GROUNDWATER RESOURCE INFORMATION PROJECT
EASTERN CAPE PROVINCE

GROUNDWATER INFORMATION SOURCE REFERENCE SHEET

SOURCE REF NR:	AR001	Own Archive		Copy attached	X
		Sourced		Copy at source	

A: SOURCE DESCRIPTION

District Municipality:

Amatole		Chris Hani		O.R Tambo	
Ukhahlamba		Cacadu	X	Alfred Nzo	

Local Municipality: **Kou-Kamma**

Institution where Information is held: **Arcus Gibb**

Branch of Institution: **Cape Town**

Contact details: Contact person: **Josh Spencer**

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B: TYPE OF INFORMATION

Information format:

Hard copy	X	Data Summary		Electronic Report	
Specify Other:					

Report / Info Title: **Krakeelrivier - Bulk Water Supply. Groundwater Investigation: Interim Hydrogeological Report**

Report Nr: **JA0230A** Date: **January_2003**

Author Details: **J. Spencer**

Author's Qualification:

Hydrogeologist	X	Govt Dept		Project Manager	
Engineer		Technician		Other	
Specify Other:					

Captured by: **Wendy Botha** Date: **16_July_2007** Signed: WB

C: GEOHYDROLOGICAL CATEGORIZATION

Project Type

Source development		Feasibility Study		Sanitation Study:	
Specify Other: Hydrogeological Report					

Reference Co-ordinate:

Latitude	Longitude
33 50' 30"	23 43' 58"

	Yes	No	Complete	Incomplete
Lithological & Construction Logs	x		x	
Hydrocensus Data		x		
Pump Testing Data	x			
Chemical Water Analysis Data	x			
Geohydrological Data	x			
Spring Data		x		
Remote Sensing Data				
Map Data	x			

Comments: Part of reports AB001 & AR002

Done for Cacadu Municipality.

Reviewed by: **Jane Baron** Date: Jul-07 Signed: JB

South Africa

Cacadu District Municipality
Province of the Eastern Cape - South Africa

Krakeelrivier – Bulk Water Supply

Groundwater Investigation: Interim Hydrogeological Report

JA0230A

January 2003

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ARCUS GIBB

Krakeelrivier – Bulk Water Supply
Groundwater Investigation: Interim Hydrogeological Report

CONTENTS

1 INTRODUCTION

The findings of a groundwater exploration project undertaken at Krakeelrivier, Eastern Cape in December 2002 are presented in this report. Borehole target positions were sited based on findings outlined in ARCUS GIBB report No. JA0230A of October 2002. Work conducted included the percussion drilling of two boreholes by RPM Drilling and pump testing by De Villiers Visser Irrigation. Furthermore, a groundwater sample was collected and analysed by Scientific Services Division, Nelson Mandela Metropolitan Municipality.

ARCUS GIBB (Pty) Ltd were contracted by the Cacadu District Municipality to supervise the drilling and pump-testing investigation with the purpose of establishing a year-round bulk water supply to service 450 households in the local community of Krakeelrivier.

2 PROJECT REVIEW

2.1 Desktop Studies and Site Visits

A preparatory desktop study including the interpretation of available geological maps, topographical maps, aerial photographs and ortho-photographs of the Krakeelrivier area was conducted in October 2002. A north-south geological cross section was constructed using the available information in order to illustrate the structural geology.

Information was gathered from the Cacadu District Municipality and the Department of Water Affairs and Forestry (DWAF) on existing boreholes established in the study area. A preliminary site visit in October 2002 served the purposes of conducting a generalised field study, assessment of existing boreholes and siting potential drilling localities. A follow-up site visit was undertaken in November 2002 where two drill targets were determined and agreed upon with the Drilling Contractor and local landowners.

2.2 Site Description and Geohydrology

The rural town of Krakeelrivier is situated approximately 230 km west of Port Elizabeth in the Eastern Cape (Figure 1). The town is located at an elevation of approximately 600 m amsl in the east-west trending Langkloof Valley, which flanks the Tsitsikamma Mountains, situated to the south of Krakeelrivier. Prominent secondary north-south orientated steep-sided 'kloofs' or juvenile valleys cross-cut the main Langkloof valley in an orthogonal arrangement at regular intervals, resulting in a distinct rectilinear drainage pattern in the local region (Figure 2).

The geology of Krakeelrivier includes Ordovician to Silurian-age quartzite, shale and feldspathic sandstone of the Table Mountain Group, and Devonian-age shale of the Bokkeveld Group, all being part of the Cape Fold Belt. Generally, sedimentary bedding in the study area is steeply inclined as a result of folding. Tensional fractures associated with the deformation of the Cape Fold Belt are present as sub-parallel sets. These fractures exhibit a distinct north-south trend with sub-vertical surfaces that intersect the Langkloof Valley syncline. The fractures show negligible displacement. Weathering and erosion accompanied by uplift and exhumation of the Cape Fold Belt has preferentially exploited the steep fracture sets, resulting in the development of secondary juvenile valleys orientated at right angles to the Langkloof Valley syncline.

Groundwater attributed to surface water infiltration in the prominent mountainous catchment area south of Krakeelrivier will migrate along east-west orientated permeable geological strata. These bedding planes are expected to feed groundwater into the steep north-south orientated fractures. The sub-vertical fracture sets in turn provide a pathway for water to migrate northwards towards Krakeelrivier, with the steeply inclined Cedarburg Formation shale acting as an aquitard to inhibit northward flow, creating a favourable trap for groundwater accumulation.

3 FINDINGS

3.1 Borehole Percussion Drilling

The drilling contract was awarded to RPM Drilling and work commenced on the 3rd of December 2002. Sites drilled included Target 1 and 2 as outlined in our memorandum of 15 November 2002, with Target 2 having been drilled first. Target 1 and 2 were sited with the intention of intersecting groundwater associated with the north-south orientated fracture trace situated towards the middle of the prominent catchment to the south of Krakeelrivier. The approximate positions of KR1 and KR2 are indicated in Figure 2. Summarised borehole data is presented in Table 1. Boehole logs are included in Appendix A.

Table 1: Summary of percussion borehole data

PARAMETER	Borehole KR1 (Target 2)	Borehole KR2 (Target 1)
Borehole depth (m)	187	176
PVC screen length (m)	188	-
Borehole diameter (mm)	203	203
Screen diameter (mm OD)	166	-
Screen diameter (mm ID)	~~156~~ 145 mm	-
Depth of water strikes (m)	14	8
	17	32
	32	-
	57	-
	111	-
Blow out yield (l/s)	2.36	0.69
Depth to static water table (m)	3.5	-

Borehole KR1 : The borehole was drilled to a depth of 187m. Water strikes were encountered at five distinct levels with the strongest flow closest to the surface at approximately 32m to 35m. No deeper strongly flowing groundwater was encountered. The well was cased with 9.5mm thick u PVC with screens around all the major water strikes. The drillers blow-out yield was estimated at 8500 l/hour. The well was thus considered suitable for testing for municipal supply.

Borehole KR2: situated approximately 300m north of Target 2 in the kloof of the Krakeel River, was drilled on the 8th of December. The borehole encountered a strong flow of groundwater at a depth 8m to 15m and the water strike was artesian for a short time. However, no further significant water strikes were encountered and the near-surface groundwater flow diminished as water was lost to the deeper formations. The well was drilled to 176m. The driller's blow-out yield was estimated to be approximately 2500 l/hour. This yield was considered insufficient to warrant casing the hole and undertaking detailed pumping tests. The borehole is not considered suitable for municipal supply. The borehole is suitable for short term irrigation and can be used for monitoring purposes.

3.2 Pump Testing

Pump testing was performed on borehole KR1. The lack of significant water strikes and a resultant low blow out yield of 0.69 litres per second indicated that borehole KR2 was not considered suitable for pump testing for municipal supply.

A step drawdown test was performed on KR1 to gauge the performance of the new borehole. In an attempt to gain information on the aquifer, two constant discharge tests were undertaken to determine the ability of the aquifer to transmit and store groundwater. De Villiers Visser Irrigation commenced pump testing on borehole KR1 on the 8th of December 2002. During the course of pump testing, a water sample was collected for laboratory analysis at Scientific Services Division, Nelson Mandela Metropolitan Municipality. A summary of the pump testing results is presented in Table 2.

Table 2: Summary of pump tests performed on borehole KR1

	Step Drawdown	Constant Discharge 1	Constant Discharge 2
Date	10-12-2002	10-12-2002	11-12-2002
Depth of borehole (m)	187	187	187
Pump inlet depth (m)	130	130	147
Available drawdown (m)	107.2	100.8	130.1
Static water level (m)	2.5	12	10
Pumping duration (mins)	5 x 60	1200	780 (pump failure)
Recovery period (mins)	108	120 (90% recovery)	Not measured

3.3 Step Drawdown on KR1

The test comprised 5 steps of 60 minutes duration. The test indicated that the driller's blow out yield was an overestimate. The results of the step tests are given in Appendix B.

The response to pumping during the constant discharge test at a flow rate 6500 l/hour indicated that this flow rate could not be maintained without excessive drawdown. The results of the step drawdown tests were thus misleading and equilibrium had not been established during the step drawdown test at this pumping rate. A lower rate of pumping of 3800 l/hour was then applied to a second constant discharge test with consistent results. The step drawdown tests results thus must be interpreted with careful reference to the constant discharge tests.

