ETHEKWINI MUNICIPALITY

Mbokodweni River Floodline at the Proposed Emansomini Pedestrian Bridge

Final Report

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Approved:	Leon Hellberg
Signature:	
For:	SiVEST Civil Engineering Division

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1 INTRODUCTION

SiVEST Civil Engineering Division was appointed by SiVEST Environmental Division to carry out a flood line assessment on Mbokodweni River, in the vicinity of the proposed pedestrian bridge between Umlazi Y Section and Emansomini. Approximate coordinates of the site are:

Latitude 30° 0'30.17"S

Longitude 30°52'26.97"E

This investigation aims to achieve the following objectives:

- Study the catchment characteristics of the Mbokodweni River
- Estimate the 100 year flood peak
- Study the river morphology adjacent to the site
- Create a hydrodynamic model of the rivers and impose the 100 year flood scenario.
- Produce a flood line drawing and a succinct report describing the methods utilised.
- Estimate the effects of the bridge on the river and surrounding areas.

Figure 1: Locality map (from Google Maps)

2 METHODOLOGY

A floodline study is the result of analyses based on two different scientific procedures. The first procedure involves hydrology, whereby storm flows are estimated from a catchment using statistics to predict the magnitude of various storm events based on historical data. The second procedure relates to hydraulics, which simulates the area under investigation during the flood flow. This involves:

a) Creating a virtual 3-dimensional frame which simulates the water course in terms of its slope, topography, and roughness,

b) Introducing the various flood scenarios calculated during the hydrological analysis, and

c) Recording the results such as water levels and velocities.

2.1 Hydrology

The objective of a hydrological study, in the context of flood line and flood risk assessments, is to estimate the peak flow rate within the river in question for a particular return period. The estimation of peak flow rates are typically achieved by stochastic or deterministic methods.

- *Stochastic methods* involve analysis of long flow records near the point of interest in the river. The flow gauging station nearest to the Emansomini bridge site has recorded data with many gaps and does not date back far enough to be considered reliable.
- *Deterministic methods* have been developed to estimate floods where reliable statistical data is not available. Simplistically, hypothetical rainfall events are imposed on a catchment area.

Stochastic methods are usually considered superior to deterministic methods, largely because real data records are involved, rather than hypothetical scenarios. Unfortunately stream flow records are seldom long enough (or have not necessarily recorded many extreme events) and are therefore seldom used.

Of the deterministic methods to be employed, the Standard Design Flood (SDF) is considered to be the most appropriate for this size of catchment.

The deterministic method of calculating flood flows for different return periods involved the following steps, as outlined in the SANRAL Drainage Manual, 6th Edition:

- Determine the catchment area of the point of interest on the river below.
- Determine the length of the watercourse above the point of interest.
- Calculate the average slope of the river within the catchment (10/85 method)
- Select the appropriate SDF basin number
- Identify the mean annual precipitation of the study area.
- Determine the appropriate design rainfall values to be used, for various return periods

Results of the calculations are summarised in section 3, while calculation tables are included in Appendix A.

2.2 Hydraulics

River morphology was assessed through inspection of highly detailed aerial photography, in order to estimate hydraulic properties such as roughness of the river itself and flood plain areas.

The site was surveyed and a 3D terrain model was then produced for use in HEC-RAS, a commonly used software for this type of flood modelling. A series of cross-sections was extracted from the terrain model and input into the hydraulic model to represent the Mbokodweni River. After assigning appropriate roughness and other parameters, the depth of inundation was modelled. HEC-RAS output data is included in Appendix B.

2.3 Effects of the constructed bridge

A bridge element was designed in HEC-RAS according to the bridge design supplied by Ethekwini Municipality Engineering Unit. The HEC-RAS model was re-run incorporating the bridge element at the proposed bridge site. The post-construction output data is also included in Appendix B.

Stormwater runoff from the bridge was estimated to determine what effect it may have on receiving areas.

3 RESULTS

The catchment of the Mbokodweni River at the point of interest shown in Figure 2.

