BHUDLU ACCESS BRIDGE AND LINK ROAD,
KWA-ZULU NATAL & EASTERN CAPE

BRIDGE REPORT

August 2015

Prepared for

Prepared by

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SUMMARY

Introduction
Royal HaskoningDHV was appointed by GM Turner and Associates to conduct consultancy services for the design of a river crossing at Umtavuna River. The purpose for the crossing would be to link the uMuziwabantu Local Municipality of Kwa-Zulu Natal and the Mbizana Local Municipality. In doing so connect the communities as well as provide a means to transport agricultural equipment between the two municipalities.

Design Determinants
The preliminary design of the river was based on the topography of the site, access to the river crossing, hydrologic investigations; hydraulic assessments; geotechnical investigations, environmental considerations and the client’s specifications.

Proposed solution
Two suitable alternatives were identified; these included a four span low level river crossing and a six span bridge.

Construction Cost Estimate
The cost of the four span low level river crossing and a six span bridge were estimated at R 5.9 million and R 6.9 million, respectively.

Conclusions and Recommendations
It was concluded that the proposed alternatives were suitable based on the findings from investigations pertaining to the design determinants.

Based on the conclusions, it was recommended that the proposal for the six span river bridge, subject to which this design will be developed to final design stage for final approval prior to construction, be adopted.

In addition to this phased construction was recommended as a solution to possible budgetary constraints.
# THE DESIGN OF BHUNDLU RIVER CROSSING AND ACCESS ROAD
## PROPOSED BRIDGE DESIGN REPORT

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1. INTRODUCTION

1.1. Terms of Reference

On Friday the 23rd of January 2015 representatives from GM Turner & Associates together with the uMuziwabantu Local Municipality met with the Ward 9 Councillor to confirm the location and access route for the proposed Bhundlu River Crossing. The proposed structure would be located on the boarder of KwaZulu-Natal (KZN) and the Eastern Cape (EC).

On the 31st of March 2015, Royal HaskoningDHV was appointed by GM Turner & Associates to conduct the consultancy engineering services for the design of the river crossing and associated roadworks at the Bhundlu River Crossing. Their specific instructions to Royal HaskoningDHV were to establish the feasibility of constructing a river crossing over Umtamvuna River by:

- Conducting hydrologic and hydraulic investigations to estimate a peak flood.
- Establishing the current environmental and geotechnical status of the land.
- Proposing a suitable structure as well as an alternative, based on the hydrologic, hydraulic, environmental and geotechnical investigations.

1.2. Subject of Report

This report is a based on Bhundlu River Crossing to be constructed on the boarder of KwaZulu-Natal (KZN) and the Eastern Cape (EC). It describes the factors taken into consideration for the river crossing and is concluded with a recommendation for the adoption of a suitable structure.

1.3. Background to Investigation

There have been negotiations between uMuziwabantu Municipality (KZN) and Mbizana Municipality (EC) to provide a direct link between the two municipalities and hence connect the communities of Nyandeni (KZN) and Nomganya (EC). These two communities are separated by Umtamvuna River and their remote locations have made it necessary for residents to employ agricultural activities as a means to obtain food. In order to cultivate and harvest, the communities require mechanized equipment such as tractors which have to cross the river to move from community to community. Owing to both communities increasing needs for such resources, the currently existing informal crossing has proved unsuitable as it can only be crossed when the river is low enough.

Subsequent to several discussions, the two municipalities have decided that uMuziwabantu Municipality will construct the river crossing, KZN portion of the access
road and the 100 m approach road on the EC side of the river crossing. The remainder of the access road on the EC side will be constructed by uMbizana Municipality.

1.4. Objectives of Report

The primary objective of this report is to therefore communicate the proposed river crossing structure. As such, secondary objectives include:

- Detailing the design determinants.
- Outlining alternatives to be considered and propose that which has been identified as the most suitable.
- Providing a construction cost estimate of the proposed structure.
- Making recommendations based on the conclusions drawn.

1.5. Scope and Limitations of Investigation

The report and investigations are limited specifically to the area demarcated as the catchment area. Data collection on the site is limited to spatial data. An account of the available design determinants such as those pertaining to hydrology, hydraulics, environmental and geotechnical considerations has been provided. In addition to this suitable alternatives have been discussed and a detailed description of the proposed structure is provided.

2. CODES AND STANDARDS

The design of the Bhundlu Bridge complies with:

(i) The agreement between GM Turner & Associates and Royal HaskoningDHV for this project.
(ii) SANRAL’s Code of Procedures for the Planning and Design of Highway and Road Structures in South Africa (February 2002).
(iii) SANRAL’s current Standard Details, available from their web site.
(iv) Directives issued by GM turner & Associates regarding the classification of roads for the hydraulic design of bridges.
(v) TMH7 Parts 1, 2 and 3 (as amended 1988)
   - Traffic Loading : NA
(vi) SANRAL's Drainage Manual.
3. DESIGN DETERMINANTS

3.1. Hydrologic Investigation

3.1.1 Methodology

Hydrologic analyses were carried out using SANRAL’s Drainage Manual (2013), followed by hydraulic assessments using the HEC-RAS River Analysis System (2005) to check the hydraulic capacity of the structure.