Transmissivity (T) is estimated to be approximately $8m^2$/day and Storativity (S) is estimated to be approximately 0.0003.

3.4 Constant Discharge on KR1

A constant discharge test at a pumping rate of 6500 l/hour was started but a rapid drawdown of 50m in the first hour of testing suggested that the well could not sustain this rate. It is possible that a pocket of water in the formation was emptied during the step drawdown test, thus causing the discrepancy in the two sets of pump tests. The test was continued at a lower pumping rate of 3800 l/hour for 660 minutes. During the night head losses resulted in a reduced pumping rate of 2500 l/hour. The test was terminated the following morning after 1200 minutes of continuous pumping with a drawdown of 112.8m.

Measured recovery after the first constant discharge test indicates that 90% recovery to the original static water level occurs within 2 hours.

Due to the head loss experienced it was decided to lower the pump to a depth of 147m and a second constant discharge test was undertaken at a rate of 3800 l/hr. A stable water level was achieved after 480 minutes of pumping at 140.7m. The test continued for a further 300 minutes at the same water level until sand from the formation entered the pump causing it to fail.

The cause of the pump failure may be due to a poorly formed gravel filter. The pump was positioned at a depth where a layer of fractured fine grained sandstone and siltstones occurred. It is possible that a fracture may have opened during the pumping testing and the fine fragments of rock may have migrated through the well screen where there was a gap in the gravel pack. It is not evident whether the sand migration into the pump was sudden or accumulative during the course of the pump tests.

3.5 Water Quality – Laboratory Test Results

The groundwater analytical results for sample KR1 are presented in Table 3, along with comparative results from a groundwater municipal supply borehole in the Longkloof area, at Misgund, and two surface water samples collected in Krakeelrivier. Table 3 includes the DWAF unit ranges for Class 0 to Class 3 categories from South African Water Quality Guidelines, Domestic Use. Laboratory test results are presented in Appendix C. The following parameters of sample KR1 exceed Class 0 unit ranges as outlined by DWAF;

- The pH of 5.8 is slightly acidic and thus falls into DWAF Class 1. The pH is however comparable with the surface water samples collected in Krakeelrivier, of 4.9 and 5.5 respectively. The groundwater at BH4 in Misgund is relatively neutral, with a pH of 6.9.

- The turbidity for KR1 is relatively high at 15.9 NTU, placing it into DWAF Class 3. This value for turbidity is double that of BH4 at Misgund (7.69 NTU), and far in excess of the surface water samples collected in Krakeelrivier, which show turbidity values of 0.42 and 0.71 NTU respectively. The turbidity is thought to be related to the precipitation of iron from the sample over time as the water was clear during pumping

- The Total Iron of 2.62mg/l and Manganese of 1.09mg/l both exceed guidelines for Class 3 water. BH4 at Misgund has a Total Iron concentration of 0.9mg/l and a manganese concentration of 1.26mg/l. The surface water samples in Krakeelrivier show relatively lower concentrations in Total Iron of 0.14 and 0.25mg/l respectively, although still falling into Class 2.

- Arsenic was detected in KR1, and exceeds guidelines for Class 3 water. Arsenic was also detected in BH4 at Misgund, where a value of <0.3mg/l was reported. No arsenic was reported in the surface water samples collected in Krakeelrivier.

4 OVERALL ASSESSMENT

4.1 Borehole Yield

The borehole yield of KR1 is estimated to be approximately 1l/s. It is noted that a full 72 hour discharge test has not been completed for this well. It has however been tested over a period of 33 hours and initial results suggest that the apparent yield can be sustained albeit with regular rest periods. Further trial pumping (preferably with rest periods and detailed measurement of drawdown and recovery) and regular monitoring during the initial phases of operation are thus considered to be essential to optimise the yield from this well.

4.2 Groundwater Quality

Assessment of the groundwater sample KR1 reveals:

- The pH of 5.8 is close to the target water quality range of 6.0 to 9.0 as stipulated in South African Water Quality Guidelines - Domestic Water Use. Therefore the pH does not represent a direct health hazard, as it is not an extreme value. An aesthetic consequence may be manifested in a slightly sour taste to the groundwater. To a limited extent, the slightly acid character enables the water to carry metals in solution and assessment of these parameters is included below.

- The groundwater appeared clear upon sample collection on site. The high turbidity value of 15.9 NTU reported by Scientific Services Division, Nelson Mandela Metropolitan Municipality does not therefore coincide with field observations. The elevated turbidity may therefore be attributed to potential oxidation of dissolved ferric iron into suspended iron hydroxides, subsequent to sampling on site.

- The total iron concentration of 2.62mg/l places the borehole water into Class 3. The main concern with a high iron concentration is mainly aesthetic, as iron lends water a brown discolouration and unpleasant taste. The concentration of iron detected at KR1 however falls within a range where aesthetic effects are pronounced, plumbing is negatively effected and children and sensitive individuals may encounter health problems after sustained consumption. It is therefore recommended that should KR1 be placed into production, the water should be passed through an appropriate treatment facility before reaching the intended households in Krakeelrivier.

- The manganese concentration of 1.09mg/l falls in a range where severe staining effects are expected over and above an unpleasant taste. The manganese concentration in KR1 does not pose a health risk to users. We recommend that water treatment is planned such as to reduce aesthetic impact.

- The concentration of arsenic detected is of concern. The arsenic concentration of 0.4mg/l falls in a range where possible adverse, chronic health effects are expected in sensitive users. Arsenic is not commonly encountered in groundwater from Table Mountain Group aquifers. KR1 is located in an area characterised by highly productive fruit tree plantations. The presence of arsenic could possibly be attributed to the breakdown of pesticides used for agricultural purposes, which in turn have infiltrated into the local hydrological system. However, the laboratory results have not been independently verified. Low levels of arsenic are not easy to detect accurately using conventional atomic absorption spectrometry, as used in this analysis. Thus these results are regarded as preliminary in nature and more detailed analyses of arsenic and potential organic pollutants are required in order to verify water quality and possible treatment requirements.

The parameters calcium, magnesium, sodium, potassium, chloride, sulphate, fluoride and nitrate plus nitrite all fall within ranges acceptable for ideal water quality. However, in light of the unacceptable concentration of arsenic detected, it is recommended that additional groundwater samples be collected at KR1 and the laboratory analysis be carried out at CSIR Environmentek in Stellenbosch.

5 FEASIBILITY OF GROUNDWATER SUPPLY

5.1 Potential Groundwater Yields

5.1.1 Boreholes located in the Kloof

Borehole KR 1 has a safe yield of approximately of 1 l/s. However the low transmissivity determined from the pump tests indicates that in order to sustain this yield regular rest periods would be advisable. We consider that a pumping regime of 10 hours followed by a 2 hour rest period should be used as a basis for further testing and preliminary design of the water supply system. The yield is thus estimated at 72000 l/day.

The kloof of the Krakeel River is still considered to have the best potential for high yielding wells of good quality groundwater. The best yielding well in the kloof has a yield of 14400 l/hour, and it is considered that a yield of that magnitude can be obtained with further drilling. We thus recommend that at least one further well is drilled this year and additional funding is secured to provide for additional wells in future. In order to provide for the full project requirements it may be necessary to have at least 4 boreholes in operation.

The performance of borehole KR2 indicates the difficult nature of the local groundwater aquifer. Despite encountering favourable geological conditions and shallow groundwater, no deep water-bearing fractures were encountered and the well was abandoned with the yield considered inadequate for further testing. In order to improve the success rate of drilling we recommend that geophysical traverses are run close to existing successful wells and potential drilling targets in order to identify potential water-bearing fracture zones.

5.1.2 Borehole located in the village

The existing borehole in the village is very poorly situated with respect to access and security of supply. The borehole and pumping station is situated immediately below a dam wall, with a furrow drain and marshland on all sides. It was not possible to access the site with the drilling rig to lift out the pump or the casing. It is possible to access the site with a smaller 4x4 vehicle equipped with a tripod and winch. However, it is not considered possible to pull-out the existing casing (probably heavily rusted) using lightweight equipment. The borehole rehabilitation is thus considered a specialist task beyond the scope of work of both the drilling and pump testing contractors involved in this drilling contract.

The old borehole is expected to a have a low yield and the reported poor recovery indicates that the aquifer may have been over-pumped in the past. The old borehole is situated in sandstones of the Baviaanskloof formation. In this formation we anticipate that yields will not exceed 1l/s due to relative size of the groundwater catchment area. The depth to the water table should be relatively shallow and hence a shallow well of approximately 60m depth may provide for a yield of 0.75 l/s which may be cost effective due to its proximity to the village.

Wells situated within the village will be prone to impacts on water quality. Discharge of wastewater effluent from the houses and the presence of a cemetery nearby are factors that can effect water quality in the aquifer. It is considered from our site investigation that a position for a future borehole close to the existing borehole would not meet the DWAF Minimum Standards and Guidelines for Community Water Supply and Sanitation Programme on the basis of the pollution risk.

5.2 Groundwater quality and treatment requirements

The results of chemical analyses indicate that the water is high in iron and manganese and will require treatment for domestic supply. Based on previous experience of abstraction of iron-rich groundwater from Table Mountain Group aquifers it is considered possible that both iron and maganese contents will increase significantly in response to pumping and that seasonal changes in iron content may also occur in relation to drawdown and aquifer recharge.

