Client: **SAPPI Southern Africa Ltd - Ngodwana Mill**

Ref #: **Order # PO 2105-052852**

Project Description: **NGODWANA DAM – SAFETY INSPECTION**

Date: **9 September 2016**

NGODWANA DAM
COMPULSORY 7-YEARLY DAM SAFETY REPORT
9 September 2016

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Approvals

Title: **SAPPI Southern Africa Ltd - Ngodwana Mill**
Order # PO PO 2105-052852
Ngodwana Dam:- Compulsory 7-Yearly Dam Safety Report – 9 September 2016

Author: Altus de Beer PrEng [Approved Professional Person]

Status of Report: Final

Company Reference: Ngodwana Dam

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Approved by "Approved Professional Person":

9 September 2016

Altus de Beer PrEng
Director: Reonet Projects (Pty) Ltd

Date

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Date

Accepted by Owner:

Date

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Executive Summary

The 44 m high Ngodwana Dam, completed in 1983, is located on the Ngodwana River, a tributary of the Elands River, Mpumalanga Province, directly upstream from the N4 highway and the SAPPI Ngodwana Paper Mill, 40 km from Nelspruit.

The dam is classified with the Department of Water Affairs [DWA] Dam Safety Office as a Category III High Risk dam, in terms of the Dam Safety Regulations, Chapter 12 of the National Water Act 1998 (Act 36 of 1998).

The dam wall was designed as an embankment dam with a sloping clay core and an un-zoned sloping chimney filter, connected to a blanket drain that terminates in toe-drains fitted with V-noth flow gauges.

The spillway is constructed on the right bank and consists of a 90 m wide X 6 m deep OGEE control structure that discharges into a 140 m long reinforced concrete return channel that terminates in a plunge pool.

The outlet works consist of a reinforced concrete dry intake tower, with intakes at three levels. The intake tower is connected to a dry, reinforced concrete conduit, located under the dam wall, through which access is gained from the downstream toe of the wall. The conduit is partitioned with a central support wall to create two sub-conduits (left and right). There are two outlet pipes, each fixed to the bottom of the two sub-conduits.

Ngodwana Dam wall is underlain by very complex and challenging foundations: The left flank foundations comprise of a 5m – 20m thick cover of partly recemented (calcified) talus blocks in a matrix of soil, resting upon a layer of completely weathered very weak tuff and agglomerate while along a major part of the right flank, the embankment and spillway structures are founded on a layer of large dislodged blocks of quartzite resting upon very weak tuff and tuffaceous shale.

Ngodwana Dam wall displayed large initial vertical and horizontal settlement, but settlements have now stabilised. Maximum vertical settlement (Beacon 7) of 200 mm occurred within the first year (1983-1984) after completion, then another 200 mm settlement during the next 15 years (1984-1999) and only 34 mm during the past 17 years (1999-2016). Total current vertical settlement is 436 mm.

Horizontal movement of the dam crest (downstream) under the water load, exactly followed the vertical settlement pattern. Total maximum horizontal movement (Beacon 6) is currently 241 mm, having stabilised to only 15 mm horizontal movement over the past 12 years (2004-2016).

The exception to this pattern is where the dam crest meets the left flank. In this locality, over the past 2 years, vertical settlement of 20mm and horizontal (downstream) movements of 10mm were recorded, indicating recent local movement of the embankment against the left flank foundation.

Measured seepage through the embankment and under the dam wall has also significantly decreased from an initial 4.5 l/s to 0.317 l/sec in 2016. The initial large settlements and the subsequent decrease in settlement and seepage are ascribed to large-scale consolidation of the very thick, initially unconsolidated, foundations.

The dam wall was initially equipped with adequate dam safety monitoring instrumentation, namely settlement beacons, V-notches for gauging seepage, standpipe piezometers for measuring the phreatic surface and pneumatic piezometers for gauging pore pressure in the upstream embankment. The pneumatic piezometers have in the meantime failed.

The dam wall is well maintained by the owner and the owner arranges for regular instrumentation gauging to be undertaken by specialist contractors. The owner also arranges for annual interim dam safety inspections, in addition to the compulsory and comprehensive 7-yearly inspections.

During this inspection, held on 10 May 2016 and on a follow-up inspection on 12 July 2016, the following key recommendations are made:

1. **Slope Stability of the Dam Wall:-** Settlement monitoring beacons are surveyed once per year and the results are included in the annual and compulsory 7-yearly dam safety inspection reports.
2. **Standpipe Piezometers:-** 7 new standpipe piezometers will be installed as indicated on the relevant drawing attached under Appendix A. This project, which is currently underway, consists of.:

2.1 **Investigations and Engineering:-** This work has already been completed by the APP and the Engineering Geologist, during 2016. The purpose of this work was to prepare the necessary design drawings, specifications and bills of quantities with which to procure the services of a specialised ground engineering contractor who will drill the holes and install the standpipe piezometers. This same contractor will also retrieve cores for analysis and testing in a soil lab.

2.2 **Drilling & Installation of Standpipe Piezometers:-** This work will be undertaken by a specialised ground engineering contractor, during the financial year that commences in October 2016. Tenders had already been called for and submitted, and recommendations made to SAPPI for the appointment of a suitable contractor.

2.3 **Post-construction Soil Lab Testing and Analysis:-** This work will be undertaken by the APP, the engineering geologist and a soils laboratory. The purpose of this work will be to develop a better understanding of the properties and behaviour of the dam wall, particularly in the vicinity of the left flank. This work would specifically lead to a better understanding of the seepage properties, the soil strength properties, the position of the phreatic line, the effectiveness of the unzoned filter, and a post-analysis of the slope stability. This work will also be undertaken during the financial year that commences in October 2016.

3. **Core Sampling:-** Soil samples will be retrieved during the construction operation mentioned in paragraph 2.2 above.

4. **Left Flank Movements:-** The left edge of the embankment showed unusually large movement in the past two years. This will be monitored.

5. **Termite Activity:-** Termite nests on the left flank and termite holes on the dam crest were noted. The active nests will be destroyed.

6. **Spillway:-** The upper section spillway joints had already been cleaned and the joint "bandages" replaced / repaired. The dam level is currently low and the spillway has stopped overflowing, so that it is now dry enough to repair the damaged "joint bandages" in the lower section of the spillway chute. This will be completed before the onset of the 2016-7 rainy season.

7. **Mechanical Equipment:-** Some mechanical equipment, most especially in the outlet works, require corrosion protection and/or replacement, in accordance with the recommendations contained in the "Mechanical Report", attached under Appendix E.

8. **Warning and Evacuation Plan:-** SAPPI is in the process of updating the contact details of all relevant parties in the Warning & Evacuation Plan. The plan is otherwise still relevant and in good order.

CONTENTS

LIST OF APPENDICES

1 OWNER AND DAM SAFETY TEAM

The current team of specialists for this 6'th compulsory dam safety inspection have been involved with safety inspections on Ngodwana Dam since at least the 3'rd compulsory inspection in July 1998. The current team is:

Designation	**Name**	**Contact Information**
Owner	SAPPI Southern Africa Ltd - Ngodwana Mill	
Owner's Representative	Carel van der Merwe	Carel.VanDerMerwe@sappi.com cell: 083 700 8733
APP and Structural Specialist	Altus de Beer PrEng	debeeraltus@gmail.com cell: 083 700 8733
Engineering Geologist	Prof A (Monte) van Schalkwyk	montevs@absamail.co.za cell: 083 922 3337
Flood Hydrology and Spillway Hydraulics Specialist	Dr WV (Bill) Pitman	pitmanwv@iafrica.com cell: 082 330 4630
Mechanical Engineer	Andre du Plessis PrEng (AR du Plessis & Associates)	andre@ardpconsulting.com cell: 082 850 4417
Settlement Beacon Surveyor	Peter Barnard (Barnard & Schneider)	sandd@tiscali.co.za tel: 011 704 0735
Piezometers	Peter de Haan (Geotechnical Engineering Monitoring Services (GEMS), formerly of Terra Monitoring)	peter@gemservices.co.za cell: 060 526 7284

2 AVAILABLE INFORMATION

2.1 LOCALITY MAP

See Appendix A for maps and drawings.

2.2 DAM WALL LAY-OUT & SECTIONS DRAWINGS

See Appendix A for maps and drawings.

2.3 LIST OF PREVIOUS REPORTS, DRAWINGS, ETC.

2.3.1 Original Design Reports (as listed in 1987 DS Report)

2.3.1.1 Geology

1. Webb and Partners; The geology at the site of a proposed dam for Sappi Fine Papers Limited - Ngodwana, Report 8027, June 1981, 9pp.
2. Brink and Matthews; Engineering geological assessment of foundation conditions below left flank of proposed embankment dam Ngodwane River, Report LOC BM 72, February 1982, 11pp.
3. Seismic Survey (Pty) Ltd; Report on seismic refraction survey - Ngodwane Dam Project - Eastern Transvaal, Job 504/03, May 1982 5pp.
4. Matthews and Associates: Engineering geological assessment of foundation' conditions within stilling basin and cutoff of left flank - Embankment Dam - Ngodwane River, Report M20/6/82, July 1982, 8pp.
5. Matthews, and Associates; Ngodwane Dam - Report on spillway slope stability, Report M20/7/83, June 1983, 8pp.
6. Report on the geology of the foundations of the Ngodwane Dam built for Sappi Fine Papers Limited, Ngodwana. Report prepared by Matthews and Associates, Engineering Geologists and Geotechnical Engineers. Report M40/8/83, August 1983.

2.3.1.2 Hydrology

1. Water Resources. Report by Prof D C Midgley. (Appendix 1)

2. Floods. Report by Prof D C Midgley. (Appendix 1)
3. Files. B G A Lund & Partner.

2.3.1.3 Dam Design

1. Files. B G A Lund & Partner.
2. Soil test results. Files, B G A Lund & Partner and W H Luwes Pr.Eng. who carried out tests.
3. Paper "The Design of Earth Embankments with reference to the Choice of Shear Strength Parameters and Control of Earth Fill Operations", by B G A Lund. 11th African Regional Conference on Soil Mechanics and Foundation. Engineering 1963.
4. Estimating Construction Pore Pressures in Rolled Earth Dams. H W Hilf, USBR.
5. SLOP 4. Computer Program for Slope Stability Analysis, CSIR.
6. Earth dam design report prepared for this study. (Appendix 2)
7. Monitoring. of Ngodwane Dam. Report prepared for this study. (Appendix 3)

2.3.1.4 Drawings

These are new drawings or adapted from existing drawings.

Drawing No	Description / Title
SK/1/1	Project site plan
SK/1/2	Leakage survey
SK/1/3	General arrangement
SK/1/4	Monitoring section through standpipe piezometers
SK/1/5	Dam break study - area inundated by flood
SK/1/6	Breaching section (Computations in Appendix 4)
SK/1/7	Monitoring - leakage study
SK/1/8	Test result of monitoring
SK/1/9	Monitoring of dam settlement
SK/1/10	Plan - cut off trench, grout curtain and monitoring pts.

SK/1/11 Longitudinal Section - Ngodwane, Elands & Crocodile Rivers.

2.3.1.5 Specifications

Files. B G A Lund & Partner.

2.3.1.6 Additional Drawings Listed in 1998 DS Report

These are new drawings or adapted from existing drawings.

Drawings No	Description
SK1/1	Project site plan
Sk1/2	Leakage survey
SK/1/3	General arrangement
SK/1/4	Monitoring section through standpipe piezometers
SK/1/5	Dam breaks-study area inundated by flood
SK/1/6	Breaching section
SK/1/7	Monitoring leakage study
SK/1/8	Test result of monitoring
SK/1/9	Monitoring of dam settlement
SK/1/9A	Ditto 6-94 to 6-98
SK/1/10	Plan-cut off trench, grout curtain and monitoring pts
SK/1/11	Long section Godwana, Elands and Crocodile Rivers
SK/1/12	Remedial Work Outlet to Culvert
SK/1/13	Remedial Work Subsurface Drain (at Wet spot)
SK/1/14	Cancelled
Sk/1/15	Seepage Records
SK/1/165A	Inst. Monitoring Standpipe Piezometers
SK/1/16B	Ditto Pneumatic Piezometers Section A
SK/1/16C	Ditto Section B

SK/1/17	Spillway study 1994
SK/1/18	Spillway study (Stevens) 1:500
SK/1/19	Spillway Survey (BGA Lund) 1:500

2.4 RECENT POST-CONSTRUCTION ANALYSES

2.4.1 Flood Estimation

See Appendix C for flood estimation analysis.

2.4.2 Dam Break Flood Analysis

See Appendix C for dam break flood analysis.

2.4.3 Spillway Retaining Wall Stability

See Appendix D for spillway retaining wall stability analysis.

3 BACKGROUND INFORMATION

3.1 LOCALITY AND PURPOSE

Ngodwana Dam is located on the Ngodwana River, a tributary of the Elands River, Mpumalanga Province, directly upstream from the N4 highway and the Ngodwana Paper Mill, 40 km from Nelspruit (See Locality Map under Appendix A – Drawings.

The dam was built for water supply to the SAPPI Kraft Ngodwana Paper Mill. At a project cost of approximately R 1.2 billion, the paper mill was one of the largest single private sector undertakings in South Africa at the time. The maximum water demand to be met for the paper mill, is 40 000 cubic meters per day. The Ngodwana River was chosen in preference to the Elands River, as it provides high quality water with a TDS of only 40 mg/l – a very desirable factor in papermaking.

4 DESCRIPTION OF THE DAM

Wall Type	Zoned embankment dam with a sloping clay core and a sloping, un-zoned chimney filter, connected to a blanket drain.
Wall Height (max)	44 meters
Crest Length	450 meters
Crest Width	6 meters
Crest Elevation	966 MASL
Toe Elevation	922 MASL
Storage Capacity	10,4 million cubic meters
Dead Storage	0,52 million cubic meters
Surface Area at FSL	87 Ha
Historical Firm Yield	WR90 = 21,6 million m^3/a JIBS = 26,3 million m^3/a
Annual Abstraction	14,6 million m^3/a
Outlet Works	The outlet works consist of a dry intake tower, with intakes at three levels (two service and one emergency bottom outlet). The intake tower is connected to a dry reinforced concrete conduit through which access is gained to the intake tower.
Completion Date	The dam wall construction took place between 1981-1983. The dam cost R 10 million to complete in 1983.
Designer	The late Mr BGA Lund PrEng was both the designer of and Approved Professional Person [in terms of the dam safety regulations of Chapter 12 of the National Water Act 36 of 1998] for the dam, until his death in 2006.

Contractor	The contractor was Peter Faber (Pty) Ltd and the grouting sub-contractor was Ground Engineering (Pty) Ltd.
Betterment Works after Completion	Installation of toe drain Construction of concrete slab at culvert outlet
Problems which occured previously	Large vertical and horizontal settlements and deflections of the embankment "Wet Spot" on downstream embankment near left flank Concerns over the origin of high water flows immediately below the embankment Concerns over high phreatic surfaces and slope stability, in particular on the left flank Failed joint sealers between spillway chute concrete slabs and concerns for undercutting erosion and "lifting" of slabs Failed water stops in construction joints between outlet conduit sections, causing leaching of adjacent embankment material into the conduits

5 GEOLOGY OF DAM SITE

5.1 GENERAL GEOLOGY

5.1.1 Embankment and Foundations

The site geology is extremely complex due to the occurrence of a variety of sedimentary, volcanic and metamorphic rocks, unconformities in the sedimentary succession, faulting, variable weathering, thick alluvium in the river section, colluvium on the left flank and large dislodged quartzite blocks on the right flank. The distribution of the material types along the dam centre line and the cut-off trench is illustrated on the attached sections in Drawing:- Ngodwana Dam (3) – Longitudinal Sections, attached hereto under Appendix A – Drawings. A summary of geological conditions as compiled for the 2009 dam safety report is included under Appendix B. See Appendix F – Photographic Record, plates 2, 3 and 4 for some of the geological conditions and construction materials that are visible on the construction-stage photographs.

5.2 GEOLOGICAL CONDITIONS - ACTUAL OR POTENTIAL PROBLEMS

5.2.1 Left Flank

The upper part of the left flank is underlain by a 5m – 20m thick cover of partly recemented (calcified) talus blocks in a matrix of soil, resting upon a layer of completely weathered very weak tuff and agglomerate. Although the embankment in founded on these low strength and potentially permeable materials, the cut-off wall was re-aligned in an upstream direction and is largely founded on a downstream dipping layer of strong Godwan Formation quartzites. Only the upper part (mostly above FSL) of the cut-off is founded on weak tuff and partly cemented colluvium. This part of the flank had been covered by an impervious blanket, and based on seepage records, it can be concluded that a reasonably watertight cut-off had been achieved.

5.2.2 Right Flank

Along the major part of the right flank, the embankment and spillway structures are founded on a layer of large dislocated (slumped) blocks of Black Reef Formation quartzite, resting upon a thin layer of weak tuff, tuffaceous shale and agglomerate of the Godwan Formation that is underlain by strong quartzite of the same formation. The cut-off is founded partly on the strong quartzite and partly on the weak rocks overlying it. The engineering properties (deformability and permeability) of these rocks are unknown.

5.2.3 River Section

The river section is underlain by a 5m – 10m thick layer of river alluvium that is underlain by medium strong tuff, lava, hornfels and quartzite of the Godwan Formation. These rocks are closely jointed in some areas. The cut-off is founded on bedrock.

5.2.4 Spillway & Return Channel

The OGEE overspill structure and chute are founded on dislodged quartzite blocks and colluvium, while the stilling basin is located in weathered, weak tuffaceous shale. The breaching section is partly founded on the dislocated quartzite blocks and partly on colluvial soil comprising gravely sand and clay.

5.2.5 Intake Tower and Outlet Conduit

The intake tower and outlet conduit is underlain by quartzite and alluvium. The presence of alluvium under the conduit needs to be verified.

5.2.6 Slope Stability Around the Dam Basin

The slopes around the dam basin are stable, i.e. no sliding failures observed.

6 DESCRIPTION OF DAM WALL MATERIAL

6.1 UPSTREAM ZONE

Clayey sand and gravel.

6.2 DOWNSTREAM ZONE

Clayey sand and gravel.

6.3 CLAY CORE

Clay and silty clay.

6.4 FILTER

Un-zoned sand and gravel filter.

7 EVALUATION OF THE HAZARD POTENTIAL

Downstream development since last report?	This is difficult to estimate, but it must be presumed that the size of Mataffin Village had increased since the last compulsory inspection in 2009.
Estimate of potential loss of life	This is also difficult to estimate, but it will be significantly higher than 10.
Estimate of potential economic loss	This too is difficult to estimate, but with certainty in the hundreds of millions of Rand.
Hazard potential rating as classified	Category III High Risk
Agreement with classification?	A "dam break event" of Ngodwana Dam would result in economic damage well in excess of R 20 million and the probability that more than 10 lives could be lost. In compliance with SANCOLD recommendations, Ngodwana Dam is therefore classified with the Dam Safety Office of the Department of Water and Sanitation [DWS] as a Category III High Risk dam. The APP thus agree with this classification.
Checking of Registration Information	The registration information as it appears on the computer printout from the DWS Dam Safety Office corresponds with the above assessment.

8 FLOOD ESTIMATES

See Appendix C – Flood Hydrology Report for more detailed information.

Catchment Area	229 km^2
MAP	1068 mm
Methods Used for Flood Estimation	HRU Region HRU Formula Rational Method TR137 SDF
1:20 (m^3/s)	338
1:50 (m^3/s)	496
1:100 (m^3/s)	650
1:200 (m^3/s)	832
RMF (m^3/s)	1,330
PMF (m^3/s)	2,563
RDF (m^3/s)	800
SEF (m^3/s)	1,330
Motivation for choice of RDF & SEF	Weighted Average of HRU Region, HRU Formula, Rational Method, TR137, SDF

9 EVALUATION OF SPILLWAY CAPACITY

See Appendix C – Flood Hydrology Report for more detailed information.

