4a Old Main Road, Judges Walk, Kloof, Kwazulu-Natal, South Africa, 3610
PO Box 819, Gillitts, 3603, South Africa
Tel: +27 (0) 31 764 7130 **Fax:** +27 (0) 31 764 7140 **Web:** www.gcs-sa.biz

Baseline Survey for a Bank Stability Assessment for the Mpofana River

Version –Final Report

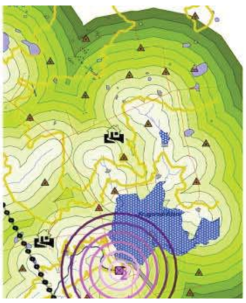
24 August 2015

WBHO

GCS Project Number: 14-452

Client Reference: WBHO 14-452




Baseline Survey for a Bank Stability Assessment for the Mpofana River

Final Report

24 August 2015

DOCUMENT ISSUE STATUS

Report Issue	Final Report		
GCS Reference Number	GCS Ref - 14-452		
Client Reference	WBHO 14-452		
Title	Baseline Survey for a Bank Stability Assessment for the Mpofana River		
	Name	**Signature**	**Date**
Author	Stephen Kelly		24 August 2015
Document Reviewer	Callie Pickering		06 March 2015
Director	Pieter Labuschagne		10 March 2015

EXECUTIVE SUMMARY

This report contains the findings of an investigation to assess the current state of the Mpofana River banks, by investigating the in situ properties of the banks and through an aerial survey along the length of the Mpofana River near Nottingham Road, KwaZulu Natal.

Due to site specific uncertainties and limited data available, GCS proposed a collaboration of different field investigation techniques to enable sensible and systematic assessment criteria. The main objective is to identify and isolate problematic zones and prioritise all sites of concern accordingly. The differing investigation methods were conducted down the length of the river at predetermined positions and then grouped, weighted and scored, and broadly applied to the river banks.

The assessment comprised two investigations. An initial investigation was conducted, with a report compiled documenting the findings which was submitted on 14 November 2014. Thereafter the report was reviewed and further fieldwork was requested. A second investigation was conducted, the initial report was amended which documented the findings of both investigations.

The field investigation was carried out between the 28 September 2014 and the 3 October 2014, and the 26 and 27 January 2015. The field investigations incorporated the following tests/assessment methods:

- A walk over survey;
- Assessment matrix applied to bank profiles including the following criteria:
    - Field erodibility
    - Estimated bank height (m)
    - Estimated bank angle (°)
    - Vegetation type
    - Bedrock exposure
    - Water Velocity
    - Material type
    - River geomorphology
- Bank pegging;
- In situ consistency tests;
- River bank material profiling; and
- Aerial Photography.

The results of each test/assessment method are outlined in the report.

Once the data was collated, two general profiles were identified namely, residual soils overlying bedrock, and possible floodplain profiles comprising alluvium overlying either boulder horizons or bedrock.

At the positions where river bank assessments were conducted, the criteria used was weighted and scored, thereby classifying these positions according to their possible susceptibly to erosion.

The river bank assessments and general profiles were used to create a conceptual model, which visually depicts the areas more susceptible to erosion and areas where floodplains are expected. This can be observed in section 6 in Figure 2.

GLOSSARY

- Riparian vegetation- The plant life and ecosystem that exists along a water way
- DPL- Dynamic Cone Penetrometer (Light)
- Point of inflection- point at which the curvature changes or inflects from one direction to the other
- Cut bank- Outside bank of a water channel which continuously undergoes erosion
- Riffle pool sequence- develops when the streams hydrological flow structure alternates between shallow and deep water, generally formed in rivers with coarse material
- EGL- Estimated Ground Level
- DSM- Digital Elevation Model
- Colluvium- Deposited loose unconsolidated sediments, generally on a shallow gradient
- Alluvium- Deposit of either or a combination of clay, silt, sand, and gravel left by flowing streams in a river valley or delta
- Floodplain- A nearly flat plain along the course of a stream or river that is naturally subject to flooding
- Hillwash- Loose deposit of rock debris accumulated through the action of gravity at the base of a cliff or slope
- Levee- A ridge of sediment deposited naturally alongside a river by overflowing water

