APPENDIX B

ADDITIONAL SPECIALIST STUDIES

APPENDIX B1:

R617 ENGINEERING INVESTIGATION

UMGENI WATER

UMKHOMAZI WATER PROJECT PHASE 1
CONCEPTUAL DESIGN FOR THE REALIGNMENT OF PROVINCIAL ROAD R617

FINAL REPORT

MAY 2018

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UMGENI WATER

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May 2018

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UMGENI WATER

UMKHOMAZI WATER PROJECT PHASE 1

CONCEPTUAL DESIGN FOR THE REALIGNMENT OF PROVINCIAL ROAD R617

FINAL REPORT

February 2018

EXECUTIVE SUMMARY

The proposed Smithfield Dam on the uMkhomazi River is part of the uMkhomazi Water Project Phase 1 (uMWP-1) and will form part of the larger uMkhomazi-Umlaza Transfer Scheme.

The uMWP-1 is earmarked to transfer water from the undeveloped uMkhomazi River to the existing Mgeni System. The uMkhomazi River is the third-largest river in KwaZulu-Natal in terms of Mean Annual Runoff (MAR).

Umgeni Water appointed Knight Piésold in November 2017 to undertake Consulting Engineering Services for the Realignment of Provincial Road R617, which falls under the uMWP-1. The appointment includes conceptual design and cost estimates for three (3) alternative options.

Previous realignment options proposed by AECOM were not acceptable to the Kwazulu-Natal Department of Transport (KZN DoT) mainly due to substandard geometrics, specifically the steep slopes.

A site visit was undertaken from 9 to 11 January 2018 to assess the existing R617, the terrain and possible route options, as well as to meet with the local communities and other affected parties including the Department of Water and Sanitation (DWS) and the KZN DoT. The initial realignment proposal by AECOM was not acceptable to Ezemvelo KZN Wildlife, since it will traverse the Impendle Nature Reserve. This was raised as an objection pertaining to the Environmental Impact Assessment (EIA) Submission. Three (3) route options were investigated taking into account the topography, river crossings and the affected communities. These options were assessed for adherence to the applicable design standards and best practice and were priced accordingly, whilst taking cognisance of the environmentally sensitive area in which the uMWP-1 is located.

Option 1 is about 6,430 km long and is located south of the existing R617. Starting on the eastern side, Option 1 peels away from the existing R617 east and south of the existing shop (Lundy's Hill Supply Store) where after it crosses the uMkhomazi River (future Smithfield Dam) approximately 170 m south of the existing old Deepdale Bridge (built 1896). From here the alignment follows the existing D1212 for about 2 km. At this point Option 1B separates from Option 1A and heads in a

north-westerly direction towards the Mdayane Village. After passing the southern part of Mdayane Village, the road makes an about turn and heads in a south-westerly direction where it re-joins the existing D1212 / R617 intersection en-route to Hlanganai. Option 1A continues to follow the existing D1212 alignment until it reaches the D1212 / R617 intersection.

Option 2 is the route furthest to the north slotting in below the Impendle Nature Reserve and is the longest route at 8,250 km long. The challenge on this route is the mountainous terrain. The uMkhomazi River will be crossed with a medium-sized yet substantial bridge to the north of the existing bridge on the R617. The alignment traverses over a mountain/hill and down again, crossing a stream before re-joining the existing R617. An additional smaller bridge will be required to cross the stream. A bridge to accommodate pedestrians and cattle will be required near the old Deepdale Bridge on the D1212 in order for school children and cattle to cross the dam basin.

Option 3 is about 7,750 km long and aims to follow the existing R617 as far as possible. The uMkhomazi River will be crossed with via a medium-sized yet substantial bridge to the north of the existing bridge on the R617. The alignment then hugs the contours whilst staying fairly parallel with the existing R617, but on higher ground in order to stay clear of the 1:100 year flood line and purchase line. As per Option 2, a small stream is crossed before re-joining the existing R617. An additional smaller bridge will be required to cross the stream. A bridge to accommodate pedestrians and cattle will be required near the old Deepdale Bridge on the D1212 in order for school children and cattle to cross the dam basin.

The challenge on Option 3 is the mountainous terrain where the road will run parallel to the existing R617 but on a higher level against a steep slope. This slope will require stabilisation and the road could potentially require a form of cantilever as it passes the steep slopes.

The proposed route options are located in an environmentally sensitive area and south of the Impendle Nature Reserve. The area is home to the near critically endangered and protected invertebrate *Pennington Protea Butterfly*, whose larvae are hosted in the *Protea Caffra* plants and the endangered *Blue Swallows*.

A detailed cost estimate was prepared for Option 1 using unit rates from recently completed, similar projects. From this a cost per kilometre rate was calculated and applied to each of Options 1A, 1B, 2 and 3 respectively.

Advantages and disadvantages of each of option were compiled with consideration for cost, environmental and social impacts, practicality and adherence to the road design standards and good practice.

On comparison of the various options, Options 1A and 1B are the only options that convincingly adhere to, or exceed, the requirements above. Based on the findings of this Study, Option 1B is the preferred route for the realignment of the R617.

UMGENI WATER

UMKHOMAZI WATER PROJECT PHASE 1

REALIGNMENT OF THE R617

FINAL REPORT

May 2018

TABLE OF CONTENTS

PAGE

<u>ANNEXURES (Submitted under Separate Cover)</u>

LIST OF FIGURES

PAGE

LIST OF TABLES

PAGE

ABBREVIATIONS, ACRONYMS, UNITS AND SYMBOLS

For ease of reference, abbreviations, acronyms, units and symbols appearing in this Report, as well as those used frequently elsewhere in transportation planning, traffic engineering and highway engineering, are listed below.

LIST OF ABBREVIATIONS AND ACRONYMS

AC	Continuously Graded Asphalt Surfacing
AADT	Average Annual Daily Traffic
AAWT	Average Annual Weekday Traffic
AASHTO	American Association of State Highways and Transportation Officials
ADE	Average Daily Equivalent
ADT	Average Daily Traffic
ADTT	Average Daily Truck Traffic
AIMSUN	Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks. Software package used to simulate traffic flow at an individual vehicle level.
AS	Semi-Gap Graded Asphalt
AU	Asphalt Ultra-Thin Friction Course
BC	Continuously Graded Asphalt Base
BLI	Base Layer Index
BRT	Bus Rapid Transit
CBD	Central Business District
COLTO	Committee of Land Transport Officials
CLUMP	Conceptual Land Use Management Plan
cncPave	cncPave Software Design Package
CRCP	Continually Reinforced Concrete Pavement
CSIR	Council for Scientific and Industrial Research
CTO	Comprehensive Traffic Observation
C/W	Carriageway
DCP	Dynamic Cone Penetrometer
DM	District Municipality
DoT	Department of Transport (KZN)
DWS	Department of Water and Sanitation
EIA	Environmental Impact Assessment
E Mod	Elastic Modulus
Excel	Microsoft Spreadsheet Software

ES	Equivalent Standard pavement class (as per TRH 4)
ETA	eThekwini Transport Authority
FWD	Falling Weight Deflectometer
FSL	Full Supply Level
FRI	Flood Recurrence Interval
GDG	Geometric Design Guidelines (SANRAL)
GIS	Geographical Information System
GUI	Graphical User Interface
HiMA	High Modulus Asphalt
HMA	Hot-Mix Asphalt
HFL	High Flood Level
I/C	Interchange
IDP	Integrated Development Plan
ILM	Incrementally-Launched Method
IRI	International Roughness Index
ITP	Integrated Transport Plan
JCP	Jointed Concrete Pavement
KPI	Key Performance Indicators
KZN	KwaZulu-Natal
LAP	Local Area Plan
LCV	Light Commercial Vehicle
LLI	Lower Layer Index
LM	Local Municipality
LOS	Level of Service
MESA	Millions Equivalent Standard Axles
MAR	Mean Annual Runoff
MLI	Middle Layer Index
MM	Metropolitan Municipality
NBC	North Bound Carriageway
NMT	Non-Motorised Transport
NOC	Non-overspill Crest
OD	Origin to Destination
P&G	Preliminary and General
PMS	Pavement Management System
PT	Public Transport
PTP	Public Transport Plan
RIP	Road Infrastructure Plan
RP	Revealed Preference

RISFSA	Road Infrastructure Strategic Framework for South Africa
SADC	South African Development Community
SAMDM	South African Mechanistic-Empirical Design Method
SANRAL	South African National Roads Agency Limited
SARTSM	South African Road Traffic Signs Manual
SBC	South Bound Carriageway
SDF	Spatial Development Framework
SDP	Spatial Development Plan
SIDRA	Signalised and un-signalised Intersection Design and Research Aid - traffic modelling software, used for analysing individual intersections
S/G	Subgrade
SP	Stated Preference
SSD	Stopping Sight Distance
St Dev	Standard Deviation
TBM	Tunnel Boring Machine
TEU	Twenty foot Equivalent Unit, the standard shipping container size
TDM	Transport Demand Management
TIA	Traffic Impact Assessment
TMH	Technical Methods for Highways
ToR	Terms of Reference
TRH	Technical Recommendations for Highways
TSS	Transport Simulation Systems, developers of AIMSUN. Based in Barcelona, Spain
UTFC	Ultra-Thin Friction Course
uMWP-1	uMkhomazi Water Project Phase 1
V/C	Volume to Capacity Ratio
VOT	Value of Time
WIM	Weigh-in-Motion

LIST OF UNITS AND SYMBOLS

am/AM	Ante Meridiem, Latin term for “before the middle of the day”, i.e. from 00:00 to 11:59
C3	Stabilised Subbase of C3 quality in accordance with TRH14
C4	Stabilised Subbase of C4 quality in accordance with TRH14
E Mod	Elastic Modulus

e	Super Elevation
e_{max}	Maximum Super Elevation
E80	Equivalent 80kN single-axle load (ESA also used)
g	Gravitational Constant (9,81 m/s^2)
G1	Gravel Material of G1 quality in accordance with TRH14
G2	Gravel Material of G2 quality in accordance with TRH14
G4	Gravel Material of G4 quality in accordance with TRH14
G5	Gravel Material of G5 quality in accordance with TRH14
G6	Gravel Material of G6 quality in accordance with TRH14
G7	Gravel Material of G7 quality in accordance with TRH14
G9	Gravel Material of G9 quality in accordance with TRH14
G10	Gravel Material of G10 quality in accordance with TRH14
h	hour (hr also sometimes used)
Hv	Heavy Vehicle
km	Kilometre
km/h	Kilometre per Hour
MPa	Mega Pascal
masl	Metres Above Sea Level
m^2	Square metre
mm	Millimetre
m/s	Metres per second
m/s^2	Metres per second squared
pa	per annum
pcu	passenger car equivalent units; heavy vehicles = 2 to 4 pcu
pm/PM	Post Meridiem, Latin term for “after the middle of the day”, i.e. from 12:00 to 23:59
R	Radius
R/m^2	Rand per square metre
veh	vehicles
veh/hr	vehicles per hour (vph also used)
vph	vehicles per hour (veh/hr also used)
^{o}C	Degree Celsius

UMGENI WATER

UMKHOMAZI WATER PROJECT PHASE 1

REALIGNMENT OF THE R617

FINAL REPORT

May 2018

1. INTRODUCTION

The proposed Smithfield Dam on the uMkhomazi River is part of the uMkhomazi Water Project Phase 1 (uMWP-1) and will form part of the larger uMkhomazi-Umlaza Transfer Scheme.

The uMWP-1 is earmarked to transfer water from the undeveloped uMkhomazi River to the existing Mgeni System. The uMkhomazi River is the third-largest river in KwaZulu-Natal (KZN) in terms of Mean Annual Runoff (MAR).

The Mgeni System comprises the Midmar, Albert Falls, Nagle and Inanda dams in KZN, and a water transfer scheme from the Mooi River (Mearns Weir and Spring Grove Dam). The Mgeni System is the main water source that supplies the eThekwini Metropolitan Municipality (MM), Umgungundlovu District Municipality (DM) and Msunduzi Local Municipality (LM) that supplies domestic and industrial water to about five (5) million people and industries.

The purpose of this Study is to investigate and recommend three (3) alternative route alignments for a section of the R617 that will be inundated by the proposed Smithfield Dam.

Figure 1-1: The old Deepdale Bridge on the left and existing the R617 Bridge to the right that will be inundated by the proposed Smithfield Dam

1.1 Scope of Report

The Scope of this Report is the Conceptual Design and Issuance of Conceptual Layout and Alignment Drawings for the Realignment of Provincial Road the R617.

Based on our interpretation of the Scope of Work, our approach to the assignment is summarised as follows:

1. Provision of three (3) route alternatives for the R617 deviation, with the focus on not impeding on the adjacent Impendle Nature Reserve.
2. The route alternatives will, amongst others, be determined by taking into consideration the topography, accessibility, drainage, and bridge/culvert structures as well as applicable design standards.
3. A high-level cost estimate will be determined for each route, based on an envisaged cost per square metre (m^2) multiplied by road length, for the alternative options. Allowance, or adjustments, will be made for additional costs for high fills and for deep cuts as required.
4. Cost estimates for bridge/culvert structures on a cost per m^2 basis will be included.
5. The advantages/disadvantages of each route option will be assessed.
6. Recommendations will be made based on the route assessments.
7. Recommendations will be made for the “best way forward” for subsequent design stages.
8. Submission of a Conceptual Design Report, including the conceptual road layout and alignment drawings (this Report).