Spillway Type	Mass concrete uncontrolled OGEE spillway is located on right bank. Control structure discharges onto a reinforced concrete chute consisting of reinforced concrete slabs and reinforced concrete sidewalls. The spillway chute terminates in a flip bucket and plunge pool. An emergency spillway with a break section is located adjacent to the service spillway, further along the right bank.
Spillway Length	90 m
Non-overspill Level	965,55 MASL
Full Supply Level	960 MASL
Freeboard = Lowest NOC – FSL	4.5m below emergency spillway crest and 5.55m below main wall non-overspill crest (was 6m before vertical settlement of 455mm)
Max Capacity (no freeboard)	1,766 m^3/s
Flood Attenuation	Negligible
RDF Freeboard	1,48 meters
Will the dam fail if overtopped?	Yes, but only with sustained, significant overtopping flow depth
Erosion assessment during RDF	Erosion of the plunge pool and of the narrow exit from the plunge pool could be expected
Erosion assessment during SEF	Same as above, but emergency breach section could also be washed away
Evaluation of Spillway Capacity	The spillway capacity is adequate

10 INSPECTION OF THE DAM

10.1 PREVIOUS COMPULSORY INSPECTIONS

Previous 5-yearly compulsory dam safety inspections and reports were undertaken during:

1987 June

1993 August

1998 July

2003 August

2009 August

The next 7-yearly compulsory dam safety inspection is due in 2023.

10.2 INSPECTION DATE, CONDITIONS AND TEAM

Date	12 July 2016
Water Level (MASL & m below or above FSL)	958.280 MASL – 1.720 meters below FSL
Recent Rain? (Wet or Dry)	Dry
Persons present at inspection	C van der Merwe (Owner's Representative) A de Beer (APP) A van Schalkwyk (Engineering Geologist) A du Plessis (Mech Eng)

10.3 CREST OF EARTH WALL

Crest Width – Any change?	6 meters, no change.
Settlement – Vertical & Horizontal (m)	Ngodwana Dam wall displayed large initial vertical and horizontal settlement, but settlements have now stabilised. Maximum vertical settlement (Beacon 7) of 200 mm occurred within the first year (1983-1984)

	after completion, then another 200 mm settlement during the next 15 years (1984-1999) and only 34 mm during the past 17 years (1999-2016). Total current vertical settlement is 436 mm. Horizontal movement of the dam crest (downstream) under the water load, exactly followed the vertical settlement pattern. Total maximum horizontal movement (Beacon 6) is currently 241 mm, having stabilised to only 15 mm horizontal movement over the past 12 years (2004-2016). The exception to this pattern is where the dam crest meets the left flank. In this locality, over the past 2 years, vertical settlement of 20mm and horizontal (downstream) movements of 10mm were recorded, indicating recent local movement of the embankment against the left flank foundation. See Appendix G – Monitoring Records, for graphs of damwall deflections over time and plotted against water level in the dam.
Erosion? Describe	None
Cracks? Describe	None
Burrow Animal Holes? Describe	Termite holes visible along crest.

10.4 UPSTREAM FACE OF EARTH WALL

Slope (Vert:Hor)	1:2.5
Slope Protection	900 φ Rip-rap over natural gravel filter
Erosion? Describe	None
Cracks? Describe	None
Settlement? Describe	None

10.5 DOWNSTREAM FACE OF EARTH WALL

Slope (Vert:Hor)	1:2.0
Slope Protection	Grass
Erosion? Describe	None
Cracks? Describe	None
Settlement? Describe	None
Bulging / Sliding?	None
Wet Patches	The "wet spot" near left flank on lower part of embankment has completely dried out.
Seepage / Leaks?	None
Turbidity of Seepage Water	Not Applicable
Burrow Animal Holes? Describe	Large termite nest on lower berm near previous "wet spot". See Appendix F – Photographic Record, plate 24.

10.6 VEGETATION

Trees or Shrubs on the Wall?	None

10.7 DRAINAGE SYSTEM

Description of Drainage System	All drains are un-zoned "natural gravel and sand" filters. Drains consist of a sloping chimney filter, connected to a blanket drain, culminating in a toe drain. A separate drain envelops the outlet conduit. See Appendix F – Photographic Record, plate 1.
"Culvert" Drain East (l/s)	0.001 l/s
"Culvert" Drain West (l/s)	0.315 l/s
Toe Drain East (l/s)	Zero (never registered seepage)

Toe Drain West (l/s)	0.001 l/s average over year.
"Internal Drains" (l/s)	Nil. Measurement discontinued due to unreliability of gauging caused by measurement of "non-seepage" flows.
Total Seepage (l/s)	0.317 l/s average over year.
Turbidity	No turbidity – clear seepage water

Seepage from the dam is measured as follows:

- V-notches at "Culvert Drains East and West" that measure flow from parts of the chimney drain and from along the culvert.
- A V-notch that measures flow from "Toe Drains East and West". "Toe Drain East" never had any flow.

A V-notch in a weir in the river is supposed to measure "Seepage 1" from the Internal Drains. However, this gauge seems to include mainly the flow from the small stream originating downstream of the dam on the left (West) flank.

It was concluded that the results of "Seepage 1" can therefore not be relied upon for calculating the total seepage from the dam and that the sum of the flow from the other V-notches should rather be used.

Flow in the above mentioned small stream seems to be fairly constant throughout the year. Earlier water tests (chemical and isotopes) have shown that this water does not originate from the dam basin.

10.8 CONCRETE WALLS

Cracks	None
Leakage	Clay and water seepage through some construction joints of the outlet conduit. See Appendix F – Photographic Record, plates 19 – 23.
Joints	Suspected torn water stops in construction joints of the outlet conduit.
Settlement	Suspected settlement of the outlet conduit responsible for torn water stops in construction

	joints.
Relative movement	A small amount of relative movement was observed of the spillway left side flank wall. The stability of this structure was back-analysed and found to be in order. See Appendix D for structural analysis.
Pressure relief holes	Pressure relief holes in spillway discharge chute slabs are sealed.

10.9 DOWNSTREAM TOE AND FLANKS

Wet Patches	A small stream runs parallel to and approximately 10m below the left side of the embankment toe. Origin of small stream is NOT from water in dam basin, i.e. it is not seepage from the dam basin.
Seepage / Leaks	None
Turbidity of Seepage Water	Not applicable
Trees within 5m of toe?	None

10.10 SPILLWAY, RETURN CHANNEL & FLANK WALLS

OGEE Condition	Good – construction joints recently cleaned
Return Channel Condition	Good - joint sealants between cill slabs of spillway discharge chute were repaired. See Appendix F – Photographic Record, plates 7-11.
Flank Walls Condition	Retaining wall on left flank displayed movements as evidenced by opening joints – probable cause is foundation settlement, but no cause for stability concern. See Appendix D – Structural Report.

Emergency Spillway Condition	Good

10.11 STILLING BASIN / PLUNGE POOL

Erosion & Scouring?	Some scouring but nothing abnormal to be concerned about

10.12 OUTLET WORKS

Number of Outlet Pipes	2
Service Outlet 1 (Type & Dia)	500 mm dia. steel
Service Outlet 2 (Type & Dia)	500 mm dia. steel
Bottom Outlet (Type & Dia)	1,000 mm dia. steel
Intake Tower	Dry intake tower
Intake Levels (MASL)	Service Intake 1 – 956.60 MASL Service Intake 2 – 950.10 MASL Service Intake 3 – 943.60 MASL
Valve Control Positions (Upstream & Downstream) & Valve Type	Bottom Outlet – Flange bolted to inside of intake tower Service Outlets – Fulton Gates external to intake tower; Butterfly Valves inside intake tower; Needle control valves at downstream outlet.
Outlet System	Two 600 mm dia. steel oulet pipes located in two side-by-side 165 meter long reinforced concrete access conduits that connects the dry intake tower with the outlet works at the toe of the embankment. The two outlet conduits are actually a single structure with a vertical separation wall.

Foundations	The intake tower is founded on competent quartzite rock and the outlet conduits are founded on quartzite and alluvium. There is evidence of movement of the outlet conduits insofar as there is evidence of ingress of clay core material into the conduits through suspected torn waterstops at two construction joints. See Appendix F - Photographic Record - plate 4 (intake tower foundations) and plates 19-23 (seepage into conduit) for a full description.
Operation and Maintenance	The valves are regularly operated, particularly the downstream control valves through which water supply to the water treatment works is regulated. Rust protection is undertaken on a regular basis.
Other observations	See Appendix E – Mechanical Report for more comprehensive details on the outlet works system.

10.13 PUBLIC SAFETY

Precautions are taken to safeguard members of the public by preventing uncontrolled access to the dam wall area and dam basin, through the provision of fencing, locked gates and a manned security boom.

10.14 INSTRUMENTATION AND MONITORING

Most of the dam safety monitoring instrumentation and observations are geared at detecting any possible problems associated with the performance of filters and drains and with slope stability.

Ngodwana Dam is fitted with V-notch gauges for monitoring seepage and with standpipe and pneumatic piezometers for monitoring the phreatic surface and pore pressures in the embankment.

The pneumatic piezometers have all failed and now only the standpipe piezometers can be relied upon to provide useful information on the phreatic surface.

Ngodwana Dam is fitted with settlement beacons on the crest of the wall as well as at some strategic locations on the downstream face of the embankment, with which to monitor movements of the dam wall, i.e. slope stability.

10.14.1 Seepage Monitoring

Seepage from the dam is measured as follows:

- V-notches at "Culvert Drains East and West" that measure flow from parts of the chimney drain and from along the culvert.
- A V-notch that measures flow from "Toe Drains East and West". "Toe Drain East" never had any flow.
- A V-notch in a weir in the river that measures "Seepage 1" from the Internal Drains will in future be discontinued because most of this gauged flow results from ingress of water from sources other than seepage, thus providing grossly inflated seepage measurements. See Appendix F – Photographic Record, plates 17 and 18.

10.14.2 Phreatic Surface Monitoring

The phreatic surface in the embankment is monitored with standpipe piezometers. New standpipe piezometers are to be installed during 2016. See Appendix F – Photographic Record, plates 15 and 16 and Appendix A – Drawings, for the positions of the new standpipe piezometers.

10.14.3 Slope Stability Monitoring

The slope stability of Ngodwana Dam is being monitored through regular and accurate surveys of the settlement beacons on the dam wall. Additional settlement monitoring beacons have been installed to monitor specific parts of the dam wall, such as the "wet spot" on the left bank toe of the embankment. See Appendix F – Photographic Record, plates 13 and 14.

10.14.4 Instrumentation Plan

The position and type of safety monitoring equipment is shown on drawing "Ngodwana Dam (1)", attached as Annexure A – Maps & Drawings.

11 EVALUATION OF STABILITY OF DAM WALL

No post-construction analysis of the stability of the dam wall had been conducted. However, based on the design information and visual observations, the embankment is evaluated as being stable and safe.

There is however one design issue and some observational issues that are cause for concern.

The design issue that gives cause for concern is the un-zoned protective filters.

The observational issues that is of concern, is a wet spot that developed low down on the left flank of the embankment since about 2006 and the sudden significant deflection of the dam wall embankment where it contacts with the left flank. See Appendix G – Monitoring Records and Graphs for the clear vertical (20mm) and horizontal (10 mm downstream) movement of the dam wall as measured in this area.

During the inspections conducted in May and July this year, it was observed that the "wet spot" had completely dried up.

The area of the embankment where the wet spot occurred, had been carefully monitored for any movements since 2008, through the installation of settlement survey beacons. Measured movements were so small in magnitude that they can be ascribed to unavoidable measuring errors. This means that no "bulging" of the embankment had been observed in the area of the "wet spot".

With regards to the un-zoned filters, the Owner has, at the recommendation of the APP, committed to the installation of additional stand-pipe piezometers on the downstream slope of the embankment, so as to monitor the phreatic surface, and thus the functioning of the un-zoned filters.

During the installation of the piezometers, undisturbed soil samples will be recovered and tested in a soils testing laboratory to ascertain the in-situ soil strength parameters. These results will be used to back-analyse the stability of the dam wall.

12 EVALUATION OF DRAINAGE SYSTEM

The drainage system is evaluated to be in good working order.

All seepage water is clear (no turbidity) and seepage rates are well within acceptable limits, indicating that the clay core and grout curtain are providing an effective seal.

Seepage is monitored through five V-notches, these being:

1. Toe-drain East
2. Toe-drain West
3. Conduit left
4. Conduit right
5. Total blanket drain seepage, or "internal drains" at "Seepage 1", located at a weir in the river immediately downstream from the dam wall. This seepage gauge will however henceforth be discontinued due it providing false (highly inflated) measurements of seepage, resulting from it being fed largely by "non-seepage" flows downstream from the dam wall.

The Owner measures seepage through the V-notches on a weekly regime. The results of measured seepage over the years are summarised in Appendix G.

13 EVALUATION OF OPERATION & MAINTENANCE

The Ngodwana Dam is well maintained and operated. The Owner has always assigned a dedicated "responsible person" to look after the dam. The Owner sets aside a budget to operate and maintain the dam in good order.

The Owner maintains in good order all relevant documentation with respect to the dam, including emergency procedures and contact details.

The Owner implements an annual inspection by the APP.

All settlement survey beacons and stand-pipe piezometers are surveyed by professionals on an annual basis.

All seepage is measured through V-notches on a weekly basis by the Owner's personnel.

Downstream control valves are operated daily and other valves tested at least quarterly. A lubrication and stroking maintenance schedule is in place for the valves.

All trees and shrubs within 5 meters of the toe of the dam wall are removed. Grass on the downstream embankment is regularly mown.

Any damage to the spillway joint sealants are promptly repaired.

Rust-proofing paint is regularly applied to the mechanical installations.

14 RECOMMENDATIONS OF PREVIOUS EVALUATIONS BY APP

Recommendations following from previous evaluations by the APP, are as follows:

1. Slope Stability of the Dam Wall:- Settlement monitoring beacons are surveyed once per year and the results are included in the annual and compulsory 7-yearly dam safety inspection reports.
2. Standpipe Piezometers:- 7 new standpipe piezometers will be installed as indicated on the relevant drawing included under Appendix A - Drawings. This project will take place in three phases over two years and is currently under way, i.e.:

   2.1 Investigations and Engineering:- This work has already been completed by the APP and the Engineering Geologist, during 2016. The purpose of this work was to prepare the necessary design drawings, specifications and bills of quantities with which to procure the services of a specialised ground engineering contractor who will drill the holes and install the standpipe piezometers. This same contractor would also retrieve cores for analysis and testing in a soil lab.

   2.2 Core Drilling & Installation of Standpipe Piezometers:- This work will be undertaken by a specialised ground engineering contractor, during the financial year that commences in October 2016.

   2.3 Post-construction Soil Lab Testting and Analysis:- This work will be undertaken by the APP, the engineering geologist and a soils laboratory. The purpose of this work will be to develop a better understanding of the properties and behaviour of the dam wall, particularly in the vicinity of the left flank. This work would specifically lead to a better understanding of the seepage properties, the soil strength properties, the position of the phreatic line, the effectiveness of the unzoned filter, and a post-analysis of the slope stability. This work will also be undertaken during the financial year that commences in October 2016.

3. Core Sampling:- Soil samples will be retrieved during the construction operation mentioned in paragraph 2.2 above.

4. Left Bank:- The "wet spot" and embankment settlements at the left bank is inspected and monitored by the APP during his annual dam safety inspections. In addition, the SAPPI staff responsible for taking seepage readings once per week, also monitors the "wet spot" (now dry) for any anomalous behaviour.

5. Spillway:- The upper section spillway joints has already been cleaned of grass and other matter and the joint "bandages" replaced / repaired. The only damage discovered during remedial works, were the "bandages" on top of the joints, not of the joint filler material itself. The spillway ceased overflowing during mid winter 2016, so that it is now dry enough to repair the damaged "joint bandages" in the lower section of the spillway chute. SAPPI has a contractor on site and aims to have it completed before the onset of the 2016-7 rainy season.

6. Mechanical Equipment:- Some mechanical equipment in the outlet works require corrosion protection and / or replacement in accordance with the recommendations of the mechanical engineer.

7. Warning and Evacuation Plan:- SAPPI is in the process of updating the contact details of all relevant parties in the Warning & Evacuation Plan. The plan is otherwise still relevant and in good order.

15 KEY DAM SAFETY ISSUES

15.1 KEY DAM SAFETY RISKS

The difficult foundation conditions, combined with the sloping un-zoned chimney filter, pose most of the safety risks for Ngodwana Dam. The key safety risks could be summarised as being:

(i) the potential for uncontrolled piping (through either the dam wall or foundations), caused or initiated by the combined effect of the sloping, un-zoned filter, high phreatic surface and erodible material in the downstream embankment;

(ii) impaired downstream slope stability caused by a high downstream phreatic surface;

(iii) sliding failure through the foundations on the left bank. Of particular concern in this regard, was the development of a "wet spot" on the embankment (now gone), near the downstream toe of the embankment, on the left flank and the generally poor foundation conditions at the left flank foundation interface, as well as the recent significant measured movements of the embankment at the left bank interface;

(iv) undercutting and / or lifting of the reinforced concrete slabs forming the spillway return channel bottom, caused by water ingress through failed joint sealers;

(v) significant movements of the dam wall and foundations; and

(vi) loss of life caused by dam break flood and inadequate advanced warning and poorly executed evacuation plan and procedures. During 1987 a dam break flood analysis was undertaken by the firm Stewart, Sviridov & Oliver (subsequently Stewart Scott Incorporated [SSI] which was recently acquired by, and trading as, Royal Haskoning DHV) that indicated a dam break flood peak of 11,000 cubic meters per second, which would, although much dissipated, travel well past Nelspruit. The dam break flood analysis showed that, in the event of a dam break failure of Ngodwana Dam, the following damage is likely to be caused:

1. Washing away of a section of the N4 highway to Nelspruit

2. Washing away of a large portion of the Ngodwana Paper Mill

3. Inundation of the Mataffin village on the banks of the Crocodile River

15.2 KEY DAM SAFETY OBSERVATIONS

The most significant **visual** observations made during the 2016 dam safety inspection is that:

i. The leakage of clay core material through the construction joint in the culvert at chanaige 66 m downstream from the intake tower;

ii. Further (negligible) leakage of clay core material in the culvert is now taking place at a construction joint located at chainage 106 m downstream from the intake tower.

iii. Termite holes on the dam crest.

iv. Termite activity near the lower berm on the left (West) flank downstream embankment.

The most significant observations that can be made from the dam safety **instrumentation monitoring**, is that:

i. The left extremity of the embankment where it meets the left bank foundations, settled by 20mm and moved downstream by 10mm over the past two years.

ii. The embankment displayed large initial vertical and horizontal settlement, but settlements have now stabilised. Maximum vertical settlement (Beacon 7) of 200 mm occurred within the first year (1983-1984) after completion, then another 200 mm settlement during the next 15 years (1984-1999) and only 34 mm during the past 17 years (1999-2016). Total current vertical settlement is 436 mm.

iii. Horizontal movement of the dam crest (downstream) under the water load, exactly followed the vertical settlement pattern.

Total maximum horizontal movement (Beacon 6) is currently 241 mm, having stabilised to only 15 mm horizontal movement over the past 12 years (2004-2016).

iv. Seepage declined to only 0.317 l/s. Measured seepage has steadily decreased from 3 l/s in 1997/1998 to less than 1 l/s in 2008/2009. Over the period 2008/2009-2012/2013 the measured seepage has again increased from under 1 l/s to about 1.5 l/s in 2015, but these "increases" could have been due to the measurement of "non-seepage" runoff at monitoring weir "Seepage 1 – internal drains", which is no longer used in the calculation of total seepage.