CONTENTS PAGE

LIST OF FIGURES

LIST OF PHOTOGRAPHS

Photographs can be observed in the Photo Log attached

LIST OF TABLES

LIST OF APPENDICES

1 INTRODUCTION

GCS (Pty) Ltd, were requested by Mr. James Liversage of WBHO to conduct a Geo-referenced survey of Mpofana River for the Mooi- Mngeni Transfer Scheme (MMTS) -2 Project.

This report describes the findings of an investigation to assess the current state of the Mpofana River banks near Nottingham Road, KwaZulu Natal.

An initial investigation was conducted along the banks of the Mpofana River, with a report compiled documenting the findings which was submitted on 14 November 2014. Thereafter the report was reviewed and further fieldwork was requested. A second investigation was conducted, the initial report was amended which documented the findings of both investigations.

The initial report giving the findings of the first field investigation may be disregarded in the light of the current report.

The purpose of this report is to outline areas of concern along the river. This will be achieved by combining the results of the following field investigation tests:

- Creating an assessment table which broadly assesses and scores the banks according to their susceptibility to erosion;
- Walk over survey;
- Bank profiling and *in situ* consistency testing (Dynamic Cone Penetrometer – DPL tests).

2 INFORMATION SUPPLIED

The following information has been used in preparing this report:

- 1:250 000 Geological Series Map, Durban 2930,
- Google Earth image,
- Report by Coastal and Environmental Services Titled,"Mooi-Mgeni Transfer Scheme Phase 2, Receiving Rivers Specialist Assessment" dated November 2012,
- National Geo-spatial Information (NGI) – 1:50 000 Topographical Series, Vector & Raster Data-set,
- National Geo-spatial Information (NGI) – 2009 Colour Aerial Photography 0.5m Resolution.

3 SITE DESCRIPTION

The Mpofana River is situated in the KwaZulu Natal Midlands, flowing from Balgowan to Caversham. The portion of the river surveyed has starting and ending coordinates of approximately 29°23’20.3986”S; 30°03’42.7024”E and 29°24'51.0103"S; 30°05’45.8682”E.

The river flows in a NW-SE direction, and has an approximate bearing of 310°, as observed in Figure 1 below. The river is approximately 7.5 km long and has a topographical height difference of approximately 106.7 m with an average gradient of approximately 1:0.014 m.

Forestry, cattle farms, private residences and natural vegetation bound the length of the river on both sides. There are numerous bridges, pump houses, fences, pipelines and buildings either traversing or situated close to (approximately 10 m) the river, and can be observed in Photograph 1 and 8.

At the time of the first field visit the river had a slow to moderate flow rate, with an increased flow rate along cut banks and sections with steep topography and decreasing to a meander with gentler topography, as observed in Photograph 2 and 3. By the second site visit, the summer rains had increased the volume of water and flow rate which had altered the structure of the banks. A comparison of the water levels can be observed in Photograph 17 to 20.

The riparian vegetation along the rivers banks consisted mainly of wattle trees and indigenous plants with very few aquatic flora.

The banks of the river ranged in material type and height throughout its length.

Some of the banks comprised rounded cobbles and boulders comprised of shale and dolerite, with cut banks >5.0 m in height and occasional shale bedrock.

Other banks comprised finer grained alluvial clay, sand and gravel with points of inflection and cut banks approximately 1.0 - 2.0 m in height adopting a riffle-pool sequence. Examples of the different banks are shown in Photograph 1 to 7.

The MMTS-1 and MMTS-2 outfalls and the extent of the servitude of aqueduct may be observed on the Locality Plan below. A ‘servitude of aqueduct’ is defined in the National Water Act 36 of 1998 as, “The right to occupy land belonging to another by means of a waterwork for abstracting or leading water.”