We have based our treatment requirements on an assumed iron content of 5mg/l and a manganese content of 1.5 mg/l. The treatment process involves aeration and settling and the use of Calcostab units to raise pH. Iron and manganese are readily precipitated during the process and removal of the limestone chips in the Calcostab will be required at least once a year depending on the volume of water treated and the iron content. The system is modular and additional units and filters can be added if the supply is increased.

5.3 Cost Implications

The results of the investigation for the provision of a Municipal groundwater supply for Krakeel Rivier have indicated that the full supply requirements cannot be met without installing further boreholes. Furthermore, water treatment will be required in order to meet an acceptable quality for domestic consumption.

The cost of drilling and testing a further two boreholes is estimated at R 260 000 (excl VAT). Details of the cost estimates are presented in Appendix D.

The costs of providing a water treatment facility to remove iron and manganese is estimated to be R 250 000 (excl VAT) for a design flow of 3.1 l/s. An expanded treatment works for the full design flow of 5.1 l/s is estimated to cost an additional R 150 000, ie total cost of approximately R 400 000 (excl VAT).

The costs given above are preliminary estimates and allow for professional fees for design documentation, drawings, reporting and travelling expenses.

From our understanding of the budget available for water supply there are insufficient funds available for project completion and full implementation by end of March 2003.

6 RECOMMENDATIONS

- The groundwater drilling programme completed in December 2002 has produced one borehole that is considered suitable for use as a production well. The yield is estimated at 1l/s, but the results of pumping tests indicates that frequent rest periods will be required in order to prevent excessive drawdowns. We consider that a pumping regime of 10 hours followed by a 2 hour rest period should be used as a basis for further testing and preliminary design of the water supply system. The yield is thus estimated at 72000 l/day.

- The results of chemical analyses indicate that the groundwater is high in iron and manganese and will require treatment for domestic supply. Based on previous experience of abstraction of iron-rich groundwater from Table Mountain Group aquifers it is considered possible that both iron and manganese contents will increase significantly in response to pumping and that seasonal changes in iron content may also occur in relation to drawdown and aquifer recharge.

- The preferred treatment method involves aeration and settling to precipitate iron and manganese. The water is then passed through crushed limestone chips in order to increase the pH which removes more of the dissolved metals before filtering.

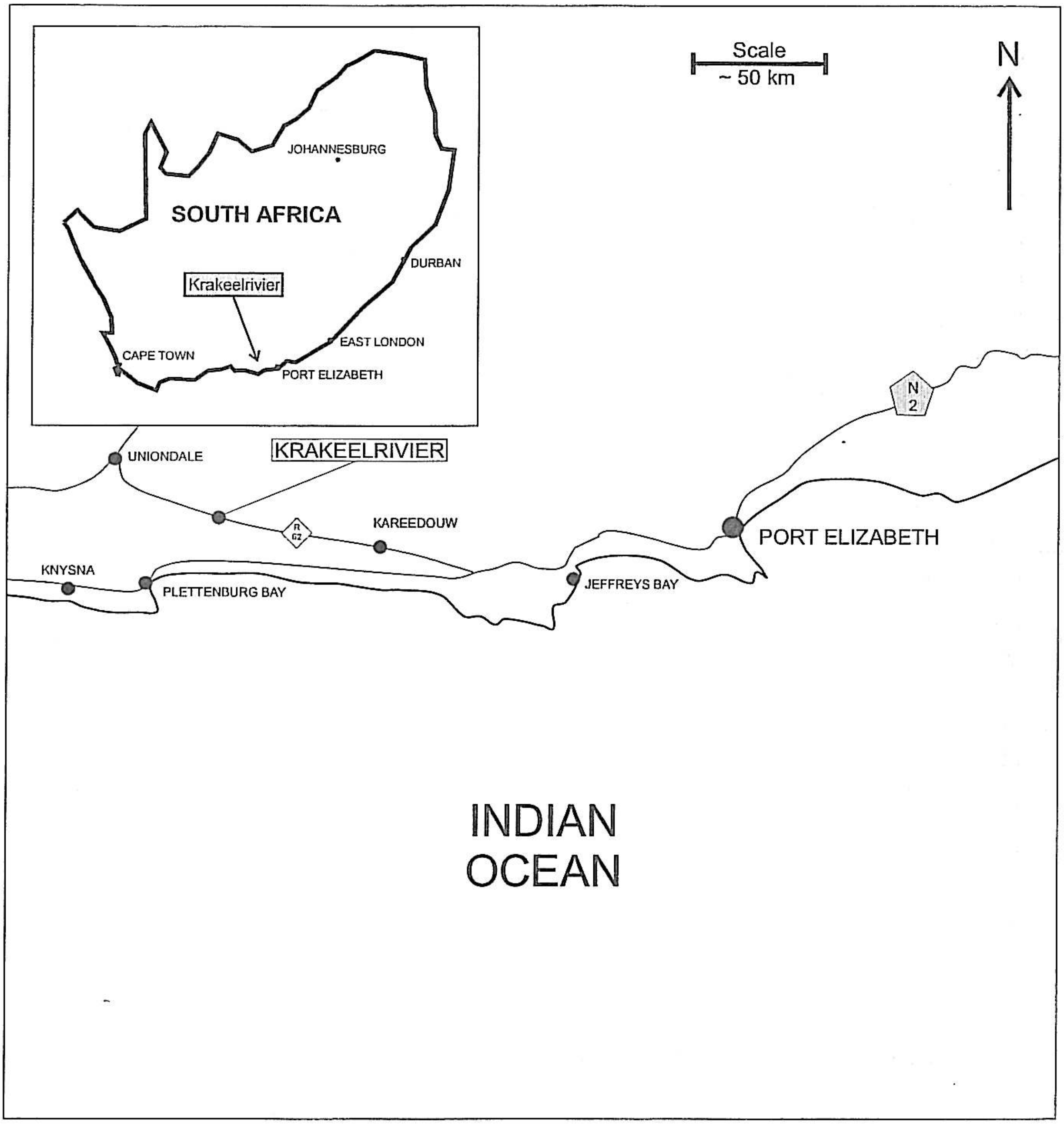
- As the yield from the borehole is only 20% of the required water supply further boreholes will be required. It is strongly recommended that detailed geophysical surveys are undertaken to improve the chances of siting successful wells.

- The results of the investigation indicate that the costs of providing a domestic supply from boreholes located in the kloof exceeds the present budgets. The additional costs for further drilling and the requirements for water treatment are estimated to be at least R 660 000.

Josh Spencer
Environmental Geologist

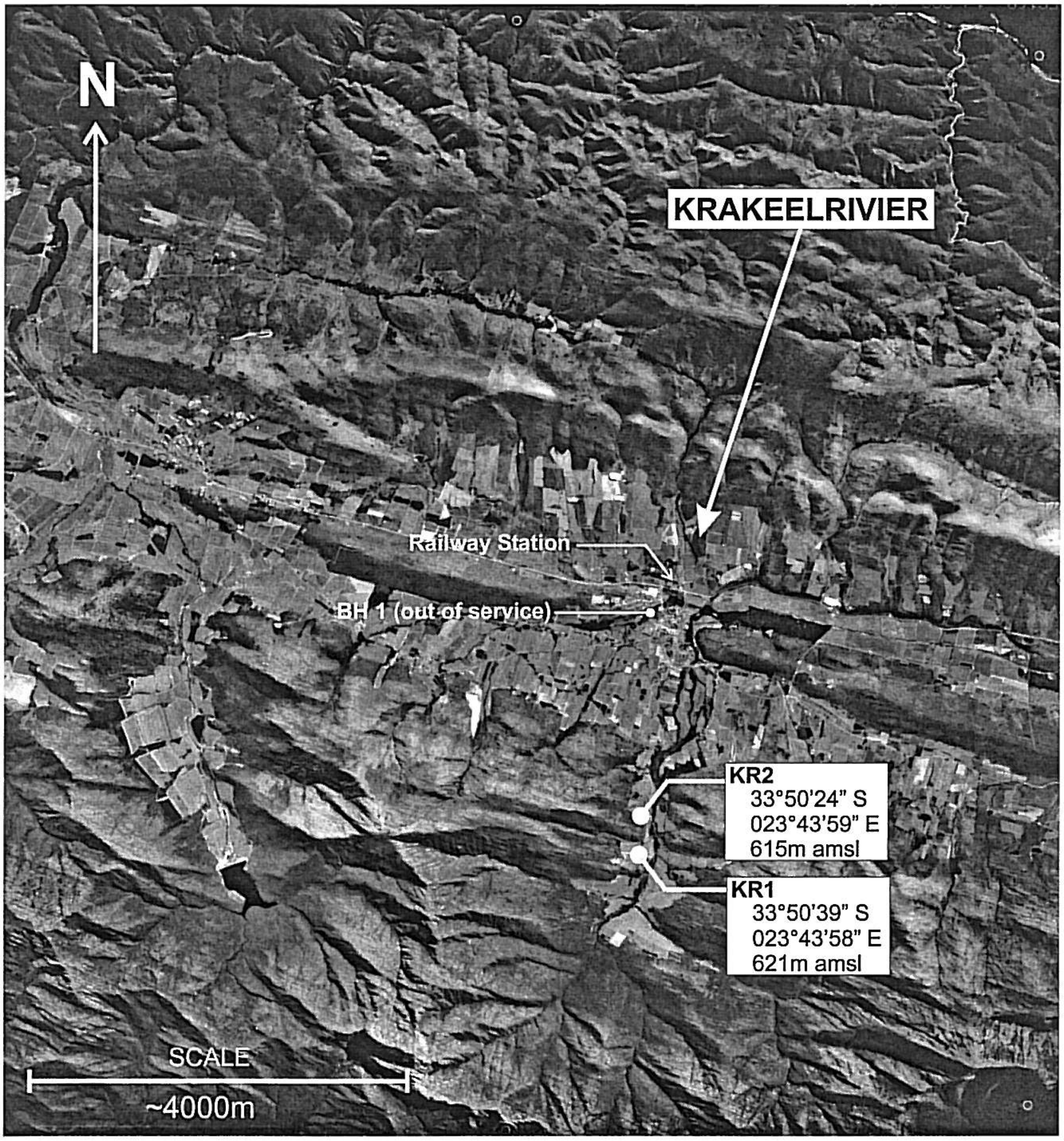
Dr Jon McStay
Director (Engineering Geologist)