15.3 KEY DAM SAFETY CONCLUSIONS

The most logical conclusions to be drawn from the above observations is that:

i. the leakage of embankment material into the outlet conduit is likely due to torn water stops, caused by movement of the conduit on its foundations;

ii. the relatively sudden and significant movement of the embankment on the left bank foundation interface could have been caused by a number of factors, alone or in combination, i.e.:- (i) settlement of the relatively poor foundation conditions underlying the embankment in that area; (ii) washing out of foundation material; (iii) losing of the "bridgeing effect" of the embankment through settlement over the years, causing "slippage" of the left edge of the embankment; etc.

iii. the large initial settlements of the dam wall (near its highest point) is likely due to the consolidation of the thick unconsolidated foundation material that underlies the dam wall foundation;

iv. the unconsolidated foundation materials are now almost fully consolidated from the dam wall loads;

v. the steadily reducing seepage might be ascribed to the reducing permeability of the consolidating foundation materials underlying the dam wall; and

vi. Seepage water is clear (no turbidity) and is very low for an earth embankment dam of this height and size.

From both the dam safety instrumentation monitoring and visual observations by dam safety specialists, it can generally be concluded that, allowance being made for the large early deflections and settlements of the dam wall, Ngodwana Dam has behaved well within expected parameters over the past 33 years and that there is no immediate concern for the safety of the dam.

16 SUMMARY AND RECOMMENDATIONS

In general, Ngodwana Dam needs to be carefully monitored from a dam safety perspective and effective detection, warning and evacuation procedures should be in place to anticipate and deal with any possible emergency situation involving a "dam break event".

The Owner generally maintains Ngodwana Dam in a good condition. The responsible person, Mr Carel van der Merwe, diligently kept records and ensured the proper maintenance of the dam.

However, Ngodwana Dam was built on complex foundations and that, together with other factors, increase the inherent risks that the dam poses to life and property. In particular, the dam safety risks associated with the difficult foundation conditions and the filter design should be closely monitored.

This would be best achieved by having:

i. properly functioning standpipe piezometers in key locations;

ii. a reliable method for gauging seepage;

iii. continued monitoring of dam wall deflections; and

iv. an effective early warning and evacuation plan that should be maintained and practised, in the event that a dam failure risk is detected or experienced.

It is recommended that the Owner implement the following specific dam safety monitoring works:

16.1 SLOPE STABILITY OF THE DAM WALL

Vertical and horizontal (downstream) movements of Monitoring Beacons on the dam are larger than what could be expected of a well-compacted embankment. It is considered that most of the movements took place within the deep unconsolidated foundation materials that comprise of alluvium and dislodged quartzite blocks. Vertical and horizontal movements are decreasing with time and have amounted to less than 1mm per year over the last six years, whilst the dam was at full supply capacity, i.e. fully loaded.

An interesting observation is that, during 1994/5, the dam water level was significantly drawn down for the first time since completion in 1983. At the same time, the deflection monitoring beacons showed that the dam wall settlements and horizontal deflection stabilised and even "re-bounded" a bit, just to sharply increase again when the dam filled to full supply capacity. This shows that there is a direct correlation between the water loads behind the dam wall and the dam wall deflections. (See Appendix G – Monitoring Records and Graphs – Dam Wall Settlements vs Water Level). The significant decrease in the rate of dam wall deflections of only 36 mm during the past 17 years (1999-2016), whilst at full supply capacity, indicates that the foundations must be almost fully consolidated.

It is recommended that settlement monitoring continue with the same regularity as is currently the practice, i.e. at least once per year.

16.2 STAND-PIPE PIEZOMETERS

The only available phreatic surface water level readings are from 6 standpipe piezometers located on the left flank upstream of the centre line, and 2 piezometers located on the middle downstream berm. Water levels in the downstream berm piezometers are well below the FSL and fluctuate very little with time. Groundwater levels decrease in a downstream direction but do not drop much from east to west. Their levels with respect to the FSL indicate an effective cut-off below the dam wall, but a high permeability of the left flank.

It is recommended that 7 new standpipe piezometers be installed as shown on the relevant drawing included under Appendix A - Maps & Drawings.

16.3 CORE SAMPLING

It is further recommended that, during the installation of the 7 new standpipe piezometers, the opportunity be used to obtain soil samples of the downstream embankment material, with the view of assessing permeability and piping risk properties. This would be achieved by using diamond core drilling in combination with auger drilling to install the standpipe piezometers.

16.4 SEEPAGE MONITORING

The V-notch "Seepage 1" measuring the flow for "internal drains" should be discontinued due to the fact that it provides false measurements of seepage flow.

16.5 CONDUIT CONSTRUCTION JOINT

The embankment material leakage as well as the recent water seepage increase in the construction joint of the outlet conduit should be carefully monitored as follows:

(i) Clean away all current embankment material leakage residue from the joint in both the left and right sub-cunduits

(ii) Closely monitor and photograph all material leakage every day for the next month at this joint

(iii) Monitor the water seepage flow and any increase in flow, at V-notches "culvert East" and "culvert West" respectively.

16.6 LEFT EMBANKMENT

The sudden and significant settlement of the left edge of the embankment should be carefully monitored through at least once annual precision surveys of the settlement beacons.

16.7 TERMITE NESTS

Termite nests must be poisened and monitored for any further activity.

16.8 MECHANICAL EQUIPMENT

The following recommendations are made by the "Mechanical Specialist" in his report attached under Appendix E:-

<u>Piping & Pipe Supports</u>

- Repair and replace steel pipe supports.
- Corrosion protection system on all pipe supports to be re-applied.
- Improve drainage on area where water is damming up below the 1000mm pipe to ensure the pipe is not submerged in water.

- Annual schedule be put in place to ensure no water damming which exposes pipe and pipe supports to corrosion.
- Included piping below the dam when thickness tests are done.

Valves

- Corrosion protection system on drain valves to be re-applied
- Scour valve drainage area be improved to ensure water does not flow back into the tunnel.

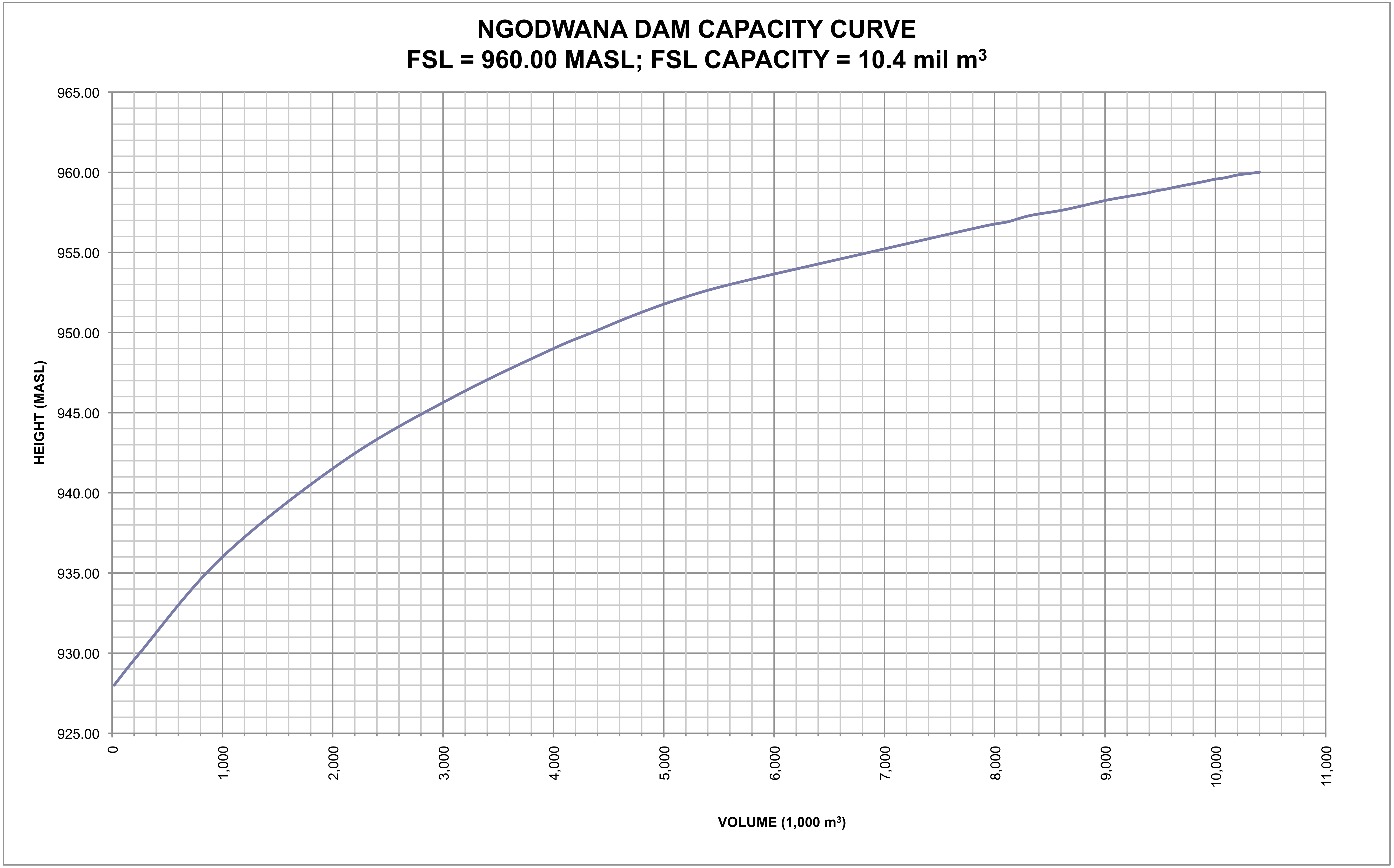
Structures

- Corrosion protection system to be touched-up.
- Grating hold-down clamp to be replaced.
- The installation of additional hand railing should be considered to improve safety on access structures.

16.9 WARNING AND EVACUATION PLAN

It is recommended that the Warning & Evacuation Plan should contain all the necessary warning and evacuation procedures as well as updated contact numbers of all affected people and organisations. The Plan is to be kept in an accessible location, which should be known to all key safety operational staff at SAPPI. The SAPPI safety operational staff should, at least once per year, check whether they are able to contact all relevant affected individuals in a timely manner to take appropriate action in the event of a "dam break flood" event.

APPENDIX A: MAPS AND DRAWINGS


NGODWANA DAM CAPACITY CURVE
FSL = 960.00 MASL; FSL CAPACITY = 10.4 mil m3
HEIGHT (MASL)
965.00
960.00
955.00
950.00
945.00
940.00
935.00
930.00
925.00
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
11,000
VOLUME (1,000 m3)

DISCLAIMER
The information shown on this plan must not be accepted as accurate or complete.

REVISIONS		
DATE:	No.:	DESCRIPTION

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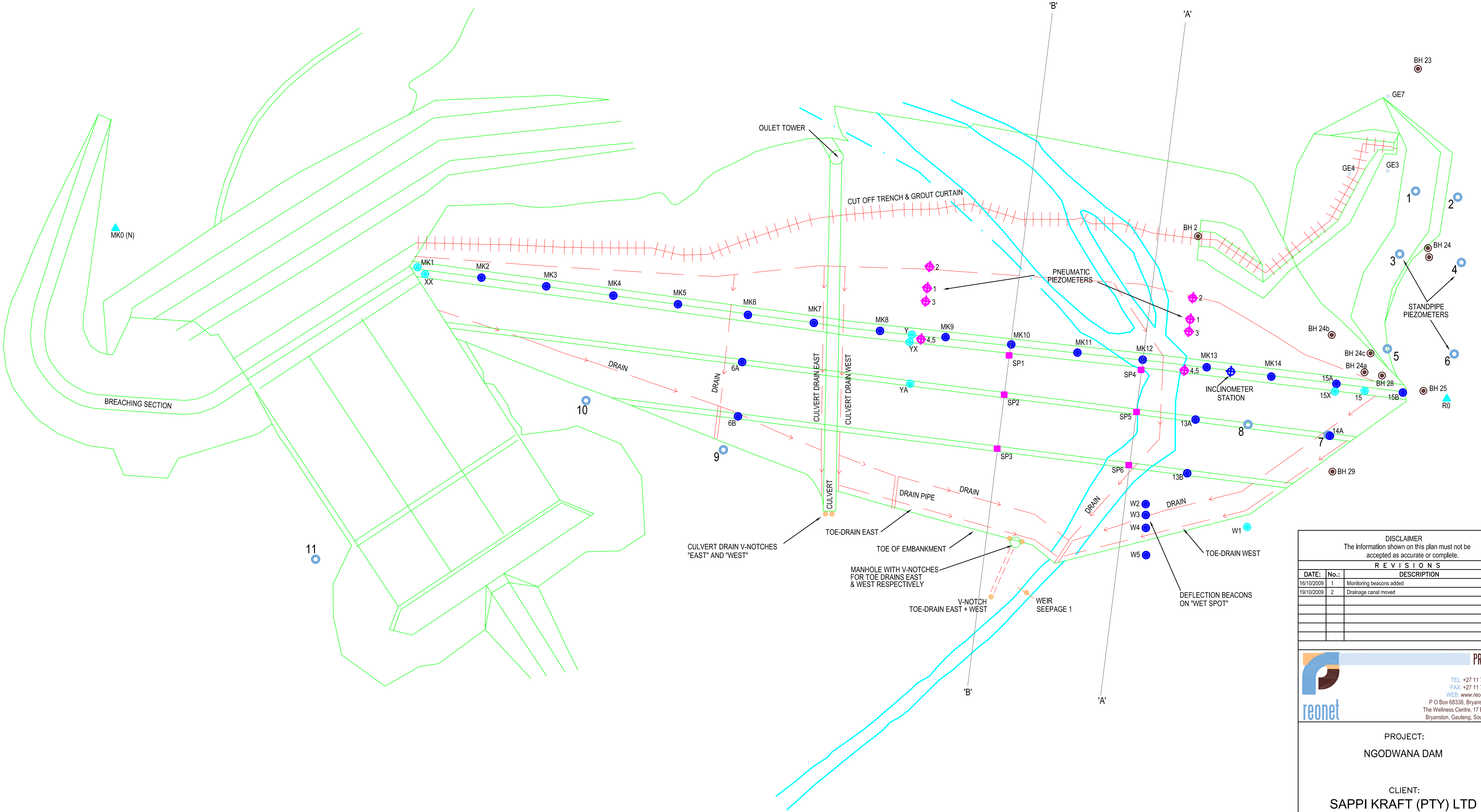
PROJECT:
NGODWANA DAM

CLIENT:
SAPPI KRAFT (PTY) LTD

DRAWING TITLE:
LOCALITY MAP
(Schematic Drawing)

PRINT ISSUED: 4 November 2009

SCALE: Not To Scale	DESIGNED:
	DRAWN: C. Sanders
DATE: NOVEMBER 2009	CHECKED: A. de Beer
PLAN No.: NGODWANA DAM (4)	REVISION:



LEGEND

BH 29	BENCHMARK		INCLINOMETER STATION
	V-NOTCH	MK0 (N)	FIXED REFERENCE BEACON
MK10	MONITORING BEACON	15	FLOATING REFERENCE BEACON
2	PNEUMATIC PIEZOMETERS	SP3	PROPOSED STANDPIPE PIEZOMETERS
6	STANDPIPE PIEZOMETERS		

NGODWANA DAM INSTRUMENTATION PLAN

(NOT TO SCALE)

DISCLAIMER
The information shown on this plan must not be accepted as accurate or complete.

REVISIONS

DATE:	No.:	DESCRIPTION
16/10/2009	1	Monitoring beacons added
19/10/2009	2	Drainage canal moved

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PROJECT:
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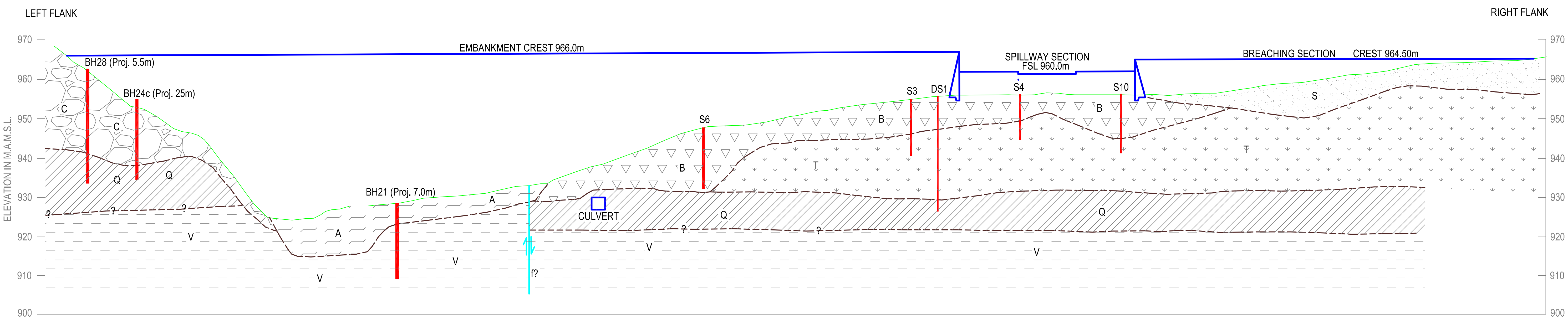
CLIENT:
SAPPI KRAFT (PTY) LTD

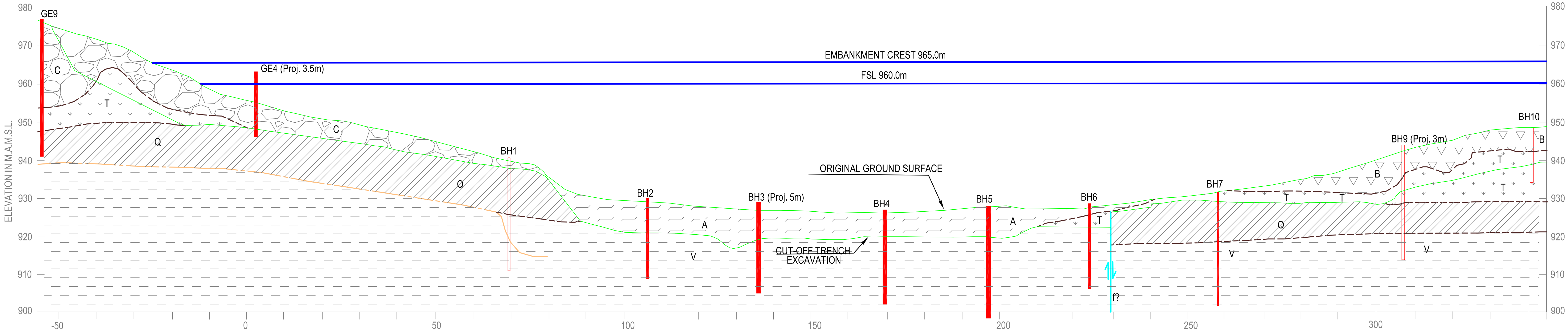
DRAWING TITLE:
INSTRUMENTATION PLAN
(Schematic Drawing)

PRINT ISSUED: 19 October 2009

SCALE: Not To Scale	DESIGNED:
	DRAWN: C. Sanders
DATE: SEPTEMBER 2009	CHECKED: A. de Beer
PLAN No.: NGODWANA DAM (1)	REVISION: 2



LONGITUDINAL SECTION ALONG CENTRE-LINE OF DAM



LONGITUDINAL SECTION ALONG CUT-OFF TRENCH

BH1	DIAMOND DRILL HOLE	
BH1	PERCUSSION DRILL HOLE	
S6	PERCUSSION DRILL HOLE (NO LOG AVAILABLE)	
f?	FAULT (UNCERTAIN)	
	GEOLOGICAL CONTACT (INFERRED)	
	EXTENT OF GROUT CURTAIN	
S	COLUVIAL SOIL	RECENT UNCONSOLIDATED DEPOSITS
C	COLLUVIAL BOULDERS AND BRECCIA	RECENT UNCONSOLIDATED DEPOSITS
A	ALLUVIUM	RECENT UNCONSOLIDATED DEPOSITS
B	QUARTZITE REMNANT BLOCKS	BLACK REEF FORMATION
T	VOLCANIC TUFF, TUFFACEOUS SHALE, AGGLOMERATE	GODWAN FORMATION
Q	QUARTZITE	GODWAN FORMATION
V	LAVA, HORNFELS, QUARTZITE	GODWAN FORMATION

