To do
Bit=2

# GROUNDWATER RESOURCE INFORMATION PROJECT
# EASTERN CAPE PROVINCE

## GROUNDWATER INFORMATION SOURCE REFERENCE SHEET

| SOURCE REF NR: KS 004 | Own Archive | X | Copy attached | X |
|---|---|---|---|---|
| | Sourced | | Copy at source | |

## A: SOURCE DESCRIPTION

| | | | | | | |
|---|---|---|---|---|---|---|
| District Municipality: | Amatole | | Chris Hani | | O R Tambo | X |
| | Ukhahlamba | | Cacadu | | Alfred Nzo | |
| Local Municipality: | Nyandeni | | | | | |
| Institution where Information is held: | Kei Water Solutions | | | | | |
| Branch of Institution: | Umtata | | | | | |
| Contact details: Contact person: | Mr B. Malghas | | | | | |
| Contact Tel: | (047) 5313973 | | | | | |
| Contact Email: | keiwater@intekom.co.za | | | | | |

## B: TYPE OF INFORMATION

| | | | | | | |
|---|---|---|---|---|---|---|
| Information format: | Hard copy | X | Data Summary | | Electronic Report | |
| | Specify Other: | | | | | |
| Report / Info Title: | LIBODE TOWN Groundwater Investigation | | | | | |
| Report Nr: | T&P 990215 | | Date: | Sept - 99 | | |
| Author Details: | Kei Water Solutions | | | | | |
| Author's Qualification: | Hydrogeologist | X | Govt Dept | | Project Manager | |
| | Engineer | | Technician | | Other | |
| | Specify Other: | | | | | |

Captured by: Mbali Thwala Date: 11/02/2004 Signed:

## C: GEOHYDROLOGICAL CATEGORIZATION

| | | | | | | |
|---|---|---|---|---|---|---|
| Project Type | Source development | X | Feasibility Study | | Sanitation Study | |
| | Specify Other: | | | | | |

| Reference Co-ordinate: | Latitude | Longitude |
|---|---|---|
| | S 31° 32,5000' | E 29° 01,0000' |

| | Yes | No | Complete | Incomplete |
|---|---|---|---|---|
| Lithological & Construction Logs | X | | | |
| Hydrocensus Data | | X | | |
| Pump Testing Data | X | | | |
| Chemical Water Analysis Data | X | | X | |
| Geohydrological Data | X | | | |
| Spring Data | 1 | X | | |
| Remote Sensing Data | X | | | |
| Map Data | X | | X | |

Comments:

Reviewed by: B. Malghas Date: 11/02/2004 Signed:

KEI
WATER SOLUTIONS
DEVELOPING THE EASTERN CAPE GROUNDWATER RESOURCES
CK 98/02531
18 FINCH STREET • SOUTHERNWOOD • UMTATA • 5100
P O BOX 903 • UMTATA • 5100
TEL/FAX: (047) 5313973

# LIBODE TOWN

## GROUNDWATER INVESTIGATION

(T & P Report No. 990215)

JAN RASMUSSEN
BOOI MALGHAS

SEPTEMBER 1999

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# 1.0 INTRODUCTION

## 1.1 TERMS OF REFERENCE

Following a telephone discussion between Mr D Nel (Wium & Saunders Inc.) and Mr Booi Malghas (KWS) on 21 April 1999, KWS were requested to submit a proposal and cost estimate for the siting and drilling of 3 production boreholes at Libode. These additional boreholes were to be drilled to make up for the deficit of 0.86 l/s, a result of the removal of boreholes B and C from the water supply system.

The approach to the study was outlined in the proposal as follows:

- A remote sensing study and evaluation of available information was to be carried
- This would be followed by a ground geophysical investigation, geological mapping exercise and hydrocensus
- Drilling supervision was to be undertaken by a qualified hydrogeologist as per the DWA&F guidelines (DWA&F, 1997).
- All successful boreholes were pump tested as to the DWA&F (1997) specifications with on site supervision by a qualified hydrogeologist. The length of the tests were to be dependent on the blowing yield.
- Water samples were to be drawn for submission to a DWA&F accredited laboratory for full macrochemical analyses.
- On completion of the work a report was to be compiled detailing all aspects of the study. Conclusions and recommendations pertaining to water quality, abstraction rates, pump duty times and pump installation depths were to be included in this document.

The proposal and cost estimate was accepted in a facsimile from Wium & Saunders dated 07 June 1999 (Ref. No. T-817).

## 1.2 LOCATION

Libode is located approximately 23 km east of Umtata adjacent to the main road to Port St.Johns (Figure 1). The geographical co-ordinates are 29 $^{0}$01' 00" east and 31° 32'30" south.

## 2.0 PHYSIOGRAPHY

The town is located on the northern slope of a gently sloping hill at an elevation of between 760 and 800 m above mean sea (amsl). Primary drainage in the area is via the perennial Mtakatye river which has its source to the north of the town in the vicinity of the Libode Forest. The river flows past the town in a south westerly directly before turning and meandering in a southeasterly direction towards the coast.

The region enjoys a temperate climate with mild winters and warm summers. The annual rainfall is between 600 and 900 mm p.a., falling mainly during the summer months.

## 3.0 GEOLOGY AND HYDROGEOLOGY

### 3.1 GEOLOGY

The geology in the area consists of mudstone and sandstone of the Beaufort Group of the Karoo Supergroup, more specifically the Adelaide Subgroup. This formation consists of brownish-red fine-grained sandstone and grey mudstone.

The sediments in the vicinity of Libode have, to a large degree, been intruded by dolerite dykes and sills.

The more resistant sandstone and dolerite are responsible for the high lying topography common in the area.

### 3.2 HYDROGEOLOGY

The hydrogeological properties of the Beaufort Group is generally poor, with groundwater movement being limited to fracture zones associated with faulting and jointing. The arenaceous nature of the sandstone layers, however, offer greater potential for secondary aquifer development, particularly where open fractures and joints are present.

The occurrence of groundwater in the weathered and fractured margins along the geological contact of sills, particularly where the sills are undulating or inclined, cannot be ruled out. Those dykes which are present also offer zones of high groundwater potential, with aquifer development in the zone of alteration immediately between the intrusive dolerite and the host rock, as well as within fracture zones in the dolerite.

According to the recently published 1: 500 000 Hydrogeological Map Series Queenstown 3126, borehole yields of between 0.50 and 2.0 l/s can be expected in these areas. However, if cognisance is taken of the Transkei National Groundwater Data Base, it is apparent that 50 % of the boreholes drilled on record are dry. It is believed that the poor drilling success in the past can largely be attributed to the fact that previous drilling was carried out in localities convenient to the local community, with limited use of scientific exploration methods.

According to DWA&F records the optimal drilling depth is estimated to be approximately 25 m below groundwater level (mean water level 17 m) as it is postulated that water bearing structures are more "open" at these shallower depths, with the chances of striking water becoming progressively less with depth. In our opinion, drilling should, where possible, take place in topographic lows in areas which have maximum recharge.

## 4.0 BOREHOLE SITING

The siting of the borehole was done into two stages, namely a desk study and a site investigation.

### 4.1 DESK TOP STUDY

During this stage of the study the following information was assessed:

- the 1:50 000 scale aerial photography
- the landsat imagery (Scene WRS No. 169-0-82)
- the published 1:250 000 geological sheet (No.3128 Umtata)
- the 1:50 000 Topographical sheet (No. 3129 CA Libode)

The assessment of the groundwater potential of the area and the possibility of siting successful production boreholes in close proximity to the target area involved the following:

- Geological and lineament mapping from the existing 1:50 000 panchromatic air-photographs within a 2 kilometre radius of the town.

- Geological and lineament mapping from digitally processed and enhanced Landsat TM imagery), within an 8 kilometre radius of Libode.

- Comparison with the published 1:250 000 geological map sheet and the 1: 50 000 topocadastral sheets.

The above information (air-photographs, Landsat imagery, published geological and topocadastral maps) were captured as fully geo-referenced digital images for incorporation into a geographical information system (*GIS*). The digital aerial-photograph and satellite imagery was processed and enhanced using specialised image-processing software. A number of Landsat false-colour-composites, mainly in the infra-red wavelengths, were also prepared. Geological and lineament mapping was then conducted on-screen.

Lineaments were mapped from the satellite and aerial-photo imagery, and coupled with those lineaments and dolerite dykes from the published geological map. The lineaments were then overlaid onto the topocadastral maps using the *GIS* to check for anthropogenic lineaments, which were then removed from the dataset.

Some prominent lineaments were captured in the *GIS,* notably the NW trending structure to the north of the town. Of particular interest from a groundwater point of view were the previously unmapped NW-NNW trending satellite lineaments, the orientation of which corresponded to the major structural orientation of the area.

Taking cognisance of the presence of the dolerite sheets and dykes, it was speculated that by targeting these features, adequate volumes of groundwater would be located.

The above information was used to compile a lineament map and to site 6 potential drilling-targets within a 2 km radius of the town (Figure 2).

### 4.2 GROUND GEOPHYSICS

With the help of the lineament map, fieldwork was carried out concentrating on those targets identified during the desk study. The targets include dyke and sill contacts, and fracture zones within the sediments.

Although magnetic traverses were carried out, the most promising targets were found to be associated with a north-south orientated fracture zone. Drilling targets, based on field observations and geological interpretations, were pin pointed in the field.

