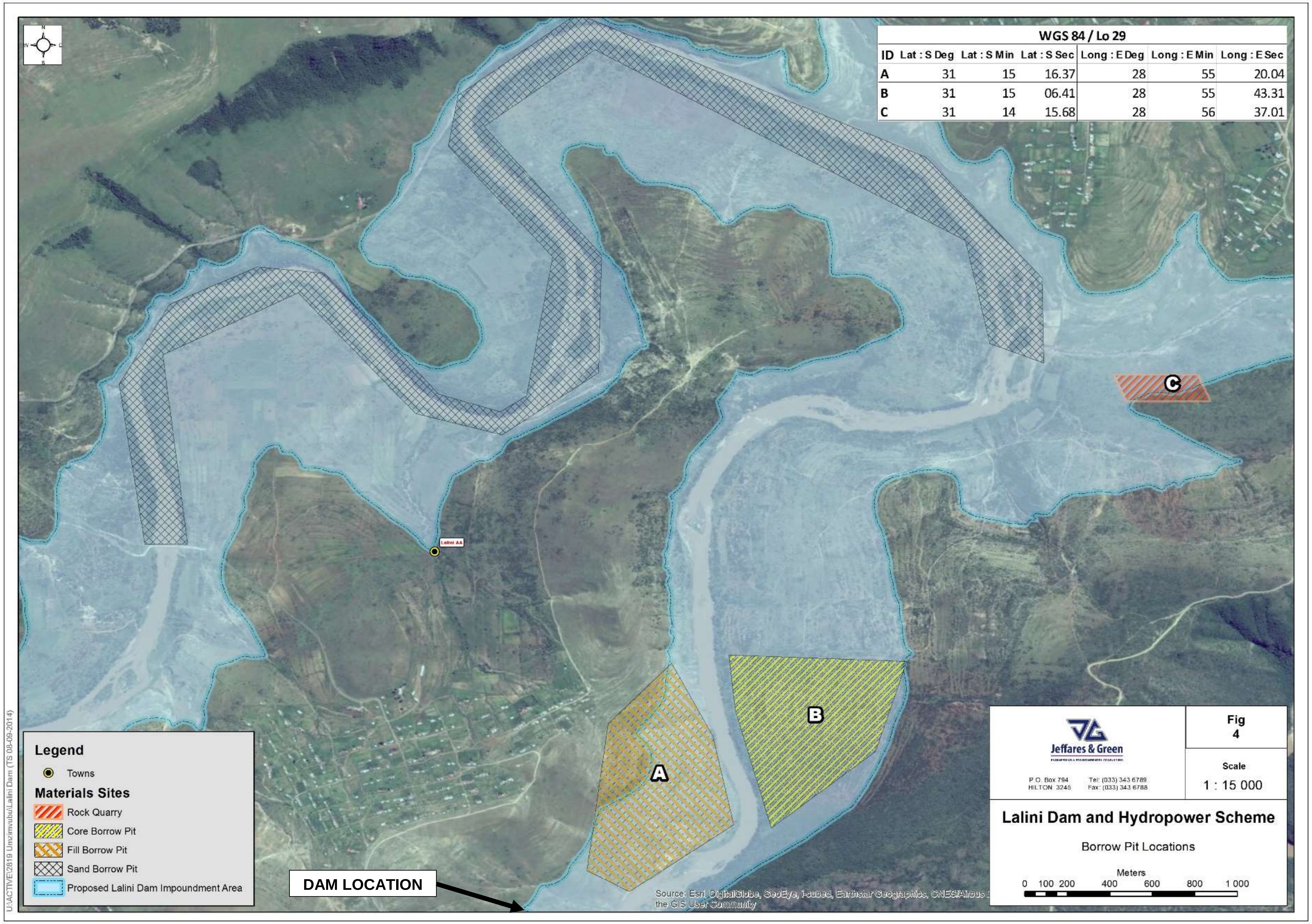

Figure 3-7: Locality of Identified Rock Quarry and Other Material Sources

The results of water pressure tests indicate that minor under-seepage is likely and that a cut-off grout curtain will be required. The need for consolidation grouting was not conclusively proven. Further detailed geotechnical investigations will be required to inform the detailed design process.

The reconnaissance for dam construction materials concentrated on areas falling within the future impoundment basin in order to avoid the negative environmental impacts and rehabilitation requirements associated with exploitation outside of the impoundment area.

The area investigated as a potential rock quarry lies on the left hand or eastern side of the Tsitsa River, approximately 3.5 km upstream of the dam. The investigation did prove good quality dolerite, but occurring beneath an excessively thick overburden mantle of unconsolidated, weathered and fractured materials. As a result of this, under normal circumstances, the site would be regarded as being marginal for use as a rock quarry, but the use of the overburden materials in road construction, if found suitable, could mitigate the use of the area as a rock quarry.

The naturally occurring sand in the channel of the Tsitsa River was found to be too finely graded for use as either concrete fine aggregate or filter medium. Its use would necessitate blending with an inert crushed rock product. Alternatively sand would have to be acquired from an approved off-site source.

For embankment dam types and for use in cofferdams, suitable core material availability was proven in adequate quantities, a short distance upstream of the dam within the impoundment basin. The area investigated as a shell borrow pit lies immediately upstream of the dam, with geology comprising mudrock and intercalated sandstone. The material tested is coarse grained, but with plastic fines, due to the preponderance of mudrock.

Based upon investigation undertaken and observations made on site, adequate embankment shell (fill) material is available in terms of quality and quantity.

Given these findings, it was determined that availability of suitable materials within reasonable distance of the dam site, and located within the impoundment basin, was sufficient for the further consideration of the following dam types:

- Roller compacted concrete (RCC) dam;
- Concrete faced rockfill dam (CFRD);
- Earth core rockfill dam (ECRD); and
- Earthfill embankment dam with earth core (EF).

3.4 Dam Capacity and Wall Height

The Lalini Dam must have sufficient capacity to store and balance the inflow, in order to sustain a reliable hydropower output. It must also have outlet works of sufficient capacity to release water to the river downstream in order to meet EWR requirements for a Class B/C ecological classification, which will constitute some one-third of the MAR_{NAT} of the river at this location.

A final requirement will be that the dam has sufficient spillway capacity to deal with the Safety Evaluation Flood (SEF) of the river at this location.

3.4.1 Basin Characteristics – Lalini Dam

A LiDAR Survey was undertaken for the Lalini Dam basin. The resultant detailed basin characteristics used for the Lalini Dam site are presented in Table 3-1 and Figure 3-8, respectively.

The detailed survey showed a reduction in stored volume per water depth when compared to the basin characteristics generated from the 20 m contours and used in previous study assessments.

The difference ranged from a 20% reduction in storage at elevation 740 m.a.s.l., to approximately 15% at elevation 770 m.a.s.l.

This change impacts the available live storage for hydropower generation when compared to the previous assessment.

Table 3-1: Detailed Basin Characteristics of the Lalini Dam

Water Level (m.a.s.l.)	Accumulated Volume (million m^3)	Area (km^2)
787.00	649.72	25.15
780.00	486.58	21.49
775.00	385.79	18.68
770.00	299.10	16.12
765.00	224.36	13.81
760.00	161.10	11.49
755.00	109.58	9.16
750.00	69.78	6.76
745.00	41.40	4.68
740.00	22.24	3.08
735.00	10.22	1.85
730.00	3.67	0.76
725.00	1.08	0.34
720.00	0.07	0.04
717.00	0.00	0.00

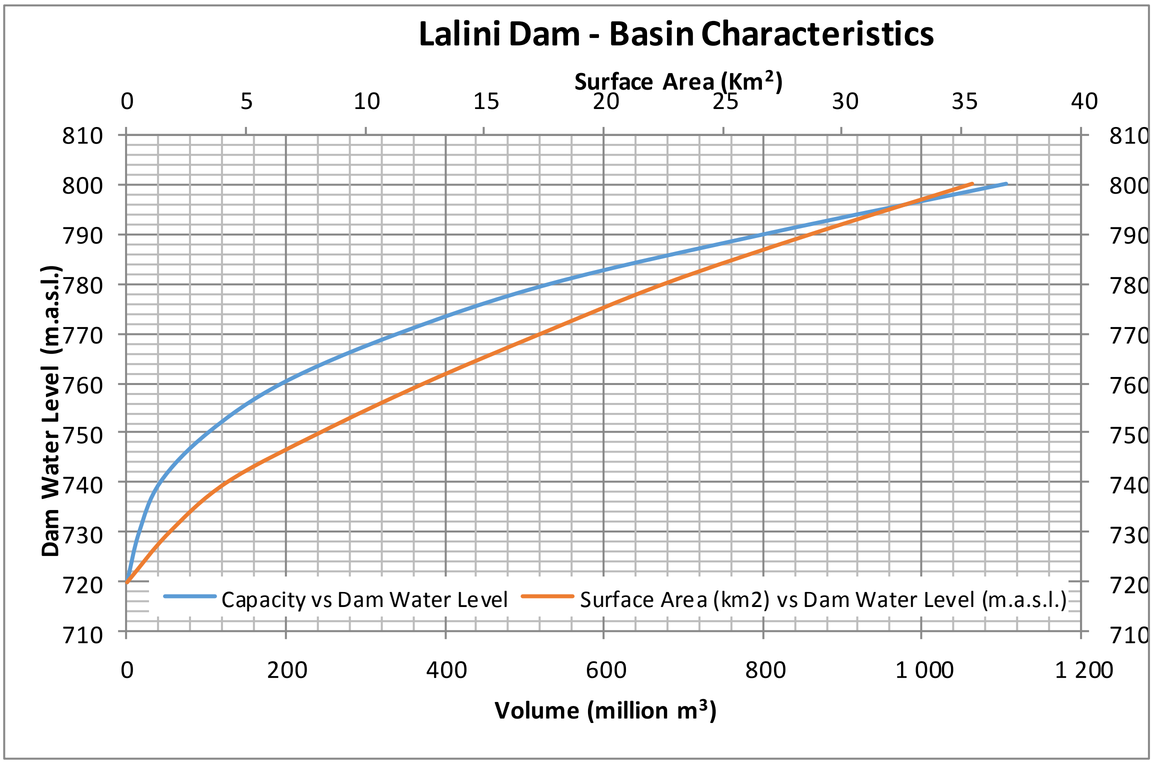

Figure 3-8: Lalini Dam Water Level versus Capacity and Surface Area

3.4.2 Inundation Impacts

The hydropower analyses, summarized below and described in detail in Report No. P WMA 12/T30/00/5212/18 were run for a range of Lalini Dam capacities from 0.10 MAR_{PD} (83 million m^3) to 0.75 MAR_{PD} (619 million m^3) operated conjunctively with a 1.18 MAR_{PD} capacity Ntabelanga Dam (490 million m^3).

Following the undertaking of a detailed topographical survey covering extended areas around the Lalini Dam site and impoundment area, it was noted that the dam wall height can only be set for a maximum full supply level (FSL) of 780 m.a.s.l. (0.6 MAR_{PD}) before overtopping the terrain on the left flank.

As the construction of saddle dams is not considered necessary or acceptable, and as this size of dam would drown a large area of settlement and existing infrastructure, the upper limit for the maximum Lalini Dam capacity was set at this value for further analysis purposes.

As regards the sediment trapping aspects of Lalini Dam it was shown that a minimum of a 0.18 MAR_{PD} dam should be built to ensure that the dam was large enough to accommodate some 50 years of predicted sedimentation based on the updated Rooseboom methodology.

The sizing of a dam often has to be a trade-off between increased capital cost, increased hydropower output, and increased social and environmental impact including the drowning of land, settlement structures, and existing civil infrastructure.

In this case, one of the key infrastructure components affected by the inundation of this valley is the existing N2 national road bridge across the Tsitsa River upstream of the proposed Lalini Dam site. In addition, the existing tarred district road from the N2 to Mtshazi and Shawbury would be partly inundated and sections would require realignment, depending on the final water level in the dam.

The road and low-level river bridge crossing from this district road to the village of Lalini would be drowned under all possible Lalini Dam capacities and the cost (greater than R150 million) of a high-level replacement bridge increases with Lalini Dam water level. See Figure 3-10.

It was therefore decided to focus on a Lalini Dam capacity and water level that could be accommodated by the existing N2 road bridge with provision for SANRAL-acceptable freeboard under 1 in 100 year return period flood conditions.

This bridge is shown in Figures 3-9 and 3-11.

Using the required SANRAL design formula, the maximum dam full supply level (FSL) resulting from this bridge freeboard calculation was 765.5 m.a.s.l. which produced a Lalini Dam capacity of some 232 million m^3 or 0.28 MAR_{PD}. It was estimated that raising the bridge to accommodate higher water levels in the Lalini Dam would cost approximately R150 million, as well as significantly increasing the cost of the above described district road realignments and new Lalini access bridge.

As described in Report Nos. P WMA 12/T30/00/5212/15 and P WMA 12/T30/00/5212/18, increasing the Lalini Dam capacity beyond this size also results in significant increased costs for the hydropower water transfer conduit and power generation plants, for which the additional return in terms of energy sales is not proportionately higher.

The social and environmental impacts in terms of lost land and resettlement impacts also start to significantly increase above this proposed “optimum” dam capacity, and the EIA team also concurred that the dam FSL be set no higher than 765.5 m.a.s.l.

Figure 3-9: N2 Road Bridge Viewed Looking Upstream

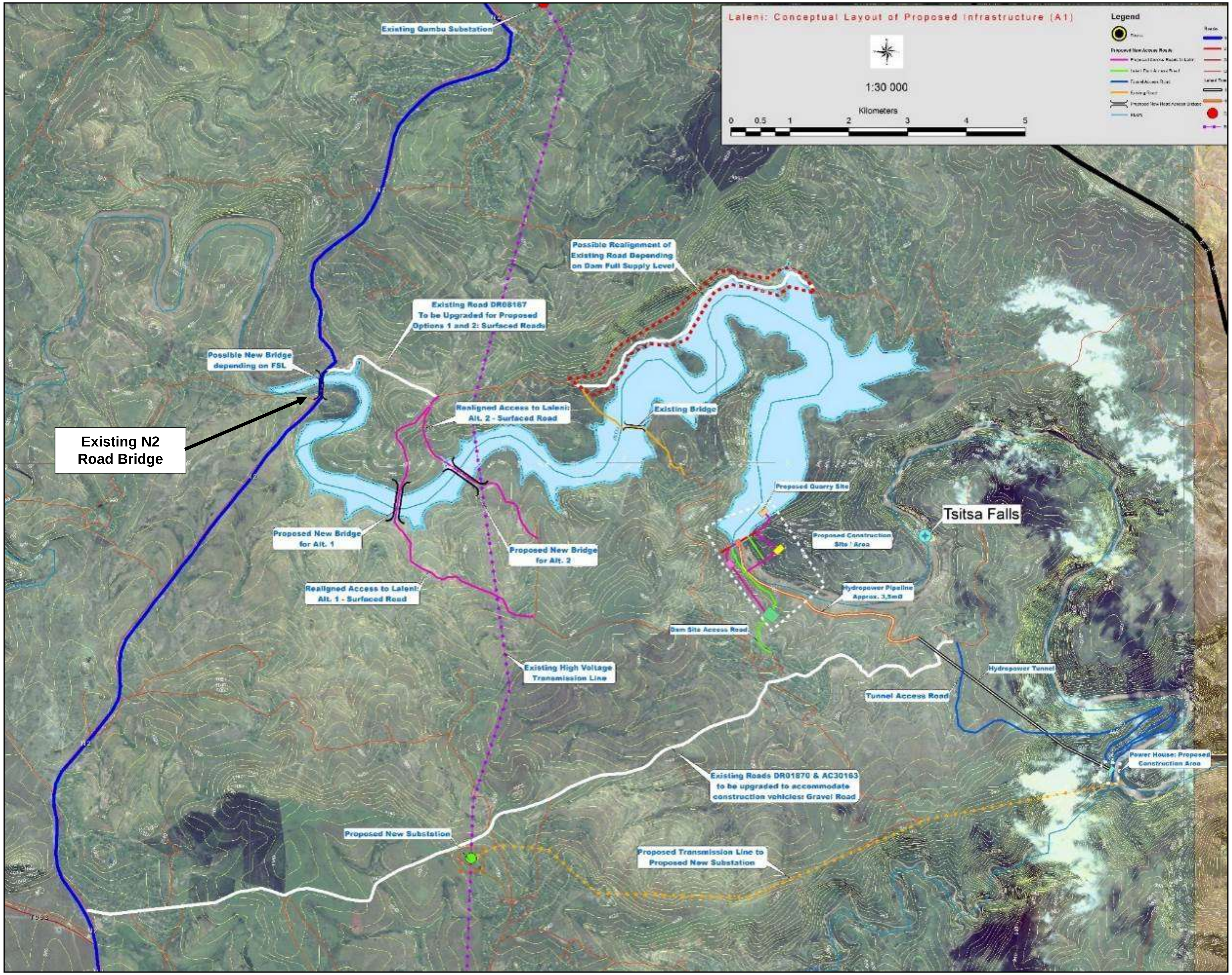

Figure 3-10: Infrastructure Affected by Rising Water Levels in the Lalini Dam

Figure 3-11: N2 Road Bridge across Tsitsa River

The process of dam type analysis was undertaken in parallel to the above investigation of "optimum" dam capacity sizing, and, for the purposes of comparison of different dam types, two capacities were adopted for detailed costing, namely 0.3 MAR_{PD} and 0.6 MAR_{PD}, in order to evaluate the likely range of viable dam capacity options.

3.5 Water Quality

Water quality sampling and testing for chemical aggressiveness was undertaken as part of the feasibility study to ascertain its suitability for use in construction.

The catchment area is known to have some of the highest sediment loadings in Southern Africa given the soil types, steep topography, eroded nature of the terrain, and the overgrazed, thinly layered soils, contributing a high percentage thereof.

The rivers in the catchment have been the subject of some recent studies by WRC and Rhodes University, and do exhibit very high sediment loads and turbidity levels. The dam itself will act as a sediment trap and settlement basin resulting in a very significant reduction in the suspended solids and turbidity of water passing through the dam outlet works.

This emphasises the importance of undertaking a concerted catchment restoration and management programme in the catchment above the dam, both before construction and continuing into the future. DEA started a 10 year catchment rehabilitation programme in April 2014.

Based upon the nature and land use of the catchment upstream of the dam, the raw water stored in Lalini Dam would typically contain the following:

- Possibly iron,
- Possibly manganese,
- Possible nitrates and phosphates,
- Turbidity,

- Suspended solids, and
- Microbiological contaminants.

Lalini Dam is purely a hydropower dam and is not intended to be used as a potable water supply source. The potable water supply to the settlements in the vicinity of the dam would initially continue to be from existing local supplies and eventually supplemented from or replaced by the tertiary pipelines to be constructed as a part of the Ntabelanga Dam Bulk Potable Water Supply Infrastructure.

A temporary potable water supply system may be required during the dam and hydropower implementation period. For such a water treatment plant, it is expected that, after debris screening and grit removal, conventional settlement and filtration processes will be sufficient to deal with the expected sediment load and turbidity. Selection of the best coagulant will be undertaken after appropriate laboratory testing of water samples, and it is therefore recommended that a water quality sampling and testing programme be instigated as soon as possible to better inform the design of such a treatment plant.

The depth of water in the dam will create thermal stratification in the body of water impounded. The outlet works are designed such that water can be drawn off from the dam at different levels based upon the monitored limnology conditions, in order to obtain the best quality water given the seasonal and depth variations that occur in normal dam operation.

It is recommended that reservoir stratification modelling be undertaken during the operation stage so that, in conjunction with reserve determination specialists, a set of operating rules can be established taking cognisance of the EWR, and optimum drawoff elevations can be established.

It is recommended that an ongoing water quality sampling and testing programme be implemented immediately so that an assessment of contaminants can be made, as well as potential nutrient sources identification to determine whether filamentous algae might become a problem.

3.6 Hydrological Studies

Full details of the hydrological analyses undertaken can be found in the Water Resources Report No. P WMA 12/T30/00/5212/5.

The water resources assessment in Phase 1 undertook to investigate three preferred dam sites and, ultimately, to provide input into the selection of the final site for detailed analyses. The three preferred dam sites were the proposed Ntabelanga, Somabadi and Thabeng dams on the Tsitsa and Kinira Rivers, respectively.

The results highlighted that the Ntabelanga Dam was the preferred dam site from a water resources perspective, not only for the provision of raw water to meet potable water demands and irrigation requirements, but also to potentially generate hydropower within the Tsitsa River system.

This was confirmed in an economic analysis of the three options described in the Preliminary Study Report No. P WMA 12/T30/00/5212/3.

A more detailed water resources assessment (Phase 2) was undertaken on the Ntabelanga and Lalini Dams, which results were used to model the hydropower generation potential of the Tsitsa River at Lalini above the Tsitsa Falls.

The same methodology adopted for Phase 1 was followed in Phase 2, with two changes:

1. Some of the input information was updated, namely:
   a. Rainfall;
   b. Land use;
   c. Sedimentation; and
   d. EWR.
2. Hydropower scenarios were included through the addition of a dam at Lalini above the Tsitsa Falls.

The results from the rainfall analysis were used in the rainfall-runoff and yield modelling exercises (as presented in Table 3-2), which had a positive impact by increasing the available stream flow across the catchment due to an overall increase in rainfall depth.

The land use inputs from Phase 1, i.e. commercial forestry, irrigation and invasive alien plants (IAPs) were updated due to the recent availability of a biodiversity study undertaken in the Ntabelanga Dam catchment, up to and including Quaternary Catchment T35E.

Commercial forestry increased from 334.0 to 380.3 km^2 and IAPs increased from 37.5 to 41.0 km^2 from Phase 1 to Phase 2.

Table 3-2: Mean Annual Precipitation of the Tsitsa Quaternary Catchments

Quaternary Catchment	Phase 2 MAP (mm)	WR2005 MAP (mm)
T35A	927.9	912.0
T35B	867.5	915.0
T35C	974.2	1 008.0
T35D	816.6	818.0
T35E	941.1	918.0
T35F	907.5	860.0
T35G	705.7	759.0
T35H	935.7	845.0
T35J	985.6	924.0
T35K	828.7	783.0
T35L	657.6	764.0

The catchment areas contributing to the Ntabelanga and Lalini Dams are approximately 1 967 km^2 and 4 422 km^2 respectively comprised of the contributing quaternary catchment areas as given in Table 3-3, and as delineated in Figure 3-12.

The catchment area contributing to the Ntabelanga and Lalini Dams in the tertiary catchment T35 is somewhat developed with approximately 10% of the catchment area under commercial forestry.

Table 3-3: Contributing Catchment Areas for the Study Area

Tsitsa River Catchment	
Quaternary Catchment	**Catchment Area (km²)**
T35A	476.5
T35B	396.8
T35C	307.0
T35D	348.9
T35E	493.5
T35F	359.6
T35G	576.2
T35H	521.0
T35J	189.0
T35K	627.1
T35L	339.5
TOTAL	**4 635.1**

All investigations for the conjunctive operation of the Ntabelanga Dam and the Lalini Dam and hydropower scheme have been based upon the 1.18 MAR_{PD} (490 million m^3) capacity Ntabelanga Dam, with various capacity options investigated for the Lalini Dam.

The sedimentation allowance estimated in Phase 1 was revised in Phase 2, from using the Rooseboom (1992) method to using the updated version of the same method, developed by the WRC (2010).

This method was also used to determine the incremental sedimentation allowance for the proposed Lalini Dam, below Ntabelanga Dam.

The new V_{50} value calculated for the Ntabelanga Dam was 35.7 million m^3. Sedimentation volumes over 50 years were also calculated for the incremental contributing catchment of the Lalini Dam, below the Ntabelanga Dam. The incremental sedimentation V_{50} value used in this study was 31.2 million m^3, which resulted in a total allowance of 66.9 million m^3 in both dams.

The updated inputs were used in the rainfall-runoff modelling based on the same configuration as in the Phase 1 study. Through a process of calibrating the poor quality stream flow data and using the new rainfall and land use inputs, better calibrations were achieved using WRSM2000. These simulated natural stream flow results were accepted and used in the stochastic and yield analyses.

The simulated natural mean annual runoff (MAR_{NAT}) in the Tsitsa River was modelled to be 428.5 million m^3/a at the Ntabelanga Dam site, with the present day mean annual runoff (MAR_{PD}) at the same site being slightly lower at 415.0 million m^3/a. This proportionally low reduction in MAR highlighted the relatively small development level within the catchment. Thus, indicating the potential for water resource development.

The simulated natural mean annual runoff at the Lalini Dam site was modelled to be 868.6 million m^3/a, with the present day mean annual runoff at the same site being slightly lower at 828.0 million m^3/a. This proportionally low reduction in MAR highlights the relatively little development within the catchment.

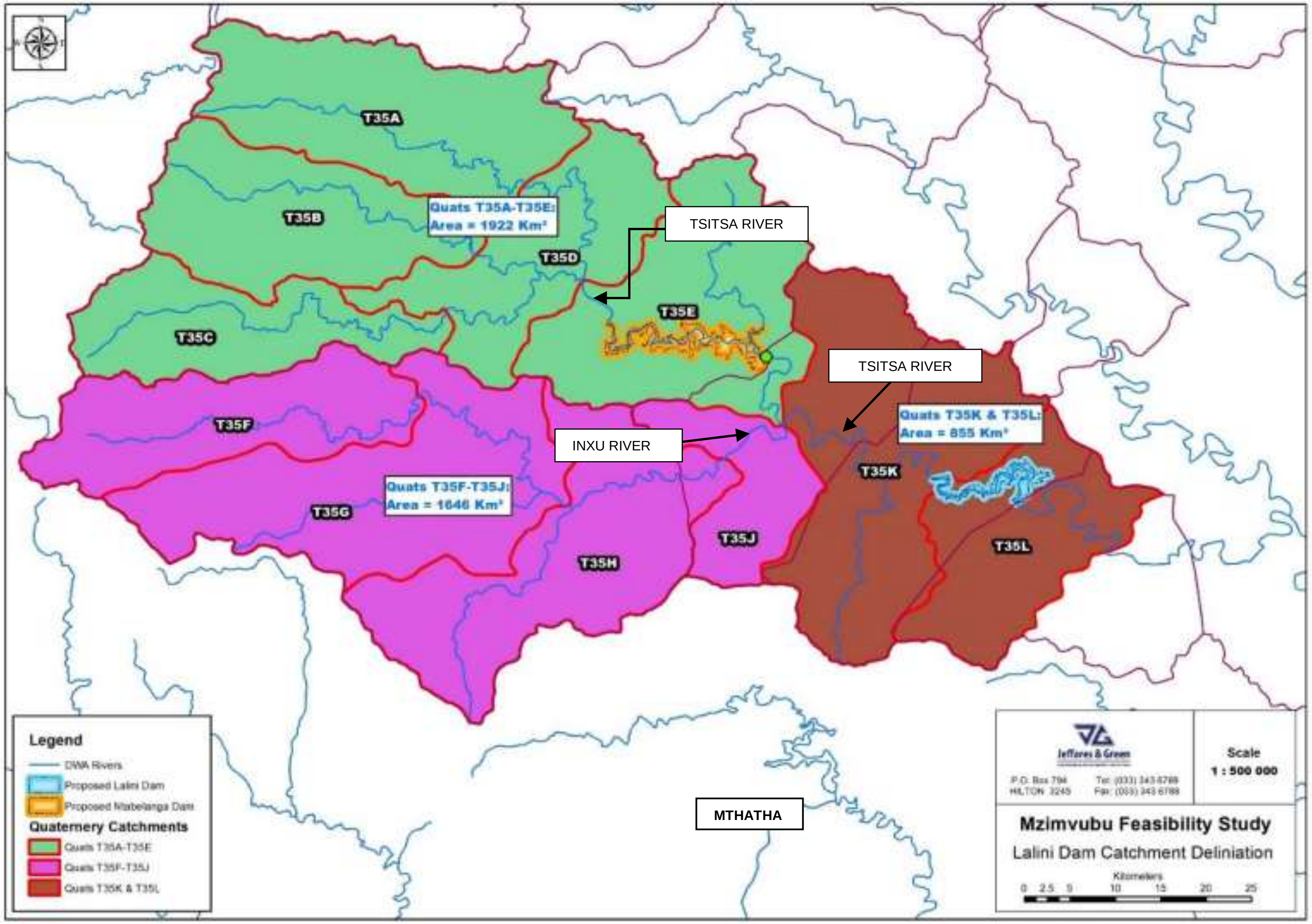

Figure 3-12: Lalini Dam Catchment Delineation

3.6.1 Reserve Determination

An Intermediate Reserve Determination for the Tsitsa/Mzimvubu River system was completed in 2013 as a component of this project.

This study focused on the riverine and estuarine ecological water requirements (EWR), including a socio-economic assessment of the catchment-wide flow scenarios. EWRs were determined for two sites, namely the selected riverine EWR site below the proposed Ntabelanga Dam site on the Tsitsa River and the estuarine EWR site on the Mzimvubu River.

The water resources of the Tsitsa River at the Ntabelanga Dam EWR site is currently in a C category (moderately modified state), mainly due to water quality impacts (a result of increased sedimentation in the system), and localised disturbances (e.g. alien invasive plants and concomitant bank erosion). The system has a moderate Ecological Importance and Sensitivity. The overall confidence in these results is medium.

The Reserve Determination Report No. P WMA 12/T30/00/5212/7 determines the Environmental Water Requirements (EWR) to be released downstream of the Ntabelanga Dam.

The recommended total releases are those required to maintain an intermediate ecological Class C of 87.249 million m^3 per annum, which equates to an average of some 7.27 million m^3 per month, or 2.8 m^3/s.

The Ntabelanga EWR is required to be released according to a seasonal pattern and this also depends on whether the river is in a status of flood or drought. EWR release rules are proposed in the Reserve Determination Report, and release criteria are based upon preceding inflows.

A reserve determination also needed to be completed specifically for the Lalini Dam and hydropower plant sites as the hydropower releases can have a significant impact upon the riverine ecology downstream of the proposed dam site and hydropower tunnel exit point.

This was undertaken as a part of the independent EIA and included the rapid determination of the EWR of the Tsitsa River downstream of the Tsitsa Falls, which indicated an ecological class of B/C. This EWR value and its recommended rules of operation were included into a new hydropower simulation modelling to improve the accuracy of estimation of the potential hydropower outputs of the scheme.

Based upon these findings, Lalini hydropower scheme operating rules were developed to ensure that environmental water requirement (EWR) recommendations were complied with, and these rules were discussed and agreed with the DWS Reserve Determination Directorate.

The EWR considered the river reach below the Tsitsa Falls to be an ecological Class B/C due to the potentially sensitive and unique environment downstream of the Tsitsa Falls, and allocating 287.0 million m^3 (33% MAR) as an annual average.

The impact of the Lalini EWR figure and required operating rules are described in more detail in the hydropower analysis section below.

3.6.2 Flood Hydrology and Spillway Capacity

As part of the dam feasibility design process, the dam spillway needed to be sized in accordance to the guidelines published by the South African National Committee on Large Dams (SANCOLD) in SANCOLD, 1991.

This section provides the SANCOLD design requirements for the Lalini Dam as well as methodologies undertaken to determine peak discharge values used to determine the Recommended Design Flood (RDF) and Safety Evaluation Flood (SEF) for the design of the Lalini Dam spillway.

The potential flood damage that could be inflicted on a hydraulic structure may be related to one or more of the following parameters:

- High Flood Level – the maximum water level reached during a flood event;
- Peak Discharge – the maximum flow rate during a flood event;
- Maximum Flow Velocity – the maximum calculated flow velocity associated with a given flow rate;
- Flood Volume – the volume of water that is released from a catchment during a flood event; and
- Flood Duration – the period of time when the discharge associated with a flood event exceeds a specified limit.

Peak discharge is the most useful parameter in design calculation requirements for structures to resist potential damage imposed by flood events. The peak discharge of a catchment is directly related to the characteristics of the storm event and characteristics of the contributing catchment area. The requirements for the design of the proposed Lalini Dam spillway, as per the SANCOLD guidelines, are presented in the following section.

3.6.3 Design Flood Guidelines

Guidelines on dam safety in relation to floods were published by the SANCOLD (1991) to facilitate the requirements for the determination of flood values for the purposes of dam design. This was undertaken to ensure that the risk of failure through inadequacy of the spillway system could be kept to acceptable levels hence, these guidelines were used in this investigation. The guidelines outline the requirements for the Recommended Design Flood (RDF) and the Safety Evaluation Flood (SEF).

The spillway should be designed such that it can safely discharge the peak flow rate associated with the RDF, without any damage to the dam wall or spillway. The SEF is used to ensure that the spillway is designed to sufficiently discharge the SEF associated peak flow rate without catastrophic failure of the dam wall or spillway (some damage is tolerated), whilst making no allowance for freeboard, thus maintaining the dam’s integrity until such a time as it can be repaired.

The SANCOLD Guidelines used to determine the RDF and SEF requirements for the design of the Lalini Dam spillway are presented in Tables 3-4 to 3-8.

These guidelines were applied for a large dam wall (greater than 30 m high), an assumed potential loss of life greater than 10 people and a great potential economic loss.

Table 3-4: Dam Size Classification

Size Class	Maximum Wall Height (m)
Small	More than 5 and less than 12
Medium	Equal to or more than 12 but less than 30
Large	Equal to or more than 30

Table 3-5: Hazard Classification

Hazard Rating	Potential Loss of Life	Potential Economic Loss
Low	None	Minimal
Significant	Not more than 10 lives	Significant
High	More than 10 lives	Great

The process under the guidelines is to classify the dam according to Tables 3-4 and 3-5 and to apply this to the category Table 3-6. As can be seen the results for Lalini Dam show it to be a large dam with high hazard rating making it a Category 3 dam under the guidelines.

Table 3-6: Dam Safety Categorisation

Dam Size Class	Dam Safety Class		
	Low Hazard	Significant Hazard	High Hazard
Small	1	2	2
Medium	2	2	3
Large	3	3	3

Table 3-7: Recommended Design Flood Values

Dam Size Class	Recommended Design Flood		
	Low Hazard	Significant Hazard	High Hazard
Small	$0.5Q_{50} – Q_{50}$	Q_{100}	Q_{100}
Medium	Q_{100}	Q_{100}	Q_{200}
Large	Q_{200}	Q_{200}	Q_{200}

Table 3-8: Safety Evaluation Flood Values

Dam Size Class	Safety Evaluation Flood		
	Low Hazard	Significant Hazard	High Hazard
Small	$RMF_{-\Delta}$	$RMF_{-\Delta}$	RMF
Medium	$RMF_{-\Delta}$	RMF	$RMF_{+\Delta}$
Large	RMF	$RMF_{+\Delta}$	$RMF_{+\Delta}$

In each of the Tables 3-7 to 3-8, the recommendations from the guidelines applicable for the Lalini Dam are highlighted in yellow. A summary of this information is provided in Table 3-9.

In summary, the Lalini Dam will be classed as a Category 3 Dam, therefore the RDF and SEF used to size the dam spillway will be equal to the 1:200 year design flood event and the Regional Maximum Flood (RMF; Kovacs, 1988) plus a category, respectively.

Table 3-9: Flood Categories Applicable to Lalini Dam

Size Classification	Large	Downstream wall height ≥ 30m
Hazard Classification	High	Great potential economic loss
Dam Safety Categorisation	**3**	
Recommended Design Flood Values	$\mathbf{Q_{200}}$	
Safety Evaluation Flood Values	$\mathbf{RMF_{+\Delta}}$	

3.6.4 Design Flood Hydrology Methods

SANCOLD (1991) specifies that for new Category 3 dams site specific hydrological calculations need to be used to estimate the design floods. The methods used to determine the design flood hydrology for the Lalini Dam were as follows:

- Statistical Methods
    - Probability Distribution Fitting to Observed Streamflow Data
- Deterministic Methods
    - Synthetic Unit Hydrograph (SUH)
    - Rational Method
- Empirical Methods
    - Catchment Parameter Method (CAPA)
    - HRU 1/71
    - Midgely and Pitman Method (MIPI)
    - Standard Design Flood (SDF)
    - Regional Maximum Flood (TR 137)

The Feasibility Design: Lalini Dam and Hydropower Scheme Report No. P WMA 12/T30/00/5212/19 – Appendix A provides a detailed description of the analyses undertaken for these various methods.

3.6.5 Flood Hydrology and Spillway Capacity Results

The cross-sectional profile in Figure 3-13 (note the exaggerated vertical scale) produces a crest length of some 365 m for the maximum FSL, and if an in-channel uncontrolled ogee spillway solution were to be employed, this spillway would occupy virtually all of the valley width, which means that the dam wall would be virtually all concrete in construction. Therefore, for rockfill or earthfill dam embankment options, other spillway solutions would be required, and both cut-through and side channel excavated spillways were therefore also investigated.

One advantage that these excavated spillways offer would be that the large volume of material excavated from them could be used in the construction of the main dam embankment. However, this has to be offset by the actual cost of such large excavation volumes in excess of actual construction requirements which would have to be disposed of as spoil, with the associated environmental consequences.

The Design Flood has been determined as described in the design note in Report No. P WMA 12/T30/00/5212/19. The design note was submitted to the DWS Hydrology Directorate for review and comment and was finalized after taking into consideration the comments received from DWS Hydrology Section thereon.

From that analysis it was determined that the Recommended Design Flood (RDF) value (which was equivalent to some 1 in 200 year return period flood) would be of the order of 3 500 m^3/s, and the Safety Evaluation Flood (SEF) would be 7 100 m^3/s (both un-routed values at this feasibility stage).

Following further analysis, it was confirmed that the freeboard requirements for the SEF would be the controlling case, and for the purposes of this spillway and dam options comparison, a total freeboard of 5.5 m was derived using the current SANCOLD guidelines on freeboard for dams (2011). See Appendix B in Report No. P WMA 12/T30/00/5212/19.

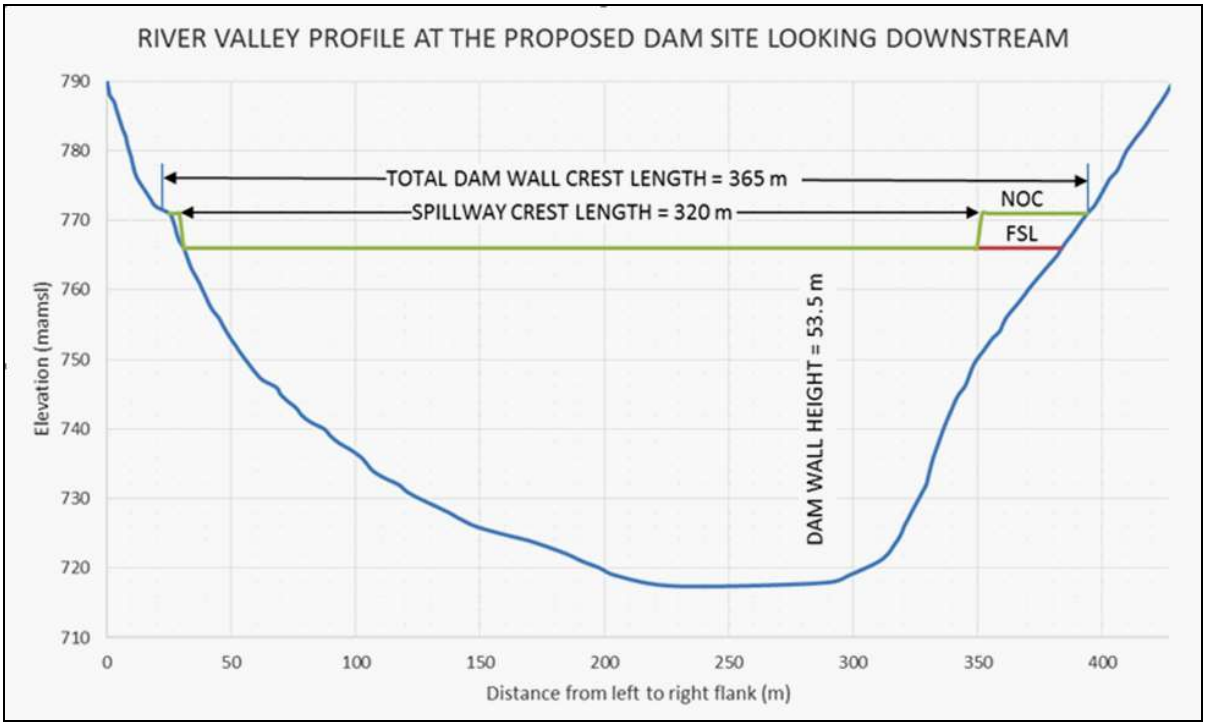

Figure 3-13: Cross-section of Valley (looking downstream) at Dam Wall Centreline

Following further dam configuration considerations, a freeboard from spillway crest to NOC crest level of 4.83 m was used, with the difference of 0.67 m freeboard being accommodated using a 1 m high parapet wall.

For the case of a RCC dam option, it was considered that some overtopping could be allowed on the left flank crest as a result of wave run up under SEF conditions, since this dam type is concrete and it is considered to be more resilient to overtopping. Such details should also be revisited as a part of the dam configuration optimisation during the detailed design stage.

To illustrate the implication of the quantum of these flood flow rates, and in order to pass this SEF with acceptable overflow depth and flow velocity, a conventional ogee spillway built along the dam wall centreline would need to have a crest length of between 200 m and 320 m.

As can be seen from the above cross-section, such a "conventional" spillway would constitute up to 88% of the crest length of the dam, and the spillway structure would span the highest section of the dam even if the spillway is offset as far to the left flank as possible, with consequential very high costs. As concrete works are by far the highest cost component of any composite dam, such an arrangement would result in an impractical and uneconomic structure for either the earthfill or rockfill embankment options.

In such embankment options, the typical solution is to build a side channel spillway and discharge chute, either built in reinforced concrete and crossing the end section of the embankment on the left flank of the dam, or aligned further outside this line and cut through the hill as a separate rock-lined channel.

Such arrangements can be applied to both rockfill and earthfill embankment dam options. However, the hydraulics of such side channel spillways are quite complex, and can only be properly optimised if laboratory modelling is undertaken, which would only be undertaken at the detailed design stage and not during this feasibility study.

The analysis undertaken for various dam types and spillway configurations is described in Report No. P WMA 12/T30/00/5212/19. Following the results of this analysis the recommendation was to implement an RCC dam with an integrated ogee spillway.

3.7 Hydropower Potential

The analysis of the hydropower potential of the Ntabelanga-Lalini conjunctive hydropower scheme is described in the Hydropower Analysis: Lalini Dam Report No. P WMA 12/T30/00/5212/18.

In reviewing studies previously undertaken by ESKOM in 2004, the study team identified a high potential hydropower generation site at Lalini, on the Tsitsa River downstream of the Ntabelanga dam site.

The primary focus for this aspect of the study was a potential conjunctive use hydropower scheme that included the Lalini Dam located some 3.5 km upstream of Tsitsa Falls, a tunnel, and a hydropower generation plant located in the gorge below the Tsitsa Falls. The Lalini Dam would be used as a head race solely for hydropower generation and, if shown to be viable, the conjunctive operation of both dams could improve the economics of the scheme as a whole.

The balancing storage of the Lalini dam is supplemented by water releases from the Ntabelanga dam, as well as the contributing catchment areas between Ntabelanga and Lalini dams. This arrangement is shown on Figure 3-14.

3.7.1 Economic Viability of Hydropower Options

As a part of Phase 2 of the feasibility study, economic analysis was undertaken for the Ntabelanga Dam hydroelectric plant (HEP) used conjunctively with the Lalini hydropower scheme. This analysis was run for the largest capacity Ntabelanga Dam operated in conjunction with the smallest capacity Lalini Dam, as well as the smallest capacity Ntabelanga Dam in conjunction with the largest capacity Lalini Dam.

A further scenario was investigated where the Lalini scheme was not built, but the Ntabelanga Dam hydropower plant was developed alone including the incremental cost of building the maximum capacity Ntabelanga Dam.

The objective of this was to determine whether to proceed with more detailed investigations for the Lalini Dam and Hydropower Scheme.

This is discussed in more detail in the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15 and the Lalini Hydropower Analysis Report No. P WMA 12/T30/00/5212/18 but, in summary, the results of both conjunctive and single plant hydropower analysis are given in Table 3-10.

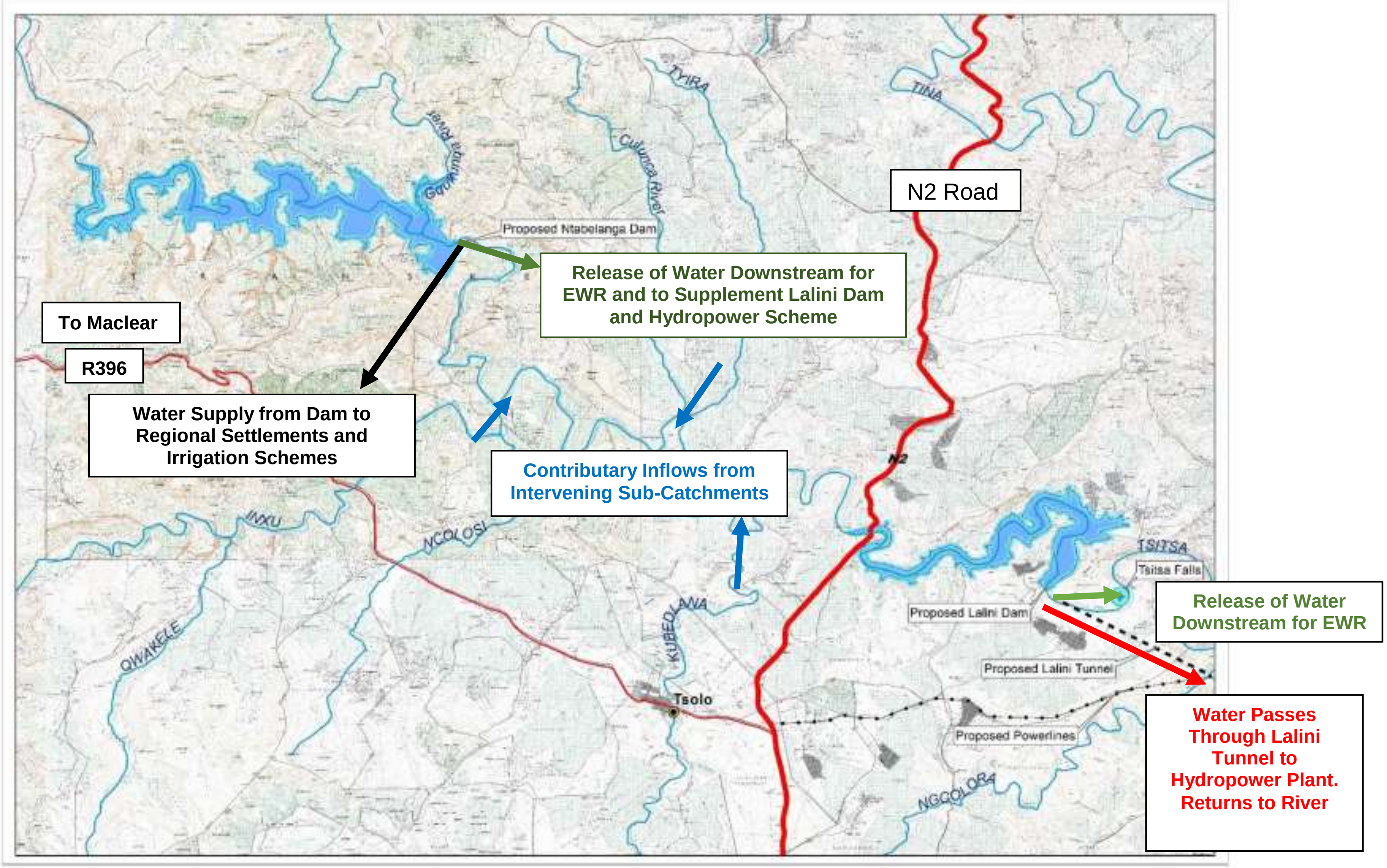

Figure 3-14: Conjunctive Hydropower Scheme

Table 3-10: Comparison of Levelized (URV) Cost of Power Produced by the Hydropower Options

					LEVELIZED COST OF POWER (R/kWh) FOR DISCOUNT RATES					
	DAM CAPACITY (MAR x)		INSTALLED HYDROPOWER		WITH FULL CAPEX INCLUDED			O&M AND REFURB COSTS ONLY		
OPTION	NTABELANGA	LALINI	NTABELANGA	LALINI	6%	8%	10%	6%	8%	10%
NTABELANGA DAM ONLY	1.18	NO DAM	5 MW	NIL	R3.24	R3.60	R3.97	R0.76	R0.67	R0.60
NTABELANGA DAM PLUS LALINI DAM	1.18	0.15	5 MW	30 MW	R0.82	R0.94	R1.06	R0.11	R0.10	R0.09
NTABELANGA DAM PLUS LALINI DAM	0.15	0.78	NIL	30 MW	R0.97	R1.11	R1.24	R0.13	R0.11	R0.10

This shows that developing the Ntabelanga hydropower option only is not viable, having a levelized cost of power ranging from R3.24/kWh to R3.97/kWh, including capital redemption. A benchmark for levelized costs for a viable hydropower scheme is currently in the range of R1.00/kWh to R1.50/kWh. Therefore, only if this option were to be grant funded would it be considered to be viable.

The conjunctive use options, however, show levelized costs well within the range currently considered to be viable, even allowing for full capital cost (“capex”) redemption.

The large Ntabelanga/small Lalini option had the lowest levelized cost of power ranging from R0.82/kWh to R1.06/kWh, including capital redemption, which could drop as low as R0.09/kWh if grant funding can be provided and only operation and maintenance and plant refurbishment costs are considered.

Given this result, a more detailed water resources, dam optimisation and hydropower analysis was undertaken on the Lalini Dam site based upon the large capacity Ntabelanga Dam (1.18 MAR) and for a range of Lalini Dam capacities from 0.10 MAR_{PD} (Mean Annual Runoff based upon Present Day flows) to 0.75 MAR_{PD}.

The Reserve Determination and operating rules were also revisited for the Lalini Dam site as the hydropower releases have a significant impact upon the riparian hydrology downstream of the proposed dam site and hydropower tunnel exit point.

The findings are given in detail in the Feasibility Design: Lalini Dam and Hydropower Scheme Report No. P WMA 12/T30/00/5212/19.

The optimum Lalini Dam size selection was based on several factors, such as unit power cost, funding requirements, as well as social and environmental impacts.

The main objective of the hydropower generation assessment was to determine the amount of energy that can be produced per year from each dam capacity option assuming that the environmental, domestic and agricultural water requirements are met first.

Given that the two dams are to be operated conjunctively, there could be a trade-off on water allocation. If the eventual domestic and irrigation water demands upon the Ntabelanga Dam were to be less than projected, then more water could be made available for release from the dam to increase hydropower generation. However, such releases would still need to follow the water reserve operating rule recommendations for environmental water requirements at both Ntabelanga and Lalini Dams.