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REVISIONS

DATE:	No.:	DESCRIPTION
13/10/09	1	Hatching & legend changed

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PROJECT:
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CLIENT:
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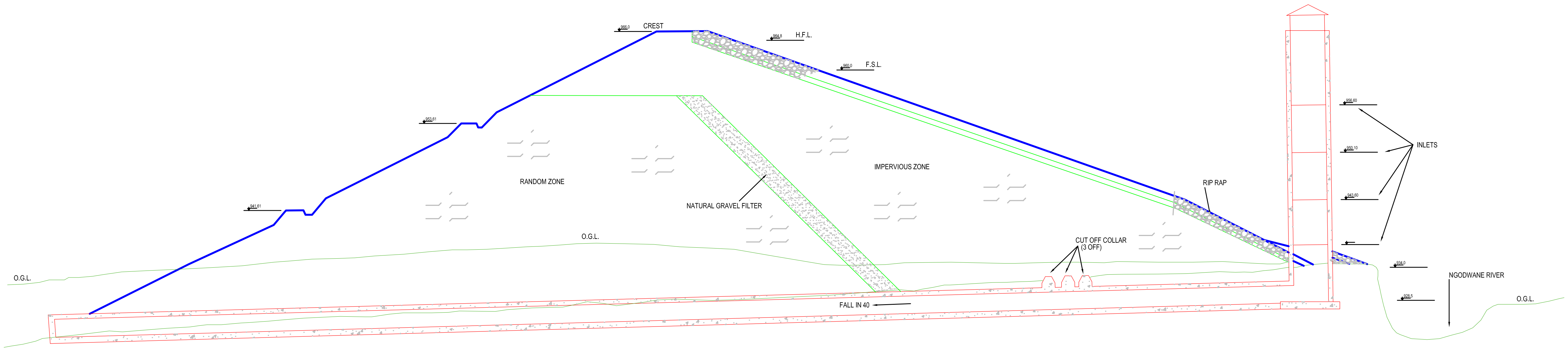
DRAWING TITLE:
LONGSECTIONS
(Schematic Drawing)

PRINT ISSUED: 13 October 2009

SCALE: Not To Scale
DESIGNED:
DRAWN: C. Sanders
DATE: OCTOBER 2009
CHECKED: A. de Beer
PLAN No.: NGODWANE DAM (3)
REVISION: 1



SECTION THROUGH OUTLET WORKS

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R E V I S I O N S

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PROJECT:
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CLIENT:
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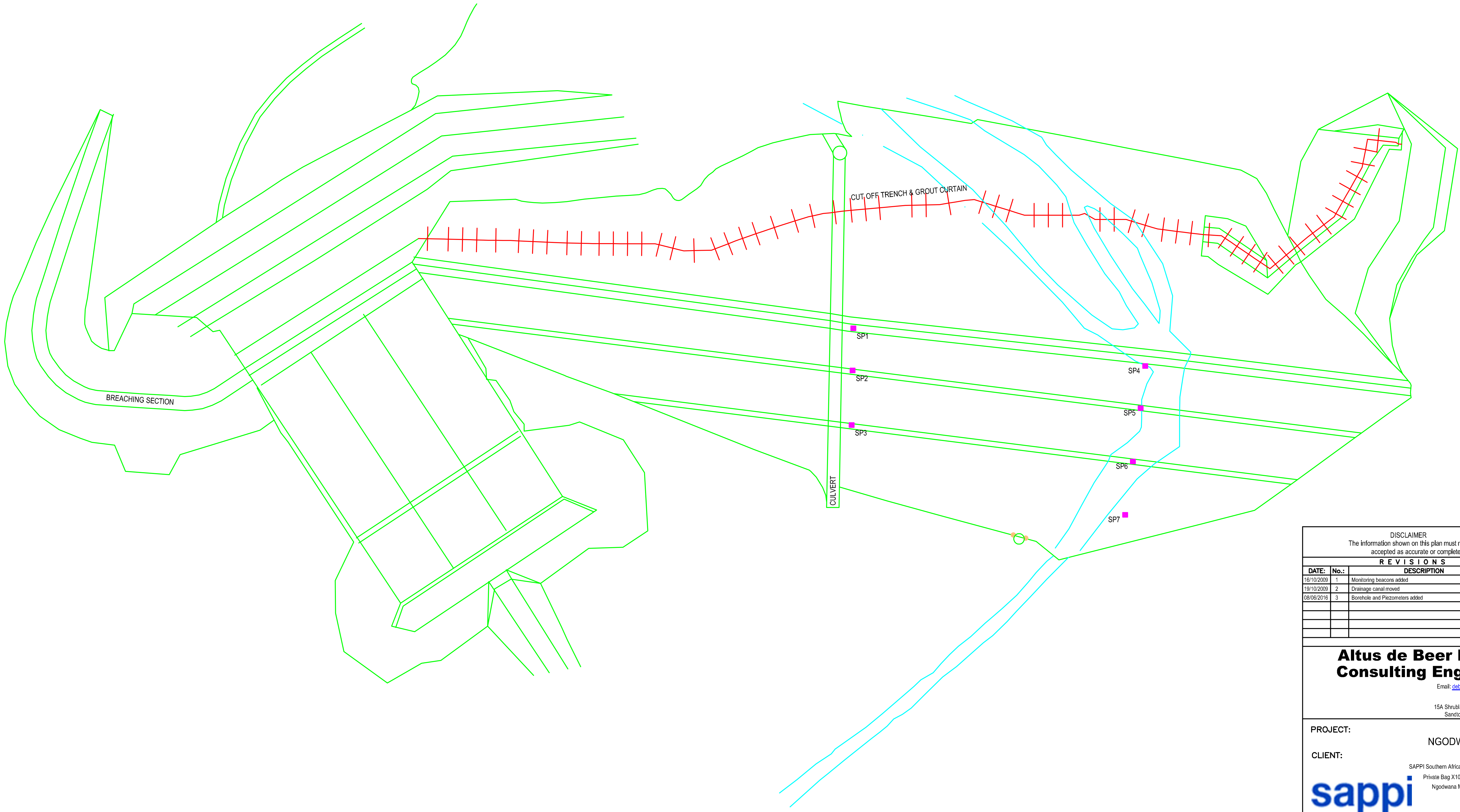
DRAWING TITLE:
SECTIONS
(Schematic Drawing)

PRINT ISSUED: 16 September 2009

SCALE: Not To Scale	DESIGNED:
	DRAWN: C. Sanders
DATE: SEPTEMBER 2009	CHECKED: A. de Beer
PLAN No.: NGODWANE DAM (2)	REVISION:



LEGEND

SP1 = BOREHOLE POSITION

DISCLAIMER
The information shown on this plan must not be accepted as accurate or complete.

REVISIONS

DATE:	No.:	DESCRIPTION
16/10/2009	1	Monitoring beacons added
19/10/2009	2	Drainage canal moved
08/06/2016	3	Borehole and Piezometers added

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DRAWING TITLE:
BOREHOLE AND PIEZOMETER PLAN
(Schematic Drawing)

PRINT ISSUED: 08 JUNE 2016

SCALE: Not To Scale
DESIGNED:
DRAWN: C. Sanders
DATE: JUNE 2016
CHECKED: A. de Beer
PLAN No.: NGODWANA DAM (1)
REVISION: 3

APPENDIX B: GEOLOGICAL REPORT

NGODWANA DAM

SAFETY INSPECTION: AUGUST 2009
ENGINEERING GEOLOGY REPORT

TEAM MEMBER / AUTHOR: A VAN SCHALKWYK

1. INTRODUCTION

The Engineering Geology Report deals with the site geology and its influence on the performance of the embankment and spillway of the Ngodwana Dam.

Reference is made to previous reports on engineering geological safety inspections by A van Schalkwyk dated 7 August 1998 and 23 September 2003. The first report contains a review of all available geological data and a detailed assessment of geological conditions.

2. SUMMARY OF GEOLOGICAL CONDITIONS

2.1 General

The site geology is extremely complex due to the occurrence of a variety of sedimentary, volcanic and metamorphic rocks, unconformities in the sedimentary succession, faulting, variable weathering, thick alluvium in the river section, colluvium on the left flank and large dislodged quartzite blocks on the right flank. The distribution of the material types along the dam centre line and the cut-off trench is illustrated on the attached sections (see **Annexure H Drawings – Dwg No Ngodwana Dam (3) – Longitudinal Sections**)

2.2 Left flank

The upper part of the left flank is underlain by a 5m – 20m thick cover of partly recemented (calcified) talus blocks in a matrix of soil, resting upon a layer of completely weathered very weak tuff and agglomerate. Although the embankment in founded on these low strength and potentially permeable materials, the cut-off wall was re-aligned in an upstream direction and is largely founded on a downstream dipping layer of strong Godwan Formation quartzites. Only the upper part (mostly above FSL) of the cut-off is founded on weak tuff and partly cemented colluvium. This part of the flank had been covered by an impervious blanket, and based on seepage records, it can be concluded that a reasonably watertight cut-off had been achieved.

2.3 River section

The river section is underlain by a 5m – 10m thick layer of river alluvium that is underlain by medium strong tuff, lava, hornfels and quartzite of the Godwan Formation. These rocks are closely jointed in some areas. The cut-off is founded on bedrock.

2.4 Right Flank

Along the major part of the right flank, the embankment and spillway structures are founded on a layer of large dislocated (slumped) blocks of Black Reef Formation quartzite, resting upon a thin layer of weak tuff, tuffaceous shale and agglomerate of the Godwan Formation that is underlain by strong quartzite of the same formation. The cut-off is founded partly on the strong quartzite and partly on the weak rocks overlying it. The engineering properties (deformability and permeability) of these rocks are unknown.

2.5 Spillway Structure

The overspill and chute are founded on dislodged quartzite blocks and colluvium, while the stilling basin is located in weathered, weak tuffaceous shale.

2.6 Breaching Section

The breaching section is partly founded on the dislocated quartzite blocks and partly on colluvial soil comprising gravely sand and clay.

3. PRESENT INSPECTION AND EVALUATION

The site visit of 27 August 2009 included an inspection of the left flank, the dam crest, the upstream and downstream slopes (including the “wet area” on the downstream slope), the seepage measuring points, the outlet culvert, the spillway chute, the return channel and the breaching section. Available records of seepage and deflection measurements were reviewed. Inspection of the structure was greatly facilitated by the high standard of maintenance (see **Plate G1**).

Plate G1. View of dam wall from left abutment.

3.1 Displacement Monitoring

Since 1983, 13 Monitoring Beacons (MK2 – MK14) and 2 Floating Reference Beacons (MK1 and MK15) on the dam crest were monitored for vertical and horizontal displacements (see **Annexure H Drawings – Dwg No Ngodwana Dam (1) – Instrumentation Plan**). The maximum movements occurred in the vicinity of the culvert (MK6 - MK 8) and have been a source of concern, both on account of the magnitude of the movements and the large horizontal (downstream) components. The downstream components could be explained by the orientation of the resultant load of a full dam, but the total recorded movements of about 400mm vertical and 200mm downstream at Beacons MK 6 and MK7, are more than what could be expected of a well-compacted embankment of this height. It is therefore considered likely that some of the movements have taken place in the foundation material which, in the area of the culvert, comprises 8m – 10m of alluvium (upstream part of the footprint) and similar thicknesses of dislodged quartzite blocks with unconsolidated soil between them (near the centre-line and downstream of it). Both the alluvium and the quartzite blocks are prone to some degree of consolidation settlement.

Plots of the maximum movements (e.g. MK6 and MK7 on **Annexure I – Monitoring Records and Results – Beacon 7 Vertical Movement vs Time vs Water Level** and **Beacon 6 Horizontal Movement vs Time vs Water Level**), show decreases with time that are consistent with consolidation settlement in poorly compacted soil. Over the last five years, movements have generally been less than 1mm per year, and it can be concluded that the dam wall and foundations are now almost fully consolidated.

During the years 2000 and 2001, a number of additional Monitoring Beacons (6A, 6B, 13A, 13B, 15A and 15B) as well as a few additional Floating Reference Beacons were installed on the crest and downstream berms, while in 2008 a row of Monitoring Beacons (W1 – W6) were installed across the "wet area" on the downstream slope. The new beacons on the crest and berms also show vertical and downstream movements, but the accumulated magnitudes are less than 20mm. After about one year of installation, movements of between 1mm and 2mm were recorded at Beacons W1 – W6.

In the first safety inspection report, it was noted that the Fixed Reference Beacon B0 above crest level on the left abutment was located on a colluvial boulder that might be subject to movement (see **Plate G2**). Sappi reported that an additional beacon was installed higher up along the flank, but from surface indications, it appears that the new beacon may also be situated on colluvium.

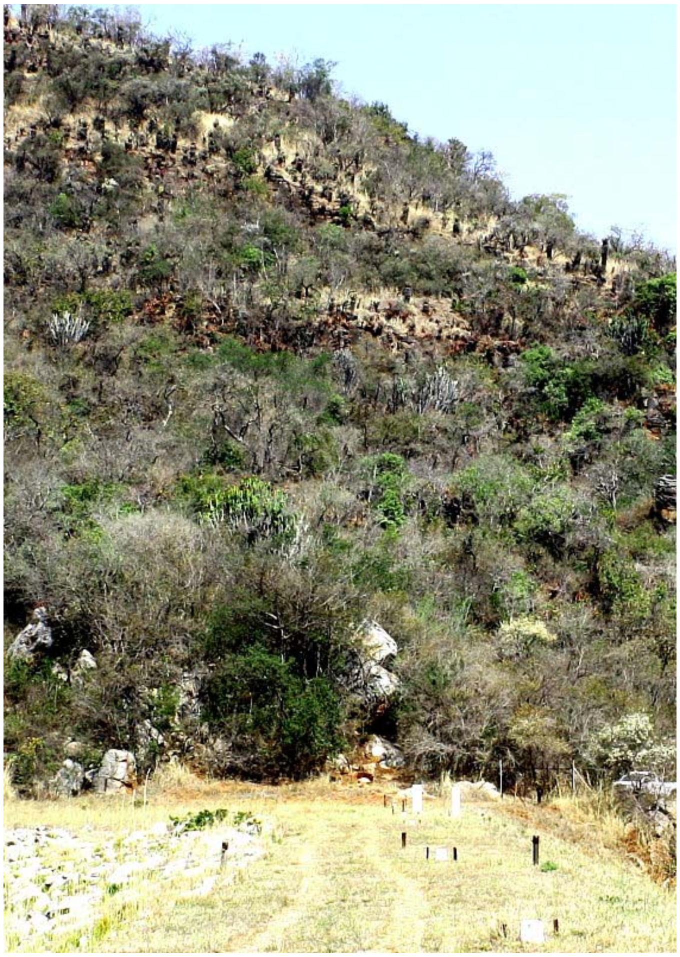


Plate G2. Beacon on left abutment.

Six standpipe piezometers located above crest level on the left flank have also been used as beacons to monitor possible movement of the steep slope that was formed during excavation for the cut-off trench. Maximum settlement since 1998 is about 30mm, but movements have decreased, and since 2003, the maximum recorded movement is 6mm amounting to less than 1mm per year.

3.2 Rip-rap

Rip-rap on the upstream slope is generally in a good condition and the rock blocks show no signs of weathering. In one area near the dam crest, there is a shallow trench in the rip-rap where blocks had been removed (see **Plate G3**). This area must be restored.

Plate G3. Trench on upstream face.

3.3 "Wet" Area on Downstream Slope

The "wet" area that was reported on in previous reports is still visible (see **Plate G4**), but is has not increased in size and appears to be much drier than before. This is reassuring since the dam was at FSL. No significant movements have been recorded by the Monitoring Beacons installed in 2009 (see **Plate G5**).

Plate G4. "Wet" area on downstream face also showing left flank (west) surface drain.

Plate G5. Beacons WD2 – WD5 across "wet area".

3.4 Seepage from Dam

Seepage from the dam is measured as follows:

- V-notches at Culvert Drains East and West that measure flow from parts of the chimney drain and from along the culvert.
- A V-notch that measures flow from Toe Drains East and West (see **Plate G6**). Toe Drain East never had any flow.
- A V-notch in a weir in the river that measures Seepage 1 from the Internal Drains (see **Plate G7**).

Plate G6. V-notch for Toe Drain East and West.

Plate G7. Weir for measuring "Seepage 1".

The total seepage from the dam is calculated as the flow from all the above measuring points. Records since 1997 show that the total seepage is sometimes (but not always) affected by the water level in the dam and sometimes (but not always) by the rainfall. Total seepage has generally decreased from a maximum of about 4,5l/sec in 1997 to a maximum of about 1,6l/sec in 2009. Most of the seepage originates from the internal drains as measured as Seepage 1 at the weir, while the remainder comes from the Toe Drain West. In October 2001, the record for Seepage 1 is exceptionally high (about 6l/sec) and this can only be attributed to a mistake.

A possible problem with the record from Seepage 1 at the weir is that some of the flow may bypass the V-notch by seepage below or around the weir. The decrease in measured flow could be the result of an increase in sub-surface flow due to washing out of fines below the weir.

Flow in a small stream originating from downstream of the dam on the left (west) flank is not being measured, but seems to be fairly constant throughout the year (see **Plate G8**). Earlier water tests have shown that this water does not originate from the dam.

Plate G8. Seepage in stream on left flank

3.5 Piezometers

The pneumatic piezometers that had originally been installed along two rows between the core and the dam crest are no longer working, and in the previous safety inspection report, it was recommended that two rows of stand-pipe piezometers must be installed to replace the defunct ones. This had not been done, and the only available water levels readings are from 6 standpipe piezometers located on the left flank upstream of the centre line, and 2 piezometers located on the middle downstream berm (see **Annexure H Drawings – Dwg No Ngodwana Dam (1) – Instrumentation Plan**). Six of these points are also being used as settlement beacons (see paragraph 3.1 above).

The collar heights of the piezometers on the left flank vary between 965,3 masl and 979, 6 masl (5,3m – 19,6m above FSL) and the water levels vary between 6m and 14m below FSL. Between 1998 and 2009, the water levels fluctuated generally less than 1m, except for the readings taken in November 2003, when the water levels were generally 1m to 2m deeper than in the years before and after. Groundwater levels decrease in a downstream direction but do not drop much from east to west. Their levels with respect to the FSL indicate an effective cut-off below the dam wall, but a high permeability of the left flank.

3.6 Spillway Chute and Plunge Pool

The spillway chute appears to be in good condition with no major signs of displacement or cracking (see **Plate G9**). During February 2009, one of the largest recorded floods of about 500m^3/s passed over the spillway. However, based on a comparison of photographs taken in 2003 and during the present visit, the plunge pool and the narrow exit channel in weak rock had not been eroded (see **Plate G10**). However, due to the limited capacity of the discharge channel, major flooding of the area downstream of the dam will occur when larger floods are passed.

Plate G9. View of spillway. Note that curved appearance is due to "photo stitching".

Plate G10. Plunge pool. Note erosion between rock blocks and side of channel.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 The dam has been maintained very well, and only a small part of the rip-rap needs to be repaired.

4.2 Vertical and horizontal (downstream) movements of Monitoring Beacons on the dam are larger than what could be expected of a well-compacted embankment. It is considered likely that part of the movements took place within the foundation materials that comprise of alluvium and dislodged quartzite blocks. Vertical and horizontal movements are decreasing with time and have amounted to less than 1mm per year over the last five years. It can be concluded that the dam wall and foundations have now been almost fully consolidated and that there are no cause for concern regarding the stability of the embankment

4.3 The “wet” area that was reported on in previous reports is still visible, but is has not increased in size and appears to be much drier than before. This is reassuring since the dam was at FSL. No significant movements have been recorded by the Monitoring Beacons installed across the “wet” area in 2009.

4.4 Total seepage has generally decreased from a maximum of about 4,5l/sec in 1997 to a maximum of about 1,6l/sec in 2009. Most of the seepage originates from the internal drains as measured at Seepage 1 at the weir, while the remainder comes from the Toe Drain West. A possible problem with the record from Seepage 1 is that some of the flow may bypass the V-notch by seepage below or around the weir. It is recommended that test pits be dug to investigate the founding conditions of the weir and to take steps to ensure that all seepage can be measured.