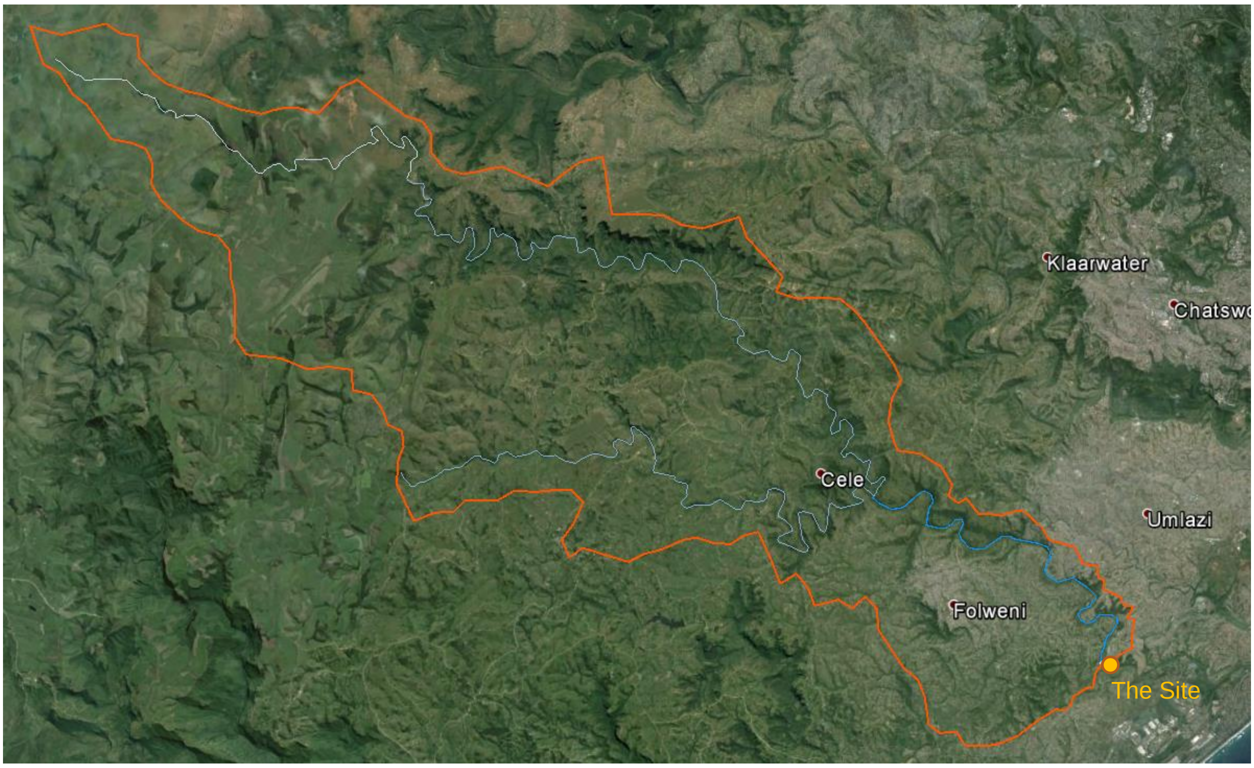


Figure 2: Catchment of Mbokodweni River at the proposed bridge site (Google Earth)

3.1 Hydrology

The catchment area for the Mbokodweni River is considered large, and worthy of a circumspect approach. The Standard Design Flood was developed by Alexander in response to record floods associated with cyclonic activity off the eastern seaboard of Kwazulu-Natal and Mozambique. Alexander's method is considered robust, and the most appropriate deterministic method to be applied in this study. See Table 1 for calculation parameters and results.

Parameter	Mbokodweni River
Catchment Area	229km²
Longest Watercourse	59km
Average Slope (10/85 method)	0.01225
SDF Basin	24 Newlands
Runoff Coefficient	0.80
Time of Concentration	8.35 hours
Average Intensity	18.60 mm/hour
Q_{100}	948 m³/s

Table 1: Summary of key hydrological parameters used for the Standard Design Flood.

3.2 Hydraulics

Figure 3 shows the geometry set up for the Mbokodweni River model in HEC-RAS in which 11 cross sections were taken through the river in the vicinity of the proposed bridge site. Parameters included in the hydraulic model included the following:

- Channel Roughness (Manning's N): 0.035
- Overbank Roughness (Manning's N): 0.045