## 5.0 BOREHOLE DRILLING

The drilling was carried out by Johan Burger of Drilling Africa from the 22 July 1999. All drilling operations were supervised by a hydrogeologist from KWS.

### 5.1 Borehole LT01

This 165 mm diameter borehole was drilled through heavily fractured and weathered shale to a depth of 53 m where fresh sandstone was intersected. Ground water was intersected in a broad fracture zone between 21 and 33 m, with the blow yield being measured at approximately 10 l/s.

Due to the high yield, it was decided to ream the borehole to 216 mm diameter to facilitate the installation of the 165 mm diameter uPVC casing (class 9). The upper 18 m of the borehole was cased with 216 mm steel casing. Due to the unstable nature of the sediments, the borehole was cased for its entire length down to the final depth of 60 m. The uPVC casing was perforated between 12 and 48 m to facilitate the inflow of groundwater into the borehole. The annulus between the borehole wall and casing was back-filled with a gravel pack to stabilise the formation. The borehole was then developed to removed any drill chippings and to wash the gravel pack.

A sanitary seal and concrete block was installed around the borehole collar to prevent the ingress of contamination of surface origin into the borehole and aquifer.

Following the development of the borehole, the electrical conductivity of the groundwater was measured at 58 mS/m and the blow yield at 10 l/s.

A log describing geology and borehole construction is attached in Appendix 1.

5.2 Borehole LT02

This borehole was drilled at 165 mm diameter to a depth of 60 m, with water-bearing fracture zones being intersected at 13, 25 and 41 m in the weathered and fractured shale. The upper 13 m of the borehole was cased with 216 mm diameter steel casing. Class 9 uPVC (diameter 140 mm) casing was then installed to the base of the borehole at 60 m, with perforations between 15 and 60 m.

A gravel pack/formation stabiliser was placed into the annulus, and a sanitary seal and concrete block was installed around the borehole collar. The borehole was developed, the final yield being measured at 6 l/s with an electrical conductivity of 60 mS/m.

A log describing geology and borehole construction is attached in Appendix 1.

## 6.0 PUMP TESTING

Pump tests were carried by Seaview Water Services in August 1999 with site supervision by KWS. The boreholes were subjected to step drawdown tests, constant discharge tests and recovery tests. Taking cognisance of the unexpectedly high yields, it was decided that the constant rate tests should be run for 72 hours.

6.1 RESULTS OF THE PUMP TESTING

A summary of boreholes is shown in Table 1.

**TABLE 1: BOREHOLE SPECIFICATIONS**

| BOREHOLE AND PUMP SPECIFICATIONS | | | | | | |
|---|---|---|---|---|---|---|
| **Borehole Number** | **Borehole Depth (m)** | **Blow Yield (l/s)** | **Major Water Strikes (m.bgl)** | **Borehole Diameter (mm)** | **Test Pump Inlet (m bgl)** | **Water Level (m bgl)** |
| LT01 | 60 | 10 | 21 - 33 | 165 uPVC | 50.50 | 5.12 |
| LT02 | 60 | 10 | 13<br>25<br>41 | 140 uPVC | 58 | 1.98 |

### 6.1.1 BOREHOLE LT01

During Step testing, 6 steps were carried out at yields ranging from 2.00 l/s to 15 l/s. After pump shutdown the borehole recovered to 2.84 m within 240 minutes. Following the evaluation of the step drawdown test, the constant discharge test was commenced at a yield of 8.00 l/s. After 90 minutes, however, the water level had drawn down to 13 m bgl, and it was decided to reduce the abstraction rate to 6.00 l/s. This abstraction rate was maintained for remainder of the 72 hour period. Recovery of the water level in the borehole after pump shutdown was monitored for 2500 minutes, after which time the borehole had recovered to within 2.26 m of the static water level.

The drawdown response of the water level during the different tests is displayed in Appendix II.

### 6.1.2 BOREHOLE LT-02

During Step testing, 5 steps were carried out at yields ranging from 2.80 l/s to 12.4 l/s. After pump shutdown the borehole recovered to 0.26 m within 360 minutes. Following the evaluation of the step drawdown test, the constant discharge test was commenced at a yield of 8.00 l/s. This abstraction rate was maintained for remainder of the 72 hour period. Recovery of the water level in the borehole after pump shutdown was monitored for 1873 minutes, after which time the borehole had recovered to within 0.74 m of the static water level.

The drawdown response of the water level during the different tests is displayed in Appendix III.

## 6.2 ABSTRACTION RECOMMENDATIONS

Based on the interpreted pump test data, the optimal pump yields and recommended abstraction management strategy is as follows:

| BOREHOLE NUMBER | OPTIMAL YIELD (l/s) | PUMP INTAKE (m.bgl) | PUMPING SCHEDULE (hrs/day) | EARLY-WARNING REST-WATERLEVEL (m.bgl) [A] | MAXIMUM REST-WATERLEVEL (m.bgl) [B] | MAXIMUM MONTHLY ABSTRACTION ($m^3$) |
|---|---|---|---|---|---|---|
| LT01 | 3.5<br>[1.85] | 22 | 11<br>[24] | 12.0 | 15.0 | 4100<br>[4800] |
| LT02 | 4.5<br>[2.28] | 18 | 11<br>[24] | 9.5 | 15.0 | 5300<br>[5900] |
| TOTAL | | | | | | 9 400<br>10 700 |

NOTE:
A - The "early-warning" **rest-waterlevel** serves as a guideline as to when the borehole is being overexploited - at this stage the daily volume of water abstracted should be lowered until the waterlevel in the borehole is re-established above this level.
B - This is a "critical" **rest-waterlevel** at which the yield of the borehole will decline rapidly and possible physical damage (borehole collapse, screen encrustation etc.) may occur in the borehole with prolonged abstraction.
**Optimal Yield** - is the maximum immediate yield at which the borehole should be pumped, a lower yield may also be used. [ ] is the estimated yield that may b sustained with continuous pumping and without "resting" the borehole.
**Maximum Monthly Abstraction** ($m^3$) ≡ "Safe Yield" of the borehole. The optimal yield and recommended pumping schedule (hrs/day) will not necessarily equate to the Maximum Monthly Abstraction - implying that the borehole will be pumped intermittently. **This monthly volume should never be exceeded.**

Considering the fact that the major water strike are shallow, it is recommended that the water level in the boreholes during abstraction do not drop below the suggested levels. It is recommended that the water level in the boreholes are measured regularly to ensure that over-abstraction does not take place.

## 7.0 WATER QUALITY

Representative groundwater samples were drawn for chemical analysis after 72 hours of abstraction, and submitted to the Pollution Control Technology laboratory in Gonubie. The laboratory certificates are attached in Appendix IV and graphical representations of the groundwater quality in Appendix V.

The groundwater can be classified as a *sodium bicarbonate* type, confirming that the aquifers from which groundwater is being abstracted is subject to recent recharge, primarily from rainfall events. According to the DWA&F (1997) classification system for water quality, the groundwater can be classified as being a Class I water. Although the water is moderately hard (DWA&F, 1996), a result of relatively high concentrations of calcium, the scaling of appliances should not be a problem.

The Sodium Adsorption Ratio of the groundwater is low, and is thus suitable for irrigation purposes.

In terms of the Class I classification, the groundwater is suitable for domestic use and can be consumed in its raw state. It is recommended, however, that a representative groundwater sample be drawn from the borehole for microbiological assessment.

## 8.0 CONCLUSIONS AND RECOMMENDATIONS

It can be concluded that the investigation was successful in locating and developing a sufficiently strong water supply to meet the long-term demands of Libode. Furthermore, the presence of a number of favourable drilling targets is a clear indication that the potential for developing additional groundwater supplies to meet future demands is high.

The importance of using modern remote sensing techniques has been highlighted, as this phase of the investigation facilitated the identification of a number of prominent geological structures which would not have been located using standard interpretive techniques.

To ensure that the groundwater supplies are not over-exploited, it is recommended that a monitoring programme be implemented. It is suggested that after 1 year of monitoring, the data should be evaluated by a hydrogeologist so that abstraction rates can be adjusted accordingly. This monitoring programme should also include regular sampling to ensure that the water quality remains suitable for human consumption.

Although the groundwater can be classified as Class I in terms of the macrochemical concentrations, it is recommended that a sample undergo microbiological analyses to determine if chlorination is required.