The hydropower assessment of the conjunctive use of the Ntabelanga and Lalini was undertaken using detailed hydrology produced in the earlier analyses stage of this feasibility study, as well as new and highly accurate topographical survey data for the Lalini dam basin.

A previous desk top hydropower assessment of the Tsitsa River system was undertaken using the hydropower module of the WRYM model and based on available data, i.e. the basin characteristics were based on the 20 m contours and the Environmental Water Requirements (EWR) were based on a Desktop Reserve.

Subsequently, more detailed studies and investigations were completed which has improved the overall confidence in the simulated hydropower generation results.

A bespoke spreadsheet-based model was developed to simulate the hydropower generation potential of the system rather than using WRYM. This decision was based on the limited flexibility of the WRYM in terms of hydropower generation simulations for multiple sites. However, the spreadsheet based model was developed using the same principles that the WRYM model is based on and was configured in the same manner.

The Hydroelectric Plants (HEPs) at each site were configured as follows:

- Ntabelanga Dam had a “mini” HEP with an installed capacity of up to 5 MW (5 x 1 MW sets);
- Lalini Dam had two separated HEPs, namely:
  - A “mini” HEP with an installed capacity of up to 5 MW (6 sets which when operated in parallel actually produce approximately 5.2 MW) ; and
  - The “main” HEP with an installed capacity of either 37.5 MW or 50 MW (comprising three or four 12.5 MW units).

These plants and their various turbine combinations were optimised with the aim of generating as much power as possible per year, given the balancing storage provided by the two dams, and taking into consideration the Environmental Water Requirements and consequent operating rules.

The following sub-sections provide detail on the aspects of the modelling that were updated from the previous part of the study.

3.7.2 *Environmental Water Requirements*

Following the Intermediate Reserve Determination completed for the Ntabelanga Dam site as a part of this study (Report No. P WMA 12/T30/00/5212/7), a Rapid Reserve Determination was undertaken for the Lalini Dam site. The results from this study are summarised in Table 3-11.

The results show that the Present Ecological State (PES) of the Tsitsa River at this site is an ecological class B/C, which is less than the assumed Desktop Reserve PES. However, the Rapid Reserve study has a better understanding of the ecological flow requirements needed for the biophysical environment and included floods and freshettes required as ecological triggers.

The total recommended release equated to 33.1% of the simulated natural flows at the dam site, i.e. 287.1 million m^3 per year, on average.

Maintenance low flow requirements increase with increasing values of the baseflow index (BFI - always less than 1), but decrease with increasing values of flow variability.

The method used for recommending a low flow figure uses a combined index of the sum of the maximum monthly Coefficients of Variation (CV's) for the January/February/March summer period (JFM) and June/July/August winter periods (JJA) divided by the proportion of total flow occurring as baseflow index (BFI).

A summary of the criteria and results of the Lalini EWR determination based on the defined Building Block Methodology (BBM) table with site specific assurance rules is as follows:

Mean Annual Runoff (MAR) = 868.63 million m^3/a
Standard Deviation (SD) = 373.46 million m^3/a
75%^{ile} exceedance flow value (Q75) = 15.50 million m^3/a

Coefficient of Variability (CV) = 0.43
Q75/ Minimum Monthly Flow (MMF) = 0.21
BFI Index = 0.36
CV (JJA+JFM) Index = 2.07
Ecological Reserve Category (ERC) = B/C

Total Environmental Water
Requirements (EWR) = 287.05 million m^3/a (33.1 % MAR)
Maintenance Low flow = 136.86 million m^3/a (15.8 % MAR)
Drought Low flow = 52.01 million m^3/a (6.0 % MAR)
Maintenance High flow = 150.18 million m^3/a (17.3 % MAR)
Distribution Type = T Region[1]

Table 3-11: Rapid Reserve Results for the Lalini Dam Releases

Month	Natural Flows (m^3/s)			Modified Flows (EWR) (m^3/s)			
	Mean	SD	CV	Low Flows Maintenance	Drought	High Flows Maintenance	Total Flows Maintenance
Oct	17.80	15.57	0.37	3.24	1.17	3.34	6.67
Nov	31.44	29.39	0.36	4.27	1.53	3.55	7.81
Dec	37.62	34.37	0.34	4.85	1.73	4.67	9.52
Jan	45.15	36.88	0.31	5.69	2.01	7.92	13.61
Feb	59.57	44.01	0.31	7.38	2.60	19.48	26.86
Mar	57.99	41.52	0.27	7.48	2.63	15.68	23.16
Apr	32.10	26.84	0.32	6.42	2.27	0.00	6.42
May	12.45	11.68	0.35	4.29	1.54	0.00	4.30
Jun	9.46	11.67	0.48	2.47	1.24	0.00	2.47
Jul	9.28	14.23	0.57	2.16	1.09	0.00	2.16
Aug	8.69	10.17	0.44	2.07	1.02	0.00	2.07
Sep	11.24	16.29	0.56	2.06	1.04	3.46	5.52

3.7.3 Hydropower Yield Modelling Assumptions

The majority of the assumptions made in the hydropower yield modelling exercise revolved around the release rules from each dam site in order to limit the impact on the associated ecology and functioning of the river system, whilst still obtaining a reasonable average monthly hydropower generation.

[1] *From Hughes Desktop Reserve Model. The original version of the desktop reserve model is described in Hughes & Munster (Hydrological information and techniques to support the determination of the water quantity component of the Ecological Reserve for rivers. Water Research Commission Report No. TT 137/00, 2000). Further details of Version 2 (a recalibration of some of the parameters and a refinement of some of the procedures used in the model) are provided in Hughes and Hannart (A desktop model used to provide an initial estimate of the ecological instream flow requirements of rivers in South Africa. Journ. Hydrol. 2003, 270, 167-181).*

The main assumptions were as follows:

1. The minimum release from the Ntabelanga Dam will conform to the results of the Intermediate Reserve Determination (Class C).

2. The maximum allowable release from Ntabelanga Dam, for the purposes of hydropower generation at Lalini Dam, is equivalent to the greater of the Simulated Naturalised Inflow into Ntabelanga Dam, or seven cubic metres per second. This release is only made when triggered by insufficient water resources at Lalini Dam.

3. The minimum and maximum releases from Lalini Dam not for hydropower generation would conform to the results of the Rapid Reserve Determination (Class B/C).

4. Spillages from either dam can account for the required releases for EWR.

5. The maximum release from Lalini Dam through the HEP will be the flow required to meet the required hydropower generation target for a specific month, assuming that the flow required is available.

6. The practical minimum operating level of the Lalini Dam, including an allowance for the 31.2 million m^3 of storage for the V_{50} sediment volume, was selected as 745.16 m.a.s.l., or 42.19 million m^3.

7. The HEP elevation is at 450 m.a.s.l., which equates to a maximum static head of 315.47 m and a minimum static head of 295.16 m.

8. Frictional head losses through the two small HEPs (one at each dam to generate hydropower from the required operational releases) were conservatively assumed to be constant at five metres.

9. Frictional head losses in the transfer conduit to the main Lalini Dam HEP vary, depending on the installed maximum turbine generating capacity. These head losses were calculated for the particular conduit diameter required for each installation option, at the flow rate applicable to the number of turbines in operation.

10. Releases from Ntabelanga Dam to Lalini Dam for the purpose of sustaining hydropower generation at Lalini were triggered when the live storage in Lalini Dam dropped below 60 million m^3.

11. The EWR releases from both dams were given first priority in the system.

12. The domestic and agricultural water requirements at Ntabelanga Dam were given priority over releases for hydropower production at Lalini.

13. Spills were not included in the releases to generate hydropower at the two smaller HEPs.

14. Conveyance losses of 10% were assumed on all releases from Ntabelanga for the purpose of hydropower generation at Lalini Dam.

15. All HEP systems were assumed to be 75 % efficient in their production of power. This is a conservative figure.

16. The flow from Ntabelanga was restricted based on outlet works capacity, i.e. the maximum flow through the HEP was limited to 42.85 million m^3/month (16 m^3/s) and the maximum release from Ntabelanga Dam was limited to 160.7 million m^3/month (60 m^3/s).

17. Both dams were started at 100 % Full Supply Capacity for all simulations.

18. The initial hydropower generation potential was firstly modelled using the stochastic information in the hydropower module of the Water Resources Yield Model (WRYM). Following this, the simulation for economic optimisation and sizing of the installed hydropower plant capacity was run on a purpose-built spreadsheet model based on the historical flow time series, with all hydropower generation results presented in average megawatts per month.

19. The system objective was to generate a monthly target hydropower output at the main Lalini HEP after meeting the EWR, domestic and agricultural water demands. These monthly targets were based upon multiples of installed turbine capacities (e.g. 1, 2, 3 or 4 turbines operating) and took cognisance of the natural monthly flow variations in the river system.

20. The hydropower simulations assumed base load hydropower generation (i.e. 24 hrs per day, 7 days per week operations). Economic analyses were also undertaken for peaking power operations outside of the simulation model.

21. The Ntabelanga Dam's storage capacity remained constant throughout all simulations at 1.18 MAR_{PD}, or 490.5 million m^3. This was as a result of the findings from the preceding part of the study. Simulations were run for Lalini Dam capacities ranging from 0.1 MAR_{PD} to 0.75 MAR_{PD}.

The model works on a "bottom up" principle as regards the water required for targeted Lalini HEP hydropower production, and on a "top down" principle as regards the water available for such hydropower production and other requirements.

A monthly volumetric balance calculation is made, commencing with a starting water level in each dam (normally starts full).

Inflow into Ntabelanga Dam is the historical present day flow for that month and year, plus monthly rainfall falling over the prevailing dam water surface area.

Outflow for that same period is the gross evaporation over the dam water surface, plus the raw water abstracted from the dam for potable and irrigation purposes. The resulting balance in the dam becomes water available for release downstream.

3.7.4 Operating Rules – Ntabelanga Dam

This dam release flows down the Tsitsa River into the Lalini Dam and, together with the incremental inflow from the intervening catchment areas, thus supplementing the volume in Lalini Dam that can be utilized for hydropower generation and EWR purposes. In-stream losses are allowed for between the Ntabelanga and Lalini Dams.

The amount of water released downstream from the Ntabelanga Dam would be determined by operating rules which the dam operators will need to follow on a weekly basis. Based upon the recommendations of the EWR studies, the *minimum* amount released is determined by the monthly EWR requirement with the same percentage occurrence as the measured inflow volume, as is given on the EWR flow duration curve for that particular calendar month.

Thus the EWR releases will mimic the prevailing rainfall-runoff conditions in the catchment in any particular month, bearing in mind the historical flow patterns that occurred historically over the 90 year record used as a simulation period.

The *maximum* that can be released from the Ntabelanga Dam is generally limited to the simulated naturalized monthly flow with the same percentage of occurrence as the prevailing inflow as determined from the flow duration curves for that same calendar month. The exception to this is where the dam spills, and no constraints are applied. This is illustrated on Figure 3-15.

It was noted that in extreme drought periods, the EWR volumes released did not always satisfy the hydropower generation needs to be sustained by the Lalini Dam balancing storage. In such cases it was discussed and agreed with DWS's Reserve Determination Directorate that up to 7 m^3/s could be released from Ntabelanga Dam downstream to sustain a minimum hydropower generation output and the EWR requirements at Lalini Dam.

Hydropower generation is achieved at Ntabelanga Dam by using the available head of water in the dam and passing the EWR releases through the mini-HEP located just downstream of the dam wall before returning this flow back to the river. This HEP diversion is limited to 16 m^3/s as EWR flows above this have a low recurrence interval, and it was considered not worth sizing the HEP plant and its conduit for a larger flow rate than this.

3.7.5 Operating Rules – Lalini Dam

The monthly inflow balancing regime as described for Ntabelanga Dam is modelled in the same way at Lalini Dam. In this case however, there is no potable or irrigation water requirement, but water is instead diverted through the 7.8 km long conduit to the main HEP located in the river gorge downstream of the Tsitsa Falls, and at an elevation of some 300 m below the Lalini Dam site. This arrangement is shown in Figure 3-15. The figure shows two tunnel options of which the deeper, direct option is recommended.

The amount of water released downstream from the Lalini Dam would be determined by operating rules which the dam operators will need to follow on a weekly basis.

Based upon the recommendations of the EWR studies, the *minimum* amount released is determined by the monthly EWR requirement with the same percentage occurrence as the measured inflow volume, as is given on the EWR flow duration curve for that particular calendar month.

In this case the water released from the Ntabelanga Dam would alter the natural Lalini inflow regime, and this will need to be taken into consideration when determining the precedent streamflow conditions in the Lalini catchment when setting the percentage occurrence factor to apply to the monthly flow duration curve, and thus the volume of EWR to be released in any particular month.

Hydropower generation is achieved at the Lalini Dam itself by using the available head of water in the dam and passing the EWR releases through the mini-HEP located just downstream of the dam wall before returning this flow back to the river. This HEP diversion is again limited to 16 m^3/s as EWR flows above this have a low recurrence interval, and it was considered not worth sizing the HEP plant and its conduit for a larger flow rate than this.

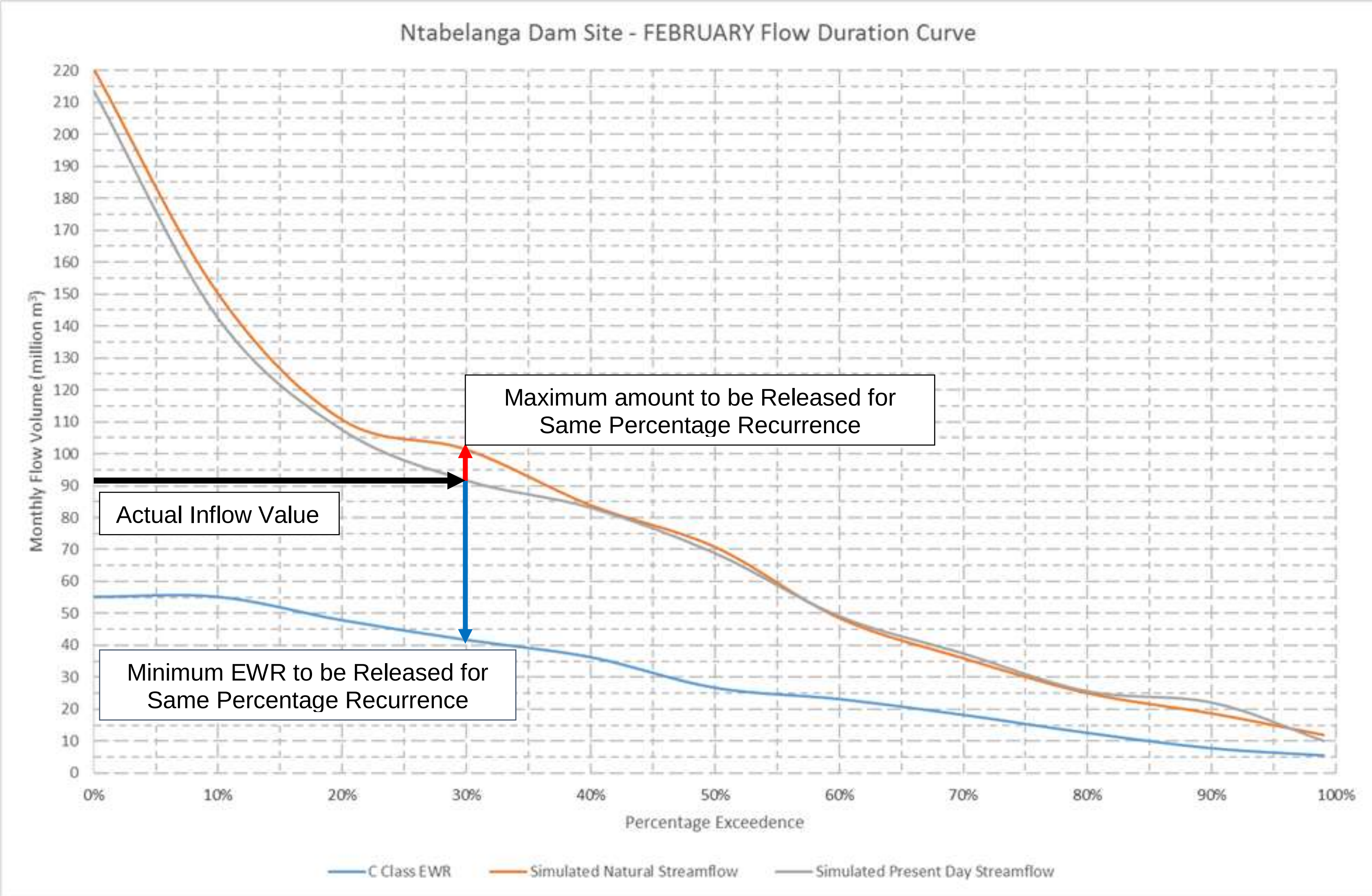

Figure 3-15: Example of Ntabelanga Dam Flow Release Rules

The hydropower simulation model always allows for the EWR to be released downstream of the Lalini dam before allowing water to be passed through the main HEP system via the conduit shown in Figure 3-16.

In order to determine how much water is to be passed through the main HEP plant, a target hydropower output was set for each month of the year. The model allows this to be undertaken quickly and iteratively until the maximum average energy output per year is achieved over the 90 year simulation period. From the results that this produced it was noted that for a base load (24/7 operations) main HEP there was no merit in installing plant of capacity greater than 50 MW and, furthermore, this maximum installed capacity was often only fully useable in the one wettest month of the year.

In addition, in the drier months of the year, it was shown that the maximum power output would drop to around 5 to 15 MW, due to the need to limit the flow rate of water returned back into the river when mimicking the naturalized flow regime, as well as times in drought cycles when both Ntabelanga and Lalini Dams would be at their lowest levels.

If the rule of not exceeding the simulated naturalized flow regime for all months and percentage occurrences is strictly adhered to, then the main Lalini HEP scheme would need to be shut down or operated at a very low output level in a significant number of months in the driest years of operation. This is exemplified in Table 3-12, which shows the percentage occurrences of various naturalised flow rates (expressed in m^3/s) over the 12 calendar months, taken from the monthly flow duration curves.

Table 3-12: Simulated Naturalized Flows at Lalini Dam

	Naturalized Flow in m^3/s at indicated %age occurrence										
MONTH	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	89.98	42.94	27.85	18.44	13.98	11.12	9.52	7.63	5.63	3.76	2.87
Nov	133.46	77.20	47.35	38.34	28.40	21.91	16.37	13.21	10.38	6.78	4.04
Dec	171.33	90.62	66.48	46.83	31.95	22.89	19.07	16.32	10.86	7.77	1.91
Jan	178.63	98.97	65.61	56.75	45.03	34.06	25.45	23.41	15.70	10.93	3.27
Feb	177.76	122.79	94.58	75.57	60.22	47.89	39.18	27.38	19.35	16.24	7.11
Mar	218.40	117.67	80.20	70.21	59.99	53.36	37.29	29.55	24.31	15.11	7.95
Apr	157.53	57.10	46.10	39.52	34.55	28.25	18.40	14.51	10.90	8.16	3.05
May	76.51	25.89	18.07	13.07	10.35	8.77	7.06	5.97	4.88	4.05	3.32
Jun	73.12	19.29	12.67	8.43	6.89	5.24	4.88	4.08	3.72	3.14	2.47
Jul	67.65	17.85	10.29	8.16	5.72	4.76	4.33	3.89	3.33	2.99	2.14
Aug	60.82	22.86	10.98	7.44	6.16	5.14	4.20	3.75	3.05	2.65	2.45
Sep	128.80	28.34	14.70	9.36	7.90	6.09	4.78	3.92	3.38	2.65	2.03
AVE	**127.83**	**60.13**	**41.24**	**32.68**	**25.93**	**20.79**	**15.88**	**12.80**	**9.62**	**7.02**	**3.55**

Table 3-13 shows the recommended minimum EWR releases in each calendar month, based upon the same percentage occurrences as the prevailing inflow conditions in the catchment.

Table 3-14 shows the water thus available to be passed through the main Lalini HEP under the same prevailing catchment conditions, being the difference between the naturalised and EWR flow figures.

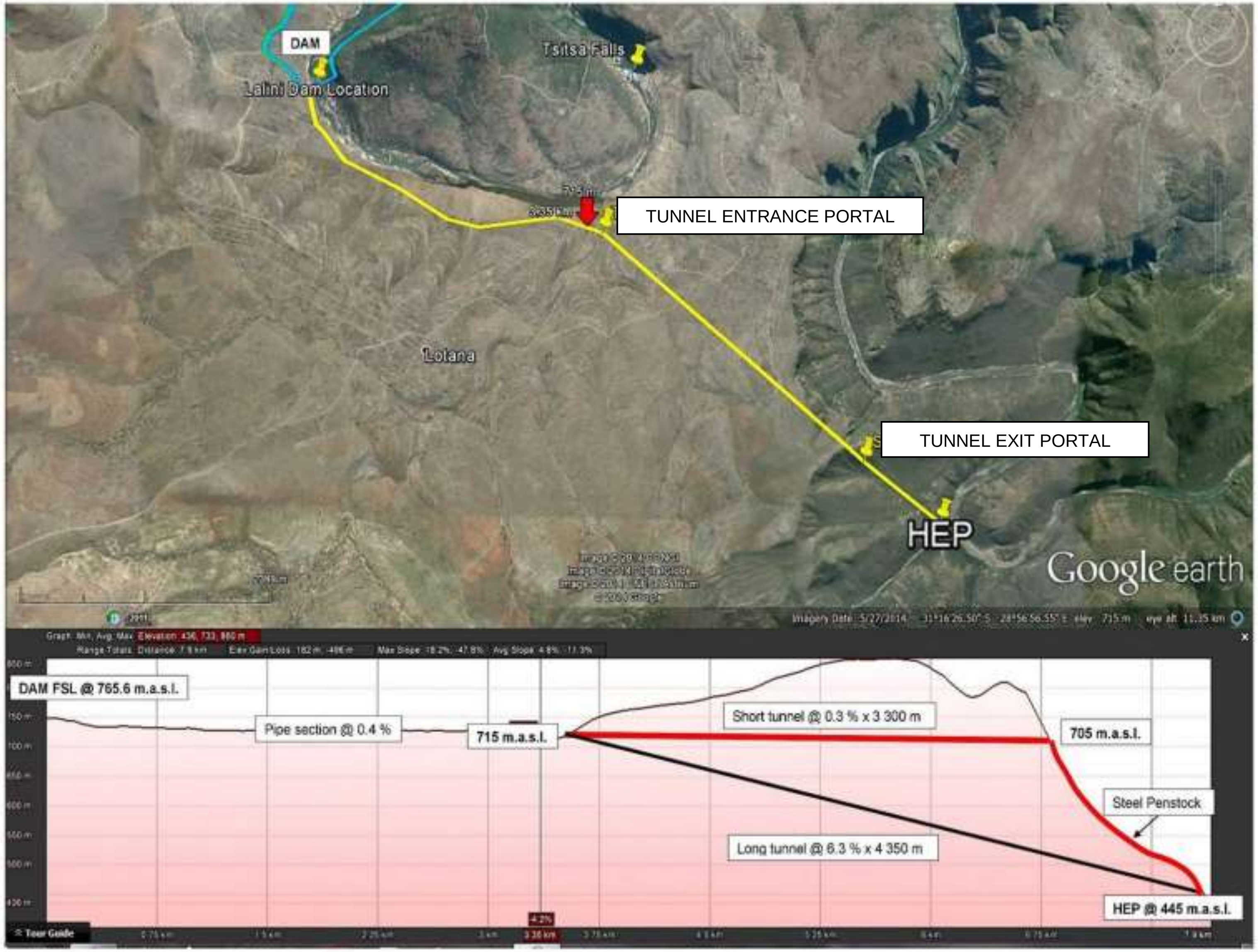

Figure 3-16: Lalini Main HEP System Arrangement

The cells highlighted in Table 3-14 are those where available average monthly flow would be insufficient to operate the main HEP at its minimum output (one turbine set operating) continuously throughout the month. In the wetter months, this only occurs between 10 and 20% of the years, but in the dry season months this reduced output could occur to a lesser or greater degree up to 60% of the years.

Table 3-13: Desktop Class B/C EWR at Lalini Dam

	EWR in m^3/s at indicated %age occurrence										
MONTH	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	9.18	9.18	9.07	8.81	8.28	7.37	6.04	4.44	2.96	1.95	1.56
Nov	10.88	10.88	10.76	10.46	9.87	8.81	7.26	5.38	3.60	2.40	1.94
Dec	13.53	13.53	13.42	13.16	12.63	11.66	10.09	7.89	5.39	3.26	1.91
Jan	25.49	25.49	22.81	20.51	18.36	14.54	12.62	9.91	6.80	4.13	2.89
Feb	51.87	51.87	45.40	39.93	35.01	26.30	22.68	17.63	11.86	6.96	4.67
Mar	46.42	46.42	39.95	34.54	29.62	21.66	17.74	13.00	8.53	5.50	4.34
Apr	9.69	9.69	9.58	9.33	8.82	7.93	6.65	5.10	3.66	2.69	2.31
May	6.48	6.48	6.41	6.24	5.90	5.31	4.45	3.43	2.46	1.81	1.57
Jun	3.63	3.63	3.58	3.47	3.25	2.89	2.42	1.93	1.55	1.33	1.26
Jul	3.18	3.18	3.13	3.03	2.83	2.51	2.10	1.68	1.35	1.17	1.10
Aug	2.95	2.95	2.91	2.82	2.64	2.35	1.97	1.57	1.26	1.09	1.03
Sep	7.43	7.43	7.34	7.13	6.72	6.00	4.78	3.70	2.52	1.73	1.43
AVE	**15.90**	**15.90**	**14.53**	**13.28**	**11.99**	**9.78**	**8.23**	**6.30**	**4.33**	**2.83**	**2.17**

Table 3-14: Flow Available for Hydropower Generation

	Flow Available for Hydropower Generation (m^3/s) at indicated %age occurrence										
MONTH	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	80.80	33.76	18.78	9.63	5.70	3.75	3.48	3.19	2.67	1.81	1.30
Nov	122.58	66.32	36.59	27.88	18.53	13.10	9.11	7.84	6.78	4.38	2.10
Dec	157.79	77.09	53.07	33.68	19.32	11.22	8.98	8.43	5.47	4.51	0.00
Jan	153.14	73.48	42.81	36.25	26.67	19.52	12.83	13.50	8.90	6.80	0.38
Feb	125.89	70.92	49.19	35.64	25.20	21.59	16.50	9.76	7.49	9.29	2.44
Mar	171.97	71.25	40.26	35.67	30.37	31.70	19.55	16.55	15.78	9.61	3.61
Apr	147.84	47.41	36.51	30.19	25.73	20.31	11.76	9.40	7.24	5.47	0.73
May	70.03	19.40	11.66	6.83	4.45	3.46	2.61	2.54	2.42	2.24	1.76
Jun	69.49	15.66	9.08	4.96	3.65	2.35	2.46	2.15	2.17	1.81	1.22
Jul	64.47	14.67	7.16	5.13	2.89	2.25	2.23	2.21	1.97	1.82	1.04
Aug	57.87	19.91	8.07	4.63	3.52	2.79	2.23	2.18	1.78	1.57	1.42
Sep	121.37	20.91	7.36	2.22	1.18	0.09	0.00	0.22	0.85	0.92	0.60
AVE	**111.94**	**44.23**	**26.71**	**19.39**	**13.93**	**11.01**	**7.65**	**6.50**	**5.29**	**4.18**	**1.38**

The flow rate required to operate a single 12.5 MW turbine unit continuously is some 6 m^3/s. The operational regime proposed is to therefore make use of the available balancing capacity in the dams to pass a minimum of 6 m^3/s through the main Lalini HEP turbines in the particularly low flow dry season months in order to ensure that a minimum of 12.5 MW can always be produced by the main HEP at all times.

Table 3-15 (based on the 37.5 MW installed capacity option) shows the impact of strictly limiting the main HEP flow throughput to the naturalized flow regime, and it is evident that the power outputs in dry season months could be low for a significant proportion of the years of simulation.

The highlighted cells in Table 3-16 show the quantum of water that would be required to be released through the main HEP extra over the naturalized flow regime values, and the percentage occurrence of when this would be required (e.g. 80% actually means this would only be required 20% of the time).

Table 3-15: Main HEP Power Output without Supplementary Release through HEP

	HEP Output (MW) - No Supplementary Release at indicated %age occurrence										
MONTH	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	37.5	37.5	37.5	18.6	11.0	7.2	6.7	6.1	5.1	3.5	2.5
Nov	37.5	37.5	37.5	37.5	35.7	25.2	17.5	15.1	13.1	8.4	4.0
Dec	37.5	37.5	37.5	37.5	37.5	21.6	17.3	16.2	10.5	8.7	0.0
Jan	37.5	37.5	37.5	37.5	37.5	37.5	24.7	26.0	17.1	13.1	0.7
Feb	37.5	37.5	37.5	37.5	37.5	37.5	31.8	18.8	14.4	17.9	4.7
Mar	37.5	37.5	37.5	37.5	37.5	37.5	37.5	31.9	30.4	18.5	7.0
Apr	37.5	37.5	37.5	37.5	37.5	37.5	22.7	18.1	13.9	10.5	1.4
May	37.5	37.5	22.5	13.2	8.6	6.7	5.0	4.9	4.7	4.3	3.4
Jun	37.5	30.2	17.5	9.6	7.0	4.5	4.7	4.1	4.2	3.5	2.3
Jul	37.5	28.3	13.8	9.9	5.6	4.3	4.3	4.3	3.8	3.5	2.0
Aug	37.5	37.5	15.5	8.9	6.8	5.4	4.3	4.2	3.4	3.0	2.7
Sep	37.5	37.5	14.2	4.3	2.3	0.2	0.0	0.4	1.6	1.8	1.2
AVE	37.52	36.14	28.84	24.12	22.04	18.77	14.72	12.51	10.20	8.06	2.67

Table 3-16: Water released through HEP extra over naturalized flow to maintain 12.5 MW

	Water Released Over Naturalized Flow (m^3/s) to Maintain 12.5 MW Output at indicated %age occurrence										
MONTH	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.00	0.00	0.00	0.00	0.30	2.25	2.52	2.81	3.33	4.19	4.70
Nov	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.62	3.90
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	1.49	6.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.62
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.56
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.39
Apr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53	5.27
May	0.00	0.00	0.00	0.00	1.55	2.54	3.39	3.46	3.58	3.76	4.24
Jun	0.00	0.00	0.00	1.04	2.35	3.65	3.54	3.85	3.83	4.19	4.78
Jul	0.00	0.00	0.00	0.87	3.11	3.75	3.77	3.79	4.03	4.18	4.96
Aug	0.00	0.00	0.00	1.37	2.48	3.21	3.77	3.82	4.22	4.43	4.58
Sep	0.00	0.00	0.00	3.78	4.82	5.91	6.00	5.78	5.15	5.08	5.40
AVE	0.00	0.00	0.00	0.59	1.22	1.78	1.92	1.96	2.06	2.46	4.62

As can be seen this additional release amount rarely exceeds an annual average of 2.46 m^3/s, but in some drought years could be up to a maximum rate of 6 m^3/s, albeit that this would be a rare occurrence.

As shown in Table 3-17, the benefits of this additional release allowance within the EWR rules are obvious, in that on average, some 10% more power can be generated by the same HEP configuration than if the additional release is not allowed.

Table 3-17: Main HEP Power Output with Supplementary Release through HEP (MW)

	HEP Output (MW) - With Supplementary Release at indicated %age occurrence										
MONTH	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	37.5	37.5	37.5	19.3	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Nov	37.5	37.5	37.5	37.5	37.1	26.2	18.2	15.7	13.6	12.5	12.5
Dec	37.5	37.5	37.5	37.5	37.5	22.4	18.0	16.9	12.5	12.5	12.5
Jan	37.5	37.5	37.5	37.5	37.5	37.5	25.7	27.0	17.8	13.6	12.5
Feb	37.5	37.5	37.5	37.5	37.5	37.5	33.0	19.5	15.0	18.6	12.5
Mar	37.5	37.5	37.5	37.5	37.5	37.5	37.5	33.1	31.6	19.2	12.5
Apr	37.5	37.5	37.5	37.5	37.5	37.5	23.5	18.8	14.5	12.5	12.5
May	37.5	37.5	23.3	13.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Jun	37.5	31.3	18.2	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Jul	37.5	29.3	14.3	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Aug	37.5	37.5	16.1	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
Sep	37.5	37.5	14.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
AVE	37.52	36.32	29.11	25.67	24.97	22.81	19.24	17.16	14.99	13.66	12.50

This situation was presented to the team undertaking the Lalini EWR study and the consensus was that such releases would not significantly change the ecological regime of the river below the HEP outlet, and therefore could be allowed.

Following review and discussion of the EWR Report the DWS Reserve Determination office has approved the operational regime whereby an additional 6 m^3/s over naturalized flow can be passed through the HEP turbines and released back to the river as and when required in any month.

3.7.6 Power Generation Options

As described in detail in Report Nos. P WMA 12/T30/00/5212/19 and P WMA 12/T30/00/5212/15, the operation of the Lalini HEP scheme as a peaking station during winter months, or as a full-time peaking station with up to 150 MW of installed power, is not recommended, and was not investigated further in the hydropower modelling process. Operation of the scheme as a peaking station produced very high periodical discharges from the HEP back into the river which were unacceptable as regards the EWR regime. Construction of additional storage in the gorge downstream of the HEP discharge in order to rebalance these peaking generation flow rates was considered to be unacceptable both in terms of cost and environmental impacts. In addition, it would be expected that such balancing storage would trap sediment and rapidly become both less effective as balancing storage and an ongoing maintenance problem. The economic analysis also showed no cost benefits for the peaking station option, and therefore the further analysis was focussed on a base load station option.

Two base case options were investigated, namely:

i) installed capacity 50 MW, and
ii) installed capacity 37.5 MW

Option i) has increased capital and operating cost implications in that the HEP plant and larger diameter conduit costs would be higher than that of option ii). Option i), however, does deliver more energy per annum into the grid system, and this is discussed further in the following sections.

The electro-mechanical specialists on the team undertook an optimisation investigation, including consultation with international hydropower turbine manufacturers, and their recommendation was that an arrangement of 3 or 4 identical turbines, each with a net power output (after efficiency and transmission losses) of 12.5 MW, would be the best operational regime. The hydropower model was therefore set up so that 1, 2 3 or 4 generating sets were activated in order to try to meet the target power output for each individual month of the year. A similar approach was taken for the Ntabelanga and Lalini Dam mini-HEPs where up to 5 x 1 MW turbines can be activated.

It should be noted that, on average, the full monthly power output targets were met in greater than 70% of the simulation months, and that there were very few months in the total 90 year simulation period whereby the HEP plant would have to be taken off-line altogether.

Tables 3-18 to 3-20 and Figures 3-17 to 3-19 summarise the results of the modelling run undertaken for the recommended conjunctive hydropower scheme (37.5 MW installed capacity option).

Table 3-18: Model Results: Ntabelanga Dam HEP

Month	Monthly Target (MW)	Avg HP Output (MW)	Avg Energy Supplied (kWh)
Oct	1.00	0.74	547 860
Nov	3.00	1.71	1 229 237
Dec	3.00	1.55	1 152 316
Jan	4.00	2.00	1 491 215
Feb	5.00	3.77	2 557 827
Mar	5.00	3.14	2 338 611
Apr	5.00	2.07	1 493 446
May	4.00	0.99	734 676
Jun	2.00	0.91	652 112
Jul	1.00	0.62	460 567
Aug	1.00	0.59	436 999
Sep	1.00	0.69	500 319
	Average Power:	**1.57 (MW)**	
		Total Energy Per Year:	**13 595 184 (kWh)**

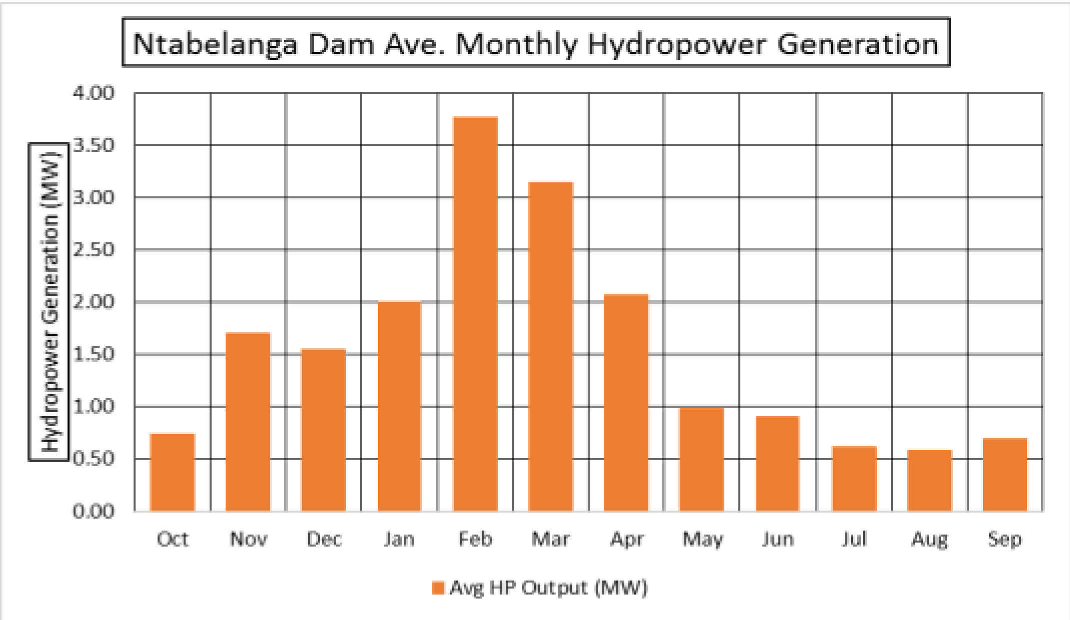

Figure 3-17: Ntabelanga Dam HEP Average Monthly Hydropower Generation

Table 3-19: Model Results: Lalini Main HEP

Month	Monthly Target (MW)	Avg HP Output (MW)	Avg Energy Supplied (kWh)
Oct	12.50	18.76	13 959 044
Nov	12.50	23.67	17 043 420
Dec	25.00	22.99	17 102 324
Jan	25.00	21.89	16 283 250
Feb	25.00	23.54	15 963 055
Mar	37.50	24.55	18 268 136
Apr	25.00	22.27	16 035 946
May	12.50	15.69	11 672 893
Jun	12.50	15.83	11 399 591
Jul	12.50	15.95	11 866 003
Aug	12.50	16.04	11 931 220
Sep	12.50	16.46	11 849 343
	Average Power:	**19.77 (MW)**	
		Total Energy Per Year:	**173 374 226 (kWh)**

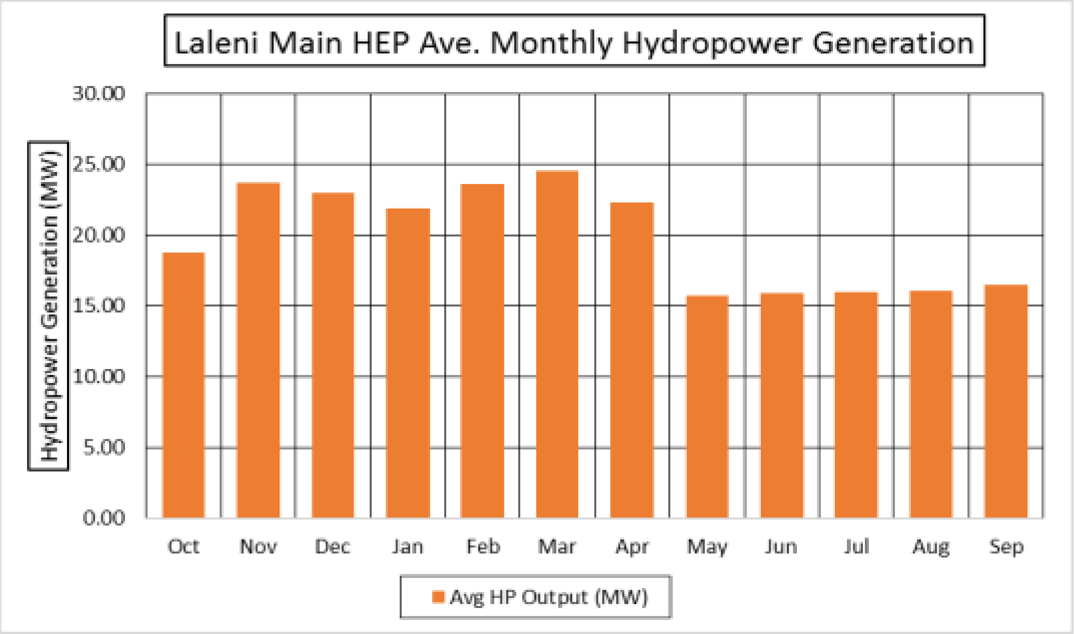

Figure 3-18: Lalini Main HEP Average Monthly Hydropower Generation

Table 3-20: Model Results: Lalini Dam Mini HEP

Month	Monthly Target (MW)	Avg HP Output (MW)	Avg Energy Supplied (kWh)
Oct	2.00	1.41	1 047 895
Nov	3.00	1.74	1 251 338
Dec	3.00	2.34	1 742 819
Jan	4.00	3.10	2 303 120
Feb	5.00	3.90	2 644 895
Mar	5.00	3.91	2 910 565
Apr	5.00	1.74	1 249 716
May	4.00	1.22	905 288
Jun	3.00	0.66	476 106
Jul	1.00	0.59	440 637
Aug	1.00	0.54	401 078
Sep	1.00	0.81	585 678
	Average Power:	**1.83 (MW)**	
		Total Energy Per Year:	**15 959 136 (kWh)**

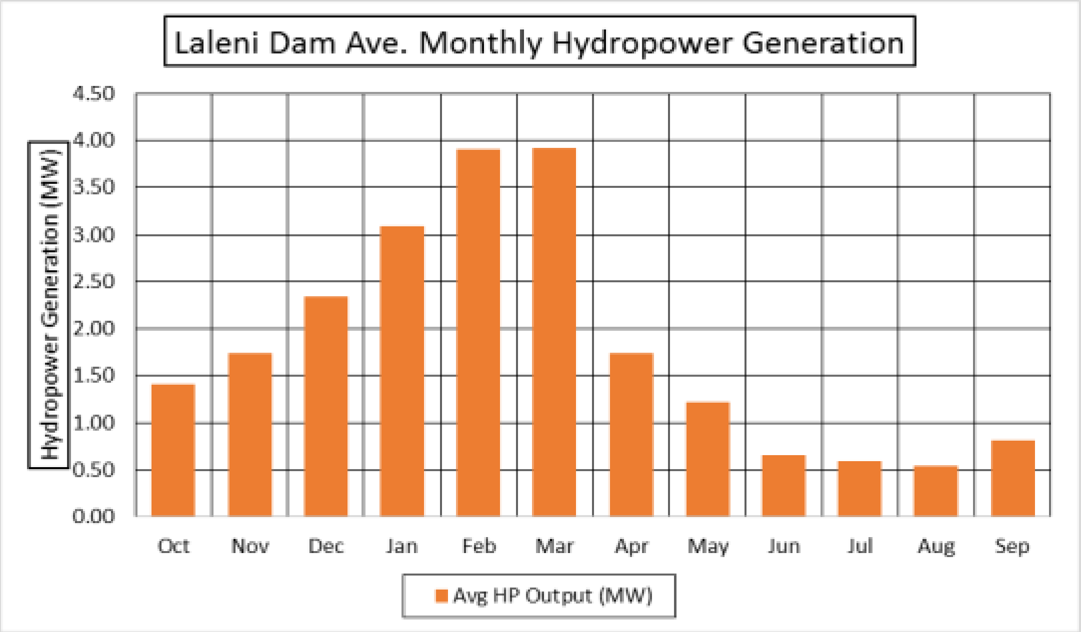

Figure 3-19: Lalini Dam Mini HEP Average Monthly Hydropower Generation

For this same preferred solution, Figures 3-20 and 3-21 show the variation in water levels, EWR releases and spills for the Ntabelanga and Lalini Dams throughout the 90 year simulation period, as well as the main Lalini HEP hydropower outputs.

These show that both dams will regularly fill and draw down as required and the full range of available balancing storage is utilized to ensure there is sufficient water to run the hydropower plants on a predominantly continuous basis.

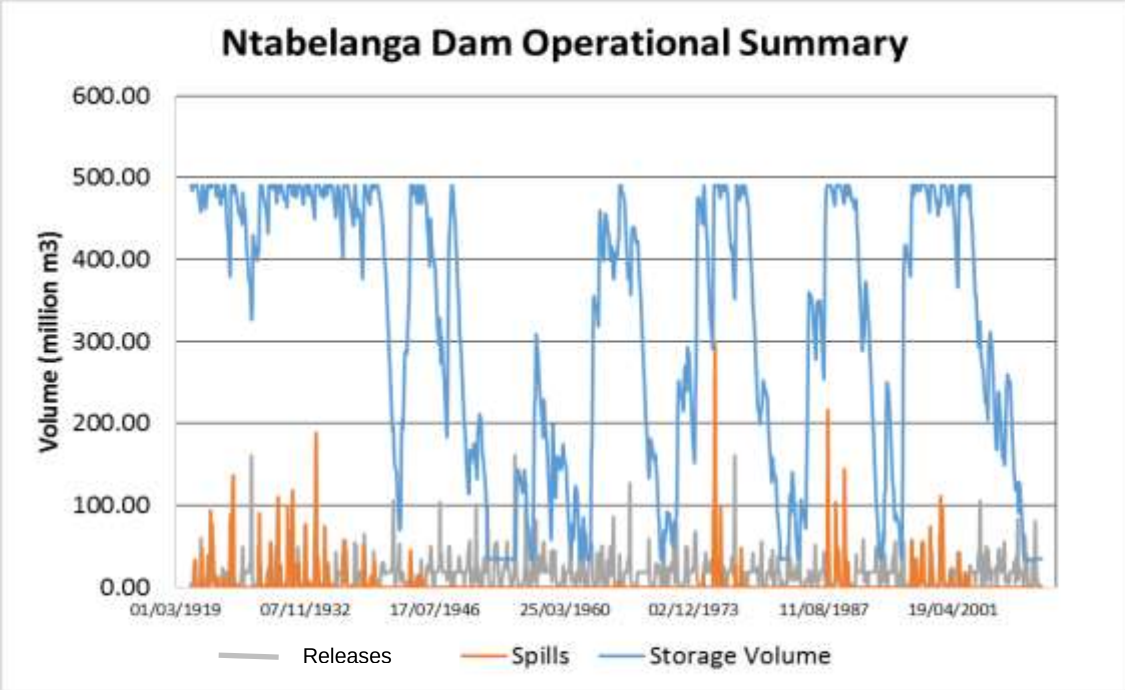

Figure 3-20: Ntabelanga Dam: Storage Volume, Releases and Spills

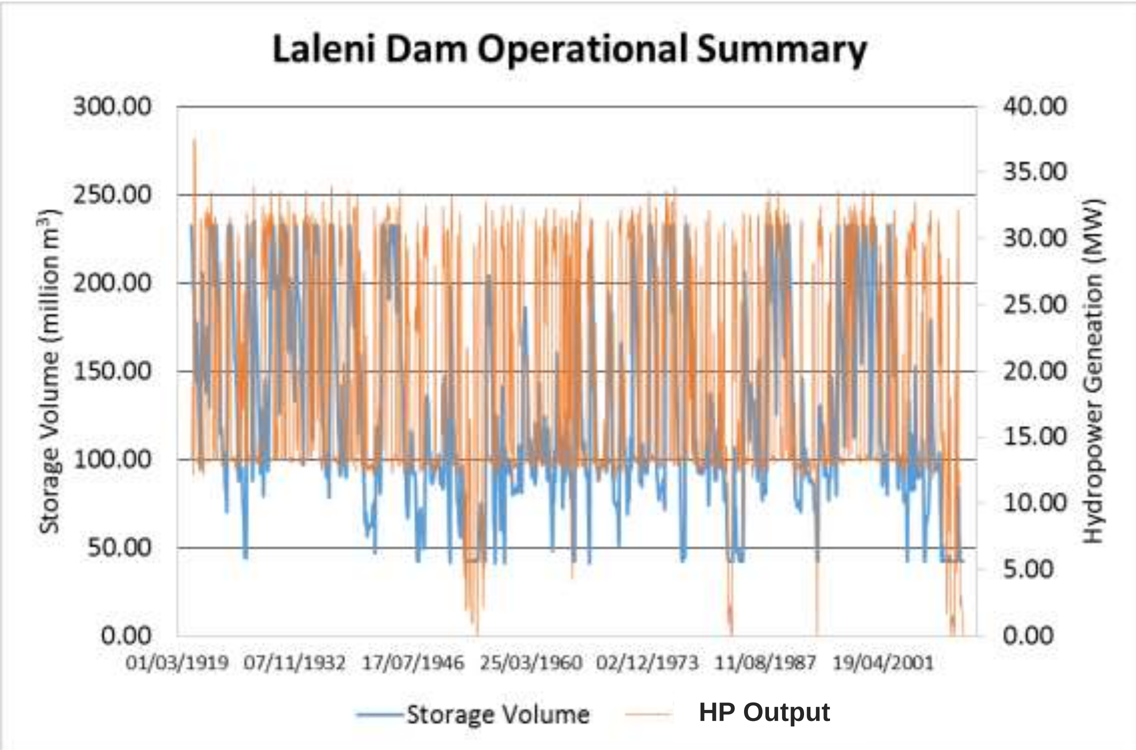

Figure 3-21: Lalini Dam: Storage Volume and Hydropower Outputs

As can be seen, there are at least three extreme drought periods and several more shorter droughts in the 90 years of simulation at which time the dams will have insufficient balancing storage to maintain the full targeted outputs of the hydropower plants. This is a pattern that is experienced regularly in southern Africa.

During these periods, hydropower output would be lower than targeted, and in a few of the months, the scheme would be shut down until dam levels recover.

This is a relatively infrequent occurrence, and other forms of energy production also have periods when installed power output reduces, including wind and solar power, which normally have average annual output availability efficiencies of between 25% and 45%.

Even nuclear and coal-fired power stations are occasionally taken off-line for periodical planned maintenance, and such drought periods could be used as an opportunity to undertake similar preventative maintenance or parts replacement on these particular hydropower plants.

Whilst the above examples give the final results of the eventually preferred Lalini Dam capacity and hydropower configuration, the hydropower simulation models were run for a number of different Lalini Dam capacities ranging from 0.1 MAR_{PD} to 0.75 MAR_{PD}, operated conjunctively with the Ntabelanga Dam at its 1.18 MAR_{PD} capacity, the results of which are summarised in the next chapter.

3.7.7 *Results and Conclusions*

The optimum Lalini Dam size selection was based on several factors, such as the cost benefits, as well as social and environmental impacts.

