DROUGHT RELIEF PROGRAM:
An Assessment of the Water Quality of Boreholes for Potable Use

January 1994 to October 1995

Summary Report 1
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INSTITUTE FOR WATER QUALITY STUDIES
DEPARTMENT OF WATER AFFAIRS AND FORESTRY

IWQS

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EXECUTIVE SUMMARY

An overview of the suitability for potable use of water from boreholes drilled for emergency water supply as part of the Drought Relief Programme, is presented in this report. Water quality was one of the important criteria that were taken into account when decisions on whether or not to equip the boreholes had to be made.

This report was produced in collaboration with Directorate of Geohydrology and summarises results of the assessment of the water quality of samples from boreholes that were analysed at the Institute for Water Quality Studies (IWQS) during the period January 1994 to October 1995. The report is the first of a series which will be issued at six monthly intervals until the Drought Relief Programme is completed.

The assessment of the potability of rural water supplies (where industrial pollution is unlikely to occur) is usually based on key microbiological, macro chemical and toxic heavy metal concentrations in the water. Logistical constraints prevented the collection of samples for microbiological and toxic metal analyses for this project. The assessment of the boreholes in terms potable use is thus solely based on the macro chemical constituents that are of primary concern to the domestic user. These constituents are: total dissolved solids, pH, nitrate, fluoride, magnesium, sulphate, sodium and chloride.

To make water quality information, as it affects decisions on the safety of the water, readily available to the manager, the IWQS developed a simple classification system. The system classifies the water quality into four classes ranging from Class 0 (excellent water quality) to Class III (poor water quality) which should not be used without treatment. Each class indicates the acceptability for potable use in terms of the effects on the user at a specific concentration range.

During the assessment period samples from 1131 boreholes were analysed. One hundred and eighty seven (187) boreholes had conflicting results where the analytical results of two or more samples taken at the same time at the same borehole did not correspond. These boreholes were not taken into account when a statistical analysis of the classification results was made because it was impossible to conclude without a doubt to which class the borehole actually belonged. To confirm the classification, resampling of the borehole was requested.

Therefore, 944 boreholes were assessed in terms of their suitability for domestic use. The boreholes are spread over several areas in the country namely:

PROVINCE	NUMBER OF BOREHOLES
Northern Province	450
Northern Cape	104
Western Cape	8
Eastern Cape	25
Kwazulu Natal	296
Mpumalanga	41
North West Province	20
Gauteng	0
Free State	0

A statistical analysis of the results indicated that:

- 26.3% of the boreholes were in Class III and are not suitable for potable use without treatment. Use of the water from these boreholes without prior treatment could have serious health effects on users, especially infants and elderly people.

- 28.4% of the boreholes were in Class II. These boreholes are suitable for short term, or emergency use only. The water from these boreholes could also affect the user's health adversely if used for an entire lifetime without treatment to remove the offending constituents from the water.

- 45.3% of the boreholes were in Class I and have good water quality suitable for lifetime use without treatment, on condition that the water quality does not change significantly due to landuse activities.

The above indicated that a significant percentage of the boreholes drilled for emergency water supply had poor water quality and are not suitable for drinking purposes. For this reason, the boreholes were not equipped even though, in some cases, the other factors were favourable for development. These boreholes may be utilised in future if the correct treatment is applied.

There are a number of issues that were not addressed in the Drought Relief Programme which should be attended to in future community water supply programmes viz.:

- Much more attention should be given to the water quality aspects during the planning stages of water supply projects. Quality assurance of the information is only possible if correct and standardised sampling, transport as well as analytical and data processing procedures are followed. Insufficient quality control especially in terms of sampling and sample handling procedures may be the main reason for the many conflicting results. It is therefore crucial to involve the Institute for Water Quality Studies right from the start in future projects.

- It is not possible to make conclusive statements on the safety of the boreholes for drinking water purposes without information on the microbiological and trace metal quality of the water. These parameters must in future be included in water quality monitoring programmes of community water supplies.