.....
Booi Malghas
Kei Water Solutions

.....
Jan Rasmussen Pr.Sci.Nat
Toens and Partners

## REFERENCES

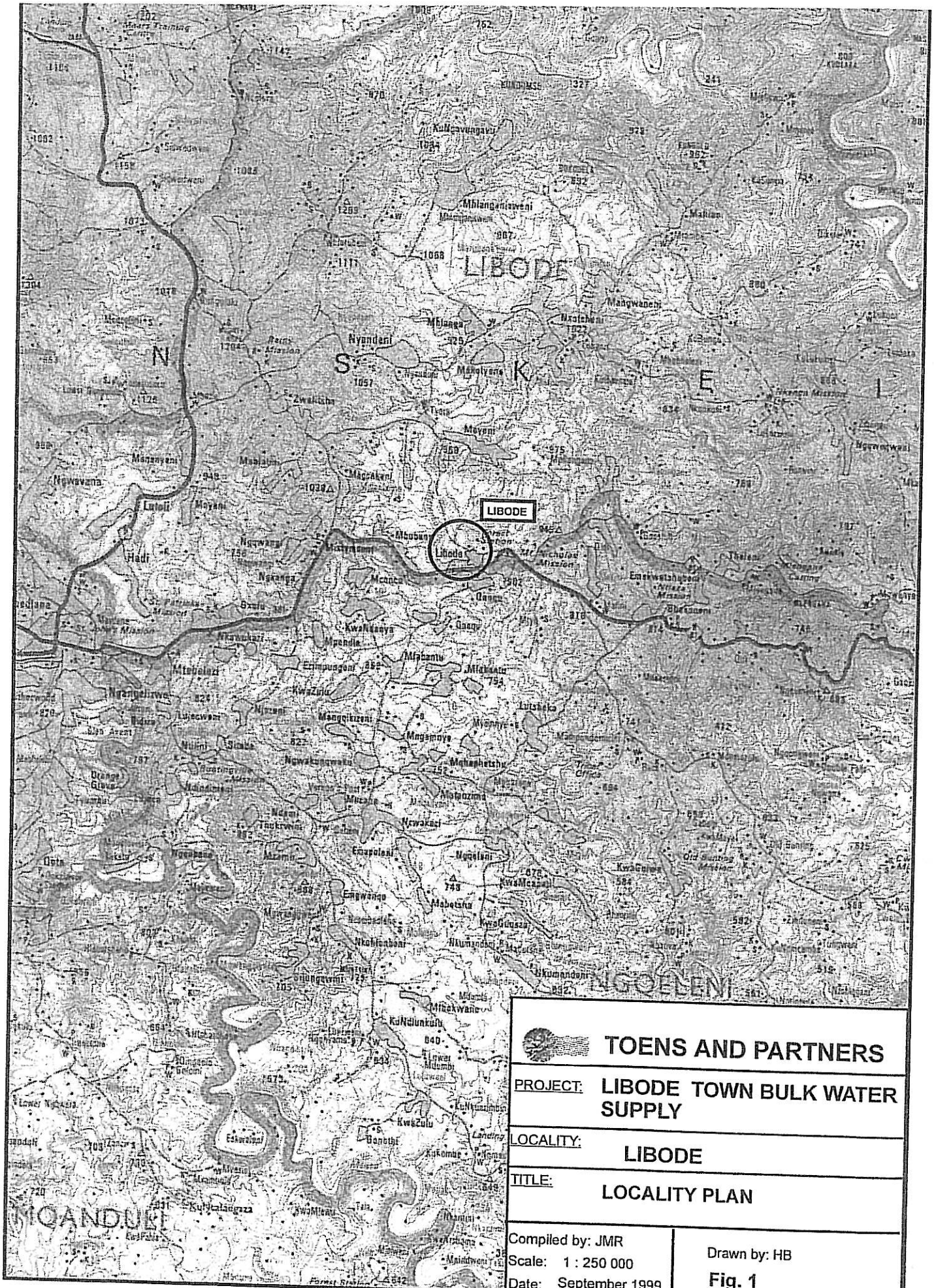
Department of Water Affairs and Forestry, 1996: **South African Water Quality Guidelines (second edition)**. Volume 1: Domestic Use.

Department of Water Affairs and Forestry, 1997: **Minimum Standards and Guidelines for Groundwater resource Development for the CWSS Programme**. Chief Directorate: CWSS and Directorate: Hydrogeology, Pretoria.

# LIST OF FIGURES

FIGURE 1:

LOCALITY PLAN




| | |
|---|---|
| | TOENS AND PARTNERS |
| PROJECT: | LIBODE TOWN BULK WATER SUPPLY |
| LOCALITY: | LIBODE |
| TITLE: | LOCALITY PLAN |
| Compiled by: JMR<br>Scale: 1 : 250 000<br>Date: September 1999 | Drawn by: HB<br>Fig. 1 |

FIGURE 2:

LINEAMENT MAP SHOWING PROPOSED DRILL SITES

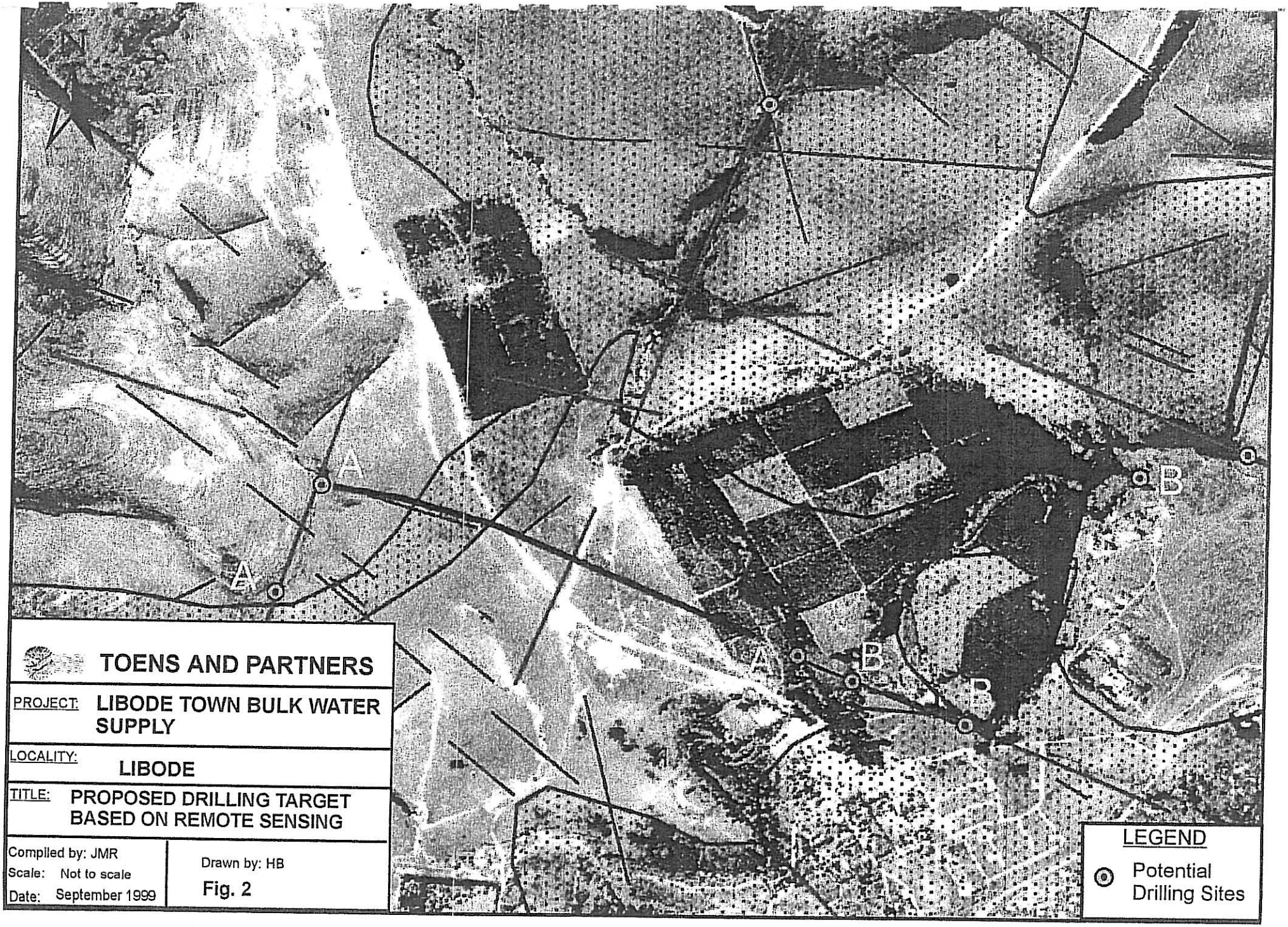
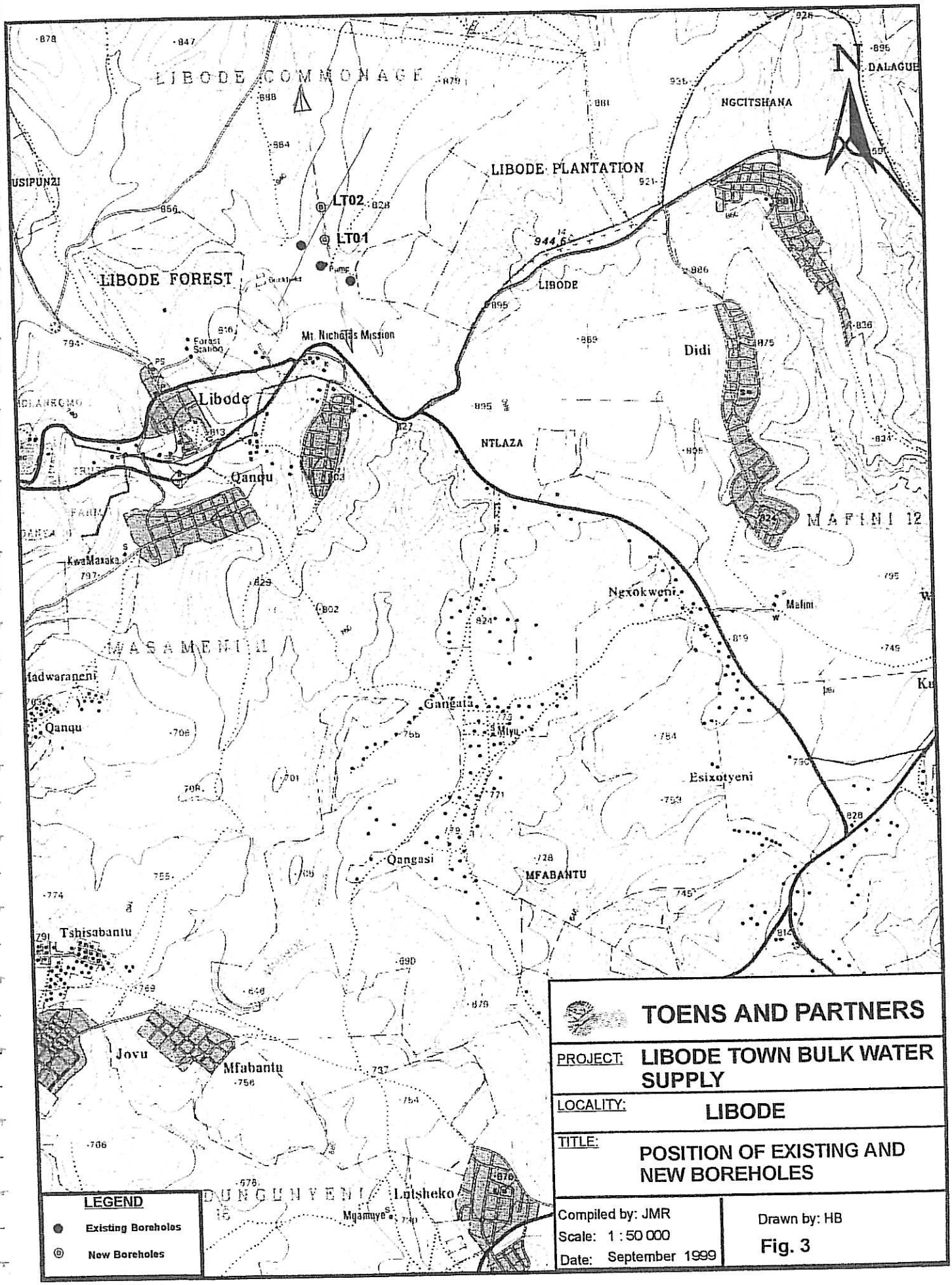