4.5 The only available water levels readings are from 6 standpipe piezometers located on the left flank upstream of the centre line, and 2 piezometers located on the middle downstream berm. Water levels are well below the FSL and fluctuate very little with time. Groundwater levels decrease in a downstream direction but do not drop much from east to west. Their levels with respect to the FSL indicate an effective cut-off below the dam wall, but a high permeability of the left flank. It is recommended that new standpipe piezometers be installed between the core and the middle berm along two lines across the embankment as shown on **Annexure H Drawings – Dwg No Ngodwana Dam (1) – Instrumentation Plan**.

4.6 No significant erosion had taken place in the stilling basin and along the narrow discharge channel. However, it appears that in the case of a major flood, the limited capacity of the discharge channel could result in flooding of the area downstream of the dam.

APPENDIX C: FLOOD HYDROLOGY REPORT

NGODWANE DAM

THIRD DAM SAFETY INSPECTION : 27 August 2009

Report for the Department of Water Affairs & Forestry

REVIEW OF FLOOD HYDROLOGY AND HAZARD POTENTIAL

By Dr W V Pitman

1. INTRODUCTION

This is the second review of the flood hydrology for Ngodwane Dam, which was first undertaken by the author for the dam safety inspection of June 1998. As it is more than 10 years since the first inspection, it is considered prudent at this stage to re-assess the flood hydrology in the light of new methodologies and calculation procedures that have come into usage since that time. Apart from new methodology, some of the original methods that relied on graphical interpretation have been computerized to ensure consistent results.

2. FLOOD HYDROLOGY

2.1 Methods for design flood determination

A total of five methods have been used to derive flood peaks for various return periods in addition to the RMF and PMF. A brief description of each method is given in Table 1.

Table 1 Description of methods for design flood determination

Method	Brief description
HRU 1/72 Regional formula	Appendix B of HRU Report No. 1/72 contains a regional map and a co-axial diagram for a quick estimation of floods for return periods ranging from 5 to 200 years. The estimates can not be considered as accurate since they rely only on catchment area and location.
HRU 1/71 Flood formula	This method takes into account veld cover, mean rainfall, catchment shape and catchment slope. It is meant to give similar – but quicker – results to that of the HRU 1/72 unit hydrograph method.
Rational method	This method is designed primarily for small catchments of the order of 10 km^2 or less. Nevertheless many hydrologists apply this method to relatively large catchments.
DWAF TR137 method	The report contains factors which, when applied to the RMF, yields quick estimates of the 50-, 100- and 200-year flood peaks.
Standard design flood (SDF)	This method is a relatively simple, but robust, method developed by Alexander (SAICE Journal, 44(1), 2002). Model parameters are provided for 29 major drainage basins/regions.

2.2 Catchment characteristics related to flood hydrology

The methods outlined in Table 1 rely on some of the following physical characteristics of Ngodwane Dam catchment, as listed in Table 2 below.

Table 2 Catchment characteristics

Physical characteristic	Value	Units
Catchment area	229	km^2
Average channel slope	0.0173	-
Length of longest watercourse	26	km
Length to catchment centre	13	km
Mean annual precipitation	1068	mm
HRU veld zone	3	-
HRU extreme rainfall zone	1	-
Francou-Rodier "k"	5	-
Francou-Rodier "k+Δ"	5.2	-
Francou-Rodier "k-Δ"	4.6	-
HRU flood zone (Appendix B)	4	-
Percentage of catchment under afforestation	28	%
Percentage of catchment with dolomitic exposure	56	%

2.3 Comparison of results obtained with different methods

Table 3 lists the results obtained with the different methods. It should be noted that the SDF method was not used in the original dam safety assessment of flood hydrology but was used in the previous (2003) assessment.

Table 3 Summary of results (flood peaks in m^3/s)

Flood event	HRU Region	HRU Formula	Rational method	TR137	SDF	Mean estimate
10-year	173	188	338	*312*	234	249
20-year	243	259	406	*427*	354	338
50-year	351	356	628	609	536	496
100-year	446	453	893	771	690	650
200-year	551	*564*	*1230*	948	*868*	832
RMF-Δ				901		901
RMF				1513		1513
RMF+Δ				1968		1968
PMF		2695	3130			2913

Note – extrapolated peaks shown in *italics*.

One does not necessarily accept the simple mean of the different methods, as it usually necessary to give greater weight to the methods deemed to be the more reliable. Before accepting the final values, it is also appropriate in this case to compare these results with the values obtained in the first dam safety report and any revisions emanating from the second review. This comparison is set out in Table 4.

Table 4 Comparison of results with previous flood estimates

Flood event	Means from Table 3	1998 Dam Safety Report	2003 Dam Safety Report
10-year	249	Not done	Not done
20-year	338	380	No change
50-year	496	560	No change
100-year	650	720	No change
200-year	832	910	No change
RMF-Δ	901	Not done	Not done
RMF	1513	1510	No change
RMF+Δ	1968	1970	No change
PMF	2913	2700	No change

Before any changes to the flood peaks can be considered, it is necessary to re-visit the adjustments that were considered necessary to account for the large areas of afforestation and dolomite in the catchment of Ngodwane Dam, as explained below.

2.4 Allowance for Afforestation and Dolomitic Exposure

In report TR137 it is stated (on page 17) that " ……….K may be reduced if (i) more than half of the area is very permeable, dolomitic or covered by plantations……….." It also states that "The reduced K may not be lower, however, than the K of the next lower number region….."

The Ngodwane Dam catchment is predominantly dolomitic (56%) and, in addition, has plantations of exotic forest covering 28% of the catchment. There is thus some justification in reducing K, provided it remains above the next lower number region – in this case 4.6. However, as the catchment is steep it would be prudent not to reduce K substantially. Accordingly, a K of 4.9 was adopted, giving a revised RMF of 1330(m^3/s) or 88% of the unadjusted estimate. This factor was used to adjust all flood peaks, but has not been applied to the mean estimates of the present analysis (for floods in the range 20- to 200-year) as listed in the second column of Table 4. The flood peaks are compared in Table 5, where it can be seen that the two sets of figures are quite close.

Table 5 Comparison of adjusted flood peaks

Return period (years)	Flood peak (m^3/s)	
	Current analysis	Previous analysis (adjusted)
20	338	330
50	496	490
100	650	630
200	832	800
RMF	1330*	1330
PMF	2563*	2400

NB * These values also adjusted as for previous analysis

2.5 Standard Design Discharge (SDD) and Safety Evaluation Discharge (SED)

As Ngodwane is a Category III dam the SDD must be the 1 in 200 year event, hence the value of 800 m^3/s was adopted for the 1998 analysis. This value was retained for the subsequent 2003 analysis. The current analysis yielded an average 200-year (unadjusted) peak of 832 m^3/s but, as can be seen from inspection of Table 3, there is a wide range of estimates derived from the various methods. Accordingly, it is recommended that the original value of 800 m^3/s be retained for the SDD.

Ngodwane Dam has a low hazard rating, hence the SED can be set equal to the (adjusted) RMF, which is 1330 m^3/s for both the original and current analysis.

The full supply area of Ngodwane Dam is 87ha, which is equivalent to 0.38% of the catchment area. This suggests that the attenuation of incoming floods is likely to be minimal and can be ignored.

3. Appraisal of Spillway

The discharge formula for the spillway remains acceptable. The spillway rating shows that a discharge of 1766 m^3/s can be passed before the breaching section is overtopped. This discharge is well in excess of the SEF of 1330 m^3/s and is about 70% of the PMF. The dam wall itself is well above the SEF level and RDD level plus freeboard, as shown below.

RDD (800 m^3/s): elevation = 964.07m (incl. freeboard allowance of 1.35m)
SED (1330 m^3/s): elevation = 963.76m

Elevation of breaching section: 964.50m
Elevation of main dam wall: 966.00m

Signed……………………………… Date…27 August 2009…
(Dr W V Pitman)

APPENDIX D: STRUCTURAL REPORT

NGODWANA DAM

SAFETY INSPECTION REPORT –AUGUST 2016

STRUCTURAL SUB-REPORT

TEAM MEMBER / AUTHOR: ALTUS DE BEER PrEng

1 GENERAL

The structural sub-report deals with all the concrete elements of the Ngodwana Dam. There are three main concrete elements on the Ngodwana Dam, i.e.:

- Spillway structure, including retaining walls, slabs and OGEE control.
- Intake tower.
- Outlet conduit.

These elements were inspected by the author on 10 May 2016. Photographs of these structural elements are included in the main report.

2 SPILLWAY STRUCTURE

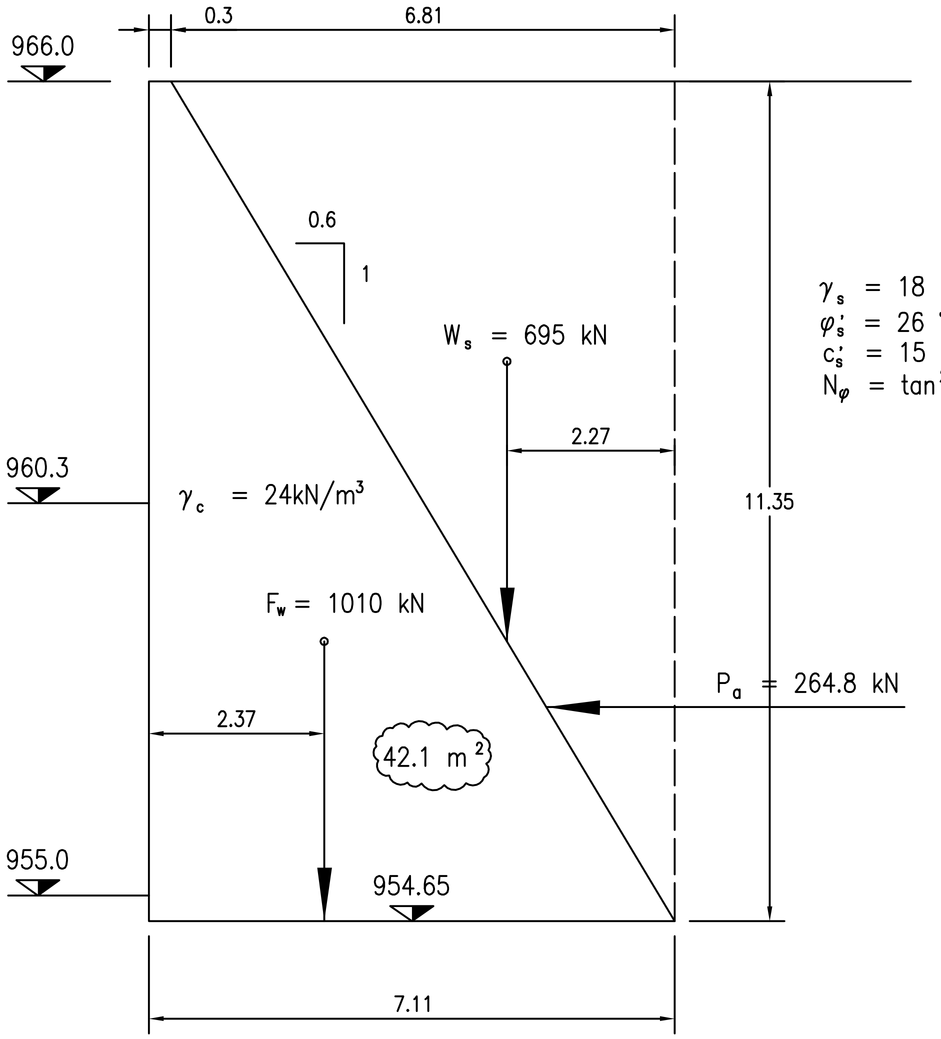
2.1 SPILLWAY FLANK WALLS

The retaining walls flanking the OGEE structure were analysed for stability during the previous inspection and again for this inspection. The critical section was taken as immediately downstream of the OGEE structure. The restraining effect of the OGEE were ignored in both cases. For this inspection, more realistic assumptions were made for the soil action on the wall, resulting in higher overall factors of safety. The assumptions and results of the stability analyses are listed in table 1 below. The Coulomb theory was used for active and passive pressures.

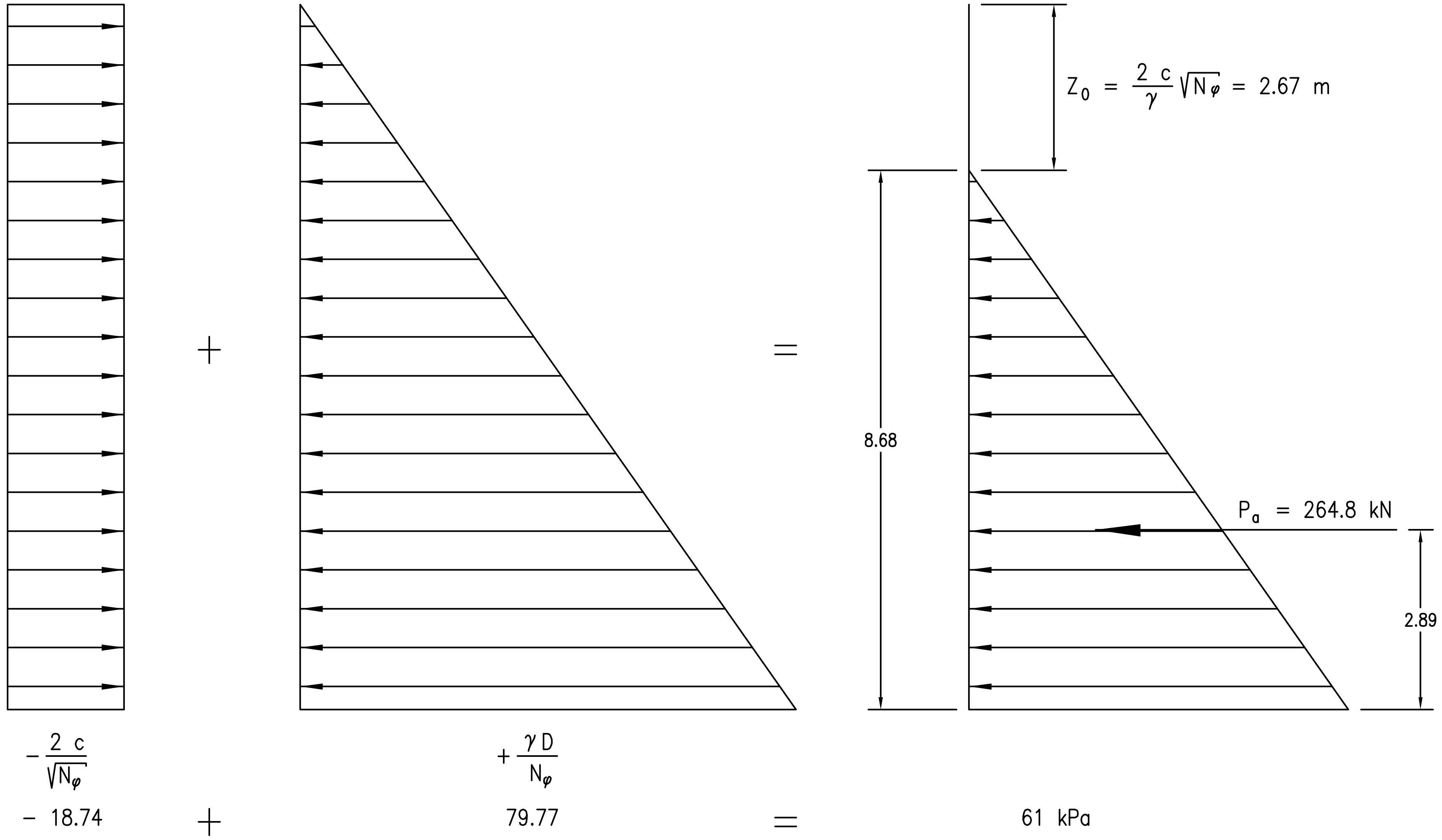
Table 1:- Stability Analysis Results for Spillway Retaining Walls.

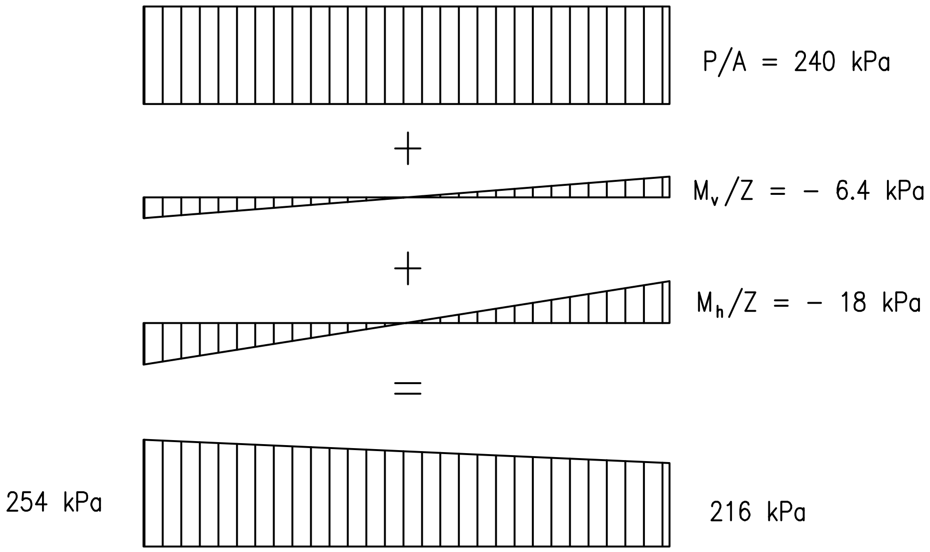
WALL	γ (kN/m^3)	Φ(degrees)	C (kPa)	FOS $_{overt.}$	FOS $_{slide}$
LEFT	18	26	15	2.6	2.3
RIGHT	20	35	0	1.8	18.3

The other structural elements and all recommendations associated therewith, are dealt with in the main report.