FIGURES



PROJECT KRAKEELRIVIER BULK WATER SUPPLY		ARCUS GIBB
DETAIL LOCALITY MAP		
Prepared by: JS / Checked by: WSB / Reviewed by: JHM	Scale: As shown / Date: January 2003	Project No.: JA0230A / Drg.No.: Figure 1 / Rev.:

This drawing is not to be used in whole, or part, other than for the intended purpose and project as defined on this drawing



PROJECT KRAKEELRIVIER BULK WATER SUPPLY	ARCUS GIBB
DETAIL AIR PHOTO SHOWING POSITIONS OF BOREHOLES KR1 AND KR2, DRILLED IN DECEMBER 2002	

Prepared by	Checked by	Reviewed by	Scale	Date	Project No.	Drg.No.	Rev.
JS	WSB	JHM	As shown	January 2003	JA0230A	Figure 2	

APPENDIX A

PERCUSSION BOREHOLE LOGS

ARCUS GIBB	PERCUSSION BOREHOLE LOG	BOREHOLE NO: BH KR1 SHEET: 1 of 2
PROJECT: Krakeelrivier Bulk Water Supply	**PROJECT NO:** JA0230A	**LOCATION:** Krakeelrivier
CLIENT: Cacadu District Municipality	**DATE LOGGED:** 4 to 7/12/02	**LOGGED BY:** J McStay

HOLE & CASING DIAMETER	WATER TABLE	DEPTH (m)	LEGEND	DESCRIPTION
Bentonite to 5m depth; 203 mm Ø steel casing to 6m depth				Pale brown gravelly sand - COLLUVIUM
				Pale orange, slightly gravelly sand - COLLUVIUM
168 mm OD PVC riser to 11m depth				Buff, medium grained quartz sand - weathered SANDSTONE
		10		White, fine grained highly weathered QUARTZITE
168 mm OD slotted PVC to 57m depth	Water strike 14m			
	Water strike 17m			Pale orange, medium grained quartz SANDSTONE, dark red iron staining
203 mm Ø hole		20		White, stained dark pink foliated fine grained QUARTZITE
				White, coarse grained crystalline QUARTZITE with vein quartz
		30		White, stained pink medium grained crystalline QUARTZITE
				Soft weathered QUARTZITE
	Water strike 36m			Fragments of coarse quartzite in weathered QUARTZITE - FRACTURE ZONE
		40		Yellow brown, slightly weathered quartz SANDSTONE
		50		
168 mm OD PVC riser to 111m depth	Water strike 57m			Fractured, white stained yellow crystalline QUARTZITE
		60		Pale grey, massive medium grained very hard QUARTZITE
		70		Grey stained dark pink and yellow QUARTZITE
Gravel pack				
		80		Pale grey yellow stained, fresh medium grained crystalline QUARTZITE
		90		
				Pale grey stained yellow coarse crystalline QUARTZITE
... See next page...		100		

CONTRACTOR: RPM Lugdrukbore Drilling	HAMMER TYPE:	DATE DRILLED: 4 to 7 December 2002
OPERATOR: G Goosen	COMPRESSOR:	COLLAR ELEVATION:
	CAPACITY:	X CO-ORD:
RIG TYPE:	PRESSURE:	Y CO-ORD:

REMARKS:

ARCUS GIBB

PERCUSSION BOREHOLE LOG

BOREHOLE NO: BH KR1

PROJECT: Krakeelrivier Bulk Water Supply

PROJECT NO: JA0230A

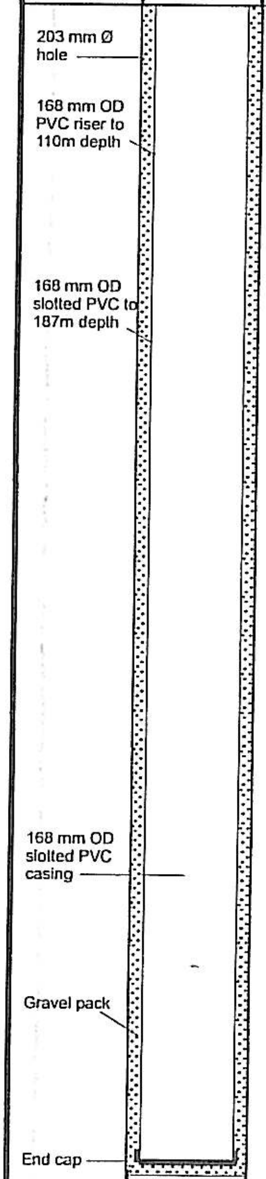
LOCATION: Krakeelrivier

CLIENT: Cacadu District Municipality

DATE LOGGED: 4 to 7/12/02

LOGGED BY: J McStay

HOLE & CASING DIAMETER	WATER TABLE		DEPTH (m)	LEGEND	DESCRIPTION
					Pale grey stained yellow coarse crystalline QUARTZITE
	Water strike	111m	110		
			120		Pink stained QUARTZITE
					Fine grained dark red brown SILTSTONE and fine grained grey QUARTZITE
					Medium grained yellow stained QUARTZITE
			130		Well rounded yellow QUARTZITE
			140		Pink stained SILTSTONE
					Yellow stained QUARTZITE
			150		White, coarse crystalline QUARTZITE
			160		
			170		
			180		Yellow stained QUARTZITE
					EOH = 187m
			190		
			200		



CONTRACTOR: RPM Lugdrukbore Drilling

OPERATOR: G Goosen

RIG TYPE:

HAMMER TYPE:

COMPRESSOR:

CAPACITY:

PRESSURE:

DATE DRILLED: 4 to 7 December 2002

COLLAR ELEVATION:

X CO-ORD:

Y CO-ORD:

REMARKS:

ARCUS GIBB

PERCUSSION BOREHOLE LOG

BOREHOLE NO: BH KR2

PROJECT: Krakeelrivier Bulk Water Supply

PROJECT NO: JA0230A

LOCATION: Krakeelrivier

CLIENT: Cacadu District Municipality

DATE LOGGED: 9 to 11/12/02

LOGGED BY: J McStay

HOLE & CASING DIAMETER		WATER TABLE		DEPTH (m)	LEGEND	DESCRIPTION
Bentonite to 5m depth	203 mm Ø steel casing to 6m depth					Grey silty fine SAND with quartzite gravel, pale yellow stained QUARTZITE, dark grey brown sandy GRAVEL and weathered QUARTZITE
						Grey stained pale brown fine gravel QUARTZITE
		Water strike	8m	10		Fractured QUARTZITE, stained dark brown along fractures
203 mm Ø hole				20		
						White glassy hard QUARTZITE
Note: no PVC casing installed		Water strike	32m	30		
				40		
				50		Grey glassy hard QUARTZITE
				60		
				70		
				80		
				90		
	... See next page...			100		

CONTRACTOR: RPM Lugdrukbore Drilling

OPERATOR: G Goosen

RIG TYPE:

HAMMER TYPE:

COMPRESSOR:

CAPACITY:

PRESSURE:

DATE DRILLED: 9 to 11 December 2002

COLLAR ELEVATION:

X CO-ORD:

Y CO-ORD:

REMARKS:

ARCUS GIBB	PERCUSSION BOREHOLE LOG	BOREHOLE NO: BH KR2 SHEET: 2 of 2
PROJECT: Krakeelrivier Bulk Water Supply **CLIENT:** Cacadu District Municipality	**PROJECT NO:** JA0230A **DATE LOGGED:** 4 to 7/12/02	**LOCATION:** Krakeelrivier **LOGGED BY:** J McStay

HOLE & CASING DIAMETER		WATER TABLE		DEPTH (m)	LEGEND	DESCRIPTION
203 mm Ø hole						Very fine quartz SAND?, Glassy hard QUARTZITE with red brown staining
				110		
						Grey, very hard glassy QUARTZITE with chip size 20mm
				120		Chip size very fine
Note: no PVC casing installed				130		Chip size 10mm
				140		Very fine chip size
				150		
				160		
						Dark grey QUARTZITE
				170		
				180		**EOH = 177m**
				190		
				200		