A
A
A
B
B
B
TOENS AND PARTNERS
PROJECT: LIBODE TOWN BULK WATER SUPPLY
LOCALITY: LIBODE
TITLE: PROPOSED DRILLING TARGET BASED ON REMOTE SENSING
Compiled by: JMR
Scale: Not to scale
Date: September 1999
Drawn by: HB
Fig. 2
LEGEND
Potential Drilling Sites

FIGURE 3:

POSITION OF PRODUCTION BOREHOLES


LIBODE COMMONAGE
LIBODE PLANTATION
LIBODE FOREST
NGCITSHANA
DALAGUE
USIPUNZI
LT02
LT01
944,6
LIBODE
Didi
Mt. Nicholas Mission
Forest Station
Libode
Qanqu
NTLAZA
MAFINI 12
KwaMaxaka
Ngxokweni
Malim
MASAMENI
Madwaraneni
Qanqu
Gangata
Miyu
Esixotyeni
Qangasi
MFABANTU
Tshisabantu
Jovu
Mfabantu
DUNGUNYENI
Lutsheko
Mgamuye
LEGEND
Existing Boreholes
New Boreholes
TOENS AND PARTNERS
PROJECT: LIBODE TOWN BULK WATER SUPPLY
LOCALITY: LIBODE
TITLE: POSITION OF EXISTING AND NEW BOREHOLES
Compiled by: JMR
Scale: 1 : 50 000
Date: September 1999
Drawn by: HB
Fig. 3

# LIST OF APPENDICES

# APPENDIX I:

# BOREHOLES LOGS

# Well Log: Lithology & Construction

| Well Ident | Name |
|---|---|
| LBD02/99 | LIBODE GROUNDWATER INVESTIGATION |

| Drill. Method | AIR PERCUSSION | Drill. Dates | 29/08/1999 |
|---|---|---|---|

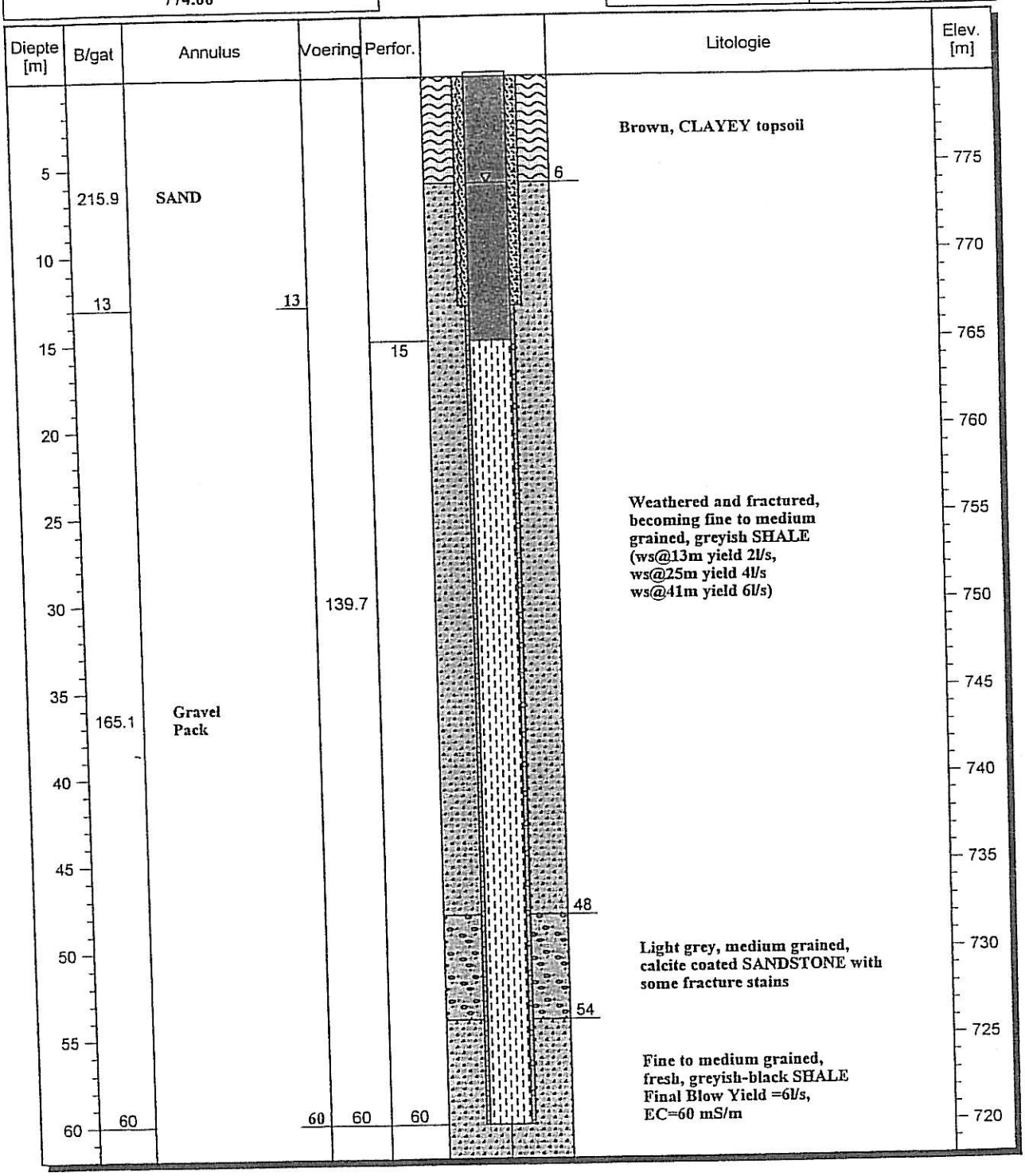
| X | 29 | Y | 3488925 | Z | 780.00 | Meas. Pt. Elev. | 780.30 |
|---|---|---|---|---|---|---|---|