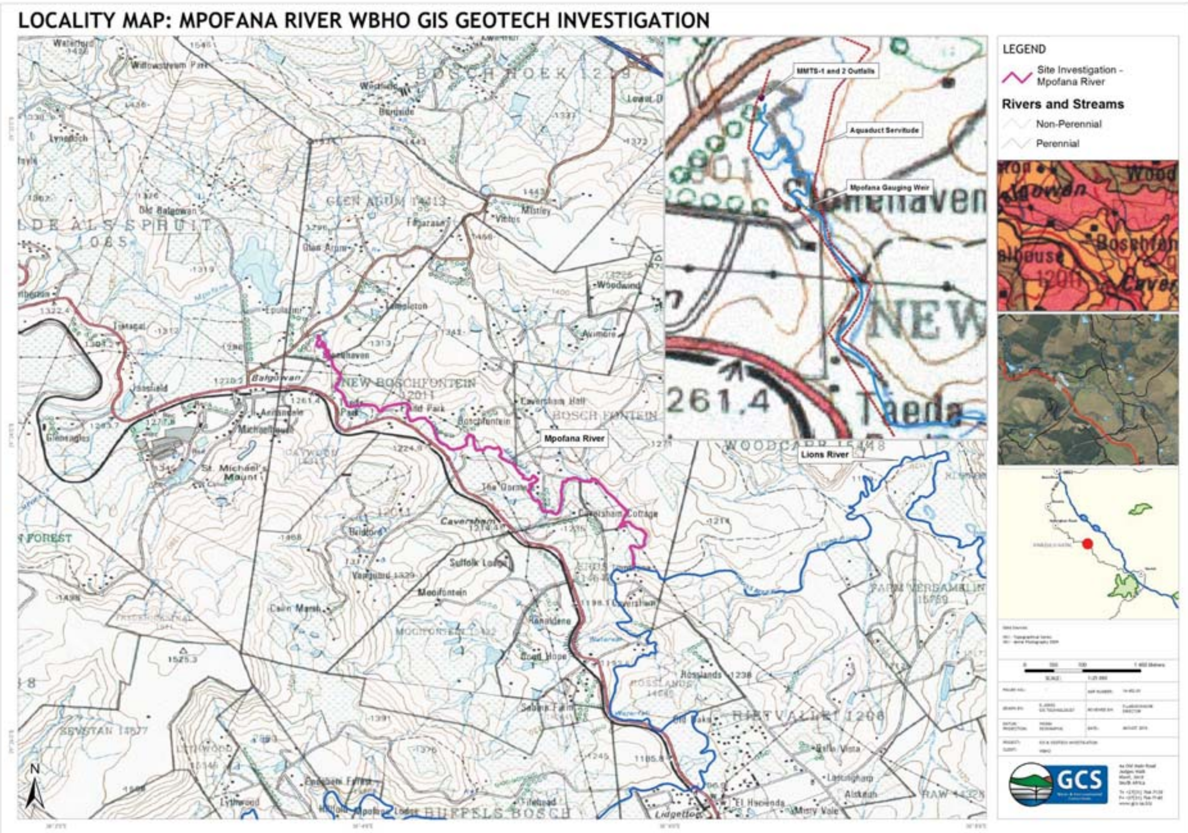


Figure 1: Locality Map

4 FIELD WORK

The field work associated with this investigation was carried out in two stages. The first visit took place from the 29 September to 3 October 2014 and the second visit took place from the 26 to 27 January 2015.

The first field visit comprised a walkover survey, river bank assessment and pegging, in situ bank material consistency testing, geological bank profiling and aerial photography over the length of the river surveyed.

The second field visit comprised geological bank profiling and in situ bank material consistency testing.

The approximate positions of the points investigated are shown on Figure 3, in Appendix A.

The positions of the pegged banks, DPL tests and bank profiles were recorded using a hand held Garmin GPS with an accuracy of 3.0 m.