CONTRACTOR: RPM Lugdrukbore Drilling OPERATOR: G Goosen RIG TYPE:	HAMMER TYPE: COMPRESSOR: CAPACITY: PRESSURE:	DATE DRILLED: 4 to 7 December 2002 COLLAR ELEVATION: X CO-ORD: Y CO-ORD:

REMARKS:

APPENDIX B

PUMPING TEST DATA

WELL ID: Krakeelrivier KR1

INPUT

Construction:	
Casing dia. (d_c)	156 mm
Annulus dia. (d_w)	203 mm
Screen Length (L)	177 Meter
Depths to:	
water level (DTW)	3.5 Meter
Top of Aquifer	0 Meter
Base of Aquifer	180 Meter
Annular Fill:	
across screen --	Gravel
above screen --	Bentonite
Aquifer Material --	Fractured Igneous and
ASSUMED S =	d'less

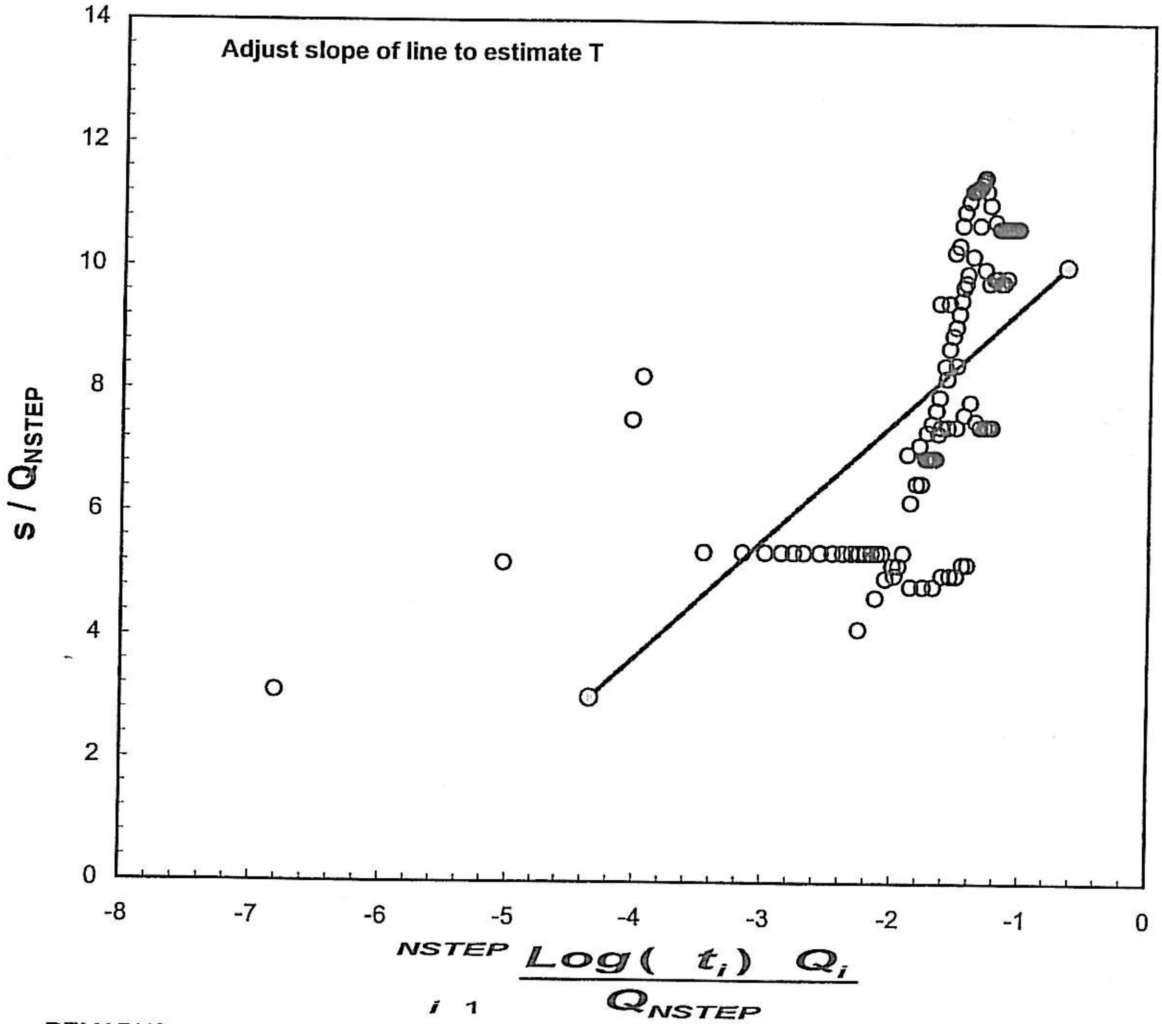
Local ID: KR1
Date: 10-12-2002
Time: 13:35

COMPUTED

Aquifer thickness = 200 Meter

Input is consistent.

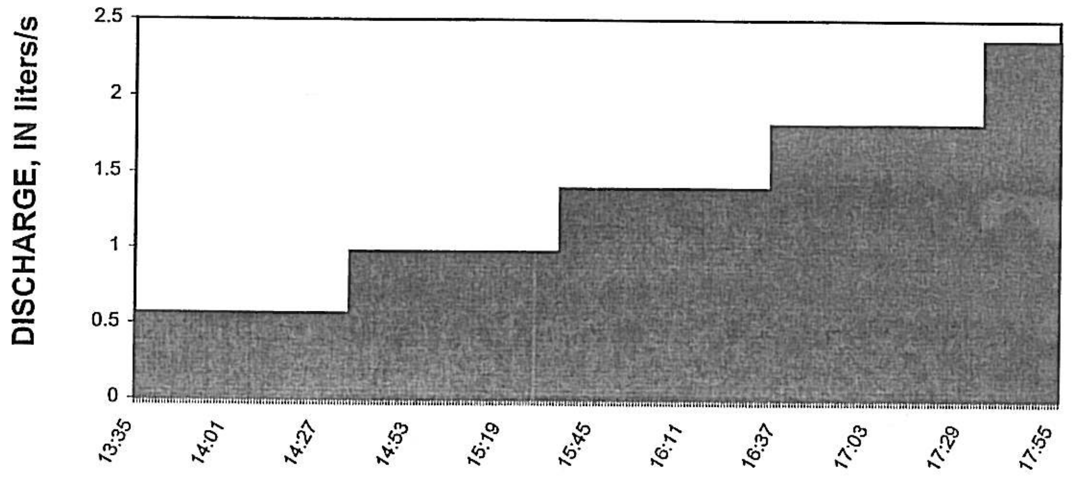
K =	0.05 Meter/Day
T =	8 Meter2/Day
S =	0.0003 d'less
$K_{annular}$ =	0.6 Meter/Day
Skin =	-0.2 d'less