Soil active pressure :

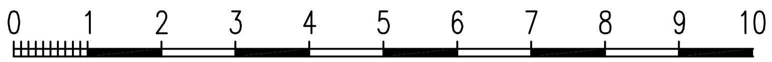




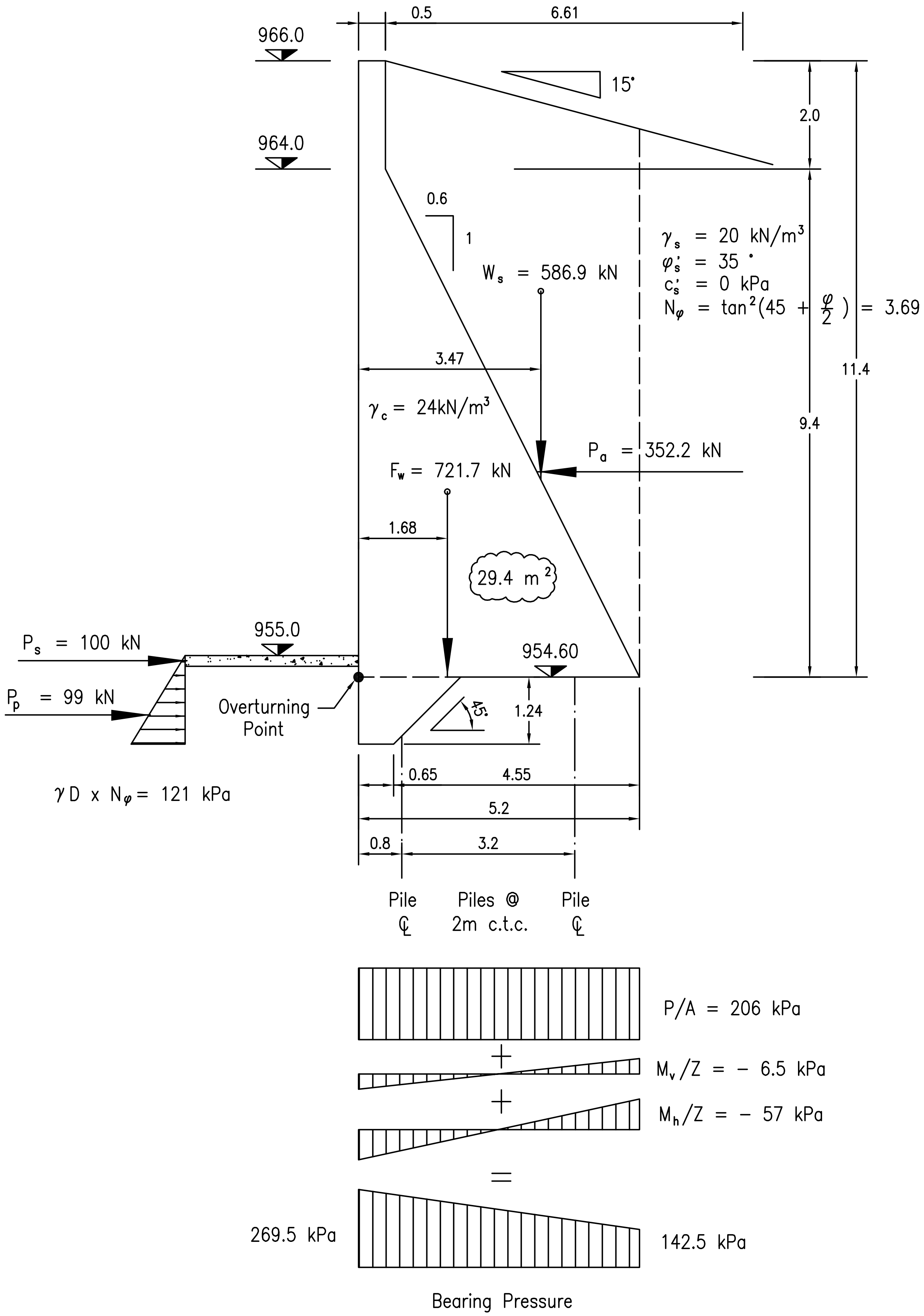
Bearing Pressure

$$FOS_{ovt} = \frac{(F_w \times 2.37) + (W_s \times 4.84)}{(P_a \times 2.89)} = 7.52$$

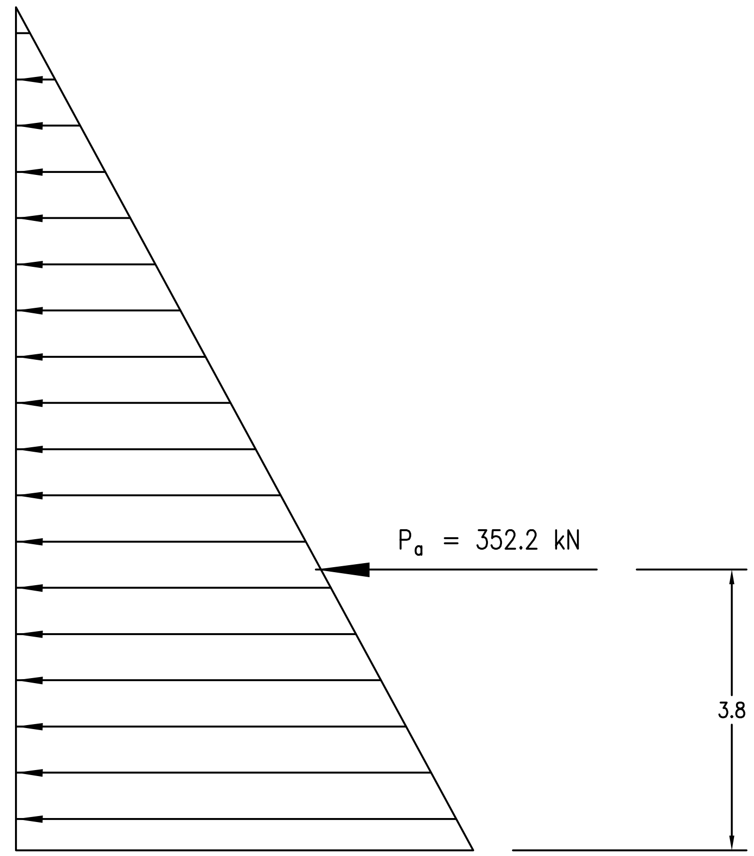
$$FOS_{slide} = \frac{(F_w + W_s)\tan \varphi/2}{P_a} = 1.48$$



REVISIONS							
DATE: No.: DESCRIPTION	NGODWANE DAM SOUTH RETAINING WALL STABILITY CALCULATION	SAPPI NGODWANE PAPER MILL	NGODWANE DAM NORTH RETAINING WALL STABILITY CALCULATION	**Altus de Beer PrEng Consulting Engineer** Email: debeeraltus@gmail.com Cell: 083 700 8733 15A Shrublands Drive, Hurlpark, Sandton 2196, South Africa	DRAWING TITLE: NGODWANE DAM SOUTH RETAINING WALL STABILITY CALCULATION	PRINT ISSUED: SCALE: AS SHOWN DATE: 12 SEPT 2016 PLAN No.: ADA9802−01	DESIGNED: A. de Beer DRAWN: R. Petrov CHECKED: REVISION:



Soil active pressure :



$$\frac{\gamma D}{N_\varphi} = 61.78 \text{ kPa}$$

$$FOS_{ovt} = \frac{(F_w \times 1.68) + (W_s \times 3.47)}{(P_a \times 3.8)} = 2.43$$

$$FOS_{slide} = \frac{(F_w + W_s)\tan \varphi/2}{P_a} = 1.17$$

Take into account Passive Pressure and Slab Constraint, then:

$$FOS_{slide} = \frac{(F_w + W_s)\tan \varphi/2 + P_p + P_s}{P_a} = 1.73$$

Pile cap forces

Left pile: − P_L = 558 x 2 = 1116 kN

Right pile: − P_R = 513 x 2 = 1026 kN

0 1 2 3 4 5 6 7 8 9 10

REVISIONS		
DATE:	No.:	DESCRIPTION

NGODWANE DAM
NORTH RETAINING WALL
STABILITY CALCULATION

SAPPI
NGODWANE PAPER MILL

NGODWANE DAM
NORTH RETAINING WALL
STABILITY CALCULATION

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DRAWING TITLE:
NGODWANE DAM
SOUTH RETAINING WALL
STABILITY CALCULATION

PRINT ISSUED:	
SCALE: AS SHOWN	DESIGNED: A. de Beer
	DRAWN: R. Petrov
DATE: 12 SEPT 2016	CHECKED:
PLAN No.: ADA9802−02	REVISION:

APPENDIX E: MECHANICAL REPORT

DCE

A.R. Du Plessis Consulting Engineers
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NGODWANA DAM MECHANICAL INSPECTION REPORT

Complied by: André du Plessis
Date: 6 June 2016

SUMMARY

DCE conducted a visual inspection on the mechanical aspects of the Ngodwana dam on 23 May 2016.

In summary the following main items should be noted:

- Pipe supports are severely corroded and needs to be replaced/repaired.
- Water damming below the 1000mm line needs to be resolved, pipe external corrosion is occurring.

It is important to resolve the corroded pipe supports, this could have a negative impact on the pipe integrity at the point of attachment to the pipe support.

The conclusion of the inspection is that the mechanical equipment is safe to operate, but that the corrosion related issues should be resolved as a matter of urgency.

TERMS OF REFERENCE

DCE-1400-15

DOCUMENT DISTRIBUTION, REVISION AND APPROVAL HISTORY

Rev	Date	Distribution
1	6 June 2016	Issue to Client

CONTENTS

1. BACKGROUND

DCE was appointed to do the 5 yearly statutory mechanical inspection of the Ngodwana dam.

A visual inspection was done on 23 May 2016.

Sappi submitted wall thickness reports on piping.

2. METHOD STATEMENT

A visual inspection was done on valves, piping, pipe supports and structures.

Results of wall thickness test reports were evaluated.

The scour valve was opened and mechanical functionality witnessed.

Recommendations were made.

3. REFERENCE DRAWINGS & DOCUMENTATION

Description	Document Number	Rev	Revision Date
NDT Report	NG15-007	-	28Aug15

4. ASSUMPTIONS

Assumptions:

- Wall thickness measurements in 2003 was incorrect.

5. FINDINGS

Piping & Pipe Supports

Wall thickness testing results, of external piping, show an average wall thickness of 9.57 mm with no significant average material loss since the last measurements in 2009 with an average of 9.66.

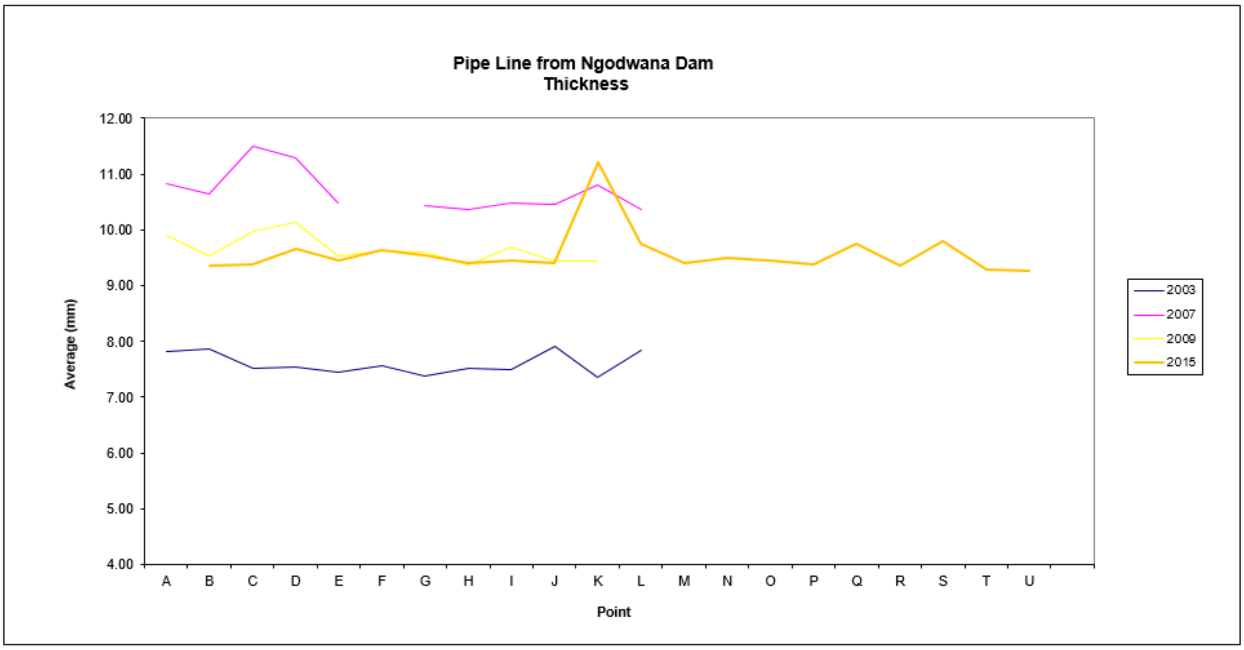
Additional measuring points where introduced not measured during previous years.

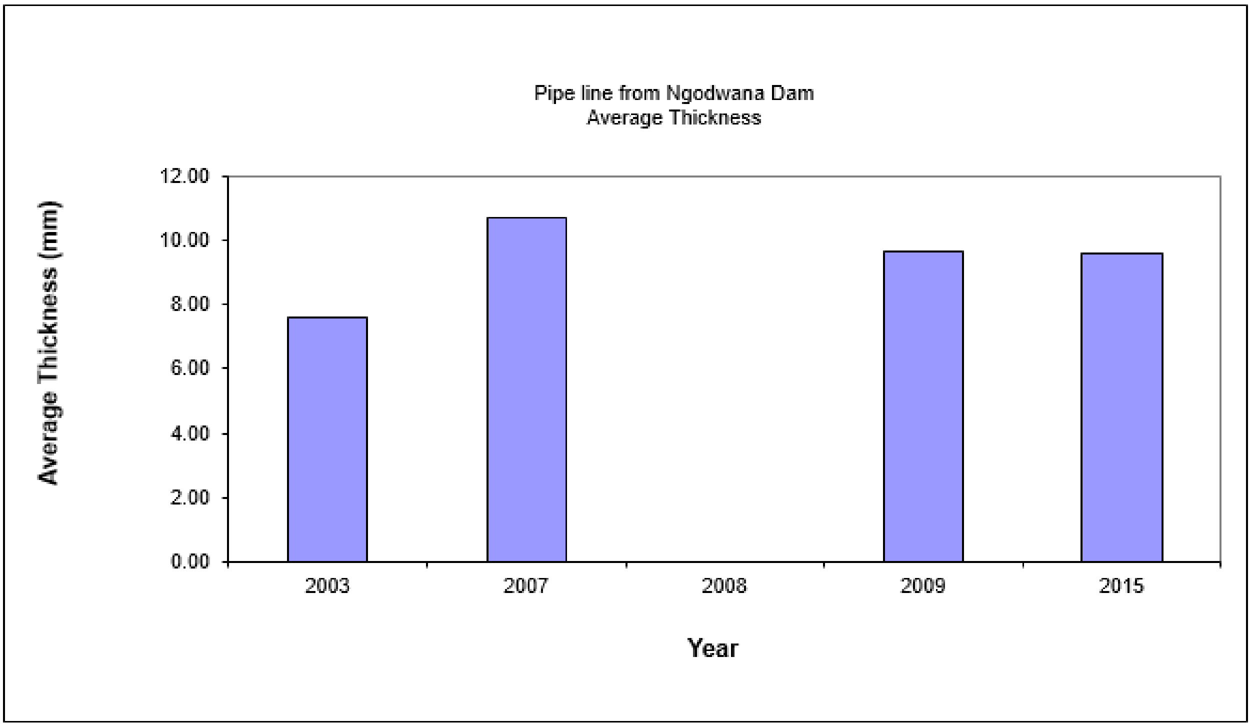
Thickness measurements at point K has increased by +- 1.75mm since measurements in 2009 which doesn't make sense.

Thicknesses in area C & D decreased by 0.5mm.

Pipe wall thickness is still sufficient.

No wall thickness measurements are available of the pipe sections below the dam wall.





Pipe supports are severely corroded.

Most of the piping corrosion protection system is in a good condition requiring spot repairs in some areas *[Photo-A1/B3]*, with the exception of a section of the 1000mm pipe where exposed to water*[Photo-A13/B13/C12]*.

Water is damming up below the 1000mm pipe, this is leading to severe corrosion of the pipe supports and bottom of the pipe in this area.

Valves

The scour valve was opened and operated satisfactory. A lubrication schedule is in place and is being followed.

While operating the scour valve it was noted that water build-up downstream of the valve occurs and then floods the tunnel under the dam wall – plant material is then carried into the tunnel. This could be contributing to the damming of water inside the tunnel.

The other valves where visually inspected externally only.

Bolts and nuts are badly corroded on drain valves at the bottom of the tower *[Photo-B1/A2//B2/A10/B10*].

Structures

Access structures where visually inspected. Some corrosion was observed *[Photo – C10/B16/A4]*.
Grating hold down clamps are corroded.

6. RECOMMENDATIONS

Piping & Pipe Supports

- Repair and replace steel pipe supports
- Corrosion protection system on all pipe supports to be re-applied
- Improve drainage on area where water is damming up below the 1000mm pipe to ensure the pipe is not submerged in water.
- Annual schedule be put in place to ensure no water damming which exposes pipe and pipe supports to corrosion.
- Included piping below the dam when thickness tests are done.

Valves

- Corrosion protection system on drain valves to be re-applied
- Scour valve drainage area be improved to ensure water does not flow back into the tunnel.

Structures

- Corrosion protection system to be touched-up.
- Grating hold-down clamp to be replaced.
- The installation of additional hand railing should be considered to improve safety on access structures.

7. ATTACHMENTS

7.1 PHOTO REFERENCE

A B C

1
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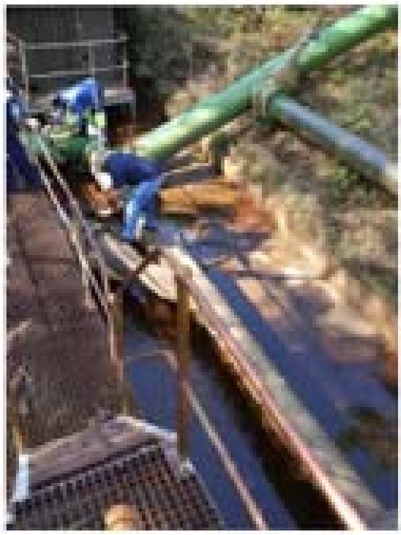
3

	A	B	C
4			
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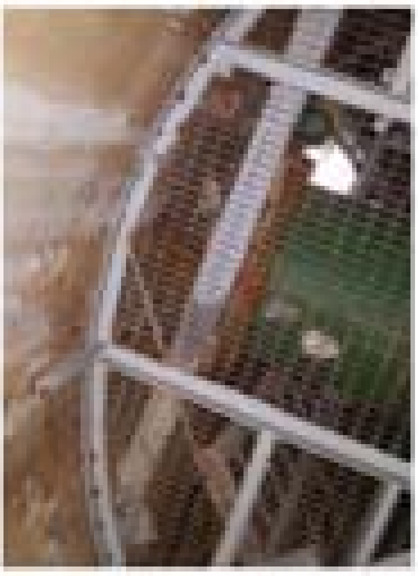
16			
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7.2 NDT REPORT

12 Mitco Industrial Park
Houtkop road
Vereeniging

VAT NO. 4170231312
REG NO. 2005/147907/23

Telephone: (016) 428 5735
Cell phone: 082 854 8055
083 280 4488
Fax: 086 588 4664/5/6
Email: ndtinspection@telkomsa.net
Web: ndtinspection.co.za

133 203 733

WT:	NG15-007
DATE:	28 August 2015

WALL THICKNESS TEST REPORT

DETAILS OF COMPONENT	*Client:*	Sappi Southern Africa	*Contact Person:*	J.Bischoff
	Description:	Mill Reservoir Main Line	*Plant:*	Outside Service
	Manufacturer:	In Service	*Item No.:*	KN/UTI -FWT - FER -SUPPL - 1130530
	Material:	Stainles steel	*Drawing No.:*	1140002
TECHNICAL DATA	*Apparatus:*	SIUI	*Type and Number:*	CTS-30A
	Calibration Date:	21 April 2015	*Surface Cond.:*	Wire Brushed / Paint removed
	Test block Type:	4mm Test block	*Calibration Rangs:*	0 mm - 30 mm
	Couplant:	GEL	*Procedure No.:*	UT-001-REV.: 3