**All measurements are in meters. Hole and casing diameters in inches.**

*Scales (1: xxx)*

| Vertical | Horizontal |
|---|---|
| | |

Water Level (m AMSL)
774.00



# Well Log: Lithology & Construction

| Well Ident | Name |
|---|---|
| LBD01/99 | LIBODE GROUNDWATER INVESTIGATION |

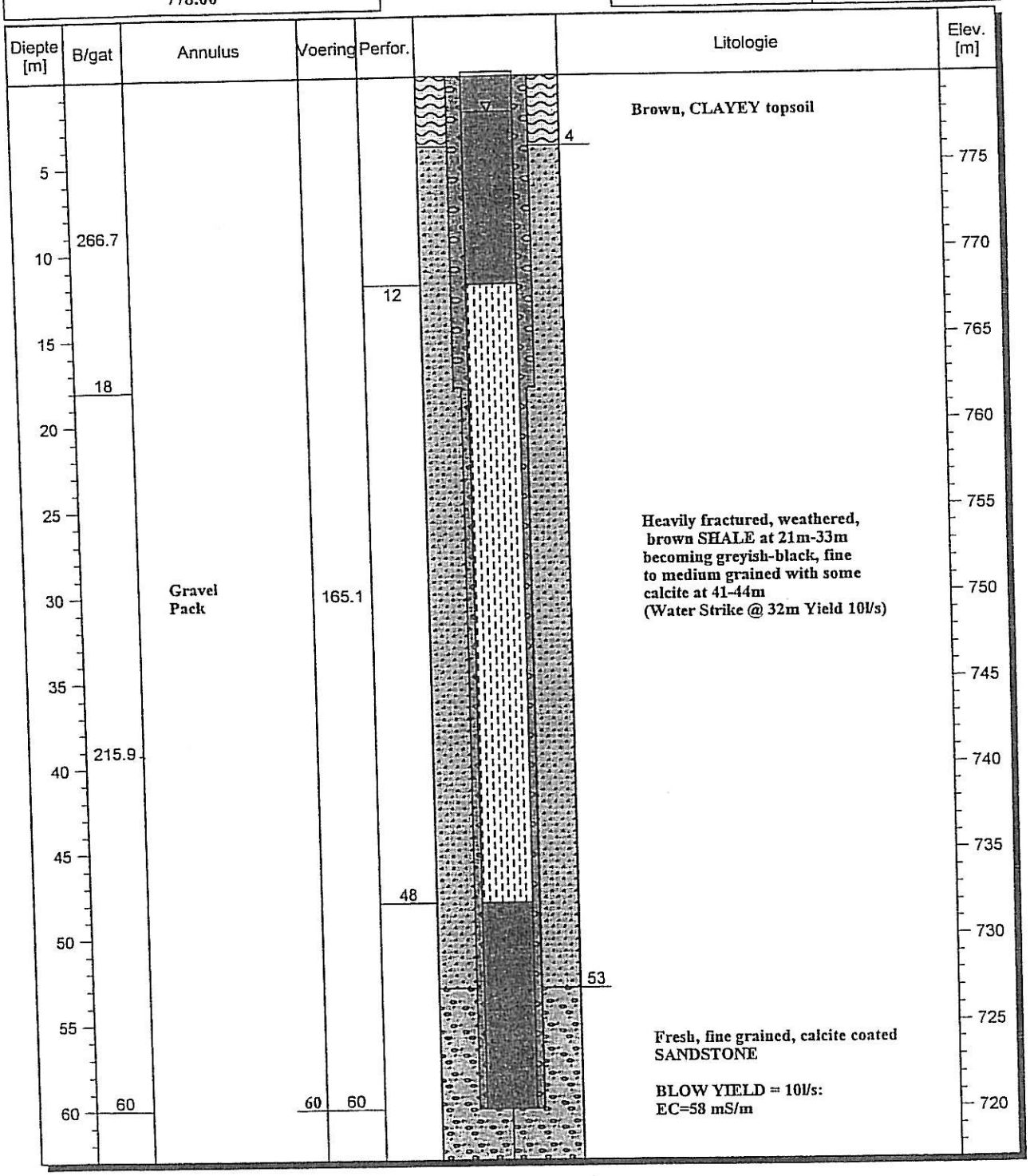
| Drill. Method | AIR PERCUSSION | Drill. Dates | 28/08/1999 |
|---|---|---|---|

| X | 3380 | Y | 3489259 | Z | 780.00 | Meas. Pt. Elev. | 780.30 |
|---|---|---|---|---|---|---|---|