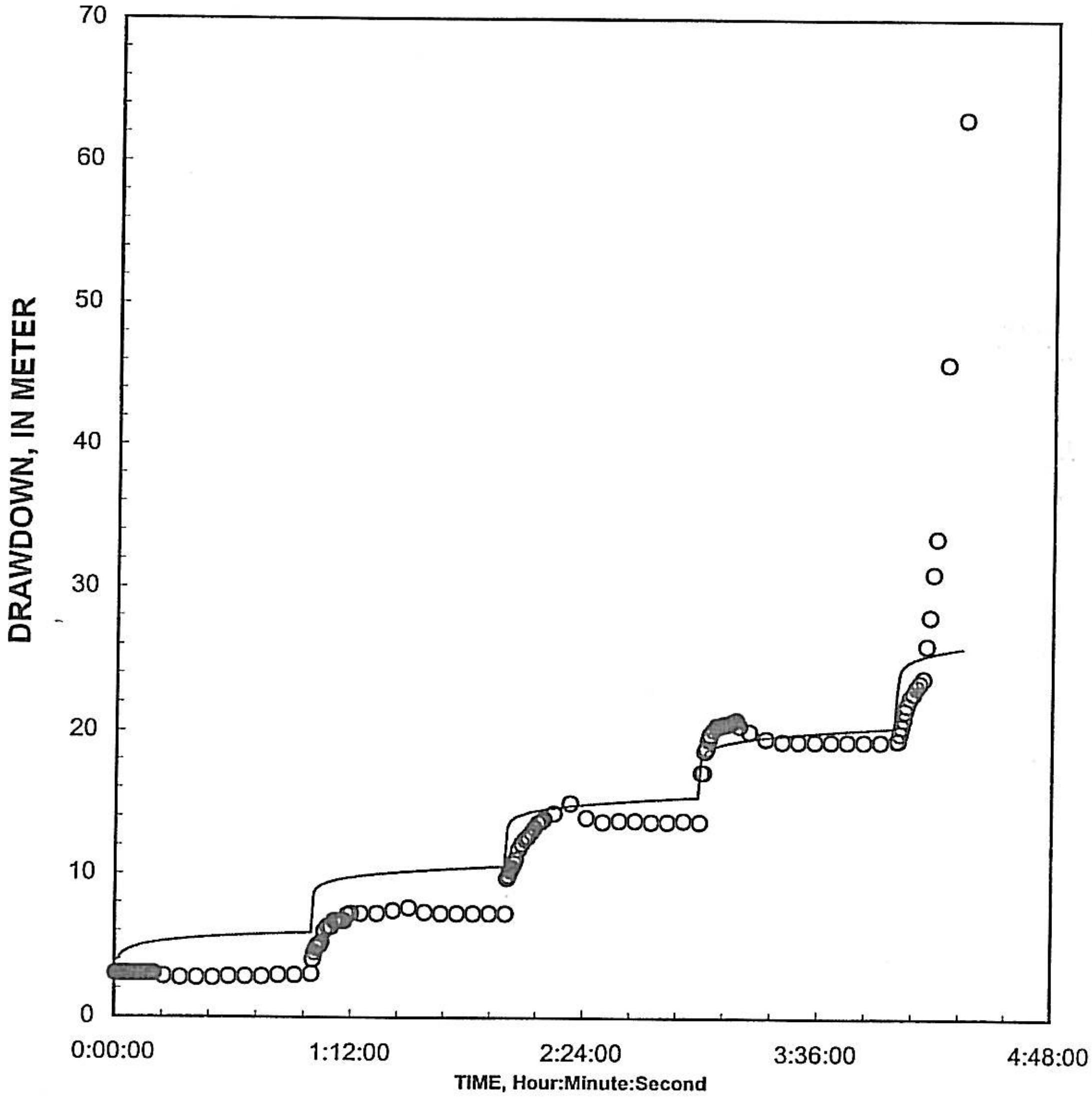


REMARKS: Step-drawdown analysis of single-well aquifer test

Test from South Vekol Valley, AZ WSP 2453
KANNULAR is estimated by fitting simulated drawdowns to measured drawdowns in a secondary plot. A reasonable storage value must be assigned by the user because storage and KANNULAR cannot be estimated independently. The estimate of T is not affected by changes in estimates of storage and KANNULAR.

WELL ID: Krakeelrivier KR1





Reduced Data

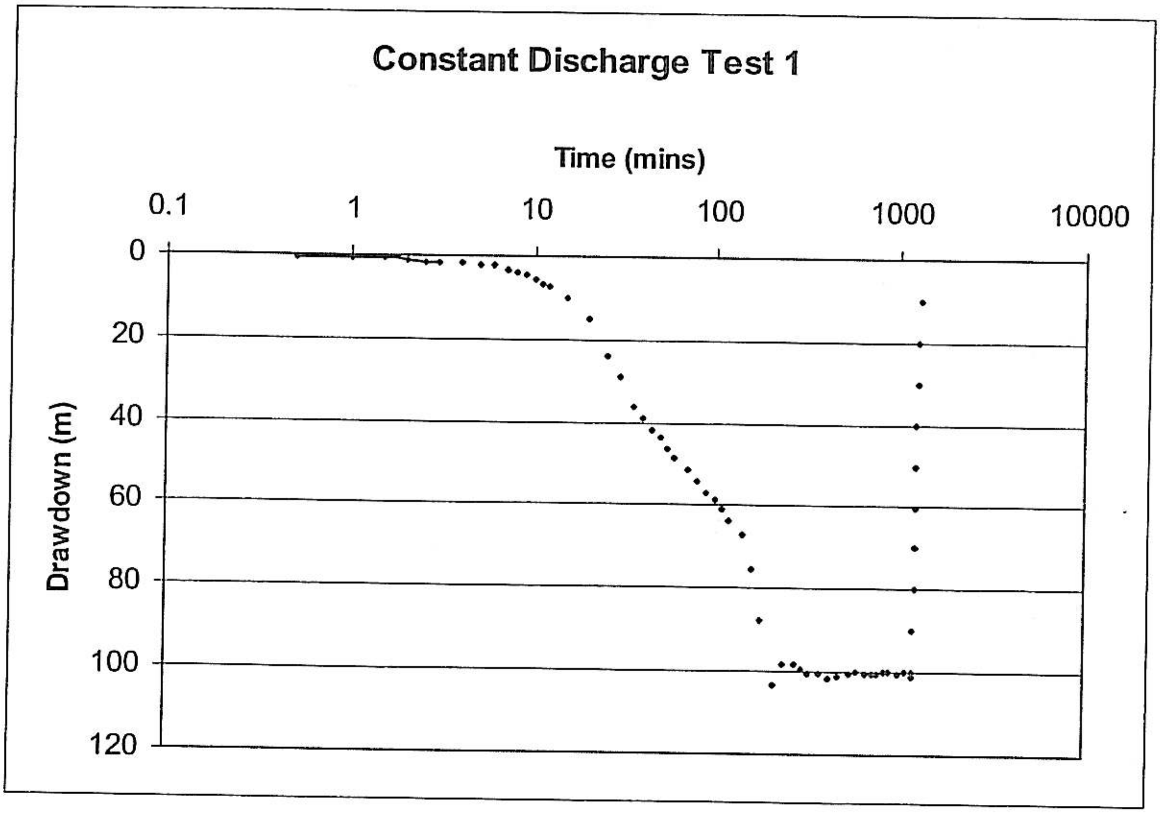
Entry	Time, Hr:Min:Sec	Water Level Meter	Entry	Time, Hr:Min:Sec	Water Level Meter
1	13:35:00	0.00	51	14:00:00	2.70
2	13:35:30	3.00	52	14:00:00	0.00
3	13:36:00	3.00	53	14:00:00	0.00
4	13:36:30	3.00	54	14:00:00	0.00
5	13:37:00	3.00	55	14:00:00	0.00
6	13:37:30	3.00	56	14:00:00	0.00
7	13:38:00	3.00	57	14:00:00	0.00
8	13:38:00	0.00	58	14:00:00	0.00
9	13:39:00	3.00	59	14:00:00	0.00
10	13:39:00	0.00	60	14:00:00	0.00
11	13:40:00	3.00	61	14:05:00	2.70
12	13:40:00	0.00	62	14:05:00	0.00
13	13:41:00	3.00	63	14:05:00	0.00
14	13:41:00	0.00	64	14:05:00	0.00
15	13:42:00	3.00	65	14:05:00	0.00
16	13:42:00	0.00	66	14:05:00	0.00
17	13:43:00	3.00	67	14:05:00	0.00
18	13:43:00	0.00	68	14:05:00	0.00
19	13:44:00	3.00	69	14:05:00	0.00
20	13:44:00	0.00	70	14:05:00	0.00
21	13:45:00	3.00	71	14:10:00	2.80
22	13:45:00	0.00	72	14:10:00	0.00
23	13:46:00	3.00	73	14:10:00	0.00
24	13:46:00	0.00	74	14:10:00	0.00
25	13:47:00	3.00	75	14:10:00	0.00
26	13:47:00	0.00	76	14:10:00	0.00
27	13:47:00	0.00	77	14:10:00	0.00
28	13:47:00	0.00	78	14:10:00	0.00
29	13:47:00	0.00	79	14:10:00	0.00
30	13:47:00	0.00	80	14:10:00	0.00
31	13:50:00	2.80	81	14:15:00	2.80
32	13:50:00	0.00	82	14:15:00	0.00
33	13:50:00	0.00	83	14:15:00	0.00
34	13:50:00	0.00	84	14:15:00	0.00
35	13:50:00	0.00	85	14:15:00	0.00
36	13:50:00	0.00	86	14:15:00	0.00
37	13:50:00	0.00	87	14:15:00	0.00
38	13:50:00	0.00	88	14:15:00	0.00
39	13:50:00	0.00	89	14:15:00	0.00
40	13:50:00	0.00	90	14:15:00	0.00
41	13:55:00	2.70	91	14:20:00	2.80
42	13:55:00	0.00	92	14:20:00	0.00
43	13:55:00	0.00	93	14:20:00	0.00
44	13:55:00	0.00	94	14:20:00	0.00
45	13:55:00	0.00	95	14:20:00	0.00
46	13:55:00	0.00	96	14:20:00	0.00
47	13:55:00	0.00	97	14:20:00	0.00
48	13:55:00	0.00	98	14:20:00	0.00
49	13:55:00	0.00	99	14:20:00	0.00
50	13:55:00	0.00	100	14:20:00	0.00