- Sustainable use of the source is only possible if the causes of poor water quality are known and properly managed. Water quality surveys should be conducted in such a way that information on landuse activities and other factors that may affect the quality of the water are obtained simultaneously.

The information contained in this report is of great significance to the Department. Apart from the above information, very little or no information is currently available on the quality of water sources used for domestic purposes by communities in rural areas. Since the information contained in this report could be regarded as representative of the water quality of boreholes that have been drilled prior to the onset of the drought relief programme, it gives, for the first time, a holistic picture of the quality of the groundwater sources used by rural communities.

Unfortunately, the picture is far from reassuring, because it is obvious that the health of many people in rural areas may be in jeopardy due to unacceptable water quality. It is, therefore, vitally important to do a detailed health related water quality survey of all water sources used by communities in the rural areas.

Reliable information is a pre-requisite for the sustained utilisation of water sources for community water supplies. The design and operation of effective water quality monitoring programme is a complex issue. Reliable information can only be produced if the programmes are well structured and tight quality control is exercised.

1. INTRODUCTION

The purpose of this report is to present an overview of the suitability for potable use of water from boreholes drilled for emergency water supply through the Drought Relief Programme. The programme was initiated by the Department of Water Affairs and Forestry in 1994 to alleviate the acute shortage of water for domestic use by communities in the rural areas, largely due to the severe drought that had been experienced in many parts of South Africa since the early 1990's.

Quality is as important as quantity in domestic water supply (WHO, 1993) so water samples were taken after the boreholes were drilled and sent to the Institute for Water Quality Studies (IWQS) for analyses and assessment in terms of suitability for potable use. This information was taken into account when decisions on whether or not to equip specific boreholes had to be made (Van Rooyen and Kotze 1995).

This report was done in collaboration with the Directorate of Geohydrology, and summarises the results of the assessment of the water quality of samples from boreholes that were analysed at the IWQS during the period January 1994 to October 1995. The report is the first of a series that will be issued at six monthly intervals until the Drought Relief Programme is completed.

Note that information on the factors that determine the quality of the borehole water are only discussed in general terms. No attempt is being made in this report to give an explanation as to the causes of the quality of the water of specific boreholes.

2. WATER QUALITY CONSTITUENTS OF CONCERN TO THE DOMESTIC USER

Water is used for a wide variety of activities in the domestic environment such as:

- Drinking (human being and domestic animals)
- Food preparation
- Washing of dishes
- Bathing (personal hygiene)
- Laundry
- Watering of edible crops (vegetables and fruits), flowers, trees

Water for potable use has generally the most stringent water quality requirements. The fitness for use of water for domestic purposes is therefore judged mostly in terms of its suitability for drinking.

The assessment of the potability of rural water supplies (where industrial pollution is unlikely to occur) is usually based on key microbiological, macro chemical and toxic heavy metal constituents in the water.

The microbiological quality of domestic water supplies is commonly assessed by means of microbiological indicators such as faecal coliforms. Indicator organisms are used because it is difficult and costly to detect the pathogens that cause water borne diseases such as cholera, gastro-enteritis, hepatitis and dysentery.

From the wealth of chemical constituents that may occur in water at concentrations which render the water unsafe to drink and a hazard to health, a few key chemical constituents (see Table 1 below) can be singled out that commonly occur in water at unsafe concentrations and that may therefore jeopardise the safety of a groundwater source in rural areas. These constituents may occur naturally in the water because of the local geology, or may be artificially introduced by human activities.

Table 1 Water Quality Constituents of particular concern to the domestic user

CONSTITUENT OF CONCERN	RELEVANCE TO DOMESTIC USER
Total dissolved salts (TDS)	Affects the taste of the water
pH	Affects taste and corrosivity of the water
Nitrate (NO_3)	Excessive amounts may be toxic to infants
Fluoride (F)	Excessive amounts result in loss of teeth and crippling skeletal abnormalities
Magnesium (Mg)	Excessive amounts give water a bitter taste
Sulphate (SO_4)	Excessive amounts cause diarrhoea
Sodium (Na) and Chloride (Cl)	Excessive amounts give a salty taste and can overload the salt balance mechanism of kidneys in infants

Apart from the above-mentioned macro chemical constituents there are several trace metals that may occur in unacceptable concentrations in the water due to the geological characteristics of an area. Trace metals that are of primary concern to the domestic user include, iron, manganese, cadmium, lead, mercury and arsenic.