4.1 Walkover survey

A walkover survey was conducted to assess the status of the river and its banks and infrastructure present. Observations were made and recorded with positions of concern noted and returned to for field testing.

4.2 River Bank Assessment and Pegging:

River bank assessments and pegging comprised walking the river and denoting areas of possible high erosion, such as cut banks and points of inflection. Thirty-two positions were identified. The positions were numbered from 1 through 32 and outlined according to whether they were on the western or eastern bank of the river by ‘A’ and ‘B’ respectively, e.g. A01 is river bank assessment 1 situated on the western bank.

The positions were assessed, in situ, according to:

- Field erodibility;
- Bank height;
- Bank angle;
- Riparian vegetation;
- Bank material type;
- Bedrock exposed;
- Water velocity.

Bank pegging was then done at these positions to provide a semi-permanent datum with which to assess degradation and erosion. Bank pegging constituted placing pegs at 1.0 m spacing from the water's edge, moving inland. The pegs were placed perpendicular to the river flow direction. These pegs are used to infer the extent of lateral erosion as the river erodes the bank.

Examples of the bank pegging can be observed in Photograph 9 and 10.

The coordinates for the approximate positions of the river bank assessments are shown in Appendix C.

4.3 In situ Material Consistency Testing:

The DPL tests, designated DPL1 through DPL35, were carried out at predetermined positions along the river and can be observed in Figure 3, Appendix A. These were conducted in order to assess the in situ consistency of the subsoils and provide an indication of the depth to bedrock. The DPL tests were advanced to refusal depths of between approximately 0.6 and 5.4 metres below EGL.

DPL test results can be observed in Appendix D.

Dynamic Cone Penetrometer (Light), or DPL tests are conducted by allowing a 10 kg steel hammer to freefall approximately 550 mm driving a steel rod and cone into the ground. The number of blows required to drive each 300 mm segment into the ground is recorded. This allows for an estimate to be made with respect to the consistency of the soils.

The coordinates for the approximate positions of the DPL tests are shown in Appendix C.

4.4 Geological Material Profiling:

The banks of the river were profiled using the South African Guidelines[1] for soil and rock logging. During the second site visit, material consistency tests were conducted in the same vicinity as the material profiles to provide more holistic information.

The geology along the length of the river varies from dark blue grey shale with sub-ordinate thin layers of sandstone of the Volksrust Formation, Ecca Group, to sporadically distributed Karoo dolerite from the Jurassic Period, observed on Figure 1.

The profiles, designated BP1 through BP27, carried out at predetermined positions can be observed in Figure 3 in Appendix A.

[1] Geoterminology Workshop (2002), "Guidelines for Soil and Rock Logging in South Africa" – SAIEG, AEG, SAICE

Material profile logs can be observed in Appendix E. The geological profiles can be observed in Photograph 11 to 16. The regional geology of the area through which the river flows through can been found in Figure 1 in section 3.

The coordinates for the approximate positions of the profiles are shown in Appendix C.

4.5 Aerial Photography

The acquisition of the aerial photography incorporated a very light weight UAS. The system comprised light wingspan combined with a u-BLOX GPS chip, an attitude sensor, a radio transmitter and an autopilot circuit board. The autopilot allows the platform/UAS to be operated automatically on the flight path and triggers the mounted camera.

The on board GPS provides the navigation positions for post-processing. Each image is tagged with a GPS position which is stored in the EXIF data, and a small attitude sensor provides the three orientation angles; roll, pitch and heading. These datasets are used to drive the platform on the planned flight path and the resulting trajectory is recorded for post-processing.

A complete automated integration process of tie point measurements, camera calibration, DSM extraction and orthomosaic production has been implemented by using photogrammetric software. The geo-reference information of the EXIF tags is used to provide absolute reference to the image processing.

The output imagery produced from post-processing, is a 7 cm resolution aerial image of the surveyed length of the Mpofana River. The geoferenced image in Geotiff format, can be used for planning or monitoring purposes.