1.2 Assumptions and Exclusions

1. Previous studies and investigations done by others, including AECOM, form the base or starting point, for these investigations and conclusions reached in this Report.
2. Geotechnical investigations and materials availability do not form part of the scope of work for this appointment. Data in this regard is mentioned for information purpose only and it is recommended that the previous studies, and if necessary, additional geotechnical studies be undertaken for more conclusive material availability and properties.

2. SITE DESCRIPTION

2.1 Project Locality

The R617 connects Howick and Kokstad in KZN. The portion of the R617 under review is located between Boston and Bulwer, as well as the southern border of the Impendle Nature Reserve. Local villages affected by the road realignment, whether directly or indirectly, including Mdayane, Mkhohlwa, Machabasini, and Nkumba.

Figure 2-1 below indicates the relative locality of the portion of R617 under review (yellow) as well as the proposed route options (red, green, black and blue). A more detailed layout is shown in **Figure 5-1** below**,** in **Section 5** of this Report.

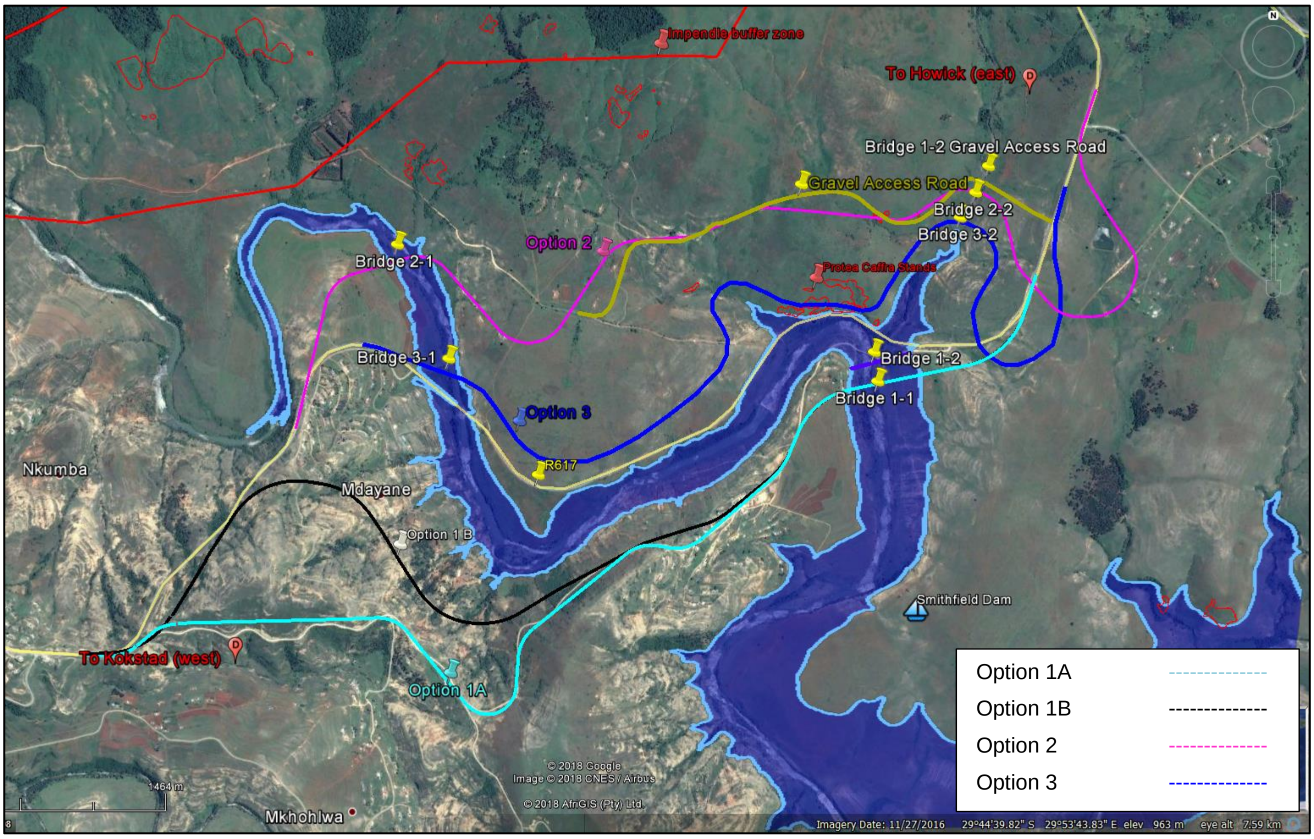

Figure 2-1: Locality Plan

2.2 Topography, Vegetation and Site Drainage

The proposed Smithfield Dam on the uMkhomazi River is situated within the Southern KZN Moist Grassland veld type ((Mucina & Dtherford, 2006)). This veld type is characterised by gently sloping valley bottoms of tall mixed grasslands.

Figure 2-2: A view of the valley of the uMkhomazi River Valley where the R617 will be realigned

2.3 Geological Setting

The geology of the area is generally comprised of the Beaufort and Ecca groups typically consisting of shales, sandstones, mudstones, coal and dolerite intrusions in the form of dykes and/or sills. The proposed quarry for the dam wall construction, which is located near the dam wall position, contains dolerite as well as shale.

Commercial quarries exist near the site, and Midmar Crushers (dolerite) is situated along the R617 about 45km from the dam site. It is envisaged that materials from borrow pits (to be identified during a geotechnical investigation in subsequent design stages) and commercial sources will be required for the road pavement and earthworks.

2.4 Climatic Conditions

The nearest small town to the proposed Smithfield Dam is Bulwer, about 14 km away. Bulwer normally receives in the order of 877 mm of rain per annum, with most rainfall occurring mainly during mid-summer. It receives the lowest rainfall (5 mm) in June and the highest (157 mm) in January. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures for Bulwer range from 17.1°C in June to 24.3°C in January. The region is the coldest during July when the mercury drops to 2.6°C on average during the night.

2.5 Land Use

Settlements, in the form of traditional homesteads, are clustered on the mid-slopes of the uMkhomazi River Valley due to the availability of water from the river and arable riparian land. This arable land is used for subsistence farming in the form of food crop cultivation and livestock grazing (DWAF & UW Corporate Services Division, 1999).

3. SITE INVESTIGATIONS

3.1 General

On 9 January 2018, officials from the Department of Water and Sanitation (DWS), KZN Department of Transport (DoT) and Knight Piésold met on site to discuss and investigate route options for the realignment of the R617.

On 10 January 2018 a meeting was held with the local Chief and Indunas of the affected communities at a council gathering in nearby Hlanganai. The route options were presented to the council and attendees were shown layout drawings indicating the proposed road realignment options. The impact of the road realignment was discussed. Following this, representatives from the council were shown the realignment options on site.

3.2 Site Investigation Findings

From the site investigation, various aspects were identified that either have an impact on or are impacted by, the realignment of the R617. These include, but are not limited to, the following:

1. The uMWP-1 is located in an environmentally sensitive area and is close to the southern edge of the Impendle Nature Reserve. It is understood that the Impendle Nature Reserve is home to a variety of endangered and/or protected animal and bird life. Encroachment on these sensitive areas may have a negative impact of the affected wildlife.

2. Other sensitive areas such as residential settlements, schools, crops and animal grazing areas, are located in close proximity to the proposed routes. Their locations and access thereto affects, and is affected by, the proposed realignment routes. In some instances, villagers' access may be cut-off depending on the alignment of the realigned road.

3. The proposed Smithfield Dam will permanently inundate some existing bridges. Currently some of these bridges are not only for vehicular traffic, but also for pedestrians and cattle. The choice of road realignment may then require additional accesses/bridges to accommodate pedestrian and agricultural traffic, e.g. cattle.

4. The Non-overspill Crest (NOC) level of the proposed Smithfield Dam is 936 metres above sea level (masl), and its Full Supply Level (FSL) is 930 masl. The road and bridges are to be designed to accommodate a High Flood Level (HFL) of 936 masl. In addition to this a certain amount of freeboard should be allowed for. The 6th Edition of the South African National Roads Agency Limited (SANRAL) Drainage Manual, Chapter 8, gives clear guidance on how this freeboard should be calculated. This aspect to confirmed and finalised during subsequent design stages.

5. The topography is considered rolling to mountainous thereby affording few opportunities to safely realign the route in accordance with the design standards, whilst being economically viable.

4. DESIGN STANDARDS

The design standards typically used are referenced in **Section 9** below.

4.1 Geometric Design Standards

In accordance with the KZN DoT requirements and recommendations, the SANRAL Design Standards in conjunction with KZN DoT's typical data, were adopted for this Study.

It is understood that the existing R617 was designed in accordance with an earlier version (1984) of *SANRAL's G2 Geometric Planning Manual*. The current *SANRAL* Geometric Design Guidelines (GDGs) describe a paradigm shift whereby the new design guidelines are more concerned with driver limitations / desires and human factors, and not solely on vehicle limitations. The approach to the design of the road realignment therefore takes cognisance of the design criteria used for the existing R617 whilst complying with the new design guidelines.

As this appointment is for a conceptual / feasibility design, the extent to which each of the referenced Design Standards (refer **Section 9** below) may be used, will be significantly less than during the latter design stages, should the uMWP-1 proceed.

According to the *TRH 26 South African Road Classification and Access Management Manual (2012),* the existing R617 is a Class R2 – Rural Major Arterial/Distributor, KZN Road Number P7-3. This corresponds with the Road Infrastructure Strategic Framework for South Africa (RISFSA) Class 2 classification. According to the South African Development Community (*SADC) Road Traffic Signs Manual (1996), Volume 1 Classification*, the R617 may be considered a Class B: B1 non-freeway numbered national, provincial, regional and metropolitan route.

4.2 Design Criteria

Based on Road Classification, and the R617 status quo, a design speed of 100km/h is desirable. **Table 4-1** below, as extracted from *SANRAL Geometric Design Guidelines (GDG),* Table 3.1, p3-8, suggests design speeds of 80-100 km/h and 60-80 km/h for rolling terrain and mountainous terrain respectively. The proposed R617 realignment route options traverse rolling, but predominantly mountainous topography, whereby adherence to the geometric design standards for 100km/h is not easily achieved and could be economically and practically unachievable. Speed restrictions of between 80 and 60km/h through portions with substandard geometrics may be required, and are considered acceptable according to the SANRAL GDG.

Table 4-1: Typical Design Speeds

TYPICAL DESIGN SPEEDS	DESIGN SPEED (km/h)
Road Type	
Rural Alignment	
Flat terrain	90-120
Rolling terrain	80-100
Mountainous terrain	60-80

Table 4-2 below summarises the typical design criteria used as per SANRAL GDG. These design criteria are based on using very conservative variables to formulate the design criteria table. It must however be noted that the GDG do make provision for less conservative or more relaxed, albeit safe and acceptable minimum requirements.

Table 4-2: Geometric Design Criteria

DESCRIPTION (Single carriageway)	CRITERIA			
Design Speed	**100 km/h**	**80 km/h**	**70 km/h**	**60 km/h**
Horizontal Alignment				
Min. Radius at e_{max} = 4%	490m	280m	200m	150m
Min. Radius at e_{max} = 6%	440m	250m	190m	130m
Min. Radius at e_{max} = 8%	390m	230m	170m	120m
Min. Radius at e_{max} = 10%	360m	210m	150m	110m
Superelevation				
Rural	8% - 10%			
High-speed Urban Roads	6% - 8%			
Minor Urban Roads	4% - 6%			
Vertical Alignment				
Maximum Grade (Flat / Rolling /Mountainous)	4% / 5% / 6%	5% / 6% / 7%	5% / 6% / 7%	6% / 7% / 8%
Minimum Grade	0,5%	0,5%	0,5%	0,5%
K-value (crest, object height = 0,6m)	60	30	18	12
K-value (Sag, comfort)	25	16	12	9
K-value (Sag, headlight) curve length	50m	30m	25m	20m
Sight Distance				
Stopping Sight Distance	200m (K-value = 190, object height = 0m)	140m (K-value = 90, object height = 0m)	110m (K-value = 60, object height = 0m)	90m (K-value = 40, object height = 0m)

4.3 Horizontal Alignment

An horizontal alignment comprises a number of curves with varying radii. The various realignment options' alignments have been evaluated against the minimum design standards as extracted from *SANRAL's GDG*, Table 4.5, p4-13, as illustrated in **Table** 4-3 below and in accordance with *A Policy on Geometric Design of Highways and Streets*, published by the American Association of State Highway and Transportation Officials (AASHTO). **Table** 4-3 below confirms that a 390 m minimum radius meets the requirements for a 100 km/h design speed (e_{max} = 8%). In turn, these minimum radii reduce to 230 m, 170 m and 120 m for design speeds of 80 km/h, 70 km/h and 60 km/h respectively. It is recommended that an e_{max} of 8% superelevation not be exceeded because experience has shown that on steeper gradients, slow moving heavy vehicles have difficulty traversing greater superelevation and tend to tip over onto their sides.