Borehole KR1
Date: 10/12/2002
Contractor: De Villiers Visser Besproeiing

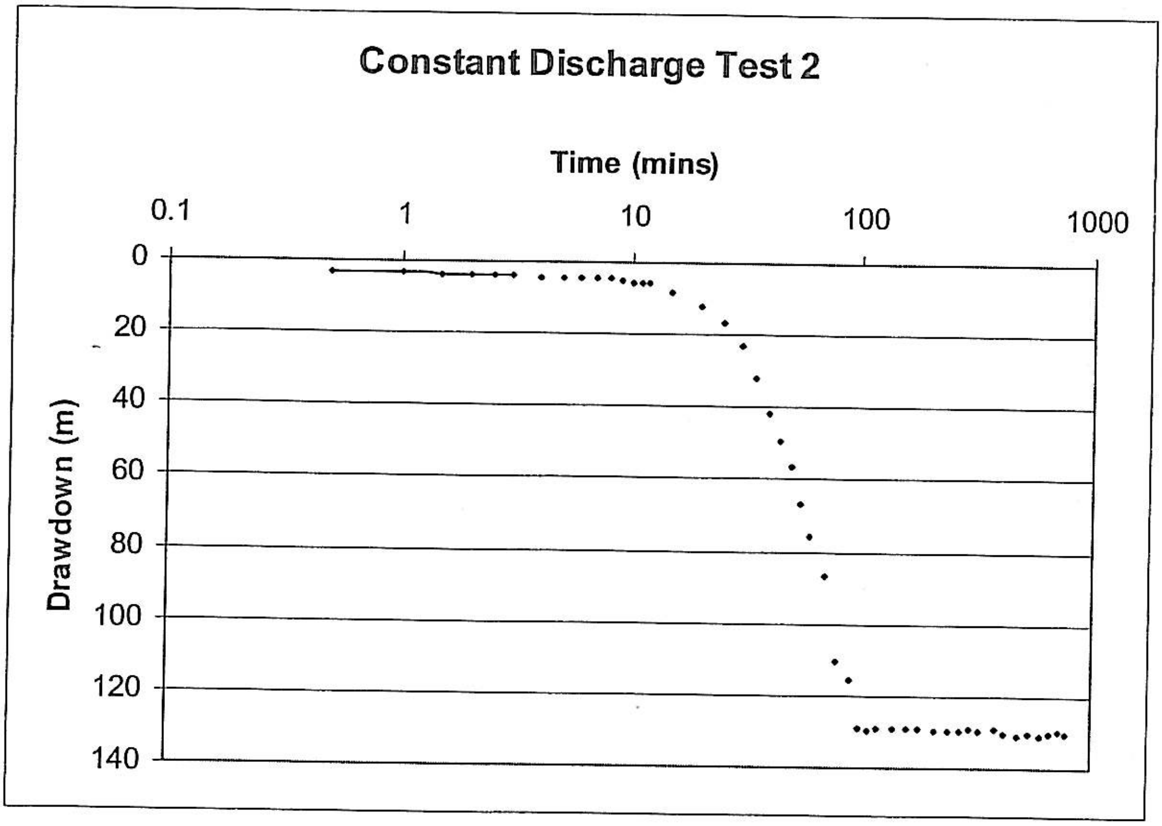
Project: Krakeelrivier Bulk Water Supply
Borehole depth: 187m
Static water level: 3.5m
Pump inlet depth: 130m

Corrected Step Drawdown for KR1

Time (mins)	Step 1	Step 2	Step 3	Step 4	Step 5
0	0.0	3.0	7.2	13.6	19.4
0.5	3.0	4.0	9.7	17.1	19.4
1	3.0	4.5	9.9	17.1	19.9
1.5	3.0	4.8	10.2	18.6	20.4
2	3.0	5.0	10.4	18.8	20.9
2.5	3.0	5.0	10.7	19.4	21.5
3	3.0	5.2	11.0	19.8	21.9
4	3.0	6.0	11.7	20.1	22.4
5	3.0	6.3	12.1	20.4	22.7
6	3.0	6.3	12.4	20.4	23.1
7	3.0	6.7	12.6	20.5	23.4
8	3.0	6.7	12.9	20.5	23.7
9	3.0	6.7	13.2	20.6	26.0
10	3.0	6.7	13.5	20.7	28.0
11	3.0	7.1	13.6	20.8	31.0
12	3.0	7.2	13.8	20.4	33.5
15	2.8	7.2	14.2	20.0	45.8
20	2.7	7.2	14.9	19.5	63.0
25	2.7	7.4	13.9	19.3	76.7
30	2.7	7.6	13.6	19.3	83.7
35	2.8	7.3	13.7	19.3	92.0
40	2.8	7.2	13.7	19.3	96.7
45	2.8	7.2	13.6	19.3	100.2
50	2.9	7.2	13.6	19.3	103.4
55	2.9	7.2	13.7	19.4	105.5
60	3.0	7.2	13.6	19.4	107.2
	Q = 0.56L/s	**Q = 0.97L/s**	**Q = 1.39L/s**	**Q = 1.81L/s**	**Q = 2.36L/s**



Constant Discharge Test 1
Time (mins)
0.1
1
10
100
1000
10000
Drawdown (m)
0
20
40
60
80
100
120



Constant Discharge Test 2
Time (mins)
0.1
1
10
100
1000
Drawdown (m)
0
20
40
60
80
100
120
140

Borehole KR1
Date: 10/12/2002
Contractor: De Villiers Visser Besproeiing

Project: Krakeelrivier Bulk Water Supply
Borehole depth: 187m
Static water level: 3.5m
Pump inlet depth: 130m

Constant Discharge on KR1 - Test 1

Time (min)	Drawdown (m)	Pump rate (L/s)
0	0.0	1.81
0.5	0.3	
1	0.3	
1.5	0.8	
2	1.0	
2.5	1.5	
3	1.7	
4	1.9	
5	2.3	
6	2.5	
7	3.2	
8	4.0	
9	4.6	
10	5.7	
11	6.8	1.72
12	7.5	
15	10.0	
20	14.9	1.61
25	23.9	
30	29.9	
35	36.0	1.42
40	39.0	
45	42.0	
50	43.8	
55	46.5	1.33
60	48.4	1.25
70	51.5	

Constant Discharge on KR1 - Test 1 continued

Time (min)	Drawdown (m)	Pump rate (L/s)
80	54.3	
90	57.0	
100	58.5	
110	60.9	
120	63.5	
140	67.0	
160	75.3	
180	87.8	
210	103.0	
240	98.0	1.06
270	98.5	
300	99.5	0.89
330	100.5	
380	100.5	
420	101.6	
480	100.8	
540	100.4	
600	100.0	
660	100.2	
720	100.4	0.69
780	100.4	
840	100.0	
900	100.0	
1000	100.4	
1100	100.0	
1200	100.8	

Recovery on KR1

Time (min)	Water level (m)
0	112
3	100
5	90
8	80
11	70
15	60
18	50
22	40
47	30
61	20
102	10

Borehole KR1
Date: 11/12/2002
Contractor: De Villiers Visser Besproeiing

Project: Krakeelrivier Bulk Water Supply
Borehole depth: 187m
Static water level: 3.5m
Pump inlet depth: 147m

Constant Discharge on KR1 - Test 2

Time (min)	Drawdown (m)	Pump rate (L/s)
0	0.0	1.25
0.5	3.4	
1	3.4	
1.5	3.6	
2	3.7	
2.5	4.0	
3	4.1	
4	4.2	
5	4.2	
6	4.2	
7	4.4	
8	4.7	
9	5.4	
10	5.6	
11	5.8	
12	6.0	
15	8.2	
20	12.0	
25	16.7	
30	22.8	
35	32.3	
40	42.0	
45	49.6	
50	56.7	
55	66.5	
60	75.7	
70	86.4	

Time (min)	Drawdown (m)	Pump rate (L/s)
80	110.3	
90	115.7	1.06
100	129.2	0.89
110	129.7	0.86
120	128.9	1.08
140	129.0	1.06
160	129.4	
180	129.0	
210	129.6	
240	129.7	
270	129.7	
300	129.2	
330	129.6	
380	129.0	
420	130.6	
480	130.7	
540	130.5	
600	130.7	
660	130.4	
720	129.8	
780	130.1	Pump failure

APPENDIX C

CHEMICAL ANALYSES

Pronoti Fax Pad Ref.138.	PAGE / OF /
TO: [redacted]	FROM: LINSLEY PUDNEY
CO: ARCUS GIBB	CO: ARCUS GIBB
DATE: 6/01/2003	PHONE NO: 041-5821650
FAX NO: 021-4245571	FAX NO: 041-5821693

Nelson Mandela Metropolitan Municipality
(PORT ELIZABETH)
OFFICE OF THE CITY ENGINEER
SCIENTIFIC SERVICES DIVISION

CERTIFICATE OF ANALYSIS

CERTIFICATE NO	PARTICULARS OF SAMPLES	Borehole Water ex Krakeelrivier	DATE RECEIVED 11/12/02
P 3789	SUBMITTED BY:	Linsley Pudney Arcus Gibb, P. O. Box 1798, Port Elizabeth. 6000. Fax No: 041-582-1693	DATE OF REPORT 18/12/02

ALL SAMPLES WERE ANALYSED ACCORDING TO APPROVED "STANDARD METHODS"

CHEMICAL RESULTS IN MILLIGRAMS PER LITRE (unless otherwise stated)

Laboratory Number	2789				
Sample Identification	Target KR 1				
pH	5.8				
CONDUCTIVITY at 25°C (mS/m)	15.8				
APPARENT COLOUR (Pt-Co units)	112				
TURBIDITY (NTU)	15.9				
TOTAL DISSOLVED SOLIDS at 180°C	98				
TOTAL ALKALINITY as $CaCO_3$	12				
CARBONATE ALKALINITY as $CaCO_3$	0				
BICARBONATE ALKALINITY as $CaCO_3$	12				
CARBONATE HARDNESS as $CaCO_3$	12				
NON CARBONATE HARDNESS as $CaCO_3$	5				
TOTAL HARDNESS as $CaCO_3$	17				
CALCIUM as $CaCO_3$	5				
MAGNESIUM as $CaCO_3$	12				
SODIUM as Na	8				
POTASSIUM as K	0.6				
CHLORIDE as Cl	16				
SULPHATE as SO_4	4.8				
FLUORIDE as F	0.4				
NITRATE plus NITRITE as N	1.9				
IRON (TOTAL) as Fe	2.62				
MANGANESE (TOTAL) as Mn	1.09				
ARSENIC as As (µg/l)	0.4				
CADMIUM as Cd	< 0.001				
ZINC as Zn	1.38				

COMMENTS :

This report relates only to sample/s supplied to the SCIENTIFIC SERVICES DIVISION and does not relate to similar samples. This report may not be reproduced, except in full, without the written approval of the Chief Scientific Officer. Although SCIENTIFIC SERVICES will endeavour to perform analyses correctly, neither SCIENTIFIC SERVICES nor its members shall be liable for loss or damage attributed directly or indirectly to the inaccuracy of analyses or their interpretation. Results not queried within 10 working days of the issuing of the report will result in the disposal of the original samples, unless SCIENTIFIC SERVICES DIVISION are advised to the contrary.