The orthomosaic was analysed for distortions according to the following:

- Aspect analysis: checking of geometry of straight lines and surface infrastructure;
- Geometric comparison by digitizing ground elements (fences, roads etc.).

4.6 2D Cross Section Bank Profiles

The DSM was used to illustrate a 2D profile of the rivers bank at select locations. The profiles identify areas where the gradient exceeds 1.5V:1H, which when coupled with the walk over survey and bank profiling offer insight to areas where excessive erosion may take place (floodplains etc.) or where the banks are stable (outcrop etc.).

The 2D river bank profiles can be observed in Appendix F. The coordinates for the positions of the 2D bank cross sections are shown in Appendix C.

5 RIVER BANK DISCUSSION

5.1 Walk Over Survey

The walk over survey documented various points of concern along the surveyed length of the river, ranging from bank characteristics to possible concerns involving infrastructure, should sufficient erosion occur to cause bank failure.

- Along the length of the river, mainly along the straight sections, bank slumping has occurred. The likely cause for slumping is the differing volumes of water flowing down the river throughout the year (wet summer rainfall period or additional water introduced into the system, compared with a dry winter period) causing different wetting and drying periods.
- Along portions of the river situated within cattle farms, cattle crossings have created preferential erosion zones, weakening the surrounding banks. In all cases the cattle crossings had removed the vegetation within the immediate area of the crossing, moving inland approximately 5.0 m on either side, further worsening the situation by increasing the surface area to erosion.
- Rudimentary reinforcement along the convex banks in the form of sub-rounded to rounded alluvial cobbles was observed along a property. The cobbles were piled up from within the river to the level of the natural levee embankment.
- Construction in some instances is observed to be within 50.0 m of the river. This includes buildings, pump houses, dams, roads etc.
- There is little to no physical protection on structures (pump houses, bridges, causeways, buildings, roads, fences and erosion surfaces etc.). Possible undercutting of the structures and/or the banks on which they are constructed, may occur with an increased flow rate.

5.2 River Bank Geology

The material along the river is generally composed of fine grained sandy Clay overlying either a dolerite/shale boulder layer or bedrock.

The colluvial deposits generally consist of slightly moist to moist dark brown to light greyish brown, loose intact, fine to medium clayey silty gravelly Sand.

The alluvial deposits generally consist of dry to slightly moist becoming wet with depth, light grey to dark brown, soft to firm becoming very stiff with depth often with very soft material interspersed throughout the profile, intact, slightly sandy to sandy Clay with occurrences of sub-rounded to rounded cobbles and boulders of various origins.

5.3 In situ Bank Consistency

The in situ bank consistency was assessed using DPL tests. The tests were conducted to identify and outline the variation in consistency and inferred depth to bedrock. The consistency tests in conjunction with the bank profile logs and landforms identified along the length of the river, allows generalized conclusions to be drawn on the relative stability of the river banks. Generally, two different profiles were identified, namely residual soils overlying bedrock and possible floodplains.

5.3.1 Residual soils overlying bedrock

The average depth of refusal of the DPL equipment used, being the inferred depth to bedrock within in the areas identified as having residual soils overlying bedrock, is approximately 1.6 m, with a minimum depth of 0.6 m and a maximum depth of 3.4 m. The inferred consistency profile is generally soft through the residual soil, becoming firm to stiff through completely weathered rock section prior to refusal being reached.

5.3.2 Possible floodplains

The average depth of refusal of the DPL equipment used, being the inferred depth to either a boulder horizon or bedrock within the areas identified as being possible floodplains is approximately 2.1 m, with a minimum depth of 0.75 m and a maximum depth of 5.4 m. The inferred consistency profile is generally soft becoming firm with depth, followed by an abrupt refusal. As commonly seen in the DPL logs, pockets of very soft material is interspersed throughout the lithology.

5.4 River Bank Assessments

River bank assessments, incorporating criteria discussed in section 4.2 above, were conducted. Pegs were placed at the positions where the river bank assessments were conducted, to provide a means by which long term monitoring of erosion can be done.