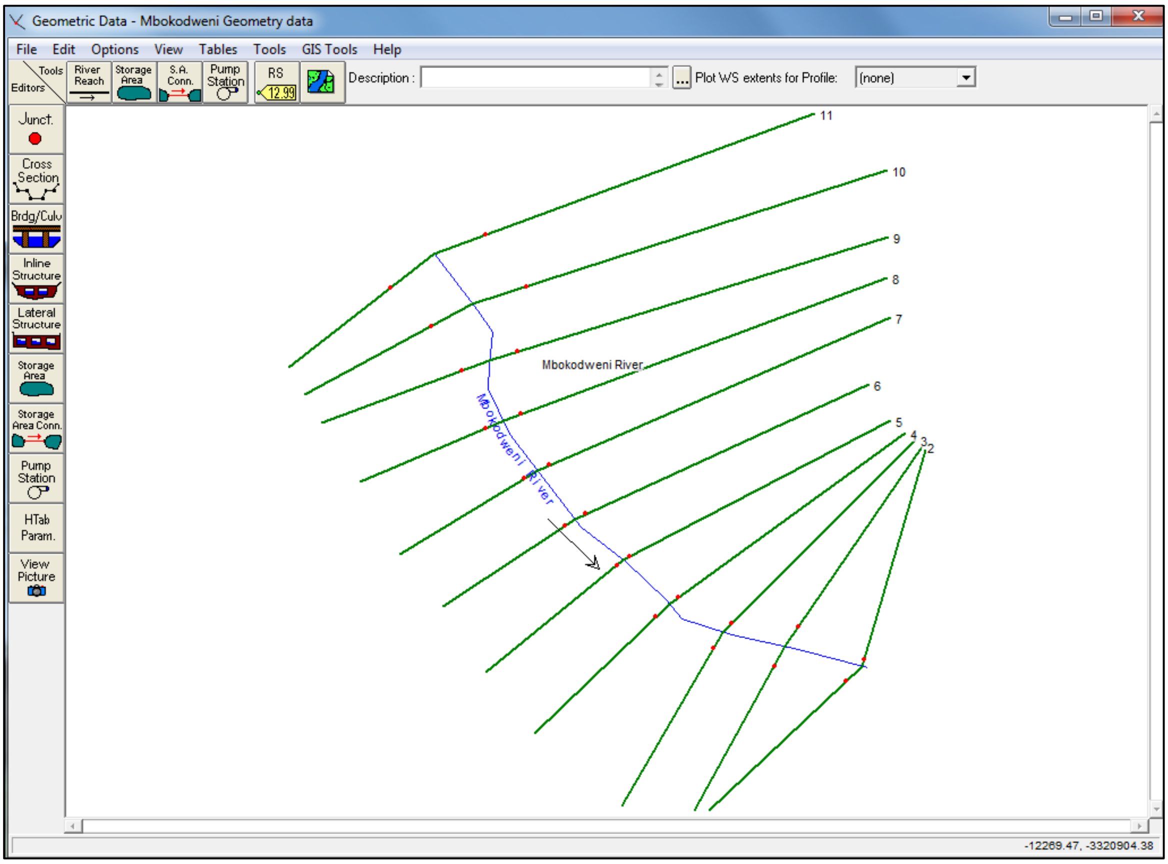


Figure 3: HEC-RAS model geometry of the Mbokodweni River

The flow value 948m^3/s was run through the model in order to determine the 100 year flood line in the vicinity of the proposed bridge site. A typical cross section through the river in flood is presented as Figure 4.

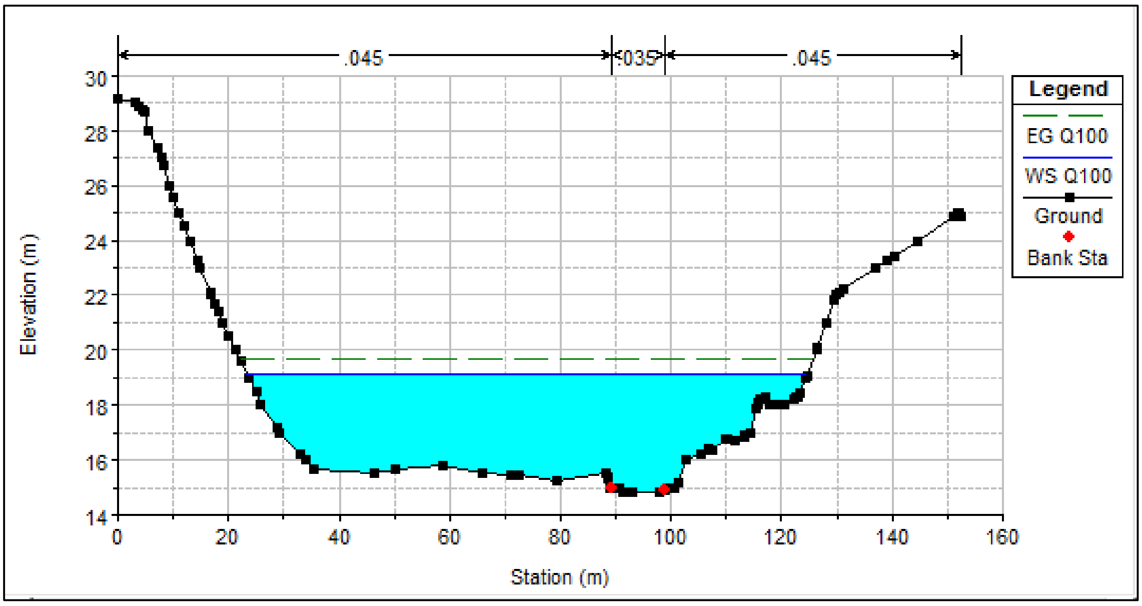


Figure 4: Cross section 4 of the HEC-RAS model during the 100 year flood.

Appendix B contains the output data from the HEC-RAS model. The plan view drawing of the 100 year flood line at the bridge site is included in Appendix C.

3.3 Effects of the constructed bridge

A bridge element was incorporated into the HEC-RAS model in order to model the effects of the proposed bridge once it has been constructed. The bridge element was designed according to the General Arrangement Drawing provided by the Ethekwini Municipality Engineering Unit, attached as Appendix D. The bridge length in the Design Drawing is 36 meters, however the HEC-RAS model output shows that the river width at the proposed bridge site during the 100year flood is estimated to reach approximately 100 meters. The pier spacing is 17.8 meters, which was taken directly from the Ethekwini Design Drawing, and the length of the bridge element between abutments in the HEC-RAS model is 89 meters in order to account for the wider river during flood. Figure 5 shows the model element had 4 piers between abutments as opposed to the Ethekwini Design containing one pier. The bridge deck and pier dimensions were modelled according to the Ethekwini Design.