The main objective of the hydropower generation assessment was to determine the average amount of energy that can be produced per year from each dam capacity option assuming that the environmental, domestic and agricultural water requirements are met first.

In summary, three Hydroelectric Plants (HEPs) were modelled:

i. a 5 MW installed capacity mini-HEP just downstream of the Ntabelanga Dam;
ii. a 5 MW installed capacity mini-HEP just downstream of the Lalini Dam, and
iii. the main HEP at Lalini located in the Tsitsa River gorge and supplied by a 7.9 km long conduit and tunnel.

These plants were all operated on a base load basis. The two mini-HEPs make use of the water released downstream to meet the EWR at each dam, and the head of water available. This means that they can generate between 0.75 and 5 MW each, depending on the head and flow available at the time.

The results from the hydropower modelling analyses for the recommended Ntabelanga Dam capacity and the range of Lalini Dam storage volumes given above are presented in Figures 3-22 and 3-23, and Tables 3-21 and 3-22.

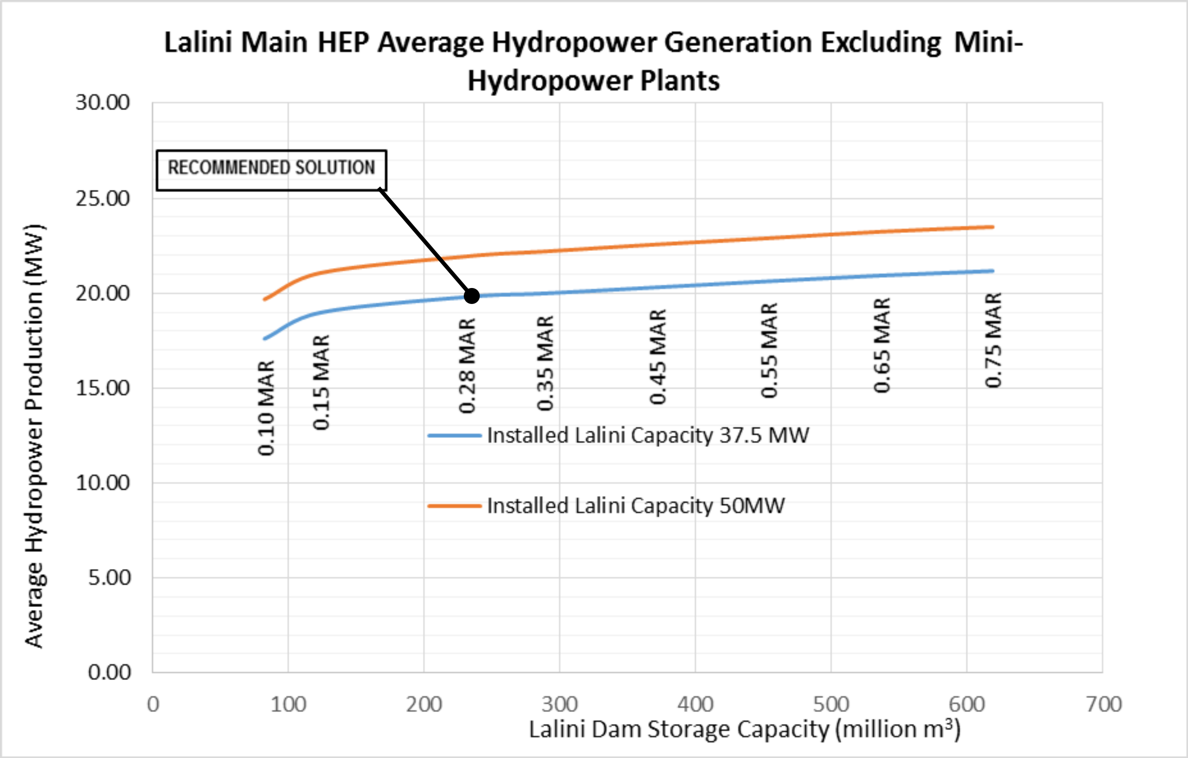

Figure 3-22: Hydropower Output: Lalini Main HEP

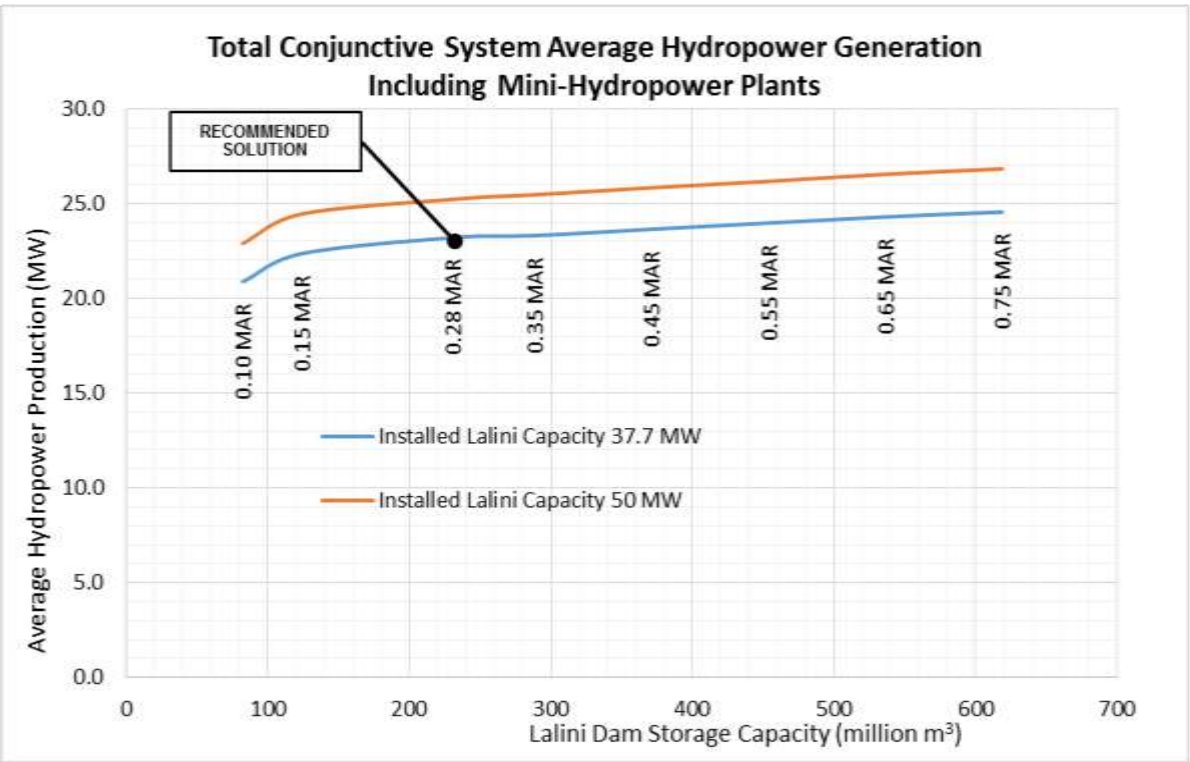

Figure 3-23: Hydropower Output: Including Mini-HEPs

Note: Recommended solution would produce an average of 23.17 MW (203 million kWh/a)

Table 3-21: Hydropower Generation Results: 37.5 MW Installed

Scenario		Lalini Dam Statistics					Lalini Dam EWR			Ntabelanga Mini-HEP Maximum Installed Capacity	Ntabelanga Mini-HEP Ave. Annual Power Output	Lalini Main HEP Installed Capacity	Lalini Main HEP Ave. Annual Power Output	Lalini Mini-HEP Maximum Installed Capacity	Lalini Mini-HEP Ave. Annual Power Output
No.	Description	FSL	MOL	Gross storage capacity	Live storage capacity	*Area	Class	Requirements		HydroPower	HydroPower	HydroPower	HydroPower	HydroPower	HydroPower
		m.a.s.l	m.a.s.l	million m^3	million m^3	km^2		million m^3/a	% MAR	MW	MW	MW	MW	MW	MW
01	1.18 MAR Ntabelanga + 0.10 MAR Lalini	751.8	745.2	82.5	40.3	7.61	BC	287.1	33.05	5	1.67	37.5	17.60	5	1.60
02	1.18 MAR Ntabelanga + 0.15 MAR Lalini	756.5	745.2	123.8	81.6	9.85	BC	287.1	33.05	5	1.66	37.5	18.98	5	1.71
03	**1.18 MAR Ntabelanga + 0.28 MAR Lalini**	**765.5**	**745.2**	**231.0**	**188.8**	**14.02**	**BC**	**287.1**	**33.05**	**5**	**1.57**	**37.5**	**19.77**	**5**	**1.83**
04	1.18 MAR Ntabelanga + 0.35 MAR Lalini	769.4	745.2	288.8	246.6	15.80	BC	287.1	33.05	5	1.45	37.5	19.99	5	1.87
05	1.18 MAR Ntabelanga + 0.45MAR Lalini	774.2	745.2	371.3	329.1	18.18	BC	287.1	33.05	5	1.40	37.5	20.31	5	1.93
06	1.18 MAR Ntabelanga + 0.55 MAR Lalini	778.4	745.2	453.8	411.6	20.67	BC	287.1	33.05	5	1.35	37.5	20.63	5	1.99
07	1.18 MAR Ntabelanga + 0.65 MAR Lalini	782.3	745.2	536.3	494.1	22.65	BC	287.1	33.05	5	1.31	37.5	20.93	5	2.05
08	1.18 MAR Ntabelanga + 0.75 MAR Lalini	785.8	745.2	618.75	576.56	24.5	BC	287.1	33.05	5	1.28	37.5	21.17	5	2.10

** Surface area at Full Supply Level*

Recommended Scheme with average output 23.17 MW

Table 3-22: Hydropower Generation Results: 50 MW Installed

Scenario		Lalini Dam Statistics					Lalini Dam EWR			Ntabelanga Mini-HEP Maximum Installed Capacity	Ntabelanga Mini-HEP Ave. Annual Power Output	Lalini Main HEP Installed Capacity	Lalini Main HEP Ave. Annual Power Output	Lalini Mini-HEP Maximum Installed Capacity	Lalini Mini-HEP Ave. Annual Power Output
No.	Description	FSL	MOL	Gross storage capacity	Live storage capacity	*Area	Class	Requirements		HydroPower	HydroPower	HydroPower	HydroPower	HydroPower	HydroPower
		m.a.s.l	m.a.s.l	million m^3	million m^3	km^2		million m^3/a	% MAR	MW	MW	MW	MW	MW	MW
01	1.18 MAR Ntabelanga + 0.10 MAR Lalini	751.8	745.2	82.5	40.3	7.61	BC	287.1	33.05	5	1.65	50	19.68	5	1.56
02	1.18 MAR Ntabelanga + 0.15 MAR Lalini	756.5	745.2	123.8	81.6	9.85	BC	287.1	33.05	5	1.71	50	21.07	5	1.66
03	1.18 MAR Ntabelanga + 0.28 MAR Lalini	765.5	745.2	231.0	188.8	14.02	BC	287.1	33.05	5	1.54	50	21.94	5	1.74
04	1.18 MAR Ntabelanga + 0.35 MAR Lalini	769.4	745.2	288.8	246.6	15.80	BC	287.1	33.05	5	1.47	50	22.20	5	1.79
05	1.18 MAR Ntabelanga + 0.45MAR Lalini	774.2	745.2	371.3	329.1	18.18	BC	287.1	33.05	5	1.41	50	22.57	5	1.85
06	1.18 MAR Ntabelanga + 0.55 MAR Lalini	778.4	745.2	453.8	411.6	20.67	BC	287.1	33.05	5	1.37	50	22.90	5	1.90
07	1.18 MAR Ntabelanga + 0.65 MAR Lalini	782.3	745.2	536.3	494.1	22.65	BC	287.1	33.05	5	1.35	50	23.24	5	1.95
08	1.18 MAR Ntabelanga + 0.75 MAR Lalini	785.8	745.2	618.75	576.56	24.5	BC	287.1	33.05	5	1.34	50	23.49	5	1.99

** Surface area at Full Supply Level*

The optimum Lalini dam size selection was based on several factors, such as the cost benefits, as well as social and environmental impacts.

The energy figures thus produced were incorporated into the economic and financial models undertaken to determine the best conjunctive use solution.

These analyses are described in the Feasibility Design of the Lalini Dam and Hydropower Scheme Report No. P WMA 12/T30/00/5212/19, and in the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15.

As described in the relevant reports, it is recommended that:

- the Ntabelanga Dam be constructed with a storage capacity of 1.18 MAR_{PD} (490 million m^3),
- the Lalini Dam be constructed with a storage capacity of 0.28 MAR_{PD} (232 million m^3),
- the Ntabelanga Dam mini-HEP be implemented with an installed generating capacity of 5 MW (5 x 1 MW unit), and
- the Lalini Dam mini-HEP be implemented with an installed generating capacity of 5 MW (5 x 1 MW unit), and
- the main Lalini HEP be implemented with an installed generating capacity of 37.5 MW (3 x 12.5 MW units).

4. FEASIBILITY DESIGN: LALINI DAM

4.1 Dam Wall and Spillway

As described in the preceding sections, an RCC gravity dam is recommended, with an ogee spillway with stepped downstream face, and a slope of 1V to 0.75H, with gradually varied step dimensions. The step dimensions could be in smaller increments in the upper area to reduce nap separation, but this must be verified and refined by spillway modelling in the detailed design stage.

The proposed layout plan, typical wall and spillway cross-sections, and longitudinal cross-sections for the recommended dam type and spillway are shown in Figures 4-1 to 4-3.

The proposed Lalini Dam has the following characteristics:

Full Supply Level (FSL):	765.58 m.a.s.l.
Non-Overspill Crest Level[2] – Left flank (NOCL):	770.41 m.a.s.l.
Minimum bed level in river at dam:	717.00 m.a.s.l.
Crest width:	6 m
Minimum operating level (MOL):	740.14 m.a.s.l.
Main outlet conduit minimum invert level:	736.14 m.a.s.l.
Maximum dam wall height to NOC:	53.41 m
Wall crest length (incl spillway):	365 m
Spillway crest length:	320 m
Gross stored volume at FSL:	232 million m^3
Mean Annual Runoff (Present Day) at dam:	828 million m^3
Storage below MOL (V_{50} sedimentation):	31.2 million m^3
Surface area of lake behind dam:	31.5 km^2
Backwater reach upstream of dam:	22 km

The dam wall height, impoundment volume, and downstream risk factors for the Lalini Dam put this structure into a Category 3 dam under gazetted Dam Safety Regulation R139 of 2012.

As discussed in Appendix A of Report No. P WMA 12/T30/00/5212/19, and as reviewed and accepted by the DWS Hydrological Services, the flood criteria for design of this dam are as follows:

1 in 200 year return period Design Flood (RDF):	3 500 m^3/s
Safety Evaluation Flood (SEF):	7 100 m^3/s

The dam releases flow into the river below the dam to meet the EWR requirements, which flow can be simultaneously used to generate an average of 1.8 MW of hydropower at the dam wall. The dam also transfers water by gravity through a pipeline, tunnel and penstock system to provide water to the main Lalini hydro-electric power scheme (HEP), which can generate up to 37.5 MW, before releasing this water back into the river below the HEP return flow outlet works.

[2] *Right-hand flank NOCL is 1 m higher than this flank*

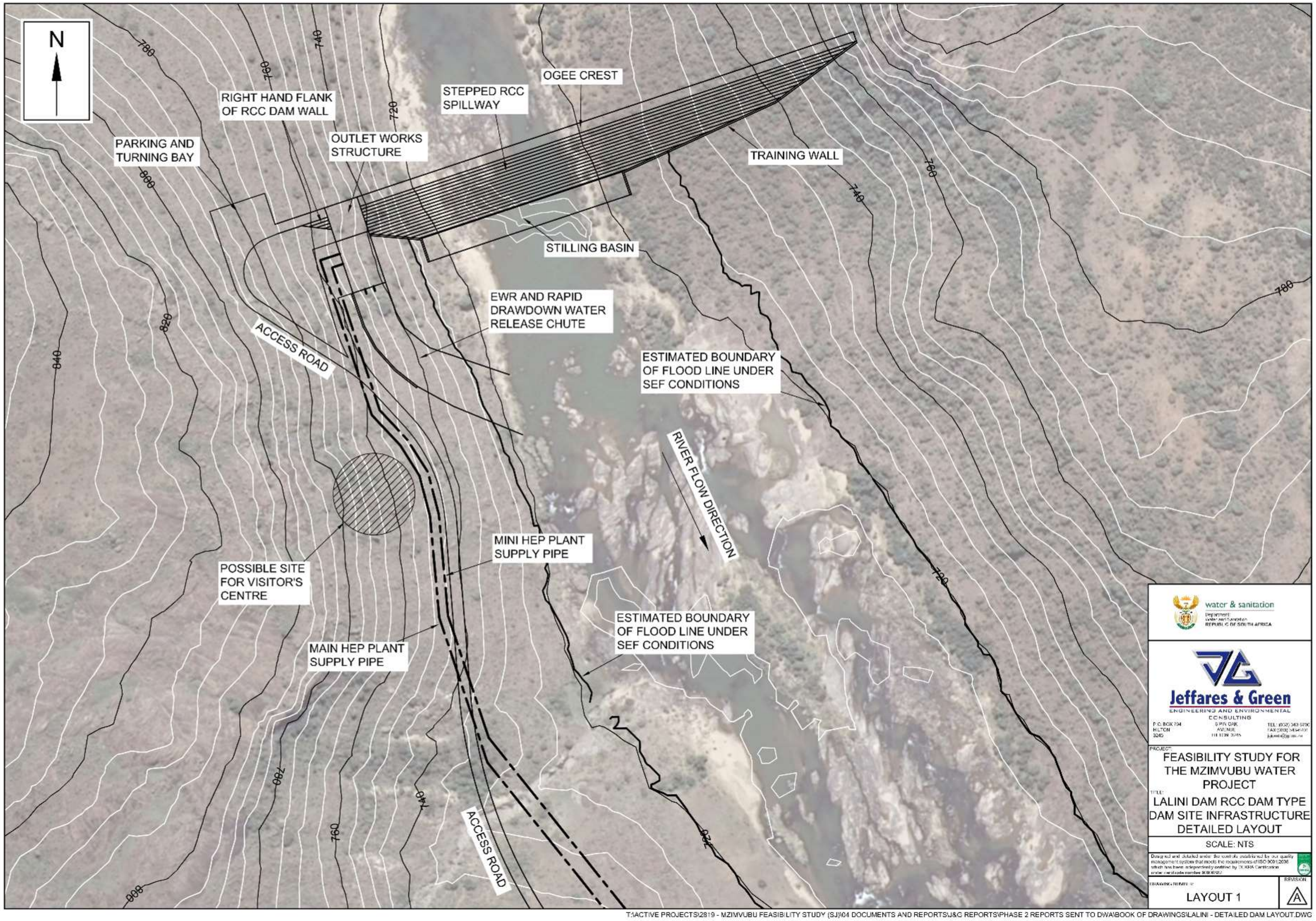

Figure 4-1: General Arrangement of the RCC Dam Option and Associated Infrastructure

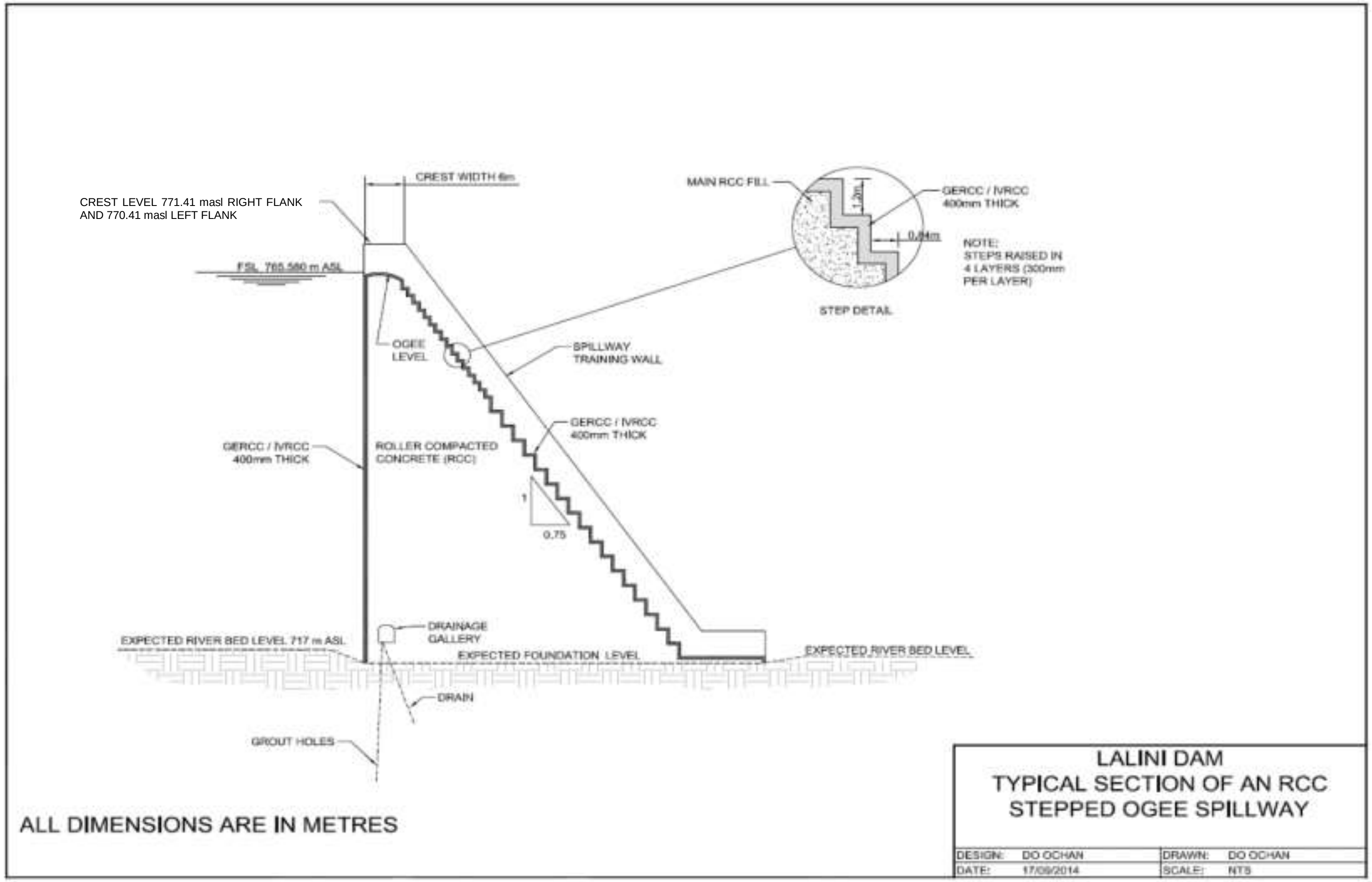

Figure 4-2: RCC Dam Wall and Spillway Typical Cross Section

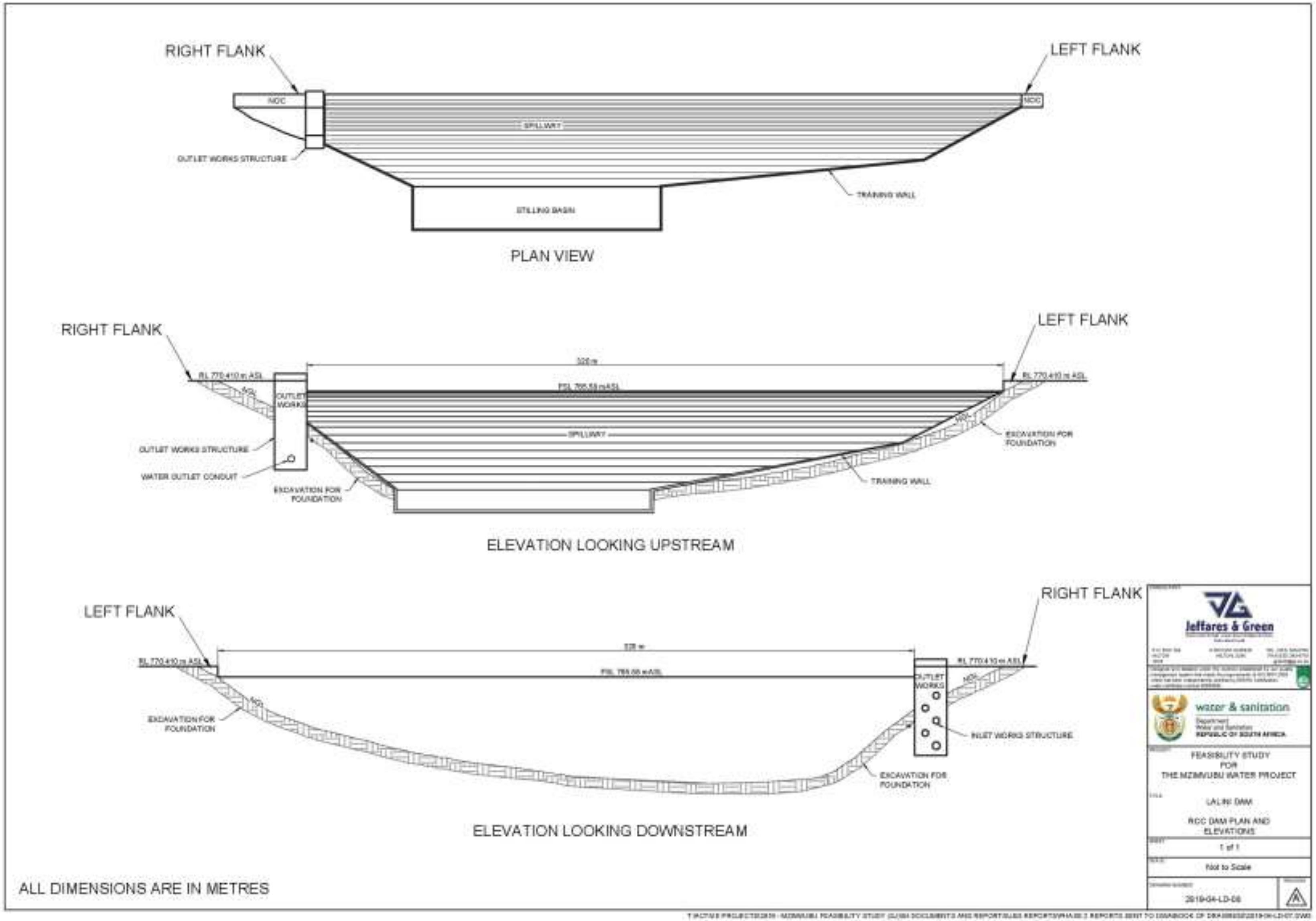

Figure 4-3: RCC Dam Wall Plan and Elevations

The geotechnical investigations have indicated that the founding conditions of both dam wall and stilling basin are in competent dolerite, which will exhibit low erodibility. The stilling basin can thus be of modest dimensions, and it is also not considered necessary to install a flip bucket at the lower end of the stepped spillway chute.

Given that the dam wall is to be entirely of RCC construction, and is built on competent rock foundations, the wall structure can therefore tolerate some overtopping under both design flood and SEF conditions. It is therefore suggested to reduce cost by not constructing the non-overspill crest to the full total free board level (as determined from Guidelines on Freeboard for dams, 2011) of the dam on the left flank.

This would result in approximately a 0.67 metre wave over-splash during a design flood event. The NOC level is therefore set to 5.83 m above spillway crest level on the right flank, to prevent overtopping of the outlet works, and 4.83 m on the left flank.

The hydraulic analysis was undertaken using the normal ogee spillway crest formula (see same methodology used in Feasibility Design: Ntabelanga Dam Report No. P WMA 12/T30/00/5212/12). Using a spillway crest length of 320 m, which, under the 3 500 m^3/s recommended design flood discharge, results in a flow depth over the crest of 3.0 m. This limits the unit discharge rate to an acceptable 10.9 m^3/s/m.

The flow depth over the 320 m spillway during the SEF event, which has a flow rate of 7 100 m^3/s, is 4.83 m with zero freeboard. The SEF event flood produces a unit discharge rate over the spillway crest of 22.2 m^3/s/m. This is at the upper end of that recommended for stepped spillways to reduce nappe separation and cavitation action.

Another issue would be the erosion impact on the left abutment of the dam under high spillage rates, and the design of a training wall and/or other methods of reducing this impact are required. Options might be to step the left flank downstream dolerite rock face to form an energy dissipating cascade, or to build a side chute in concrete to protect the rock from erosion. These additional scour protection works of the downstream section of the left hand abutment may counteract the cost savings achieved by lowering the left hand flank crest height. This decision should therefore be revisited during the detailed design stage to determine the optimum technical and cost solution.

Another option might be to have a two stage ogee crest level which channels the design flood through the centre of the dam, and only when flows are above this value would the left hand section of the spillway come into play. This may require a slightly lower ogee crest level and higher freeboard due to the upstream maximum water level constraints imposed by the N2 bridge.

The spillway, chute and stilling basin arrangement must therefore be investigated in more detail and optimised during the detailed design stage, which could include both Computational Fluid Dynamics (CFD), and physical laboratory modelling. CFD is optional, given that it requires very intense computational power and can be time-consuming, but physical modelling is considered essential.

Research is currently being undertaken at the University of Stellenbosch regarding the impacts on discharge efficiency of high flows over ogee-crested stepped spillways, and it is evident that much attention must be paid to ensuring that the nappe adheres to the ogee crest and does not separate. Physical modelling will therefore inform the design and, if necessary, changes in freeboard, ogee length and/or step profile might result.

4.1.1 Dam Stability Analysis

Given that the RCC option is the preferred option, a stability analysis was run to ensure that the typical dam profile being used for comparison purposes would be viable.

CADAM software was used for the structural analysis.

The model was set up based on simple beam theory. This is a methodology mainly used for gravity dam design.

Figure 4-2 above shows the proposed cross section of the central uncontrolled Ogee spillway. This is considered to be the deepest section and for which the structural analysis was performed.

The following information and assumptions were used in undertaking the analysis:

- Lalini Dam would have a maximum height of 53.41 m from the river bed level and a total crest length of 365 m;
- Floods would be discharged by means of un-controlled Ogee stepped spillway;
- Concrete density of 2 400 kg/m³;
- Concrete grade C15/53 would be used mainly for the RCC;
- Solid dolerite founding condition with minimum cohesion of 0.3 MPa and minimum angle of friction of 35°;
- Horizontal component of peak ground acceleration = 0.15 g; and
- Vertical component of peak ground acceleration = 0.08 g.

The loading conditions adopted are shown in Table 4-1.

Table 4-1: Loading Conditions

Type	**Case**	**FSL**	**RDF**	**SEF**	**Silt (S)**	**Tail water(TW)**	**Drained (D)**	**Undrained (UD)**	**Seismic (SM)**
Normal	1	√			√		√		
	2		√		√	√	√		
Abnormal	3		√		√	√		√	
	4			√	√	√	√		
	5	√			√	√	√		√
Extreme	6		√		√	√	√		√
	7			√	√	√		√	

Tables 4-2 and 4-3 present the results obtained from the various load cases in Table 4-1. The analysis results are compared with the allowable factors of safety and maximum stresses according to various international guidelines. Analysis was run for downstream wall slopes of both 1V:0.70H and 1V:0.75H.

These feasibility level results show that factors of safety for sliding and overturning are very close to those allowable for the 1V:0.70H downstream slope option, and are conservative for the 1V:0.75H downstream slope option. In both options, some of the tensile stress results are higher than allowable.

Table 4-2: Analysis Results and Comparison (1V:0.70H Slope)

Type	Case	Tensile Stress (MPa)		Compressive Stress (MPa)		Sliding (residual) Factor of safety (FOS)		Downstream overturning Factor of safety (FOS)	
		R	A	R	A	R	A	R	A
Normal	1	+0.15	0.0	-1.5	-3.0	1.4	1.5	1.32	1.5
	2	+0.35	0.0	-1.7	-3.0	1.3	1.4	1.3	1.4
Abnormal	3	+0.52	0.2	-1.7	-4.5	1.1	1.1	1.1	1.2
	4	+0.47	0.2	-1.8	-4.5	1.2	1.1	1.2	1.2
	5	-0.2	0.2	-1.0	-4.5	2.4	1.1	1.7	1.2
Extreme	6	-0.03	0.35	-1.3	-4.5	2.1	1.0	1.5	1.1
	7	+0.64	0.35	-1.8	-4.5	0.98	1.0	0.87	1.1

*__Legend__ - **A** = Allowable - = Compression **R** = Result + = Tension*

Table 4-3: Analysis Results and Comparison (1V:0.75H Slope)

Type	Case	Tensile Stress (MPa)		Compressive Stress (MPa)		Sliding (residual) Factor of safety (FOS)		Downstream overturning Factor of safety (FOS)	
		R	A	R	A	R	A	R	A
Normal	1	+0.02	0.0	-1.3	-3.0	1.8	1.5	1.54	1.5
	2	+0.2	0.0	-1.5	-3.0	1.47	1.4	1.4	1.4
Abnormal	3	+0.34	0.2	-1.6	-4.5	1.2	1.1	1.2	1.2
	4	+0.3	0.2	-1.7	-4.5	1.3	1.1	1.3	1.2
	5	-0.32	0.2	-0.94	-4.5	2.7	1.1	1.8	1.2
Extreme	6	-0.15	0.35	-1.14	-4.5	2.3	1.0	1.6	1.1
	7	+0.48	0.35	-1.7	-4.5	1.1	1.0	1.1	1.1

*__Legend__ - **A** = Allowable - = Compression **R** = Result + = Tension*

The eventual geometry of the dam wall would be determined following an extensive detailed design process including finite element and numerical elastic analyses, and this is normally a balance between minimising cost and meeting all of the allowable safety criteria.

This would include consideration of various cross section profiles, mix designs, and tensile crack control/induction methodologies. This will also include considering whether a sloped (rather than vertical) upstream face, or horizontally arched upstream face option is a beneficial and economic solution.

Typically RCC dams are built with downstream slopes of between 1V:0.70H and 1V:0.80H, but this can be steeper on the upper part of the embankment if a non-symmetrical slope approach (base slope shallower than higher up the wall) is adopted.

For the feasibility design and costing of the Lalini Dam, a simple symmetrical profile as given in Figure 4-2 has been adopted, with a slope of 1V:0.75H.

Outputs from the CADAM stability model runs on the RCC dam option are given in Figures 4-4 and 4-5.

At the detailed design stage, a detailed structural analysis should be performed on the finally selected dam, spillway and outlet works configuration using this and other available engineering methods and best practice, to optimise the dam structure.

CADAM - Stability drawing

Page 1

By Martin Leclerc, M. Ing.
NSERC / Hydro-Quebec / Alcan Industrial Chair on Structural Safety of Concrete Dams, École Polytechnique de Montréal, Canada

Project:		**Dam location:**		**Analysis performed by:**	
Dam:		**Date:**	26/09/2014	**Project engineer:**	
Owner:					

Usual combination (effective stress analysis)

Joint #	Crack (% joint)	Normal (kPa)	Principal (kPa)	Uplift (kPa)	Crack (% joint)	Normal (kPa)	Principal (kPa)	Uplift (kPa)
1		0.261	0.261	5.690		-8.227	-13.917	0.000
2		1.163	1.163	25.310		-36.597	-61.906	0.000
3		2.064	2.064	44.930		-64.966	-109.896	0.000
4		2.966	2.966	64.550		-93.336	-157.885	0.000
5		3.867	3.867	84.170		-121.705	-205.875	0.000
6		4.769	4.769	103.790		-150.075	-253.864	0.000
7		5.670	5.670	123.410		-178.444	-301.854	0.000
8		6.572	6.572	143.030		-206.813	-349.843	0.000
9		7.473	7.473	162.650		-235.183	-397.833	0.000
10		8.375	8.375	182.270		-263.552	-445.822	0.000
11		9.276	9.276	201.890		-291.922	-493.812	0.000
12		10.178	10.178	221.510		-320.291	-541.801	0.000
13		11.079	11.079	241.130		-348.661	-589.791	0.000
14		11.990	11.990	260.750		-377.040	-637.796	0.000
15		13.102	13.102	280.370		-405.620	-686.142	0.000
16		14.674	14.674	299.990		-434.659	-735.265	0.000
17		16.837	16.837	319.610		-464.291	-785.389	0.000
18		19.647	19.647	339.230		-494.568	-836.606	0.000
19		23.112	23.112	358.850		-525.502	-888.933	0.000
20		27.220	27.220	378.470		-557.078	-942.346	0.000
21		31.940	31.940	398.090		-589.266	-996.796	0.000
22		37.239	37.239	417.710		-622.033	-1052.224	0.000
23		43.079	43.079	437.330		-655.341	-1108.566	0.000
24		-101.372	-101.372	306.156		-689.151	-1165.761	0.000
25		-101.037	-101.037	319.302		-723.429	-1223.744	0.000
26	100.000	694.101	N/A	613.910		-1269.281	-1269.281	613.910

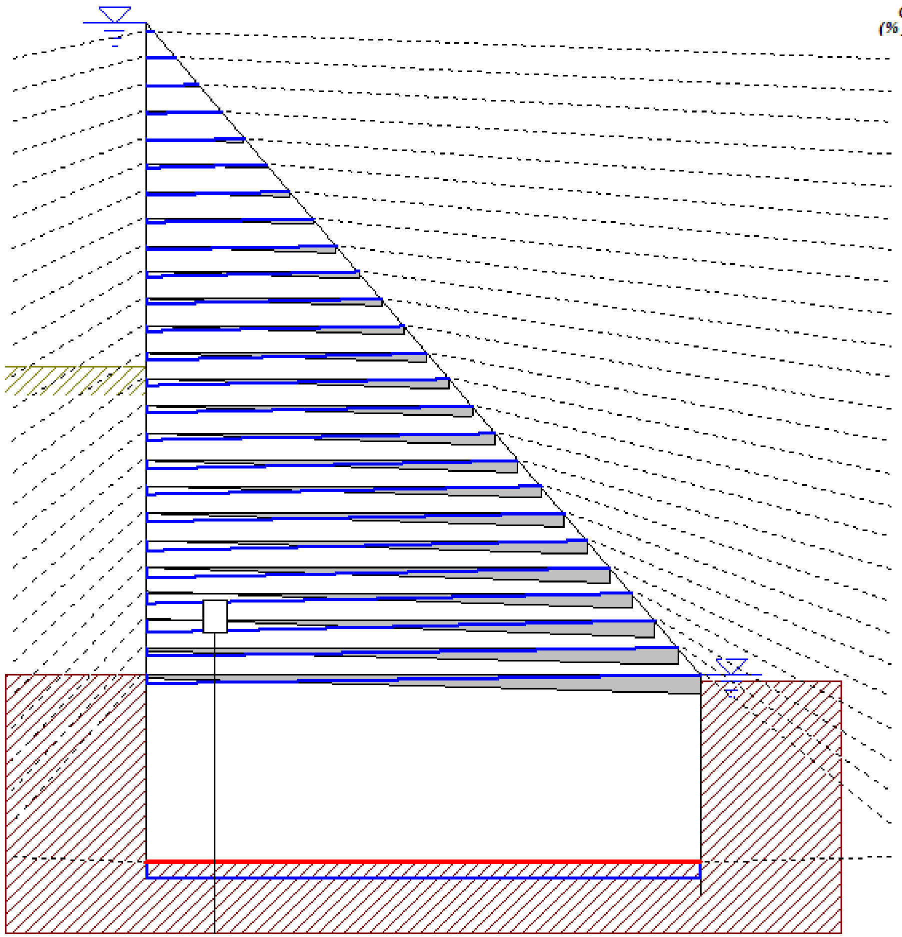

Figure 4-4: Stress Distribution on the Lift Joint Under Service Load

CADAM - Stability drawing

Page 2

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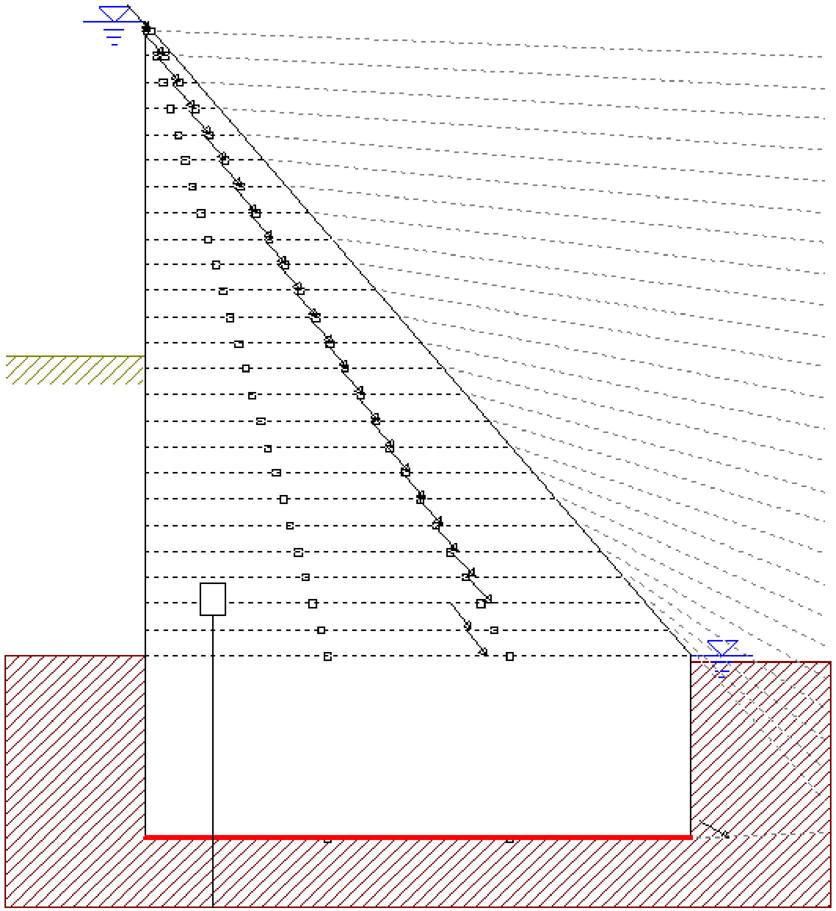
NSERC / Hydro-Quebec / Alcan Industrial Chair on Structural Safety of Concrete Dams, École Polytechnique de Montréal, Canada

Project:		**Dam location:**		**Analysis performed by:**	
Dam:		**Date:**	26/09/2014	**Project engineer:**	
Owner:					

Usual combination (stability analysis)



Joint #	SSF (peak)	SSF (residual)	OSF (U/S <-)	OSF (-> D/S)	USF	Normal (kN)	Shear (kN)	Moment (kN·m)	Res. Pos. (% joint)
1	> 100	1.164	3.846	1.393	2.400	-1.9	1.7	0.2	67.761
2	78.092	1.164	3.846	1.393	2.400	-38.0	32.6	14.5	67.761
3	44.717	1.164	3.846	1.393	2.400	-119.8	102.9	81.0	67.761
4	31.631	1.164	3.846	1.393	2.400	-247.3	212.4	240.3	67.761
5	24.645	1.164	3.846	1.393	2.400	-420.4	361.1	532.8	67.761
6	20.301	1.164	3.846	1.393	2.400	-639.2	549.0	998.9	67.761
7	17.337	1.164	3.846	1.393	2.400	-903.8	776.2	1679.2	67.761
8	15.187	1.164	3.846	1.393	2.400	-1214.0	1042.7	2614.2	67.761
9	13.556	1.164	3.846	1.393	2.400	-1569.9	1348.4	3844.4	67.761
10	12.276	1.164	3.846	1.393	2.400	-1971.4	1693.3	5410.2	67.761
11	11.244	1.164	3.846	1.393	2.400	-2418.7	2077.4	7352.1	67.761
12	10.396	1.164	3.846	1.393	2.400	-2911.6	2500.8	9710.6	67.761
13	9.685	1.164	3.846	1.393	2.400	-3450.3	2963.5	12526.2	67.761
14	9.075	1.163	3.846	1.393	2.400	-4034.6	3467.7	15840.1	67.761
15	8.515	1.158	3.847	1.393	2.400	-4664.6	4027.2	19711.4	67.779
16	7.998	1.150	3.849	1.392	2.400	-5340.3	4644.4	24216.4	67.831
17	7.526	1.140	3.853	1.390	2.400	-6061.7	5319.3	29432.6	67.921
18	7.096	1.128	3.858	1.388	2.400	-6828.7	6051.8	35437.3	68.046
19	6.706	1.117	3.864	1.386	2.400	-7641.5	6842.0	42307.9	68.200
20	6.352	1.105	3.872	1.383	2.400	-8499.9	7689.9	50121.6	68.379
21	6.032	1.094	3.880	1.379	2.400	-9404.1	8595.4	58955.8	68.577
22	5.741	1.083	3.889	1.376	2.400	-10353.9	9558.6	68887.8	68.789
23	5.478	1.073	3.899	1.372	2.400	-11349.4	10579.4	79995.0	69.012
24	5.863	1.313	5.833	1.685	3.582	-15311.2	11658.0	73498.8	62.392
25	5.648	1.302	5.848	1.680	3.582	-16654.2	12794.1	84653.7	62.582
26	0.852	0.597	1.993	0.965	1.468	-11618.6	19466.1	267046.0	106.892
	3.000	*1.500*	*1.200*	*1.200*	*1.200*				

Figure 4-5: Stability Analysis Results for Service Load

4.1.2 River Diversion Works

Consideration was given to the construction methodology and sequencing with particular attention to river diversion during construction.

Two different flood events were considered for the design of the diversion works. The 1 in 5 year flood of magnitude 750 m^3/s was used for the RCC dam type and the 1 in 20 year flood of magnitude 1 400 m^3/s was used for embankment dam types.

A diversion tunnel was a possibility but this was considered to cost significantly more than the temporary diversion conduits described below. The diversion tunnel option could still be considered, but would require additional geotechnical investigations to verify ground conditions adjacent to the dam wall.

For the purposes of the comparison of dam types, the flood control works design focused on making as much use as possible of required permanent works. These aspects will be revisited during the detailed design phase, and it will also be an option for the contractors to propose alternative methodologies in their bids if this project goes out to tender.

In the preferred case of an RCC dam option, minor overtopping during construction is acceptable. Given this, a 1 in 5 year flood event of magnitude 750 m^3/s was considered adequate for the design of the diversion works. The diversion conduit would be contained within the spillway section adjacent to the proposed permanent outlet works.

The diversion conduit would be designed so that when no longer required as a temporary river diversion, i.e. just before impoundment of the completed structure has commenced. The diversion section entrance would be permanently closed using stop logs, filled with pumped concrete and grouted.

4.2 Outlet Works

As described above, the dam wall and spillway would be constructed using RCC, and it is proposed that the draw-off and outlet works be housed in a reinforced concrete structure running through the right hand section of the dam wall, as is shown on the layout drawings. This is shown on Figure 4-6.

The draw-off and outlet works will have multi-purpose functions which are described in the following sub-sections. The dam outlet works arrangements will be subject to review during the detailed design stage and may therefore change from this feasibility level design approach.

4.2.1 EWR Releases

The recommended total releases at Lalini Dam are those required to maintain an intermediate ecological Class B/C of 287.1 million m^3 per annum (i.e. some 33% of MAR_{NAT}), which equates to an average of some 23.93 million m^3 per month.

The EWR is required to be released according to a seasonal pattern and this also depends on whether the river is in a state of flood or drought. EWR release rules are proposed in the reserve determination report, and release criteria are based upon preceding inflows.

Given that water released for EWR can also be passed through a hydropower generation turbine before release, it was decided to consider both EWR and hydropower releases together before making a decision on outlet conduit capacity.

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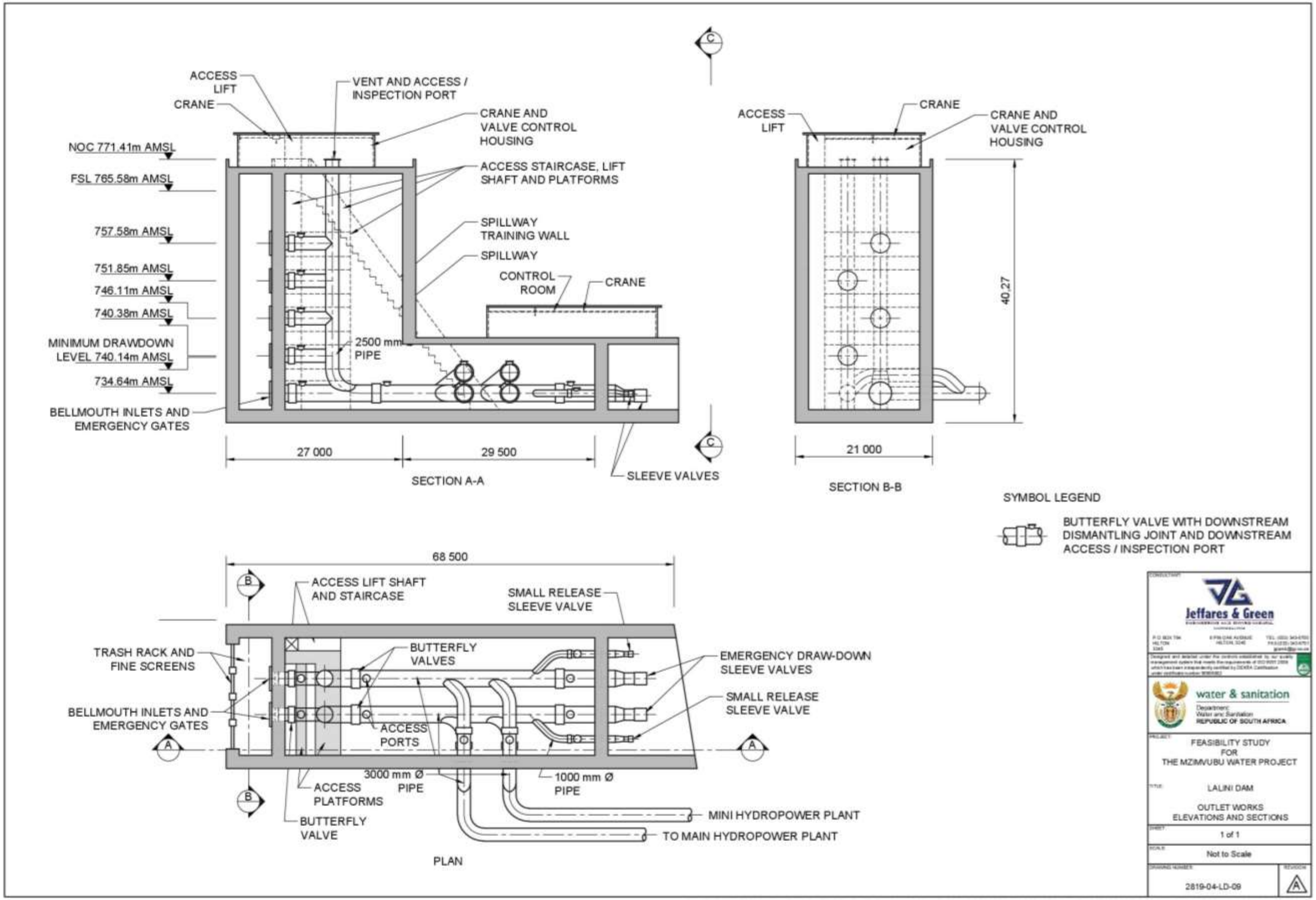


Figure 4-6: Outlet Works Elevations and Sections

The hydropower outlet pipeline requirements are described below, but it was also recommended by the reserve determination team that freshets should be released periodically to replicate natural flood occurrences, and that the capacity of the separate EWR outlet should be 60 m^3/s. As described below, this allowed the Emergency Drawdown Pipe and EWR release freshet outlet to be combined, which are each sized at 3.0 m diameter.