Table 4-3: Values of Super Elevation for Above Minimum Radii of Curvature, e_{max} = 8%, as extracted from SANRAL GDG

Table 4.5: Values of superelevation for above min radii of curvature (%): e_{max} = 8 %										
RADIUS (m)	DESIGN SPEED (km/h)									
	40	50	60	70	80	90	100	110	120	130
7000	NC	NC	NC	NC	NC	NC	NC	RC	RC	RC
5000	NC	NC	NC	NC	NC	NC	RC	RC	RC	2,1
4000	NC	NC	NC	NC	NC	NC	RC	RC	2,1	2,6
3000	NC	NC	NC	NC	NC	RC	RC	2,3	2,8	3,3
2000	NC	NC	NC	RC	2,1	2,6	2,6	3,3	4,0	4,7
1500	NC	NC	RC	2,1	2,7	3,2	3,3	4,2	5,0	5,8
1400	NC	NC	RC	2,2	2,8	3,4	3,5	4,5	5,3	6,1
1300	NC	NC	RC	2,4	3,0	3,6	3,7	4,7	5,6	6,4
1200	NC	NC	RC	2,6	3,2	3,8	4,0	5,0	5,9	6,7
1000	NC	RC	2,3	2,9	3,6	4,3	4,7	5,7	6,6	7,4
900	NC	RC	2,5	3,2	3,9	4,6	5,1	6,2	7,1	7,8
800	NC	2,0	2,7	3,5	4,2	4,9	5,5	6,6	7,5	8,0
700	NC	2,3	3,0	3,8	4,6	5,3	6,1	7,2	7,9	
600	RC	2,6	3,4	4,2	5,0	5,8	6,7	7,7	8,0	
500	2,1	3,0	3,9	4,8	5,6	6,4	7,3	8,0		
400	2,5	3,5	4,5	5,4	6,3	7,1	8,0			
300	3,1	4,2	5,3	6,3	7,2	8,0				
250	3,5	4,7	5,9	6,9	7,8					
200	3,9	5,4	6,5	7,5	8,0					
180	4,4	5,7	6,8	7,8						
160	4,7	6,0	7,2	8,0						
140	5,1	6,4	7,6							
120	5,5	6,9	8,0							
100	6,1	7,4								
90	6,4	7,7								
80	6,7	8,0								
70	7,1									
60	7,5									
50	8,0									

The horizontal alignment data for each of the three (3) realignment options is summarised and assessed later in this Report.

4.4 Vertical Alignment

The vertical alignment of each of the realignment options has been designed in accordance with the requirments of *SANRAL's GDG* and *A Policy on Geometric Design of Highways and Streets*, published by the AASHTO.

The vertical alignment data for each of the three (3) realignment options is summarised and assessed in **Section 5** below.

4.4.1 Curve Lengths

From the SANRAL GDG, p4-22, paragraph 2, it is required that the length of a vertical curve in metres should not be shorter than the design speed in km/h. In the case of freeways, the minimum length should not be less than twice the design speed in km/h. Based on this, vertical curves should not be shorter than 200 m for a 100 km/h design speed. Each vertical alignment's curve lengths have been checked for compliance.

4.4.2 Maximum Grades

Table 4-4 below gives the maximum grades for various design speeds for changing topography, as extracted from the SANRAL GDG, p4-24. A maximum acceptable gradient would therefore be in the order of 5 to 7% for predominantly mountainous terrain at design speeds of between 80 km/h and 100 km/h. Practically, and noting the vastly varying up/down oscillating terrain, a maximum gradient of 8% is considered acceptable in this particular application.

Table 4-4: Maximum Gradients

Table 4.11: Maximum gradients			
Design speed (km/h)	Topography		
	Flat	Rolling	Mountainous
	Gradients (%)		
60	6	7	8
80	5	6	7
100	4	5	6
120	3	4	5

4.4.3 Critical Grades

Grades exceeding the critical length for the specified gradient as given in **Table** 4-5 below should typically receive a climbing lane. Critical grade length compliance has been undertaken on the preferred realignment option only.

Table 4-5: Critical Grades

Table 4.10: Lengths of grade for 15 km/h speed reduction	
Gradient (%)	Critical length of grade (m)
2	550
3	380
4	300
5	240
6	180
7	140
8	100

4.4.4 Curve Types, Stopping Sight Distance and K-Values

Vertical alignments contain the following vertical curve types, as shown in **Figure** 4-1 below:

- Bulging Crest Curves

- Bulging Sag Curves
- Slanted Crest Curves
- Slanted Sag Curves

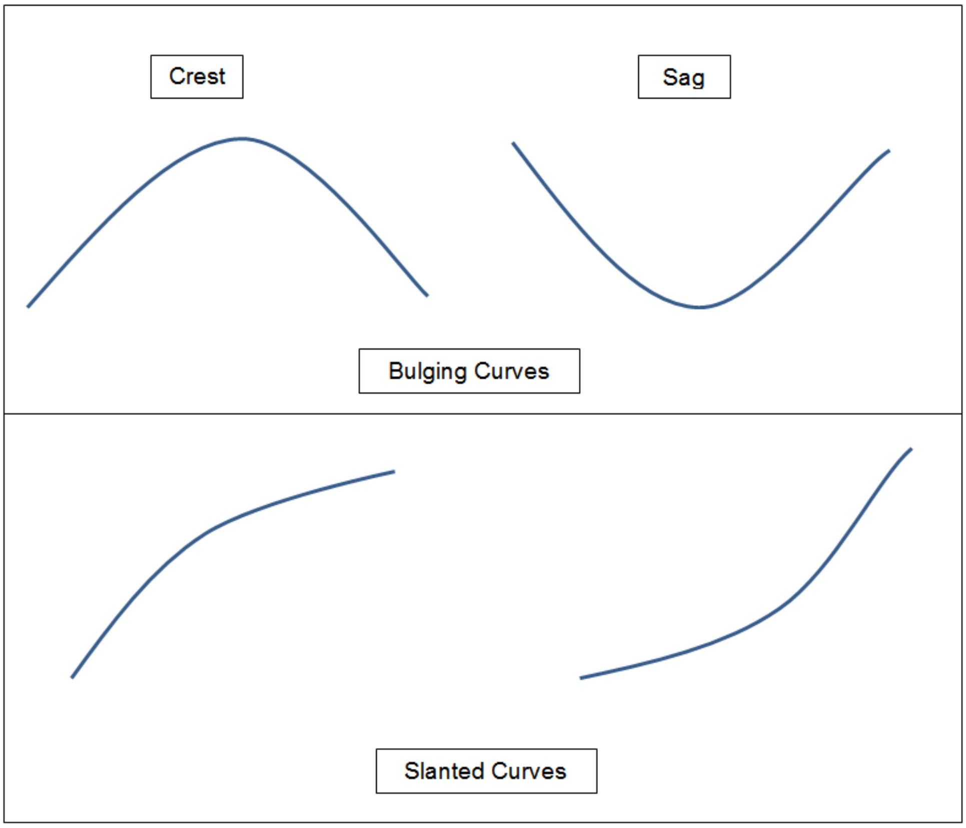

Figure 4-1: Illustration of Vertical Curve Types

In accordance with the SANRAL GDG, Chapter 3: Design Controls, using the appropriate Stopping Sight Distance (SSD) when designing new or investigating existing vertical alignments is vital. The SSD is the governing factor when K-values are calculated for vertical curves. SANRAL GDG, Table 3.5, p3-16, summarises the SSDs applicable for varying design speeds. It should be noted that this table does not make any allowance for an increase or decrease in SSD due to a downhill or uphill grade.

Table 4-6 and *** Values** as per tables in SANRAL GDG

Table 4-7 below list the SSDs calculated using the formula below to make provision for the effect of grades:

$$SSD = v(0.694 + \frac{0.004v}{0.3 \pm G})$$

where: *SSD* = *Stopping Sight Distance (m)*
G = *Percentage gradient divided by 100 (+ up, - down)*
v = *Initial speed (km/h)*

The SANRAL GDG equation for SSD (above) applies a deceleration rate of 3 m/s^2 and a gravitational constant (g) of 10 m/s^2. A Policy on Geometric Design of Highways and Streets, Fourth Edition, AASHTO, Ch.3, Cl. 3.1.2., p114, states that a deceleration rate of 4,5 m/s^2 is considered acceptable. It should be noted that both the AASHTO and the SANRAL GDG make provision for a 2,5 second reaction time. Taking this into account, the SSD formula is modified using a deceleration rate of 4,5 m/s^2, gravitational constant of 9,81 m/s^2 (as per AASHTO), and becomes:

$$SSD = 0.694v + \frac{v^2}{254\left(\frac{a}{g}\right) + Absolute\ Grade}$$

where: *SSD* = *Stopping Sight Distance (m)*
a = *Deceleration rate (m/s^2)*
g = *Gravitational constant (9,81m/s^2)*
v = *Initial speed (km/h)*

Table 4-6 and *** Values** as per tables in SANRAL GDG

Table 4-7 below were populated using the acceptable deceleration rate of 4,5 m/s².

Table 4-6: Summary of Stopping Sight Distance (Uphill)

Stopping Sight Distance Uphill (m)						
Initial Speed (km/h)	**SSD No Grade***	**SSD with 1% Grade**	**SSD with 2% Grade**	**SSD with 3% Grade**	**SSD with 4% Grade**	**SSD with 5% Grade**
30	33	29	28	28	28	28
40	49	41	41	41	41	40
50	67	56	56	55	55	54
60	88	72	72	71	71	70
70	112	90	90	89	88	87
80	139	110	109	108	107	106
90	168	132	130	129	127	126
100	199	155	153	151	150	148
110	234	180	177	175	173	171
120	270	206	204	201	199	197
130	310	234	231	229	226	223

* Values as per tables in SANRAL GDG

Table 4-7: Summary of Stopping Sight Distance (Downhill)

Stopping Sight Distance Downhill (m)						
Initial Speed (km/h)	**SSD No Grade***	**SSD with 1% Grade**	**SSD with 2% Grade**	**SSD with 3% Grade**	**SSD with 4% Grade**	**SSD with 5% Grade**
30	33	29	29	29	29	30
40	49	42	42	43	43	43
50	67	57	57	58	59	59
60	88	74	74	75	76	77
70	112	92	93	94	95	97
80	139	113	114	115	117	118
90	168	135	136	138	140	142
100	199	159	161	163	165	167
110	234	184	187	189	192	195
120	270	212	215	218	221	224
130	310	241	244	248	252	256

* Values as per tables in SANRAL GDG

The SANRAL GDG, Table 4.12, p4-27, gives the minimum K-value for crest curves. These K-values are populated using SSDs that do not take the effect of grades into account. As a result, the K-values may be considered too conservative in some cases and impractical. For a more realistic assessment of the K-values, SSDs taking the effect of grades into consideration were used for K-value calculation.

The K-values were calculated using the following formulae below, with an assumed object height of 0,6 m and eye height of 1,05 m:

Where the required SSD is contained within the length of the vertical curve (Equation 1):

$$K = \frac{s^2}{200(h1^{0.5} + h2^{0.5})^2}$$

Where the curve length is shorter than the required site distance, lesser values of K can be used (Equation 2):

$$K = \frac{2s}{A} - \frac{200({h_1}^{0.5} + {h_2}^{0.5})^2}{A^2}$$

where:

	K	*= Distance required for a 1% change of gradient (m)*
	s	*= Stopping Sight Distance (m)*
	h_1	*= Driver eye height (m)*
	h_2	*= Object height (m)*
	A	*= Algebraic difference in gradient between approaching and departing grades (%)*

All the existing carriageway's vertical curves are longer than the required SSD, so only Equation 1 above is applicable. **Table 4-8** below summarises the K-values calculated for crest curves, taking the effect of grades into consideration.

Table 4-8: Calculated K-values for Crest Curves (including effect of grade on SSD)

K-Value for Bulging Crest Curves - SSD Contained within Curve Length			
Initial Speed (km/h)	**K-Value No Adjustment**	**K-Value Adjusted 1% Grade**	**K-Value Adjusted 5% Grade**
30	2	1	1
40	4	3	2
50	7	5	5
60	12	8	8
70	19	13	12
80	30	19	17
90	44	27	25
100	61	37	34
110	85	50	45
120	113	66	60
130	148	85	77

The vertical alignment's crest curve K-values were assessed for compliance with those calculated in **Table 4-8** above for the 100 km/h design speed.

The previously discussed *Curve Types, SSDs and K-Values design approach* allows for a more practical, yet acceptable method of complying with the SANRAL GDG and has been applied as necessary during this design.

4.5 Design Speed

The design speed is 100 km/h, but restrictions may be applicable where the geometric standards cannot be achieved.

4.6 Cross Section Development

The existing cross section consists of a 9 m (10-10,5 m in places) wide carriageway with one 3,5 m lane per direction with shoulders varying in width between 1 m and 1,5 m. Climbing lanes are provided where necessary.

The existing cross section appears to fall midway between the Type 2C Primary Road Cross Section (KZN DoT Drawing Number SD 0206/B) and the larger Type B2 High Standard Primary Road (KZN DoT Drawing Number SD 0205/B). Based on the previous study undertaken by AECOM and the predominant cross section on the existing R617, the use of the Type 2C Primary Road Cross Section is preferred. This cross section allows for a 10 m-wide carriageway with 3,5 m lanes and 1,5 m-wide surfaced shoulders. Where an auxiliary/climbing lane of 3m wide is required, the surfaced carriageway width increases to 12,4 m.