TEST RESULTS

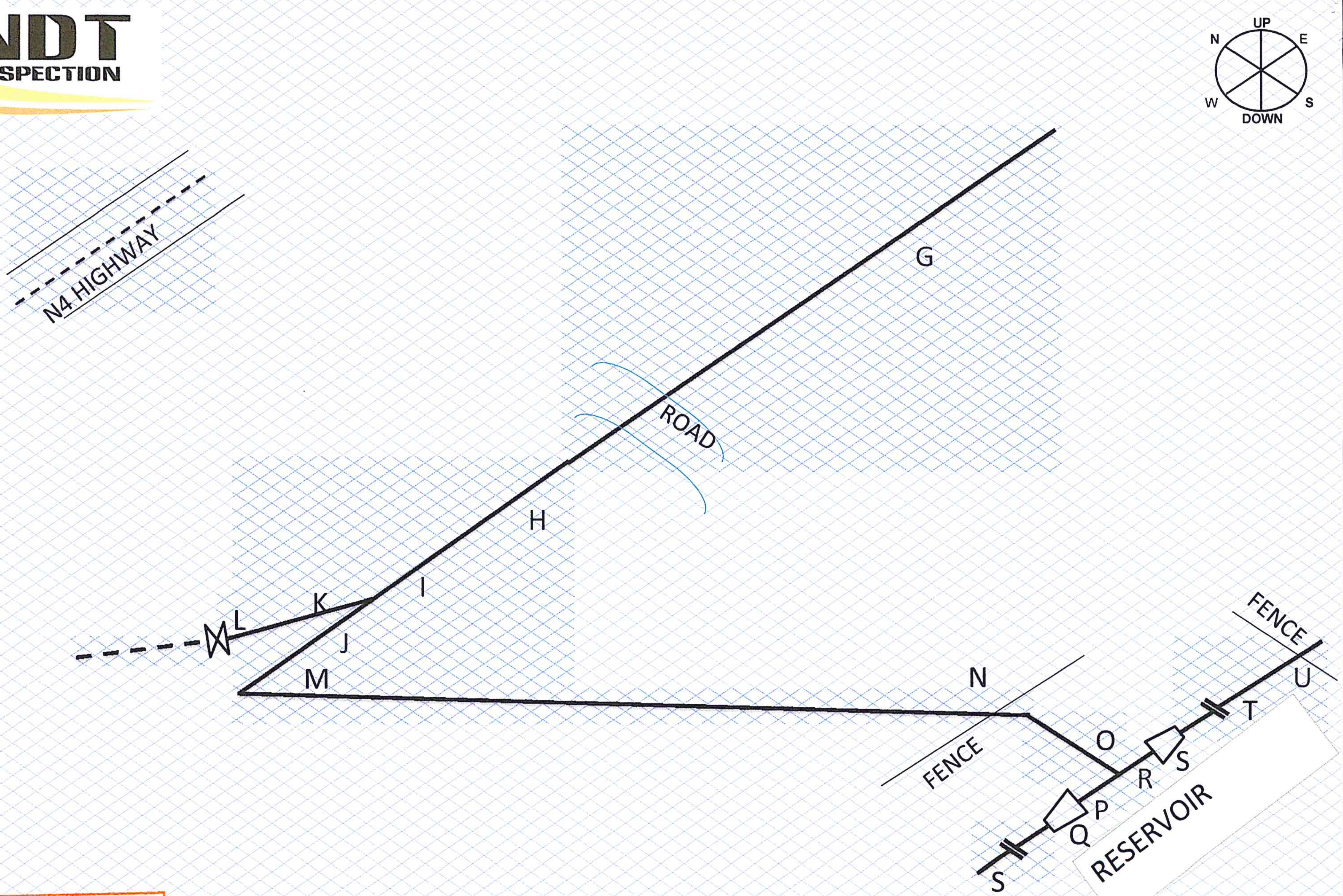
Position	A	B	C	D	E	F	G	H	I
1	N/A	9.3	9.1	9.5	9.2	9.3	9.3	9.1	9.2
2	N/A	9.7	9.3	9.4	9.4	9.7	9.5	9.5	9.2
3	N/A	9.1	9.3	9.8	9.6	9.9	9.6	9.4	9.5
4	N/A	9.3	9.8	9.9	9.6	9.6	9.8	9.6	9.9

Position	J	K	L	M	N	O	P	Q	R
1	9.0	11.6	9.6	9.1	9.2	9.5	9.6	9.7	9.2
2	9.3	10.7	10.1	9.7	9.5	9.7	9.4	10.0	9.4
3	10.2	11.5	10.0	N/A	9.9	9.4	9.1	9.6	9.2
4	9.1	11.0	9.3	9.4	9.4	9.2	9.4	9.7	9.6

Position	S	T	U						
1	9.9	9.3	9.4						
2	9.6	9.4	9.4						
3	9.9	9.3	9.5						
4	9.8	9.2	9.2						

Performed by:	E.Benade	*Inspection Authority:*
Qualification:	SNT-TC-1A II	
Date:	28 August 2015	*Date:*

NDT INSPECTION
J.S. BENADE
SNT TC 1A L1 RT/MT/PT
SAQCC WELDING INSPECTOR L1



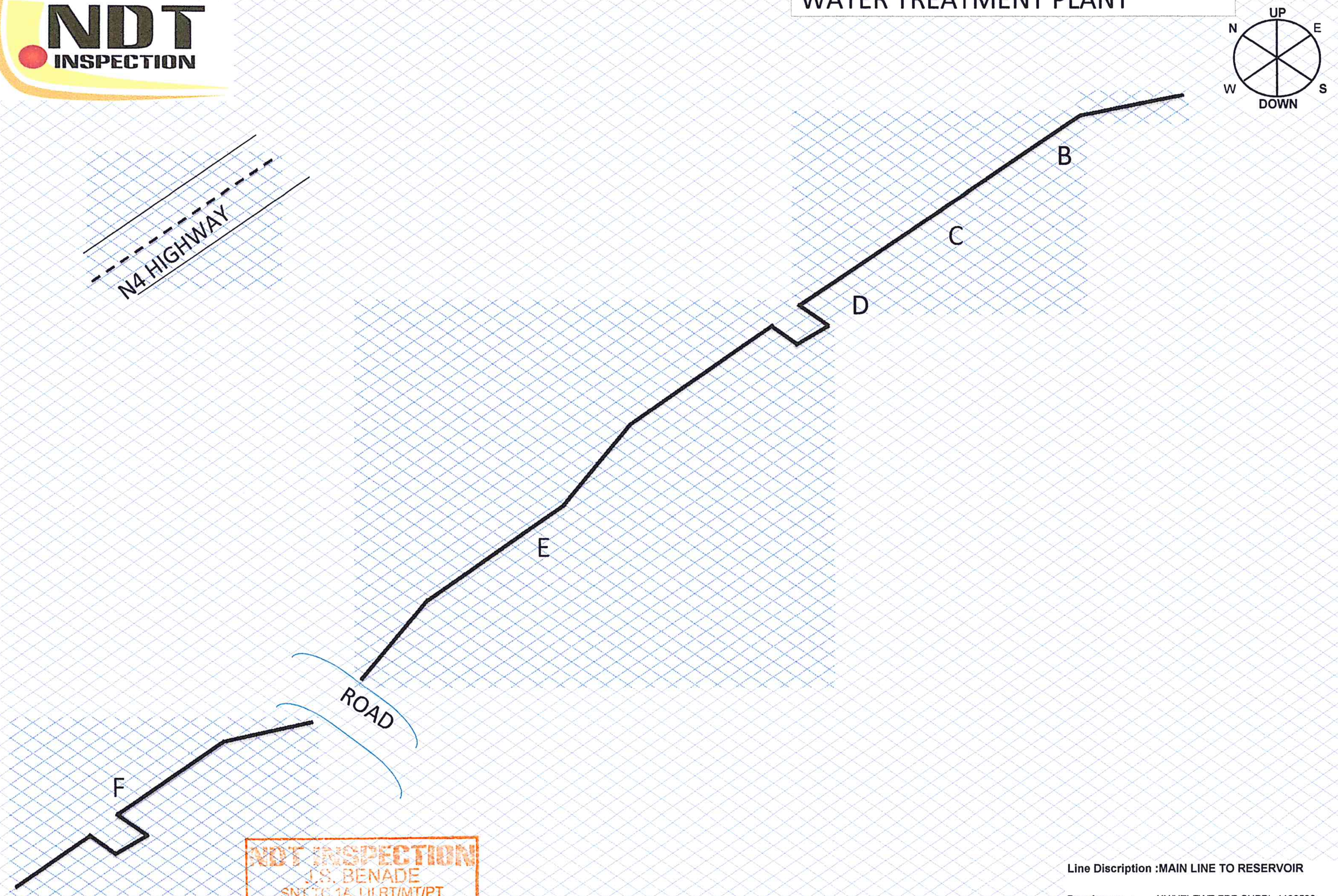
NDT INSPECTION
J.S. BENADE
SNT-TC-1A- LII RT/MT/PT
SAQCC WELDING INSPECTOR L1

Line Discription :MAIN LINE TO RESERVOIR

Drawing no : KN/UTI-FWT-FRE-SUPPL-1130530
Raport no : : NG15-007 1 OF 2
DRAWN BY : E.Benade

Sappi Outside services

WATER TREATMENT PLANT



NDT INSPECTION
J.S. BENADE
SNT TC 1A LII RT/MT/PT
SAQCC WELDING INSPECTOR L1

Line Discription :MAIN LINE TO RESERVOIR

Drawing no :	KN/UTI-FWT-FRE-SUPPL-1130530			
Raport no : :	NG15-007	1	OF	2
DRAWN BY :	E.Benade			

Sappi Outside services

APPENDIX F: PHOTOGRAPHIC RECORD

NGODWANA DAM PHOTOGRAPHIC RECORD

10 May 2016 – 6'th COMPULSORY DAM SAFETY INSPECTION

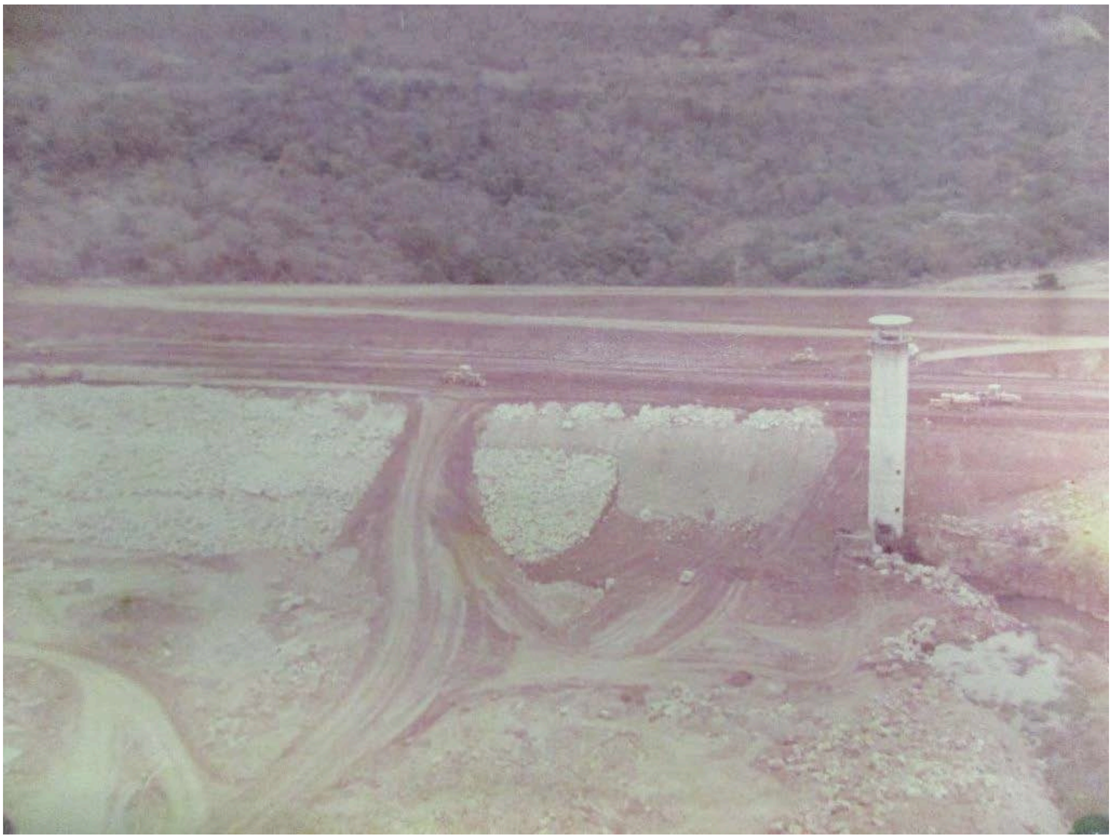
CONSTRUCTION-STAGE PICTURES (circa 1983)

Plate 1:- View from right bank across service spillway in foreground. Note filter drain (light-coloured strip of material) along centre of embankment.

Plate 2:- Upstream view from downstream of the dam wall. Note soil borrow areas in the dam basin left of the river channel.

Plate 3:- View towards left flank, showing partly constructed embankment and exposed left bank foundations comprising a cover of partly recemented (calcified) talus blocks in a matrix of soil, resting upon a layer of completely weathered very weak tuff and agglomerate

Plate 4:- Downstream view from inside dam basin. Note rock cuts adjacent to inlet tower indicating good founding conditions.



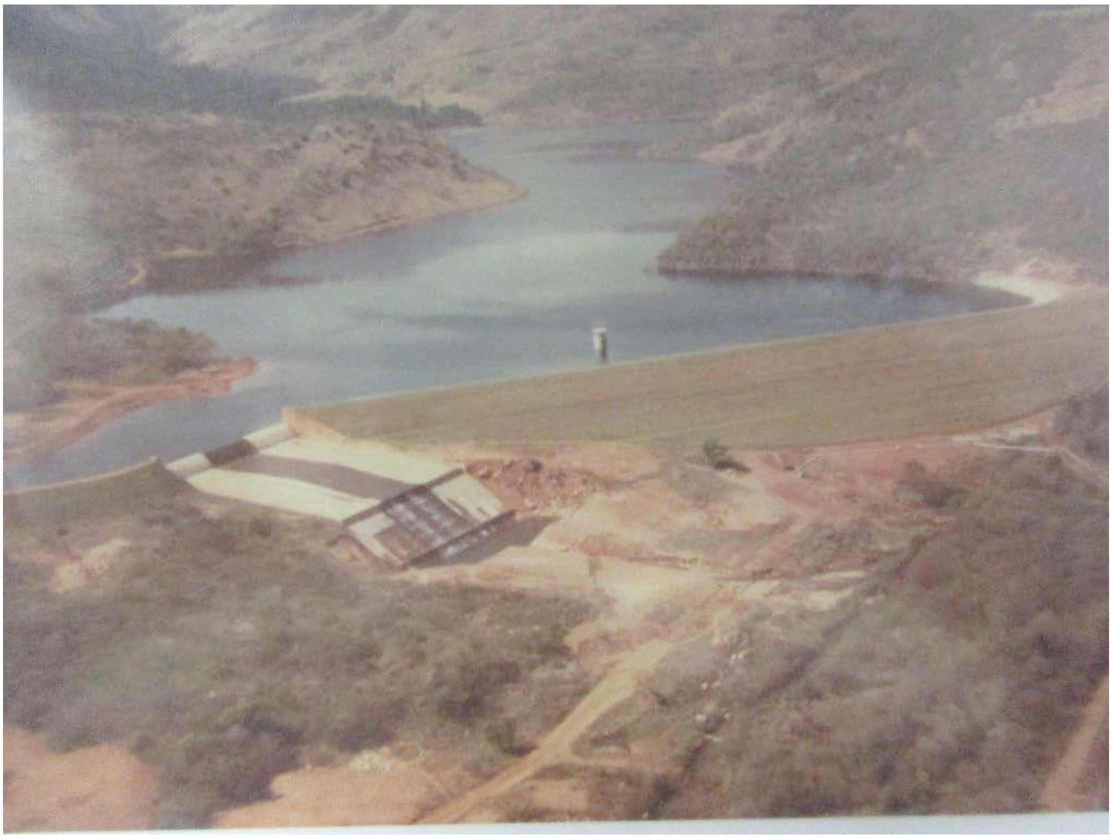
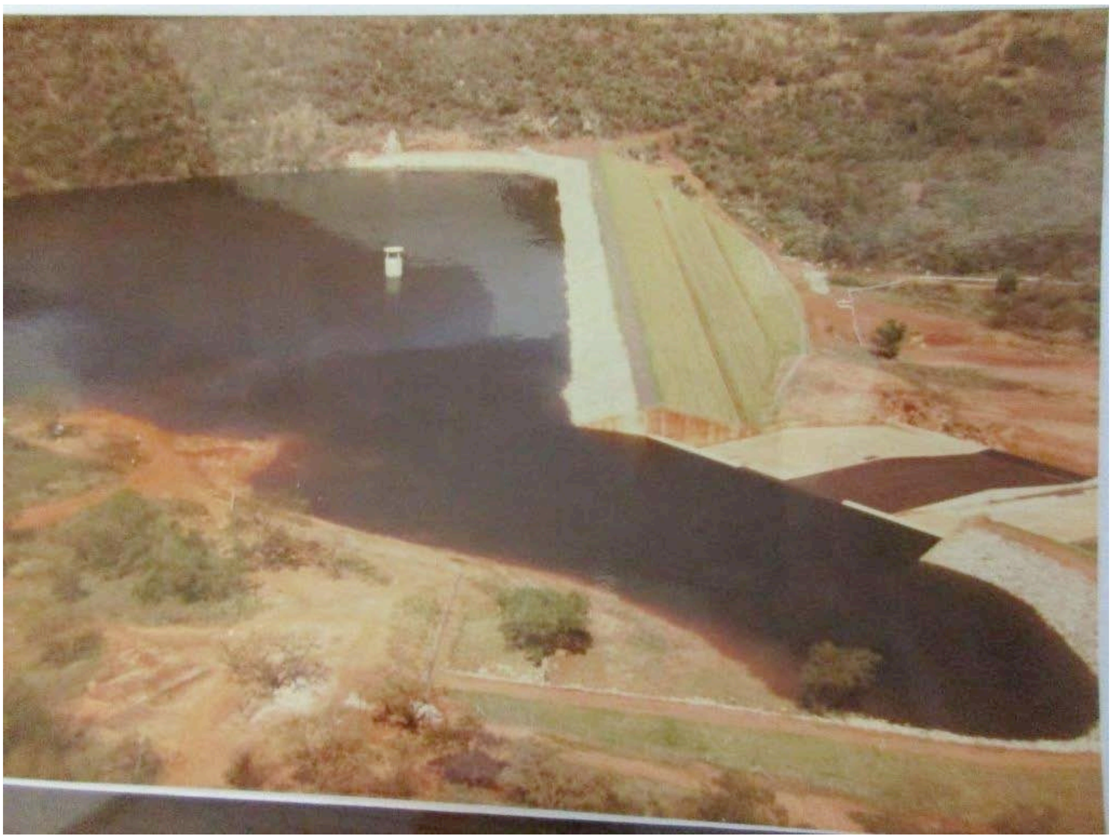


Plate 5:- Upstream view of downstream face of dam wall after first filling

Plate 6:- View from right bank after first filling



GENERAL VIEWS OF DAM WALL AND APPURTENANT STRUCTURES

Plate 7:- View from right bank emergency breaching section across service spillway in foreground (2016-05-10)

Plate 8:- View from left bank with emergency breaching section in far right background (2016-05-10)

Plate 9:- Service spillway OGEE control structure (2016-05-10)

Plate 10:- Service spillway return channel with “kink” and “flip bucket”. Note new repair bandages over construction joints. (2016-05-10)

Plate 11:- View of spillway control structure and return channel – Note repair bandages over construction joints (2016-07-12)

Plate 12:- Dry intake tower and embankment crest viewed from right bank / spillway (2016-05-10)

SURVEY BEACONS & PIEZOMETERS

Plate 13:- Survey beacons on crest of dam wall, viewed from left flank (2016-05-10)

Plate 14:- Survey beacons at “wet spot” on embankment slope near left flank. The “wet spot” was dry at time of inspection. (2016-05-10)

Plate 15:- Survey beacons (top left and bottom right). Faulty piezometers on berm (centre of picture). (2016-05-10)

Plate 16:- Faulty piezometers on berm to be replaced with new standpipe piezometers (2016-05-10)

SEEPAGE COLLECTORS & V-NOTCH GAUGES

Plate 17:- V-notch gauge at outlet for combined “toe-drain East and toe-drain West” (2016-05-10)

Plate 18:- “Seepage 1” v-notch gauge in old river bed – to be discontinued due to ingress of other seepage, i.e. not from “dam” seepage (2016-05-10)

DAM SAFETY-RELATED PICTURES

Plate 19:- Outlet conduit:- left-side compartment, right wall, 66 m from intake tower:- seepage of embankment material through construction joint (2016-05-10)

Plate 20:- Ditto as above (2016-07-12)

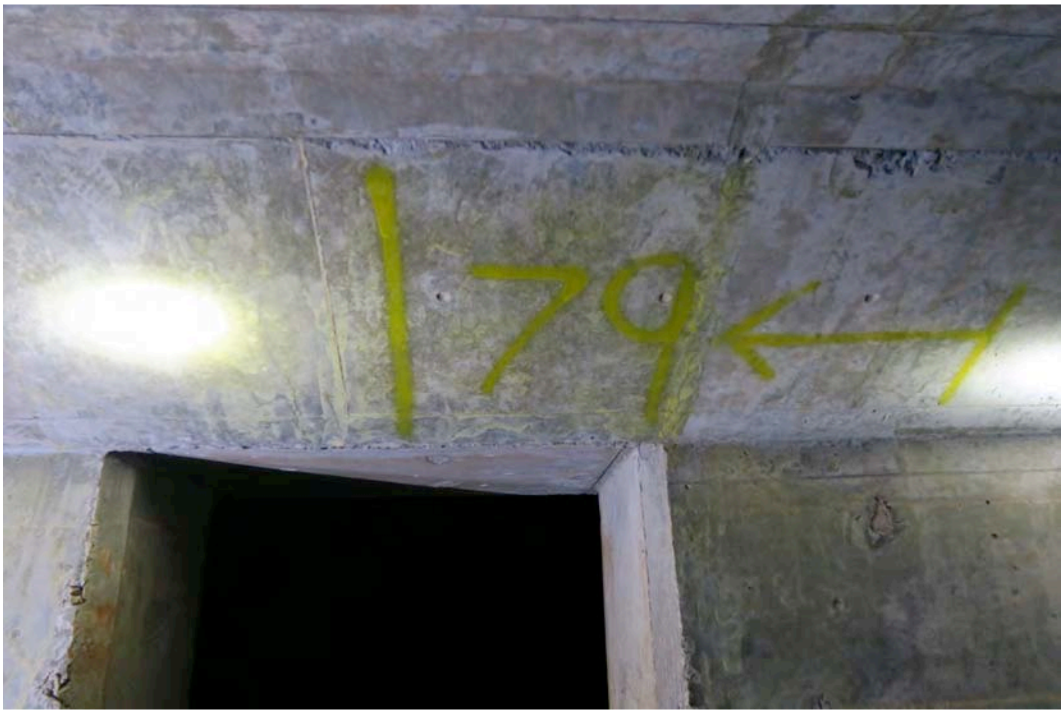


Plate 21:- Outlet conduit:- left-side compartment, right wall, 79 m from intake tower:- access opening into right-side compartment (2016-07-12)

Plate 22:- Outlet conduit:- right-side compartment, right wall, 66 m from intake tower:- seepage of embankment material through construction joint (2016-07-12)

Plate 23:- Outlet conduit:- right-side compartment floor, 66 m from intake tower:- upstream view of seepage of embankment material down the conduit floor (outlet pipe on left and dividing wall on right) (2016-07-12)

Plate 24:- Termite activity near left flank upper berm (2016-05-10)

APPENDIX G: MONITORING RECORDS

The monitoring records and summarised results for the Ngodwana Dam rainfall, water level, seepage, settlement and piezometer readings are attached overleaf, in both tabular and graphical form, for almost the entire record since completion of the dam wall.