All of the criteria used were weighted and scored, with the percentage total score observed in Table 2 below.

The positions of the river bank assessments and bank pegging can be observed in Figure 3 in Appendix A.

These different criteria were assessed and given scores ranging between 1 and 5, weighted according to their influence on stability of the banks, summed and then presented as a percentage. The results were then placed in the following ranges.

Range	Erosion susceptibility rating
0-50	High
51-60	Medium
61-100	Low

The river bank assessments with individual ratings are shown below in Table 1.

The unweighted assessment sheets can be observed in Table 2 in Appendix B.

It must be noted that no formal environmental procedures were followed in creating the assessments. This assessment may only be taken on the strength of observations made during the walk over survey, river bank assessments and pegging.

Table 1 Percentage Total Score for River Bank Assessments

Bank Number	Score Percentage
A01	65
A02	47
A03	48
B04	43
A05	40
A06	53
A07	45
A08	40
A09	40
A10	35
B11	40
B12	51
B13	44
B14	44
A15	60
A16	52
A17	61
B18	72
B19	53
B20	48
B21	60
A22	69
A23	65
B24	59
A25	43
A26	61
A27	65
A28	39
B29	69
A30	56
A31	56
A32	56

6 CONCEPTUAL MODEL

Based on the field assessments mentioned in Section 5, the following can be said concerning the susceptibility of the river's banks to erosion, when the flow rate and water volume in the river is increased:

- Portions of the river which are deemed to be possible floodplains consisting of fine sandy Clay alluvium overlying either boulder horizons or bedrock with variable consistency, have a moderate to high propensity for erosion.
- Portions of the river which are deemed to have residual soil overlying bedrock (generally sections of the river where shale bedrock is observed), consisting of either a silty gravelly Sand or sandy Clay colluvium or hillwash, overlying a closely to medium jointed very soft to soft rock Shale, have a low to moderate propensity for erosion. However reassessment should be undertaken once the water level has been raised to assess the response of the rock mass.
- River bank gradients exceeding 1.5V:1H are deemed to be of concern and will have possible increased erosive potential. However, should the bank consist of bedrock this erosive potential decreases in contrast to those banks composed of alluvium within possible floodplains;
- The scenarios mentioned above have been combined with the river bank assessments and bank gradients, and a visual conceptual model is shown in Figure 2 below.
- Areas of high, medium and low risk are depicted in red, orange and green respectively. The areas outlined with blue show the banks along the river (side of the river dependant) which are considered potential floodplains and carry potential risk of erosion. Those areas not highlighted in blue are deemed carry low to no risk of erosion.