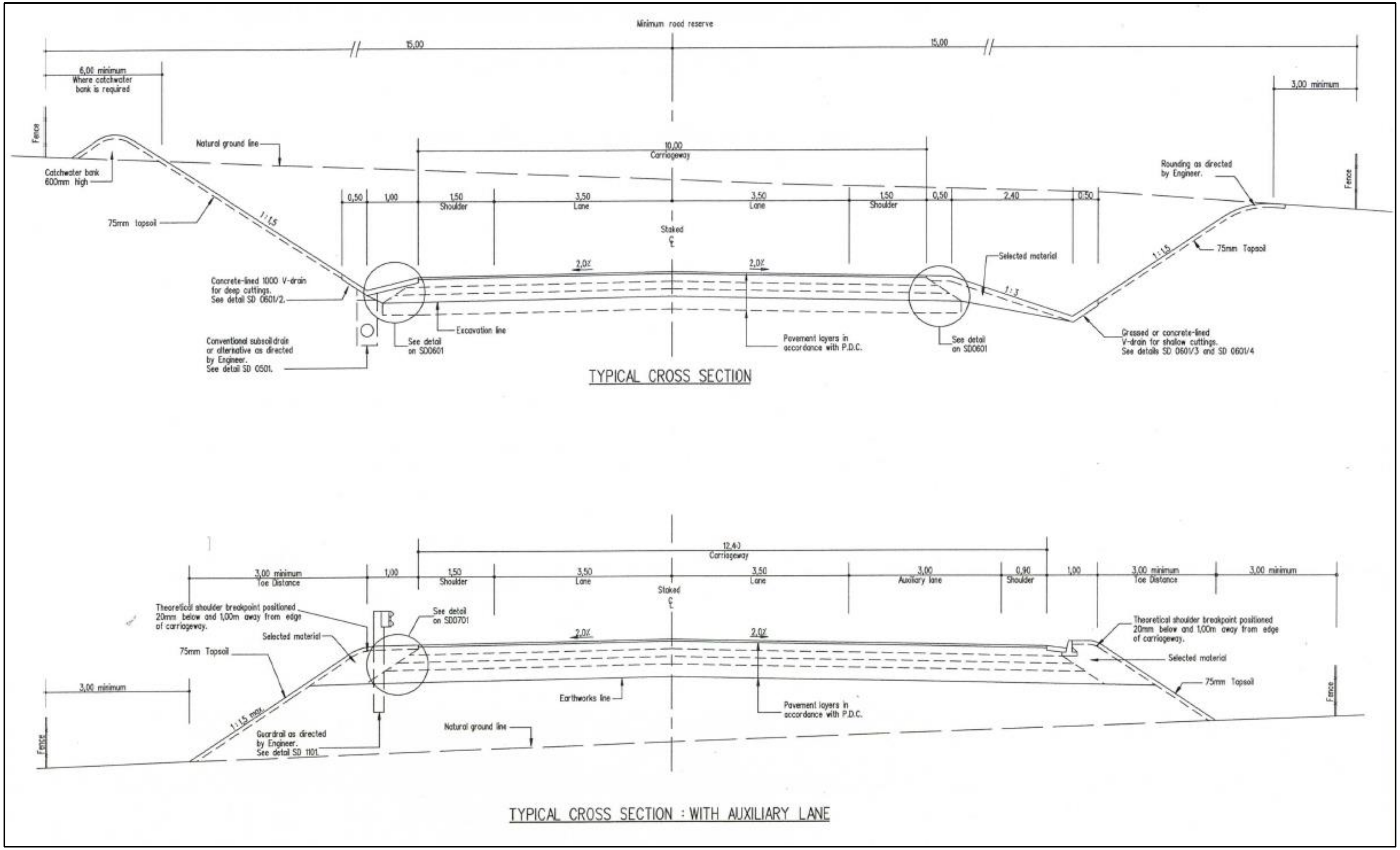

Figure 4-2: Typical Cross Section - Type 2C Primary Road Cross Section (KZN DoT Drawing Number SD 0206/B)

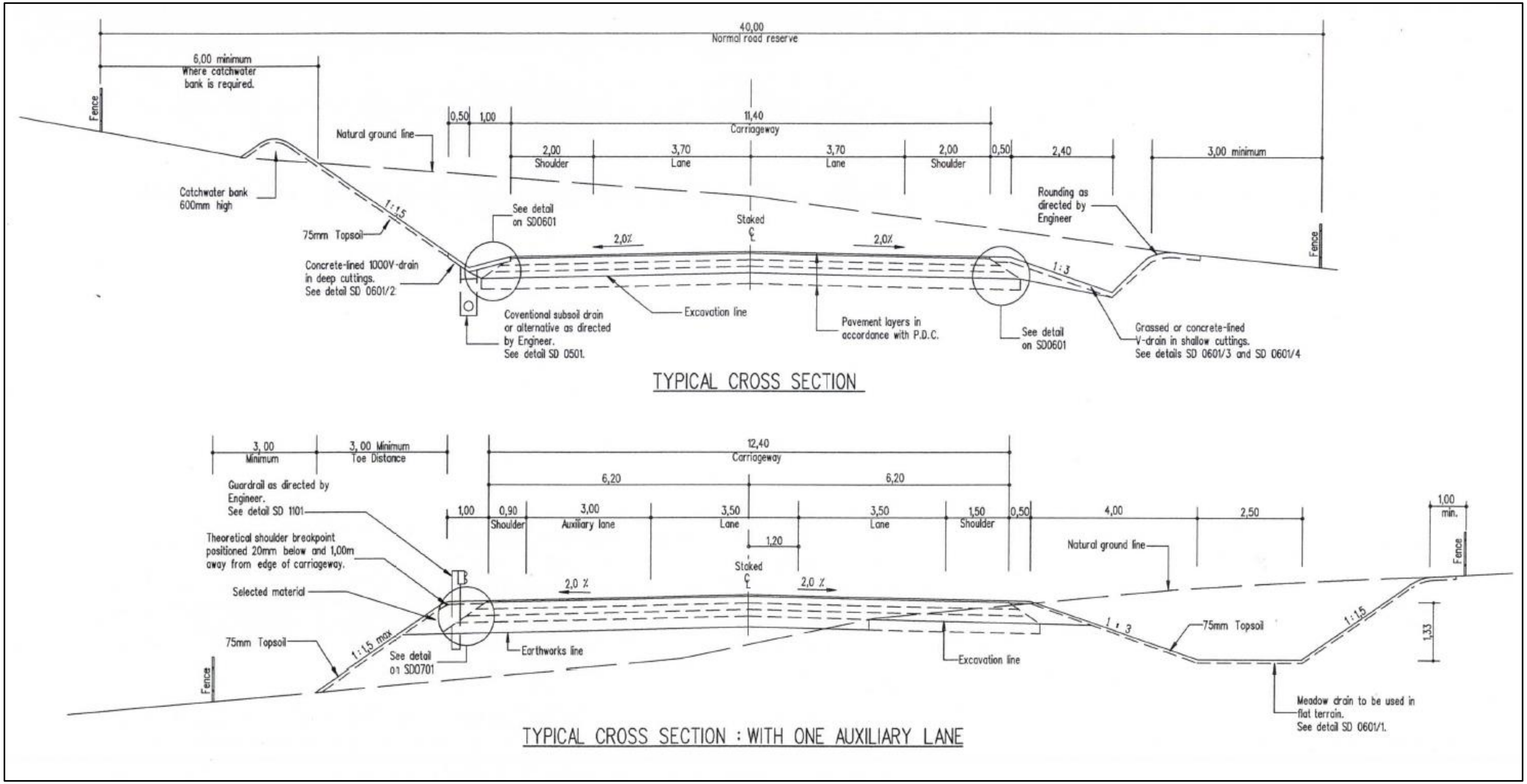

Figure 4-3: Typical Cross Section - Type B2 High Standard Primary Road (KZN DoT Drawing Number SD 0205/B)

Figure 4-4: The existing Provincial Road R617 Cross Section through cutting

a) Cut slopes

A cut slope of 1V:1.5H is preferred, since cuttings through rocky areas are envisaged to be more stable, thus permitting increasing the cut slopes to 1V:1H. During subsequent design stages, detailed geotechnical and materials investigations will be required to confirm slope stability in cuttings.

b) Fill slopes

A fill slope of 1V:1.5H is applied throughout. During subsequent design stages, detailed geotechnical and materials investigations will be required to confirm slope stability on high fills.

4.7 Road Reserve

Demarcation of the existing road reserve is not clearly defined. The preferred cross section, Type 2C Primary Road Cross Section makes provision for a 30m-wide road reserve. In instances of deep cuts, high fills and bridges, the road reserve may require localised wideneing to facilitate the deep cuts and high fills.

4.8 Traffic

According to ad-hoc electronic traffic counts done in 2011 near Smithfield Dam site the Average Daily Traffic (ADT) was 2056 and the Average Daily Truck Traffic (ADTT) was 408 as per AECOM's Traffic Impact Assessment (TIA) Report. The percentage heavy vehicles is 19,8%. Traffic growth analyses are not part of this assignment and have not been taken into account, save for using the higher level cross section. During subsequent design stages additional and more current TIAs will be reqired.

4.9 Conceptual Pavement Design

Pavement structures as suggested during the previous study undertaken by AECOM have been proposed for the R617 realignment and associated gravel accesses. This allows for ease of comparison for costing estimates.

4.9.1 Surfaced Roads (R617)

A typical pavement structure that can be implemented for the construction of the surfaced roads consists of the following layers:

- 30 mm Asphalt surfacing
- 150 mm Base (G4) compacted to 98% mod. AASHTO density;
- 150 mm Subbase (G5) compacted to 95% mod. AASHTO density;
- 150 mm Upper Selected (G7) compacted to 93% mod. AASHTO density;
- 150 mm Lower Selected (G9) compacted to 90% mod. AASHTO density, and
- 150 mm Roadbed/Fill (G10) compacted to 90% mod. AASHTO density.

4.9.2 Gravel Accesses

A typical pavement structure that can be implemented for the construction of the gravel access roads consists of the following layers:

- 150 mm Gravel wearing course (G6) compacted to 95% mod. AASHTO density;
- 150 mm Selected subgrade (G7) compacted t0 93% mod. AASHTO density, and
- 150 mm Roadbed/Fill (G10) compacted to 90% mod. AASHTO density.

[Aside: Substitution with a C3 cemented subbase may be better suited, based on the project location and its climatic conditions].

During subsequent design stages, findings of the geotechnical and materials investigations will provide better insight into the quality and quantity of suitable road construction materials in the area, and the need for materials from commercial sources.

4.10 Drainage Requirements

The R617 realignment is located in the vicinity of the greater uMkhomazi River Catchment. Extensive erosion is evident and cognisance of this should be taken when designing the stormwater drainage systems and road crossings.

In order to determine a suitable Flood Recurrence Interval (FRI) for design, reference to SANRAL Drainage Manual 6th Edition (2013) is recommended and will be applicable in subsequent design stages.

Minor drainage including road surface drainage and side drains has not been designed for under this appointment (conceptual design only), however, based on the knowledge of the area and its climatic conditions, envisaged quantities have been approximated for the cost estimates.

4.11 Bridges and Structures

The drainage of major drainage structures are typically evaluated in accordance with the SANRAL DRAINAGE MANUAL 6th Edition (2013), for both the major culvert structures and the river bridge structures along a route.

For the purposes of this appointment, bridges input is limited to bridge type, length, height and width, this data was used for the cost estimates.

4.12 Services and Utilities

The design of services and utilities does not form part of this appointment, however, an allowance has been made in the cost estimates for services and utilities.

4.13 Ancillary Works

All road marking and signage provision is to comply with SANRAL and KZN DoT Standards and the Southern African Road Traffic Signs Manual (SARTSM). Allowance for ancillary works and related items are included in the cost estimates.

4.14 Land Requirements

The implication of providing the realigned R617 and potential climbing lanes, will result in greater width of the road prism. The realignment options may result in additional land being required outside the existing road reserve. The extent of land required will be influenced by the standard of road improvement accepted.

The cost implications pertaining to the land requirements are beyond the scope of work (mandate) of this appointment, but it is envisaged that land requirements will have a significant impact on the total capital cost of the project.

5. ASSESSMENT OF R617 REALIGNMENT DESIGN OPTIONS

The three (3) realignment options are shown on **Figure 5-1** below.