The interpretation and implications of the monitoring records are more fully discussed in the body of the report.

2016 DAM LEVEL, DAM VOLUME, SEEPAGE AND RAINFALL RECORDS

			Seepage 1		Culvert East		Culvert West		Toe Drain West		Rain
Date	Dam Volume	Dam Level	Flow Depth	Flow Rate	Flow Depth	Flow Rate	Flow Depth	Flow Rate	Flow Depth	Flow Rate	
	Ml	m	mm	L/sec	mm	L/sec	mm	L/sec	mm	L/sec	mm
16/01/05	9360,00	30,690	46	0,831	2	0,000	26	0,200	2	0,000	22
16/01/12	9256,00	30,530	47	0,877	4	0,002	24	0,163	2	0,000	17
16/01/19	9152,00	30,450	47	0,877	3	0,001	24	0,163	1	0,000	15
16/01/26	9048,00	30,310	48	0,924	3	0,001	24	0,163	2	0,000	20
16/02/02	9048,00	30,260	44	0,744	4	0,002	31	0,310	2	0,000	0
16/02/09	8944,00	30,150	45	0,787	2	0,000	29	0,262	2	0,000	16
16/02/16	8840,00	30,020	45	0,787	2	0,000	30	0,285	1	0,000	10
16/02/23	8840,00	30,000	44	0,744	2	0,000	31	0,310	1	0,000	28
16/03/01	8944,00	30,120	50	1,024	2	0,000	31	0,310	2	0,000	60
16/03/08	8840,00	30,050	44	0,744	3	0,001	30	0,285	4	0,002	12
16/03/15	9360,00	30,690	44	0,744	3	0,001	30	0,285	4	0,002	70
16/03/22	9568,00	31,200	44	0,744	4	0,002	31	0,310	2	0,000	10
16/03/29	9880,00	31,450	43	0,702	1	0,000	33	0,362	1	0,000	0
16/04/05	9984,00	31,480	44	0,744	2	0,000	32	0,335	1	0,000	0
16/04/12	9984,00	31,560	43	0,702	2	0,000	33	0,362	2	0,000	7
16/04/19	10088,00	31,600	44	0,744	2	0,000	32	0,335	2	0,000	32
16/04/26	10088,00	31,650	45	0,787	4	0,002	34	0,390	4	0,002	2
16/05/03	9984,00	31,540	45	0,787	4	0,002	34	0,390	4	0,002	0
16/05/10	9880,00	31,440	44	0,744	4	0,002	32	0,335	4	0,002	0
16/05/17	9880,00	31,440	44	0,744	5	0,003	32	0,335	3	0,001	5
16/05/24	9672,00	31,180	44	0,744	3	0,001	30	0,285	4	0,002	0
16/05/31	9672,00	31,070	44	0,744	3	0,001	30	0,285	5	0,003	0
16/06/07	9568,00	30,950	40	0,586	4	0,002	31	0,310	5	0,003	0
16/06/14	9464,00	30,850	41	0,623	3	0,001	31	0,310	4	0,002	0
16/06/21	9360,00	30,710	43	0,702	4	0,002	33	0,362	4	0,002	0
16/06/28	9256,00	30,550	43	0,702	4	0,002	33	0,362	5	0,003	0
16/07/05	9189,00	30,410	43	0,702	4	0,002	33	0,362	4	0,002	0
16/07/12	9048,00	30,280	44	0,744	4	0,002	34	0,390	3	0,001	0
16/07/19	8944,00	30,150	43	0,702	4	0,002	34	0,390	3	0,001	0
16/07/26	8840,00	30,070	43	0,702	4	0,002	34	0,390	4	0,002	0
16/08/02	8736,00	29,800	43	0,702	4	0,002	32	0,335	3	0,001	0
16/08/09	8736,00	29,800	44	0,744	2	0,000	32	0,335	3	0,001	0
16/08/16	8736,00	29,800	44	0,744	2	0,000	32	0,335	3	0,001	0
16/08/23	8632,00	29,700	44	0,744	1	0,000	32	0,335	2	0,000	0
16/08/30	8528,00	29,560	44	0,744	0	0,000	32	0,335	2	0,000	0
Ave	9295,69	30,61	44,20	0,754	2,97	0,001	31,03	0,315	2,86	0,001	326

Total Seepage = 0,317 l/sec

BARNARD & SCHNEIDER
in association with
AIRBORNE
TECHNOLOGIES
sales@airbornetechnologies.co.za

Professional Land Surveyors & Town Planning Consultants
Aerial, Engineering & Topographical Surveys
Sectional Title Consultants
Tel +2711 704 0735 Email Address : sandd@global.co.za
PO Box 3438 Randburg 2125
8 Comrie Road Bryanston Extension 8 Sandton

Mr Carel van der Merwe
Sappi Kraft
Private Bag X1001
NGODWANA
1209

Date: 12th August 2016
My Ref: PRB/3989

Dear Sir,

Enclosed herewith please find the monitoring results for the crest beacons and the extended downstream face beacons as measured on 8th-10th August 2016, together with results for the wet area beacons.

The maximum vertical difference from a year ago occurs at beacon 15B which has dropped 11mm in elevation from 966.074 in 2015, to 966.063. Beacons 14A & 15 have also dropped 9mm in elevation. On the crest, most of the beacons have dropped slightly, apart from in the middle where beacons 7 & 10 are the same elevation & beacons 8, 9 & YA which are 1mm higher. In the wet area, all the beacons are slightly lower with a maximum difference of 2mm from the 2015 survey.

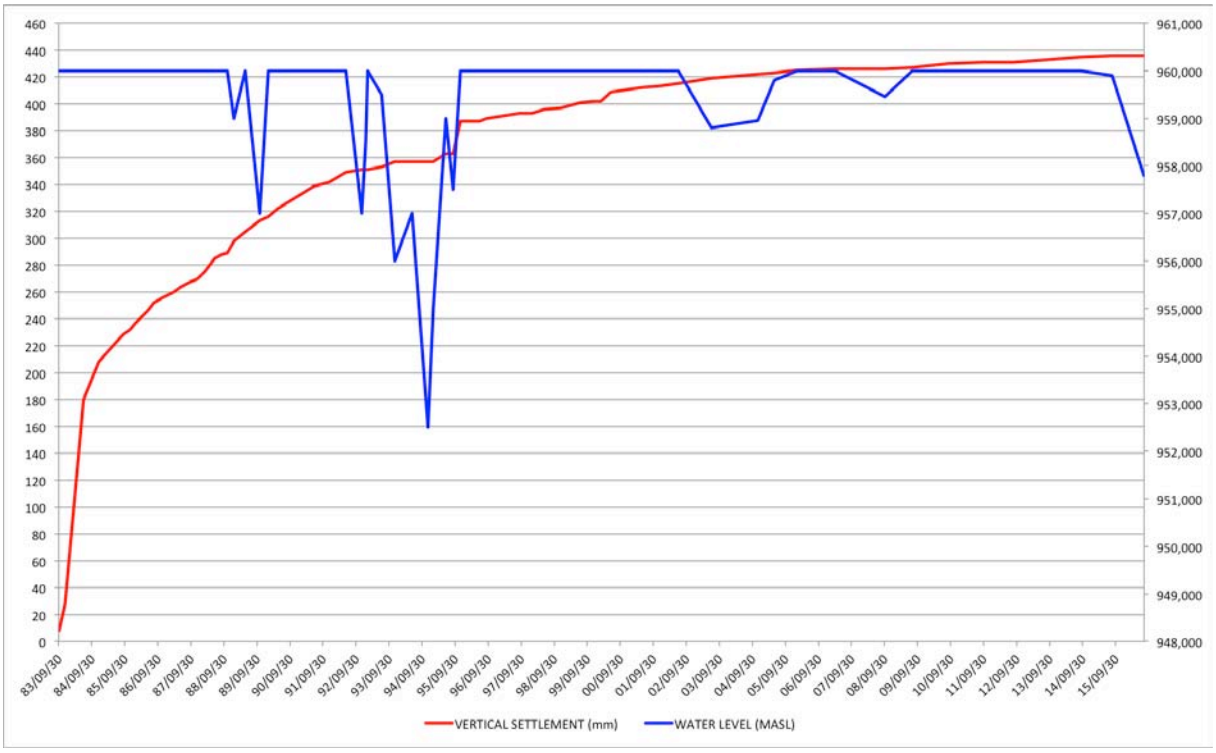
As stated in my previous report, the steel marker on beacon W4 has somehow been bent appreciably towards the west. We are now surveying the same position as we did in 2015 & all the beacons in the wet area have no significant movement. On the southern end of the dam, there is much larger movement than we are accustomed to in that beacons 13A, 14, 14A, 15, 15A & 15X have shifted between 6 & 19mm (beacon 15) to the west. This movement is also indicated in the elevations as stated in the 2nd paragraph.

The water level of the dam at the time of survey was very low.

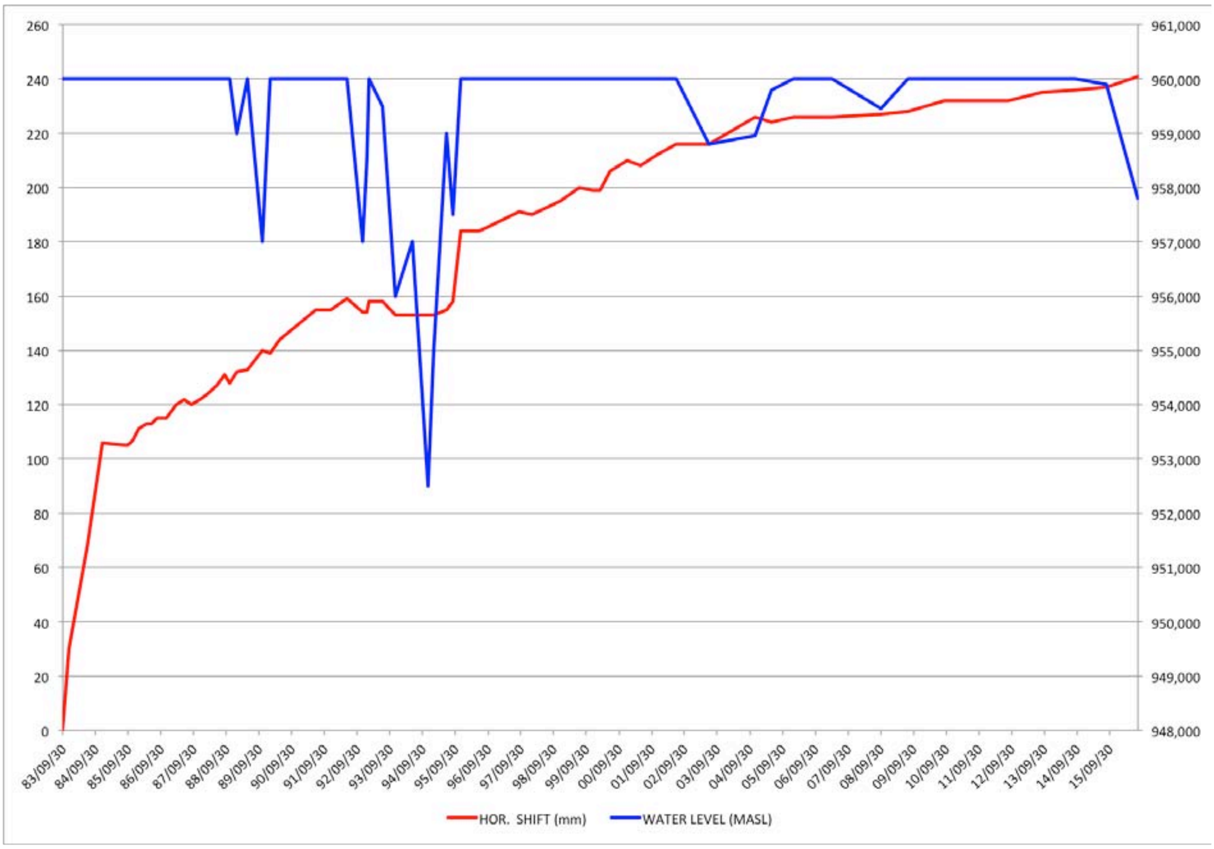
Yours faithfully,

P R Barnard
Professional Land Surveyor

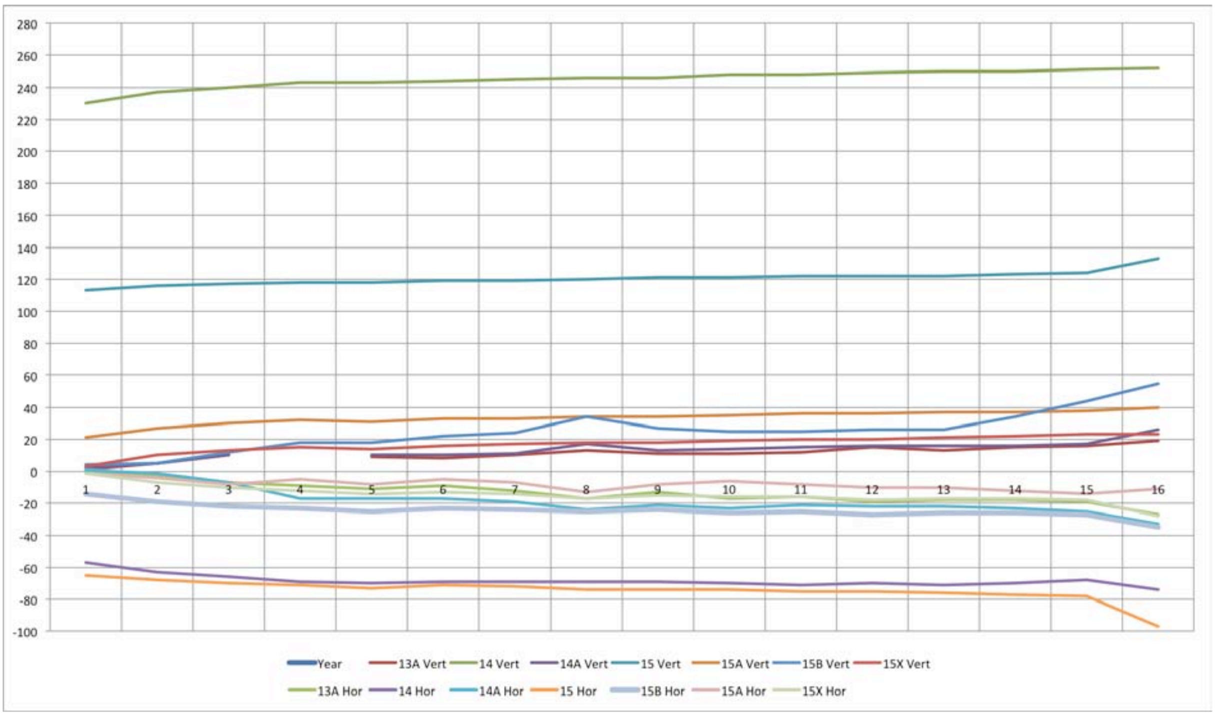
BEACON 7 VERTICAL SETTLEMENT AGAINST DAM LEVEL 1983 - 2016



BEACON 6 HORISONTAL (DOWNSTREAM) SHIFT AGAINST DAM LEVEL 1984 - 2016



DAM WALL LEFT FLANK MOVEMENTS 2001 – 2016



SAPPI-NGODWANA DAM
HYDROLOGICAL INSRTUMENTATION MONITORING

Instrument type: Stand pipe piezometer readings (meter depth)

	Date of reading									
	2005-01-05	2006/05/22	2008/07/30	2009/08/11	2010/08/17	2011/08/22	2012/08/03	2013/10/07	2016/05/06	
Piezometer No										
1	16,300	16,325	16,520	16,610	16,645	16,720	16,730	16,815	Dry	
2	24,150	24,400	24,380	24,385	24,400	24,430	24,435	24,300	Not Found	
3	18,450	18,535	18,563	18,575	18,575	18,500	18,570	18,450	No reading	
4	29,530	29,610	29,590	29,560	29,565	29,600	29,610	29,600	Not found	
5	20,755	20,675	20,850	20,910	20,965	20,965	20,980	20,950	No reading	
6	27,670	27,985	27,850	27,875	27,855	27,865	27,900	27,900	Not found	
7	18,740	18,885	19,000	19,075	19,130	19,225	19,225	19,260	No-reading	
8	17,058	17,165	17,300	17,365	17,435	17,500	17,590	17,550	No-reading	

Instrument type : Magnetic settlement (meter depth equivalent)

	Date of reading									
	2005-01-05	2006/05/22	2008/07/30	2009/08/11	2010/08/17	2011/08/22	2012/08/03	2013/10/07	2016/05/06	
Total casing length m	28,189	28,18	28,179	28,182	28,182	28,182	28,182	28,180	28,180	
Magnet number										
1	5,022	5,022	5,022	5,022	5,022	5,022	5,024	5,022	5,022	
2	9,104	9,103	9,103	9,103	9,104	9,103	9,105	9,103	9,103	
3	13,062	13,060	13,060	13,060	13,057	13,060	13,060	13,060	13,059	
4	17,049	17,045	17,044	17,042	17,042	17,042	17,044	17,041	17,041	
5	12,151	21,147	21,145	21,147	21,144	21,147	21,144	21,143	21,143	
6	24,507	24,503	24,501	24,503	24,500	24,500	24,503	24,499	24,499	

Date	Water level in settlement tubing
2012/08/03	22,960
2013/10/07	23,095
2016/05/06	0,000