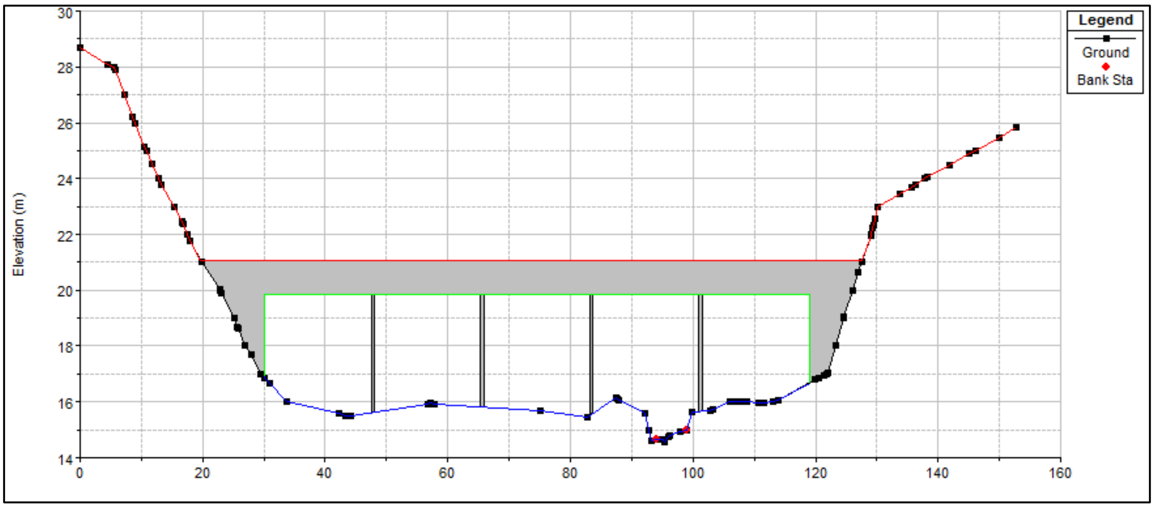


Figure 5: Bridge element in the HEC-RAS model

The model was then re-run with the bridge element in place between river cross sections 4 and 5, as seen in Figure 6.

The output data of the model including the bridge element is contained in Appendix B. By comparing the data with those of the pre-construction data, one can see that there is approximately a 0.09 m rise in the water surface elevation in the cross sections 11 to 5 upstream of the bridge. Similarly there is an increase in the water velocity in cross sections 11 to 5 of approximately 0.15m/s. There is no change in the data downstream of the bridge element.

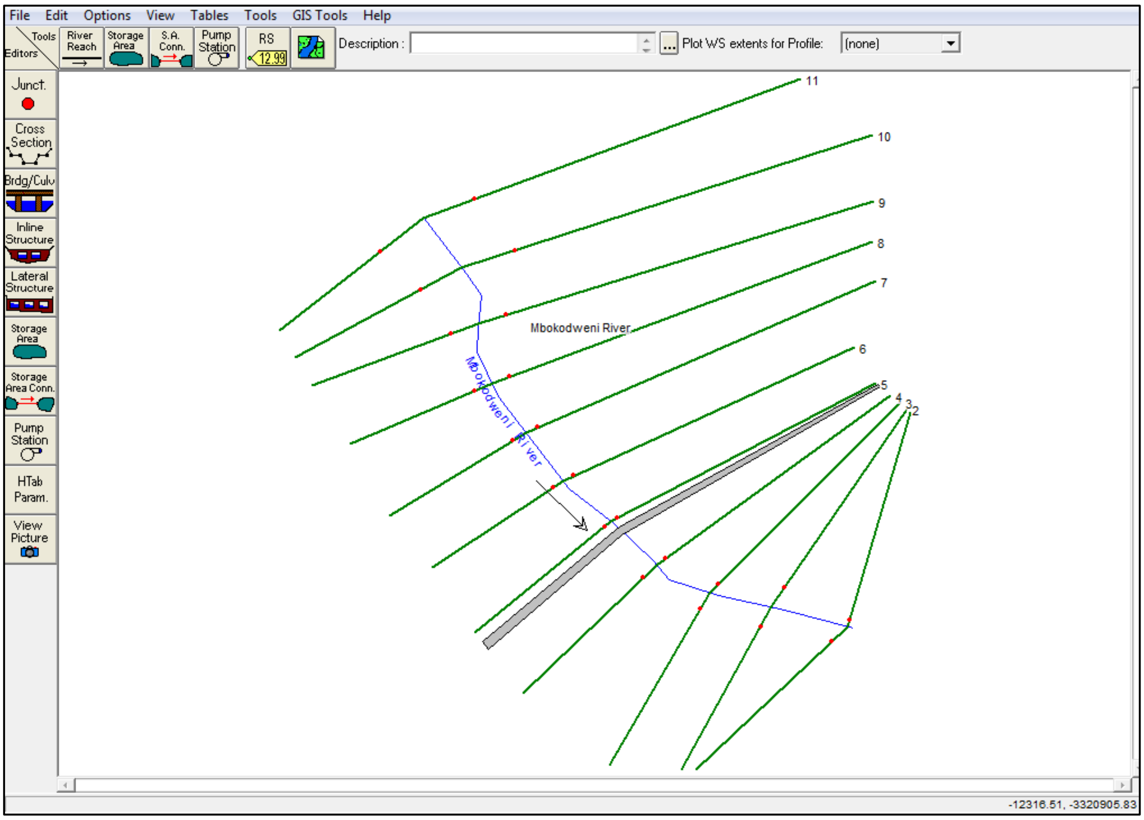


Figure 6: Plan view of the bridge element in the HEC-RAS model geometry

It was also necessary to assess the predicted effect on stormwater runoff volumes of the pedestrian bridge after construction. The bridge has a length of 89 meters between abutments. One can be conservative and estimate that an approach ramp of 20 meters on either side of the bridge is to be constructed. This results in an overall concrete length of 129 meters. The bridge width is 2.6 meters. These dimensions yield a hardened surface area of 336m^2. The table below summarises the additional stormwater runoff associated with the bridge after construction.