4.2.2 *Hydropower Generation Outlet Works*

The outlet works pipework configuration allows for large and small release discharges directly into the stilling basin. The off-take pipework to the Lalini mini-hydropower plant is sized for the maximum hydropower output which equates to 16 m^3/s. In this case, a 3.0 m diameter pipe was deemed to be sufficient.

A second outlet conduit is required to supply the main HEP, and from the hydropower analysis it was determined that the maximum flow in this conduit would be 25 m^3/s. A 3.0 m diameter outlet pipeline was also recommended in this case.

4.2.3 *Emergency Drawdown Facilities*

It is a normal requirement to be able to rapidly drawdown (RDD) the dam water level in the case of an emergency. This requires that the dam water level be reduced from FSL to one third of its full water depth in 90 days.

For the Lalini Dam, this means that some 214 million m^3 of water would need to be released in 90 days. This is an average flow of 27.5 m^3/s, with a peak flow of approximately 40.5 m^3/s. This is taken into consideration for the outlet works feasibility design.

Some dams have completely separate emergency drawdown systems, and given that these are very rarely used, can be a cause of problems if they silt up or are not maintained properly.

Under an emergency rapid drawdown situation, it is proposed that all four outlet bellmouths would be opened as well as the downstream discharge valves on both of the outlet conduits.

Under such conditions the required peak drawdown rate of 40.5 m^3/s and average of 27.5 m^3/s will be achieved. Given that a 3.0 m diameter outlet is recommended for the EWR case, the maximum velocity under RDD conditions would be 2.9 m/s which is acceptable.

In addition to the upstream emergency gates and butterfly valves on all of the offtakes upstream, there would be sleeve valves at the outlet of each of the rapid drawdown and small release conduits. Given the velocities involved, these sleeve valves are more suitable for flow control and tight closure.

It is recommended that such a system be modelled and optimised using physical modelling or possibly computational fluid dynamics modelling (CFD) during the detailed design stage, to ensure that surge and vibration effects are minimised or avoided altogether.

4.2.4 Outlet Works Capacity to Discharge EWR Floods/Freshets

The EWR values and release rules thereof were only developed at the end of this study period following an additional reserve determination exercise undertaken through the separate EIA study.

The recommendations made, following a basic assessment, were as shown in Table 4-4.

Whilst the proposed 60 m^3/s capacity of the flood release/rapid drawdown facility meets Class 1 and 2 flood release requirements, outlet cannot meet the requirements for Class 3 and 4.

In recent years, there has been ever increasing attention paid to the flood/freshet releases aspects of large dam design. The installation of outlet works capable of discharging high flood values is costly and must be designed and operated with great care. For example, the Berg River dam has a flood release capacity of 200 m^3/s, and some vibration caused by transient pressure was experienced which required further studies and remedial actions to be undertaken.

The Lalini Dam hydropower simulations indicated that the dam would spill only 74 times in 1080 months, which spills would likely not always be sufficient to meet the Class 3 and Class 4 flood release requirements as described in Table 4-4. The main question is how large to size the flood outlet works capacity.

Table 4-4: Recommended EWR Flood Rules for the Tsitsa River below Lalini Dam

Floods	**Flood size (range) m^3/s**	**Fish**	**Invertebrates**	**Vegetation**	**Geo-morphology**	**Actual Flood Value in SPATSIM**
Class 1	0-10				10 m^3/s Average 10 days	10 m^3/s Average 10 days Sep, Oct, Nov, 2 x Dec, 3 x Jan, 2 x Feb
Class 2	11-25	25 m^3/s Average 4 days	20 m^3/s Average 4 days	20 m^3/s Average 4 days	20 m^3/s Average 6 days	25 m^3/s Average 6 days Sep, Oct, Nov, Dec, 2 x Jan, Feb, Mar
Class 3	100-170	100 m^3/s Peak 6 days	170 m^3/s Peak 5 days	150 m^3/s Peak 6 days	200 m^3/s Peak 4 days	170 m^3/s Peak 5 days Feb
Class 4	200-350			200 m^3/s Peak 6 days		200 m^3/s Peak 4 days Mar

Recent studies have been undertaken on this subject on the Smithfield Dam, which were reported at SANCOLD 2014 in the paper entitled "Evaluating the sizing of the outlet infrastructure of Smithfield Dam to accommodate EWR flood flow releases"[3].

[3] *J Lombard, FGB de Jager & E van Niekerk, AECOM*

The paper discussed the optimum sizing of the dam outlet works comparing the designed "limited" outlet capacity of 41 m^3/s with the "unlimited" peak EWR flood requirement of 235 m^3/s. The modelling ran scenarios for various flow release trigger levels based upon precedent inflow and dam water level taking into consideration that it would not be normal to release large floods in a drought year.

Given that the distribution of flow duration curve of that dam was heavily skewed such that flows above 41 m^3/s only occurred with a probability of occurrence of less than 3%, it was concluded as follows:

"The impact of outlet capacity limits on EWR for Smithfield Dam:

- *Negligible difference in EWR supply between unlimited and limited dam release capacities*
- *EWR target and supply volumes are identical above an exceedance probability of 3%*
- *Undersupply is less than 10% of EWR target*

In comparing a limited 41 m^3/s versus the maximum 235 m^3/s outlet capacity, the conclusion was that there was:

- *only marginal improvement in benefit to the downstream environment if a maximum flood outlet capacity was installed,*
- *such a large outlet works increased construction difficulties, and*
- *this could result in massive financial over-expenditure."*

The B/C Class EWR and naturalized flow duration curves at Lalini Dam for the wettest month of March are given in Figure 4-7.

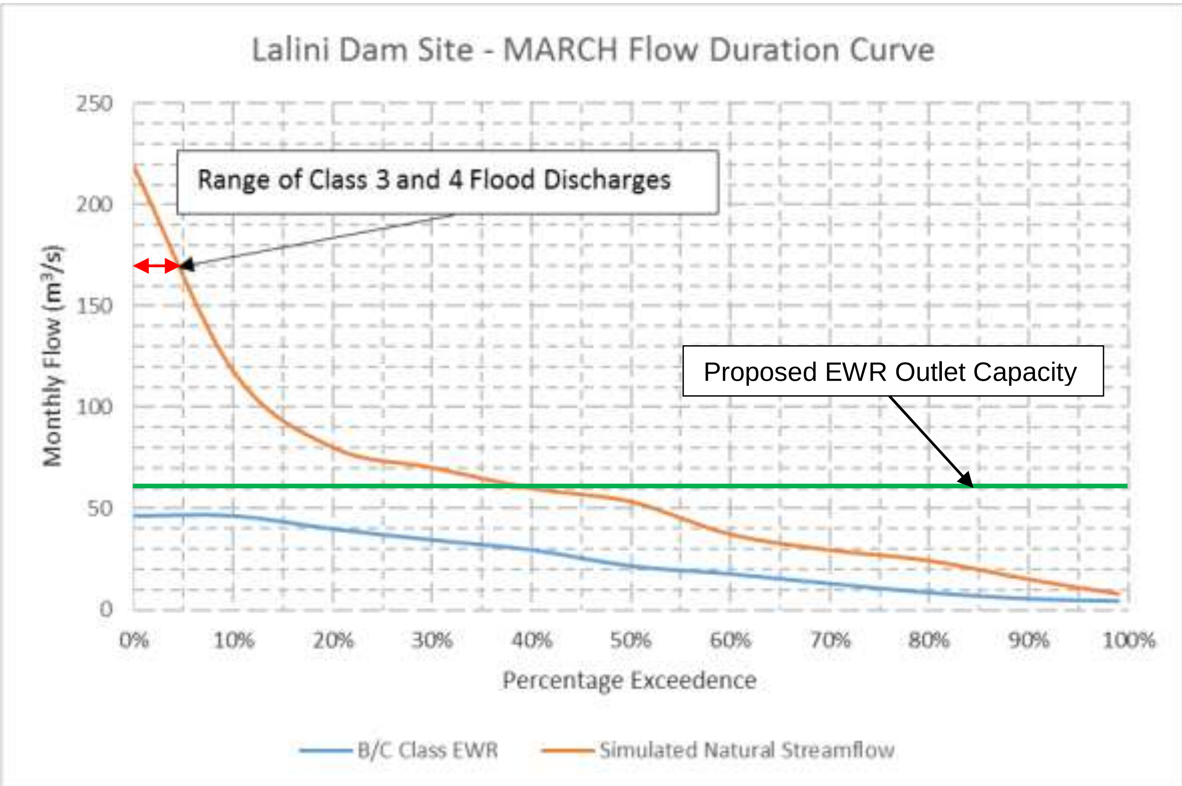


Figure 4-7: Flow Duration Curves at Lalini Dam for March

As can be seen the 60 m^3/s outlet works capacity are more than adequate to meet the Class B/C EWR at all times, and the percentage occurrence of flows in the range of 170 m^3/s and above is less than 4% (see Figure 4-7). This is a similar situation to the Smithfield Dam example.

Given the above, it is recommended that more detailed consideration of this issue be undertaken during the detailed design stage of scheme implementation, before a final decision is made on the optimum Lalini Dam flood release outlet works capacity.

Discussion of this issue at SANCOLD 2014 included suggestions that the flood regime should be modelled in more detail – probably at a finer resolution by employing daily flood simulation modelling – and consensus reached with the reserve determination team as to the flood release rules that would trigger the various classes of floods, and the impact of limiting the installed flood outlets capacity to less than the peaks indicated under Classes 3 and 4.

If there is still an insistence that these larger flood/freshet releases be catered for, then a single dedicated larger gated outlet would need to be incorporated into the detailed design. The capacity of this facility would be designed to release the incremental discharge above 60 m^3/s.

This outlet facility would typically take the form of a rectangular conduit through the body of the dam, which is controlled by a downstream radial or vertical gate with an upstream vertical service gate (refer EWR outlet on Midmar Dam). The service gate would remain closed during normal operation of the dam as an additional safety measure.

4.2.5 Summary of Outlet Works Parameters

Table 4-5 summarises the outlet works and pipeline parameters required to meet the above functionality requirements.

Table 4-5: Summary of Outlet Works Parameters

		Flow scenario					
		Peak demand		EWR		RDD	
Description	**Pipe dia.**	**Flow**	**Velocity**	**Flow**	**Velocity**	**Flow**	**Velocity**
Intake stack	2.5 m	25.0 m^3/s	5.1 m/s	60.0 m^3/s	6.1 m/s	40.5 m^3/s	4.1 m/s
EWR and RDD pipe	3.0 m	N/A	N/A	60.0 m^3/s	4.2 m/s	40.5 m^3/s	2.9 m/s
Outlet pipe to mini HEP	3.0 m	16.0 m^3/s	2.3 m/s	N/A	N/A	N/A	N/A
Outlet pipe to main HEP	3.0 m	25.0 m^3/s	3.5 m/s	N/A	N/A	N/A	N/A

***EWR**: Environmental Water Requirements* ***RDD**: Rapid Draw Down*

4.3 Dam Foundations

The foundation levels for this RCC dam type are based upon borehole core log descriptions and seismic velocity profiles. *Van den Berg and Parrock (2009)* recommend the following foundation criteria for dams exceeding 60 m in height:

Table 4-6: Recommended Foundation Design Criteria for RCC Dams

Foundation Design Criteria						
E_{mod}	**RMR**	**Weathering**	**UCS**	**RQD**	**Joint Spacing**	**Joint Condition**
> 4.5 GPa	> 40	Medium to Slightly Weathered	> 20 MPa	> 30%	> 300 mm	Rough, Unaltered

E_{mod}: Elastic Modulus
RMR: Rock Mass Rating
UCS: Uniaxial Compressive Strength
RQD: Rock Quality Designation

Whilst its wall height is less than 60 m, it is proposed that the Lalini Dam foundation levels should also follow these same principles. The longitudinal section in Figure 3-6 shows the recommended foundation excavation profile, which is based upon the results of the rotary core drilling and seismic refraction survey undertaken during this Feasibility Study.

This foundation profile targets the founding on medium hard to hard rock, complying with the parameters recommended in Table 4-6 as well as the 2 000 m/s seismic velocity profile.

This places the foundation in an intermediate to generally hard excavation category and it is likely that some blasting will be necessary to achieve excavation to good quality foundation rock.

However, blasting must be minimised so as to avoid excessive blast fracturing, which compromises the integrity of the foundation rock. *Van Schalkwyk et al (2009)* recommend stopping bulk blasting about one (1) m above the expected founding level and proceeding below this with controlled blasting or powerful excavating equipment.

It is recommended that the profile is reviewed during the detailed design stage as more drilling information becomes available during the detailed design geotechnical investigations. This further investigation should be planned to check for faults, fractures and lineaments below the dam footprint, although it is not expected that such problems will be identified. Furthermore, all foundation excavations must be continuously monitored, verified, and the final excavation mapped by an experienced geotechnical professional during construction.

A budget has been allowed in the cost estimates for drilling, grouting and test drilling programme, covering the upstream heel areas of the dam foundation footprint, the outlet works, the spillway, and the temporary river diversion works conduit. Lugeon testing during the core drilling undertaken to date showed very low or no uptakes, and therefore only limited grouting is expected to be required.

4.4 Dam Construction Materials Requirements

As reported in the Lalini Geotechnical Investigations Report Number P WMA 12/T30/00/5212/10, various site investigations have been undertaken, including core drilling, trial pit excavation, laboratory testing of samples, and seismic refraction geophysics.

This has provided adequate information on founding conditions, construction materials quantities and quality, and key design parameters.

Figure 3-6 above shows the interpretation of the founding conditions as identified through the core drilling undertaken on the proposed dam centreline.

Figure 3-7 shows the finally selected materials quarries and borrow pits locations.

Required quantities of material for the construction of the recommended RCC dam are as follows:

Rock for concrete aggregate: 235 258 m^3
Sand for concrete aggregate: 39 210 m^3

4.4.1 Quarry for the Production of Concrete Aggregate

Competent, hard dolerite rock underlies the middle to upper right flank, either near-surface or as an outcrop. The positions of boreholes drilled for the evaluation of dam foundations are indicated in the Geotechnical Investigations report, but a summary is described herein.

The boreholes drilled generally show a deep weathering profile over the area investigated with a thick overburden mantle, which under normal circumstances would render the site marginal to unsuitable for exploitation as a rock quarry, due to the excessive thickness of unusable overburden material that would require removal and spoiling.

In this case, the residual and weathered dolerite overburden has potential usage as road construction material, which if confirmed as being suitable could make the site feasibly exploitable. This would require verification by means of a more detailed investigation and testing programme.

The potential quarry site identified as having suitable dolerite material, (see Site C on Figure 3-7) and that is within the future inundated basin, is located approximately 3.5 km upstream of the dam on the eastern side of the Tsitsa River. Whilst this is some distance from the dam site, existing tracks can be developed by the contractor as temporary haul roads, which would all be drowned after construction. The drilling undertaken at this site indicated adequate rock aggregate for both dam and concrete structures construction.

Once encountered below the overburden, the un-weathered dolerite is of good quality, as confirmed by the strength, mineralogical and durability tests undertaken. The estimated volume of good quality dolerite rock available for the manufacture of crushed rock aggregates, excluding poor quality overburden, is in excess of 400 000 m^3 which is nearly double that required for a RCC dam type.

Samples of core material were retrieved from the core boxes and submitted for petrographic analysis to evaluate rock mineralogy, texture, degree of alteration and identification of alteration products, as well as unconfined compressive strength tests to determine intact rock strength. These have demonstrated that this material has low alteration, would provide very good foundations, and would be very suitable for concrete aggregate purposes.

4.4.2 Sand for Concrete Aggregate

A stretch of the Tsitsa River, which lies within the impoundment basin has been proposed as a potential sand source. Sand samples were retrieved from within the river channel at various locations along this section of the river. The estimated volume of exploitable sand from this section of the river is approximately 960 000 m^3. This is in excess of what is needed for any of the original dam types investigated. The Tsitsa River in the project area generally flows in a relatively incised channel with sand deposits confined to the river channel. Therefore these deposits are relatively narrow and would require selective seasonal exploitation during the dry season.

The laboratory test results carried out on the sand indicate that, chemically, the sand complies with the minimum requirements specified by SANS 1083 (2006) for fine concrete aggregate.

However, the grading of the sand indicates the sand is too fine both for concrete and filter design (FEMA 2011). The current grading can be modified by blending the sand with crusher sand to comply with the above mentioned design standards.

An alternative to this would be to import sand from suitable sources a distance away from the dam site. It is recommended that this be noted when finalising the detailed design and the eventual contractor could be given the option of either blending or sourcing from offsite to achieve the correct grading at the lowest cost.

4.4.3 Other Concrete Constituents

As a part of the detailed costing of the RCC concrete mix, an analysis was undertaken of the sources of fly-ash, cement, and concrete additives from the South African major suppliers of these materials. These companies included Lafarge, Ash Resources, etc. All of these materials are readily available albeit with significant transport costs. The costs of these materials as provided by the manufacturers have been taken into account when building up the cost estimates for the project.

This is reported further in the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15.

4.4.4 Stilling Basin Excavation

The necessity of a stilling basin downstream of the spillway will depend upon the final design configuration of dam and spillway, and could range from a simple protective apron located at the base of the spillway to an extensive stilling pool structure extending significantly downstream of the dam wall.

It is expected that the river bed in this location will comprise competent dolerite and thus most of the excavated material from such a stilling basin could be used for concrete aggregate.

It is recommended that physical (and possibly CFD) modelling is undertaken to optimise the spillway performance, and the stilling basin shape and depth.

4.5 Recommendations for Further Detailed Geotechnical Investigations

Based upon the results of the feasibility level investigations, founding conditions are suitable for an RCC dam. Additional, detailed investigations considered necessary to bring the level of detail up to that required to undertake the detailed design and tender documentation for the proposed construction of the dam and appurtenant works are described in the Geotechnical Investigations Report.

It is recommended that the detailed rotary core drilling investigation concentrates on infill drilling of the foundation footprint on both dam flanks, spillway components, appurtenant structures and to prove sufficient reserves of rock aggregate for construction.

It is recommended that an inclined borehole be drilled through the dolerite / sandstone contact on the mid left flank and that another inclined borehole is drilled beneath the river section from the left river bank. Provision must also be made for additional drilling on both the upstream and downstream dam foundation footprints.

An Environmental Management Plan for the quarry and borrow areas was prepared during the EIA process and submitted to Department of Mineral Resources (DMR) for approval. An additional requirement for the quarry and borrow areas, since 8 December 2014, is an environmental authorisation from DMR. An EIA therefore needs to be done for the quarry and borrow areas.

4.6 Conclusions and Actions to Be Taken

Based on the Feasibility Study findings, conclusions are drawn in terms of the items listed below. The future actions that need to be taken following the Feasibility Study are indicated below, against each conclusion:

i. Dam and hydropower scheme detailed design and related issues;
ii. Water quality sampling and testing;
iii. Updating of Costs;
iv. Other technical and economic considerations;
v. Consumption and sale of energy produced;
vi. Operating rules;
vii. Implementation of the Reserve; and
viii. Scheme financing and implementation.

These conclusions are summarized in the following sections.

4.6.1 Lalini Dam Design and Related Issues

Following the feasibility design process, the findings concluded in Table 4-7 are relevant to the detailed design and construction stage of this project.

Table 4-7: Conclusions on Lalini Dam Design and Related Issues

Findings	Remarks
a) A Gravity RCC type of dam is the recommended optimum solution.	To be further refined and optimised in the detailed design stage.
b) The dam has a centrally located ogee spillway with stepped chute.	To be optimised in the design phase. Physical modelling of spillway, chute, and plunge pool is recommended

c) A multi-level outlet structure must be built to ensure good quality water for use in hydropower plants and that the water quality and temperature requirements of the downstream aquatic system can be satisfied.	The EWR requires a multi-level outlet structure. Operating rules to be established.
d) The required normal operation outlet capacity of the dam needs to be based upon flow ranges for the EWR and hydropower plant peak output requirements.	River outlet capacity to be optimised in the design phase considering these requirements, which will need to be in line with both the reserve and the conjunctive operational regime.
e) The emergency drawdown outlet capacity will allow rapid drawdown of the dam to one-third of its maximum water depth within 90 days.	Layout to be finalised in the design phase. Modelling of outlet hydrodynamics is recommended to optimise system performance under high flows, and ensure no surge or vibration problems occur.
f) Results from the geotechnical investigations indicate that foundations are on competent rock, and that adequate materials are available close to the dam wall for the proposed maximum sized dam.	Additional geotechnical work is required for the design phase to improve information available and to check for any foundation anomalies. The source/availability of suitably graded sand for concrete upstream in the river channel still needs to be confirmed.

4.6.2 Other Technical Considerations

A summary of other technical issues for associated works is given in Table 4-8.

Table 4-8: Conclusions on Other Technical Issues

Findings	Remarks
a) Technically feasible re-alignments can be achieved for existing roads affected by the inundation caused by construction of the dam. See Section 6.	Details of road realignment to be optimised in the design phase.
b) Land inundated includes residential development, agricultural developments and associated infrastructure. See Section 7.	This aspect was considered in more detail in the EIA. The dam boundary (purchase) line and servitudes for infrastructure need to be determined as part of the detail design stage.

4.6.3 Water Quality

Water quality recommendations regarding thermal stratification and the need for a multi-level outlet structure are summarized in Table 4-9.

Table 4-9: Conclusions on Water Quality Issues

Findings	Remarks
a) A multi-level intake for the outlet structure is required in terms of the Reserve requirements.	Four outlet levels have been included in the Feasibility Design Report in accordance with the recommendation of the Reserve Determination Report.
b) Water quality sampling should be undertaken and water quality and thermal stratification models built to inform the final design. Operating rules and results must be included in the final Environmental Management Plan.	The approved Reserve must be complied with.

c) The upstream catchment is severely degraded with poor land use management practices. Erosion is amongst the highest in the country.	A 10 year extensive catchment restoration and on-going management programme was started in April 2014 spearheaded by the Department of Environmental Affairs.

4.6.4 Operating Rules

Comments on the establishment of operating rules for the dam are given in Table 4-10.

Table 4-10: Comments on Dam Operating Rules

Findings	Remarks
a) Operating rules need to be established for the dam. The operating rules need to take the existing users in the different river reaches, the inflow from tributaries downstream, the water quality issues such as the seasonal variability etc., into consideration.	It is recommended that a release pattern be determined, based on the operating rules of the dam as well as the ecological requirement and hydropower requirements downstream of the dam. Cognisance must be taken regarding the EWR requirements under low flow conditions as this affects the flow that can be passed through the main hydropower plant during certain low flow seasons. The 6 m^3/s flow allowed even under extreme drought conditions provides sufficient flow to generate 12.5 MW under these conditions.

4.6.5 Implementation of the Reserve

Comments on the implementation of the Reserve are given in Table 4-11.

Table 4-11: Comments on Implementation of the Reserve

Findings	Remarks
a) On an on-going basis, monitor the effectiveness of the proposed ecological releases on the riverine and estuarine environment, and implement refinement of the releases if needed.	Reserve implementation and monitoring to be performed by Reserve Determination Office and the DWS Regional Office
b) Institute a monitoring programme for the systematic monitoring of the pertinent data for assessing or modelling water quality in the reservoir. This programme should include: ● Hourly or daily meteorological data (air temperature, dew point temperature, wind speed, wind direction, and percentage sunshine); ● Inflow rates; ● Inflow and in-lake water quality; and ● Release rates.	Reserve implementation and monitoring to be performed by Reserve Determination Office and the DWS Regional Office.
c) Monitor nutrient loads flowing into the dam. It is also recommended that monitoring of the inflow water chemistry be implemented and that the inflowing nutrient loads are examined on an annual basis.	To be addressed and implemented in detailed design and operation phases.

4.6.6 *Scheme Financing and Implementation*

Comments on scheme financing and implementation issues are given in Table 4-12.

Table 4-12: Comments on Scheme Financing and Implementation

Findings	Remarks
a) The maximum capacity dam, conduit, hydropower plant and appurtenant infrastructure, which would allow for the conjunctive hydropower option to be developed, is estimated at R3 966 million (including escalation, engineering, EMP, VAT).	Costing to be updated after detail design.
b) The above cost includes impacts on roads and other infrastructure as well as some costs allowed for the ongoing catchment management programme, as well as environmental and social mitigation measures.	Impact on roads and other infrastructure, and associated costs need to be finalised during design.
c) Significant grant funding will be required to reduce the unit cost of water to a level that can sustain all operation, maintenance, power, and recurrent plant replacement costs. The potential capping of raw water tariffs for the new farmers should be considered, in order to make the water more affordable to resource-poor farmers.	To be considered in the funding model.
d) Government needs to fund the capital cost of this Strategic Integrated Project. This could be motivated in terms of the aim of the project, namely poverty alleviation and social upliftment of the very large number of indigent beneficiaries.	To be considered in the funding model.
e) The roles and responsibilities of various Government departments, WUAs, municipalities, and other government entities in terms of the implementation of the project must be clarified and such organisations need to commit to allocated responsibilities.	Refer to the Legal, Institutional and Financing Arrangements Report (No. P WMA 12/T30/00/5212/16).

4.6.7 *Consumption and Sale of Energy*

Recommendations regarding the consumption and sale of energy are summarized in Table 4-13.

Table 4-13: Recommendations Regarding Consumption and Sale of Energy

Findings	Remarks
a) The Ntabelanga-Lalini conjunctive scheme would consume up to 13 MW of power from the ESKOM grid (average consumption of 90 million kWh/annum), and supply up to 47.5 MW of power into the ESKOM grid, (average hydropower production of 203 million kWh/annum).	Institutional arrangements will be required to receive a permit from NERSA to operate as a non-ESKOM generator, and an agreement must be signed with ESKOM to connect to the existing regional grid network, for the purpose of both consumption of power by the scheme and evacuation of surplus power into the grid.

b) Power consumed by the scheme will be arranged in accordance with standard ESKOM power supply arrangements.	Applications to ESKOM for power supplies to the various scheme components will need to be made in a timely manner to ensure that such supplies are in place prior to the commencement of construction.
c) Power sold into the grid will need to be on the basis that the revenue creates a monthly cashflow rather than only attracting credits against other existing ESKOM accounts.	The sale of Green Energy Certificates as currently undertaken by Amatola Green Power appears to be the solution. Long-term energy sale agreements need to be drawn up with AGP or similar agency before committing funds to the implementation of the scheme.

5. FEASIBILITY DESIGN OF LALINI HYDROPOWER SCHEME

5.1 Overview

In summary, the main scheme components comprise:

- The Lalini Dam, with inflow supplied by natural runoff from the upstream catchment, as well as both the spillage and the controlled release of water from the Ntabelanga Dam;
- Lalini dam outlet works for the conveyance of raw water to a mini-hydroelectric plant (HEP);
- Lalini dam outlet works to release water downstream to supply Environmental Water Requirements (EWR), and to rapidly draw down the reservoir in an emergency situation;
- A gravity flow raw water conveyance conduit and penstock from the Lalini Dam to the main HEP;
- An HEP plant, control and switchgear, and output transformer station; and
- Inter-connecting power lines to evacuate the energy into the ESKOM grid.

Power lines to the dam site and the main HEP site must be constructed as advance works and configured so that they will also supply power from the national grid to the works during the construction period, as well as evacuating power from the hydropower plant.

Other associated infrastructure to be developed would be:

- temporary and permanent access roads and servitudes for the construction and operation of the scheme;
- new, replacement or realigned roads, power lines, services, buildings, and other infrastructure impacted by the dam and its impoundment;
- water supply, power supply and telecommunications to the dam, tunnel, and HEP sites for the construction period and operational stage;
- administration and operations buildings;
- operations staff housing;
- wastewater treatment works for the above; and
- solid waste disposal facilities.

A visitor's information centre can encourage tourism and promote economic development by providing visitors with a view of the works and information on the project, including the cultural and tourism activities in the area.

5.2 Scheme Options

Based upon the hydropower analysis undertaken in Lalini Dam Hydropower Analysis Report No. P WMA 12/T30/00/5212/18, the feasibility design focussed on three Lalini main hydropower options:

- Base load station: installed capacity 37.5 MW,
- Base load station: installed capacity 50.0 MW, and
- Peaking station: installed capacity 150 MW.

5.3 Hydropower Plant Sizing

The Hydropower Analysis Report No. P WMA 12/T30/00/5212/18 describes the findings of the modelled hydropower outputs of the Ntabelanga and Lalini Dams when used conjunctively, and recommended an optimum HEP configuration. This analysis was undertaken for the "base load" case of 24 hours/day operations.

The monthly hydropower generating regime is affected by the seasonal variations in river flow, the availability of water in each dam, the operational rules that determine minimum EWR releases at both dams, as well as maximum flow releases at Ntabelanga Dam in the dry season months.

Peaking options have also been considered to determine the cost benefits of operating the scheme to maximize income from energy sales by supplying higher power for fewer hours per day (using the same available daily water allowance) and targeting peak tariff periods.

The recommendations of the cost benefit analysis was to operate the scheme as a base load plant, but to be able to utilize the fully installed capacity for peaking during winter months when prevailing circumstances allow, and if environmentally acceptable.

The result of this was that, for the preferred 0.28 MAR_{PD} Lalini Dam, the main HEP plant should have an installed generating capacity of 37.5 MW in the form of 3 x 12.5 MW Pelton wheel turbine generator sets.

The resulting hydropower production outputs for this main HEP are as shown on Table 3-19 and Figure 3-18. The resulting hydropower production outputs for the mini-HEP located close to the Lalini Dam are as shown on Table 3-20 and Figure 3-19, and the HEP has an installed capacity of 5 MW.

5.4 Water Transfer Conduit

Following a reconnaissance mission, three hydropower conduit route options and HEP configurations were investigated as shown in Figure 5-1.

After consideration of the advantages and disadvantages of these options, the longer route (Option 3) was selected which had the least environmental and aesthetic impact, an accessible site for the hydroelectric plant (HEP) and the highest generating head which maximises the potential revenue through energy sales.

The 7.9 km long conduit routing for Option 3 was optimised once the final Lalini Dam configuration had been confirmed, and was based upon ensuring that gravity flow is maintained at all dam water levels, and pressures are contained within an acceptable working envelope under all operational conditions, which required a surge analysis to be undertaken.

The optimum route required that the conduit pass through an intervening ridge to maintain gravity flow, and this required tunnelling through competent sandstone and dolerite, which was investigated at a feasibility level by the core drilling of several boreholes along the planned conduit route.

The eventual solution was to build the first 3.6 km long section of the conduit from the dam outlet to the inlet portal of the tunnel in pipeline laid in a trench, and the remainder in tunnel.

The final route and long-section of this solution is shown in Figure 5-2 (selected solution was the "long-tunnel" solution).

Figure 5-1: Hydropower Water Transfer Conduit Options

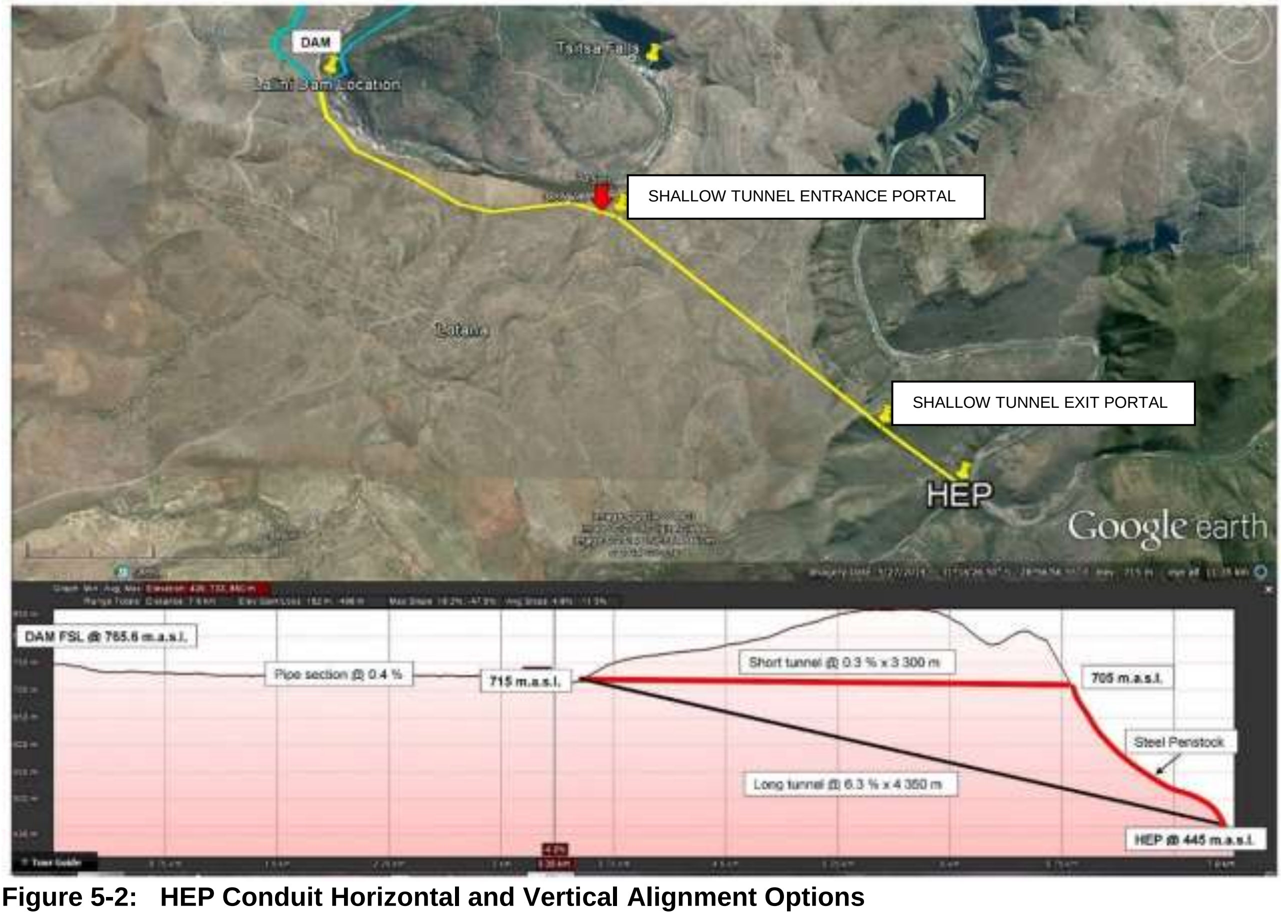


Figure 5-2: HEP Conduit Horizontal and Vertical Alignment Options

5.5 Conduit Material and Sizing

The selection of conduit sizing was based upon:

- Hydraulics: to ensure that head losses were minimized to maintain positive minimum pressures, to contain maximum pressures under surge conditions, and to maximize power production; and
- Cost benefits: to ensure that the conduit was economically sized based upon a discounted cash flow analysis for various diameters.

Options were also investigated as to whether the tunnel section should be a lined pressure tunnel or a dry tunnel with a pipeline laid through it.

Various conduit materials were also considered based upon the expected range of diameters from 2.5 m to 4.5 m (dependent upon the installed hydropower capacity), and the working pressure which ranged from 70 m to 340 m head of water.

The recommended solution is to construct the conduit in welded steel from dam to HEP, with the first 3.6 km laid just below ground and parallel to the river, and the remainder laid on plinths within a dry drill and blast tunnel, which will allow for future inspection and maintenance of the pipeline.

Optimum pipeline sizes for the above three hydropower options are as follows:

- Base load station: installed capacity 37.5 MW: 2.5 m dia.
- Base load station: installed capacity 50.0 MW: 3.0 m dia.
- Peaking station: installed capacity 150 MW: 4.5 m dia.

5.6 Hydropower Plant Supply Conduit Configuration

The HEP operational regime rules heavily influence the optimum plant and supply conduit configuration.

Given that the hydropower scheme comprises the conjunctive use of both Ntabelanga and Lalini Dams, the operating rules of both dams as determined by Environmental Water Requirements (EWR) must be considered.

5.6.1 Operating Rules

The HEP operational regime options are discussed in detail in the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15, and the Hydropower Analysis: Lalini Dam Report No. P WMA 12/T30/00/5212/18. Section 3.7.5 herein summarises these operational rules.

Costing and economic analysis have been undertaken for these scenarios, and the recommended solution is that of the 37.5 MW installed capacity and a 2 500 mm diameter conduit.

5.6.2 Optimum Conduit Diameter for Base Load Case

A discounted cash flow analysis was undertaken which considered the relevant capital, operating and maintenance costs of the conduit and associated works for the base load case operation indicated in Table 5-1, and for a range of steel conduit diameters from 2 000 mm to 3 500 mm. The detail of this is given in the Cost Estimates and Economic Analysis Report.

The costs were discounted back to present values for a typical range of discount rates. As each diameter produces a different annual energy production due to the varying head losses, the expected revenue from energy sales per annum was credited back into the calculation and also discounted back to a present value.

The net present value of costs and income was then divided by the present value of the kWh of energy produced to give a unit reference value (URV) of energy produced by each pipeline diameter in Rand/kWh. Table 5-1 shows a summary of these results, and the 2 500 mm diameter option has the lowest URV for all discount rates.

Another factor is the maximum flow velocity in the pipeline, which for the 2 500 mm diameter pipeline was 3.97 m/s. DWS will allow up to 5 m/s continuously on outlet systems but given that this is raw water which could have an abrasive element, and that smaller pipes have a lower total energy output and higher URV, it was decided to select the 2 500 mm diameter pipe as the preferred conduit size.

Table 5-1: Discounted Cash Flow Analysis to Size Conduit for Base Load

Lalini Dam to HEP Conduit					
NOM. PIPE DIA (mm):>		**2000**	**2500**	**3000**	**3500**
MAX VELOCITY (m/s):		**6.21**	**3.97**	**2.76**	**2.03**
NPV COSTS (Net cost minus Power Sales) (R)	4%	400 259 867	397 413 533	534 867 580	715 607 209
	6%	659 379 777	691 942 489	837 085 458	1 017 978 486
	8%	838 171 137	895 288 740	1 045 430 771	1 225 993 887
	10%	964 493 569	1 039 058 660	1 192 448 411	1 372 378 383
NPV POWER (kWh)	4%	2 890 962 807	3 212 706 923	3 309 189 011	3 344 840 932
	6%	2 289 478 028	2 544 281 058	2 620 689 381	2 648 923 674
	8%	1 865 529 177	2 073 149 639	2 135 409 226	2 158 415 299
	10%	1 558 034 199	1 731 432 602	1 783 429 948	1 802 643 932
Net Cost URV (R/kWh)	4%	0.138	**0.124**	0.162	0.214
	6%	0.288	**0.272**	0.319	0.384
	8%	0.449	**0.432**	0.490	0.568
	10%	0.619	**0.600**	0.669	0.761

This selected pipe size is also coincident with the largest diameter of steel pipe in standard production in the two steel pipe factories currently operating in South Africa.

5.6.3 Conduit Diameter for Peaking Case

As described above, the flow rate for the peaking case is up to 75 m^3/s. Given that this case involves intermittent operation of the scheme for varying hours per day, the same discounting techniques are not necessarily as appropriate for pipe sizing purposes. In this case the maximum head loss and flow velocity are the key factors.

Following the hydraulic analysis to determine head losses and flow velocity, it was recommended that a 4 500 mm diameter pipe size be used, which limits total head losses through the system to 35 m and the maximum flow velocity to 4.7 m/s.

It should be noted that such a pipeline would require a special fabrication plant to be established at the site, and would probably require special importation of steel plate of the thickness required. This would have major implications regarding cost and delivery times.

5.7 Conduit Tunnel Section Alternatives

The following section relates to the preferred conduit alignment - Option 3 - and not to the other Options 1 and 2 (see Figure 5-1) which were investigated and dismissed as described in the Feasibility Design: Lalini Dam and Hydropower Scheme Report No. P WMA 12/T30/00/5212/19.

The initial approach was to minimise the length of the tunnel section of the selected hydropower conduit route in order to reduce costs.

Following the first field reconnaissance mission, a decision needed to be made as to which tunnel profile and alignment the geotechnical investigations should focus.

Generally, shallow tunnel alignments have the advantage if a surge shaft is required. This can however also have the disadvantage of shallow overburden pressure being insufficient to contain water pressures in the tunnel if used as a pressure conduit.

The minimum gradient for tunnel construction is normally set to 0.2% to allow for drainage.

Maximum gradients vary and depend on the construction method. For tunnel boring machine (TBM) construction, the maximum grade is normally about 1%, as defined by train haulage limitations. However, TBM construction is not considered to be a likely solution for this relatively short length of tunnel, unless the successful contractor happened to have a suitable TBM readily available at the time of tendering.

In this case, the most likely solution would be a drill and blast construction method, for which gradients of up to 10% can be considered.

The minimising of the tunnel section length was achieved through adopting a relative shallow grade in the tunnel section of 0.3%, with the tunnel commencing where the pipeline section encounters rising ground level, at an elevation of approximately 715 m.a.s.l. This is the alignment shown in Figure 5-2.

This gradient results in the tunnel exiting the hill at an elevation of 705 m.a.s.l. and a tunnel length of 3 300 m. From this outlet portal, a steel penstock would then need to be constructed down the hillside to the HEP plant, which is located at 445 m.a.s.l.

Once this alignment had been selected, the limited study timescale dictated that the geotechnical investigations should immediately proceed, and part of the available budget for such investigations was allocated for drilling some cores along the tunnel route.

It was recognized that the limited budget allocation would not be enough to undertake fully comprehensive and deep drilling investigations of the tunnel alignment, and the results are therefore only a general indication of the sub-surface geology and rock type. Significant additional investigations would therefore be required in the implementation stage to properly inform the detailed design.

Figure 5-3 shows a plot of the boreholes undertaken during this investigation.

As shown, the boreholes encountered moderately to highly weathered sandstone at the surface, but soon moved into very competent sandstone, which is the predominant rock throughout. Boreholes T2 and T4 encountered competent dolerite which is a feature of the area. Contact interfaces between the sandstone and dolerite were relatively unaltered and tight.

The findings of the geotechnical investigations are given in detail in the Geotechnical Investigations Report No. P WMA 12/T30/00/5212/10.

The overall findings concluded that the main body of the hill along the tunnel alignment would be highly suitable for tunnelling and had a low or non-existent water table. An average of the various tests and classifications showed an RMR of 72, which is Class II good rock.

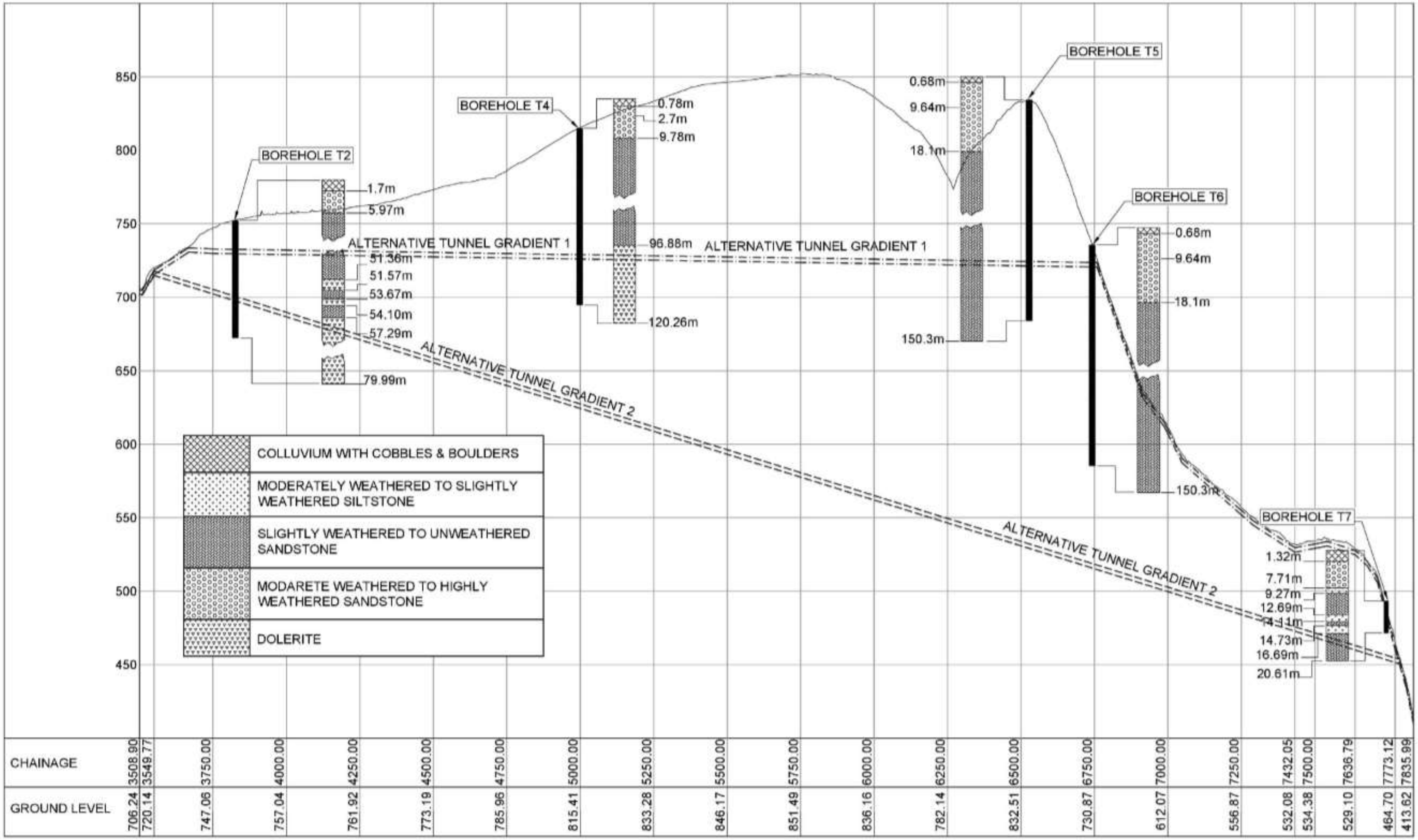


Figure 5-3: Boreholes Drilled along Tunnel Alignment

5.7.1 Shallow Tunnel Advantages and Disadvantages

The advantages of a shorter, shallow grade tunnel shown in Figures 5-3 and 5-4 would be that construction could be undertaken from both portals simultaneously, and that water supply and dewatering would be straight forward.

However, an access road and working platforms would need to be constructed to both portals, which is fairly problematical as regards the outlet portal location, with its accessibility challenges. Such an access road would also leave a permanent scar on the steep hillside with a potential for future erosion problems.

A further site reconnaissance visit to specifically investigate tunnelling options and access roads highlighted the difficult prevailing conditions for construction in this proposed penstock location. The steep gradients of up to 35% make conduit construction particularly onerous and this is made worse by the nature of the ground surface which is highly weathered sandstone and “mobile” tallus.

The unsuitability of this slope as regards stability, founding and bedding, and the difficulties in access and handling of large diameter pipes of 13 tonnes each on such gradients, would make this penstock construction very expensive. Whether the penstock was built on plinths or buried underground, this servitude area would continue to be difficult to access and maintain. It could also be a vulnerable section as far as the potential for future erosion and damage to the penstock is concerned.

This area has also been identified as a sensitive ecological area of high significance where infrastructure development should be limited as far as possible.

5.7.2 Deep Tunnel Advantages and Disadvantages

A second deeper and longer alignment was also considered as shown in Figure 5-5.

This option used the same upstream portal location and elevation, but was graded at 6.3% so that it exited lower down in the valley and close to the HEP location at an elevation of 445 m.a.s.l.

This has its own advantages and disadvantages. The advantage is that it avoids the difficulties described above regarding the penstock construction, and leaves no exposed surface works along its entire route. This also avoids having to construct an access road to the outlet portal on a steep hillside location. Instead the outlet portal construction access road and platform can be shared with that required to construct the HEP plant itself.

The disadvantages would be that the tunnel section of the overall conduit would need to be longer (albeit avoiding the costly and difficult construction of the penstock section), and would have to be constructed only from the lower portal upwards to effect gravity drainage, and removal of excavated materials. Drill and blasting downhill to an elevation of greater than 150 m below the portal has many difficulties, including dewatering challenges.

5.7.3 Pressurized Tunnel Option

Another option was to design the tunnel section as a pressurized conveyance component rather than an adit through which a steel pipe is laid. Whilst the rock through which the tunnel is to be constructed is envisaged to be very competent, there will be sections at the start and end of the tunnel where there would need to be a transition between the piped section and the tunnel. This transition also coincides with sections where the overburden and rock strength is insufficient to balance the internal hydraulic pressure, and where the tunnel would need to be lined.

Even when surge shafts are installed, all pressure tunnels are subject to hydraulic stressing due to the transient pressure surge effects. If the tunnel was not lined this could inevitably lead to water loss through the opening of cracks and seepage paths created by these internal positive pressures.