NOTE: Logistical constraints prevented the collection of samples for microbiological and toxic metal analyses. Samples were taken by the drill operators, directly after the boreholes were drilled. The drilling sites were mostly far removed from towns or cities where proper laboratory facilities exist. Microbiological samples need to be kept cool (below $4^{\circ}C$) and analysed within 8 to 24 hours for good results, and trace metal samples also require special care, therefore, only samples for macro chemical analysis could be taken.
The water quality assessment of the boreholes in terms of potable use is thus solely based on the macro chemical constituents listed in Table 1.

3. FACTORS LINKING GEOLOGY TO QUALITY

Groundwater often occurs in association with geological materials containing soluble minerals, so higher concentrations of dissolved salts are normally expected in groundwater relative to surface water. The type and the concentration of salts depend on the geological environment, the source and the movement of the water. The geological setting is perceived to control the hydrochemical composition of groundwater but there are also numerous other processes and factors such as silicate hydrolysis, carbonate dissolution, ion-exchange and redox reactions which participate in the formation of what is understood as water quality. The mineral composition of the saturated medium is, thus, not necessarily the main controlling factor.

In many cases effects originating from soils and the unsaturated zone override possible influences from the saturated zone. This is especially the case with the constituents such as ammonia, nitrite and nitrate which can originate from the atmosphere, roots of legumes, plant debris and animal and human excrement. These constituents can be leached from the near-subsurface horizons to a water table during major recharge events. The lack of denitrifying mechanisms such as the availability of organic carbons can cause nitrate to accumulate in aquifer water. In relatively oxygenated aquifer systems nitrate can be generated by oxidation of other nitrogen species such as ammonia and nitrite. The mineral composition in this case is not the primary source of nitrate, but rather the aquifer system itself creates conditions for transport and accumulation of nitrate in combination with existing land use activities. Other important constituents such as sodium, calcium, magnesium, chloride, sulphate, bicarbonate and fluoride are, in the absence of pollution sources, believed to originate mainly from minerals present in the aquifer. However, weathering processes dominated by reactions of carbonic acid with minerals such as carbonates and silicates once again contribute significantly to the natural mineralization of groundwater. These processes are strongly influenced by climatic factors. The geologic medium in areas, therefore, does not independently act as a source of constituents, since hydraulic parameters determine the dynamics and direction of mineralization processes of groundwater. The relative abundance of constituents, dissolved in groundwater at concentrations that could be expected under natural conditions, are given in Table 2 below (Chapman,1992).

Table 2 Relative abundance of dissolved constituents in groundwater

Major Constituents (1.0 to 1000 mg/*l*)	**Secondary Constituents (0.01 - 10.0 mg/*l*)**	**Minor Constituents (0.0001 - 0.1 mg/*l*)**
Sodium	Iron	Arsenic
Calcium	Aluminium	Barium
Magnesium	Potassium	Bromide
Bicarbonate	Carbonate	Cadmium
Sulphate	Nitrate	Chromium
Chloride	Fluoride	Cobalt
Silica	Boron	Copper
	Selenium	Iodide
		Lead
		Lithium
		Manganese
		Nickel
		Phosphate
		Strontium
		Uranium
		Zinc

Source: After Todd, 1980

4. HEALTH EFFECTS OF KEY MACRO CHEMICAL CONSTITUENTS

A more detailed description of the health effects of the key chemical constituents is given below to aid the reader in the interpretation of the assessment results.