Parameter	
Bridge Surface Area	336m^2
Runoff Coefficient (concrete surface)	1
100 year Average Rainfall Intensity	195.3 mm/hour
Bridge Runoff	0.0184m^3/s

Table 2: Additional Stormwater Runoff associated with Mbokodweni Pedestrian Bridge after construction

4 DISCUSSION

While every effort has been made to predict, as accurately as possible, the effects of a hypothetical 100 year flood on the river in question, designers should allow for significant error that is the norm in hydrological calculations. This may be done at the discretion of the developer, and may take the form of a freeboard allowance or a buffer zone.

Post-construction of the bridge, the HEC-RAS model revealed that the water surface elevation during a 100 year flood was estimated to increase by 0.09meters which is considered a negligible value. The placement of a Pedestrian Bridge as designed by Ethekwini would thus not impose any significant effect on the flow in the river.

Post-construction stormwater runoff from the bridge would be approximately 0.0184m^3/s. This value can be considered to have a negligible effect on receiving areas.

5 REFERENCES

The South African National Roads Agency Limited (2006) *Drainage Manual, 5th Edition.* Kruger A, Gomes N. The South African National Roads Agency Limited, Pretoria, South Africa

Alexander WJR (1991) *Flood Hydrology for Southern Africa.* Department of Civil Engineering, University of Pretoria.

APPENDIX A

Hydrology

Description of catchment	Standard Design Flood - Emansomini Pedestrian Bridge
River detail	Mbokodweni
Calculated by	L. Kidgell
Date	28-04-2015

Physical characteristics

Size of catchment (A)	229.2	km²	Time of Concentration (T_C) $T_c = \left(\frac{0,87\ L^2}{1000\ S_{av}}\right)^{0,385}$	8.35	hours
Longest watercourse (L)	59.1	km			
Average slope (S_{av})	0.012250423	m/m			
SDF basin (0)#	24		Time of concentration, t (= 60 T_C)	501	minutes
2-year return period rainfall (M)	76	mm	Days of thunder per year (R)	15	days/year

TR102 n-day rainfall data

Weather Service station	Newlands	Mean annual precipitation (MAP)		910	mm
Weather Service station number	240 269	Coordinates	29–59'	&	30–39'

Duration (days)	Return period (years)						
	2	5	10	20	50	100	200
1	76	114	145	181	235	284	340
2	95	142	181	224	290	348	415
3	105	154	192	235	298	354	415
7	126	179	219	262	325	378	436

Rainfall

Return period (years), T	2	5	10	20	50	100	200
Point precipitation depth (mm) $P_{t,T}$	43.37	71.30	92.73	114.81	144.84	168.62	193.31
Area reduction factor (%), ARF (= $(90000-12800\ln A+9830\ln t)^{0,4}$)	92%	92%	92%	92%	92%	92%	92%
Average intensity (mm/hour), I_T (= $P_{t,T}$ x ARF / T_C)	4.78	7.87	10.23	12.67	15.98	18.60	21.33

Run-off coefficients

Calibration factors	C_2 (2-year return period) (%)	15	C_{100} (100-year return period) (%)	80

Return period (years)	2	5	10	20	50	100	200
Return period factors (Y_T)	0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient (C_T), $C_T = \frac{C_2}{100} + \left(\frac{Y_T}{2,33}\right)\left(\frac{C_{100}}{100} - \frac{C_2}{100}\right)$	0.15	0.38	0.51	0.61	0.72	0.80	0.87
Peak flow (m³/s), $Q_T = 0.278 \times C_T I_T A$	45.69	192.49	330.28	489.91	734.41	947.50	1180.97

Table 3C.7

		2	5	10	20	50	100	200
T_C < 6 hours	Modified Hershfield equation	-	-	-	-	-	-	-
		38.46	64.88	84.86	104.85	131.27	151.26	171.24
6 hours < T_C < 24 hours	Linear interpolation between modified Hershfield equation point rainfall and 1-day point rainfall from TR102	43.37	71.30	92.73	114.81	144.84	168.62	193.31
T_C > 24 hours	Linear interpolation between n-day point rainfall values from TR103	-	-	-	-	-	-	-

APPENDIX B

HEC RAS Data

HEC-RAS Plan: Pre-Construction River: Mbokodweni River Reach: Mbokodweni River Profile: Q100

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Mbokodweni River	11	Q100	948.00	15.21	19.7250		20.10	0.002419	3.45	424.71	188.42	0.56
Mbokodweni River	10	Q100	948.00	15.00	19.6828		20.05	0.001958	3.39	429.53	170.60	0.52
Mbokodweni River	9	Q100	948.00	14.93	19.6422		19.95	0.001955	3.45	434.04	150.18	0.52
Mbokodweni River	8	Q100	948.00	14.98	19.6135		19.91	0.001979	3.51	426.95	136.76	0.52
Mbokodweni River	7	Q100	948.00	15.15	19.5291		19.86	0.002484	3.61	386.02	122.00	0.57
Mbokodweni River	6	Q100	948.00	14.97	19.3373		19.79	0.003357	4.27	331.82	104.01	0.67
Mbokodweni River	5	Q100	948.00	14.57	19.2706		19.73	0.003332	4.45	329.65	100.47	0.67
Mbokodweni River	4	Q100	948.00	14.81	19.1079		19.65	0.003706	4.56	312.34	101.14	0.71
Mbokodweni River	3	Q100	948.00	14.69	18.9957		19.57	0.004107	4.72	307.10	106.28	0.74
Mbokodweni River	2	Q100	948.00	14.45	18.4440	18.34	19.41	0.007438	5.96	250.07	106.59	0.98
Mbokodweni River	1	Q100	948.00	13.78	18.3359	18.08	19.22	0.006408	6.04	258.91	100.54	0.92