CHIEF SCIENTIFIC OFFICER .... (PAGE 1 OF 1)

RECEIVED

2003 -01- 06

Fronoti Fax Pad Ref.138.	PAGE: 1 OF 1
TO: [redacted]	FROM: L. Pudney
CO:	CO:
DATE: 10/1/2003	PHONE NO:
FAX NO. 021/4245571	FAX NO:

Nelson Mandela Metropolitan Municipality

(PORT ELIZABETH)
OFFICE OF THE CITY ENGINEER
SCIENTIFIC SERVICES DIVISION

CERTIFICATE OF ANALYSIS

CERTIFICATE NO.:	PARTICULARS OF SAMPLES:	Krakeelriver Water Sample	DATE RECEIVED 13-02-01
P 6184	SUBMITTED BY.	Mr L. Pudney Gibb Africa (Pty) Ltd., P. O. Box 1798, Port Elizabeth. 6000. Fax No: 582-1693	DATE OF REPORT 01-03-01

ALL SAMPLES WERE ANALYSED ACCORDING TO APPROVED "STANDARD METHODS"

CHEMICAL RESULTS IN MILLIGRAMS PER LITRE (unless otherwise stated)

Laboratory Number	6184	6185	SABS *	SABS*	SABS *
Sample Identification	At Upper Weir	Furrow MH in Village	Ideal Limit	Acceptable Limit	Max Allowable Limit
pH	4.9	5.5	6.0-9.0	5.0-9.5	4.0-10.0
CONDUCTIVITY at 25°C (mS/m)	5.6	7.5	70.0	150	370
TRUE COLOUR (Pt-Co units)	161	74	15	20	50
TURBIDITY (N.T.U.)	0.42	0.71	0.10	1.00	10.0
TOTAL DISSOLVED SOLIDS at 180°C	46	54	450	1000	2400
TOTAL ALKALINITY as $CaCO_3$	0	1	N/S	N/S	N/S
CARBONATE ALKALINITY as $CaCO_3$	0	0	N/S	N/S	N/S
BICARBONATE ALKALINITY as $CaCO_3$	0	1	N/S	N/S	N/S
CARBONATE HARDNESS as $CaCO_3$	0	1	N/S	N/S	N/S
NON-CARBONATE HARDNESS as $CaCO_3$	10	17	N/S	N/S	N/S
TOTAL HARDNESS as $CaCO_3$	10	18	N/S	N/S	N/S
CALCIUM as $CaCO_3$	6	8	N/S	N/S	N/S
MAGNESIUM as $CaCO_3$	4	10	N/S	N/S	N/S
SODIUM as Na	8	9	100	200	400
POTASSIUM as K	0.8	0.6	25	50	100
CHLORIDE as Cl	13	18	100	200	600
SULPHATE as SO_4	2.7	3.1	200	400	600
FLUORIDE as F	<0.1	0.1	0.7	1.0	1.5
NITRATE plus NITRITE as N	<0.1	0.3	6.0	10	20
IRON (TOTAL) as Fe	0.14	0.25	0.01	0.20	2.00
MANGANESE (TOTAL) as Mn	0.005	0.025	0.050	0.100	1.00

COMMENTS : *SABS 241-1999 Specification: Drinking Water (N/S = None Specified)

CHIEF SCIENTIFIC OFFICER : .... (PAGE 1 OF 1).

APPENDIX D

PRELIMINARY COST ESTIMATES: WATER TREATMENT

ARCUS GIBB

CONSULTING ENGINEERS

CIVIL STRUCTURAL ELECTRICAL MECHANICAL AGRICULTURAL ENVIRONMENTAL GEOTECHNICAL PROJECT MANAGEMENT

14 KLOOF STREET CAPE TOWN 8001 - P O BOX 3965 CAPE TOWN 8000 SOUTH AFRICA
TEL: (021) 469-9100 FAX: (021) 24-5571 REG NO: 69 02878 07

CALCULATIONS

PROJECT :	Krakeel Iron Rich Borehole Water Treatment	Project No:	JA0230A
SUBJECT :	PRELIMINARY COST ESTIMATES	Date:	16-Jan-2003
PREPARED BY :	Dave Crombie	Page	of

Daily Flow — 440 m3/day

Spray stab
Estimates for work to be done by Contractor
Design Flow — 6.6 m3/hr - 3.1 l/s — 264 m3/day estimated demand; 264 m3/day maximum

DESCRIPTION				AMOUNT	TOTAL
Simple aeration/settling					
Calcostab Units and Filters					36 318
Pipework					82 930
Controls & Instrumentation					600
					500
Civil works					
SUB-TOTAL					500
P&G					120 848
NET CONSTRUCTION COST		30.0 %		36 254	
Contingencies					157 103
Pre Tender Escalation		15.0 %		23 565	
SUB-TOTAL		5.0 %		9 033	
Contract Price Adjustment					189 702
GROSS CONSTRUCTION COST		4.0 MTH		8 016	
Engineeing Fees	Form B1				R 197 717
	Adjustment to Form B1 rates : 0%		32 665		
	Time based work/CSIR		0		
			10 000		
			42 665		
	Disbursements			42 665	
	Site Supervision			3 954	
	Total	3 MTH		4 500	
SUB-TOTAL					51 119
VAT					248 836
TOTAL PROJECT COST		14 %			34 837
					R 283 673
ROUNDED TO					
					R 290 000

ENG FEES	Form B1
DISBURSEMENTS	Documents, drawings, travelling expenses and geotechnical investigation included
SITE SUPERVISION	Resident Engineer on part time basis allowed for contract duration Control testing included
SURVEY	Design fees based on topo survey and cadastral data linked to Gibb computer Survey not included in disbursements

ARCUS GIBB

CONSULTING ENGINEERS

CIVIL STRUCTURAL ELECTRICAL MECHANICAL AGRICULTURAL ENVIRONMENTAL GEOTECHNICAL PROJECT MANAGEMENT

14 KLOOF STREET CAPE TOWN 8001 - P O BOX 3965 CAPE TOWN 8000 SOUTH AFRICA
TEL: (021) 469-9100 FAX: (021) 24-5571 REG NO: 69 02878 07

CALCULATIONS

PROJECT :	Krakeel Iron Rich Borehole Water Treatment	Project No:	JA0230A
SUBJECT :	PRELIMINARY COST ESTIMATES	Date:	16-Jan-2003
PREPARED BY :	Dave Crombie	Page	of

Daily Flow			440 m3/day
Spray stab			
Estimates for work to be done by Contractor			
Design Flow	18.3 m3/hr -	440 m3/day estimated demand	
DESCRIPTION	5.1 l/s	440 m3/day maximum	
Simple aeration/settling		AMOUNT	TOTAL
Calcostab Units and Filters			50 620
Pipework			149 435
Controls & Instrumentation			600
			500
Civil works			
SUB-TOTAL			500
P&G			201 655
NET CONSTRUCTION COST	30.0 %	60 497	
Contingencies			262 152
Pre Tender Escalation	15.0 %	39 323	
SUB-TOTAL	5.0 %	15 074	
Contract Price Adjustment			316 548
GROSS CONSTRUCTION COST	4.0 MTH	13 376	
Engineeing Fees Form B1			R 329 924
	53 322		
Adjustment to Form B1 rates : 0%	0		
Time based work/CSIR	10 000		
	63 322	63 322	
Disbursements		6 598	
Site Supervision	3 MTH	4 500	
Total			
SUB-TOTAL			74 420
VAT			404 344
TOTAL PROJECT COST	14 %		56 608
			R 460 953
ROUNDED TO			R 470 000

ENG FEES	Form B1
DISBURSEMENTS	Documents, drawings, travelling expenses and geotechnical investigation included
SITE SUPERVISION	Resident Engineer on part time basis allowed for contract duration Control testing included
SURVEY	Design fees based on topo survey and cadastral data linked to Gibb computer Survey not included in disbursements

DOCUMENT CONTROL SHEET (FORM IP180/B)

CLIENT : Cacadu District Municipality

PROJECT : Krakeelrivier Bulk Water Supply **PROJECT No** : JA0230A

TITLE : Groundwater Investigation: Interim Hydrogeological Report

	Prepared by	Reviewed by	Approved by
ORIGINAL	NAME J Spencer	NAME J McStay	NAME J McStay
DATE	SIGNATURE	SIGNATURE JMcStay	SIGNATURE JMcStay
REVISION	NAME	NAME	NAME
DATE	SIGNATURE	SIGNATURE	SIGNATURE
REVISION	NAME	NAME	NAME
DATE	SIGNATURE	SIGNATURE	SIGNATURE
REVISION	NAME	NAME	NAME
DATE	SIGNATURE	SIGNATURE	SIGNATURE

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