1) Total dissolved salts (TDS):

High salt concentrations in water are not only aesthetically unpleasing but can also be detrimental to the health of consumers. The concentration of sodium chloride in sea water is approximately 35 000 mg/*l*, or a 3,5%(m/v) salt concentration. The concentration of salt in serum in the body is around 0,9% (isotonic solution) i.e., 9000 mg/*l*, or one quarter the sodium chloride concentration of sea water. The relatively high concentration of salt in serum and blood is the reason why blood tastes very salty. To absorb water from the stomach, the salt concentration must be lower than that of the serum, otherwise water is abstracted from the body. A human being cannot survive on sea water, and will become more thirsty and dehydrated if he or she attempts to drink sea water. The isotonic concentration of 9000 mg/*l* provides a ceiling above which water is not absorbed by the body.

Water is readily absorbed where the salt concentration is a quarter or less of the isotonic concentration. A pleasant tasting water generally has a salt concentration a tenth or less of the isotonic value i.e., 900 mg/*l* or less. This is the underlying reason for the WHO guideline that the TDS of water should preferably be less than 1000 mg/*l*. As the 1000 mg/*l* ideal is exceeded the water tastes progressively more salty.
Salt concentrations above a quarter of the isotonic value (2250 mg/*l*) will have a pronounced salty taste. Concentrations above this value to about half the isotonic value (i.e., up to 4500 mg/*l*) can still be consumed by healthy adult individuals, but will have a very salty taste.

Individuals whose kidneys are not functioning optimally are at greater risk, and adverse health effects can be more frequent on drinking such saline water (TDS greater than 2450 mg/*l*). High TDS concentrations (> 2500 mg/*l*) may also pose a greater danger of dehydration and salt overload in infants, especially where they contract gastro-enteritis and diarrhoea, and in the elderly, particularly where high blood pressure and renal disease already exists.

2) Electrical conductivity (EC):

The electrical conductivity is a more convenient way to measure TDS and is generally determined on site with a portable meter. It is directly related to the TDS where the "average" conversion factor is 6,5 mg/*l* per mS/m electrical conductivity. The factor used here was 6,67.

3) <u>Nitrate plus nitrite as N</u> ($NO_3 + NO_2$ as N):

Elevated nitrate concentrations can cause methaemoglobineamia or *blue baby syndrome*. Infant methaemoglobinaemia has been described when nitrate-nitrogen concentrations of drinking water were between 6 and 10 mg/*l* nitrate as N, but this is extremely rare. Between 10 and 20 mg/*l* nitrate as N, the *blue baby syndrome* may occur, but is the exception rather than the rule. Above 20 mg/*l* there is a real danger of the occurrence of the *blue baby syndrome* especially if the following combination of circumstances occur:

i) The infant is i)under 2 years of age, ii) usually bottle fed rather than breast fed, and iii) suffering from iron deficiency anaemia, iv) with an unusual, nitrate reducing intestinal flora, and v) probably with a degree of achlorhydria (insufficient stomach acidity).

4) <u>Fluoride</u> (F):

Fluoride is a very interesting element from a physiological and metabolic viewpoint because it is a very reactive element, interacting with many of the transition metals. Fluoride, in small amounts, hardens teeth with the formation of fluoro-apatite in the tooth. However, when excessive concentrations of fluoride are ingested, the tooth enamel becomes discoloured and softens with the teeth rotting away. The bony skeleton of man and animals also hardens and spontaneous fractures occur, particularly in the vertebral column, with vertebral collapse and crippling. This crippling is most recognised in farm animals such as cows consuming water with a fluoride concentration in excess of 12 mg/*l*.

Many other elements affect the outcome of elevated intakes of fluoride. They may increase the resistance or making the individual more susceptible to the side effects. Some of the elements which interact with fluoride are:

Aluminium; It has been well demonstrated that intake of aluminium with fluoride will partially protect against the toxic effects of fluoride at moderate intakes (up to about 3,5 mg/*l*) by reducing absorption of the fluoride through the formation of a fluoride aluminium complex.

Manganese; It can complex fluoride and also reduce its availability. This happens in the case of tea, which contains a fair amount of fluoride and manganese. In the same way excess fluoride can induce a relative manganese deficiency, resulting in some of the symptoms of manganese deficiency such as joint and cartilage abnormalities. Part of the mechanism of fluoride toxicity on joint integrity may be mediated through an induced manganese deficiency.