Flood peaks were calculated using the average peak flow values estimated from a combination of methods, namely; the Rational Method, the Alternative Rational Method, the Standard Design Flood Method, the Empirical Method and the SCS-SA Method.

3.1.2 Flood Estimation

The principal catchment parameters used to estimate the Peak Flows ($Q_T$) as per return period:

- Catchment area $A = 230$ km$^2$
- Longest collector $L = 41.78$ km
- Time of concentration $T_c = 5.46$ hrs
- Catchment Basin $= 25$
- 1085 Gradient $= 14.84$ mm/m

The estimated average flood peaks have been tabulated in Table 3-1 below.

<table>
<thead>
<tr>
<th>Return Period (Years)</th>
<th>2</th>
<th>5</th>
<th>10</th>
<th>20</th>
<th>50</th>
<th>100</th>
<th>200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Flow ($m^3$/s)</td>
<td>119</td>
<td>211</td>
<td>274</td>
<td>409</td>
<td>574</td>
<td>820</td>
<td>1154</td>
</tr>
</tbody>
</table>

3.2. Hydraulic Assessment

3.2.1 Flood Frequency and Freeboard Requirements

The access road off the D1100 that runs over the structure is classified as a Class 5 road for drainage.

In accordance with SANRAL’s Drainage Manual Figure 8.2 the design flood frequency is 10 years for a Class 5 road with $Q_{20}$ of 409 $m^3$/s.
The $Q_T (Q_{10})$ requires a positive freeboard of $0.64 \, m \approx 0.7 \, m$ to the deck soffit (SANRAL Drainage Manual Figure 8.3).

### 3.3. Topography

There are very few noteworthy features on the site. There are minimal tree trees, and the vegetation consists primarily of grass and shrubs. Actual preparation and excavation of the site will be simple since there are no features which cannot be removed as the site is covered only in low vegetation. The flood plain traversed by the river, upstream to downstream is relatively flat. Figure 3-1 below shows a sub-section of the site including its features and provides an indication of the location of the proposed river crossing with a red rectangular box.

![Figure 3-1: Site Topography and Location for Proposed River Crossing](image)

### 3.4. Access to River Crossing

Access to the river crossing from the KZN side is off the District Road (D1100) onto a municipal gravel road and then onto an informal 4x4 track leading to the crossing. Similarly, access to the EC side is off a district road onto a municipal gravel road and then onto an informal 4x4 track. Therefore, access to the river crossing from both the KZN and EC side will be from the nearest district roads.
3.5. Road Geometry

3.5.1 Geometry

The proposed route will be designed for a design speed of 40km/h. In order to remain within the minimum and maximum grade requirements a considerable volume of earthworks will be required.

3.5.2 Typical Cross-Section

The proposed typical cross section is represented in Figure 3-2 below.

![Figure 3-2: Proposed typical cross section](image)

3.5.3 Drainage

No formal drainage currently exists.

It is proposed that formal drainage channels be constructed in the form of grass lined meadow drains and concrete pipe culverts (with headwalls and apron slabs) where necessary. Portions of the drains may need to be lined (with concrete or reno mattress) due to steep longitudinal grades.

3.5.4 Pavement

No pavement layers currently exist for the majority of the length of the proposed routes.

It is proposed that the road bed be prepared to 90% modified AASHTO density using the in-situ material. Additionally, 150mm gravel wearing course will be constructed on top of this. Moreover, portions of the gravel wearing course may need to be replaced by concrete surfacing due to steep longitudinal grades.
3.5.5 Access/ Driveways

All existing accesses/driveways will be re-graded to suit the proposed alignment.

Extent of works for the upgrading can be summarised as follows:

- Clear and grub
- Construct bridge
- Construct earthworks and bridge approaches
- Construct side and cross drainage
- Construct pavement layer
- Tie in to driveways/ accesses
- Landscaping

3.6. Geotechnical Investigation

3.6.1 Investigation

Three boreholes were drilled at the site of the proposed river crossing at the locations indicated in Figure 3-1. Their coordinates are specified in Table 3-2. These were evaluated by G.M. Turner & Associates. The full geotechnical report including the borehole logs has been attached in Appendix C.