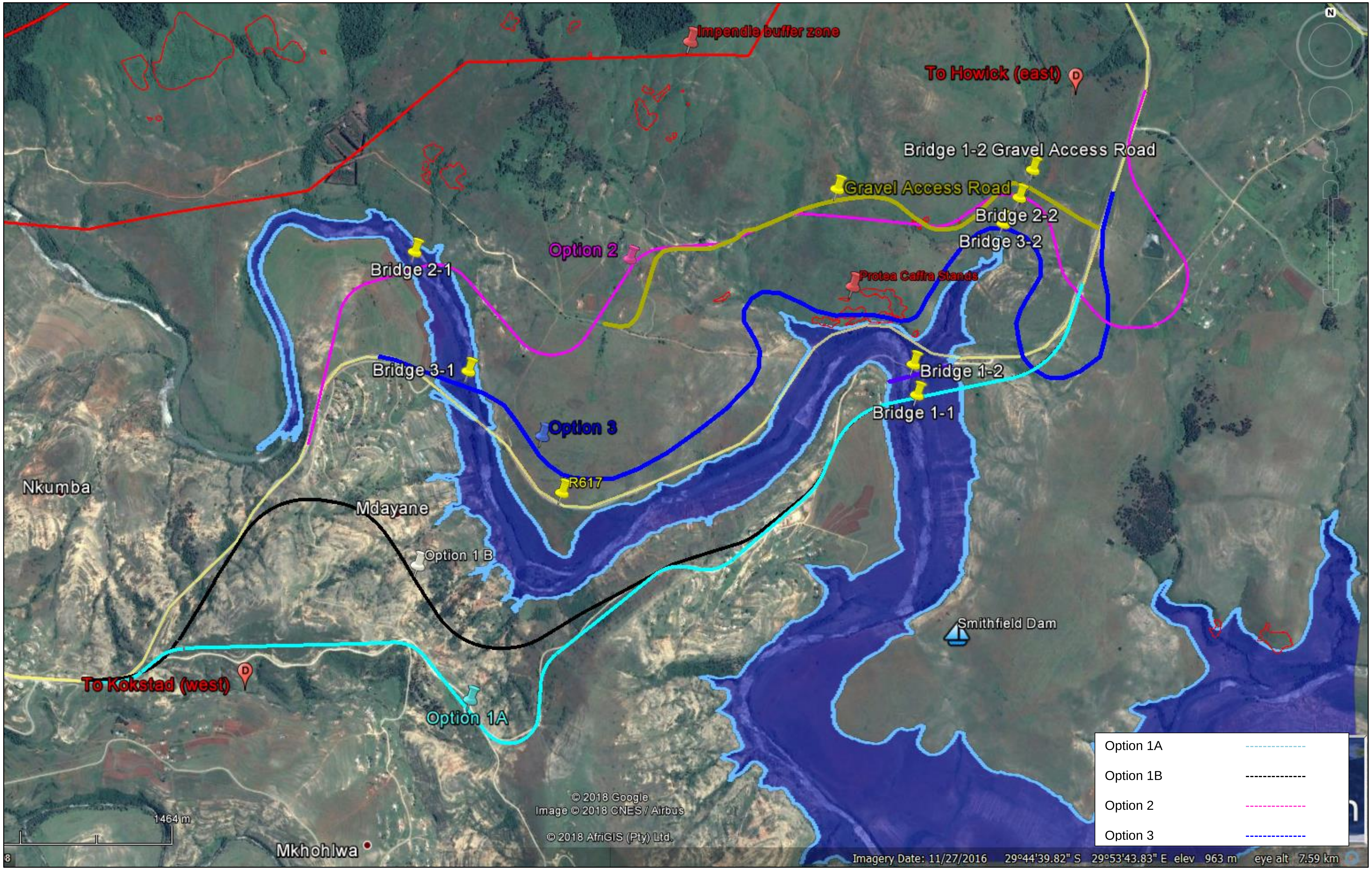

Figure 5-1: Realignment Options for the R617

5.1 Option 1

Option 1 is indicated in **CYAN (1A) / BLACK (1B)** in **Figure 5-1** above**.** This route is about 6,43 km long and is located south of the existing R617. Starting on the eastern side, Option 1 peels away from the existing R617 east and south of the existing shop (Lundy's Hill Supply Store) where after it crosses the uMkhomazi River (future Smithfield Dam) approximately 170 m south of the existing Deepdale Bridge (built in 1896). From here the alignment follows the existing D1212 for about 2 km. At this point Option 1B (**Black**) separates from Option 1A (**Cyan**) and heads in a north-westerly direction towards the Mdayane Village. After passing the southern part of Mdayane Village, the road makes an about turn and heads in a south-westerly direction where it re-joins the existing D1212 / R617 intersection en-route to Hlanganai. Option 1A (**Cyan**) continues to follow the existing D1212 alignment until it ties back in to the existing R617 in the vicinity of the existing D1212 / R617 intersection follows the existing gravel road D1212.

Option 1 will require a large bridge structure about 400-500 m long to cross the uMkhomazi River. During subsequent design stages, once a more accurate survey becomes available, the exact position, and dimensions of the bridge can be determined. During the site visit it became evident that the Deepdale Bridge structure is used by cattle to reach their grazing areas across the river. The proposed Smithfield Dam will inundate this bridge. In addition to providing vehicular passage over the dam, the new bridge will have to accommodate pedestrians and cattle. To achieve this, the road over the river bridge could potentially be made wider, or it could have a separate carriageway for cattle and pedestrians. Another option is to provide a separate bridge structure for the cattle and pedestrians, in the interests of safety for all.

Options 1A and 1B are sufficiently clear of the habitat of the near critically endangered and protected invertebrate *Pennington Protea Butterfly*, whose larvae are hosted in the *Protea Caffra* plants (indicated by red bands in **Figure 5-1** above). These route options are also sufficiently clear of the endangered *Blue Swallows* (indicated by red Impendle Buffer Zone demarcation).

Option 1B is preferred over Option 1A in terms of geometrics, shorter length and because much of the route can be constructed whilst still maintaining access to villages using the D1212.

5.1.1 Geometric Analysis for Options 1A and 1B

5.1.1.1 Horizontal Alignment

The horizontal alignment data and superelevation checks for Option 1B are summarised in **Table 5-1** below. Note that these are for the most part, similar to Option 1A as they follow a similar/same alignment. Option 1B is shown as it is preferred over Option 1A.

Table 5-1: Horizontal Alignment Data for Option 1B

No.	Type	Length	Radius	Direction	Start Station	End Station	Minimum Required Radius for 6% Super Elevation	Check	Minimum Required Radius for 8% Super Elevation	Check	Minimum Required Radius for 10% Super Elevation	Check
1	Line	208.679		15° 39' 40"	0	208.679						
2	Curve	422.498	390		208.679	631.177	400	FAIL	390	OK	300	OK
3	Line	623.154		77° 43' 50"	631.177	1254.331						
4	Curve	376.333	390		1254.331	1630.664	400	FAIL	390	OK	300	OK
5	Line	93.906		22° 26' 30"	1630.664	1724.57						
6	Curve	194.424	390		1724.57	1918.994	400	FAIL	390	OK	300	OK
7	Line	272.196		51° 00' 20"	1918.994	2191.19						
8	Curve	146.544	390		2191.19	2337.734	400	FAIL	390	OK	300	OK
9	Line	296.868		72° 32' 00"	2337.734	2634.602						
10	Curve	77.848	390		2634.602	2712.45	400	FAIL	390	OK	300	OK
11	Line	451.622		61° 05' 50"	2712.45	3164.073						
12	Curve	32.487	680		3164.073	3196.56	400	OK	390	OK	300	OK
13	Line	223.857		58° 21' 40"	3196.56	3420.417						
14	Curve	600.974	390		3420.417	4021.391	400	FAIL	390	OK	300	OK
15	Line	454.225		146° 39' 00"	4021.391	4475.616						
16	Curve	317.773	390		4475.616	4793.388	400	FAIL	390	OK	300	OK
17	Line	55.035		99° 58' 00"	4793.388	4848.423						
18	Curve	471.436	390		4848.423	5319.859	400	FAIL	390	OK	300	OK
19	Line	595.501		30° 42' 20"	5319.859	5915.361						
20	Curve	380.421	390		5915.361	6295.781	400	FAIL	390	OK	300	OK
21	Line	137.567		86° 35' 40"	6295.781	6433.348						

Alignment Option 1B comfortably exceeds the requirements of the design standards for a superelevation e_{max} = 8%.

5.1.1.2 Vertical Alignment

The vertical alignment data for Option 1B is summarised in **Table 5-2** below (without K-value and SSD adjustments). This data indicates that Option 1B meets the vertical alignment requirements for a design speed of 100 km/h for all but one vertical curve, without applying K-value and SSD adjustments.

When applying a less conservative yet more practical design approach (which includes K-value adjustments and limiting the required SSD, as described in **Section 4** above, to the vertical alignment for traversing such mountainous terrain, the requirements for a design speed of 100 km/h are readily achieved. This data is summarised in **Table 5-3** below (including K-value and 0,9 x SSD adjustments). It may be possible during subsequent design stages to refine the vertical alignment further, thereby permitting a 120 km/h design speed should the need arise.

Table 5-4 below summarises the location of critical grades necessitating the need for climbing lanes, where applicable, in each direction. The need for these climbing lanes is based purely on gradient and has not taken traffic needs into consideration.

Table 5-2: Option 1B – Vertical Alignment Summary (without K-value and SSD adjustments)

Critical Design Requirements				
	Speed	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)
	60	120	20	12
	80	160	30	30
	100	200	50	60
	120	240	70	110

VA Data For Option 1B									Proposed Posting Speed	Spec. for 80 km/h				Spec. for 100 km/h				Spec. for 120 km/h			
No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value		Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result
1	0	984.799		-5.63%					100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK
2	290.397	968.46	-5.63%	-7.22%	1.59%	Crest	323	203.068	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
3	730.407	936.704	-7.22%	0.63%	7.85%	Sag	280	35.672	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No	Meets Spec	No	N/A	No
4	1923.772	944.249	0.63%	4.08%	3.44%	Sag	565	164.027	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
5	2644.19	973.62	4.08%	-0.30%	4.38%	Crest	360	82.253	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No
6	3632.668	970.655	-0.30%	1.24%	1.54%	Sag	835	542.257	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
7	4415.753	980.365	1.24%	6.97%	5.73%	Sag	500	87.334	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
8	5041.01	1023.915	6.97%	4.86%	2.11%	Crest	305	144.712	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
9	5798.451	1060.707	4.86%	3.29%	1.56%	Crest	790	504.919	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
10	6433.348	1081.614	3.29%						100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK

Table 5-3: Option 1B – Vertical Alignment Summary (including K-value and 0.9 x SSD adjustments)

Critical Design Requirements				
	Speed	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)
	60	120	20	11
	80	160	16	26
	100	200	25	53
	120	240	36	78

VA Data For Option 1B									Proposed Posting Speed	Spec. for 100 km/h				Spec. for 120 km/h			
No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value		Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result
1	0	984.799		-5.63%					100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK
2	290.397	968.46	-5.63%	-7.22%	1.59%	Crest	323	203.068	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
3	730.407	936.704	-7.22%	0.63%	7.85%	Sag	280	35.672	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No
4	1923.772	944.249	0.63%	4.08%	3.44%	Sag	565	164.027	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
5	2644.19	973.62	4.08%	-0.30%	4.38%	Crest	360	82.253	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
6	3632.668	970.655	-0.30%	1.24%	1.54%	Sag	835	542.257	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
7	4415.753	980.365	1.24%	6.97%	5.73%	Sag	500	87.334	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
8	5041.01	1023.915	6.97%	4.86%	2.11%	Crest	305	144.712	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
9	5798.451	1060.707	4.86%	3.29%	1.56%	Crest	790	504.919	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
10	6433.348	1081.614	3.29%						100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK

Table 5-4: Option 1B – Vertical Alignment (Critical Grades / Climbing lanes)

VA Info									South Bound				North Bound			
Ref. No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value	Length from previous PVI	Grade	Critical Length	Requires Climbing Lane	Length from previous PVI	Grade	Critical Length	Requires Climbing Lane
1	0	984.799m														
2	290.397	968.460m	-5.63%	-7.22%	1.59%	Crest	323	203.068	290.397	-0.06	#N/A	#N/A	290.397	0.06	180	YES
3	730.407	936.704m	-7.22%	0.63%	7.85%	Sag	280	35.672	440.01	-0.07	#N/A	#N/A	440.01	0.07	140	YES
4	1923.772	944.249m	0.63%	4.08%	3.44%	Sag	565	164.027	1193.365	0.01	550	YES	1193.365	-0.01	#N/A	#N/A
5	2644.19	973.620m	4.08%	-0.30%	4.38%	Crest	360	82.253	720.418	0.04	300	YES	720.418	-0.04	#N/A	#N/A
6	3632.668	970.655m	-0.30%	1.24%	1.54%	Sag	835	542.257	988.478	0.00	550	YES	988.478	0.00	550	YES
7	4415.753	980.365m	1.24%	6.97%	5.73%	Sag	500	87.334	783.085	0.01	550	YES	783.085	-0.01	#N/A	#N/A
8	5041.01	1023.915m	6.97%	4.86%	2.11%	Crest	305	144.712	625.257	0.07	140	YES	625.257	-0.07	#N/A	#N/A
9	5798.451	1060.707m	4.86%	3.29%	1.56%	Crest	790	504.919	757.441	0.05	240	YES	757.441	-0.05	#N/A	#N/A
10	6433.348	1081.614m	3.29%						634.897	0.03	380	YES	634.897	-0.03	#N/A	#N/A

5.1.2 Advantages of Options 1A & 1B

- Shortest route (6,43 km);
- Least disruptive to communities in terms of access to the R617 and public transport facilities;
- Does not have an impact on endangered and protected species;
- Some communities will gain better access than what they currently experience, and
- Preferred option in terms of compliance with the geometric design standards, including:
    - Acceptable grades (max. 7,85%), which assist in providing a better Level of Service (LOS) for road users, particularly heavy vehicles that would otherwise have difficulty maintaining speed up hills and have deceleration and braking challenges on steep downhills;
    - Larger horizontal radii allowing for better increased safety, visibility, and a higher comfort value as the route flows better than one with smaller, tighter radii, and
    - Through the use of larger horizontal radii, the need for superelevation is reduced considerably, which in turn is safer for slow moving heavy vehicles which have been known to tip onto their sides when negotiating high superelevation on curves at low speeds.

5.1.3 Disadvantages of Options 1A & 1B

- Access to the farms north of the uMkhomazi River will be cut off, since old bridges will be inundated by the proposed Smithfield Dam as shown in **Figure 5-2** below.
- Access to these properties will have to be provided by means of a new gravel access road and a small bridge;
- Some sections of the road will require steep, deep cuttings, as shown in **Figure 5-3** below; and
- Realigning the R617 using Option 1 will divide existing settlements in places, and in this case the recommended mitigation is that the affected communities be relocated to more suitable and safe locations either in the villages or elsewhere.

Figure 5-2: The Proposed Bridge Site for Option1

Figure 5-3: The Existing D1212 Road that needs to be widened with expected stabilisation of the cutting on the right

5.2 Option 2

Option 2 is indicated in **MAGENTA** on **Figure 5.1** above. This option is the route furthest to the north slotting in below the Impendle Nature Reserve and is the longest route (8,25 km). The challenge on this route is the mountainous terrain. The uMkhomazi River will be crossed with a medium-sized yet substantial bridge to the north of the existing bridge on the R617. The alignment traverses over a mountain/hill and down again, crossing a stream before re-joining the existing R617. An additional smaller bridge will be required to cross the stream. A bridge to accommodate pedestrians and cattle will be required near the old Deepdale Bridge on the D1212 in order for school children and cattle to cross the dam basin.