Zinc; It is required for normal growth, and especially for the integrity of the immunological system. Excess fluoride can lead to an induced zinc deficiency, with the consequent detrimental effects of an impaired system, and increased susceptibility to infection.

In summary: The beneficial effect of fluoride in hardening tooth enamel in the growing phase is seen at low fluoride concentrations, usually between 0,7 and 1,0 mg/*l*. In the intermediate concentration level of 1,5 to 4,0 mg/*l* mild detrimental effects are usually seen, most evident in staining of the teeth. Above the concentration of 4,0 mg/*l* the many detrimental effects of fluoride are often seen with long term use. These are both direct effects of toxicity in terms of interfering with bone structure and integrity, as well as the secondary trace nutrient deficiencies induced for a number of the essential trace metals.

5) Sulphate (SO_4):

Sulphate in concentrations of 400 to 600 mg/*l* may cause a transient diarrhoea in some new users. However, at this concentration adaptation rapidly occurs, and water containing sulphate at such levels can be consumed for long periods without detrimental effect. Above 600 mg/*l* the initial diarrhoea will most likely be more severe, and adaptation will not occur so readily, although there is always a measure of adaptation to increased sulphate intakes with prolonged intake. At levels above 600 mg/*l*, even as high as 1000 mg/*l* there may very well be complete adaptation in some individuals. However, sensitive individuals, particularly infants, may experience chronic diarrhoea at such high sulphate concentrations.

6) Magnesium (Mg):

Magnesium up to 200 mg/*l* will only have aesthetic effects, and will impart a distinct bitter taste to water above 100 mg/*l*. At concentrations of 200 to 300 mg/*l* the main effect will still be the bitter taste, however, there will be a tendency to diarrhoea in sensitive individuals, particularly infants, and especially if the magnesium is found in the water as magnesium sulphate ("Epsom salts").

7) Sodium (Na):

In healthy adults sodium concentrations of up to 600 to 700 mg/*l* will have primarily taste effects. However, in persons with impaired kidney function, who are unable to excrete the excess sodium, the sodium loading can elevate blood pressure and thus exacerbate an already abnormal situation. Healthy adults can tolerate high levels of sodium, especially for short periods, without ill effect. However, infants are at risk from sodium overload, and an increase in the infant mortality rate from diarrhoeal disease may be observed when the sodium concentration in water is greater than 400 mg/*l*.

8) Chloride (Cl):

The comments for chloride are analogous to those for sodium, i.e., that the persons at risk with concentrations above 600 mg/*l* are infants and certain adults, namely those with high blood pressure, requiring a salt restricted diet.

9) pH:

Water with a pH less than 4 usually has a sour taste. Further, there is the danger that metals may be dissolved from the distribution system, with possible toxic effects. Corrosion problems are likely to be severe at acidic pH values below 4 units.

In alkaline water, with a pH above 10, free hydroxide is present, and an irritation of the mucous membranes will be marked. In addition the water will taste soapy.

5. SAMPLE HANDLING AND ANALYSIS AND FLOW OF INFORMATION

Water samples for macro chemical analysis were collected at each borehole after the borehole was drilled and developed, i.e. during the blow test and/or during the pumping tests. The water samples collected could either be mailed to IWQS or hand delivered to the Directorate of Geohydrology. All samples received by post at the IWQS were sent by hand to Geohydrology for identification purposes. At Geohydrology a unique sample point number was allocated to each borehole and the "header information" (all the information required to link a specific sample to the sampling point) was logged into the Geohydrology database. All samples supplied with correct identification numbers were thereafter delivered to IWQS for analysis. The header information on Geohydrology's data base was sent to the Laboratory Information Management System (LIMS) at IWQS via Govnet.

Samples were analysed for a basic set of macro chemical constituents (pH, fluoride, nitrate, sulphate, chloride, sodium, magnesium, total dissolved solids (TDS), electrical conductivity (EC), phosphate, ammonium, calcium, alkalinity and silica) in the laboratory according to standard analytical procedures. The results were transferred to the Water & Sanitation database (created in the LIMS) where they were linked with the rest of the "header information" from the Geohydrology database. The results were simultaneously sent to the Hydrological Information System (HIS) via Govnet and then to the Geohydrology database where the data is stored.