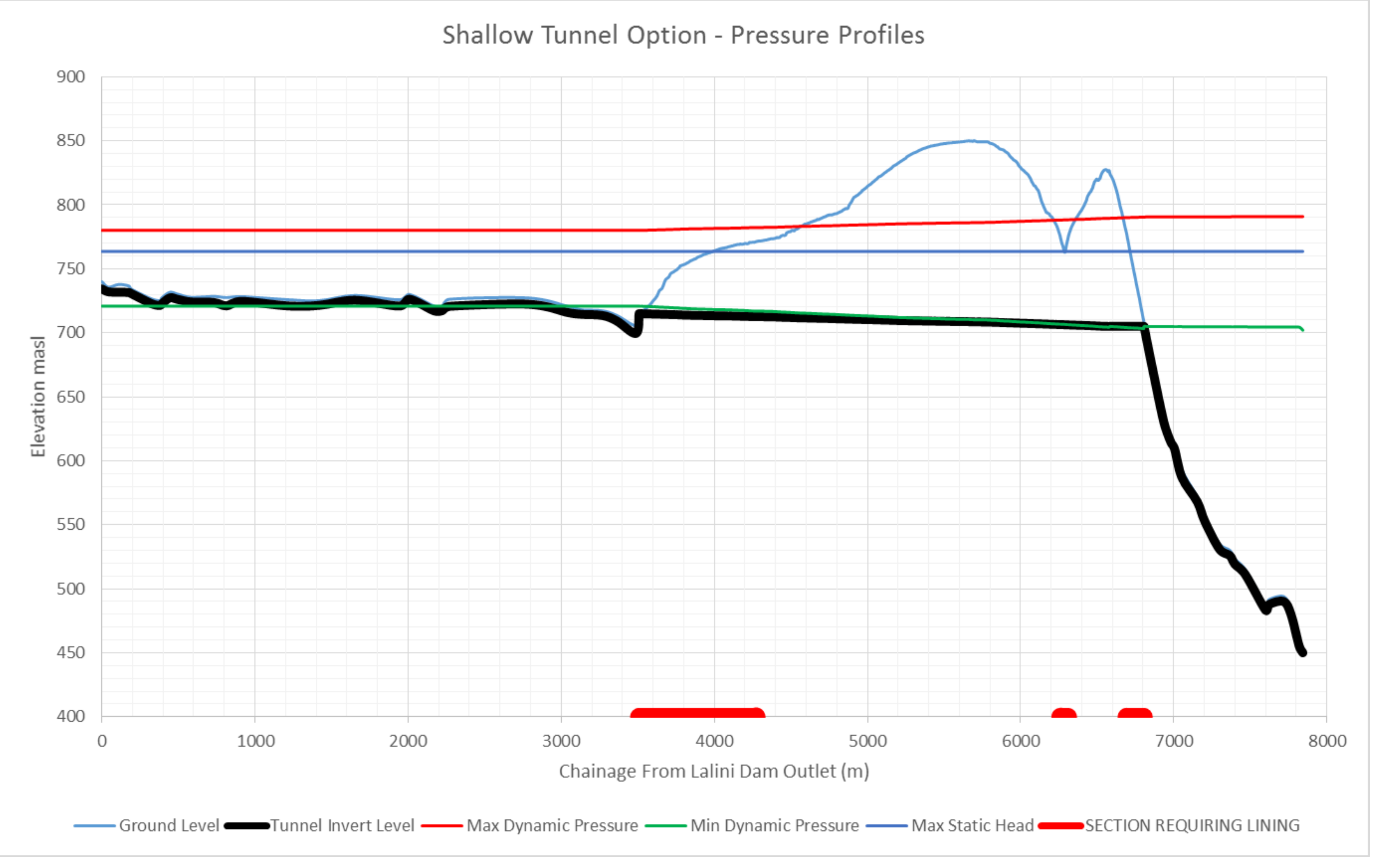


Figure 5-4: Shallow Tunnel Option: Pressure Profiles and Lining Requirements

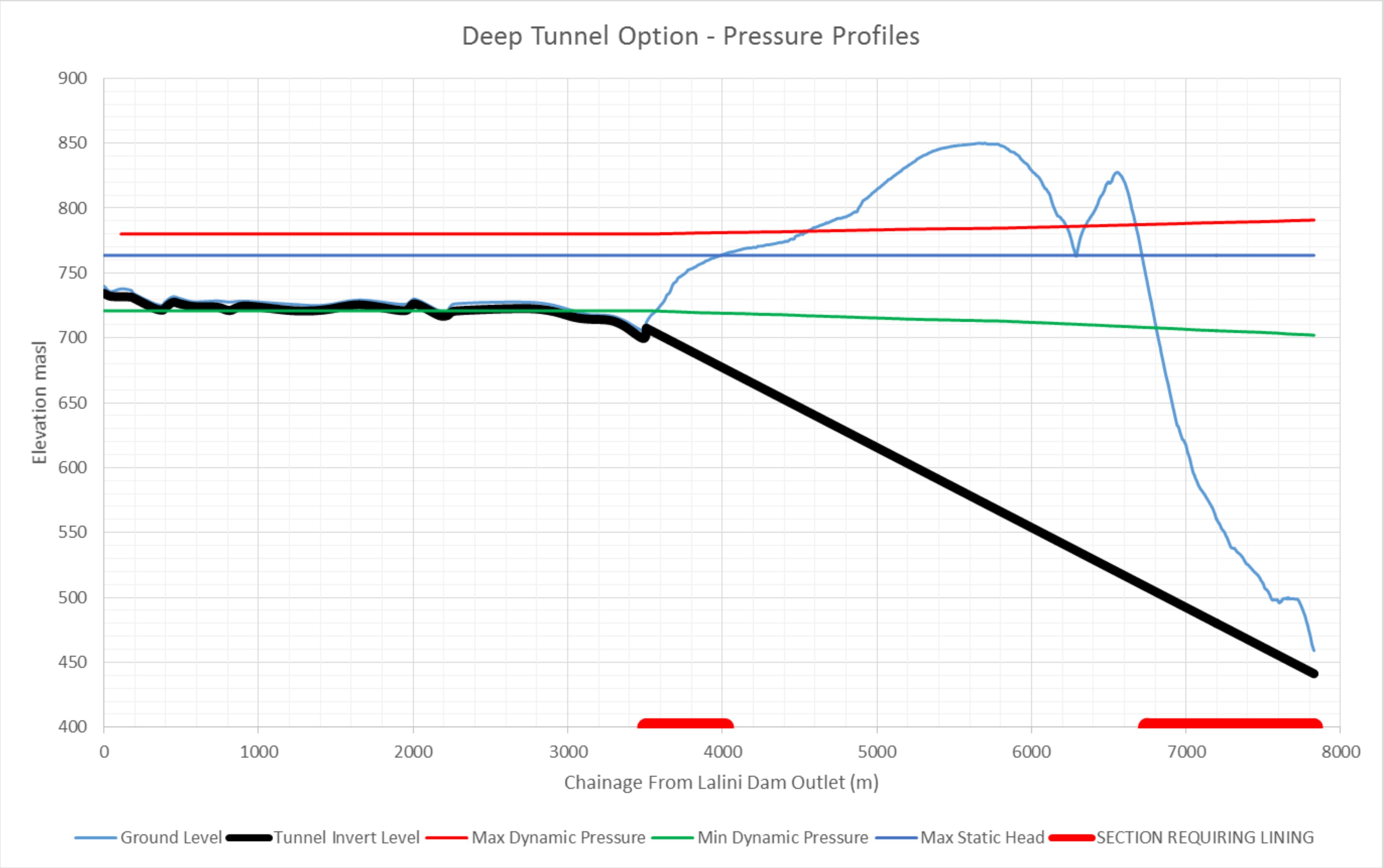


Figure 5-5: Deep Tunnel Option: Pressure Profiles and Lining Requirements

Analysis was undertaken to estimate for which sections each tunnel option would be able to be designed as a pressure tunnel.

A surge analysis was undertaken for the expected conduit sizing for the 37.5 MW installed capacity scheme. Unlike pumping stations, turbines do not instantaneously stop or start. The surge analysis thus simulated the sequential opening and closing of the control valves of the three turbines, each over more than 120 seconds, which would be a normal cold start and shut-down process.

The resulting minimum and maximum dynamic pressures along the conduit system have been calculated and are summarized in Table 5-2.

Table 5-2: Summary of Surge Analysis

			PRESSURE ELEVATION IN CONDUIT (m.a.s.l.)					
SURGE CONDITIONS			Tunnel Start (km 3.6)		Tunnel End (Km 6.85)		Turbines (km 7.85)	
Reservoir	**Tunnel**	**Valves**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**
FSL	Shallow	Opening	780.1	748.1	797.7	745.4	792.8	736.0
FSL	Shallow	Closing	776.8	752.1	794.6	751.7	792.1	741.4
FSL	Deep	Opening	780.5	747.9			792.5	736.1
FSL	Deep	Closing	776.9	752.1			791.8	741.5
MOL	Shallow	Opening	753.3	720.9	770.4	718.4	765.1	709.0
MOL	Shallow	Closing	750.1	725.1	767.6	724.7	765.1	714.4
MOL	Deep	Opening	753.4	720.9			765.2	709.1
MOL	Deep	Closing	750.1	725.1			765.1	714.5

Several criteria must be met if an unlined pressure tunnel section is to be considered suitable, as follows:

1. The crown of the water conduit must always be below the minimum dynamic water head (allowing for transients) to avoid negative pressure.
2. The maximum dynamic water pressure must not be above minimum principal stress σ 3 of the rock mass to prevent hydraulic jacking. For this analysis, a density of 26 kN/m^3 is considered for the vertical stress. A minimum for the ratio of horizontal to vertical stress of 0.5 is assumed on the safe side.
   (σ horizontal (σ 3) = 0.5 x σ vertical (γ x h).
   Also a factor of safety of 1.1 is considered. If the max dynamic water pressure is higher than minimum principal stress, then a 100% watertight lining (steel or glass-fibre lining, concrete lining with membrane, etc.) is mandatorily required, with consequent cost implications.
3. The maximum static water pressure should be below ground water level to prevent water loss. If this is not achieved, then the situation has to be assessed in detail, and grouting might be required for rock mass sealing. Also water lost will increase the local groundwater level, which could cause piping or slope failure.

Analysis was undertaken for both the shallow and deep tunnel options and the pressure envelopes thus derived are shown in Figures 5-4 and 5-5.

In the case of the shallow tunnel, criteria 1 becomes an issue as the minimum hydraulic grade line is coincident with the tunnel alignment.

In both cases, criteria 2 results in the need to line sections of both tunnels as the overburden depth is insufficient to generate sufficient principal stress to resist the maximum dynamic water pressure.

In the case of the shallow tunnel some 927 m of the 3 300 m tunnel length (28%) would need to be fully lined if used as a pressurized conduit. In fact it would be likely that the tunnel would be fully lined from chainage 6 200 m to the portal rather than the two short sections shown. This would increase this requirement from 927 m to 1 310 m (40%).

In the case of the deep tunnel some 1 590 m of the 4 320 m tunnel length (37%) would need to be fully lined if used as a pressurized conduit. Such lining would be undertaken using either in-situ fabricated steel or glass reinforced plastic.

There are advantages and disadvantages to a pressurized tunnel versus a tunnel carrying a pipeline.

a) Advantages

1. The pressurized tunnel would have a larger diameter than a conduit with a pipeline laid through it, and would produce less head losses.
2. Construction would be less complex in that the installation of the steel pipeline would not be required. (However, the lining operation could produce a more complex overall construction process).
3. Construction cost could be slightly lower than the tunnel with a pipeline laid through, but this would need to be verified in the detailed design stage, once more geotechnical investigation is undertaken to determine tunnelling conditions and the water-tightness of the rock.

b) Disadvantages

1. The unlined section would produce water loss to some degree. This would reduce the hydropower output. This water loss would affect the local groundwater table and could find its way to the surface with unforeseeable consequences.
2. Great care would be required to prevent unexpected or excessive hydraulic transient pressures, which could hydro-fracture the unlined rock section. An expensive surge shaft would likely be required.
3. The flow velocities in the pressurized tunnel option would be significantly lower than the pipe-lined option, which could lead to sediment deposition within the tunnel section. The pipeline section would be self-cleansing and could otherwise be de-silted by periodical pigging if necessary.
4. The unlined tunnel section could be subject to rock degradation and spalling, which debris could pass through to the turbines.
5. Servicing and inspection of the tunnel would only be possible with the system closed down. For the other option, the pipeline could be inspected externally whilst in operation.
6. Significant transition works will be required at the interfaces between the piped conduit and the pressure tunnel section. This is normally in the form of embedded steel lining at the portals which must be pressure tight, and flanged connections to the piped sections. Access hatches would also be required for future inspection and maintenance of the tunnel.

5.7.4 Proposed Tunnel Section Configuration

The scope of geotechnical investigations undertaken at this stage was limited, and it is therefore recommended that significant additional geotechnical investigation drilling be undertaken to better ascertain tunnelling and rock mass conditions along the proposed tunnel alignment. This will be required to inform the detailed design of alternative solutions before a final decision is made.

However, for this feasibility design stage, it is considered preferable to design this section of the conduit as a dry tunnel through which the pipeline is laid continuously to the HEP plant.

The tunnel section would be sized such that there is room to install the steel pipeline on plinths, and to undertake the external butt welding of joints, and making good of the external coating.

It is suggested that the mini-rail system that is normally installed within the tunnel during construction be designed so that it can be used for transporting men, materials and equipment to the working face, removal of muck from the drill and blast operations, as well as carrying each steel pipe length and construction materials for plinths from the entrance portal to its point of installation. The welding of joints would be undertaken progressively from the lower end to the upper end of the tunnel.

Upon completion of the pipeline installation within the tunnel, there would be room alongside the pipeline for future inspection to be undertaken, which would include maintenance of both pipeline and tunnel.

Allowance has been made in the design of this solution for a reinforced and rock bolted shotcrete soffit lining to prevent any spalling of the tunnel roof from damaging the pipeline.

A typical section of the proposed feasibility design of the tunnel is shown in Figure 5-6.

This same configuration would apply to other pipeline diameters that might be considered for the peaking operation options, being 3 000 mm and 4 500 mm diameter respectively. Thus in those cases the tunnel would be proportionately larger, and have the same clearances around the pipeline.

As regards tunnel vertical alignment, it is also proposed for this feasibility design that the deeper, longer alignment be adopted. This will avoid the need to construct an additional access road to the tunnel outlet portal, and the construction of the penstock section down the steep and potentially vulnerable route to the HEP.

The HEP will require a permanent and high specification access road to be constructed and this can also be used for the construction of the longer tunnel.

5.8 Regulation of Flow below HEP Outlet

When operated as a base load (24/7) station with an installed capacity of 3 x 12.5 MW, there would be no need to regulate the recombined EWR and HEP discharges downstream of the HEP plant outlet, as these would fall within the accepted operating rules determined following the Reserve Determination study.

It is possible for the HEP station to be operated as a peaking station in the winter months in years when the flow regime is not in a drought condition. Should this be the case, then a typical scenario would be that the full installed capacity turbines were operated over (say) 8 peak hours per day instead of 12.5 MW over 24 hours, thus using the same daily volume of water available, but being able to supply up to 37.5 MW for peak daily demand periods only.

In order to ensure that the recombined flows are balanced, regulated, and normalized back to a 24 hour regime, a regulating dam and storage facility would need to be constructed in-stream with a minimum storage capacity of 16 hours of the daily HEP flow under the prevailing conditions. In this case, this would require a minimum balancing dam capacity of 375 000 m^3.

Should a full-time peaking station be installed (up to 150 MW), then this requirement increases significantly as the peaking operations would be concentrated to 3 to 5 hours per day, and the balancing storage requirement would rise to as high as 2 million m^3.

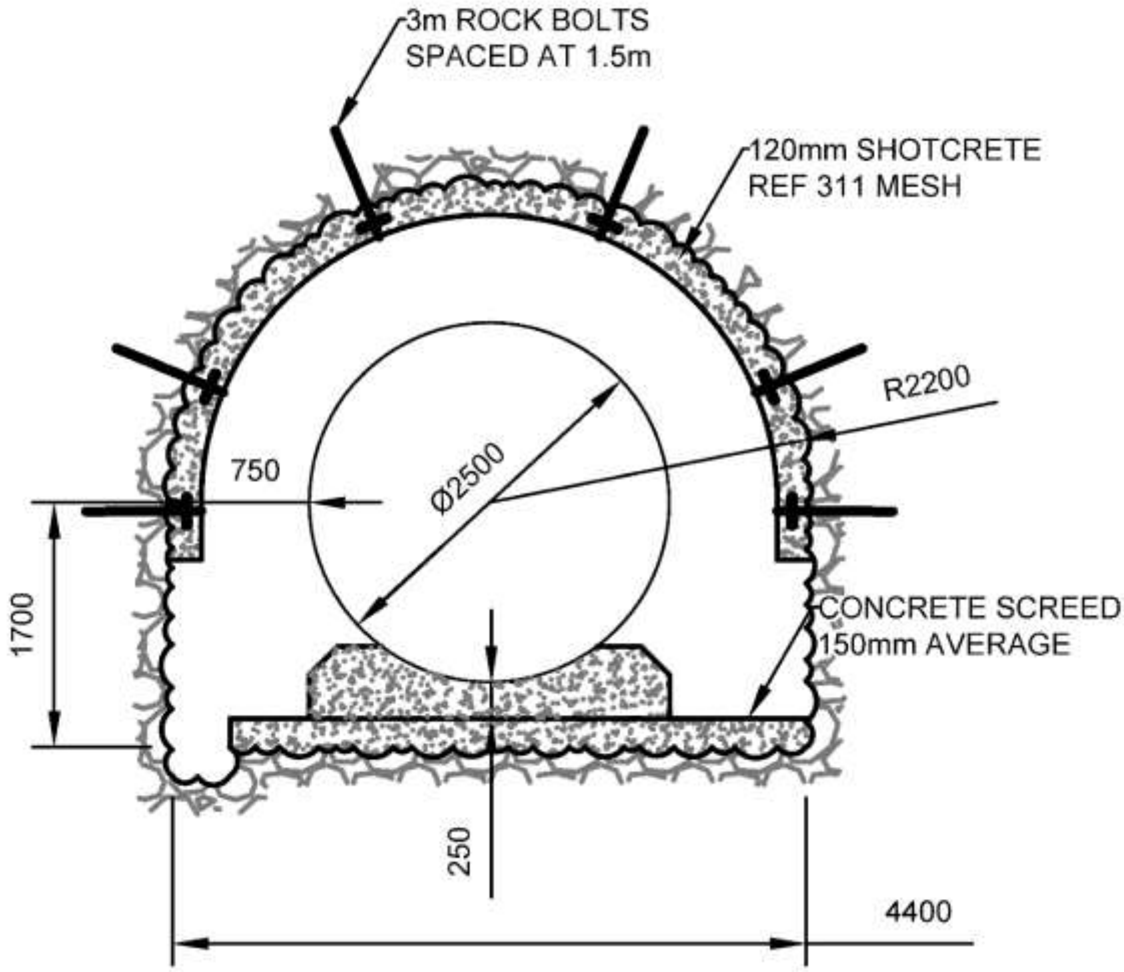


Figure 5-6: Typical Tunnel Section

For the former option, this balancing storage would extend approximately 500 m downstream of the HEP discharge location, and for the latter peaking option this body of balancing storage could extend as far as 1 500 m downstream and require a dam wall height of 15 m or more.

Such in-stream balancing storage would have its own impact on the environment by drowning the river bed flora and fauna at that location and significantly changing its natural state. It would also be very difficult to adequately regulate outflow rates from this storage.

The storage would also act as a sediment trap and would rapidly lose its capacity to regulate flow.

In conclusion, it is considered to be highly unlikely that such a balancing regime would be practical or environmentally acceptable, and this further supports the conclusion that the most likely solution is the 37.5 MW installed capacity and a 2 500 mm diameter conduit, operated as a base load station.

5.9 Main Hydropower Plant Configuration

5.9.1 Electro-Mechanical Equipment

Internationally-renowned hydropower plant manufacturers from Europe were consulted to determine suitable hydropower generating plant types, design details, performance, costs, installation requirements and general arrangements.

For the 37.5 MW and 50 MW plant options, and the likely monthly generating regime, it was recommended that three or four 12.5 MW units would be best suited to match the head versus flow regime. The basis of feasibility design presented herein is for the 37.5 MW solution.

The turbines proposed are of the vertical Pelton type with 6 jet nozzles. Depending upon the eventual procurement process and manufacturer selected, the number and configuration of jet nozzles could vary.

The proposed arrangement is overhung (see Figure 5-7), i.e. the turbine runner is mounted directly onto an extended and reinforced generator shaft. All remaining (small) axial thrust and radial loadings on the turbine runner created by rotational speed, jet impact and weight are therefore taken by a suitably designed generator shaft/bearing system. The main cooling of the generator is by water cooling and therefore requires a two cycle cooling system.

Typical arrangements and a photo of plants of a similar capacity are given in Figures 5-7 to 5-10. Please note these are generic examples and not specific to this project.

5.9.2 Main Hydropower Plant Structure

The structure to house the HEP is designed to meet the functionality requirements of the plant as well as the construction and installation sequencing required for this type of turbine.

A two-stage basement concrete placement is required, and cut-outs in the basement are required to allow operational valves and turbine jet volute casings to be accessed and maintained. Channels are also included below the Pelton wheel runner to carry the water away from the plant once the jet energy has been absorbed.

Each of these channels must be able to carry a minimum of 6.5 m^3/s, and upon leaving the structure basement, the flow is discharged down the bank of the river via a stepped energy dissipating cascade system founded on good rock and constructed using reinforced concrete and gabion systems.

Specific spacing of each generator is important to avoid interference with each other with respect to both vibration and high voltage current. This results in a long and narrow building layout as shown in Figure 5-11. This figure is for a 3 x 12.5 MW turbine solution. If an additional turbine is to be installed, then the building would be proportionately longer.

This building would require adequate lighting, heating, and ventilation and will have a sound-proofed control room at one end.

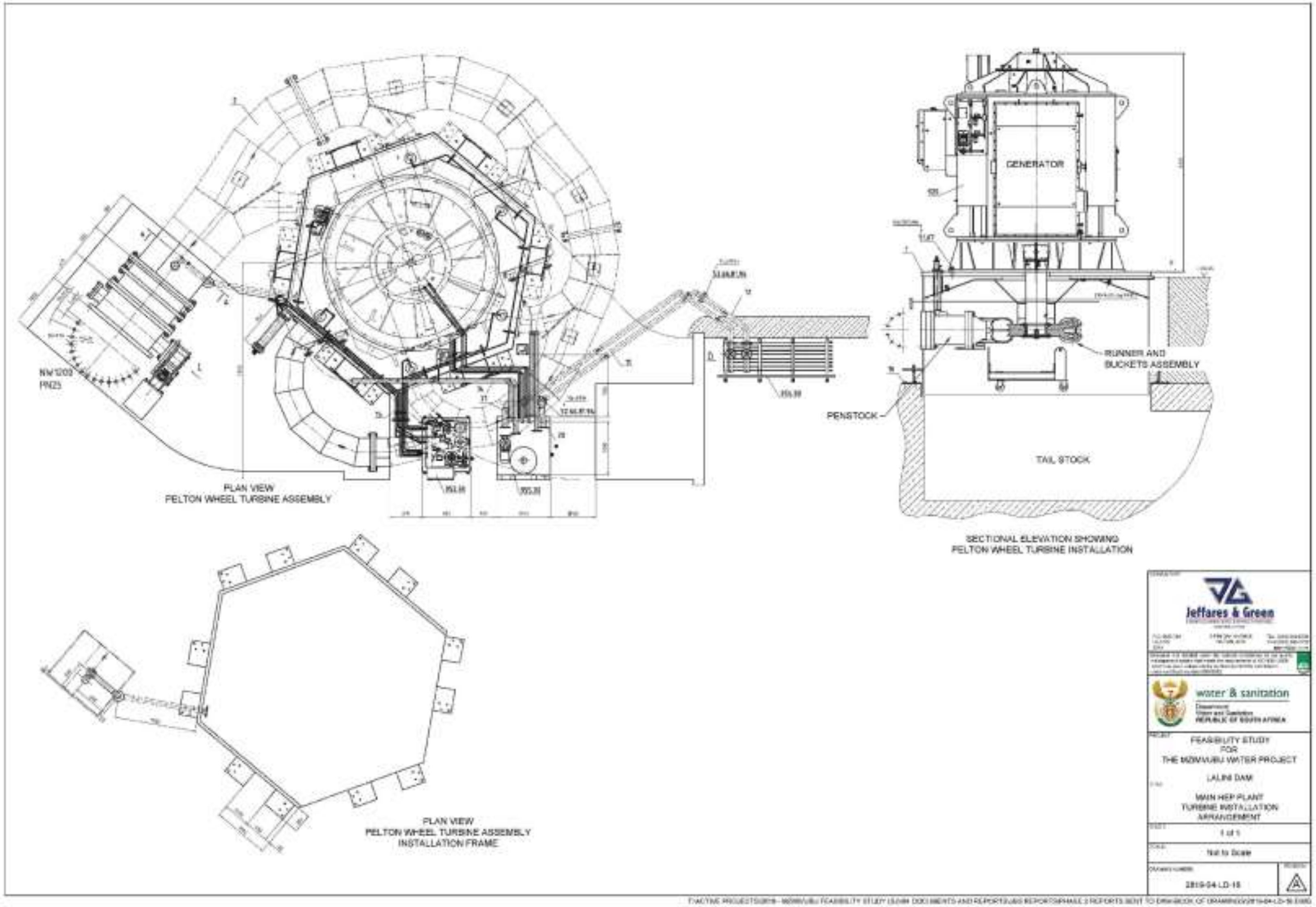


Figure 5-7: Installation Arrangement of a Similar Pelton Wheel Turbine

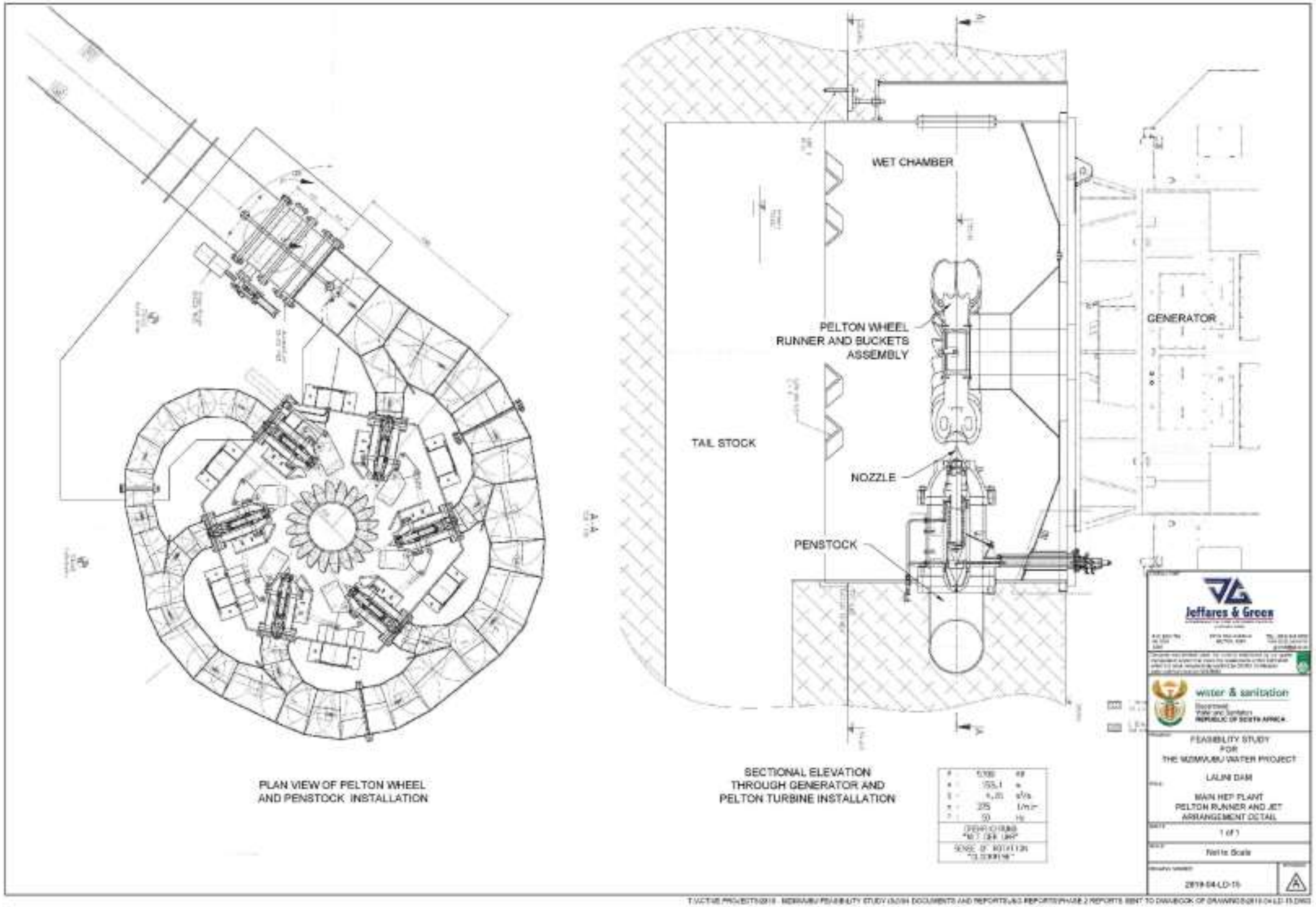


Figure 5-8: Detail of Pelton Runner and Jet Arrangement

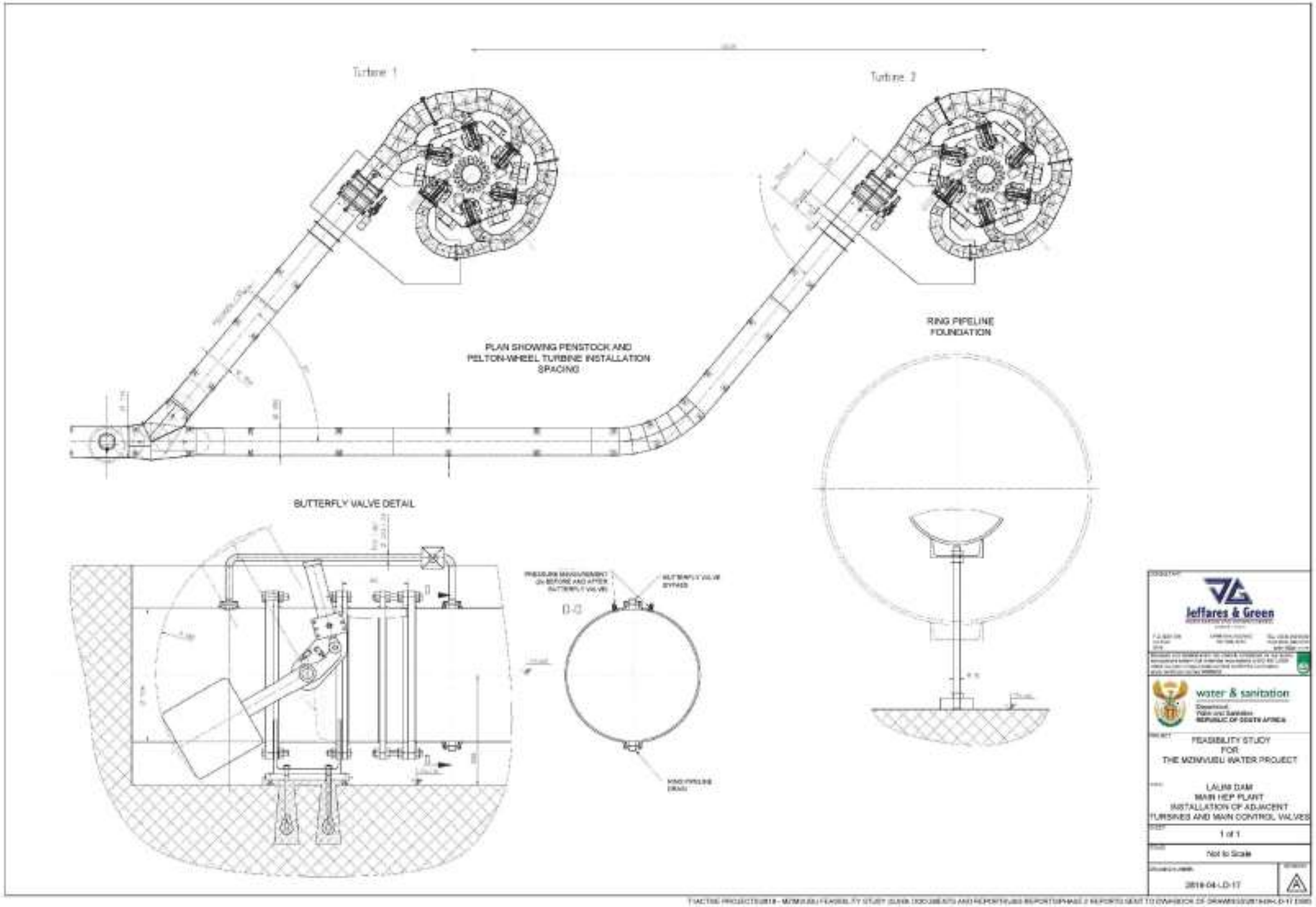


Figure 5-9: Typical Installation of Adjacent Turbines and Main Control Valve

Figure 5-10: Photo of Similar Sized Pelton Wheel Generator Installation

The generator is the heaviest single component of the generating set, and each would have a weight of some 75 tonnes, with each turbine weighing some 35 tonnes.

The building would be equipped with a suitable overhead crane, and has access doors between each generator set so that transport vehicles can reverse into the building for delivery and replacement of these components.

The HEP building is positioned adjacent to the tunnel exit portal so that the pipeline penstock exiting the tunnel can be connected to the HEP inlet pipework below the hard-standing area.

This site layout and cross-section is shown on Figures 5-12 and 5-13.

This shows a diagram of the earthworks and hard-standing areas required between the tunnel and HEP building, as well as the discharge cascades returning hydropower flow back to the river.

This hard-standing platform and access road thereto would be required as a first priority so that the tunnel and HEP building construction can be undertaken.

This will also require a power supply and water supply to be brought to the location for construction and long-term usage.

The water supply would be developed by a package plant abstracting from the river, and the power supply could share the same powerline as would eventually be used to evacuate energy from the HEP into the grid. However, the means of implementing this power supply aspect would be at the discretion of ESKOM. Whether this water supply is temporary only will depend upon when and if the operator housing can be connected to the existing water supply system at Lotana.

It is proposed that operators of the HEP would be housed in the same staff housing compound as is to be developed for the Lalini Dam, and would commute via the access road each day.

A small ablution and mess block should be provided at the HEP building.

As shown on the layout diagram, a separate transformer compound is located next to the control room end of the HEP building.

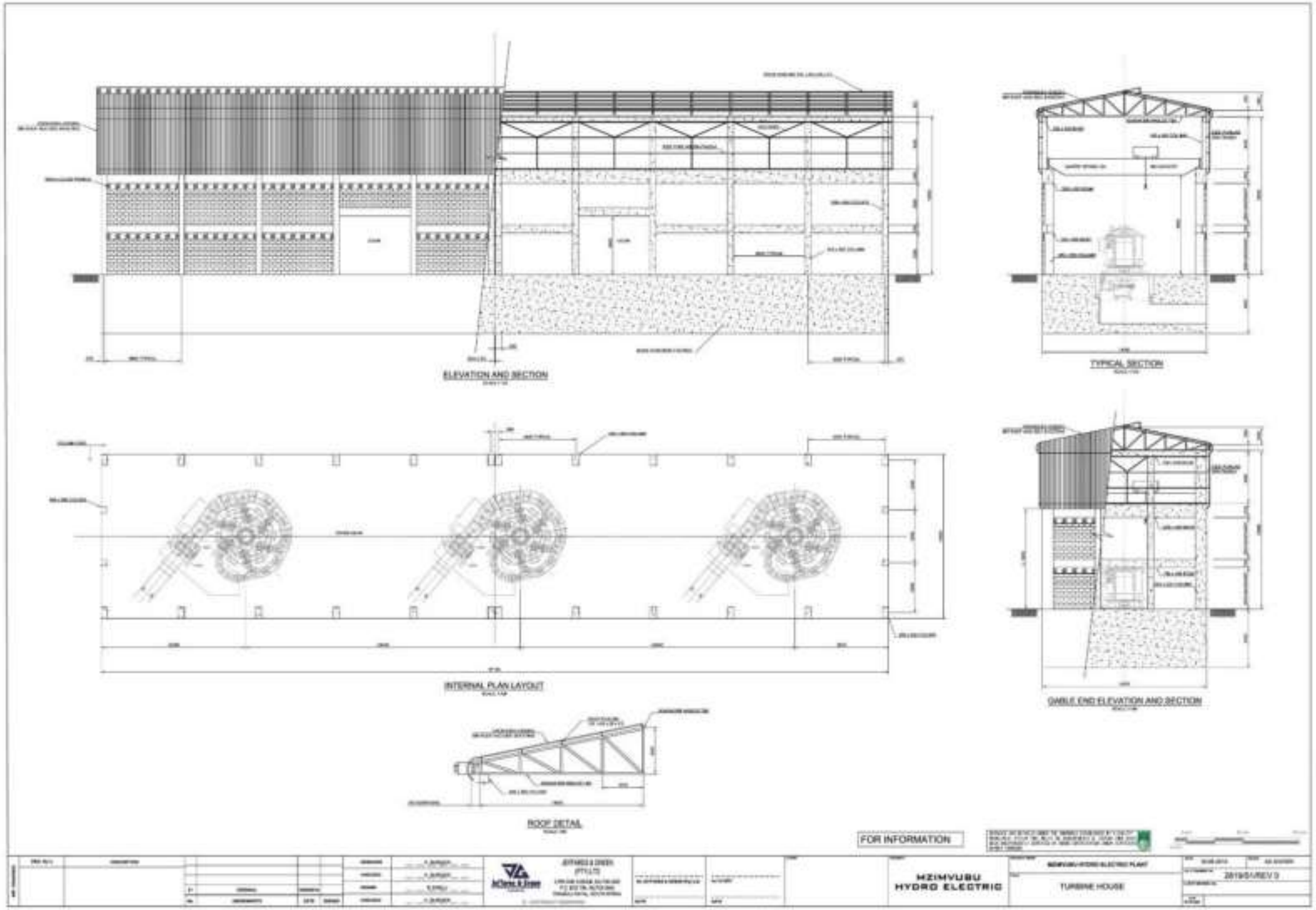


Figure 5-11: Hydroelectric Power Plant Building (3 Turbine Option)

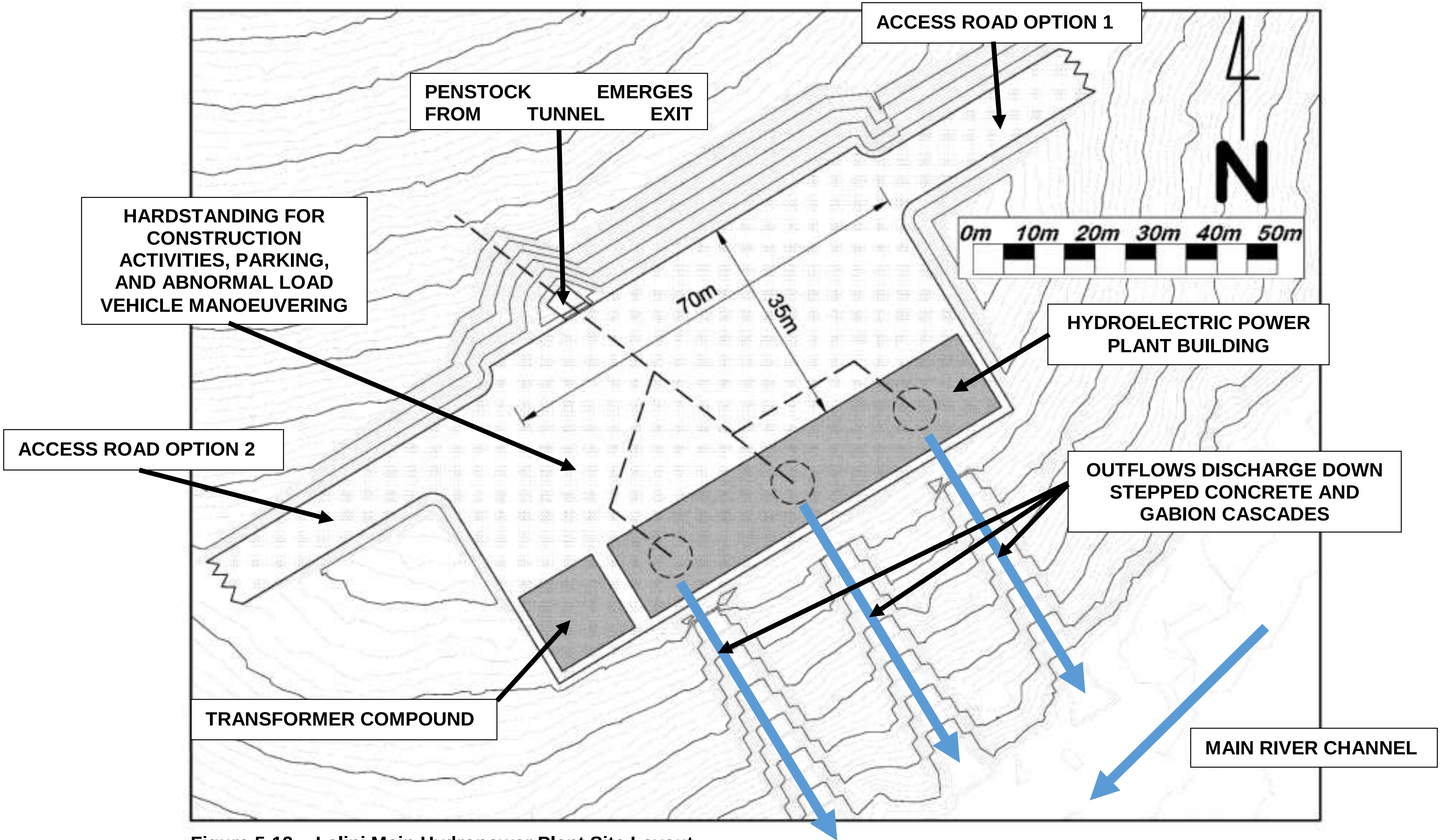


Figure 5-12: Lalini Main Hydropower Plant Site Layout

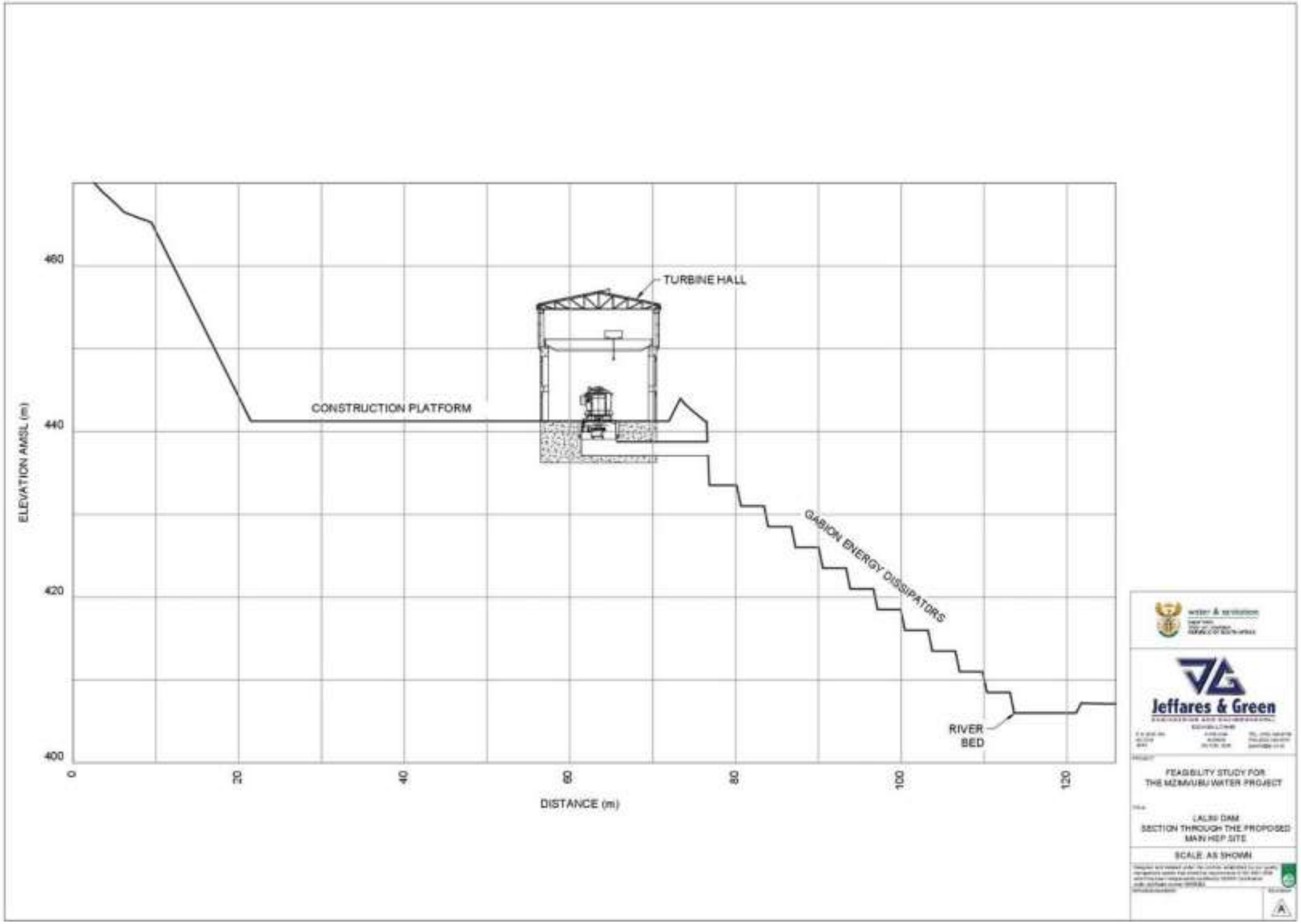


Figure 5-13: Turbine House and Outlet Works Cross-section

5.10 Lalini Dam Mini-Hydropower Plant

As with the Ntabelanga Dam, the environmental water requirements (EWR) released from the Lalini Dam into the river above Tsitsa Falls creates an opportunity for some additional hydropower to be generated at this location.

The Hydropower Analysis Report No. P WMA 12/T30/00/5212/18 describes the conjunctive scheme hydropower modelling simulations undertaken and indicates that up to 5 MW can be generated in the wetter months, with seasonal availability of EWR determining outputs that can be achieved in other seasons.

The results of the analysis for the 0.28 MAR_{PD} Lalini Dam are as shown in Table 3-20 and Figure 3-19.

This determined that the hydropower plant configuration should be based upon a target operating range of between 1 and 5 MW.

Hydropower plant suppliers were asked to suggest which types of turbines should be used for this application and provided the following option:

- The operation of 6 turbines in parallel - 3 pairs with one synchronous and one asynchronous generator. The synchronous generator of each unit is started in the beginning (blackstart capability, able to run in island mode), the asynchronous unit follows later depending on available flow.

- For easy maintenance and stable operation all turbines are of the same size. The speed of asynchronous units will be 750 rpm, the synchronous units speed has to be defined depending on the efficiency expectations (600 rpm or also 750 rpm).

- Each turbine set is equipped with a tachometer for speed control, 2 PT100 sensors (1 per bearing) to check bearing temperature and also 2 vibration sensors (1 per bearing).

Typical “Andritz” pump-turbine units suggested were:

- Pump - Turbine FPT40-700 T1, T3 & T5 with asynchronous generator.
- Pump - Turbine FPT40-700 T2, T4 & T6 with synchronous generator.

The final decision of which supplier of turbines would be made following a competitive tendering process, and these quoted turbines are only by way of an example.

The total number of installed turbine units can produce the following performance:

Table 5-3: Lalini Mini-Hydropower Plant Output Performance

Scenario	Head (m)	Flow (m^3/s)	Duty	Power Output (kW)
Minimum	22	6.0	T1/T2/T3/T4	956
Average	40	9.0	T1/T2/T3/T4	2 606
Maximum	45	16.0	T1/T2/T3/T4/T5/T6	5 212

Figure 5-14 shows a proposed layout of the hydropower turbine house together with the inlet and outlet pipework arrangements.

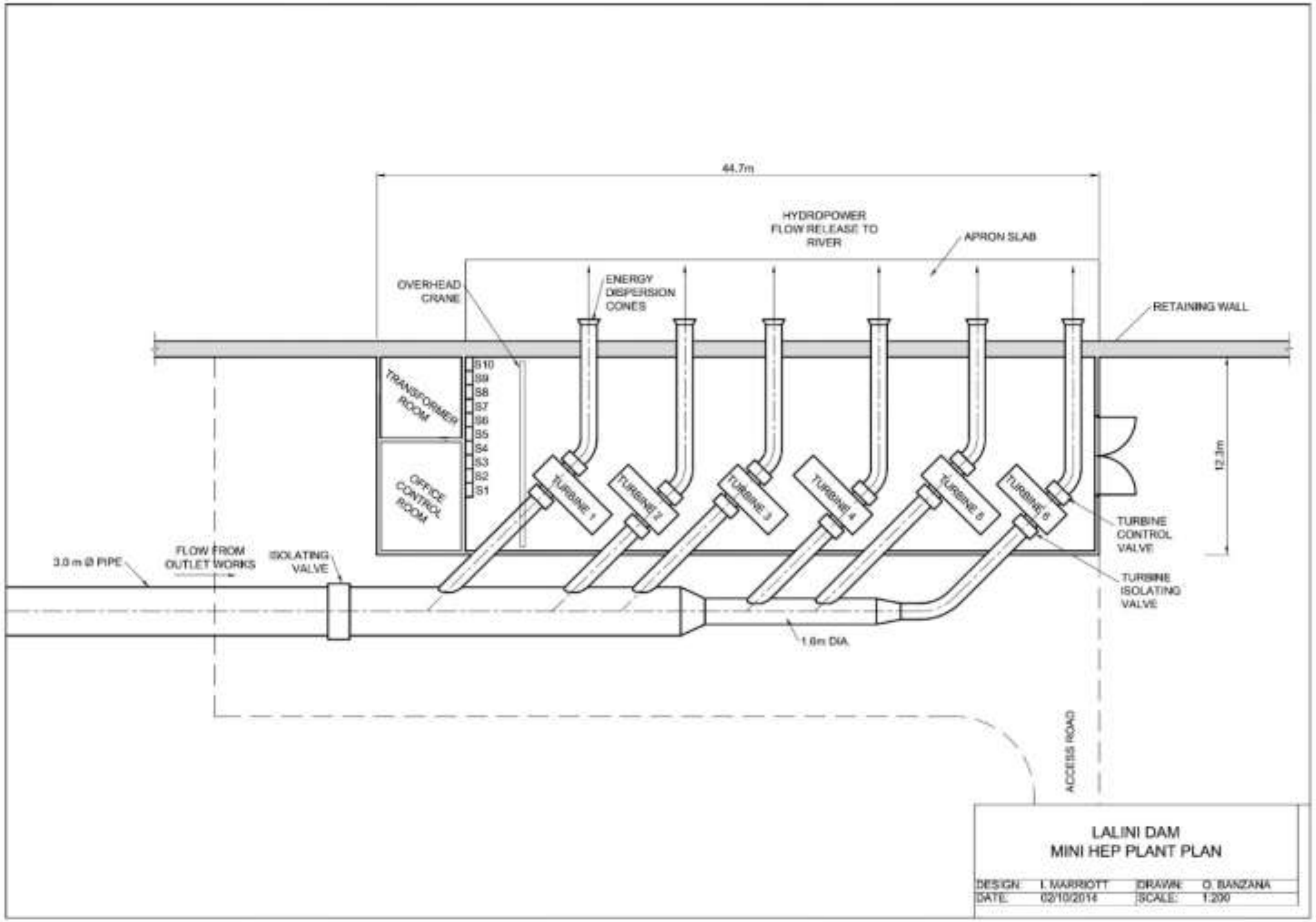


Figure 5-14: Lalini Dam Mini-HEP Layout

When the hydropower plant is not in use, release of water for EWR purposes can still be made via a sleeve valve in the main dam outlet works.