Figure 3-3: Location of Borehole logs on Site
Table 3-2: Coordinates of Borehole Logs on Site

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Elevation (m)</th>
<th>x-coordinate</th>
<th>y-coordinate</th>
<th>Groundwater Table Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BH1</td>
<td>755</td>
<td>-70230.724</td>
<td>+3399215.029</td>
<td>752.8</td>
</tr>
<tr>
<td>BH2</td>
<td>752</td>
<td>-70220.307</td>
<td>+3399207.006</td>
<td>750</td>
</tr>
<tr>
<td>BH3</td>
<td>751</td>
<td>-70207.124</td>
<td>+3399198.847</td>
<td>749</td>
</tr>
</tbody>
</table>

3.6.2 Findings

The bedrock is generally moderately fractured very hard Dolerite in boreholes (BH) 1, 2 and 3 at elevations of 751 m, 749 m and 744.5 m, correspondingly. The layer overlying the bedrock comprises of sub-rounded cobbles and boulders containing dolerite and occasional shale. Lastly, the profile of BH3 shows a top layer of slightly slity sandy clay containing fine roots.

It is recommended that the foundations of the river crossing structure be designed to act in end-bearing. Alternative foundations to be used include caisson and/ or pile foundations.

However, pile foundations are highly recommended for the following reasons:

- The depth to competent bedrock is significant as in some cases it is up to 6.5 m below the Energy Grade Line (EGL).
- Boulder bed is considerably thick and extends up to 6.5 m below EGL.
- Shallow groundwater conditions exist.

In using pile foundations, it is recommended that only oscillator and/ or rotapiles be used because they are able to penetrate alluvial boulder beds of significant thickness. In addition to this, a maximum net allowable bearing pressure of 2 000 kN/ m² is considered applicable, provided the piles are socketed into competent weathered bedrock.

3.7. Environmental Factors

3.5.1 Environmental Process

The environmental authorization process for the project is underway.

3.5.2 Environmental Conditions

The site is located inland and thus exposure to aggressive reinforced concrete deterioration mechanisms such as chloride ingress and carbonation, more common in the marine environment, are minimal. Nonetheless, sufficient cover to the reinforcements
has been provided to ensure structural integrity and safety as well as not compromise on durability.

3. ALTERNATIVES CONSIDERED

3.1. Rationale for Alternatives Considered

In selecting alternative structural forms suitable for the river crossing, consideration has been given to the design goals applicable to new structures, these include:

- Safety (strength, robustness, etc.)
- Durability and serviceability
- Economy and constructability
- Aesthetics

It is proposed that a bridge structure be adopted for the river crossing based on:

- The significant catchment size of 230 km².
- The positive freeboard required as the estimated design flood peak flow of 274 m³/s > 100 m³/s (see Figure 8.3 of SANRAL's Drainage Manual (2013)).
- The design flood level of 754.2 m.

In addition to this, the SANRAL's Drainage Manual (2013) guidelines for bridge and culvert classification suggest that a structure with L ≥ 20 m and any span ≥ 1.5 m, is to be considered a bridge structure. Refer to Figures 4-1 and 4-2 which illustrate the relevant bridge and culvert classification criterion.
3.2. Alternative Structural Forms

Thus the following two structures were proposed as suitable alternatives:

(i) A low level simply-supported four span (15 + 15 + 15 + 15) bridge structure.
(ii) A simply supported six span (8 + 15 + 15 + 15 + 15 + 8) bridge structure.

3.1.1 Low Level River Crossing

This alternative comprises a 1 m deep reinforced concrete voided deck slab:

Advantages of this option are:

- Optimised second moment of area to weight ratio. Consequently, concrete volume and accordingly structure weight is improved compared to the same structure with an in-situ solid slab.
- Structural continuity and minimum deck joints.
- Easy erection of formwork and construction.

Disadvantages of this option:

- Structure is designed for a return period (i.e. 1:2 years) lower than the design flood return period (i.e. 1:10 years).
- Design flood return period of 1:10 years results in submergence of the structure. Thus, occasional disruption of vehicle and pedestrian traffic due to flooding during seasons with high rainfall is to be anticipated.

3.1.2 Simply Supported Bridge

This alternative comprises a reinforced concrete voided slab deck with a slab thickness of 200 mm above the voids and 200 mm below the voids. Voids will be 600 mm in diameter and will be drained at the low point. The internal ribs are 350 mm wide and the edge ribs are 500 mm to accommodate the higher edge loads imposed by the cantilevers.

Advantages of this option are:

- Also an improved concrete volume compared to the same structure with an in-situ solid slab.
- Structural continuity and minimum deck joints.
- Structure is able to accommodate 1:10 year design flood.
- No disruption of vehicle and pedestrian traffic due to flooding.
- Easy erection of formwork and construction.
Disadvantages of this option:

- More costly than the low level river crossing

4. PROPOSED BHUNDLU RIVER CROSSING

4.1 Simply Supported Bridge

4.1.1 Structural Configuration

The structure is a reinforced concrete bridge as seen in Figure 4-1.