This route passes through some farmsteads and green fields, making it less environmentally friendly (indicated in **Figure 5-4** below). Option 2 falls within the habitat of the near critically endangered and protected invertebrate *Pennington Protea Butterfly*, whose larvae are hosted in the *Protea Caffra* plants (indicated by red bands in **Figure 5-1** above). This route option is sufficiently clear of the endangered *Blue Swallows* (indicated in **Figure 5-1** above, by red Impendle Buffer Zone demarcation).

Figure 5-4: Option 2 that follows the "Jeep track" to the right

5.2.1 Geometric Analysis for Option 2

5.2.1.1 Horizontal Alignment

The horizontal alignment data and superelevation checks for Option 2 are summarised in

Table 5-5 below**.**

Table 5-5: Horizontal Alignment Data for Option 2

No.	Type	Length	Radius	Direction	Start Station	End Station	Minimum Required Radius for 4% Super Elevation	Check	Minimum Required Radius for 6% Super Elevation	Check	Minimum Required Radius for 8% Super Elevation	Check	Minimum Required Radius for 10% Super Elevation	Check
1	Line	262.13		17° 15' 10"	0	262.128								
2	Curve	344.42	390		262.128	606.55	490	FAIL	400	FAIL	390	OK	300	OK
3	Line	620.35		326° 39' 10"	606.55	1226.899								
4	Curve	369.44	320		1226.899	1596.334	490	FAIL	400	FAIL	390	FAIL	300	OK
5	Line	389.64		32° 48 00"	1596.334	1985.977								
6	Curve	874.98	320		1985.977	2860.956	490	FAIL	400	FAIL	390	FAIL	300	OK
7	Line	442.81		189°27' 50"	2860.956	3303.762								
8	Curve	17.815	320		3303.762	4021.577	490	FAIL	400	FAIL	390	FAIL	300	OK
9	Line	30.666		60° 56' 20"	4021.577	4052.243								
10	Curve	225.19	390		4052.243	4277.437	490	FAIL	400	FAIL	390	OK	300	OK
11	Line	571.13		94° 01' 30"	4277.437	4848.571								
12	Curve	189.85	390		4848.571	5038.42	490	FAIL	400	FAIL	390	OK	300	OK
13	Line	203.39		66° 08'00"	5038.42	5241.814								
14	Curve	133.78	390		5241.814	5375.594	490	FAIL	400	FAIL	390	OK	300	OK
15	Line	149.66		85° 47' 10"	5375.594	5525.256								
16	Curve	361.22	390		5525.256	5886.473	490	FAIL	400	FAIL	390	OK	300	OK
17	Line	85.508		32° 43' 10"	5886.473	5971.981								
18	Curve	718.85	390		5971.981	6690.564	490	FAIL	400	FAIL	390	OK	300	OK
19	Line	64.048		138° 17' 20"	6690.564	6754.612								
20	Curve	450.96	390		6754.612	7205.569	490	FAIL	400	FAIL	390	OK	300	OK
21	Line	64.142		72°02' 10"	7205.569	7269.711								
22	Curve	405.93	390		7269.711	7675.639	490	FAIL	400	FAIL	390	OK	300	OK
23	Line	574.09		12° 24' 00"	7675.639	8249.728								

Option 2's horizontal alignment for the most part, meets the requirements of the SANRAL GDG Design Standards for a superelevation e_{max} of 8% at a 100 km/h design speed. Three (3) substandard horizontal radii (R = 320 m) are located in the early reaches of the horizontal alignment where steep and choppy terrain cannot accommodate a minimum 390 m radius. Although the smaller radii could be considered acceptable if the e_{max} is increased to 10%, it is not advised as this could pose a danger to slow moving heavy vehicles as described in **Section 4** above. An option would be to apply speed restrictions along the sections with substandard radii, but this is not desirable.

The horizontal alignment for Option 2 is therefore not recommended.

5.2.1.2 Vertical Alignment

The vertical alignment data is summarised in **Table 5-6** below (without K-value and SSD adjustments). This data indicates that Option 2 fails to meet the vertical alignment requirements for a design speed of 100 km/h in most instances, without applying K-value and SSD adjustments. A reduced speed of 80 km/h would meet the standards.

When applying a less conservative yet more practical design approach, (which includes K-value adjustments and limiting the required SSD (as described in **Section 4** above) to the vertical alignment for traversing such mountainous terrain, the requirements for a design speed of 100 km/h are readily achieved. This data is summarised in **Table 5-7** below (including K-value and 0.9 x SSD adjustments).

Table 5-8 below summarises the location of critical grades necessitating the need for climbing lanes, where applicable, in each direction. The need for these climbing lanes is based purely on gradient and has not taken traffic needs into consideration, which is beyond the scope of work for this appointment.

Table 5-6: Option 2 – Vertical Alignment Summary (without K-value and SSD adjustments)

Critical Design Requirements				
	Speed	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)
	60	120	20	12
	80	160	30	30
	100	200	50	60
	120	240	70	110

VA Data For Option 2										Spec. for 80 km/h				Spec. for 100 km/h				Spec. for 120 km/h			
No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value	Proposed Posting Speed	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result
1	0.000	1062.592		-6.11%					100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK
2	668.605	1022.533	-6.11%	-0.75%	5.37%	Sag	210.000	39.13	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No	No	No	N/A	No
3	1,176.773	1020	-0.75%	-5.80%	5.30%	Crest	424.333	80	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No
4	1,942.542	975.565	-5.80%	2.73%	8.53%	Sag	298.547	35	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No	Meets Spec	No	N/A	No
5	2,387.296	987.695	2.73%	-6.29%	9.02%	Crest	586.365	65	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No
6	2,846.360	958.803	-6.29%	1.27%	7.57%	Sag	264.862	35	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No	Meets Spec	No	N/A	No
7	3,332.847	965	1.27%	-4.09%	5.36%	Crest	428.743	80	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No
8	3,700.000	950	-4.09%	0.00%	4.09%	Sag	210.000	51.401	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	No	No	N/A	No
9	4,000.000	950	0.00%	4.52%	4.52%	Sag	210.000	46.488	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No	No	No	N/A	No
10	4,921.500	991.647	4.52%	-1.61%	6.13%	Crest	490.086	80	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No
11	6,254.169	970.215	-1.61%	-6.02%	4.41%	Crest	352.948	80	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No
12	6,805.854	937	-6.02%	0.00%	6.02%	Sag	209.808	35	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No	No	No	N/A	No
13	7,310.929	936.868	0.00%	4.34%	4.34%	Sag	300.000	51.843	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No
14	8,249.728	980.087	4.34%						100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK	No	N/A	N/A	No

Table 5-7: Option 2 – Vertical Alignment Summary (including K-value and 0.9 x SSD adjustments)

Critical Design Requirements				
	Speed	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)
	60	120	20	11
	80	160	16	26
	100	200	25	53
	120	240	36	78

VA Data For Option 2									Proposed Posting Speed	Spec. for 100 km/h				Spec. for 120 km/h			
No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value		Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result
1	0.000	1062.592		-6.11%					100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK
2	668.605	1022.533	-6.11%	-0.75%	5.37%	Sag	210.000	39.13	100	Meets Spec	Meets Spec	N/A	OK	No	Meets Spec	N/A	No
3	1,176.773	1020	-0.75%	-5.80%	5.30%	Crest	424.333	80	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
4	1,942.542	975.565	-5.80%	2.73%	8.53%	Sag	298.547	35	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No
5	2,387.296	987.695	2.73%	-6.29%	9.02%	Crest	586.365	65	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No
6	2,846.360	958.803	-6.29%	1.27%	7.57%	Sag	264.862	35	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No
7	3,332.847	965	1.27%	-4.09%	5.36%	Crest	428.743	80	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
8	3,700.000	950	-4.09%	0.00%	4.09%	Sag	210.000	51.401	100	Meets Spec	Meets Spec	N/A	OK	No	Meets Spec	N/A	No
9	4,000.000	950	0.00%	4.52%	4.52%	Sag	210.000	46.488	100	Meets Spec	Meets Spec	N/A	OK	No	Meets Spec	N/A	No
10	4,921.500	991.647	4.52%	-1.61%	6.13%	Crest	490.086	80	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
11	6,254.169	970.215	-1.61%	-6.02%	4.41%	Crest	352.948	80	100	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK
12	6,805.854	937	-6.02%	0.00%	6.02%	Sag	209.808	35	100	Meets Spec	Meets Spec	N/A	OK	No	No	N/A	No
13	7,310.929	936.868	0.00%	4.34%	4.34%	Sag	300.000	51.843	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
14	8,249.728	980.087	4.34%						100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK

Table 5-8: Option 2 – Vertical Alignment (Critical Grades / Climbing Lanes)

VA Info									Southbound				North Bound			
Ref. No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value	Length from previous PVI	Grade	Critical Length	Requires Climbing Lane	Length from previous PVI	Grade	Critical Length	Requires Climbing Lane
1	0.000	1062.592		-6.11%									0			
2	668.605	1022.533	-6.11%	-0.75%	5.37%	Sag	210.000	39.130	668.605	-0.06	#N/A	#N/A	668.605	0.06	180	YES
3	1176.773	1020.000	-0.75%	-5.80%	5.30%	Crest	424.333	80.000	508.168	-0.01	#N/A	#N/A	508.168	0.01	550	NO
4	1942.542	975.565	-5.80%	2.73%	8.53%	Sag	298.547	35.000	765.769	-0.06	#N/A	#N/A	765.769	0.06	180	YES
5	2387.296	987.695	2.73%	-6.29%	9.02%	Crest	586.365	65.000	444.754	0.03	380	YES	444.754	-0.03	#N/A	#N/A
6	2846.360	958.803	-6.29%	1.27%	7.57%	Sag	264.862	35.000	459.064	-0.06	#N/A	#N/A	459.064	0.06	180	YES
7	3332.847	965.000	1.27%	-4.09%	5.36%	Crest	428.743	80.000	486.487	0.01	550	NO	486.487	-0.01	#N/A	#N/A
8	3700.000	950.000	-4.09%	0.00%	4.09%	Sag	210.000	51.401	367.153	-0.04	#N/A	#N/A	367.153	0.04	300	YES
9	4000.000	950.000	0.00%	4.52%	4.52%	Sag	210.000	46.488	300	0.00	550	NO	300	0.00	550	NO
10	4921.500	991.647	4.52%	-1.61%	6.13%	Crest	490.086	80.000	921.5	0.05	240	YES	921.5	-0.05	#N/A	#N/A
11	6254.169	970.215	-1.61%	-6.02%	4.41%	Crest	352.948	80.000	3407.809	-0.02	#N/A	#N/A	3407.809	0.02	550	YES
12	6805.854	937.000	-6.02%	0.00%	6.02%	Sag	209.808	35.000	551.685	-0.06	#N/A	#N/A	551.685	0.06	180	YES
13	7310.929	936.868	0.00%	4.34%	4.34%	Sag	300.000	51.843	505.075	0.00	550	NO	505.075	0.00	550	NO
14	8249.728	980.087	4.34%						938.799	0.04	300	YES	938.799	-0.04	#N/A	#N/A

5.2.2 Advantages of Option 2

- A few currently isolated communities will gain better access to the R617 than what they currently experience, and
- During construction the existing R617 as well as the D1212 will not be affected.

5.2.3 Disadvantages of Option 2

- Longest route (8,25 km);
- Option 2 is in close proximity to the environmentally sensitive Impendle Nature Reserve;
- It is understood that the Impendle Nature Reserve is home to endangered / protected birdlife and positioning the road to close could be detrimental to said birdlife;
- Positioning the route so far north from the R617's current alignment will impact negatively on most of the communities and villages in the project area, since Option 2 is located too far from most communities and therefore additional access roads will be required;
- Three (3) bridges will be required along this alignment, which will result in a substantial cost increase; and
- This option is not recommended in terms of (non-) compliance with the geometric design standards, including:
  - Steeper grades (max. 9,02%), which will result in heavy vehicles having difficulty maintaining speed up hills and have deceleration and braking challenges on steep downhills. Slower moving heavy vehicles affect the level of service experienced by other road users who get stuck behind the said vehicles;
  - Some horizontal radii are substandard for an e_{max} of 8% (recommended) at a design speed of 100 km/h. To counter this, 80 km/h speed restrictions over these sections will be required which is undesirable on roads such as the R617; and
  - If the superelevation rate is increased beyond that recommended above, slow moving heavy vehicles may be at risk of tipping over.

5.3 Option 3

Option 3 is indicated in **BLUE** in **Figure 5-1** above, which is about 7,75 km long and aims to follow the existing R617 as far as possible. The uMkhomazi River will be crossed with via a medium-sized yet substantial bridge to the north of the existing bridge on the R617. The alignment then hugs the contours whilst staying fairly parallel with the existing road, but on higher ground in order to stay clear of the HFL and purchase line. As per Option 2, a small stream is crossed before re-joining the existing R617. An additional smaller bridge will be required to cross the stream. A bridge to accommodate pedestrians and cattle will be required near the old Deepdale Bridge on the D1212 in order for school children and cattle to cross the dam basin. The old Deepdale Bridge will be inundated by the proposed Smithfield Dam.

The challenge for Option 3 is the mountainous terrain where the road will run parallel to the existing R617 but on a higher level against a steep slope. This slope will require stabilisation and the road could potentially require a form of cantilever as it passes the steep slopes.