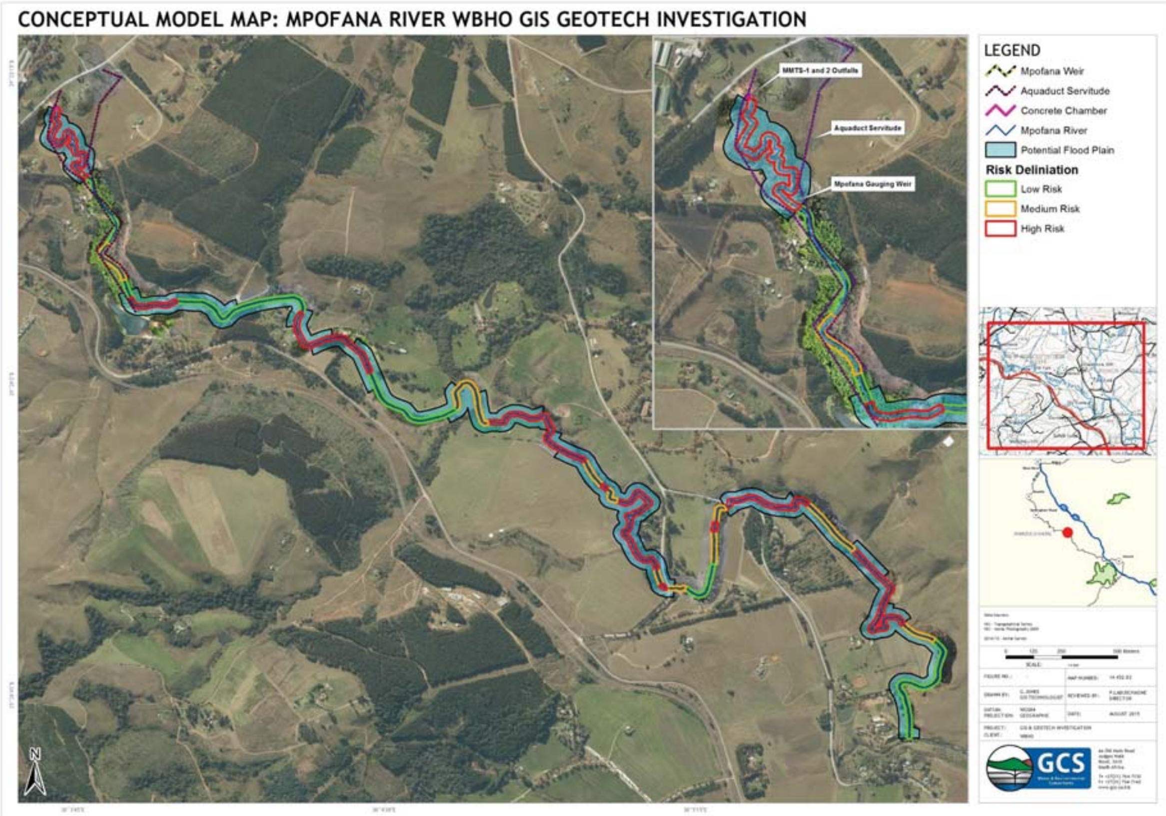


Figure 2 Visual Conceptual Model

7 RE-ASSESSMENT PLAN

When re-assessment is conducted after 5 years, it is essential for accurate comparisons to be made, and that all tests are conducted within the close vicinity of the originals. The following plan should be adhered to:

- DPL tests to assess the in situ consistency conducted within a 5m radius of the original test positions;
- Aerial survey should be conducted using equipment with the same output resolution (7cm) to allow for accurate overlays in order to identify areas where erosion has taken place. From the new aerial survey, 2D bank profiles can be extracted;
- Geological profiling of the banks allowing assessment to be made with regards to potential erosion and the depth to water level;
- The bank pegging should be assessed in addition to re-doing the river bank assessments. The same criteria should be used when re-doing the river bank assessments.

8 CONCLUSION

This report contains the findings of an investigation to assess the current state of the river's banks, by assessing the in situ properties of the banks, through an aerial survey and by along the length of the Mpofana River near Nottingham Road, KwaZulu Natal.

The report describes the findings of the investigation carried out to determine the current state of the river's banks and the in situ properties of the banks.

The fieldwork component of the investigation took place in two visits. During the first visit a walk over survey, in situ consistency testing, geological profiling, river bank assessments and pegging, and aerial photography were conducted. During the second visit geological profiling of the banks and in situ consistency testing was conducted.

Once the data was collated, two general profiles were identified, namely residual soils overlying bedrock, and possible floodplain profiles comprising alluvium overlying either boulder horizons or bedrock.

At the positions where river bank assessments were conducted, the criteria used was weighted and scored, thereby classifying these positions according to their possible susceptibly to erosion.

The river bank assessments and general profiles were used to create a conceptual model, which visually depicts the areas more susceptible to erosion and areas where floodplains are expected. The conceptual model can be observed in Figure 2.

9 RECOMMENDATIONS

Ground conditions described in this report pertain specifically to the positions investigated. It is important that GCS conduct the re-assessment in 5 years, to determine the influence on the river banks and to avoid unnecessary expense and delay to the project.