Figure 4-1: Proposed Bhundlu Bridge River Crossing

*Deck*

Six \((8 + 15 + 15 + 15 + 15 + 8)\) simply supported reinforced concrete voided deck slabs of a total length of 76 m constitute the deck. The deck is 6.5 m wide with a single vehicle lane and pedestrian walk way. Its cross section is a 1 m thick voided deck slab as described in 3.1.2. The soffit of the deck is at an elevation of 755.50 m.

*Abutments*

Reinforced concrete abutments are proposed for the bridge. The abutments will be founded on founding structures recommended by the geotechnical engineers.

*Piers*

Reinforced concrete piers that are 0.6 m wide founded on pile foundations are proposed for the bridge.
5. CONSTRUCTION COST ESTIMATION

The following estimates are based on preliminary component quantities and recently tendered rates for works of a similar character and magnitude in KwaZulu-Natal. Refer to Appendix D for a detailed summary of cost estimates.

The following estimates include:

- Contractor’s establishment
- Contract price adjustment
- VAT

**Bhundlu River Crossing (Alternative 1)**

60 m x 6.5 m wide four span continuous voided slab deck low level river crossing

Total Cost Estimate: R 5 904 131

**Bhundlu River Crossing (Alternative 2)**

76 m long x 6.5 m wide six span continuous voided slab deck bridge

Total Cost Estimate: R 6 978 718
6. CONCLUSION AND RECOMMENDATIONS

The following can be conclusions may be drawn:

1. The catchment area of the site is significantly large.

2. The calculated 1:10 year peak flood suggests that the optimal design requires a positive free board.

3. Actual preparation and excavation of the site will be simple as there are no features which cannot be removed, and the site is covered only in low vegetation.

4. The cost of construction for the proposed six span 76 m bridge is estimated at approximately R 6.9 million.

Based on the above conclusions, and on critical judgement of the river crossing, its location and its projected use as a means to connect the uMuziwabantu and uMbizana communities as well as manoeuvre mechanized agricultural equipment back and forth it is recommended that:

1. The proposal in principle, subject to which this design will be developed to final design stage for final approval prior to construction, be adopted.

2. Construction is phased such that, for example, the foundations, substructure and superstructure are constructed in stages to cater for budgetary constraints.

_________________________  __________________________
T D Mbanjwa                G A Visser
Civil Engineer             Principal for Royal HaskoningDHV

August 2015
APPENDIX A

PHOTOGRAPHS OF THE SITE
APPENDIX B

LOCALITY SKETCH
Figure B1: Locality Plan
APPENDIX C

GEOLOGICAL INFORMATION
APPENDIX D

CONSTRUCTION COST ESTIMATES
### Table D1: Alternative (i) Four Span Low Level River Crossing Bridge

<table>
<thead>
<tr>
<th>Bhundlu River Crossing</th>
<th>4 Span River Bridge</th>
<th>Qty/m</th>
<th>Length</th>
<th>Total Qty</th>
<th>Rate</th>
<th>Amount</th>
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<tr>
<td>Concrete m³</td>
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<td>210</td>
<td>R 1 700</td>
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<tr>
<td>Outside Shuttering m²</td>
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<td>480</td>
<td>R 900</td>
<td>R 432 000.00</td>
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<td></td>
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<tr>
<td>Circular Shuttering m²</td>
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<tr>
<td>Reinforcing t</td>
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<td><strong>Total Deck Cost</strong></td>
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<tr>
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<td>R 900</td>
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<tr>
<td>Circular Shuttering m²</td>
<td>0</td>
<td>0</td>
<td>R 1 000</td>
<td>R 0.00</td>
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<tr>
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<tr>
<td><strong>Pile Caps / Foundations</strong></td>
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<tr>
<td>Drilling m</td>
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<td>0</td>
<td>R 1 200</td>
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## Table D2: Alternative (ii) Six Span Bridge

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<th>Bhundlu River Crossing</th>
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**Site establishment For Pilling Rig**

R 750 000.00

**Total Substructure Cost**

R 2 549 801.56

**Sub Total A**

R 4 404 581.56

Accessories

10%

R 440 458.16

**Sub Total B**

R 4 845 039.72

**P & G:**

20%

R 969 007.94

**Accommodation of Traffic:**

10%

R 0.00

**Sub Total C**

R 5 814 048

**Contingencies:**

10%

R 581 404.77

**Sub Total D**

R 6 395 452

**CPA:**

8%

R 511 636.19

**Sub Total E**

R 6 907 089

**VAT**

14%

R 71 629.07

**TOTAL**

R 6 978 718

**Cost / m²**

R 14 127