Option 3 falls within the habitat of the near critically endangered and protected invertebrate *Pennington Protea Butterfly*, whose larvae are hosted in the *Protea Caffra* plants (indicated by red bands in **Figure 5-1** above). This route option is sufficiently clear of the endangered *Blue Swallows* (indicated by red Impendle Buffer Zone demarcation).

5.3.1 Geometric Analysis for Option 3

5.3.1.1 Horizontal Alignment

Option 3's horizontal fails to meet requirements of the design standards for a 100 km/h design speed as shown in **Table 5.9** below. Speed restrictions to between 60 and 80 km/h would be required for this tight horizontal geometry.

The horizontal alignment for Option 3 is therefore not recommended.

Table 5-9: Horizontal Alignment Data for Option 3

No.	Type	Length	Radius	Direction	Start Station	End Station	Minimum Required Radius for 4% Super Elevation	Check	Minimum Required Radius for 6% Super Elevation	Check	Minimum Required Radius for 8% Super Elevation	Check	Minimum Required Radius for 10% Super Elevation	Check
1	Line	221.38		11° 12' 00"	0	221.379								
2	Curve	119.55	360		221.379	340.925	490	FAIL	400	FAIL	390	FAIL	300	OK
3	Line	299.36		352° 10' 20"	340.925	640.289								
4	Curve	101.35	360		640.289	741.635	490	FAIL	400	FAIL	390	FAIL	300	OK
5	Line	70.183		8° 18' 10"	741.635	811.819								
6	Curve	156.22	360		811.819	968.035	490	FAIL	400	FAIL	390	FAIL	300	OK
7	Line	96.238		33° 10' 00"	968.035	1064.273								
8	Curve	651.1	280		1064.273	1715.378	490	FAIL	400	FAIL	390	FAIL	300	FAIL
9	Line	10.323		166° 24' 00"	1715.378	1725.701								
10	Curve	509.7	450		1725.701	2235.402	490	FAIL	400	OK	390	OK	300	OK
11	Line	4.961		231° 17' 50"	2235.402	2240.363								
12	Curve	184.89	210		2240.363	2425.257	490	FAIL	400	FAIL	390	FAIL	300	FAIL
13	Line	7.281		180° 51' 00"	2425.257	2432.538								
14	Curve	453.33	210		2432.538	2885.867	490	FAIL	400	FAIL	390	FAIL	300	FAIL
15	Line	192.44		57° 10' 00"	2885.867	3078.308								
16	Curve	205.21	210		3078.308	3283.517	490	FAIL	400	FAIL	390	FAIL	300	FAIL
17	Line	122.24		1° 10' 40"	3283.517	3405.757								
18	Curve	353.03	210		3405.757	3758.79	490	FAIL	400	FAIL	390	FAIL	300	FAIL
19	Line	18.254		97° 29' 50"	3758.79	3777.043								
20	Curve	104.06	210		3777.043	3881.105	490	FAIL	400	FAIL	390	FAIL	300	FAIL
21	Line	24.996		69° 06' 20"	3881.105	3906.101								
22	Curve	125.52	210		3906.101	4031.616	490	FAIL	400	FAIL	390	FAIL	300	FAIL
23	Line	12.177		103° 21' 00"	4031.616	4043.793								
24	Curve	99.944	210		4043.793	4143.737	490	FAIL	400	FAIL	390	FAIL	300	FAIL
25	Line	60.374		130° 37' 10"	4143.737	4204.111								
26	Curve	476.16	210		4204.111	4680.268	490	FAIL	400	FAIL	390	FAIL	300	FAIL
27	Line	232.16		0° 42' 20"	4680.268	4912.43								
28	Curve	183.96	210		4912.43	5096.39	490	FAIL	400	FAIL	390	FAIL	300	FAIL
29	Line	469.93		50° 53' 50"	5096.39	5566.324								
30	Curve	352.69	280		5566.324	5919.01	490	FAIL	400	FAIL	390	FAIL	300	FAIL
31	Line	112.59		123° 04' 00"	5919.01	6031.6								
32	Curve	83.169	280		6031.6	6114.769	490	FAIL	400	FAIL	390	FAIL	300	FAIL
33	Line	80.863		140° 05' 10"	6114.769	6195.632								
34	Curve	44.912	280		6195.632	6240.545	490	FAIL	400	FAIL	390	FAIL	300	FAIL
35	Line	96.331		149° 16' 30"	6240.545	6336.875								
36	Curve	221.65	280		6336.875	6558.529	490	FAIL	400	FAIL	390	FAIL	300	FAIL
37	Line	42.733		103° 55' 10"	6558.529	6601.263								
38	Curve	97.548	380		6601.263	6698.81	490	FAIL	400	FAIL	390	FAIL	300	OK
39	Line	165.72		118° 37' 40"	6698.81	6864.535								
40	Line	112.6		113° 40' 00"	6864.535	6977.136								
41	Curve	494.88	280		6977.136	7472.016	490	FAIL	400	FAIL	390	FAIL	300	FAIL
42	Line	275.64		12° 24' 00"	7472.016	7747.654								

5.3.1.2 Vertical Alignment

The vertical alignment data for Option 3 is summarised in **Table 5-10** below (without K-value and SSD adjustments). This data indicates that Option 3 meets most of the vertical alignment requirements for a design speed of 100 km/h, without applying K-value and SSD adjustments. Since the horizontal alignment only meets 60 to 80 km/h design speeds, the vertical alignment will follow suit.

When applying K-value adjustments and limiting the required SSD for the vertical alignment for traversing such mountainous terrain, the requirements for a design speed of 100 km/h are for the most part, achievable. However, the horizontal alignment parameters will override this as far as the design speeds are concerned. This data is summarised in Table 5-11 below (including K-value and 0.9 x SSD adjustments).

Table 5-12 below summarises the location of critical grades necessitating the need for climbing lanes, where applicable, in each direction. The need for these climbing lanes is based purely on gradient and has not taken traffic needs into consideration, which is beyond the scope of work for this appointment. Traffic considerations form part of the subsequent design stages and are not consider further during Conceptual Design.

Table 5-10: Option 3 – Vertical Alignment Summary (without K-value and SSD adjustments)

Critical Design Requirements				
	Speed	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)
	60	120	20	12
	80	160	30	30
	100	200	50	60
	120	240	70	110

VA Data For Option 3									Proposed Posting Speed	Spec. for 80 km/h				Spec. for 100 km/h				Spec. for 120 km/h			
No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value		Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result
1	0.000	1018.649		-7.18%					100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK
2	282.182	998.39	-7.18%	-1.29%	5.89%	Sag	210.000	35.666	80	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No	No	No	N/A	No
3	895.170	990.475	-1.29%	-6.93%	5.64%	Crest	210.000	37.223	80	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No	No	N/A	No	No
4	1,767.484	929.998	-6.93%	2.67%	9.61%	Sag	641.251	66.748	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	No	N/A	No
5	2,560.453	951.202	2.67%	7.14%	4.47%	Sag	476.210	106.64	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
6	3,210.541	997.615	7.14%	-6.49%	13.63%	Crest	782.590	57.427	80	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No	Meets Spec	N/A	No	No
7	3,861.134	955.405	-6.49%	-1.41%	5.08%	Sag	457.318	89.994	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
8	4,387.137	948.007	-1.41%	-0.56%	0.85%	Sag	548.436	647.92	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
9	5,641.609	940.983	-0.56%	0.60%	1.16%	Sag	1,125.895	968.94	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
10	7,302.656	950.983	0.60%	6.54%	5.94%	Sag	554.476	93.373	100	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
11	7,747.654	980.087	6.54%						100	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK	No	N/A	N/A	No

Table 5-11: Option 3 – Vertical Alignment Summary (including K-value and SSD adjustments)

Critical Design Requirements				
	Speed	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)
	60	120	20	11
	80	160	16	26
	100	200	25	53
	120	240	36	78

VA Data For Option 3									Proposed Posting Speed	Spec. for 80 km/h			Spec. for 100 km/h				Spec. for 120 km/h			
No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value		Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result	Min. Curve Length	Min. K Sag	Min. K Crest (Object height 0.6m)	Final Result
1	0.000	1018.649		-7.18%					100	N/A	N/A	OK	N/A	N/A	N/A	OK	N/A	N/A	N/A	OK
2	282.182	998.39	-7.18%	-1.29%	5.89%	Sag	210.000	35.666	100	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	No	No	N/A	No
3	895.170	990.475	-1.29%	-6.93%	5.64%	Crest	210.000	37.223	80	N/A	Meets Spec	OK	Meets Spec	N/A	No	No	No	N/A	No	No
4	1,767.484	929.998	-6.93%	2.67%	9.61%	Sag	641.251	66.748	100	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
5	2,560.453	951.202	2.67%	7.14%	4.47%	Sag	476.210	106.643	100	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
6	3,210.541	997.615	7.14%	-6.49%	13.63%	Crest	782.590	57.427	100	N/A	Meets Spec	OK	Meets Spec	N/A	Meets Spec	OK	Meets Spec	N/A	No	No
7	3,861.134	955.405	-6.49%	-1.41%	5.08%	Sag	457.318	89.994	100	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
8	4,387.137	948.007	-1.41%	-0.56%	0.85%	Sag	548.436	647.919	100	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
9	5,641.609	940.983	-0.56%	0.60%	1.16%	Sag	1,125.895	968.937	100	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
10	7,302.656	950.983	0.60%	6.54%	5.94%	Sag	554.476	93.373	100	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK	Meets Spec	Meets Spec	N/A	OK
11	7,747.654	980.087	6.54%						100	N/A	N/A	OK	N/A	N/A	N/A	OK	No	N/A	N/A	No

Table 5-12: Option 3 – Vertical Alignment (Critical Grades / Climbing Lanes)

VA Info									Southbound				Northbound			
Ref. No.	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value	Length from previous PVI	Grade	Critical Length	Requires Climbing Lane	Length from previous PVI	Grade	Critical Length	Requires Climbing Lane
1	0.000	1018.649		-7.18%									0			
2	282.182	998.390	-7.18%	-1.29%	5.89%	Sag	210.000	35.666	282.182	-0.07	#N/A	#N/A	282.182	0.07	140	YES
3	895.170	990.475	-1.29%	-6.93%	5.64%	Crest	210.000	37.223	612.988	-0.01	#N/A	#N/A	612.988	0.01	550	YES
4	1767.484	929.998	-6.93%	2.67%	9.61%	Sag	641.251	66.748	872.314	-0.07	#N/A	#N/A	872.314	0.07	140	YES
5	2560.453	951.202	2.67%	7.14%	4.47%	Sag	476.210	106.643	792.969	0.03	380	YES	792.969	-0.03	#N/A	#N/A
6	3210.541	997.615	7.14%	-6.49%	13.63%	Crest	782.590	57.427	650.088	0.07	140	YES	650.088	-0.07	#N/A	#N/A
7	3861.134	955.405	-6.49%	-1.41%	5.08%	Sag	457.318	89.994	650.593	-0.06	#N/A	#N/A	650.593	0.06	180	YES
8	4387.137	948.007	-1.41%	-0.56%	0.85%	Sag	548.436	647.919	526.003	-0.01	#N/A	#N/A	526.003	0.01	550	NO
9	5641.609	940.983	-0.56%	0.60%	1.16%	Sag	1,125.895	968.937	1254.472	-0.01	#N/A	#N/A	1254.472	0.01	550	YES
10	7302.656	950.983	0.60%	6.54%	5.94%	Sag	554.476	93.373	1661.047	0.01	550	YES	1661.047	-0.01	#N/A	#N/A
11	7747.654	980.087	6.54%						4537.113	0.07	140	YES	4537.113	-0.07	#N/A	#N/A

5.3.2 Advantages of Option 3

- Little disruption to communities in terms of access to the R617 and public transport facilities;
- A few currently isolated communities will gain better access than what they currently experience; and
- During construction the existing R617 and the D1212 will not be affected significantly.

5.3.3 Disadvantages of Option 3

- Fails to meet geometric design standards for a preferred 100 km/h design speed.
- Design speed will need to be reduced to between 60 and 80 km/h to achieve minimum design standard compliance.
- From an environmental perspective, Option 3 should not be considered due falling within the habitat of the near critically endangered and protected invertebrate *Pennington Protea Butterfly*, whose larvae are hosted in the *Protea Caffra* plants (indicated by red bands in **Figure 5-1** above).
- Additional bridges will be required for this alignment which will increase costs substantially;
- Steep side slopes will require stabilisation and specialist rock anchoring or similar; and
- A form of cantilever may be required to support the road as it traverses alongside steep slopes, i.e. hugging steep contour lines.

6. COST ESTIMATES FOR THE REALIGNMENT OF THE R617

6.1 Roads

For the roads costing a detailed cost estimate comprising calculation of major cost items, as well as allowance for lessor and/or ancillary works, was undertaken for the roadworks component of Option 1B, which is the preferred option. Assumptions and allowances were made for items not yet confirmed or quantifiable, and those items that are directly affected by external and yet unknown aspects including for example, geotechnical investigations and materials availability and suitability. Unit rates are based on recent, similar project items and are market related and competitive. A contingency of 15% was then added to reach an estimated construction cost for the roadworks of Option 1B. This value was then divided by the length of this route option in order to achieve a realistic cost per kilometre rate that could be applied to Options 2 and 3 respectively.

Unit rates, including Preliminary and General (P&G) items, and all ancillaries (excluding VAT), used for the roads include:

- Surfaced Road R50 million/km
- Gravel Road R3 million/km

The detailed cost estimate for Option 1B, which is the preferred option, is summarised in **Table 6-1** below in accordance with COLTO: Standard Specifications for Road and Bridge Works for State Road Authorities, 1998 Edition. Item numbers preceded by the letter B refer to items of payment described under particular or specific project specifications, formulated in accordance with COLTO. The contents of each specific project specification forms part of the Tender and Contract Documentation compiled during latter stages of the engineering services.