**All measurements are in meters. Hole and casing diameters in inches.**

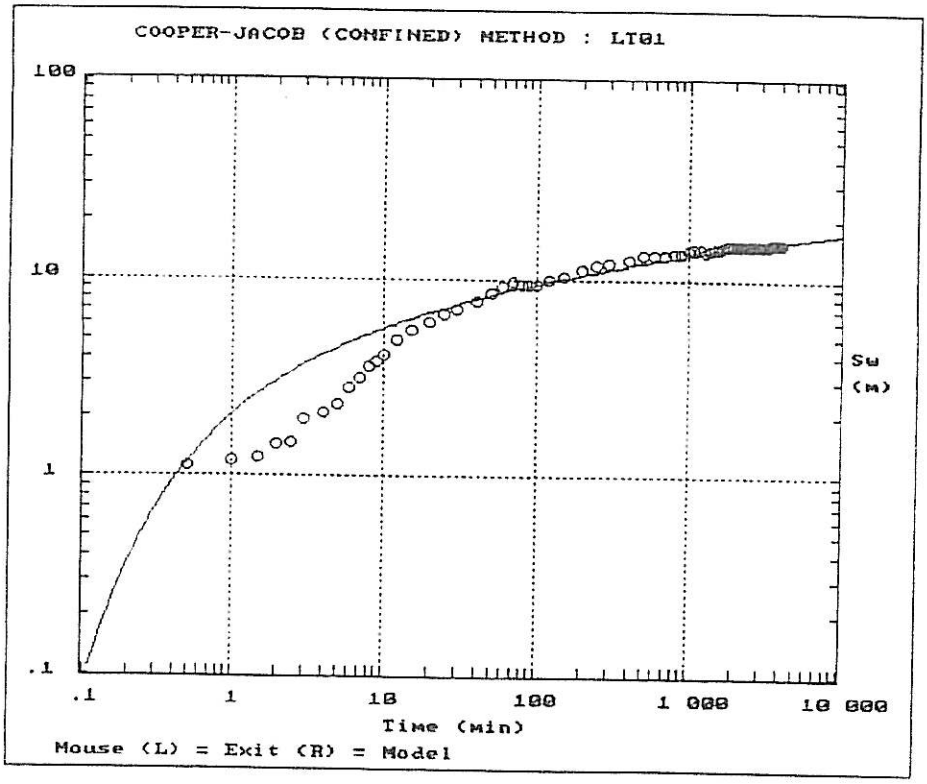
*Scales (1: xxx)*

| Water Level (m AMSL) | Vertical | Horizontal |
|---|---|---|
| 778.00 | | |

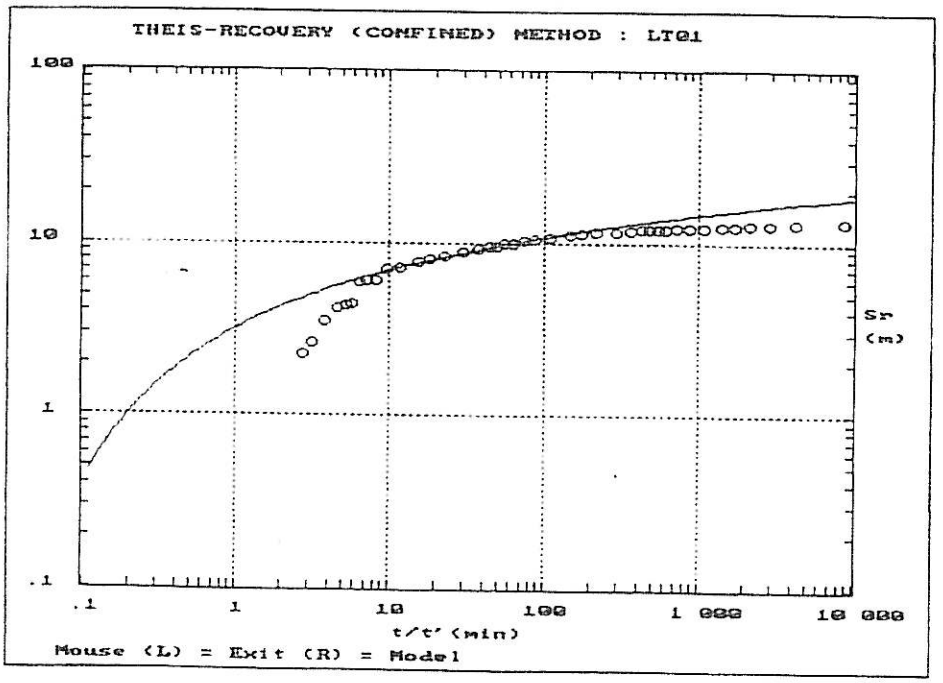


# APPENDIX II:

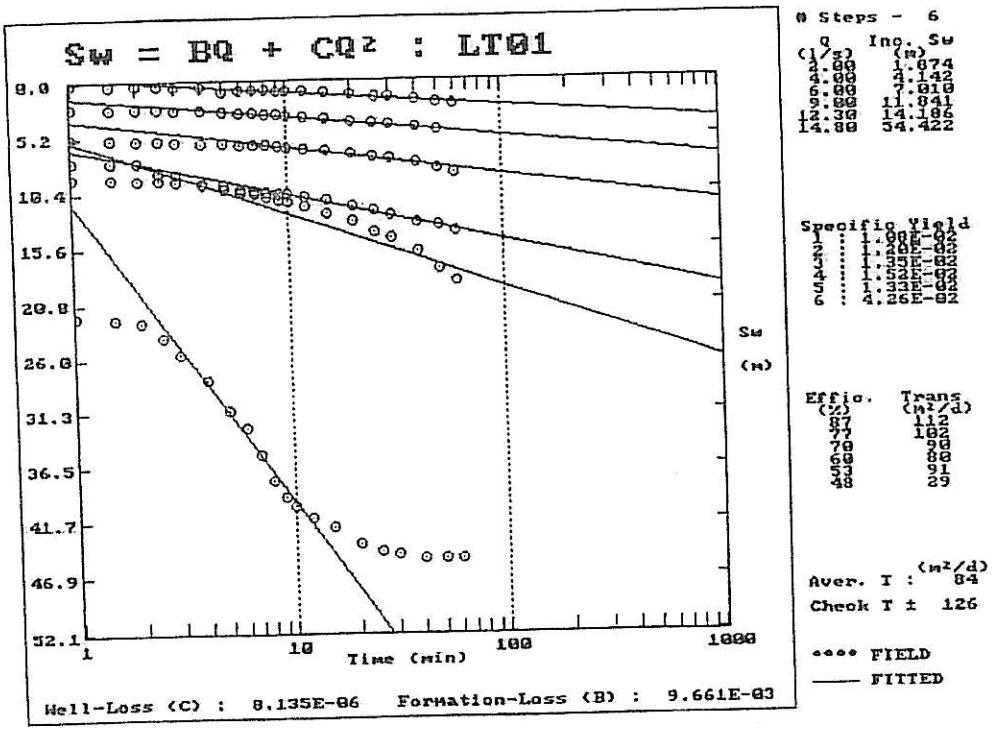
# DRAWDOWN CURVES LT01



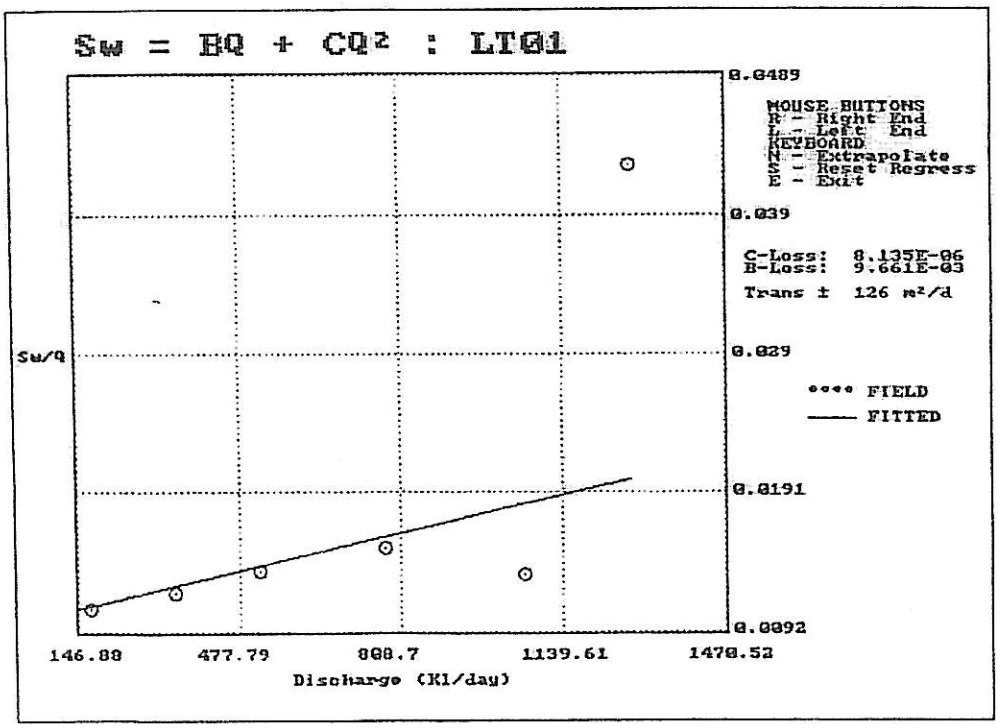

CONSTANT DISCHARGE TEST




RECOVERY TEST

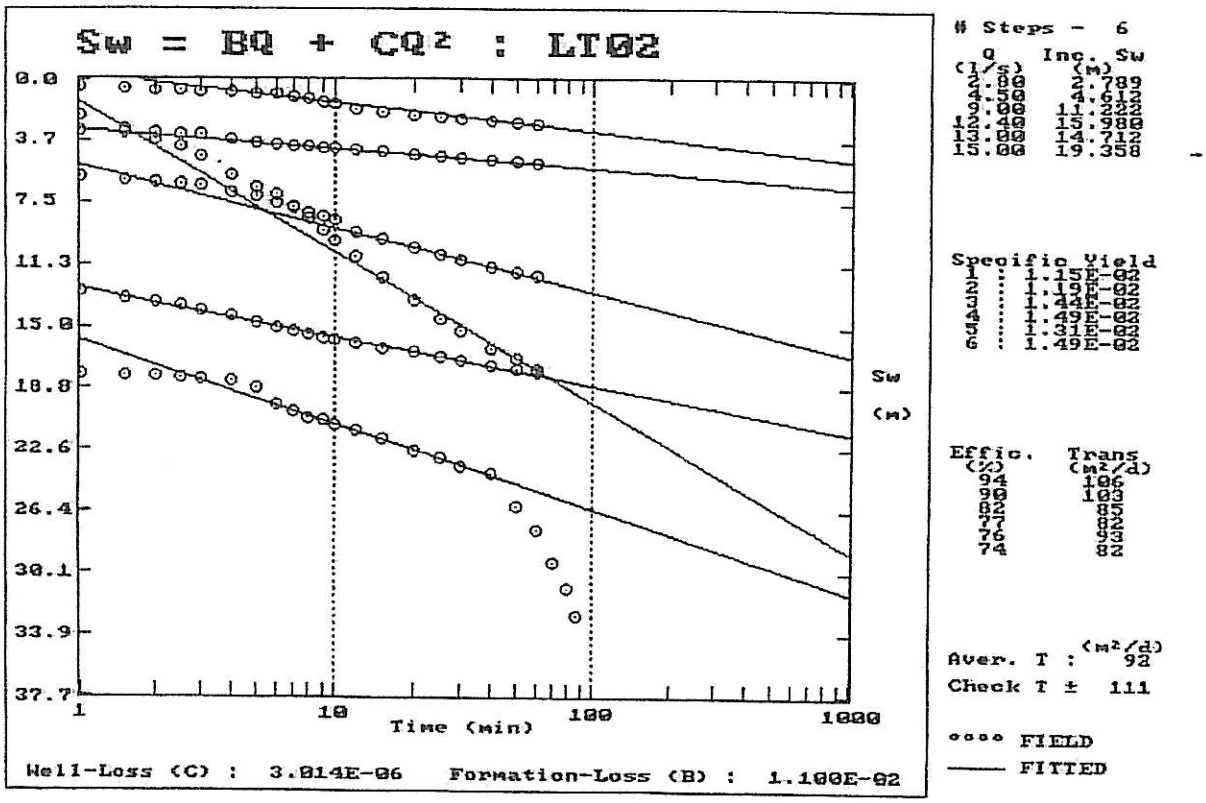



STEP DRAWDOWN TEST

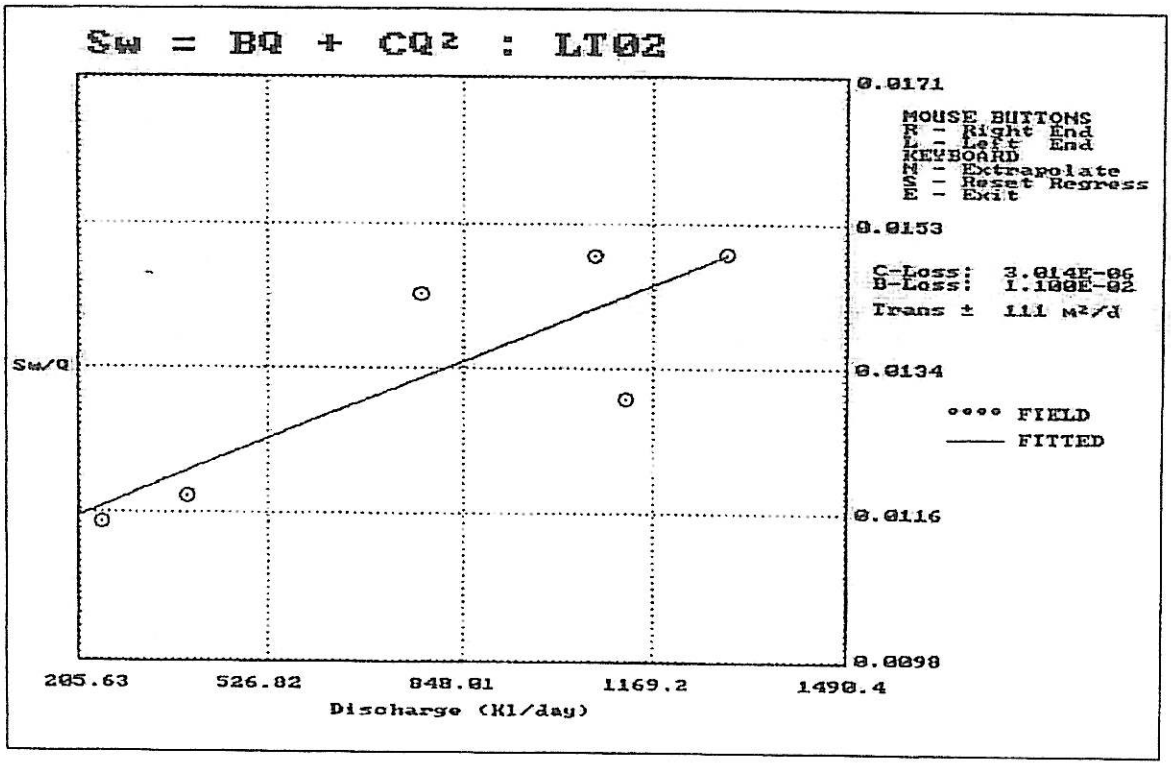


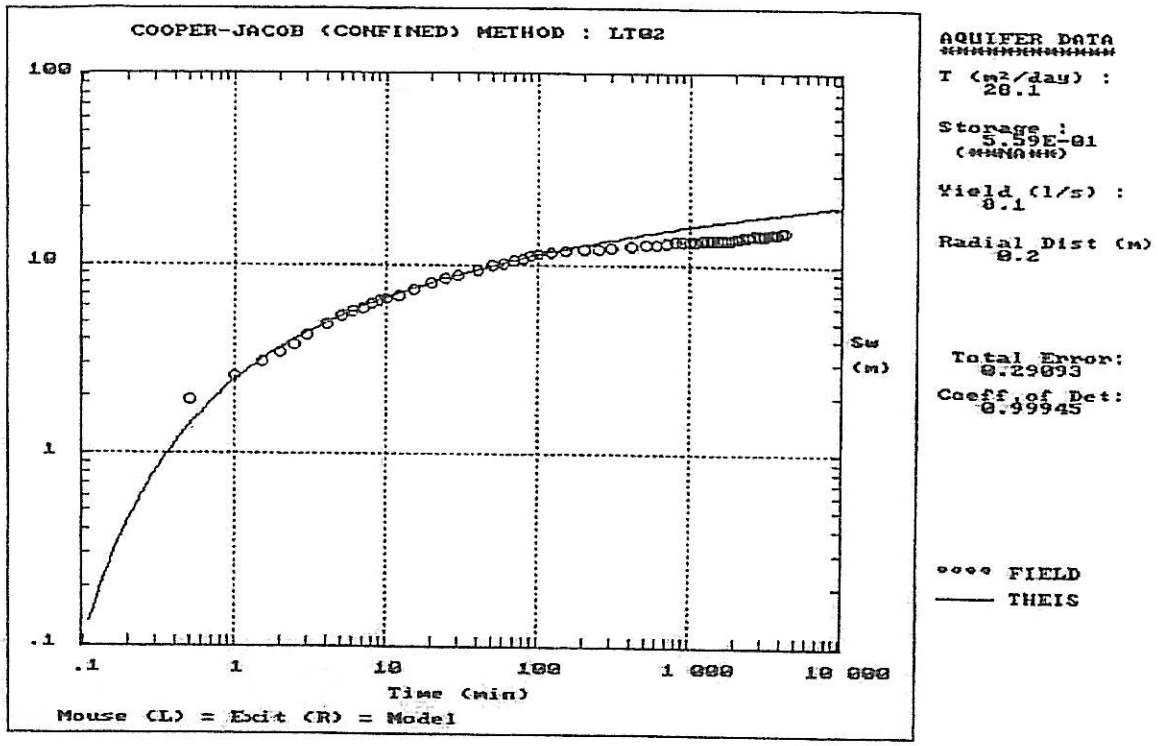
# APPENDIX III:

# DRAWDOWN CURVES LT02

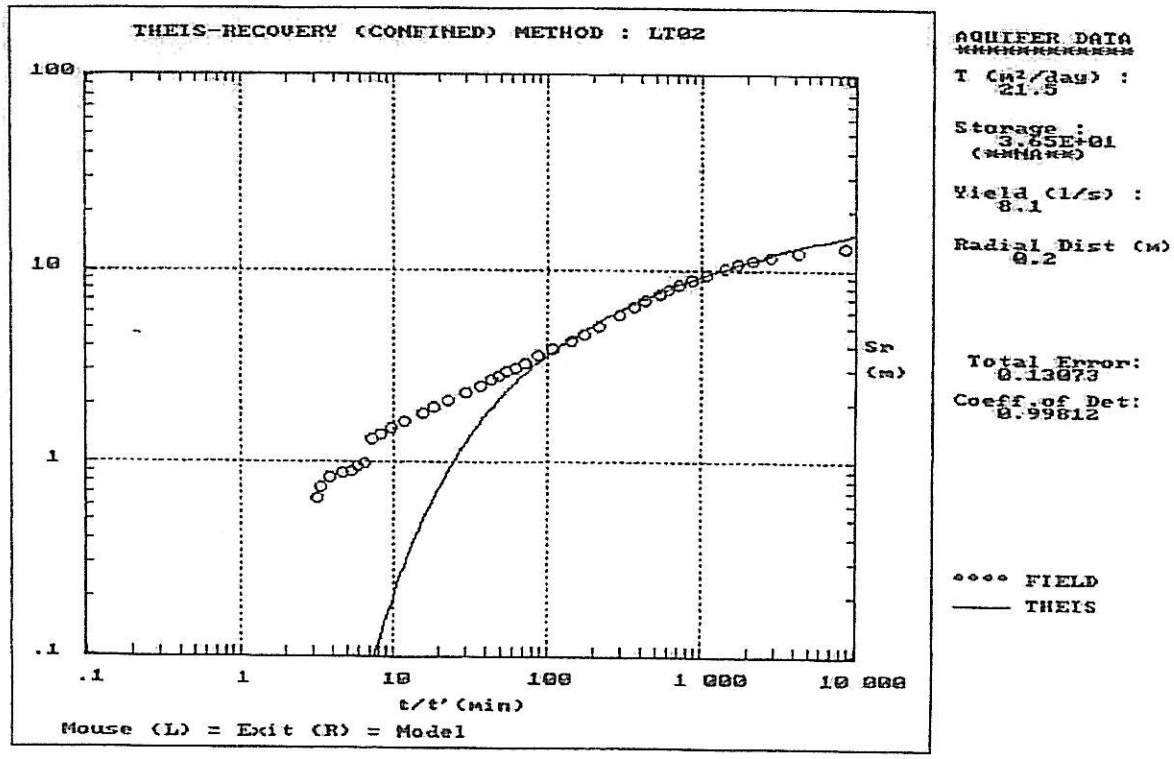



STEP DRAWDOWN TEST






CONSTANT DISCHARGE TEST




RECOVERY TEST

# APPENDIX IV:

# LAB CERTIFICATES

# POLLUTION CONTROL TECHNOLOGIES

Water Conservation and Wastewater Specialists
&
Water Quality Laboratory

13 WILSON STREET
ASTWARD HO
ONUBIE

E-mail: pctwayne@mweb.co.za

P.O. BOX 150
GONUBIE
5256