HEC-RAS Plan: Post_constructio River: Mbokodweni River Reach: Mbokodweni River Profile: Q100

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Mbokodweni River	11	Q100	948.00	15.21	19.8145		20.15	0.002156	3.30	441.57	188.42	0.53
Mbokodweni River	10	Q100	948.00	15.00	19.7719		20.11	0.001778	3.27	444.76	171.57	0.49
Mbokodweni River	9	Q100	948.00	14.93	19.7335		20.02	0.001777	3.33	447.77	150.53	0.50
Mbokodweni River	8	Q100	948.00	14.98	19.7064		19.98	0.001806	3.40	439.67	137.10	0.50
Mbokodweni River	7	Q100	948.00	15.15	19.6284		19.94	0.002254	3.49	398.16	122.44	0.55
Mbokodweni River	6	Q100	948.00	14.97	19.4563		19.88	0.002991	4.11	344.22	104.41	0.63
Mbokodweni River	5	Q100	948.00	14.57	19.3979	18.14	19.82	0.002958	4.27	342.47	100.94	0.64
Mbokodweni River	4.8		Bridge									
Mbokodweni River	4	Q100	948.00	14.81	19.1079		19.65	0.003706	4.56	312.34	101.14	0.71
Mbokodweni River	3	Q100	948.00	14.69	18.9957		19.57	0.004107	4.72	307.10	106.28	0.74
Mbokodweni River	2	Q100	948.00	14.45	18.4440	18.34	19.41	0.007438	5.96	250.07	106.59	0.98
Mbokodweni River	1	Q100	948.00	13.78	18.3359	18.08	19.22	0.006408	6.04	258.91	100.54	0.92

APPENDIX C

Flood line Drawing

FOR INFORMATION ONLY

THIS DRAWING HAS BEEN PREPARED UNDER THE CONTROLS ESTABLISHED BY THE SiVEST QUALITY MANAGEMENT SYSTEM AND MEETS THE REQUIREMENTS OF THE SETA QUALITY GRADING SYSTEM THAT IS ISO COMPLIANT

GENERAL NOTES

1. THIS DRAWING PROVIDES INFORMATION RELATED TO THE FORM OF THE WORK WHEN COMPLETED TOGETHER WITH GUIDANCE, WHERE FUNDAMENTAL TO THE DESIGN, FOR THE SEQUENCE OF CONSTRUCTION. THIS DRAWING DOES NOT PURPORT TO INCLUDE ANY NECESSARY PRECAUTIONS, ITEMS OR COMPONENTS REQUIRED FOR CONSTRUCTION SAFETY. ALL SUCH PRECAUTIONS MUST BE TAKEN AND ITEMS OR COMPONENTS SUPPLIED BY THE CONTRACTOR.
2. ANY DISCREPANCIES ARE TO BE CONFIRMED WITH THE ENGINEER ON SITE PRIOR TO WORK PROCEEDING.
3. ONLY WRITTEN DIMENSIONS SHALL BE USED.

REFERENCE DRAWINGS

Revision Details	By	Date	Suffix

DURBAN OFFICE
4 Pencarrow Crescent
La Lucia Ridge Office Estate
Umhlanga Rocks 4320
South Africa
Tel +2731 5811500
Fax +2731 5662371
email: info@sivest.co.za

Client

ETHEKWINI MUNICIPALITY

Project Title

EMANSOMINI PEDESTRIAN BRIDGE BASIC ASSESSMENT

Drawing Title

MBOKODWENI RIVER 100 YEAR FLOODLINE

Scale 1:500

ON ORIGINAL PLAN 0 10 20 30 40 50

DRAWN
BY : LK DATE: 2015/05/14

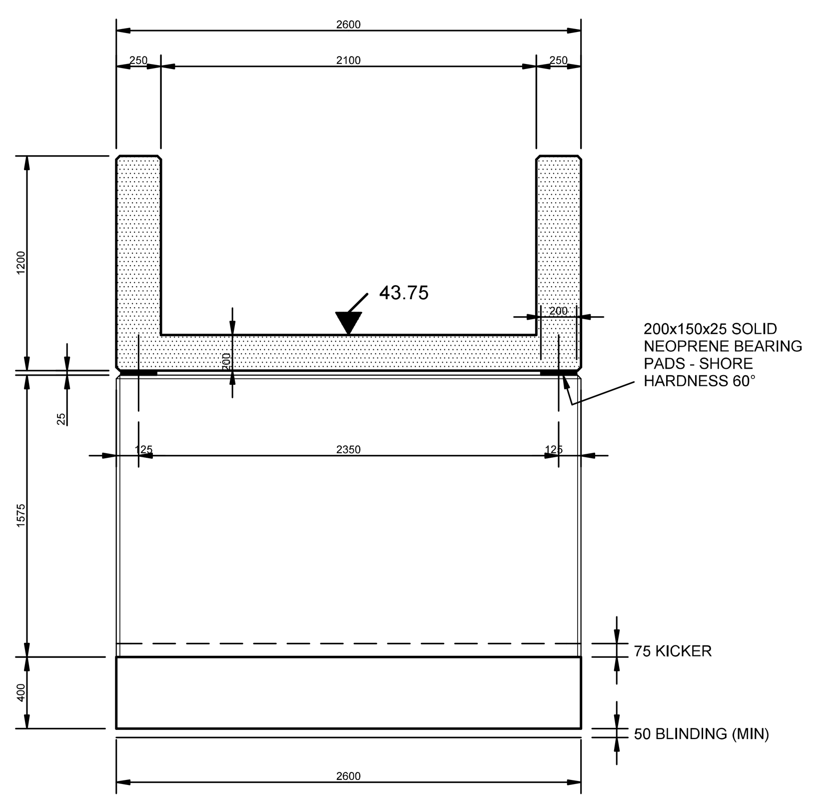
DESIGNED
BY : LK DATE: 2015/05/12
SIGNATURE :