The full Bill of Quantities for Option 1B is included for comparative and information purposes only, in Annexure A.

Table 6-1: Detailed Cost Estimate Summary for Option 1B (Surfaced Road)

Description	Amount
COLTO: Standard Specifications for Road and Bridge Works for State Road Authorities, 1998 Edition	-
SECTION 1300: CONTRACTOR'S ESTABLISHMENT ON SITE AND GENERAL OBLIGATIONS	19,300,000.00
SECTION 1400: HOUSING, OFFICES AND LABORATORY FOR THE ENGINEER'S SITE PERSONNEL	7,631,450.00
SECTION 1500: ACCOMMODATION OF TRAFFIC	8,388,188.00
SECTION 1700: CLEARING AND GRUBBING	1,538,500.00
SECTION 2100: DRAINS	25,608,130.00
SECTION 2200: PREFABRICATED CULVERTS	8,694,100.00
SECTION 2300: CONCRETE KERBING, CONCRETE CHANNELLING, CHUTES AND DOWNPIPES, AND CONCRETE LININGS FOR OPEN DRAINS	8,207,500.00
SECTION 2400: ASPHALT AND CONCRETE BERMS	763,500.00
SECTION 3100: BORROW MATERIALS	4,045,000.00
SECTION 3200: SELECTION, STOCKPILING AND BREAKING DOWN THE MATERIAL FROM BORROW PITS, CUTTINGS AND EXISTING PAVEMENT LAYERS, AND PLACING AND COMPACTING OF THE GRAVEL LAYERS	1,479,728.00
SECTION 3300: MASS EARTHWORKS	107,256,867.00
SECTION 3400: PAVEMENT LAYERS OF GRAVEL MATERIAL	11,014,153.00
SECTION 3500: STABILIZATION	3,200,061.00
SECTION 3600: CRUSHED STONE BASE	8,080,290.00
SECTION 4100: PRIME COAT	2,291,102.50
SECTION 4200: ASPHALT BASE AND SURFACING	11,816,046.00
SECTION 5200: GABIONS	4,523,000.00
SECTION 5400: GUARDRAILS	7,187,000.00
SECTION 5600: ROAD SIGNS	371,500.00
SECTION 5700: ROAD MARKINGS	408,400.00
SECTION 5900: FINISHING THE ROAD AND ROAD RESERVE AND TREATING OLD ROADS	420,500.00
SECTION 8100: TESTING MATERIALS AND WORKMANSHIP	5,550,000.00
COLTO: Specific/Particular Specifications (Prefaced with "B")	-
SECTION B8500: LABORATORY AUDIT	115,000.00
SECTION B10100: ROADSIDE EQUIPMENT	43,500.00
TOTALS	-
SUBTOTAL	**247,933,515.50**
Contingencies (15% of SUBTOTAL)	**37,190,027.33**
TOTAL (Excl. VAT)	**285,123,542.83**

Option 1B is 6,430 km long, which approximates to R44,342,697.17/km. For simplicity and for the purposes of this Study, this figure has been rounded up to R50,000,000.00/km.

The cost of the gravel road is an estimated R3,000,000.00/km and is based on a unit rate of R375/m^2 which includes ripping and processing the in-situ road layer and applying a

200 mm gravel wearing course. The rate assumes that founding conditions and existing materials are suitable. This estimate is subject to change based on the geotechnical investigation findings carried out during subsequent design stages.

6.2 Bridges

For the bridges component as applicable to each of Options 1, 2 and 3, unit rates (R/m^2) based on bridge deck areas for three (3) different bridge types, P&G allowance included (excluding VAT), were used:

- Major Bridge R30,000/m^2
- Lesser Bridge R25,000/m^2
- Pedestrian/Cattle Access Bridge R20,000/m^2

A number of factors influence the costing, which may include the following, amongst others:

- Specific site conditions including high fills, steep valleys, etc.;
- Hydraulic and hydrological factors – acceptance of hydrological method and return periods, the greater the return period the greater the size and height of bridge required;
- Geotechnical conditions which will determine the need for piling or spread footings;
- Road alignment including whether the bridges are located on horizontal or vertical curves, with or without superelevation, etc., and
- Construction economics (simply put, did the contractor price to win the work if he was desperate).

These are refined and optimised in the preliminary and detail design phases. At concept design stage any costing should be considered a budget figure to be used in the evaluation of the routes chosen. The R/m^2 rates as provided are industry aligned and are updated and modified based on construction costs from recent projects. Detailed costing Bills of Quantities are generally prepared once the route has been optimised into a preferred and alternate route with attendant bridge structures, with geotechnical drilling complete and acceptance of hydrological return periods providing an assurance of required bridge height and length.

Summarised cost estimates for each alignment option and the different type of structures involved per option are given in **Table 6-2 to 6-4** below:

Table 6-2: Cost Estimate for Roads (All options)

No.	Description	Unit	Quantity	Rate (Rand)	Amount			
					Option 1A	Option 1B	Option 2	Option 3
1	**ROADWORKS**				**6.50 km**	**6.43 km**	**8.25 km**	**7.75 km**
2	Road length (surfaced)							
3	Option 1A	km	6.50	50,000,000.00	325,000,000.00			
4	Option 1B	km	6.43	50,000,000.00		321,500,000.00		
5	Option 2	km	8.25	50,000,000.00			412,500,000.00	
6	Option 3	km	7.75	50,000,000.00				387,500,000.00
7	Road length (gravel) [Estimate]							
8	Option 1A	km	1.00	3,000,000.00	3,000,000.00			
9	Option 1B	km	1.00	3,000,000.00		3,000,000.00		
10	Option 2	km	2.00	3,000,000.00			6,000,000.00	
11	Option 3	km	2.00	3,000,000.00				6,000,000.00
12	Cost of Road (surfaced)	R			325,000,000.00	321,500,000.00	412,500,000.00	387,500,000.00
13	Cost of Road (gravel)	R			3,000,000.00	3,000,000.00	6,000,000.00	6,000,000.00
14	**Subtotal Cost of Roads**	**R**			**328,000,000.00**	**324,500,000.00**	**418,500,000.00**	**393,500,000.00**

Table 6-3: Cost Estimate for Structures (All Options)

No.	Description	Unit	Quantity	Rate (Rand)	Amount			
					Option 1A	Option 1B	Option 2	Option 3
16	**BRIDGES**							
17	Major Bridge over Umkhomazi River (Bridge 1-1)							
18	_Length (conservative)	m	450.00					
19	_Width	m	11.40					
20	_Height	m	27.00					
21	_Bridge Deck Area	m²	5,130.00	30,000.00	153,900,000.00	153,900,000.00		
22	Cattle/Pedestrian Access Bridge over Umkhomazi River (Bridge 1-2)							
23	_Length (conservative)	m	450.00					
24	_Width	m	2.50					
25	_Height	m	27.00					
26	_Bridge Deck Area	m²	1,125.00	20,000.00	22,500,000.00	22,500,000.00	22,500,000.00	22,500,000.00
27	Bridge over Umkhomazi Tributary (Bridge 2-1)							
28	_Length (conservative)	m	35.00					
29	_Width	m	11.40					
30	_Height	m	5.00					
31	_Bridge Deck Area	m²	399.00	25,000.00			9,975,000.00	
32	Bridge over Umkhomazi (Bridge 2-2)							
33	_Length (conservative)	m	170.00					
34	_Width	m	11.40					
35	_Height	m	10.00					
36	_Bridge Deck Area	m²	1,938.00	30,000.00			58,140,000.00	
37	Bridge over Umkhomazi Tributary (Bridge 3-1)							

No.	Description	Unit	Quantity	Rate (Rand)	Amount			
					Option 1A	Option 1B	Option 2	Option 3
16	**BRIDGES**							
38	_Length (conservative)	m	35.00					
39	_Width	m	11.40					
40	_Height	m	5.00					
41	_Bridge Deck Area	m²	399.00	25,000.00				9,975,000.00
42	Bridge over Umkhomazi (Bridge 3-2)							
43	_Length (conservative)	m	250.00					
44	_Width	m	11.40					
45	_Height	m	10.00					
46	_Bridge Deck Area	m²	2,850.00	30,000.00				85,500,000.00
47	**Subtotal Cost of Bridges**	**R**			**176,400,000.00**	**176,400,000.00**	**90,615,000.00**	**117,975,000.00**

Table 6-4: Cost Estimate Summary for Roads and Structures Combined (All Options)

No.	Description	Unit	Quantity	Rate (Rand)	Amount			
					Option 1A	Option 1B	Option 2	Option 3
47	Subtotal Cost of Bridges	R			176,400,000.00	176,400,000.00	90,615,000.00	117,975,000.00
48	Total Roads and Bridges (Excl. VAT)	R			504,400,000.00	500,900,000.00	509,115,000.00	511,475,000.00
49	**Total Roads and Bridges (Incl. 14% VAT)**	**R**			**575,016,000.00**	**571,026,000.00**	**580,391,100.00**	**583,081,500.00**
			km		**6.500**	**6.430**	**8.250**	**7.750**
			R/km		**77,600,000.00**	**77,900,466.56**	**61,710,909.09**	**65,996,774.19**

7. DESIGN RECOMMENDATIONS FOR THE REALIGNMENT OF THE R617

7.1 Discussion

Three (3) realignment options were considered for the R617, namely Options 1A & 1B, 2 and 3 respectively. Based on the mountainous terrain, adherence to design standards (particularly geometrics) was challenging. Each route options has advantages and disadvantages (refer **Section 5** above), which in turn have a direct impact on route recommendations. The selection of the preferred route has been separated into three (3) criteria:

- Environmental and Socio-economics;
- Practicality and adherence to design standards and best practice; as well as
- Costs.

7.1.1 Environmental and Socio-economics

The uMWP-1 is located close to an environmentally sensitive area and its footprint borders the Impendle Nature Reserve, which is home to endangered and protected birdlife.

Realigning the R617 will have an impact on the villages and communities located along the existing and/or new realigned R617. Access to the R617 and transport facilities is either easier or more difficult depending on village location. Furthermore, some communities will have to be relocated.

The extent of the impact on environmental and socio-economic issues on the area and the communities is covered by specialists in these fields. However, some route options are more environmentally and socio-economically acceptable than others.

Options 1A and 1B for the most part, follow the existing gravel road and therefore will be less disruptive to the affected communities. These routes are located further away from the Impendle Nature Reserve than the others, and therefore their impact on the reserve will be less. Option 2 and more so Option 3, are positioned very close to the Impendle Nature Reserve and could have a significantly negative environmental impact. Option 3 will affect the commuting of communities, but to a lesser extent than Option 2.

Options 1A and 1B are the only options that are clear of the habitat of the near critically endangered and protected invertebrate *Pennington Protea Butterfly*, whose larvae are hosted in the *Protea Caffra* plants (indicated by red bands in **Figure 5-1** above). These route options are also sufficiently clear of the endangered *Blue Swallows* (indicated by red Impendle Buffer Zone demarcation on **Figure 5-1** above).

In terms of the environmental and socio-economic aspects, Options 1A and 1B are the preferred options.

7.1.2 Practicality and Adherence to Design Standards and Best Practice

In terms of adherence to the design standards and best practice philosophies, Options 1A and 1B are the preferred options. Option 1B is, however, preferred over Option 1A due to it being shorter, more compliant in terms of geometrics and it allows for most of the D1212 to remain open and unaffected during construction.

Option 2 for the most part adheres to the design standards, however, due to some substandard horizontal radii, speed restrictions down to 80 km/h are required, which is undesirable. Using adjusted K-values and SSD ratios, Option 2's vertical alignment is compliant for a 100 km/h design speed albeit is has some steep grades in the order of 9%.

Option 3's horizontal alignment fails to meet the minimum requirements and is deemed compliant for a design speed of between 60 and 80 km/h, which is undesirable. Option 3's vertical alignment (with K-value and SSD adjustments) is, however acceptable.

All three (3) options will require substantial bridge and culvert structures, and will traverse difficult mountainous terrain, which results in tight horizontal radii and steep grades. However, Options 2 and 3 fail to convincingly meet the requirements for a 100 km/h design speed and are therefore not recommended.

Option 1B is therefore the preferred option in terms of practicality and adherence to design standards and best practice

7.1.3 Financials

Financial considerations play a major part in determining the viability of a project. Certain options may exhibit prohibitive costs making the projects unfeasible. However, cost should not be the only aspect considered when deciding on options.

Based on the comparative cost estimate for the proposed realignment options, it is clear that those options with lower roadworks costs correspond to higher bridge costs and *vice versa*. The choice of unit rates used for roads and bridges can also sway the costs considerably. Based on the cost estimate above, the various realignment options compare favourably financially, within 2%.

If the lowest cost approach is applied, then Option 1B would be the preferred option (see **Table 6-2** above). Based on the estimates being so close, recommending a particular option based purely on price would not be sensible.

8. CONCLUSION AND RECOMMENDATION

Based on the information available and the Terms of Reference (ToR), also taking cognisance of the environmental and socio-economic aspects, the practicality and adherence to standards and financial aspects, it is recommended that Option 1A or 1B be considered for subsequent design stages. For reasons discussed in **Sections 6 and 7** above, Option 1B is, however, considered to be the best option for the realignment of the R617, and Option 1B is therefore recommended.

9. REFERENCES

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ANNEXURE A
Cost Estimate Breakdown

Bill of Quantities for Option 1B

ANNEXURE B
DRAWINGS
Submitted under Separate Cover