If one pair of turbines needs to be taken out of service for maintenance or repair, then the other sets can be run at higher flow rates to maintain power output during that period.

The options for utilisation of the hydropower produced at the Lalini Dam are further discussed in detail in the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15.

Following confirmation of the locations of the appurtenant works such as spillway, outlet works, pipelines, hydropower plant, water treatment plant, roads and other related infrastructure, drilling and trial pitting will be required to augment the feasibility level investigations in proving suitable founding conditions and to prove adequate reserves of rock aggregate and sand.

6. ASSOCIATED INFRASTRUCTURE

6.1 Introduction

The construction and operation of the proposed Lalini Dam and its hydropower scheme will require other associated infrastructure to be implemented and will also impact on the existing infrastructure and land use in this region.

Not only will the main scheme components require the permanent allocation of land, but other associated infrastructure will also require additional land allocations, upgrades or replacement of existing infrastructure, changes in land use, and will have other social impacts.

Once the project moves into the detailed design and implementation stage, it is probable that some of the feasibility designs will be revised which will require changes in the boundaries and extents of the expropriation and servitudes described herein.

6.2 Roadways to Construct and Operate the Schemes

Some major road works will be required for the construction and long-term operation of the schemes. The feasibility design of these are described in the Feasibility Design Lalini Dan and Hydropower Scheme Report No P WMA 12/T30/--/5212/19.

In general, road designs, realignments and upgrades have been designed in accordance with the South African Technical Recommendation for Highways (TRH) standards for such work as detailed in the following documents;

1. TRH 4 : Structural design of Flexible Pavements
2. TRH 17: Geometric Design of Rural Roads
3. TRH 20: The Structural Design, Construction and Rehabilitation of Unpaved Roads

6.2.1 Roads and Bridges at Lalini Dam and Associated Works

a) Main Access Road

Figure 6-1 shows the existing District Road DR 08170 linking the N2 national road near to the Tsolo to Maclear road junction with the village of Lotana in the vicinity of the dam and hydropower infrastructure locations.

This existing gravel road also services the settlements of Madadeni, Gwali, Upper Lotana, Cingcosdwadeni, Ngcolorha, Manzimabi, Mahoyana, and Mbutho.

This 17.4 km “Main Access Road” provides the best access to the dam and tunnel construction sites from the main road and does not have any major bridge crossings to contend with. Some donga crossings would need to be widened and upgraded to carry heavy loads.

In addition to construction traffic, this road would be the main route used for the delivery of the heavy electromechanical components of the HEP, which will require abnormal load vehicles able to transport loads of up to 100 tonnes.

Thus it is proposed that this road be upgraded geometrically and structurally to cater for heavy construction traffic and abnormal vehicles that are anticipated to be used in the construction activities. This district road would, however, remain a gravel surfaced road. Provision has been made in the costing to refurbish the upper base courses to a high standard gravel road once construction has been completed in order to ensure that the road is handed back to the Provincial Roads Department in an acceptable state.

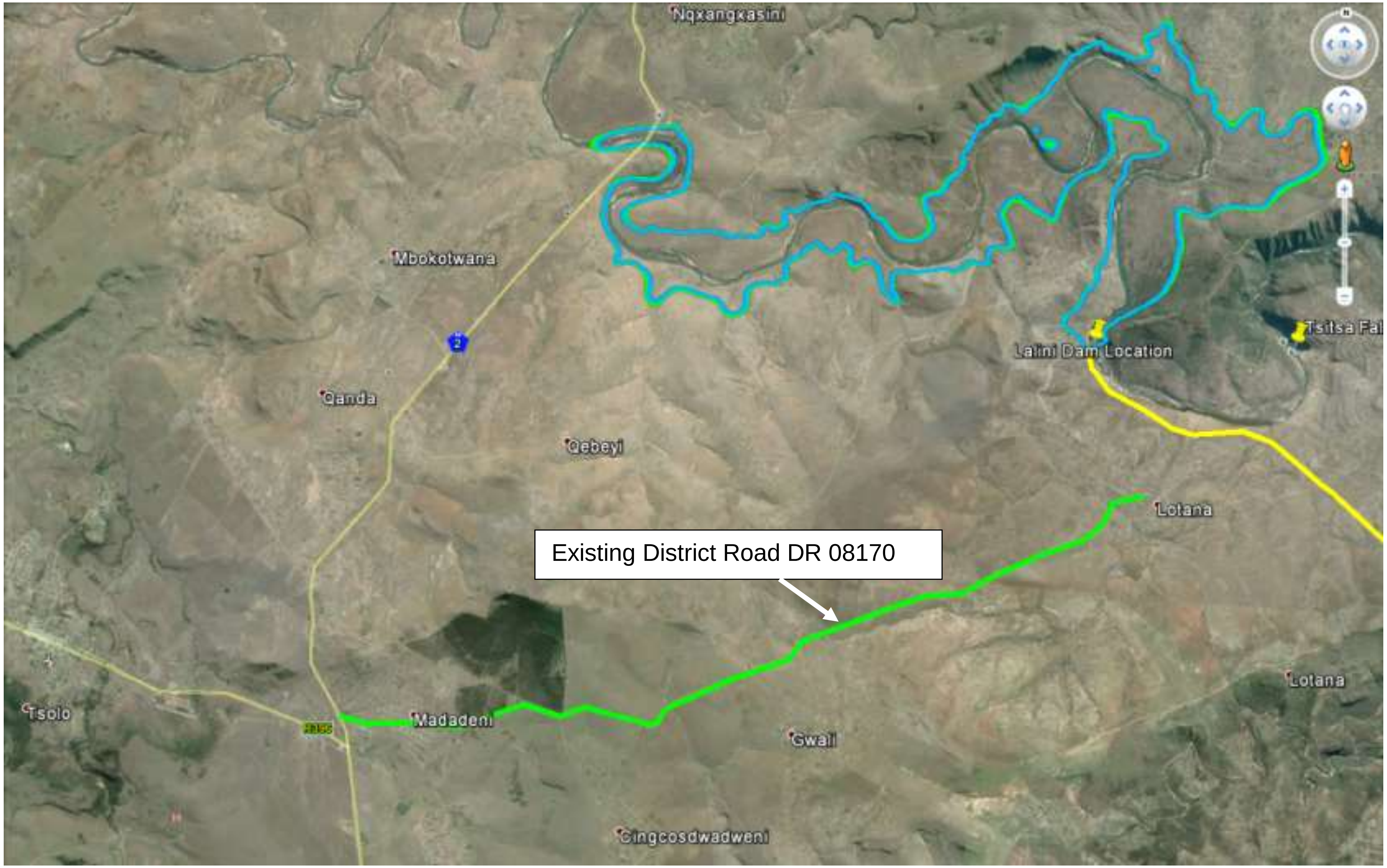


Figure 6-1: Main Access Road to Lotana Village

From this main access road, several new roads will need to be constructed for both construction and permanent access purposes. These are shown on Figure 6-2.

a) Dam and Pipeline Access Roads

The 4.2 km roads shown in blue will be new roads. These roads will be initially established as gravel haul roads for use by normal construction vehicles. However as this will be the main permanent access route to the Lalini Dam and mini-hydropower plant, the road would be upgraded to a double sealed surface, once main construction activities have ceased.

b) Tunnel Entrance Portal Access Road

This 1.3 km road shown in dark green will be a new road to the upper entrance to the tunnel. The road would be constructed as a gravel haul road for use by normal construction vehicles. It will mainly be used during the construction of the tunnel portal section, and during the delivery and installation of the pipeline section within the tunnel. As frequent access to the tunnel in the future would not be required, this could remain a gravel road.

However, as this section of road is relatively short it is recommended that this also be upgraded to a double sealed surface, once main construction activities have ceased.

c) Access to the Main HEP and Tunnel Exit Portal

The access road to the main HEP building and outlet portal of the tunnel is the highest priority road. This road has exacting requirements in terms of gradients and load carrying capacity, and yet has to traverse the most difficult terrain on the whole project.

This road will be used as the main construction haul link for the tunnel and HEP building construction. It will also be the route along which the abnormal loads (greater than 70 tons) travel when delivering the hydropower electro-mechanical and transformer components, and for servicing and replacement of such plant in the future.

Two options were investigated, and these are shown as HEP Access Road Option 1 (red) and HEP Access Road Option 2 (light green) in Figure 6-2. Option 2 is split into two sections with the orange section being an upgrade of an existing gravel road on top of the plateau with easy access and flat grades, and the green section being a new road down the escarpment in very difficult terrain, with more complex and costly design criteria.

Option 1 provides serious challenges in that it requires large cuts and fills to be constructed at significant costs. Therefore Option 2 was also investigated. Option 2 follows the valley wall of a south west tributary of the Tsitsa River flowing from Gwali to the HEP location.

The geometric design criteria for Option 2 were the same as for Option 1, and it was easier to achieve vertical alignment grades ranging between 1.5% and 10%, with the requirement of retaining walls reduced proportionally to that of Option 1.

Whilst this access road provides more suitable operational conditions for the abnormal vehicles, it would be, at 8.1 km long, significantly more expensive to construct than Option 1, which is 5.3 km long.

Technically Option 2 will be easier to construct, but it will be significantly longer and more expensive, and will also impact a larger area of sensitive vegetation.

Whilst option 1 is the recommendation from the feasibility study, both options should be revisited at detailed design stage in the light of further geotechnical investigations, detailed Environmental Impact studies and more detailed technical and financial optimisation. Neither of these proposed routes were included in the EIR submitted to DEA. An application must therefore be made to DEA for an environmental authorisation after this route has been optimised.

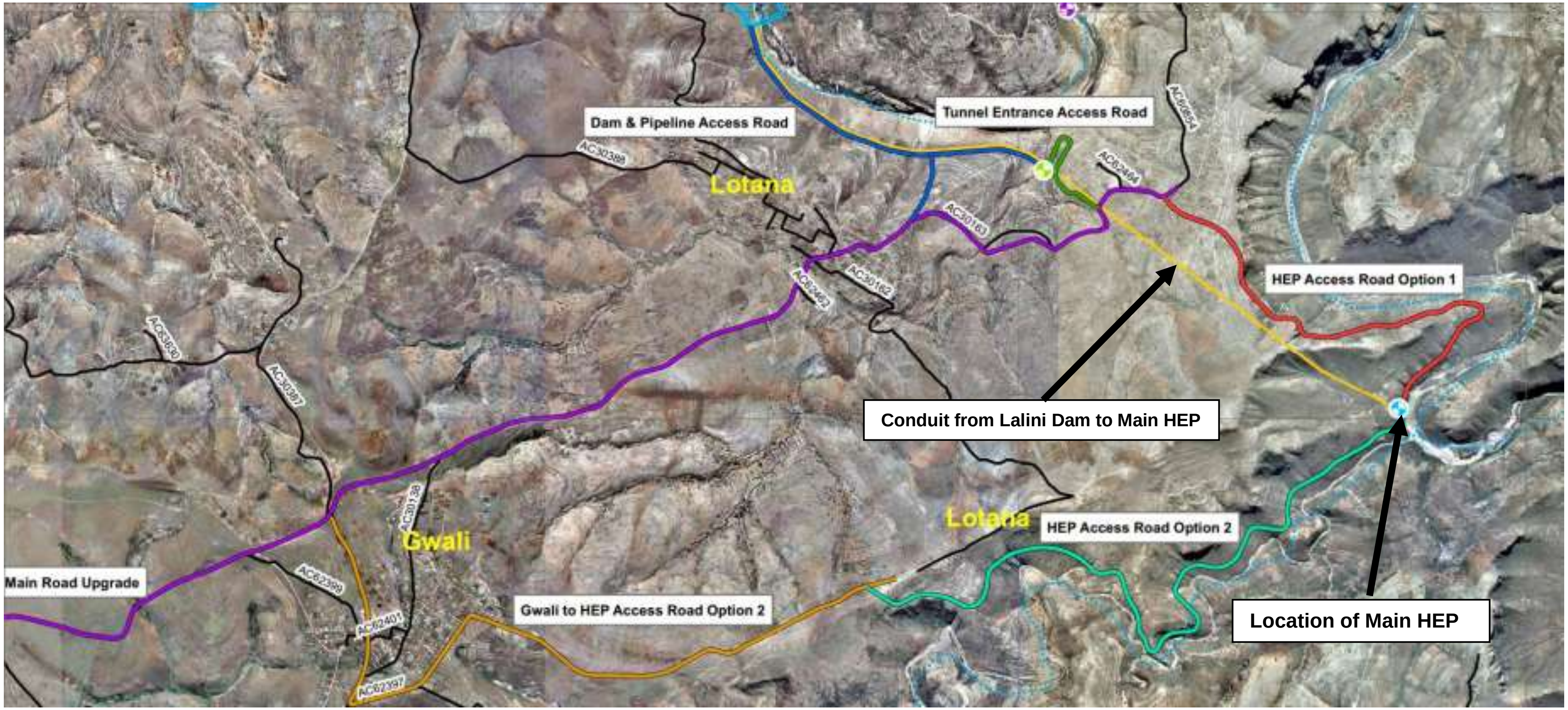


Figure 6-2: Main Access Road and Other Roads to Lalini Scheme Construction Sites

d) Gwali to HEP Option 2 Existing Road Upgrade

This 8.2 km long section of road would need to be upgraded if Option 2 were to be adopted. The geometric standards and layer works would be the same as for the Main Access Road.

At this feasibility design level of study, Option 1 has been adopted as being the preferred option, but it is recommended that further detailed investigation and optimisation of the HEP Access Road route be undertaken at the detailed design stage. This optimisation should take all relevant factors into consideration, such as technical aspects, construction difficulty, cost and permanent impact on the environment.

e) Roads and Bridges: Upgrades and Realignment

Other major road works will be required to undertake the realignment of infrastructure that will become inundated once the Lalini Dam has been commissioned. The layouts of these roads are shown on Figure 6-3.

f) Mtshazi Main Road

The impoundment of Lalini Dam will inundate some existing roads as well as drowning an existing river crossing vehicular bridge. The latter connects the village of Lalini with the settlements of Mtshazi, Shawbury, and the main N2 national road to Qumbu and Mthatha.

District Road DR 08167 shown in pink is a tarred road, is the main access from these villages to the N2, and is also a main tourist route for visitors to the Tina (a.k.a Thina) and Tsitsa Falls.

This 10.4 km road is currently in a pot-holed state, and some 40% of the existing route will need to be realigned to ensure that it passes outside of the future inundated area.

g) Lalini Bridge Relocation

The existing link road from the above Mtshazi road to Lalini village crosses the Tsitsa River via a low level single track vehicular bridge, which was constructed by SANRAL. This carries both vehicular and pedestrian traffic and is the main route for Lalini residents to travel to Mtshazi, Shawbury and the main N2 national road.

This existing low level bridge and its section of road will be permanently drowned by the impoundment of Lalini Dam. See Figure 6-3.

Alternative routes were sought to replace this route, which included a new road from Lalini along the south bank of the river and connecting to the N2. Unfortunately this would increase the travelling distance for journeys from Lalini to Mtshazi and Shawbury by 15 km. This would be highly unacceptable for pedestrians which include children going to school. If this option were adopted, then a high level footbridge would also be required to cater for the pedestrian users. This option would however still not be an acceptable solution as far as additional travel distance and time required by the vehicular road users.

The EIA study team were consulted and it was suggested that in such circumstances the solution should follow the principles of a “like-for-like” replacement. In order to meet the SANRAL standards, the bridge deck soffit would be required to be at an elevation providing 1.4 m freeboard above the 1 in 100 year flood level. This results in a bridge deck length of 450 m.

Figure 6-3: Roads/Bridges for Upgrade and Realignment before and during Lalini Works Construction

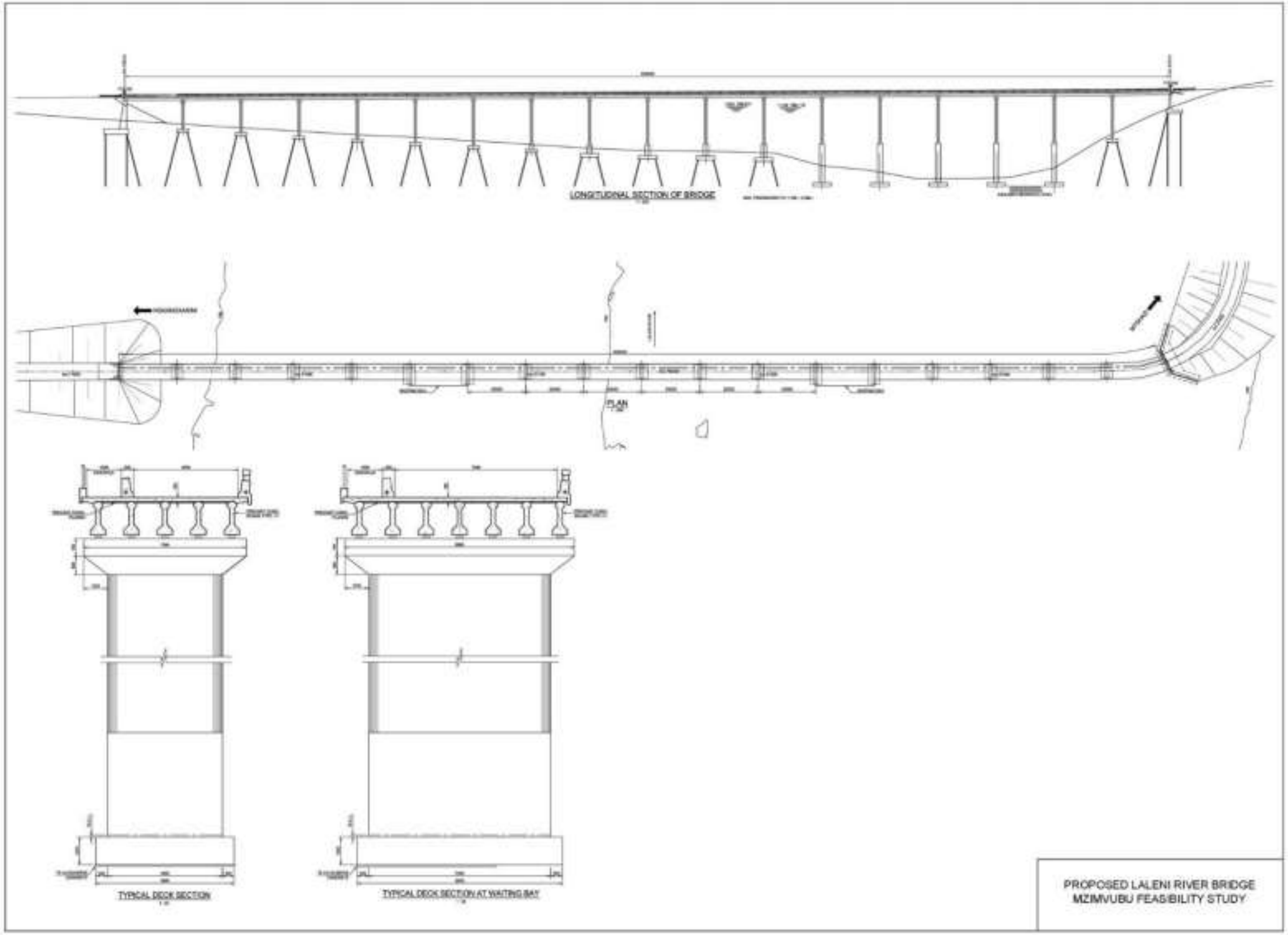


Figure 6-4: Proposed Lalini Bridge over Inundated River Section

The alignment of the part new, part upgraded, link road and new bridge is shown in yellow on Figure 6-3. A general arrangement of the proposed bridge is given in Figure 6-4.

This multi-purpose bridge was therefore designed which has a single track vehicular way and a barrier-protected pedestrian walkway. Given the long length of the bridge, the vehicular carriageway has two widened waiting bays for vehicles to pass each other. The bridge must meet SANRAL design standards.

The 4.4 km new link road connecting the bridge to the existing Mtshazi road and to the existing main road into Lalini, would be designed to the same standards and have the same layer works as for the district road DR 08167 above, and would therefore be a tarred surface road.

6.2.2 Road Servitudes at Lalini

Many of the works to be undertaken would be upgrades to existing road alignments for which servitudes have already been allocated. Where new roads or road realignments are required, the servitude width will be between 20 and 30 m depending upon the standard of the road and the terrain through which it is passing. This will be confirmed during the detailed design stage of implementation.

6.3 Lalini Dam Associated Infrastructure

The layout of the infrastructure associated with the Lalini Dam is shown on Figure 6-5.

This shows the area of land that will be required to accommodate the proposed visitor's centre on the right flank of the dam wall, the operations offices, and accommodation village.

6.4 Camps and Permanent Staff Accommodation

Several construction contracts are likely to be awarded to undertake the various components of this project. The construction of the works will provide employment opportunities for between 300 and 1 000 people for varying periods.

Most of these jobs will be filled with labour commuting or being transported from local communities including the small villages close to the works as well as from the urban areas such as Qumbu, Maclear, Tsolo and Mthatha, and it is not therefore expected that a significant amount of permanent camp accommodation would be required.

The contractors would normally make this decision at tender stage in their approach and methodology, and costs for these requirements are included within the P&G items. There will, however, need to be some permanent staff accommodation built for the operational staff and their families, who will need to live close to the works.

The estimated operational staff levels of the Lalini Dam and HEP are as given in Table 6-1.

These are considered to be the maximum numbers required, and these numbers may reduce depending upon who operates the dam and HEP and the calibre of staff assigned to these operations.

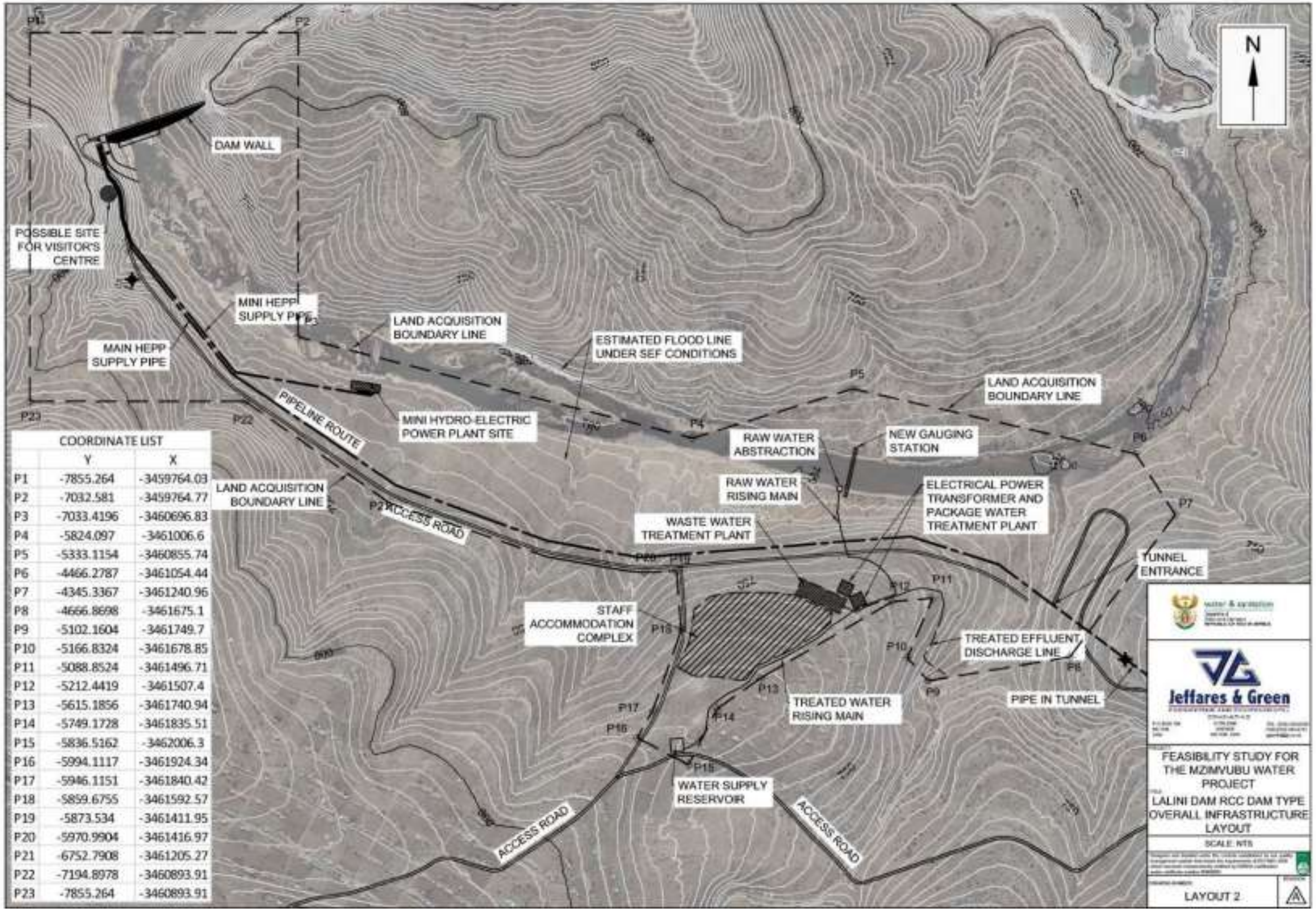


Figure 6-5: Layout of Lalini Dam and Associated Infrastructure

Table 6-1: Estimated Staff Requirements at Lalini Dam and Hydropower Plant

Lalini Dam				
Position	**Haygrade[4]**	**Day Shift**	**Night Shift**	**Total Shifts/Day**
Senior Water Control Officer	G	1	1	2
General Worker	A	4	2	6
Totals		**5**	**3**	**8**
Lalini Hydropower Plants (Both)				
Position	**Haygrade**	**Day Shift**	**Night Shift**	**Total Shifts/Day**
Certified Engineer (also covers dam)	L	1		1
Senior Plant Superintendent	J	1		1
Artisan Electrician	H	1	1	2
Artisan Millwright / Fitter & Turner	H	1		1
Artisan Aid	C	4	2	6
Totals		**8**	**3**	**11**

Given the permanent road network that will be established to access all of the Lalini infrastructure components, it is proposed that a staff accommodation housing estate is constructed as shown at a suitable location within short commuting distance to both the dam and HEP.

Allowance will also be made to additionally accommodate official visitors such as head office management, and the occasional VIP.

Provision has therefore been made for a housing estate containing some 16 stands on which one, two- and three-bedroom staff houses can be built. These will also have fitted kitchens, bathrooms, lounge and dining rooms, and will have mains electricity, water, and waterborne sanitation. If more housing is eventually required, there is sufficient land available for this purpose within the boundary shown.

Allowance has been made in the project budget for construction of 4 x one bedroom, 10 x two bedroom, and 2 x three bedroom houses. These requirements would be reviewed during the design stage.

Electricity will be supplied via an ESKOM connection, water supply[5] from a small package plant drawing from the river downstream of the dam (using the proposed new flow gauging station as an abstraction weir), and a wastewater treatment facility will also be built, with its discharge of treated effluent either directly to the river or via a tributary which flows into the river. The housing complex will also have street lighting, tarred roads and surface water drainage.

[4] *The Hay system of job evaluation is a point factor method of job evaluation that measures three factors common to all jobs – know-how, problem solving and accountability. The classification system focuses on internal job relationships and maintaining internal equity.*

[5] *This would likely be a temporary supply until the regional system is adequately upgraded as a part of the project.*

6.5 Power Supplies and Grid Connections

Table 6-2 summarizes the expected power load requirements during the construction and operation of the scheme as well as the grid access connection capacities required to deliver the generated hydropower into the local grid system

The connections required for loads 1 and 2 would be used both for the works construction and longer term to operate the works. This would also include the supply of power to the housing, offices, water supply and wastewater treatment plant.

Discussions with ESKOM have resulted in suggestions that the main grid connection to the Lalini scheme would be via a 132 kV line to the existing 132 kV grid system. This is as indicated on Figure 6-6.

This line should be constructed as advance works under the project to ESKOM's approved standards rather than ESKOM themselves undertaking the construction. The reason for this is that the construction power supply is required to be in place before any construction can start and ESKOM stated that they would need up to three years to implement if they were tasked with this component of the scheme.

This 132 kV line would therefore initially provide a power supply to the Lalini scheme, but would later be switched and synchronized so that the net surplus power generated by the Lalini HEPs could be fed back into the national grid to facilitate revenue generation.

Within the Lalini scheme itself, a further 22 kV power line will need to be constructed from the Lalini main HEP transformer/switching compound to provide power to the dam, tunnel and infrastructure works, which later can be used to evacuate the surplus power generated at the Lalini mini-HEP back into the national grid. This 22 kV line should also be expediently constructed under the advance works rather than be assigned to ESKOM to implement. The proposed alignments of the 132 kV and 22 kV lines are as indicated in Figure 6-6, and these maximize the usage of existing and proposed road corridors which can serve as joint servitudes, thus minimizing the land requirements.

These alignments must be optimized during the detailed design stage. An amendment to the environmental authorisation or a new EIA will be required if these routes need to be revised from those authorised by DEA. The EIA study recommended an alternative route, which differs from the route in Figure 6-6, to mitigate the visual impact of the power line, but this alternative route may not be technically acceptable.

6.6 Water Supply

The villages of Lalini and Lotana both have existing water supplies but it is not certain that these would have sufficient capacity to meet the short and longer-term requirements at the Lalini Dam and staff accommodation complex.

A separate water supply should therefore be developed to supply potable water to the offices and temporary accommodation during the construction period, and for the permanent accommodation village and administration offices in the longer term. This will typically have a capacity of approximately 150 m^3/day, and it is usual for this facility to be a modular package plant.

Table 6-2: Power Requirements for Scheme

Ref. No.	Use description	Eskom infrastructure required from:	Capacity	Required for construction	Required for permanent use	Load Locations	
						Latitude	Longitude
New Loads Required on ESKOM grid							
1	Power supply for Lalini tunnel and HEP	Year 2018	5 MW	Yes	Yes*	31°17'53.54"S	28°59'10.76"E
2	Power supply for Lalini dam and associated works	Year 2018	10 MW	Yes	Yes*	31°15'54.61"S	28°55'05.82"E
Hydropower Plants to Feed into ESKOM grid						**HEP Plant Locations**	
3	Lalini mini-hydropower plant	Year 2021	Seasonal output of 1 MW to 5 MW	No	Yes	31°15'58.25"S	28°55'08.37"E
4	Lalini Main Hydro Power Plant	Year 2021	Seasonal output of 12.5 MW to 37.5 MW.	No	Yes	31°17'55.04"S	28°59'10.67"E

* Permanent use would be at a much lower power requirement for operations, housing, water supply, wastewater treatment, HEP black-start, lighting, valves, and control systems, etc.

** It should be noted that the mini-HEP located at the Ntabelanga dam will be inter-connected separately to the national grid system and operated independently from these Lalini HEPs.

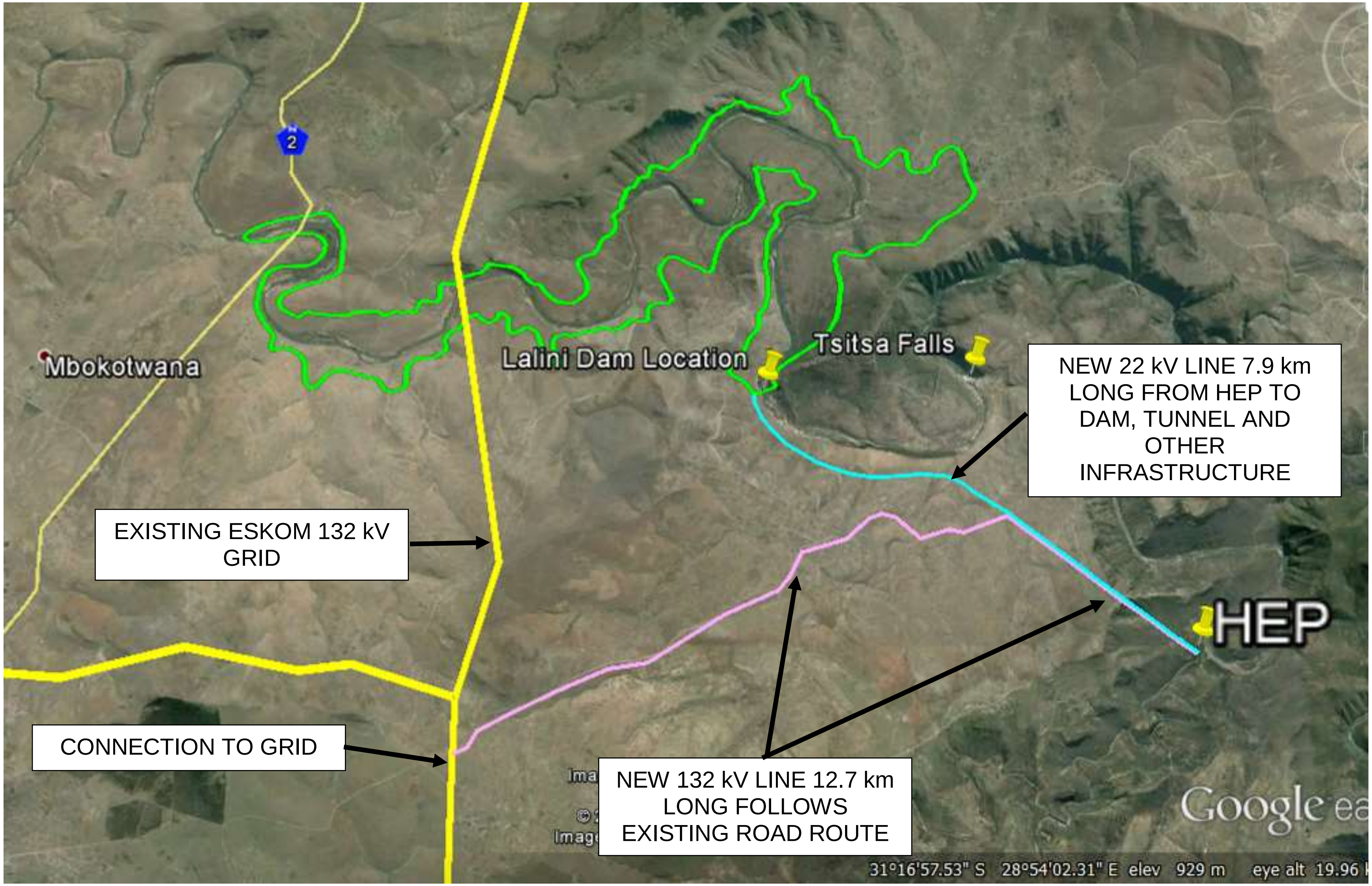


Figure 6-6: Proposed 132 kV and 22 kV Power Line Alignments

It is recommended that this plant not be sized any larger than 150 m^3/day to cater only for the dam, tunnel, and other works, as construction water supply would normally be the contractor's responsibility.

Once the main water supplies in the region have been improved under the project, this temporary water supply could be decommissioned.

6.7 Wastewater Treatment Plant

A wastewater treatment plant will be required to treat effluents produced by the Lalini Dam operations centre and housing complex. This would be appropriately sized for this purpose and it is probable that this requirement could be met by using a screening and pre-treatment process followed by a reed bed system, before discharging treated effluents back to the river to approved quality standards.

It is not recommended that such a wastewater treatment plant be designed or used to treat the effluent from the construction activities, as this would be oversized and would have to deal with industrial pollutants as well as domestic effluents. The contractors themselves must be made responsible for the safe and environmentally sensitive disposal of all of their effluents and waste products, leaving only domestic effluents for the permanent wastewater treatment plant to deal with.

At the main HEP site, the ablution facilities could discharge to a septic tank system as usage will be of low volume.

6.8 Telecommunications

Whilst the cellular network in the region has reasonably good coverage, adequate communication systems will need to be assured before the construction activities commence. This should include increasing the reliability and coverage of the cellular network system, as well as providing land lines, and data lines with sufficient transmission speeds for modern communications equipment.

This is normally dealt with by requesting quotations from the nationally-based telecommunications service providers, and this is also considered to be an important advance infrastructure requirement.

6.9 Visitor's Information Centre

The Lalini Dam and its body of water, and the hydropower plants, will provide opportunities for tourism and recreation, which in turn can lead to job creation. Many large dams take up such opportunities and offer visitor facilities to encourage tourism and thus promote economic development.

A visitor's information centre can form the focus of such an initiative by providing visitors with a view of the works and information on the project, including the cultural and tourism activities in the area. A location for this centre is suggested above on Figure 6-5. It is recommended that such a building be of interesting architecture in keeping with the local culture and terrain.

Consideration could also be given to combining this building for both visitors and as the administration and operations centre. If this building could be completed early enough as a part of the advance infrastructure, then it could be used as the Client and Resident Engineers offices during construction as was the case at Katse Dam.

6.10 Flow Gauging Stations

Gauging stations should be constructed as priority works in order to establish the ongoing monitoring of the river flows prior to and after construction of the dam. The Hydrological Services section of the Department of Water and Sanitation has undertaken a reconnaissance of the scheme and the following sections summarize their recommendations for the Lalini section of the river. The Ntabelanga Dam related gauging stations are dealt with under the separate RID for that component of the project, in Report No. P WMA 12/T30/00/5212/17.

a) Tsitsa Upstream of Lalini

If the preferred Lalini Dam scenario is to be implemented the existing DWS gauging structure T3H006 in the Tsitsa, just downstream of the N2 road bridge, will be inundated by the dam when full. In that case a new structure needs to be constructed to replace T3H006 immediately upstream of the influence sphere of the Lalini Dam, upstream of the N2 road (See Figure 6-7).

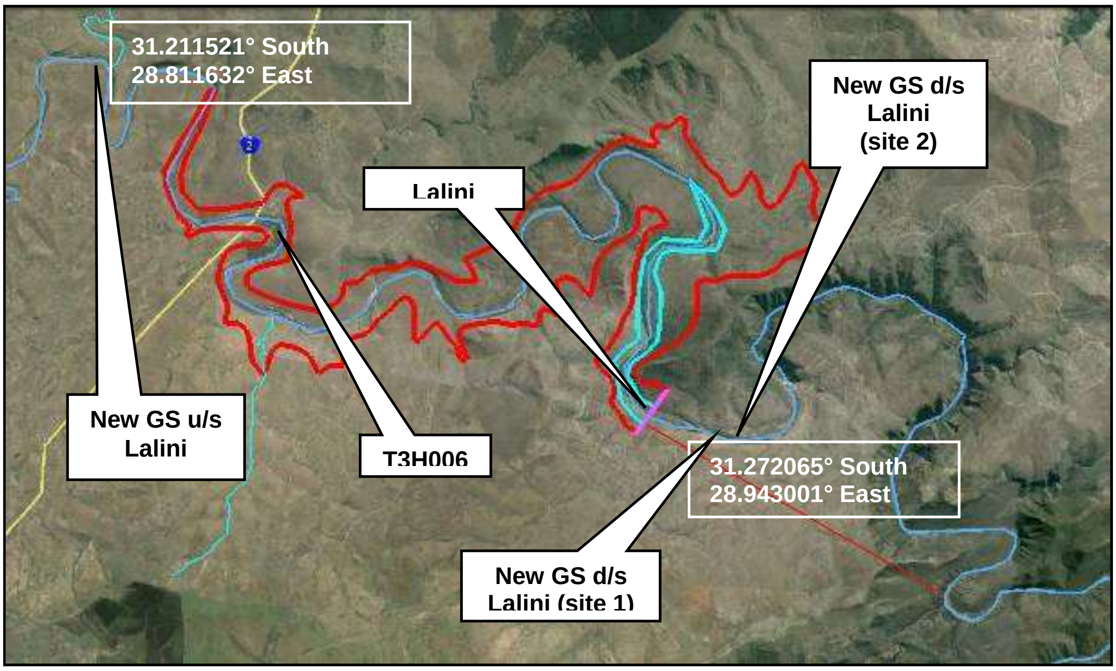


Figure 6-7: Recommended New Gauging Weir Sites Upstream and Downstream of Lalini Dam

b) Tsitsa Downstream of Lalini

Two potential gauging sites downstream of Lalini have been identified approximately 1.3 km and 1.6 km downstream of the wall (See Figure 6-7).

Site 2 is preferred as conditions appear more favourable, however both sites were recommended for assessment in the environmental process, as they are only 300 m apart.

If foundation conditions at site 2 are poorer than expected, it might be necessary to utilise site 1, but constructing a higher than normal gauging structure to overcome the complex flow conditions expected at this site.

c) Tsitsa downstream of the Lalini Dam hydropower turbines

A gauging structure should be located and designed in such a manner that flows coming down the Tsitsa and from the main HEP outlet discharge point will not impact on the gauging station accuracy due to residual turbulence (See Figure 6-7). A gauging structure could be incorporated into the HEP building outlet works, at the end of the outlet canal from each of the three turbines, before the water cascades down into the river.

DWS Hydrological Services requires that they undertake the technical specification of these gauging stations in-house, but the detailed design and construction should be included and implemented under the Ntabelanga Dam component of the project so that they can commence flow measurement as early as possible.

6.11 Priority Infrastructure

The following are considered to be works components that should be constructed in advance of the main works, or at least as the first priority if these components are part of the main contract:

- Main access roads, including roads at Lalini Dam site shown on the layout;
- Bridge across the river replacing the low level bridge linking Mtshazi and Lalini village;
- Power supplies;
- Temporary water supply and gauging station[6];
- Other gauging stations[7]; and
- Telecommunications.

Also optional:
- Staff accommodation – if to be used by DWS and/or the supervising Engineer and staff during construction – do not allow contractor to use; and
- Wastewater treatment plant – if staff accommodation is built.

Most of the above works require an environmental authorization (EA), and have been included in the EIA process, except for the power supply lines to the construction sites, as these routes had not been determined. It is important to check the EA for details of the infrastructure authorised and obtain approval for any deviations prior to implementation.

The Feasibility Study also identified the needs and benefits of a concerted catchment rehabilitation and management programme. This has been handed over to the Eastern Cape Provincial Department of Environmental Affairs, who commenced a 10 year programme during April 2014.

6.12 Compensation and Mitigation Works

The EIA study team might identify other mitigations, offsets, and compensation works that will require engineering inputs and construction activities.

Some of these mitigation items might be a condition of the environmental authorisation and could include, *inter alia*:
- Wetland offsets;
- Relocation of homesteads affected by the scheme;
- Additional feeder roads, footbridges, etc.;
- Improvements to local water supplies not included in the proposed scheme;
- A sanitation programme; and
- Improvements to clinics, schools and police stations in the areas affected by the dam.

Budgets described as offset activities in Table 10.1 have been allowed in the cost estimates for these other potential works, the implementation of which should be carried forward and investigated during the detailed design stage.

[6, 7] *If the gauging stations are not constructed under the Ntabelanga Dam works, which would be preferable*

Funding for some of the mitigation items (roads, schools, clinics, etc.) could be provided by the relevant Government departments.

7. LAND MATTERS AND SERVITUDES

7.1 Acquisition of Land

All of the affected land for Lalini Dam wall and HEP, dam basin and associated infrastructure is State-owned and administered by traditional leaders in the region. Acquisition of this land therefore involves the relocation and compensation (replacement and/or financial) of the current occupants for their infrastructure (dwelling, cultivated lands, etc.) and other losses.

An Asset Register of all the areas affected by the project footprint has been prepared as part of the EIA study. This register is based on aerial surveys and Google images and was verified by field observations.

A Relocation Policy Framework (RPF) has been drafted during the EIA study to guide the relocation and compensation of affected communities. The RPF forms the basis of the Relocation Action Plan to be agreed with traditional leaders, ward councillors and affected communities during the implementation phase. The Asset Register also forms an integral part of the land acquisition process.

Recommendations in the RPF include:

- Thorough identification of abandoned homesteads and recording of field ownership is required.
- The locations of ancestral graves at abandoned homesteads affected by the project must be ascertained.
- Certain structures will require replacement so that the relevant family's socio-economic activities can continue.
- All graves within the full supply level of the dam should be relocated, with the permission of the next-of-kin and a permit from the Eastern Cape Provincial Heritage Resources Authority (ECPHRA).
- No associated infrastructure may be located within 100 m of graves outside the full supply level, and if unavoidable, these graves should also be relocated.
- A destruction permit is required from ECPHRA; if possible a single permit should be obtained for all affected structures.
- Avoid involuntary resettlement wherever possible.
- Undertake consultations with displaced people about acceptable alternatives and strategies and include them in the planning, implementing and monitoring processes.
- Choose the relocation site to ensure that the minimum disruption to displaced families and host communities occurs.
- Sensitise host communities to the pending arrival of the displaced communities;
- Establish a forum or resettlement committee through which resettlement and integration can be controlled by those affected.
- A formal accessible grievance procedure should be implemented and communicated to both the displaced and host communities.
- Ensure that the receiving environment is prepared and has adequate infrastructure, facilities and social services to support both the displaced and host communities, prior to moving the displaced communities.

The use of State land around the dam basin by others, access to the water body by non-State entities (boat clubs, etc.) and related matters shall be in accordance with DWS policies and should be based on formal agreements between DWS, Provincial Government and those entities. It is also within the jurisdiction of Provincial Government to sign agreements on State land.

The zoning of the dam basin for various uses (boating, recreation, development, nature reserve areas, etc.) is the responsibility of DWS Directorate: Integrated Environmental Engineering who needs to prepare a Resource Management Plan for the dam.

7.1.1 Temporary Servitude for Construction

A temporary servitude (access to the land) for construction of the dam may be required prior to finalisation and implementation of the Relocation Action Plan. This aspect needs to be investigated further during detail design phase.

7.1.2 Permanent Servitude for Right of Way

A permanent servitude for right of way will be required for the new roads to be constructed to give access to the dam and other associated works that are not yet accessed by formal roads. A registered permanent servitude is required for infrastructure, such as roads, pipelines and power lines, even if constructed on State-owned land. This aspect needs to form part of the detail design phase.

7.2 Dam Basin Expropriation Boundary

Figure 7-1 shows the probable land expropriation required for the Lalini dam basin area which will be inundated. The area to be acquired for the dam basin (dam boundary line) is based upon the DWS requirement of *"the 1:100 year flood line (HFL) plus 1.5 m vertical for steep areas or 15 m horizontal for flat areas*".

The settlements that might be impacted directly or indirectly by this expropriation requirement are indicated on the figure in green. The co-ordinates of these preliminary expropriation boundaries are given in Appendices in the Land Matters Report No. P WMA 12/T30/00/5212/8. .

The expropriation line will need to be reviewed during the detailed design and a survey carried out to install permanent beacons defining the expropriated land. This will involve some "smoothing" of the boundary of the expropriated land into straight lines between beacons, and DWS will acquire that land in terms of the surveyed lines.

Given that this project will impact upon the river and its basin upstream of the dam wall, there will be a need to address the relocation and compensation issues for affected persons living near to, or using land within, the river's riparian zone. Refer to DWS EIA Report Nos. P WMA 12/T30/00/5314/1 to 17.

As these works are to be gazetted as Government Water Works, and given the expropriation powers likely to become available to Government as provided for under the Infrastructure Development Bill, there would not be a legal requirement to compensate affected people for the particular usage of riparian land. However, given the emotive nature of resettlement and the potential disagreement and unrest that might be caused by an insensitive consultation and compensation policy, great discretion is recommended in this case.

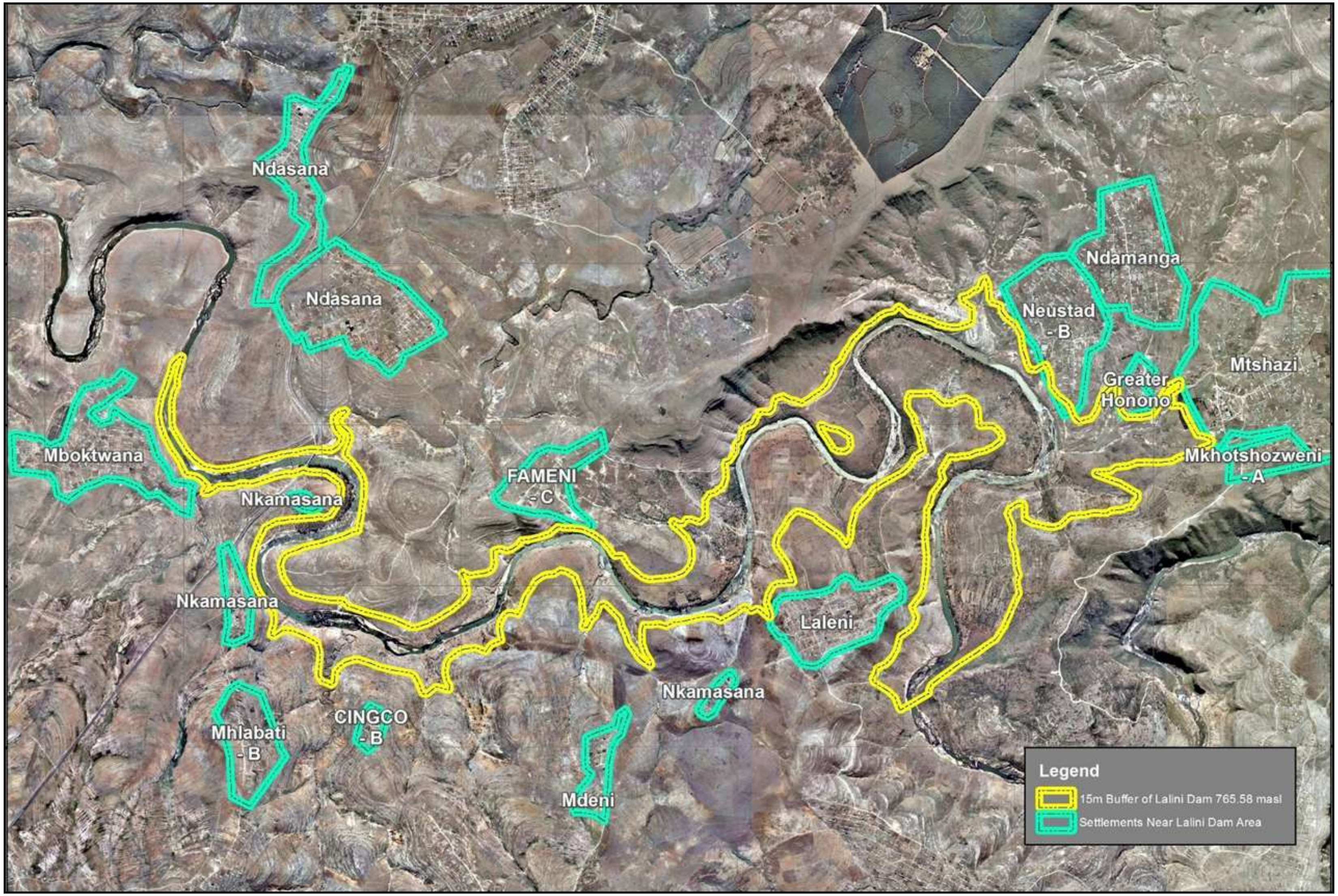


Figure 7-1: Lalini Dam Basin Area

The DWS has legal powers to expropriate land, and uses both the Water Act and the Constitution in doing so. It is therefore reiterated that it is a legal requirement to compensate all affected parties and this means that different kinds of compensation are often required for different people on the same portion of land.