CHECKED ON BEHALF OF SiVEST
BY : LH Pr No: *
SIGNATURE : DATE :

SiVEST Drawing Number 12527-5000
Revision 0

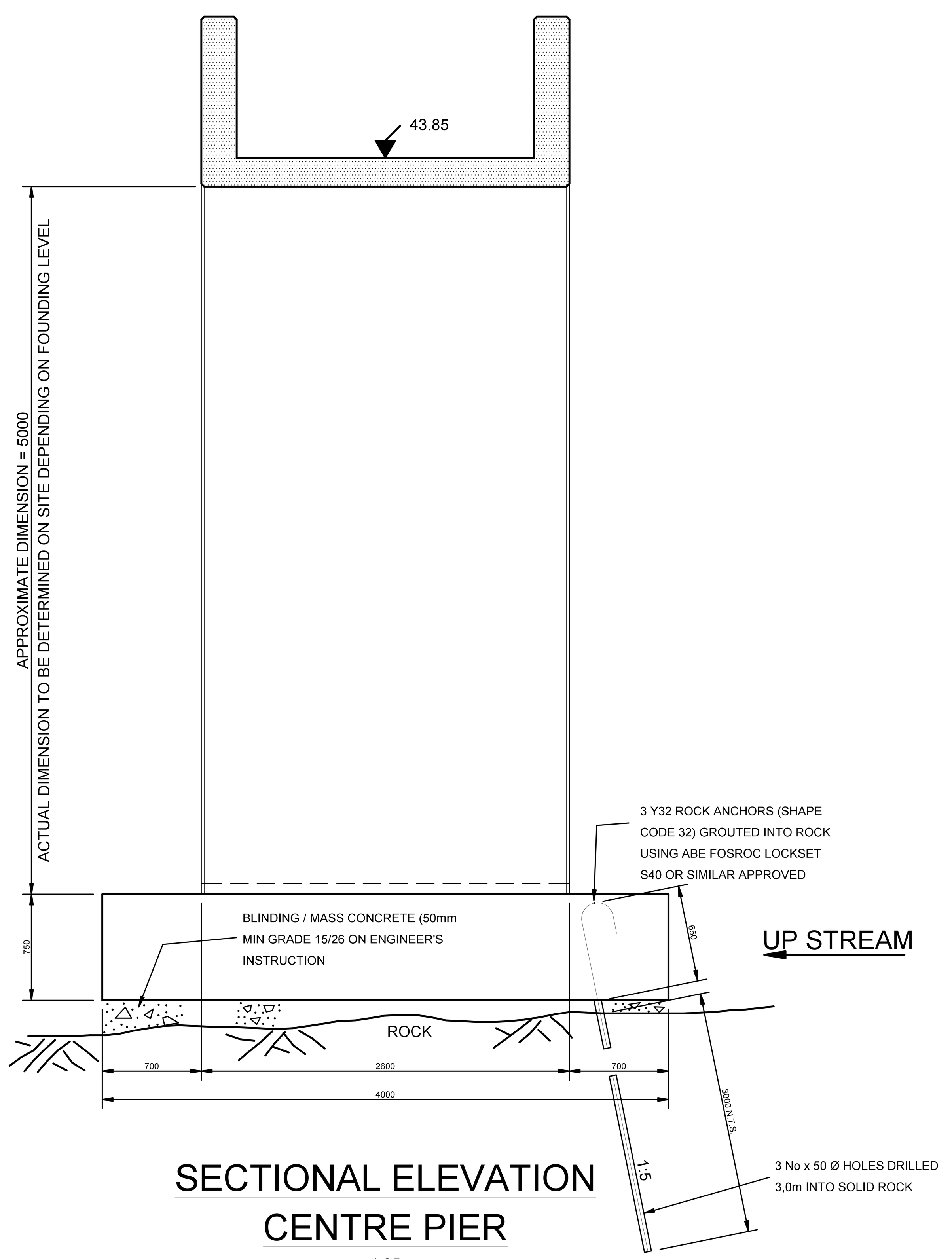
APPENDIX D

Bridge design drawing



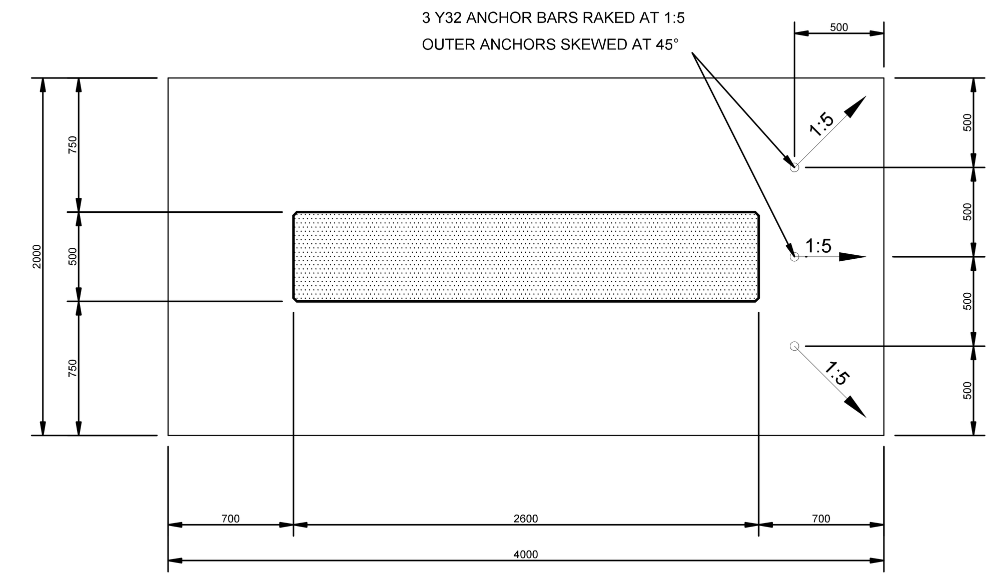
SECTIONAL ELEVATION NORTH / SOUTH ABUTMENTS

1:25



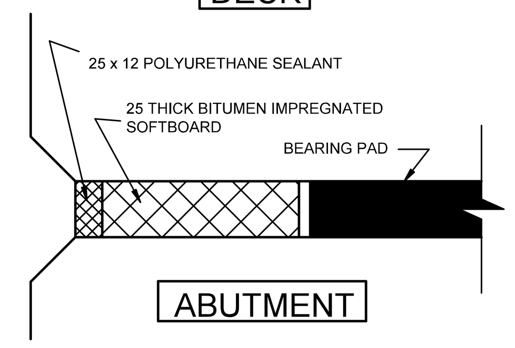
SECTIONAL ELEVATION CENTRE PIER

1:25

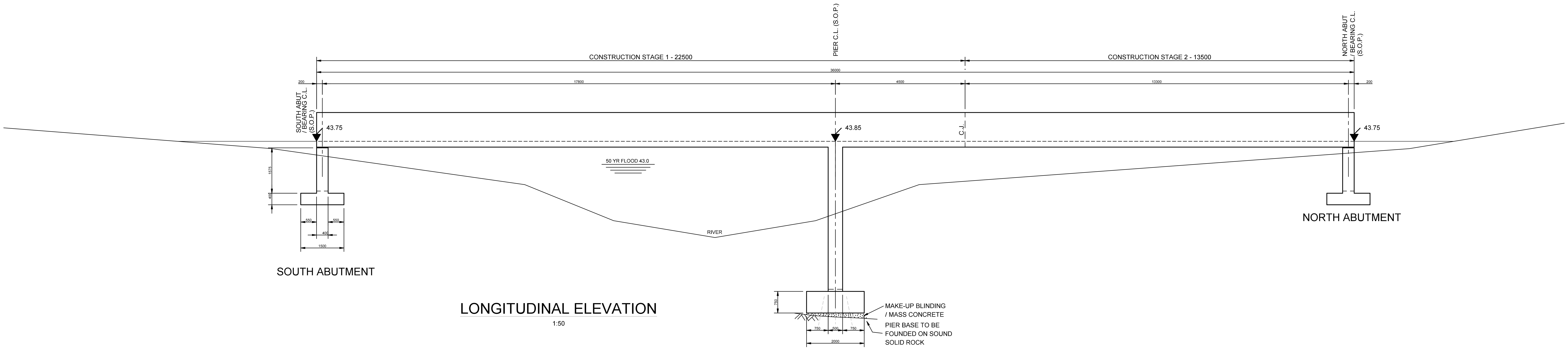


PLAN OF CENTRE PIER BASE

1:25



DETAIL OF SEALING BETWEEN ABUTMENT AND DECK



LONGITUDINAL ELEVATION

1:50

ETHEKWINI MUNICIPALITY
ENGINEERING UNIT

ROADS PROVISION - STRUCTURES

REDUCED PLAN USE SCALE BELOW

0 10 20 30 40 50 60 70

70mm ON ORIGINAL PLAN

Revision	Date	Description

NOTE: No construction work to commence until land and servitude acquisitions have been completed

Acquisitions completed

Date Engineer

UNDERGROUND SERVICES CHECKED

SERVICE	DATE	SIGNATURE
S.W.DRAINS		
SEWERS		
WATER MAINS		
G.P.O.CABLES		
ELECTRIC CABLES		
S.A.R. CABLES		
E.S.C. CABLES		
OIL PIPE LINE		

NOTE: Only underground services affected by new construction work are shown. Care must be taken during excavations for road foundations, trenches etc., to avoid damage to underground services such as sewers, drains, cables, water mains and connections. Wherever possible these must be located before work proceeds.

Contract No: 1R - xxxx

Project Title: CONSTRUCTION OF A PROPOSED PEDESTRIAN BRIDGE, BURBREEZE, WARD 62

Drawing Title: GENERAL ARRANGEMENT

Scales: AS SHOWN

Reference

Designed: J.v.H.

Date: 08-2014

Checked

Drawn: P.G.F

Manager Structures

Deputy Head : Roads Provision

A.M. Peters

Head Engineering

Drawing: XXXXX

Sheet: 1 of Sheets

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