TEL: (0431) 404735
FAX: (0431) 402235

Date of Issue: 17 August 1999

| CLIENT: Kei Water Solutions, Umtata | | |
|---|---|---|
| Date delivered: | 11/08/1999 | Contact name: B Malgas |
| Sample 1 | CT 01, 10/08/99 | |
| Parameter | No. 1 | Units |
| pH | 6.86 | |
| Conductivity | 53.5 | mS/m |
| Turbidity | 1.7 | NTU |
| Alkalinity | 184 | mg/l |
| Chloride (as Cl) | 54.3 | mg/l |
| Sulphate (as $SO_4$) | 0.5 | mg/l |
| Sodium (as Na) | 52.3 | mg/l |
| Calcium (as Ca) | 26.7 | mg/l |
| Calcium (as $CaCO_3$) | 66.7 | mg/l |
| Magnesium (as Mg) | 17.7 | mg/l |
| Magnesium (as $CaCO_3$) | 72.9 | mg/l |
| Total Hardness | 139.6 | mg/l |
| Potassium (as K) | 0.7 | mg/l |
| Fluoride (as F) | <0.1 | mg/l |
| Iron (as Fe) | 0.13 | mg/l |

# POLLUTION CONTROL TECHNOLOGIES

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&
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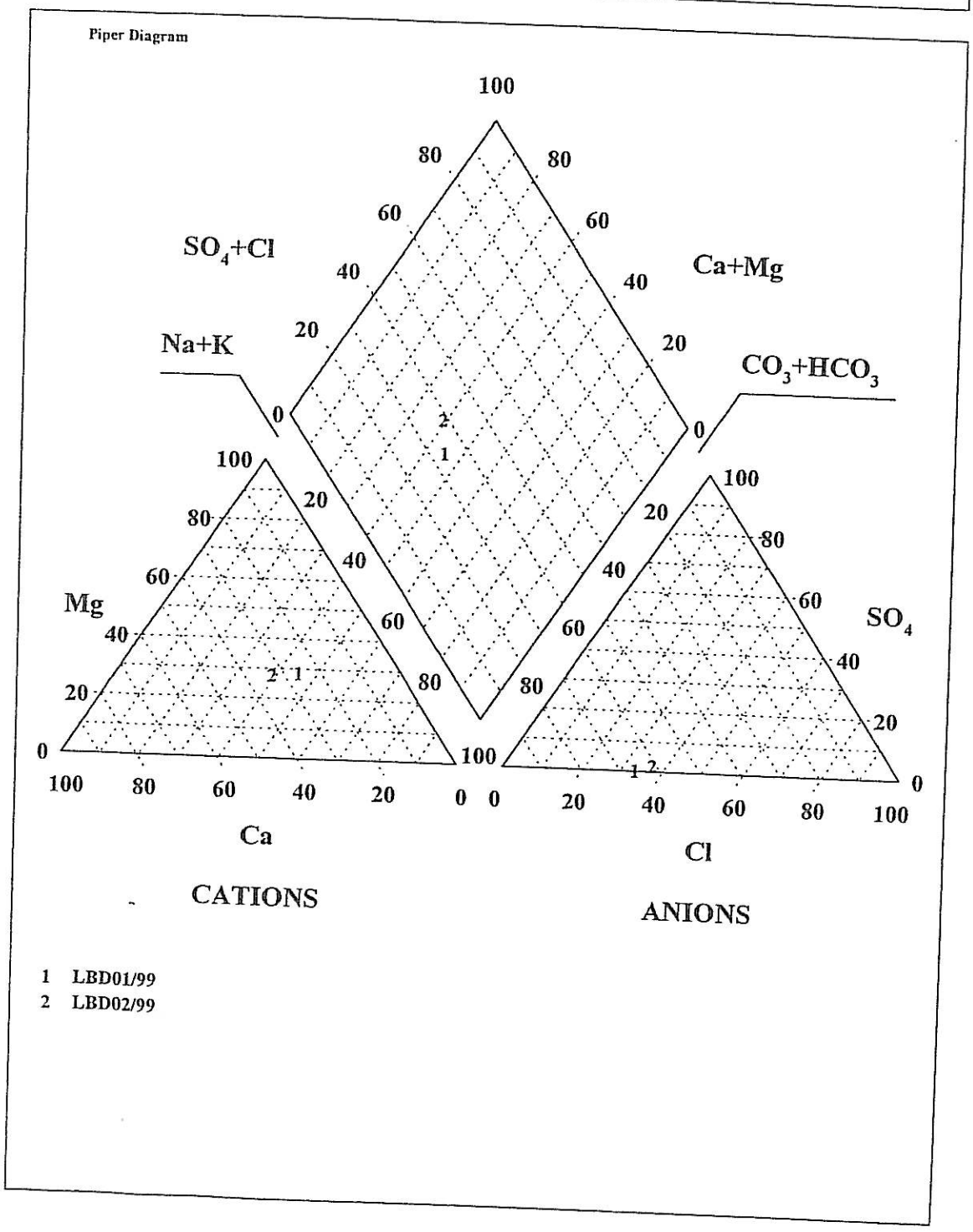
Date of Issue: 30 August 1999