Provided sufficient cadastral information, etcetera are available, the legally prescribed procedures to be followed in order to acquire portions of such land normally take at least 12 (twelve) to 18 (eighteen) months to get through. The less formalised land allocation and ownership issue that will prevail in this case could easily prolong this acquisition process.

7.3 Fencing of Project Site

7.3.1 Dam Basin

The dam basin shall be fenced off along the purchase line where required in accordance with DWS standards. The size and type of gates, the number and positions required and the type of locks or padlocks to be used shall be decided upon by the DWS.

7.3.2 Security Fencing

Security fencing shall be provided around the dam wall, outlet works, the dam site, the ESKOM switch yard, and other sensitive areas as may be necessary. Security fencing shall be in accordance with DWS standards. ESKOM will determine the fencing standards for their switch yard.

7.3.3 Fencing Around Non-State Owned Infrastructure

It is anticipated that other non-State infrastructure such as tourism sector entities, fishing or boating clubs may construct structures on State land. The use of State land, access to the water body and related issues shall be in accordance with DWS policies and agreements.

Any fencing provided around such structures shall comply with DWS fencing standards and agreements with these entities shall incorporate the obligation of the entities to maintain such fences on a regular basis.

8. REQUIREMENTS FOR PROJECT IMPLEMENTATION

8.1 Approval of Project

The Minister will need to approve the construction of the Lalini Dam and Hydropower Scheme (used conjunctively with Ntabelanga Dam) as a Government Water Works in accordance with Section 109 of the National Water Act, 1998 (Act No. 36 of 1998). This approval is contained in Appendix A. The implementation of the project shall adhere to the general criteria prescribed in Chapter 11 of the Act.

8.2 Environmental Authorisation

The project also requires environmental authorisation (EA) in terms of the National Environmental Management Act (NEMA) by the National Department of Environmental Affairs. This authorisation states conditions of compliance for the implementation of the project. The EA must therefore be read in conjunction with this RID for implementation of this project.

Three separate authorisations were submitted to DEA for the components of the project which could be implemented by separate entities, namely, DEA Ref. No.:

- 14/12/16/3/3/2/677 - Dam construction application;
- 14/12/16/3/3/2/678 - Electricity generation application; and
- 14/12/16/3/3/1/1169 - Roads application.

Refer to the DWS Environmental Impact Assessment for the Mzimvubu Water Project Report Nos. P WMA 12/T30/00/5314/1 to 17, and a copy of the environmental authorization included herein as Appendix B.

8.3 Other Requirements

Other approvals required for project implementation, which were included in the EIA process, are listed below. Refer to the Environmental Impact Assessment for the Mzimvubu Water Project: Environmental Impact Assessment Report, DWS Report No: P WMA 12/T30/00/5314/3, for more information.

a) Water Use Licence

The construction of the dams and associated infrastructure involves a number of water uses listed in terms of section 21 of the National Water Act, 1998 (No. 36 of 1998) (NWA). An Integrated Water Use Licence Application (IWULA) has been prepared for submission to DWS.

b) Borrow areas and quarries

Construction materials such as sand, gravel and rock material will be required for the construction of the dam and roads. Existing licenced quarries and borrow pits in the area may not be adequate or suitable to provide all the required construction materials and a new rock quarry and borrow pits for sand and earthfill material will be necessary.

The impacts of the new borrow areas and quarries were investigated in the EIA, and EMPLs have been compiled for approval by the Department of Mineral Resources (DMR).

Although the DWS is exempted from the mining permit application process in terms of section 106 of the Mineral and Petroleum Resources Development Act (MPRDA) (28 of 2002), and is exempted from section 41 in terms of the Memorandum of Understanding between the DMS and DWS, DWS is however not exempted from the Environmental Authorization application process.

Prior to the 8 December 2014, the exempted applicants were required to submit an EMP for approval. However, on the 8 December 2014, all the sections pertaining to the environment were repealed in the MPRDA (28 of 2002) and are replaced by the NEMA EIA Regulations (2014).

As for the implementation date, all applicants (whether exempted or not), are required to apply for an environmental authorization (EA) for all listed activities on the mine/quarry/ borrow pit areas.

Application for an EA must be made on the official application form in terms of section 16(1)(a) of the NEMA EIA Regulations (2014). DWS was required to submit a fully completed EA application form.

Under section 5 of the application form - activities to be authorized — the applicable listings for a Basic Assessment are listing notices 1 and 3 contained in Regulation Notice 983 and 985 respectively, as per regulations 19 and 20 of the Environmental Impact Assessment Regulations 2014. The applicable listing for a Scoping and EIA is listing notice 2 contained in Regulation Notice 984, as per regulations 21, 22, 23 and 24 of the Environmental Impact Assessment Regulations 2014.

All listed activities for each borrow pit and the hard rock quarry must be listed according to the above listing notices for evaluation. Only activities listed on the application form will be considered when issuing an environmental authorization and the onus is on the applicant to ensure that all listed activities related to the proposed project are included on the application.

Please note that for exempted applications such as the current application that includes more than one mine area (ie. 5 borrow pits and 1 hard rock quarry), a scoping, EIA and EMP programme is required.

The required content of the Scoping report, EIA and EMP programme is listed in Appendices 2, 3 and 4 of the NEMA EIA Regulations (2014) respectively.

DWS were requested to submit the Environmental Authorization application form on or before the 15th May 2015, which was undertaken within that deadline.

c) Heritage Permits

The proposed project involves a number of activities listed in terms of section 38 of the National Heritage Resources Act, 25 of 1999 (NHRA), which require authorisation from the relevant heritage authorities.

A Heritage Impact Assessment (HIA) has been conducted as part of the EIA process. The HIA has been submitted to the Eastern Cape Provincial Heritage Resources Authority and the South African Heritage Resources Agency (SAHRA) for decision-making regarding heritage resources.

The following approvals are also required for project implementation, but were not included in the EIA process:

d) Waste Management Licence

No Waste Management Licence (WML) application was included in this EIA process and if applications are required, they will have to be applied for separately.

e) Licences for the removal of protected trees

Tree species that are protected in terms of the National Forests Act (Act No. 84 of 1998) have been identified within the project footprint. A licence must be obtained from the Department of Agriculture, Forestry and Fisheries (DAFF) to disturb, to damage or to destroy/remove such trees.

8.4 Approval of Design

The Lalini Dam is a Category 3 dam which requires an Approved Professional Person and professional team to be approved by the Minister via the delegated authority of the Dam Safety Office in consultation with the Engineering Council of South Africa (Section 117 of the National Water Act, 1998).

A licence to construct the dam is required in terms of Dam Safety legislation (Chapter 12 of the National Water Act, 1998) before construction can commence and a licence to impound before water may be stored in the dam.

8.5 Electricity supply

Application should be made to ESKOM so that sufficient permanent power is provided to the site for construction and operation purposes. The details of the required electricity supply need to be finalised during the design phase taking into account the likely pumping requirements for the resource poor farmers to be settled on the scheme.

It is proposed that power produced by the conjunctive scheme could be evacuated into the ESKOM grid generating revenue via a wheeling arrangement as defined under ESKOM wheeling guidelines, or through the trading of “green energy”. Further discussion of this is made in the Legal, Institutional and Financing Arrangements Report No. P WMA 12/T30/00/5212/16.

This will need to be urgently discussed and the terms and conditions agreed with ESKOM and green energy trading agencies with immediate effect, as this could affect the overall economic and financial viability of the scheme as a whole.

8.6 Construction Timing

Any construction work undertaken in the river channel and spillway shall as far as possible take place during the dry season (winter) in order to avoid possible flooding and associated damage of the works during the wet season.

Any construction on the works should take the arrangement for the continuous supply of water into consideration and the works should be designed and constructed to ensure minimal interference with the flow of water in the river that currently supplies existing water supply schemes.

8.7 Construction Housing

The contractor will be responsible for accommodation for his employees during construction. Accommodation on site is normally not permitted in terms of the environmental authorisation. This aspect needs to be confirmed in the conditions of the EA and this information included in the tender specifications for all construction tenders.

8.8 Agreement between IWRP and Infrastructure Development

The conditions specified in the Memorandum of Agreement between the Chief Directorates Integrated Water Resource Planning (IWRP) and Infrastructure Development dated March 2005 shall be adhered to. The RID shall also be applicable to any other implementing agent (such as TCTA or Amatola Water) that may be appointed to implement certain (or all) components of this project.

8.9 Compliance with Applicable Legislation, Regulations and Policy

The Legal, Institutional, and Financing Arrangements report takes into account the legislative compliance of the conjunctive scheme comprising the Ntabelanga and Lalini Dams, the regional bulk infrastructure for drinking water supply systems, the raw water bulk infrastructure for irrigation purposes, and the hydropower production components. Whilst there are several options for these arrangements put forward in that report, significant further work will need to be undertaken during the implementation phase that will determine which institutional and financing model will be applied.

This section of the RID therefore gives an outline of the compliance issues as related to the construction of the Lalini Dam and hydropower scheme and associated infrastructure. The aspects to be complied with during implementation will depend on the final institutional and funding model adopted.

8.9.1 National Water Act

The National Water Act, 1998 (Act No. 36 of 1998) (NWA) is the primary piece of legislation governing the use, and protection of the country’s water resources. The planning, construction, and operation of the Mzimvubu Water Project must be undertaken within the legal framework of this Act and its accompanying regulations.

Chapter 11 of the NWA details the requirements for the Department of Water and Sanitation when establishing and operating a government water works. These requirements cover consultation and environmental impact assessment; financing; and water allocation/charges.

In addition, dam safety is dealt with in Chapter 12 of the NWA, which stipulates the control measures; dam registration; and regulations to govern the management of the risks that dams inherently pose.

In terms of the Lalini Dam, there are three legal requirements that must be met relating to the construction of a dam:

- Environmental Compliance
- Dam safety

  The current Dam Safety Regulations were published in Government Notice R. 139 on 24 February 2012 in terms of section 123(1) of the NWA. These regulations are applicable to all dams with a safety risk. The regulations require a licence to construct; a quality control programme during construction; a licence to impound; an operation and maintenance manual; an emergency preparedness plan; a completion report and certificate; and registration on the DWS database.

- Water Use Licence

  Any new water use as defined in Section 21 of the NWA is subject to licensing. This includes the storage of water as a water use. A written licence is required prior to construction. The water use licence application was prepared during the EIA process.

The building of the Lalini Dam and hydropower scheme will be implemented as a Government Waterworks in compliance with Section 109 of the NWA.

8.9.2 Environmental Compliance

a) Compliance with Environmental Authorisation

An environmental impact assessment was carried out to obtain environmental authorisation (EA) for the project from DEA (refer 4.12.2 and 4.12.3 above). Compliance with the conditions of the environmental authorisation (EA) is compulsory for the implementation of this project (before, during and after construction of the dam and associated infrastructure). It is therefore also necessary to study the environmental impact assessment report (EIR) to ensure that all environmental requirements for the project are met, and impacts due to non-compliance are avoided. A summary of the main mitigation measures specified in the EIR for design, construction and operation of the Lalini Dam and associated infrastructure are given below. Some of these measures will also be conditions of the EA.

b) Key mitigation measures

While a comprehensive set of mitigation measures has been provided in the Environmental Management Plan[8] (EMP), the following mitigation measures have been identified as essential to minimise significant environmental impacts, and implementation of these measures is a condition to the project proceeding.

c) Key mitigation measures to be implemented during the pre-construction phase

- A walk-down of the areas impacted by the access road to the hydropower plant and haul roads must be undertaken before clearing. Search and rescue of protected vegetation must be undertaken by a suitably qualified specialist. Floral species need to be relocated to similar habitat types, outside of infrastructure footprint areas.
- The haul road linking the sand borrow areas furthest from the dam wall to the Lalini Dam construction site must be realigned to avoid going through the village of Lalini, if possible.
- Protected tree species Podocarpus fulcatus and P. latifolius were located along the sections scheduled for road upgrades. The following must be ensured:
  - Possible re-alignment of the roads where protected tree species were found, in order to avoid cutting and destroying the trees;
  - Where protected trees will be disturbed, ensure effective relocation of individuals (if possible) to suitable similar habitat; and
  - Permit applications must be obtained from relevant authorities.
- Rescue and relocation of medicinal important floral species, Red Data List (RDL) and protected floral species is essential to minimise impacts from inundation.
- RDL faunal species or species of conservational concern found within the operational footprint area must be relocated to similar habitat within the vicinity of the study area with the assistance of a suitably qualified specialist.
- No hunting or trapping of faunal species is to occur.
- The construction footprint needs to remain as small as possible, especially in the sensitive habitats.
- Aquatic bio-monitoring must take place and if any trends are observed where impacts on the aquatic ecology is becoming unacceptable, measures to reduce the impacts must be immediately implemented.
- Baseline studies must be undertaken for noise, air quality, and water quality.

[8] *and its associated implementation programme*

- An investigation must be undertaken by a qualified specialist to determine whether any waterfall dependant plants in the gorge and on the cliff could be significantly impacted and whether they require relocation. All findings of the investigation must be implemented.
- Areas of increased sensitivity, as shown in the sensitivity maps developed should ideally be avoided in terms of the placement of infrastructure (other than the dams) in order to minimise the footprints within wetland features. Where it is not possible, mitigation measures to limit the impacts (such as ensuring the design of crossings allows for the retention of wetland soil conditions as presented in the EMP) must be implemented.
- Support structures for pipelines must be placed outside of riparian features, channelled valley bottom wetlands and drainage lines. Should it be essential to place such support structures within these features, the designs of such structures must ensure that the creation of turbulent flow in the system is minimised, in order to prevent downstream erosion. No support pillars should be constructed within the active channels. In order to achieve this all crossings of wetlands should take place at right angles wherever possible.
- Where new roads traverse wetland / riparian habitats, with special mention of drainage lines, channelled valley bottom wetlands and riparian habitat, disturbance to any wetland crossings must be minimised and suitably rehabilitated. The crossing designs of bridges must ensure that the creation of turbulent flow in the system is minimised, in order to prevent downstream erosion. All crossings of wetlands should take place at right angles wherever possible.
- The design of culverts / bridges should allow for wetland soil conditions to be maintained both upstream and downstream of the crossing to such a degree that wetland vegetation community structures upstream and downstream of the crossing are maintained. In this regard, special mention is made of:
  - The design of such culverts and/or bridges should ensure that the permanent wetland zone should have inundated soil conditions throughout the year extending to the soil surface;
  - The design of such culverts and/or bridges should ensure that the seasonal wetland zone should have water-logged soils within a depth of 500 mm below the soil surface during the summer rainfall period; and
  - Temporary wetland zone areas should have waterlogged soil conditions occurring within a depth of 300 mm below the land surface during the summer rainfall period.
- Ensure that no incision and canalisation of the wetland system takes place as a result of the construction of the culverts.
- It must be ensured that flow connectivity along the wetland features is maintained;
- The Ecological Water Requirements (EWR) as set out in the Reserve Determination Volume 1: River (Report P WMA 12/T30/00/5212/7) for the Ntabelanga Dam and the Lalini Dam, must be adhered to at all times.
- The installation of multiple level outlets, with outlets at no more than 6.5 m intervals from 7 m below the full supply level of the dam and proper operation is required to mitigate the effect of water quality changes downstream of the proposed dams.
- The archaeological site identified in the proposed Lalini Dam basin should be mapped and excavated/sampled, authorised by a permit from ECPHRA. Thereafter the site may be destroyed once a destruction permit has been issued by ECPHRA.
- A detailed survey of potential Early Iron Age sites should be undertaken once crops have been harvested and vegetation clearance has occurred.
- New roads and pipelines should be realigned as much as possible to avoid structures.

- The proposed access road for construction vehicles through Lotana village must be realigned to avoid the village.
- Fieldwork to identify heritage resources affected by roads and electrical infrastructure must be undertaken, and mitigation measures recommended, once final infrastructural locations and routes have been finalised, surveyed and pegged.
- All graves outside the full supply levels within 300 m of associated infrastructure should be demarcated by the Engineer's environmental representative, in consultation with the next-of-kin, for the duration of construction. These graves should not be disturbed.
- The proposed power line linking the Lalini hydropower plant to the grid must be realigned to avoid the crest line of ridges, if technically acceptable.
- All access roads impacted by inundation must be compensated by providing new roads and bridges.
- The RPF must be implemented in a consultative manner.
- A dedicated Project Management Unit should be set up to manage and coordinate the implementation of the various components and aspects of this mega project effectively.
- A Decisions Register must be established and maintained, and must be available to any member of the public who wishes to access it. The register should include all commitments made to stakeholders during the public participation process, which are recorded in the Issues and Responses Report.
- An employment and skills development policy, maximising employment opportunities and skills development for local communities and promoting gender inclusivity and equity must be developed.
- A procurement policy, promoting business opportunities for local communities and gender inclusivity and equity, must be developed.
- An investigation on the necessity and design specifications for an eel-way should be undertaken and the findings implemented.
- As some roads and bridges will be inundated by the dam, new bridges and road realignments will be required. This will influence travel routes, distances and travel times. Where the proposed realignments will result in significant increases in travel times and distances, alternative routes must be provided in order to maintain or improve the current level of service in the areas concerned.

d) *Key mitigation measures to be implemented during the construction phase*

- An alien vegetation control programme must be implemented on construction sites, as encroachment of alien vegetation is already apparent in the study area and is expected to increase as a result of the disturbances resulting during the construction process.
- Rehabilitation of disturbed areas, utilising indigenous wetland vegetation species, will assist in retaining essential wetland ecological services, particularly flood attenuation, sediment trapping and erosion control, and assimilation of nutrients and toxicants, thus reducing the impacts of construction related activities.
- Prohibit the collection of plant material, outside of the proposed dam basins, for firewood or for medicinal purposes during the construction phase by construction staff.
- Restrict vehicles as far as possible to travel on designated roadways to limit the ecological footprint.
- No hunting or trapping of faunal species is to occur.
- The construction footprint needs to remain as small as possible, especially in the sensitive habitats.
- Sections of power lines that require bird diverters must be identified and implemented.

- Aquatic bio-monitoring must take place, starting six months prior to construction activities, and if any trends are observed where impacts on the aquatic ecology is becoming unacceptable, measures to reduce the impacts must be immediately implemented.
- Identified areas where erosion could occur must be appropriately protected by installing the necessary temporary and/or permanent drainage works as soon as possible and by taking other appropriate measures to prevent water from being concentrated in rivers/streams and from scouring slopes, banks or other areas.
- Storm water control measures must provide for erosion and sedimentation control, and for reinforcement of banks and drainage features, where required.
- Possible control measures include the use of gabions or reno mattresses and geotextiles, re-vegetation of profiled slopes, erosion berms, drift fences with hessian and silt traps.
- It must be ensured that flow connectivity along the wetland features is maintained.
- Monitor rivers and wetlands for incision and sedimentation.
- Implement a water quality and quantity monitoring programme.
- The EWR as set out in the Reserve Determination Volume 1: River (Report P WMA 12/T30/00/5212/7) for the Ntabelanga Dam and the Lalini Dam, must be adhered to at all times.
- Develop a Water Management Method Statement (WMMS), including measures for water conservation, for approval by the Engineer prior to the commencement of the works.
- Construction personnel accommodation on site must be as limited as possible.
- Construction workers should, as much as possible, be recruited from neighbouring communities and transport provided to the construction site(s).
- Local residents should be recruited to fill semi-skilled and unskilled jobs.
- Women should be given equal employment opportunities and encouraged to apply for positions.
- Ensure that the appropriate procurement policies are put in place and closely followed.
- Ensure that all consultation is gender inclusive.
- Ensure that the Decisions Register is maintained, and is available to any member of the public who wishes to access it.

e) *Key mitigation measures to be implemented during the operation phase*

- Implement a communication strategy for the operation phase.
- No hunting or trapping of faunal species by operational staff is to occur.
- Aquatic bio-monitoring must take place and if any trends are observed where impacts on the aquatic ecology is becoming unacceptable, measures to reduce the impacts must be immediately implemented.
- An alien vegetation control programme must be maintained, as encroachment of alien vegetation is already apparent in the study area and special attention needs to be given to areas disturbed during the construction process.
- Rehabilitation of disturbed areas, utilising indigenous wetland vegetation species, will assist in retaining essential wetland ecological services, particularly flood attenuation, sediment trapping and erosion control, and assimilation of nutrients and toxicants.
- The EWR as set out in the Reserve Determination Volume 1: River (Report P WMA 12/T30/00/5212/7) for the Ntabelanga Dam and the Lalini Dam, must be adhered to at all times.
- During operation and maintenance of infrastructure, vehicles must remain on designated roads and not be permitted to drive through sensitive wetland / riparian habitat, particularly on the edges of the dam where loss of wetland habitat and therefore ability of the wetlands to provide ecological services, is already compromised.

- Maintenance personnel must ensure that any tools and/or waste products resulting from maintenance activities are removed from the site following completion of maintenance.
- Regular maintenance of all roads, with specific mention of wetland / riparian crossings, must take place in order to minimise the risk of further degradation to wetland / riparian habitat.
- Ensure that the Decisions Register is maintained, and is available to any member of the public who wishes to access it.
- The use of the access road to the hydropower plant by vehicles must be controlled by way of a manned boom gate or other suitable control system.

f) Biodiversity Offsets

The Mzimvubu Water Project will inundate wetland and riparian habitats that are breeding and foraging areas for protected and endangered cranes. The access road to the hydropower plant site also traverses a highly sensitive area. These impacts have been assessed by the ecologist to be of high significance. It is not possible to avoid, minimize or rehabilitate the impact completely.

The only mitigation measure that could potentially reduce the residual negative impact significantly is an offset. One of the difficulties associated with a biodiversity offset is that during the EIA, it was not possible to establish whether suitable offset areas exist in the catchment, especially if a like for like principle is applied.

The process to be followed would be to compile a detailed Baseline Report of the areas to be lost, to reach agreement of the offset ratios/principles, identify offset options, then implement and manage them indefinitely.

Although the likelihood of successful and sustainable implementation of a biodiversity offset is questionable, the Environmental Assessment Practitioner (EAP) is confident that some form of conservation initiative aimed at cranes could be implemented somewhere in the province. This option has also not been investigated any further during the EIA, but offers a wider selection of implementation options.

In order to estimate a budget for implementing a traditional biodiversity offset, the area of wetlands and riparian vegetation to be inundated was calculated (approximately 412 ha at the Ntabelanga Dam and 623 ha at the Lalini Dam site), multiplied by an offset ratio associated with the vegetation type (8:1 for Ntabelanga and 17:1 for Lalini) and multiplied by a factor of 3 to allow for the practical packaging of land parcels, in order to estimate an amount of land that would have to be acquired and set aside for protection.

Any current use of this land will have to be compensated for. This is expected to be mostly grazing as dwellings are seldom located in wetlands or river beds and banks. If a budget of R2 000 per ha is used to cover these costs, then approximately R90 million is required to make the land available.

An additional R10 million will be required to implement the offset. The Environmental Assessment Practitioner (EAP) therefore recommended that the planning and initiation of some form of crane conservation project, such as contributing funds to existing projects that protect cranes or their foraging and breeding areas elsewhere in the province, be stipulated as a condition of the authorisation of this project, and that a budget amount of R100 million be incorporated into the planning process, split between the Ntabelanga Dam and the Lalini Dam schemes.

8.9.3 Environmental Management Programme

An environmental management programme for construction was prepared as part of the EIA process and submitted to DEA for approval.

It is a requirement for project implementation that the EMP and its implementation programme forms part of the tender and contract documentation for construction of the dam and other infrastructure. Compliance with the EMP is compulsory for all contractors and sub-contractors appointed for this project.

An Environmental Management Plan (EMP) for the rock quarry and borrow areas (sand and earthfill materials) was prepared as part of the EIA process and submitted to Department of Mineral Resources for approval. An additional requirement for the quarry and borrow areas, since 8 December 2014, is an environmental authorisation from DMR. An EIA therefore needs to be done for the quarry and borrow areas.

The conditions and requirements contained in the environmental authorisation from DMR and EMP shall be incorporated into the tender documents for the quarry and borrow areas for both Ntabelanga and Lalini components of the conjunctive scheme. These conditions and requirements are compulsory during the development, operation and closure of the quarry and borrow areas.

9. INSTITUTIONAL ARRANGEMENTS

9.1 National Water Institutional Arrangements in South Africa

Figure 9-1 shows the current water institutional arrangements in South Africa. The various key roleplayers are described below.

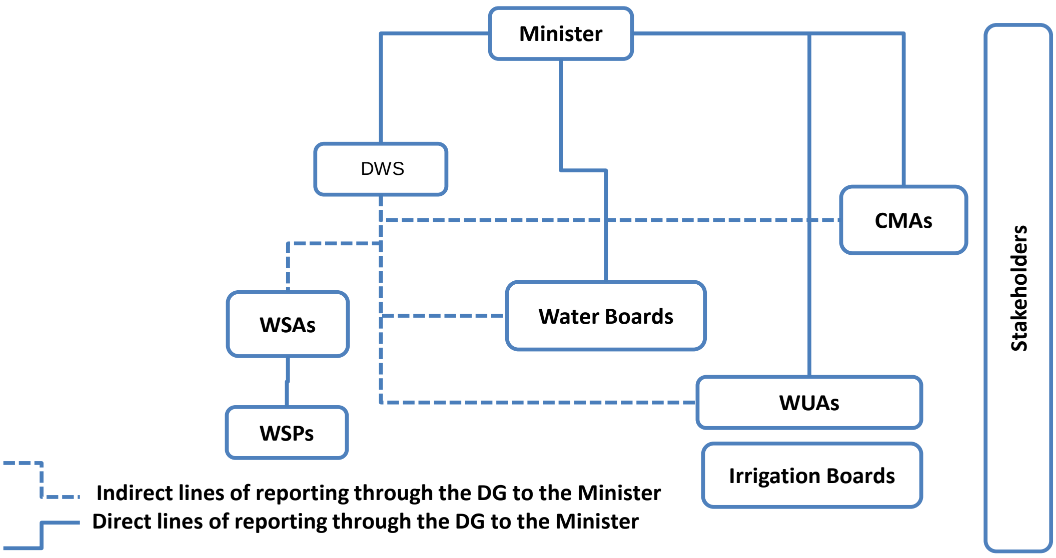


Figure 9-1: Current Water Institutional Arrangements in South Africa

9.1.1 Department of Water and Sanitation

The Department of Water and Sanitation (DWS) is responsible for the planning and implementation of this project as well as water sector policy, support, regulation and water resource management.

9.1.2 Water Boards

Water Boards are state-owned regional water services providers who may provide both bulk services to more than one Water Services Authority area (regulated directly by DWS) and retail services on behalf of Water Services Authorities (regulated by contract with the Water Services Authority). The Minister of Water and Sanitation is the primary regulator of a Water Board.

9.1.3 Catchment Management Agency

Catchment Management Agencies (CMA) undertake water resource management at a regional or catchment level and involve local communities, within the framework of the national water resource strategy. Regulation of CMAs is the responsibility of the Minister of Water and Sanitation.

9.1.4 Water User Associations

Water User Associations (WUA) operate at a restricted localised level, and are in effect co-operative associations of individual water users who wish to undertake water related activities for their mutual benefit. A water user association may exercise management powers and duties only if and to the extent these have been assigned or delegated to it. Regulation of WUAs is the responsibility of the Minister of Water and Sanitation.

9.1.5 Irrigation Boards

Irrigation boards were established in terms of law in force before the commencement of the NWA. The Act mandates that a board may continue to exist until it is declared to be a water user association or until it is disestablished in terms of the law by or under which it was established. The NWA contends that Irrigation Boards must submit a proposal to transform to a WUA, within 6 months of commencement of the NWA.

9.1.6 Water Services Authorities

Water Services Authorities (WSA) can be a metropolitan municipality, an authorised district municipality or an authorised local municipality which is responsible for ensuring provision of water services within their area of jurisdiction. Whilst these municipalities and WSAs fall under the responsibility of the Department of Cooperative Government and Traditional Affairs, the DWS also plays a regulatory, monitoring and evaluation role for the WSAs.

9.1.7 Water Services Providers

A Water Services Provider (WSP) is a WSA or any person who has a contract with a Water Services Authority or another water services provider to sell water to, and/or accept wastewater for the purposes of treatment from, that authority or provider (bulk water services provider); and/or has a contract with a Water Services Authority to assume operational responsibility for providing water services to one or more consumers (end users) within a specific geographic area (retail water services provider). Management of a WSP is through a contract with a WSA.

9.2 Changes Proposed in the National Water Policy Review

9.2.1 Establishment of Regional Water Utilities

The Minister of Water and Sanitation is responsible for the effective development and management of regional bulk infrastructure. The Department of Water and Sanitation has proposed the establishment of Regional Water Utilities as contained in the National Water Policy Review document dated 30 August 2013. The purpose of these institutions will be to plan, build, operate, support and maintain regional bulk infrastructure.

It is envisioned that Regional Water Utilities can fill the current gap where WSAs have no or limited capacity for managing and developing regional bulk infrastructure. According to the Strategic Framework for Water Services (2003), water boards are able to operate at a regional level as a bulk water services provider. The role and structure of water boards may change over time with the development of Regional Water Utilities.

9.2.2 Disestablishment of Water User Associations and Irrigation Boards

The transformation of Irrigation Boards to Water User Associations has been slow, with 129 that have still not transitioned since 1997. Transformed WUAs have also not sufficiently achieved participation of other users such as municipalities. In addition, the DWS is finding it challenging to provide oversight to a large number of WUAs. As a result of these, and other reasons, the DWS has decided that as CMAs are established in WMAs, the WUAs and IBs will be disestablished and functions will be delegated to CMAs and Regional Water Utilities.

9.3 Water Institutional Arrangements in Project Area

9.3.1 Department of Water and Sanitation Regional Offices

The DWS Eastern Cape Region has offices in King Williams Town and East London. The DWS officials are responsible for the governance of the water resources, and the planning of regional bulk infrastructure in the area. In addition, due to the fact that the Umzimvubu-Tsitsikamma CMA is not functional as yet, the EC DWS office fulfils these functions as well. The operation of DWS dams in the province is contracted to Amatola Water.

9.3.2 Amatola Water Board

Amatola Water is one of 20 water boards and utility organisations belonging to the South African Association of Water Utilities and mandated by the South African Government to operate as a water services provider to municipal authorities and certain other water customers, as provided for in national water legislation.

The utility`s primary business is to service the bulk treated water requirements of urban, peri-urban and rural communities situated within a gazetted services area (see blue boundary in Figure 9-2[9]) which is some 43 400 km² in extent and is located within the central region of the Eastern Cape Province. With its headquarters in East London in the Eastern Cape Province, Amatola Water operates eleven water treatment plants and seven sub-regional, bulk distribution networks in a designated services area of 45 794 km² covering most of the Amathole and part of the Chris Hani District Municipalities.

It offers comprehensive contract services to municipalities for water abstraction, treatment, bulk supply and water quality monitoring for domestic, industrial and agricultural use. In response to market demands and opportunities Amatola Water has developed its supplementary servicing capability.

Service agreements are devised for the operation and maintenance of customer-owned water treatment plant and reticulation installations. Amatola Water supports these services with complementary managerial, technical, laboratory and related specialist advisory services tailored to the needs of major industrial and other institutional customers (www.amatolawater.co.za).

9.3.3 Catchment Management Agency

No CMA is established in the catchment as yet.

9.3.4 Water User Associations

No WUAs are established to date. Considering the intent of DWS to disestablish WUAs, it is not recommended to establish such bodies.

9.3.5 Irrigation Boards

No Irrigation Boards are established in the area.

9.3.6 Water Services Authorities

The three WSAs that will benefit from the Mzimvubu Water Project are: OR Tambo DM; Alfred Nzo DM; and Joe Gqabi DM. The WSAs have the ultimate responsibility to ensure service delivery in their jurisdiction, and more specifically are responsible for the governance of any WSP; water services development planning; and the technical and financial sustainability of the infrastructure. The historical poor performance of some of the WSAs in performing these functions is a concern.

9.3.7 Water Services Providers

The OR Tambo DM and the Alfred Nzo DM both perform the WSP function in their jurisdiction. Joe Gqabi DM, has contracted the local municipalities within its jurisdiction to perform this function. The part of the Mzimvubu Water Project that falls within Joe Gqabi DM lies in the Elundini LM.

[9] *From presentation to Portfolio Committee on Water Affairs and Forestry 2006*

Figure 9-2: Amatola Water Area of Operation

9.4 Energy Related Institutions

9.4.1 Department of Energy

The Department of Energy (DoE) is responsible for ensuring that diverse energy resources are available, in sustainable quantities and at affordable prices in support of economic growth and poverty alleviation. It must further provide for energy planning, increased generation and consumption of renewable energies, and contingency energy supply. The DoE has an important role to play in the decision making regarding the hydropower plant planning, ownership, management, and the provision of electricity into the national grid.

9.4.2 National Energy Regulator of South Africa

As the energy regulation body of South Africa, National Energy Regulator of South Africa (NERSA) is an important stakeholder in this project. Any decisions regarding the selling of electricity generated from the hydropower plant must first be approved by NERSA before it can be implemented.

9.4.3 ESKOM

ESKOM is the national electricity supplier in South Africa. As such, it is an important institutional stakeholder in the planning and implementation stages of this project.

There are various options as far as the extent of involvement of ESKOM as an owner and/or operator of the envisioned hydropower plants, or at least as the operator of the national grid for transmission of surplus electricity generated by the plant.

9.5 Possible Institutional Arrangements for the Mzimvubu Water Project

9.5.1 Ntabelanga Dam

The DWS can operate and maintain the Ntabelanga dam or contract this function to Amatola Water as it does for 21 other dams in the EC Province.

This could be facilitated through an addendum to the current dam management contract.

Alternatively, if the DWS establish a Regional Water Utility, this function may be delegated to this new body. The DWS will remain the owner of the dam regardless of the management arrangement chosen.

9.5.2 Regional Primary and Secondary Bulk Infrastructure

Amatola Water has cemented its reputation as a high quality water management institution through its consistent good performance in the Blue Drop certification programme. Although the water board does not operate any infrastructure within the project footprint area, the water board works closely with all of the DMs.

Amatola Water would be the obvious institution to take on the ownership and management of the water and waste water treatment works, and the regional bulk infrastructure associated with the Mzimvubu project. This regional bulk infrastructure also includes the raw water system that is planned for the distribution of water for agricultural purposes. The ownership, management and operations of this could reside with Amatola Water up to the property boundaries of each planned farm.

Alternatively, if the DWS establish a Regional Water Utility, these functions may be delegated to this new body.

9.5.3 Tertiary Potable Water Distribution Networks

Amatola Water, together with engineering consultants, are in the process of planning and implementing regional bulk water schemes for provision of potable water to the end users, which schemes include many of the settlements in the proposed Ntabelanga Dam water supply area. These schemes are being implemented on the basis of integration with the proposed Ntabelanga Dam primary and secondary bulk water pipeline system.

Preliminary layouts have been developed for the tertiary network that can deliver water from the primary and secondary systems to the DM's customers. The final design and implementation of these tertiary systems will remain the responsibility of the DMs who are the applicable Water Services Authorities (WSA) in the area – namely Alfred Nzo District Municipality, OR Tambo District Municipality, and Joe Gqabi District Municipality.

This infrastructure, once it is built and commissioned, will be owned, operated and maintained by these WSAs. Thereafter, all capital and operations and maintenance responsibilities will reside with these WSAs. They will need to ensure sufficient revenue is generated from consumers, coupled with grant income from the fiscus to manage this infrastructure in a sustainable manner.

These WSAs may sub-contract part or all of the functions to operate and maintain the infrastructure to a third party, but still remain legislatively responsible for the function.

The capability and capacity of the three DMs to manage the tertiary infrastructure from the Mzimvubu Water Project needs to be reviewed and strengthened.

9.5.4 Irrigation Raw Water Infrastructure

Bulk raw water supply infrastructure for irrigation purposes will be provided to the border of each of the proposed new farming units. The construction, management and operation of the on-farm developments will be the responsibility of the farm owner. The recommendation is that the new farmers be provided with the necessary financial and technical support until they are able to run viable commercial farming enterprises independently.

9.5.5 Hydropower Scheme

The hydropower scheme is considered to be an essential element in the long term sustainability of the Mzimvubu Water Project, as it has the potential of providing a significant and continuous surplus income stream to subsidise the costs associated with the capital investment, and the operation and maintenance of the infrastructure. Careful consideration as to whether, and through what mechanisms, DWS can retain ownership of the plant is required. Investigation into these options has not yet been undertaken.

The options as they are seen at present include, but are not limited to:

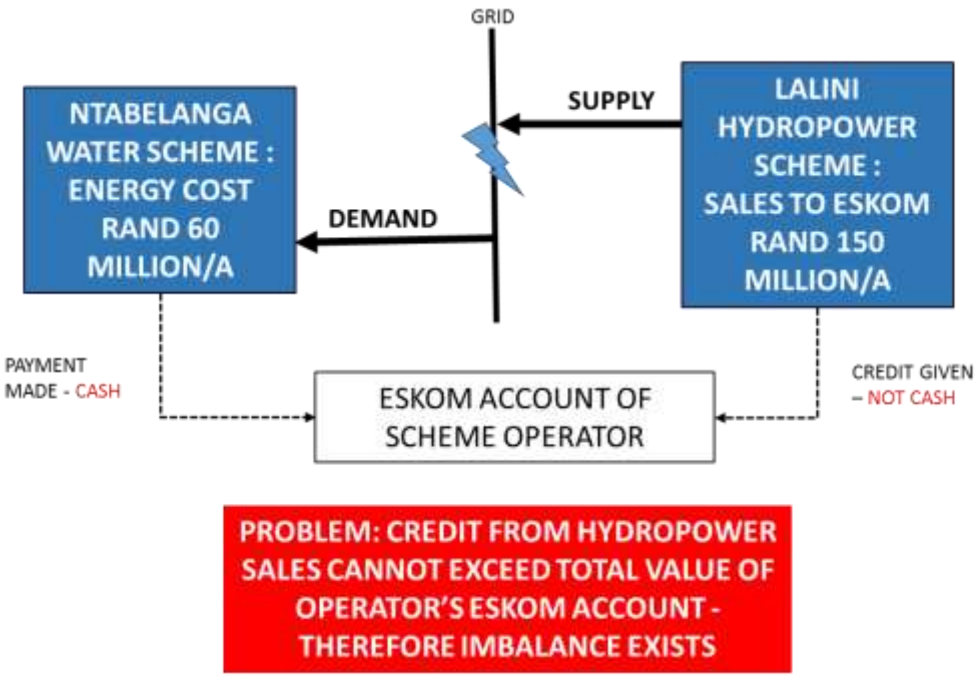
- DWS own, manage, operate and maintain the hydropower plant,
- DWS retain ownership, but enter into an agreement with a public (ESKOM) or private (IPP) body to manage and operate the hydropower plant, or
- The hydropower plant is transferred to ESKOM who own, manage and operate the plant.

The first two options would require a bilateral trade/wheeling arrangement with ESKOM. Bilateral trading involves generators and buyers (typically large customers) entering into bilateral contracts for the sale of electricity. Wheeling will occur when there is a bilateral trade and involves the transportation of electrical energy over the network of a party that is not the owner of that energy.

The wheeled power is injected by the "seller" (a generator) into the network of the party owning the network and extracted by the "buyer" (an electricity consumer) at a point of delivery (POD) on the network. A wheeling arrangement does not directly reduce the capacity required on the network and therefore network access charges are payable by the generator for the cost of the delivery of the energy to the buyer. This is illustrated in Figure 9-3.

The "wheeling" transaction results in a financial reconciliation on the ESKOM bill for the energy bought under the bilateral trade and includes the use-of-system charges associated with the delivery of the energy (wheeling charges) (ESKOM Wheeling of Energy Brochure, September 2012).

This transaction does not involve ESKOM paying the independent generator in cash for the energy delivered into the grid. Instead, a credit is given to the generator entity for its normal power consumption. This means that if the energy delivered into the grid has a value greater than that billed to the generator by ESKOM, there would be an imbalance and no additional cash payment would be forthcoming from ESKOM. As an example, it is likely that the revenue from the energy delivered to the grid from the Ntabelanga and Lalini conjunctive scheme would significantly exceed the total energy consumption bill of Amatola Water[10] which would mean that a wheeling arrangement would probably not be viable.



Note: Financial figures given are for illustration purposes only

Figure 9-3: Basic Concept of the Wheeling of Energy

[10] *Currently Amatola Water's ESKOM account is R30 to 40 million per annum which would rise to about R 90 million, if it became the conjunctive scheme operator..*

9.5.6 Amatola Green Power

Amatola Green Power (Pty) Ltd (AGP) is an electricity trading company based in Port Elizabeth operating independently from ESKOM or municipalities, subject to the Electricity Act and the National Electricity Regulator. The technology and energy sources that AGP utilises for the generation of electricity are environmentally friendly, reducing the emission of Green House Gasses into the atmosphere, hence the reference to Green Power.

In February 2009 the National Energy Regulator of South Africa (NERSA) awarded AGP with a Licence to trade Green Power within the framework of the voluntary willing buyer, willing seller market (Licence No TRD01/ELC/09). The licence is very restrictive in its conditions and in order to record a successful transaction, the trader has to submit proof of compliance with the licence and the market rules to NERSA.

AGP rents the electrical networks from ESKOM and Municipalities via wheeling agreements which are entered into and pays a fee where required.

AGP could have a role to play in the Mzimvubu Water Project in the wheeling of power generated by the proposed hydropower plants.

The final decision as to the institutional arrangements for the hydropower plant should be based on the option that has the highest financial return to maximise the economic benefits for DWS, and the Eastern Cape, but must also be sustainable from an institutional perspective.

9.6 Implications of the Revised Raw Water Pricing Strategy

The Lalini component of the conjunctive scheme does not include usage of raw water for the purposes of potable water supply or irrigation. The Raw Water Pricing Strategy therefore is more pertinent to the Ntabelanga Dam component, but this full section is retained herein for completeness. The Raw Water Pricing Strategy (2007) is under review at present. The information below is taken from the Revised Water Pricing Strategy for Raw Water – new elements/approaches (August 2013). Several of the proposed changes have an implication for the Mzimvubu Water Project. The report also includes relevant elements that will be retained from the existing Strategy.

The strategy focuses on the use of raw water from the water resource and/or supplied from government waterworks and the discharge of water into a water resource or onto land. It covers the setting of prices by DWS as well as by water management institutions as defined in the NWA and does not deal with the pricing of water services. However, the raw water charges are imposed on all water users, and thus affect the input costs of water services, and therefore the water services tariffs down the value chain.

9.6.1 Understanding the changes

The new pricing strategy aims to achieve the goals of protecting the poor (equity) and the application of business principles (setting charges based on full cost recovery). The benefits are summarised in Table 9-2.

Table 9-1: Proposed Improvements on the Pricing Strategy

User Group	Improvements to the strategy	
	Equity	**Application of Business Principles**
High Assurance Users	No equitable share applied. Ensures that those users who get the highest assurance of supply pay for that privilege	
Industrial Users	No equitable share applied. Ensures that users who use water for commercial purposes pay the full cost of water	
Municipal Users	Subsidises the water resources related costs of providing a basic water supply, which are not covered in the equitable share.	Ensures the costs of providing water to the municipality above 50 lcd for the indigent population are fully covered by water use charges
Agriculture Users	Phase in water charges for resource poor farmers over ten years to enable them to establish themselves effectively before having to pay the full costs. Phase in the future infrastructure build charge to commercial farmers over ten years to enable them to adjust to the increase in tariffs.	Ensure that commercial agriculture users pay the full cost of water with transparent and targeted subsidies determined by DAFF and Treasury in relation to national agricultural objectives.

9.6.2 Water Use Categories

The proposed new categories are as follows:

- Stream-flow Reduction Activities
- Agriculture
- Municipal
  - Metros
  - Small towns
  - Poor rural municipalities
- Industrial/Mining
- High Assurance Use, and
- Hydropower

The main changes in these categories are the split of the formerly Domestic and Industrial category into two separate groups, Municipal and Industrial/Mining, as well as the addition of the High Assurance Use, representing users with an assurance of supply of 99.5%.

A category of hydropower has also been introduced to be able to charge for water use by small scale hydropower plants that are due to be developed as part of the energy mix in the country.

9.6.3 Water Resources Management Charge

Current water use charges are in many cases too low. This results in non-viable institutions, sub-optimal water resources services and overall deterioration of the water resources. There is therefore a need to adjust to higher real charges within a limited time period to accommodate the cost of effective and financially sustainable water management institutions, taking cognisance of affordability constraints within user sectors. There is also a need for fiscal support for the activities of CMAs.

The new raw water pricing strategy therefore introduces a water resources management charge (WRMC) to cover the costs of the management and operations of CMAs. The charges will be based on registered volumes for each user, and will not be subsidised. The calculation of the charge will be per water user category based on the activities and assurance of supply.

Agriculture is at present subsided with regards to the water resource charge via a cap on the maximum charge per m^3. This capping is to be removed over a five year period, decreasing at 20% per annum, and the full WRMC is to be applied after those five years to the irrigation sector with targeted subsidies to be applied as determined by DWS in consultation with DAFF and National Treasury and as supported by fiscal subsidies. Such subsidies will be determined in line with national development objectives, and with transformation objectives relating to race and gender and to the reduction of inequality in South Africa. These subsidies will be paid directly to DWS.

The WRMC for resource poor farmers and tree growers will be phased in over ten years, from the date of registration of the water use, with no charge imposed for the first five years, and the charges then imposed incrementally at 20% per annum until the full charge is imposed by year ten.

9.6.4 Water Resources Infrastructure Charges

If water use charges are too low, they will lead to underinvestment, lack of maintenance and unwarranted fiscal subsidies. There is therefore a need to adjust to higher real charges over time to accommodate the cost of investing in supply capacity to meet rising demand and to maintain and refurbish existing infrastructure. There is also a need to invest in economic regulation of infrastructure financing and management. The charges are applicable to all users receiving water from a government waterworks.

The charges will include:

- Operations and Maintenance (O&M) charge
- Depreciation and Refurbishment Charge
- Future Infrastructure Build Charge (FIBC - replaces the Return on Assets Charge)
- Basic Human Needs Water Charge (BWC)
- Capital Unit Charge

Table 9-2: Water Charges under Different Scenarios

Charge to be Levied	Existing Schemes			New Projects	
	Commercial portion of schemes funded from exchequer	Social portion of schemes funded from exchequer	Funded off-budget and debt has been repaid	Fully or partially funded by Government (social)	Off-budget funded portion of scheme
Operation and Maintenance	Yes	Yes	Yes	Yes	Yes
Depreciation/ Refurbishment	Yes	Yes	Yes	Yes	Yes
Future Infrastructure Build Charge	Yes	No	Yes	No	No
Basic Human Needs Charge	No	Yes	No	No	No
Capital Unit Charge	No	No	No	No	Yes

Operation and Maintenance charges will be recovered on a scheme or system basis or on a national basis for basic human needs. These charges (which include direct and indirect costs) can be recovered either on an actual cost recovery basis or through an Operations and Maintenance (O&M) Charge that is based on the forecast of annual O&M costs and of water use.

The depreciation charges will be used to refurbish existing assets on a prioritised basis, as and when required. Thus, the depreciation portion of the revenue will be used for the refurbishment of infrastructure assets from a dedicated refurbishment fund. On schemes funded off budget, the depreciation charge will only be applicable once the loans have been repaid. If refurbishment is required during the repayment period, a refurbishment charge will be arranged by agreement between the parties. The hydropower water use category is exempt from the depreciation charge.

The Future Infrastructure Build Charge (FIBC) is intended to fund infrastructure that is aimed at the stimulus of social and economic development. Where infrastructure development has both a commercial and social use, the FIBC will only fund the social portion, and the remainder of the funding will need to be financed through loans.

The Basic Human Needs Water Charge (BWC) is intended to cover a portion of the water resources related depreciation and O&M costs of ensuring the provision of water for basic human needs.

Water that has the BWC levied on it will not also pay for the FIBC levy. Any water use above the BWC volume for municipalities, and all registered water use by non-natural persons and other enterprises, excluding hydropower, will have to pay the FIBC.

The FIBC levied on agriculture will be phased in over ten years to reach the same level as the other sectors, to give agriculture time to adjust to the considerable change in the cost of water.

The Capital Unit Charge (CUC) is intended to fund the cost of loan funding raised for the development of off-budget schemes. All social users on schemes with CUC levied on will be exempt from paying CUC because it will be subsidised. This charge will apply to all future schemes yet to be developed.

9.6.5 *Specific Application to Hydropower*

Charges for hydropower generation are proposed to be based on c/kWh (cent per kilowatt hour) of energy generated and a fixed charge based on kW installed, instead of the cent per cubic meter of water use charged for raw water abstraction, which is neither practical nor applicable.

If, however, a hydropower generation operator requires water to be released from a dam to generate power at times that such water would NOT be used by other downstream water users, resulting in a loss of water stored in a dam, the abstraction related water resources management and infrastructure charges should apply to this volume of water. In such instances the hydropower generator would need to acquire a water use licence for the taking of water which qualifies as a section 21 (a) water use in terms of the NWA.

Small hydropower plants with a capacity of less than 20 MW should be charged as follows:

Table 9-3: Proposed Hydropower Usage Tariffs

	Hydropower plant integrated within DWS's infrastructure at the dam (Scenario A)	**Hydropower plant developed downstream of DWS's infrastructure and downstream of the dam wall (Scenario B)**
Fixed charge	R10.00 / kW per annum	R5.00 / kW per annum
Variable charge	R 0.01 / kWh	R0.01 / kWh

9.6.6 *Implications for the Mzimvubu Water Project Economic Modelling*

This section again relates to the conjunctive Ntabelanga-Lalini scheme and not just to the Lalini Dam and Hydropower Scheme, as it is envisaged that both schemes must operate conjunctively under a suitable Special Purpose Vehicle or similar entity.

From the above changes to the raw water pricing strategy, one can see a number of salient points that must be taken into account:

- It is most likely that the benefits of the additional income DWS will generate through the FIBC, BMC and other charges will *not* be realised in time for the project, and loan/grant funding will need to be sourced.
- With the socio-economic status of the people in the project area primarily being indigent, the users will benefit from the way the BWC will be structured, as rural municipalities will most likely only be expected to pay 25% of the charge. This reduction in cost should allow for better sustainability of the WSAs. The funding gap between the BWC and the full cost of providing the water will be subsidised by national grants such as the Equitable Share. The FIBC will need to be paid by the WSAs for all water use above that allocated for basic needs. This highlights the importance of the metering and control of water use to ensure that all water above basic needs is paid for by users.