| CLIENT: KEI WATER SOLUTIONS, UMTATA | | |
|---|---|---|
| Date delivered: | 23/08/1999 | Contact name: B Malgas |
| Sample 1 | LT 01 71 hr | |
| Parameter | No. 1 | Units |
| pH | 7.07 | |
| Conductivity | 62.6 | mS/m |
| Turbidity | 0.9 | NTU |
| Alkalinity | 208 | mg/l |
| Chloride (as Cl) | 72.9 | mg/l |
| Sulphate (as $SO_4$) | 5.2 | mg/l |
| Sodium (as Na) | 55 | mg/l |
| Calcium (as Ca) | 41.2 | mg/l |
| Calcium (as $CaCO_3$) | 102.9 | mg/l |
| Magnesium (as Mg) | 21 | mg/l |
| Magnesium (as $CaCO_3$) | 86.5 | mg/l |
| Total Hardness | 189.3 | mg/l |
| Potassium (as K) | 1.1 | mg/l |
| Fluoride (as F) | <0.1 | mg/l |
| Iron (as Fe) | Insufficient sample | mg/l |

# APPENDIX V:

# GRAPHICAL REPRESENTATION OF WATER QUALITY

# Piper Diagram

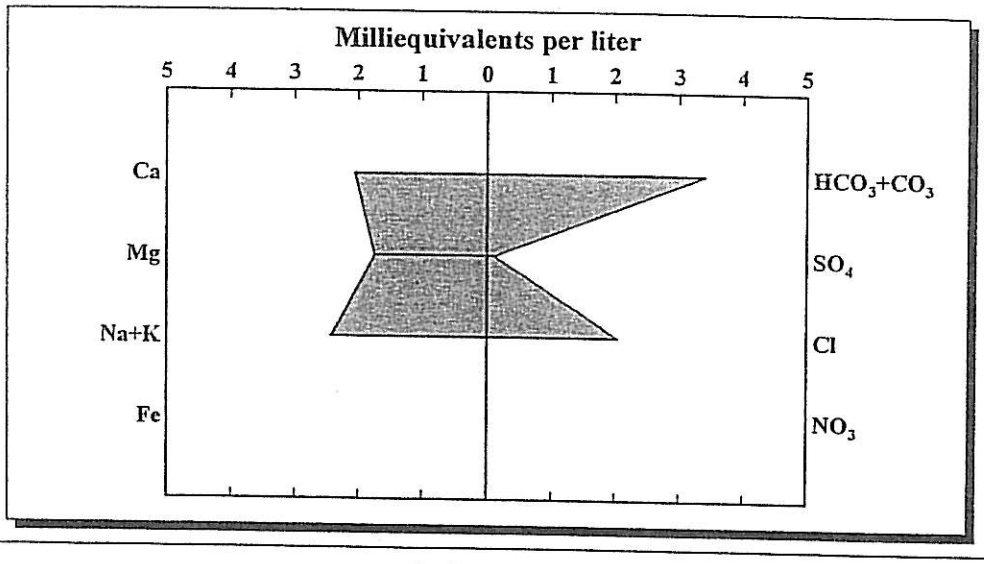



1 LBD01/99
2 LBD02/99

| Well Ident |
|---|
| LBD02/99 |

## *STIFF Diagram*

| Name | Type |
|---|---|
| LIBODE GROUNDWATER INVESTIGATION | |




### *Cations*

| | *Ca* | *Mg* | *Na* | *K* | *Fe* |
|---|---|---|---|---|---|
| *Milliequivalents per liter* | 2.0559 | 1.7275 | 2.3925 | 0.02813 | |
| *Milligrams per liter* | 41.20 | 21.00 | 55.00 | 1.10 | |

### *Anions*

| | *HCO3* | *CO3* | *SO4* | *Cl* | *NO3* |
|---|---|---|---|---|---|
| *Milliequivalents per liter* | 3.40912 | | 0.10826 | 2.05651 | |
| *Milligrams per liter* | 208.00 | | 5.20 | 72.90 | |

| BOD | COD | Dissolved Oxygen | F | B | SiO2 |
|---|---|---|---|---|---|
| TDS | Hardness 189.30 | Alkalinity 208.00 | Conductivity 62.60 | pH 7.07 | SAR 1.7395 |

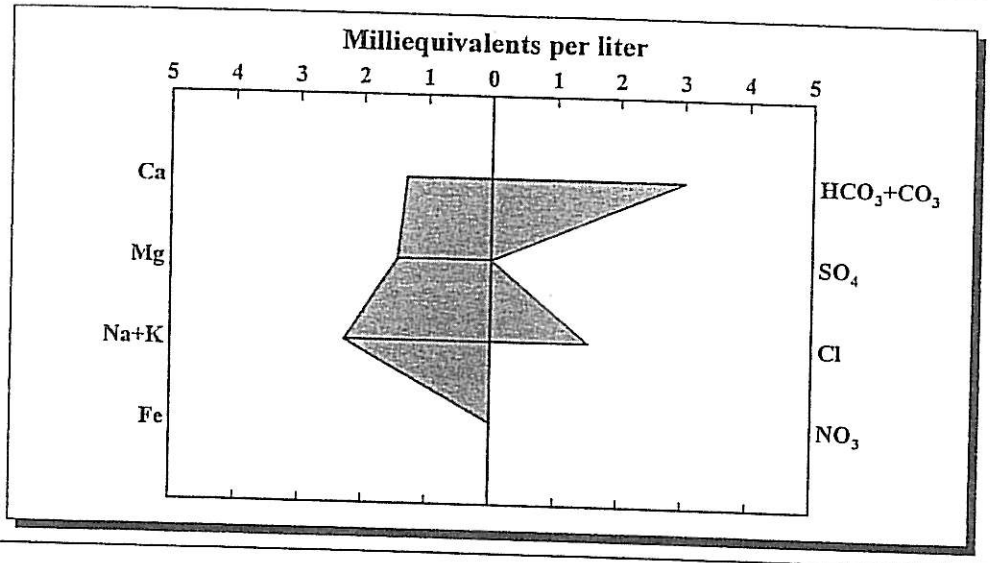
| *Water Type* | Cations (epm) | Anions (epm) |
|---|---|---|
| *Sodium Bicarbonate* | 6.20 | 5.57 |

| Aquifer | Error Balance (%) |
|---|---|
| | 5.35 |

| Well Ident |
|---|
| LBD01/99 |

## *STIFF Diagram*

| Name | Type |
|---|---|
| LIBODE GROUNDWATER INVESTIGATION | |




### *Cations*

| | *Ca* | *Mg* | *Na* | *K* | *Fe* |
|---|---|---|---|---|---|
| *Milliequivalents per liter* | 1.3323 | 1.4560 | 2.2750 | 0.01790 | 0.0070 |
| *Milligrams per liter* | 26.70 | 17.70 | 52.30 | 0.70 | 0.13 |

### *Anions*

| | *HCO3* | *CO3* | *SO4* | *Cl* | *NO3* |
|---|---|---|---|---|---|
| *Milliequivalents per liter* | 3.01576 | | 0.01041 | 1.53180 | |
| *Milligrams per liter* | 184.00 | | 0.50 | 54.30 | |

| BOD | COD | Dissolved Oxygen | F | B | SiO2 |
|---|---|---|---|---|---|
| TDS | Hardness 139.60 | Alkalinity 184.00 | Conductivity 53.50 | pH 6.86 | SAR 1.9268 |

| *Water Type* | Cations (epm) | Anions (epm) |
|---|---|---|
| *Sodium Bicarbonate* | 5.09 | 4.56 |

| Aquifer | Error Balance (%) |
|---|---|
| | 5.50 |

# Schoeller Diagram

Schoeller Diagram