- The agricultural users that are envisioned to benefit from the new infrastructure, will not be required to pay water use charges for the first 5 years after registration of water use, but thereafter they will be liable in increasing percentage until at year 10 they will be required to cover the full charges as per their registered water use. If it is deemed necessary for some or all of the users to receive subsidies beyond this period, this will need to be resolved by the Department of Agriculture, Forestry and Fisheries and National Treasury.

- If ownership of the hydropower plant resides outside of the DWS, it will be subject to a per kW "water use" charge.

A summary of planned raw water charges for the various water use categories within the conjunctive scheme is given in Table 9-5.

9.7 Recommendations

A clear understanding by the implementing entity of current mandates and accordingly roles and responsibilities within the project will be fundamental. It will thus be important to avoid interposing structures or creating entities to undertake roles and responsibilities that are already supposed to be undertaken by existing entities. As a part of the sectoral co-ordination process, terms of reference will need to be provided to each entity or structure that will be involved in the implementation and operation of the scheme.

The role of the Presidential Infrastructure Co-ordinating Commission (PICC) and the impact of the Infrastructure Development Act will need to be taken into consideration, as this may provide for existing inter-governmental platforms being replaced with new approaches. It is assumed that the PICC will continue to co-ordinate the planning and management of the project, presumably through the TCTA, who have been mandated with this role under the SIP3 programme.

It is suggested that a "Regional Co-ordination Unit" be tasked with co-ordination of sectoral role players at a regional level. At present, the Eastern Cape Socio Economic Consultative Council (ECSECC) has been tasked to champion this role on behalf of the Integrated Wild Coast Development Forum, and it is through this organization that such Provincial co-ordination might best be channelled during implementation notwithstanding recognition of the role that the TCTA is still playing as regards SIP3 co-ordination.

DWS itself must licence water use to achieve the broader socio-economic objectives. It currently still has a large role to play in motivation and instigation of the sourcing of grant funding to implement the scheme components prior to any other Special Purpose Vehicle (SPV) or similar body being appointed to manage this process.

In the medium to longer term, the overall scheme components design, construction and operation should be linked, and be managed by a special purpose vehicle/implementing agency, such as the TCTA or a new RWU, as this would have advantages from a risk management perspective. TCTA have undertaken this role very successfully on several large projects, including the Berg River Dam in Western Cape, and would be well qualified to undertake this role. They already have the experience and capabilities to source government grants, donor funding, and other project finance at very beneficial terms and conditions.

It is recommended that the hydropower component be operated within the same ring-fenced conjunctive scheme as the potable and bulk raw water supply components, so that the financing, operation, maintenance and management, and cashflows can be integrated to maximize the economic and social benefits of this region.

This would require the appointment of a specialist service provider with the skills and capacity to manage, operate and maintain the hydropower plant and associated works.

One other option that could be considered would be to invite interest in suitable IPP investors to bring partial equity into the financing equation (i.e. a PPP arrangement), although this might not be attractive to such IPPs due to a limited internal rate of return.

The institutional and financial flow diagram in Figure 9-4 assumes the overall management of the conjunctive scheme by a Special Purpose Vehicle (SPV) such as the TCTA, and shows the various organisations involved in the scheme, the flow of revenue from energy and bulk water sales, financing arrangements, and operational roles and responsibilities should the recommended model be adopted.

The PICC, Inter-Ministerial Committee (IMC) and three key departments (Department of Energy (DoE), DWS and DAFF) all play important roles in oversight and regulation - ensuring that the project is planned, constructed and managed to the standards required in national legislation, and fulfils the agreed regional priorities for economic growth and social upliftment. Co-ordination and co-operation at this senior level is essential if the project is to be successful.

The SPV is central to the project, playing a hands-on oversight and co-ordination role, is responsible for contractual management of the services providers, and a regional co-ordination role with all the relevant stakeholders in the Eastern Cape.

Importantly, the SPV is also responsible for initiating and managing the financing of the project, and the repayment of any loans/grants as required. This critical planning aspect of the project will be a determining factor for the finalization of institutional and contractual arrangements. Due to the nature of the role that this SPV needs to play right from the initiation of project design, it is imperative that the appointment of such an organization to fulfil this role is done as a matter of urgency.

The financing and implementation of all the capital components of the conjunctive scheme (but not the tertiary systems, which would be the responsibility of the WSPs/DMs) would fall under the SPV.

Once the scheme has been implemented and commissioned, the operating costs of the SPV will be covered through the net income generated from the energy sold into the ESKOM grid. The TCTA is an already established organization that specializes in these functions and would be a clear front-runner in the choice of an SPV company.

One option would be that ESKOM would purchase the power generated by the two hydropower schemes, and all the income from these sales will be paid to the SPV. In turn, ESKOM would invoice all energy costs for the entire project to the SPV (and not the water supply scheme operator). However, ESKOM only allow this on the basis of crediting existing user accounts, and the surplus generated would not be made available to the SPV in the form of cash payment.

Table 9-4: Summary of the Planned Raw Water Charges per Water Use Category

WATER USE CATEGORY	WATER RESOURCE MANAGEMENT CHARGES	INFRASTRUCTURE RELATED CHARGES	WASTE DISCHARGE CHARGES	PHASING IN OF CHARGES
Municipal and Industrial	Full cost recovery on abstraction and waste discharge related costs	On-budget GWS: Depreciation; FIBC, O&M Off-budget GWS: CUC, Refurbishment, and O&M; and FIBC post payment of loans;	Full costs of mitigation charge	WRM charges in place Waste discharge charges to be implemented after registration of waste users as per catchment specific plans
High Assurance Use	Full cost recovery on abstraction and waste discharge related costs	On-budget GWS: Depreciation; FIBC, O&M Off-budget GWS: CUC, Refurbishment, and O&M; and FIBC post payment of loans;	Full costs of mitigation charge.	WRM charges in place Waste discharge charges to be implemented after registration of waste users as per catchment specific plans
Stream Flow Reduction Activities: Commercial growers	Excludes cost of Dam Safety Control and waste discharge management	N/A	N/A	N/A
Stream Flow Reduction Activities: Resource poor growers	Excludes cost of Dam Safety Control and waste discharge management; Waived for first 5 years after registration and phased in over the five year period that follows. Subsidy starts at 100% for five years, then reduces by 20% annually.	N/A	N/A	No charge for forest plantations ≤ 10 hectares. WRMC phased in over ten years

WATER USE CATEGORY	WATER RESOURCE MANAGEMENT CHARGES	INFRASTRUCTURE RELATED CHARGES	WASTE DISCHARGE CHARGES	PHASING IN OF CHARGES
Irrigation: Commercial farmers	Full recovery of allocated costs	GWS: Full recovery of Depreciation plus O&M on existing schemes. FIBC phased in over 10 years. Full financial cost recovery for new schemes. Targeted subsidies to be provided as determined by DAFF and National Treasury	N/A	FIBC to be phased in over 10 years
Irrigation: Resource poor farmers	Waived for first 5 years after registration and phased in over the five year period that follows. Subsidy starts at 100% for five years, then reduces by 20% annually.	GWS: FIBC, O&M and Depreciation charges waived for a 5 year period and phased in over the five year period that follows on existing and new schemes. Subsidy starts at 100% for five years, then reduces by 20% annually. Capital subsidies available under certain conditions. Targeted subsidies to be provided by DWS for water resources infrastructure or purchase of water allocations.	N/A	Consumptive charges subsidised for 10 years from date of registration. Subsidy starts at 100% for five years, then reduces by 20% annually. WRMC: Phased in over 10 years
Hydropower	N/A	Fixed charge in installed capacity and variable charge per kilowatt hour	N/A	All charges immediate on registration or authorization of water use

A preferred solution would be that Amatola Green Power purchase the energy produced by the hydropower plants in cash and recoup their purchase cost in the form of sales of green energy certificates (see the Legal, Institutional and Financing Arrangements Report No. P WMA 12/T30/00/5212/16).

In turn, ESKOM would invoice the SVP for all energy consumed by the project (and not the water supply operator). Apart from its own operational costs, the SPV could also appoint an outsourced hydropower scheme operator to operate and maintain the Ntabelanga-Lalini conjunctive hydropower scheme, which costs would also be borne by the SPV from its net surplus energy income. It is also possible that, through recruitment of suitably qualified and skilled staff and training of others, the hydropower operations could be undertaken in-house by the dam and bulk water supply operator.

The power production could be purely a contracted operation and maintenance service, in which case the capital funding would be funded entirely through the finance raised by the SPV. Alternatively, this finance could be partly provided by the operator via a PPP arrangement, although the financing models indicate that any repayable finance above 25% of capital cost would nullify the surplus revenue benefits accruing to cross-subsidize the overall conjunctive scheme. Thus, the difference will be that the PPP option would offer less opportunity to cross-subsidize the energy costs of the water supply scheme components, but this would on the other hand require less grant funding.

The main purpose of the hydropower components of the scheme are therefore to generate sufficient surplus income to finance the SPV operation, to repay loans or even grant funding, and to subsidize the power cost for the production and delivery of bulk raw and potable water.

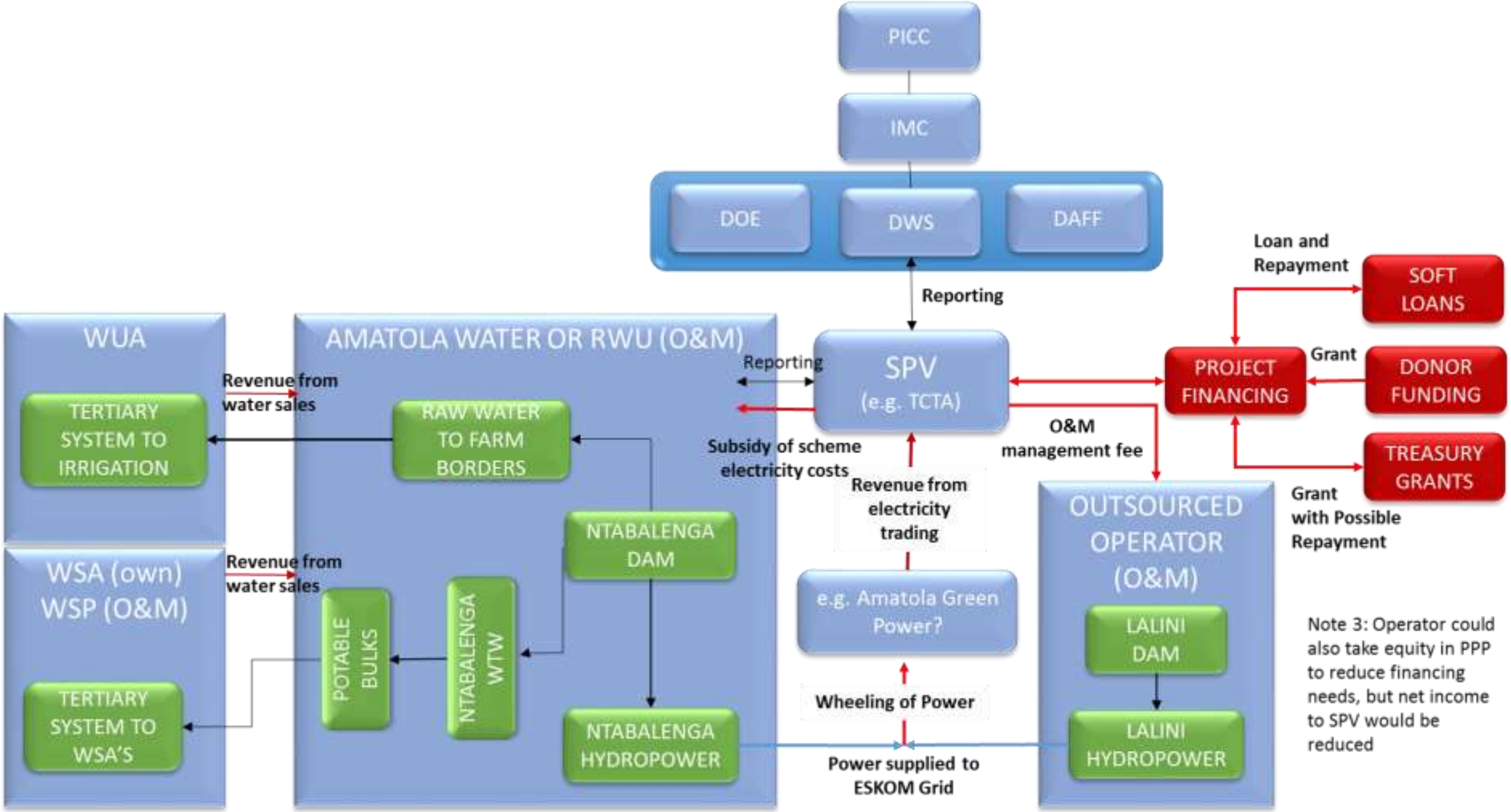
As is shown on the economic and financial modelling the degree of capital grant funding required will mostly depend upon the affordability of water supplied to irrigation and potable water users, and the financial sustainability that this brings to the water supply operator’s business.

The Ntabelanga dam and associated water supply scheme would be funded by the finance sourced through the SPV, but would need to be managed and operated by a regional water utility – at present a function fulfilled by Amatola Water. If they continued to be the operator, Amatola Water would need to cover its operation and maintenance costs through the revenue generated from water sales. Their overall costs of water provision would be significantly reduced due to the subsidized provision of electricity (possibly up to 100% subsidy).

The same operator would also be required to operate the Ntabelanga hydropower plant as well as the delivery of bulk raw water to the new farming units.

A Water User Association (WUA) would represent these new farmers, and they, and the WSAs/DMs would have to pay the operator – e.g. Amatola Water - for the bulk water provided. These organisations will need to ensure that they collect sufficient revenue to cover these bulk water purchases as the operator will rely solely on this income to cover the cost of the operation and maintenance.

Thus the benefit from the surplus energy income will be passed down the value chain to these end users, as the water supply operator will have very low or no energy costs to incorporate into their bulk water charge, thus keeping the bulk water tariff significantly lower.



Note 1: Regional Water Utility (RWU) could eventually include tertiary systems to customers

Note 2: Hydropower operation could also be undertaken in-house by main scheme operator

Figure 9-4: Institutional Roles and Responsibilities and Financial Flow Diagram

Cognisance must be taken that whilst the bulk potable water supply scheme would likely proceed with very high priority, and would be commissioned within a similar timescale to the other major scheme components, but there is a risk that the same might not be the case for the irrigation scheme.

In this latter case, a significantly sensitive and lengthy process will be required to deal with the land reform issues, and to identify and establish new emerging commercial farmers. This process could have many pitfalls along the way, and it is still a possibility that the irrigated agriculture component of the project would either not be realized as commercial farming, or would take much longer to come to the commissioning stage.

Should this happen, in addition to lowering the job creation potential and regional economic development, a further downside would be that the water supply operator would not receive the expected revenue from these bulk raw water supply sales.

The above risks must be realized and taken into consideration from the outset of the implementation of the scheme as they have very significant economic, social and financial cost implications for the whole project.

Another matter to consider is that in order to receive the benefits and surplus revenue from the hydropower components, these should also be ready for commissioning as soon as possible so that the cross-subsidies thus produced are available as soon as possible. If not, then some other “bridging” arrangements might be required to fill this subsidization gap.

Local content of goods and services provided to implement and operate the conjunctive scheme should be maximized to prevent leakage of such economic and employment benefits to other parts of the country, or even abroad. This will maximize the intended upliftment benefits of the project on this region.

9.8 The Way Forward

Budgets for further engineering, facilitation and other activities have been allowed for in the cost estimates, but these activities will need to be urgently initiated, managed and implemented, in a co-ordinated manner.

This will require the co-ordination, planning and management entity to delegate responsibility for this to a dedicated Project Implementation Unit, who themselves will need to co-ordinate with all of the other sectoral roleplayers.

The following list covers the currently envisaged main activities, and others may arise as the implementation process proceeds.

The complexities surrounding the set up and management of a multi-purpose scheme should not be under estimated. Lessons from previous projects across Africa should be taken to heart, and robust, yet flexible legal, institutional and financial arrangements need to be put in place to maximise the resilience and sustainability of the project into the future.

Future activities that will need to be undertaken for the conjunctive scheme include, inter alia:

- ✓ *Appointment of an Implementing Agent/SPV to co-ordinate, plan and manage the integrated scheme components.*
- ✓ *Implementation of the EMP for the works to be constructed, and appointment of service providers to manage and monitor these processes.*
- ✓ *Preparation and implementation of the Relocation Action Plan based upon the Relocation Policy Framework prepared during the EIA process.*
- ✓ *Coordination with the Catchment Restoration and Management Programme – spearheaded by the Department of Environmental Affairs.*
- ✓ *Discussions with DoE, ESKOM and Amatola Green Power regarding the establishment of the principles, terms and conditions and the subsequent application for the establishment of a "wheeling" arrangement for the power produced by the Ntabelanga and Lalini hydropower schemes.*
- ✓ *Applications to ESKOM for power supplies to the works.*
- ✓ *Discussions and agreement with Amatola Water and the three affected DMs, DAFF, and the Eastern Cape Department of Rural Development and Agrarian Reform regarding future institutional arrangements for the ownership, funding, operation and management of the water supplies sourced from the Ntabelanga Dam.*
- ✓ *Additional geotechnical investigations to inform the design of the Ntabelanga Dam, the Lalini Dam, the other associated capital works, and hydropower components.*
- ✓ *Detailed design and tender documents of Ntabelanga Dam and appurtenant works.*
- ✓ *Detailed design and tender documents of the Ntabelanga water treatment works, primary and secondary potable water distribution systems, and bulk raw water distribution system.*
- ✓ *Detailed design and tender documents of Lalini Dam and appurtenant hydropower works.*
- ✓ *Detailed design and tender documents of associated and advance works.*
- ✓ *Appointment of a facilitation unit to manage the consultation and implementation process for land reform and irrigation development.*
- ✓ *Development of a Resource Management Plan that should, inter alia, spell out potential tourism and aquaculture spinoffs from the scheme.*
- ✓ *Appointment of a facilitation unit to provide advice, training and financial assistance to new emerging farmers who would be investing in the new irrigated farm units.*
- ✓ *Procurement and appointment of contractors to construct the capital works – several different contracts.*
- ✓ *Procurement and appointment of Construction Administration and Supervision service providers – several different contracts.*

10. PROJECT COSTS

10.1 Capital Costs

The cost estimate for the Lalini Dam and hydropower scheme, and associated infrastructure is given in Table 10-1.

This does not include any of the Ntabelanga Dam and associated infrastructure which is dealt with in the Record of Implementation Decisions: Ntabelanga Dam and Associated Infrastructure Report No. P WMA 12/T30/00/5212/17.

Table 10-1: Lalini Dam Capital Cost Estimates

COMPONENT	R'million
Lalini dam and associated works	802
Lalini Access Roads and Bridges	487
Lalini land compensation/mitigation costs	50
Lalini water delivery tunnel, shafts and penstocks	756
Lalini hydropower E&M equipment	175
Lalini hydropower civil works	49
Lalini power transmission lines to grid	29
Sub-Total Lalini Dam and HEP	*2 347*
Engineering and EMP Costs (12%)	*282*
Sub-Total Lalini Dam and HEP incl Eng and EMP	*2 629*
Escalation[11] in Each Year @ 5.5% p.a.	*648*
Sub-Total Lalini Dam and HEP incl Eng, EMP and Esc	*3 277*
VAT (14%)	*459*
Add in R22 million per year for catchment management (no esc)	230
Allowance for other offset activities (50% of R100 million)	50
Total Lalini Dam and HEP (incl Esc + VAT)	**4 016**

More detailed costing breakdowns and cashflow projections for each individual project component are given in Report No. P WMA 12/T30/00/5212/15.

It should be noted that there are several risks involved in the accuracy of the above cost estimate:

- Estimating at feasibility level has a confidence level of ± 20%
- Escalation rates could increase or decrease, especially given the currently volatile nature of the economy;
- Rand foreign exchange rates are also volatile and this will affect the cost of all imported materials, services and equipment;
- The timing of the various components implementation may change which, if later, would increase the escalation cost; and
- The amount of non-grant finance is unknown, and if significant will increase costs, depending on the terms of such loans, interest rates and foreign exchange rates.

[11] *Escalation was calculated based upon the expected expenditure cashflow profile as determined by the Implementation Programme. 5.5% p.a. escalation was applied to the proportion of expenditure expected in each future year on a compound basis from the cost estimate base year of 2014.*

One example of the impact of the above risks is that every month's delay in fully implementing a R4 billion project increases escalation cost by R17.9 million (at 5.5% p.a.).

10.2 Estimated Operation and Maintenance Costs

Operation and maintenance costs will to some extent depend upon the institutional arrangements set up to operate the scheme, and the structures and management costs of the one or more entities involved. Economies of scale can be lost if the management and operation of the works is split between several different organisations.

An estimate has been made of the likely management, maintenance and operational costs of these works based upon current costs and salary scales. More details are given in the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15.

Maintenance costs per annum are based upon the percentages of capital cost recommended in the DWS Water Supply Planning and Design Guidelines.

Operational staff costs have been sourced from those currently applied to similar works operated by Amatola Water.

The following are estimates of these annual operating and maintenance costs, but these should be treated with caution pending decisions being made on the eventual institutional arrangements:

Operation and Maintenance Costs	: R20.83 million/a
Staffing costs	: R 6.80 million/a
Power costs	: R 3.00 million/a
Total	: R33.63 million/a

These costs are taken into account in the financing options detailed in the Legal, Institutional and Financing Arrangements Report No. P WMA 12/T30/00/5212/16.

10.3 Project Financing Options

Given the results of the economic analyses, that this is a Strategic Infrastructure Project, and that the majority of beneficiaries are in the indigent category, it is clear that significant grant subsidization funding of the project will be required. This would cover the main capital works, but may also need to include financial assistance to the prospective investors in the proposed commercial farming units.

The Department of Water and Sanitation: Directorate for Economic Regulation is currently undertaking studies to *Revise the Pricing Strategy for Raw Water Use Charges and Develop a Funding Model for Water Infrastructure Development and Water Use and a Model for the Establishment of an Economic Regulator.*

The funding model envisioned in the above studies is one that must focus on the mechanisms and sources to access capital required to develop proposed infrastructure as well as the income required to repay this capital. The final product will be a cost accumulation model that can assess the financial implications of alternative funding options to meet demand.

According to the deliverable “Financial Model User Manual” (March 2013):

“A key function of the model is to determine the impact of a new scheme on:

- *The tariffs to be charged (split between Irrigation and Domestic & Industrial) and as determined by the Pricing Strategy,*
- *The grant funding required (determined by policy considerations relating to social versus economic infrastructure), and resulting from any short-fall on tariffs, and*
- *The projected cash flows over twenty years, demonstrating debt utilisation and distinguishing between capital, operating and debt repayment flows. The cash-flow should also distinguish between sources of revenue (tariffs, up-front payment from users, loans and grants).*

The following inputs are required by the model to generate the above outputs:

- *The projected capital costs (including timing of cash flows)*
- *Operations and maintenance costs (for twenty years)*
- *Cost of capital (Weighted Average Cost of Capital – WACC)*
- *Expected growth rates in utilisation of water supplied by the scheme (Year 1 usage plus expected growth rate thereafter). The volume utilised will need to be split per Scheme Management Parameters (SMP) and per irrigation, domestic and industrial usage. As a default, the existing system ratio will be applied to the new scheme.*
- *Available funding. As a default the model will assume that no grant funding is available. However if it is indicated that a percentage of the scheme is for social users who cannot afford to pay, then this percentage of the capital costs should be indicated as a grant requirement, with the remaining balance allocated to the tariff calculation. The model can also incorporate the input of a maximum tariff. An output generated will then be the grant funding required to make the project sustainable”.*

The financial implications of various institutional arrangement options are given in the Cost Estimates and Economic Analysis Report No. P WMA 12/T30/00/5212/15, and the Legal, Institutional and Financing Arrangements Report No. P WMA 12/T30/00/5212/16.

11. PROJECT IMPLEMENTATION PROGRAMME

The current implementation programme is given in Appendix C. This will be regularly reviewed and updated by DWS as the implementation of the project proceeds.

It should be noted that:

a) the current project implementation programme is regarded as the shortest time for project implementation,
b) the programme assumes sufficient funding is available to implement all components simultaneously, which will result in high cash flow,
c) the project programme would be extended if the Decision Support phase takes longer to implement due to sourcing of funding, institutional arrangements, etc., and
d) the programme could also be extended to reduce the peak cash flow.

APPENDIX A

MINISTERIAL PROJECT APPROVAL

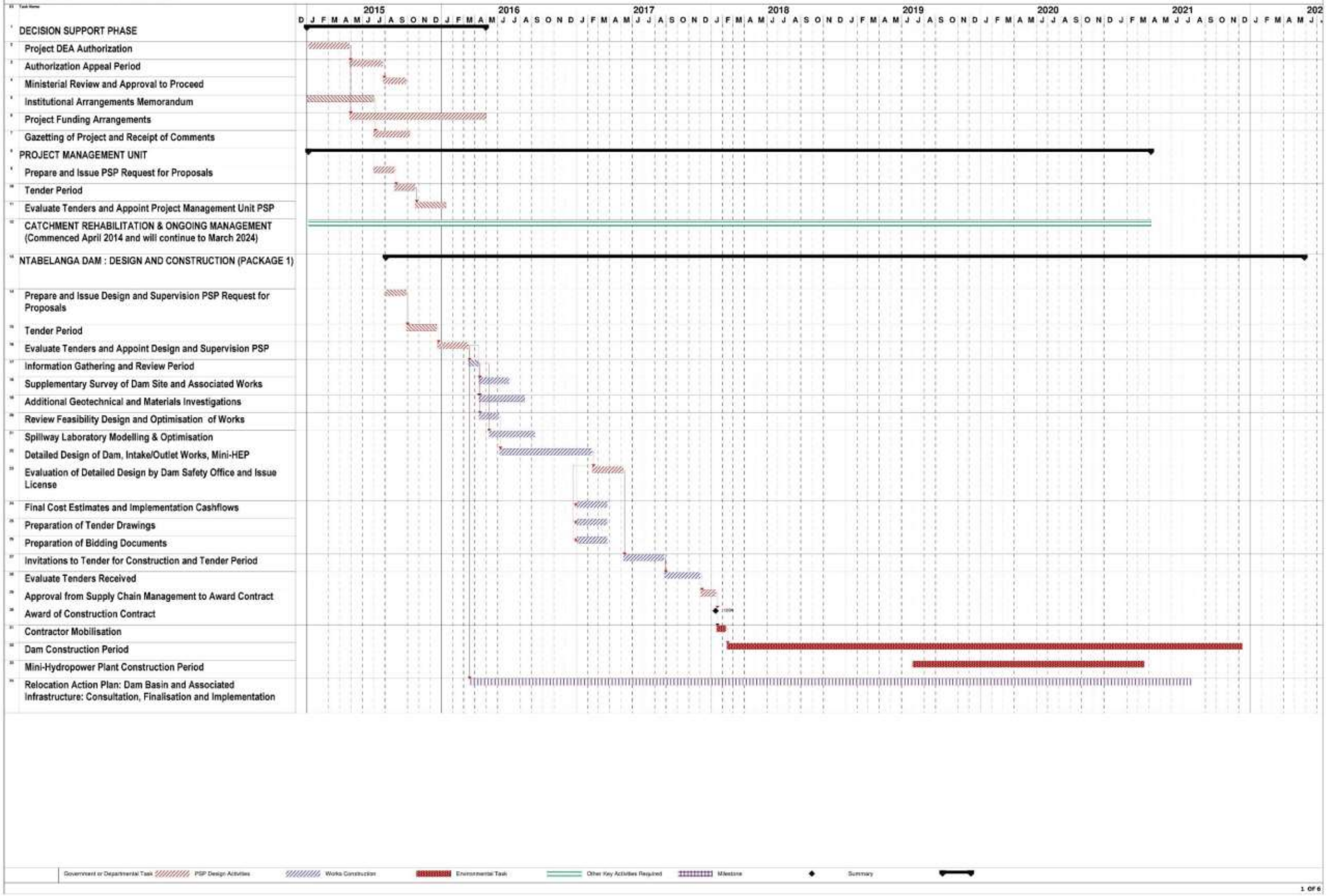
APPENDIX B

ENVIRONMENTAL AUTHORIZATION

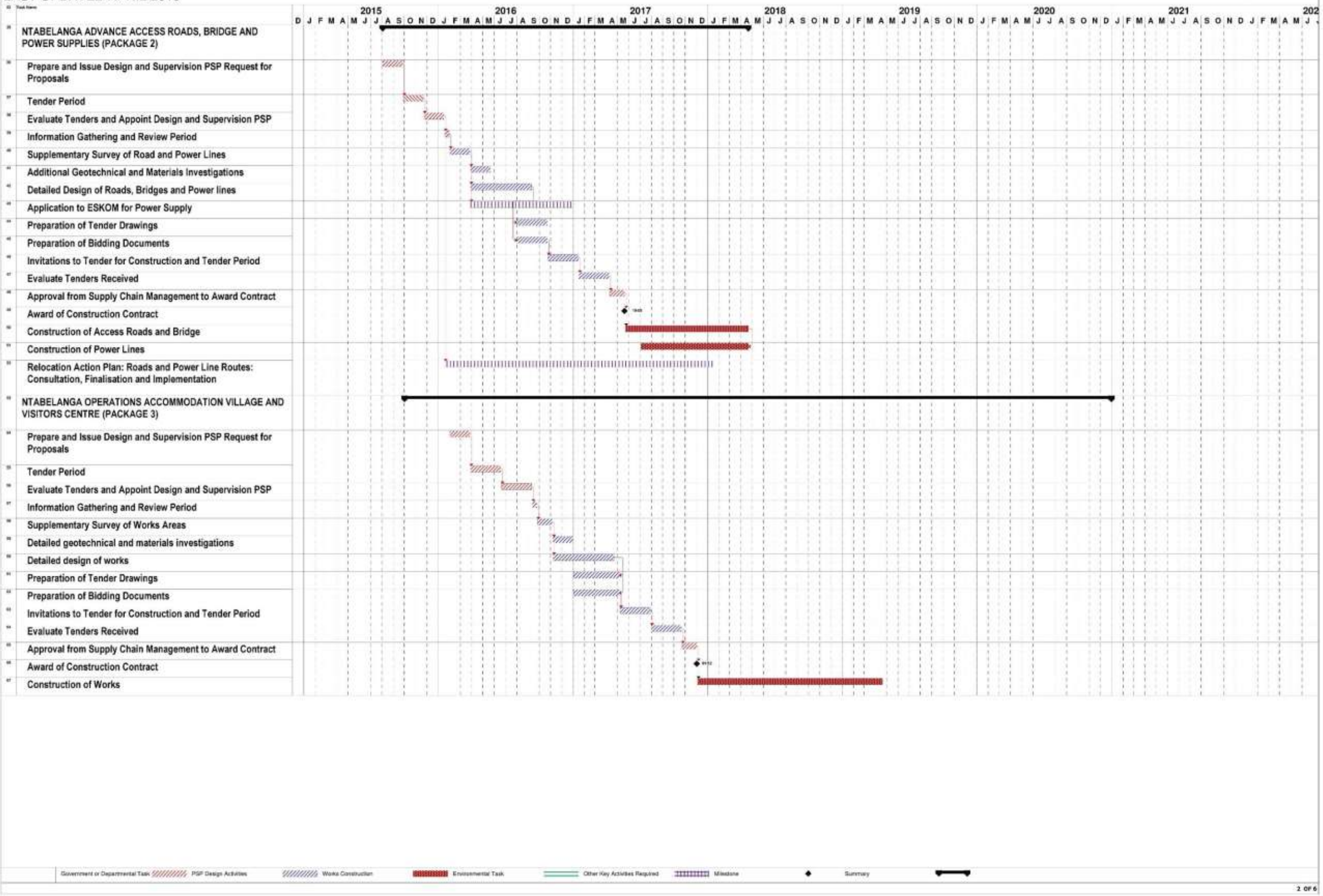
APPENDIX C

DRAFT IMPLEMENTATION PROGRAMME

MZIMVUBU WATER PROJECT: IMPLEMENTATION PROGRAMME
LAST UPDATED APRIL 2015



MZIMVUBU WATER PROJECT: IMPLEMENTATION PROGRAMME
LAST UPDATED APRIL 2015



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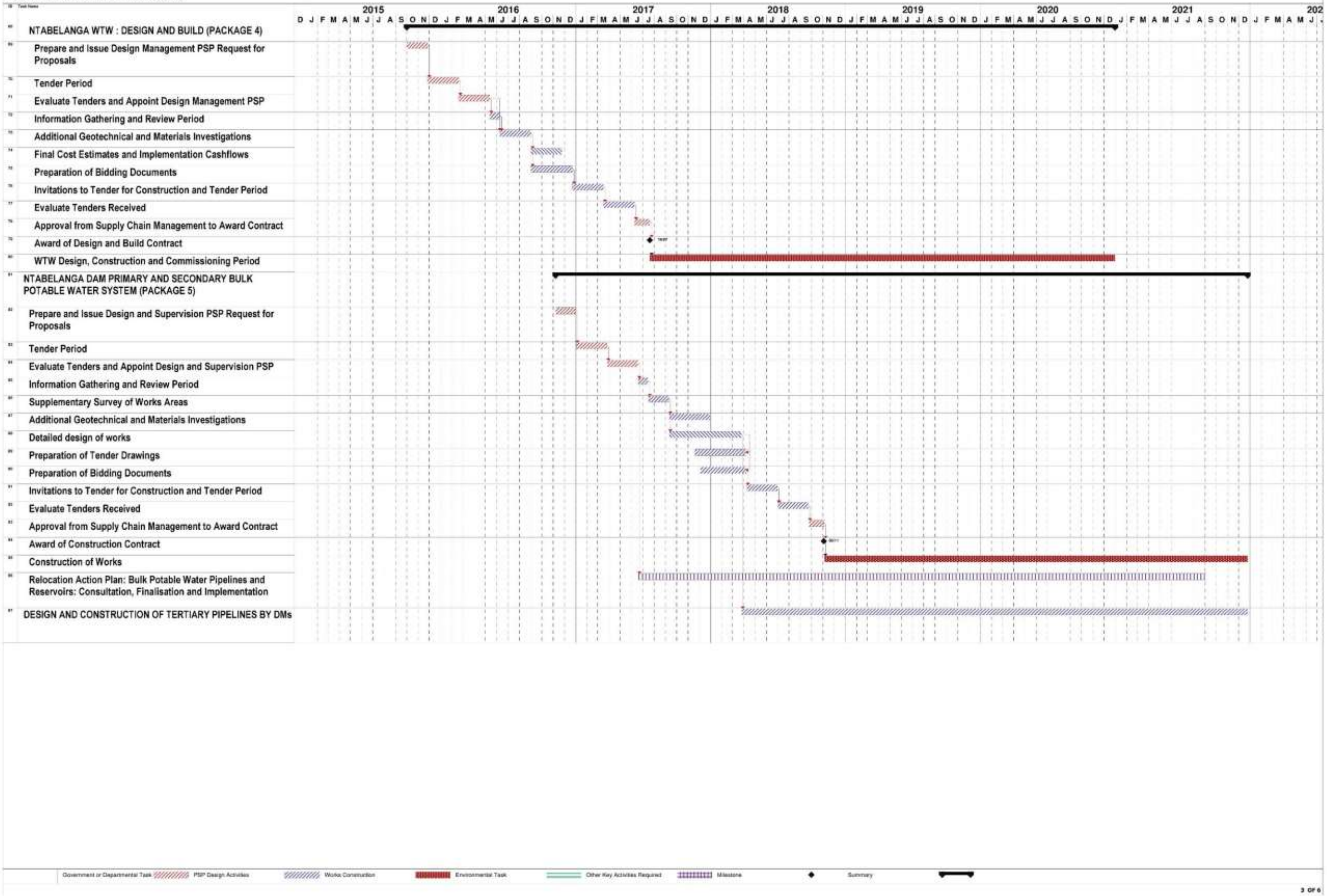
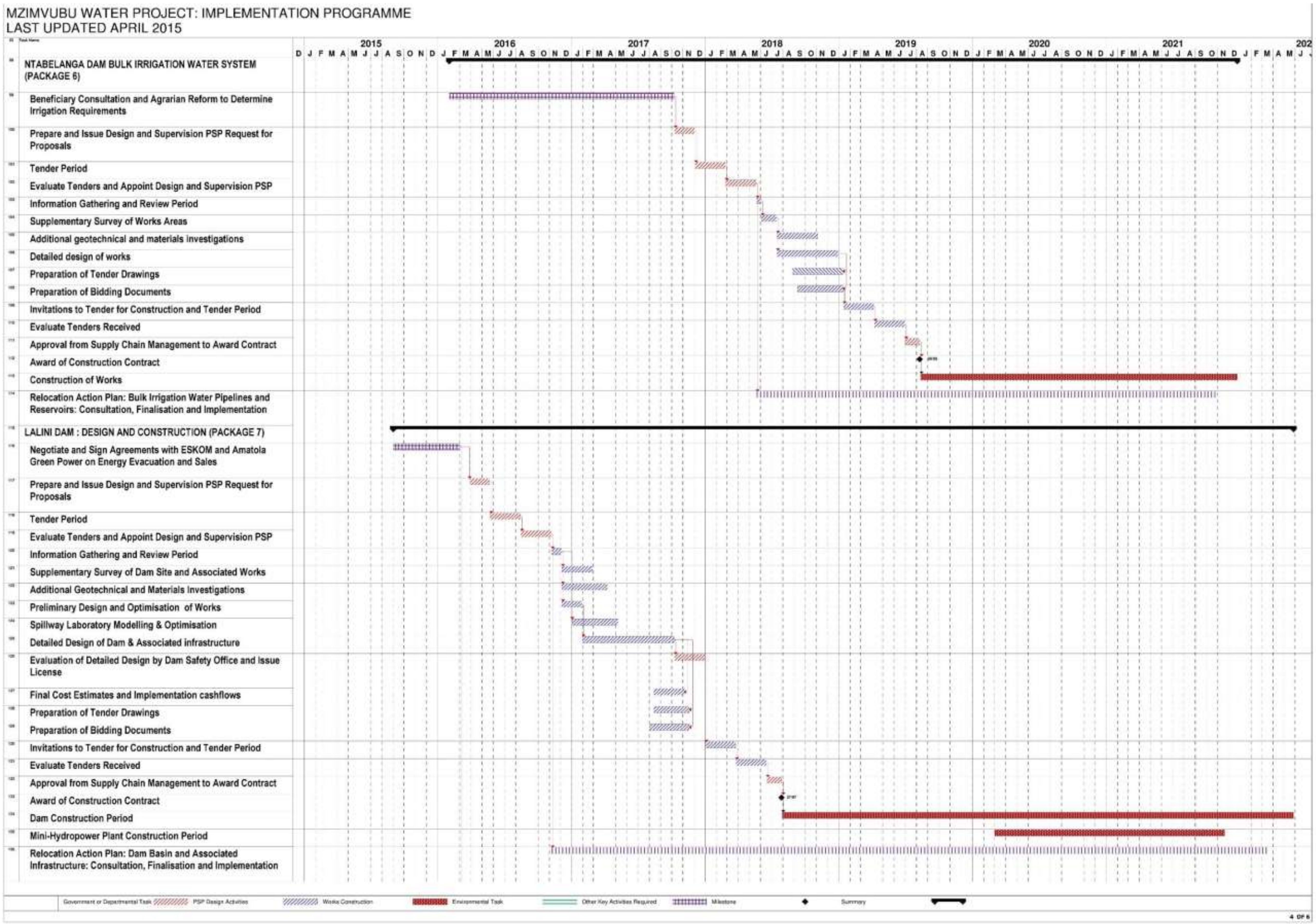
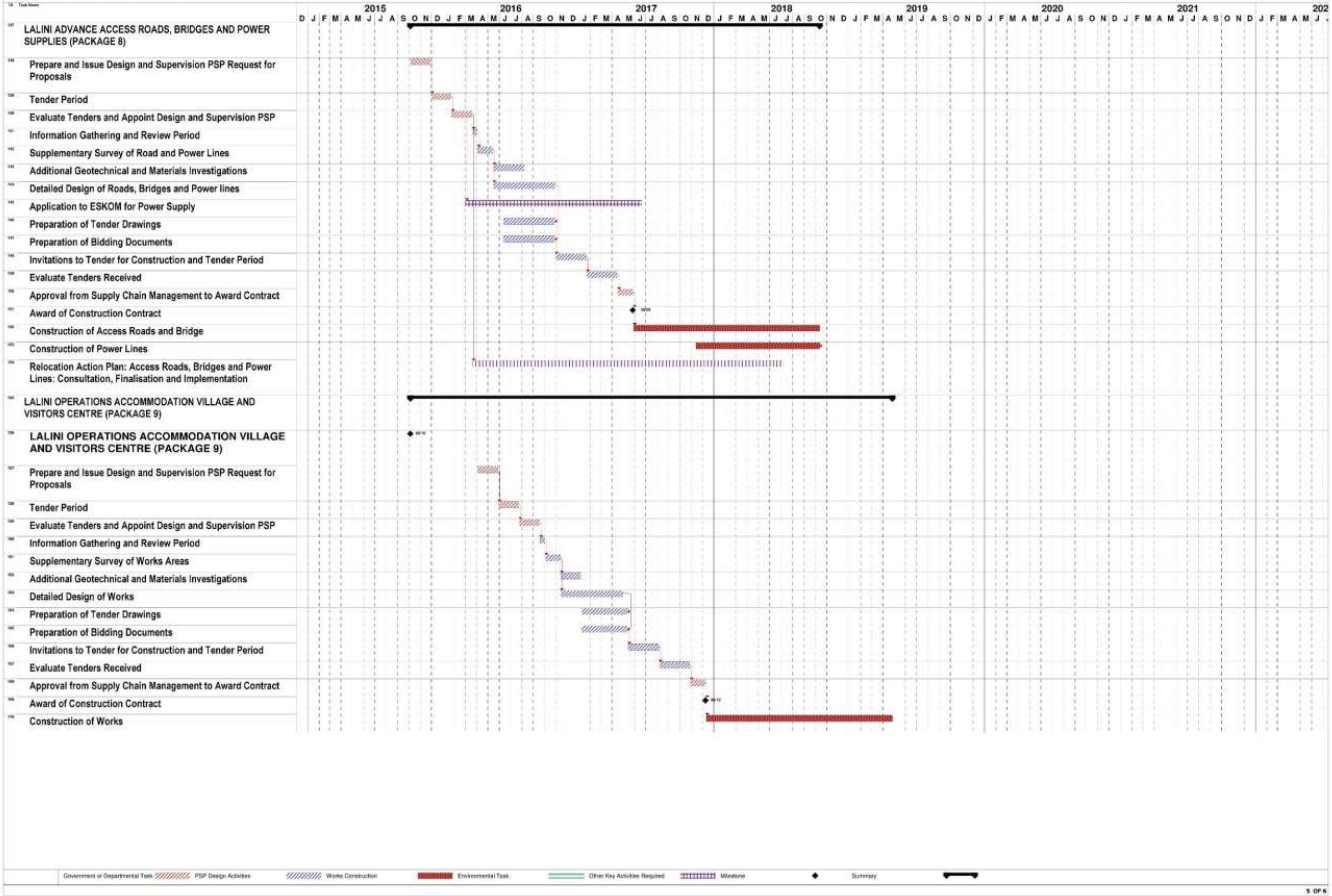
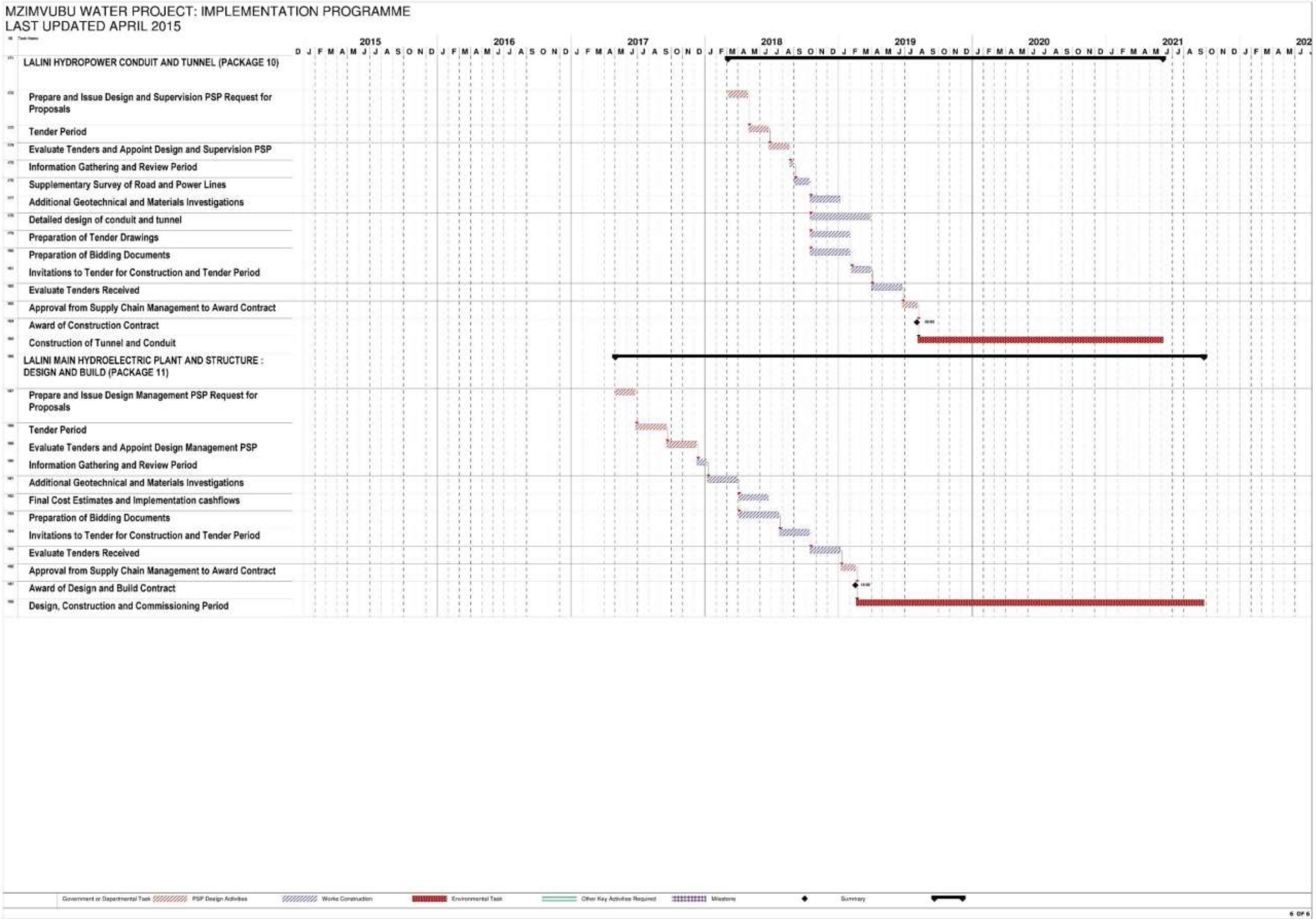



MZIMVUBU WATER PROJECT: IMPLEMENTATION PROGRAMME
LAST UPDATED APRIL 2015
2015
2016
2017
2018
2019
2020
2021
NTABELANGA DAM BULK IRRIGATION WATER SYSTEM (PACKAGE 6)
Beneficiary Consultation and Agrarian Reform to Determine Irrigation Requirements
Prepare and Issue Design and Supervision PSP Request for Proposals
Tender Period
Evaluate Tenders and Appoint Design and Supervision PSP
Information Gathering and Review Period
Supplementary Survey of Works Areas
Additional geotechnical and materials investigations
Detailed design of works
Preparation of Tender Drawings
Preparation of Bidding Documents
Invitations to Tender for Construction and Tender Period
Evaluate Tenders Received
Approval from Supply Chain Management to Award Contract
Award of Construction Contract
Construction of Works
Relocation Action Plan: Bulk Irrigation Water Pipelines and Reservoirs: Consultation, Finalisation and Implementation
LALINI DAM : DESIGN AND CONSTRUCTION (PACKAGE 7)
Negotiate and Sign Agreements with ESKOM and Amatola Green Power on Energy Evacuation and Sales
Prepare and Issue Design and Supervision PSP Request for Proposals
Tender Period
Evaluate Tenders and Appoint Design and Supervision PSP
Information Gathering and Review Period
Supplementary Survey of Dam Site and Associated Works
Additional Geotechnical and Materials Investigations
Preliminary Design and Optimisation of Works
Spillway Laboratory Modelling & Optimisation
Detailed Design of Dam & Associated infrastructure
Evaluation of Detailed Design by Dam Safety Office and Issue License
Final Cost Estimates and Implementation cashflows
Preparation of Tender Drawings
Preparation of Bidding Documents
Invitations to Tender for Construction and Tender Period
Evaluate Tenders Received
Approval from Supply Chain Management to Award Contract
Award of Construction Contract
Dam Construction Period
Mini-Hydropower Plant Construction Period
Relocation Action Plan: Dam Basin and Associated Infrastructure: Consultation, Finalisation and Implementation
4 OF 6

MZIMVUBU WATER PROJECT: IMPLEMENTATION PROGRAMME
LAST UPDATED APRIL 2015




MZIMVUBU WATER PROJECT: IMPLEMENTATION PROGRAMME
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2015
2016
2017
2018
2019
2020
2021
LALINI HYDROPOWER CONDUIT AND TUNNEL (PACKAGE 10)
Prepare and Issue Design and Supervision PSP Request for Proposals
Tender Period
Evaluate Tenders and Appoint Design and Supervision PSP
Information Gathering and Review Period
Supplementary Survey of Road and Power Lines
Additional Geotechnical and Materials Investigations
Detailed design of conduit and tunnel
Preparation of Tender Drawings
Preparation of Bidding Documents
Invitations to Tender for Construction and Tender Period
Evaluate Tenders Received
Approval from Supply Chain Management to Award Contract
Award of Construction Contract
Construction of Tunnel and Conduit
LALINI MAIN HYDROELECTRIC PLANT AND STRUCTURE : DESIGN AND BUILD (PACKAGE 11)
Prepare and Issue Design Management PSP Request for Proposals
Tender Period
Evaluate Tenders and Appoint Design Management PSP
Information Gathering and Review Period
Additional Geotechnical and Materials Investigations
Final Cost Estimates and Implementation cashflows
Preparation of Bidding Documents
Invitations to Tender for Construction and Tender Period
Evaluate Tenders Received
Approval from Supply Chain Management to Award Contract
Award of Design and Build Contract
Design, Construction and Commissioning Period
Government or Departmental Task
PSP Design Activities
Works Construction
Environmental Task
Other Key Activities Required
Milestone
Summary
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