At IWQS an assessment of the suitability for potable use was made according to a simple classification system (described in Section 5 below).

SAMPLE HANDLING, ANALYSIS AND FLOW OF INFORMATION. *cont.*

Each weekday a data sheet containing the classified water quality information of all samples taken at a specific borehole (a borehole "Water Quality Report") was downloaded from the LIMS database. These reports were compiled, checked for anomalies and sent to Geohydrology once a week. At the same time the information was sent to the DWAF Regional Offices.

The Directorate of Geohydrology is responsible for communicating the reports to the engineers in the provinces. All recommendations and actions are carried out by geologists and engineers. A flowchart summarising sampling, handling and analysis as well as the flow of information is shown in Figure 1.

NOTE:

HIS = Hydrological Information System
Govnet = Government computer network
LIMS = Laboratory Information Management System

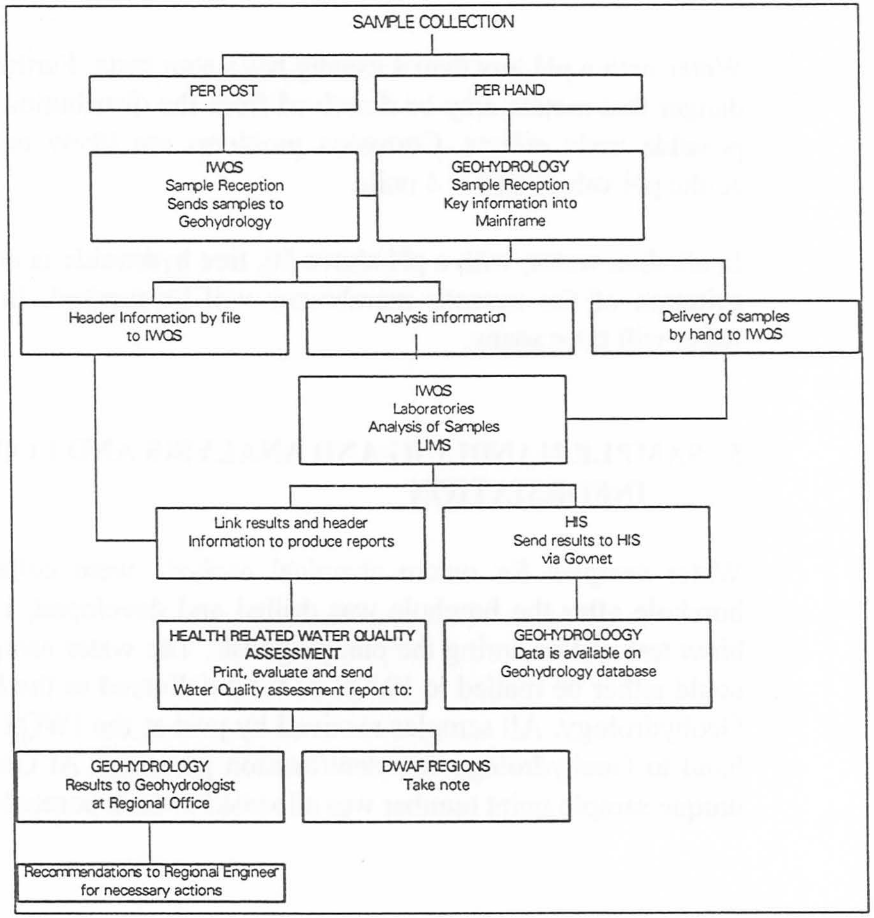


Figure 1: The schematic route followed by drought relief water samples

6. WATER QUALITY ASSESSMENT CRITERIA

A simple classification system was developed at the IWQS for the assessment of the potability of borehole water. This classification system makes water quality information, as it affects decisions on the safety of the water, readily available to the manager.

The system classifies the water quality into four classes. Each class indicates the acceptability for potable use in terms of the effects on the user at a specific concentration range namely:

Class 0: Ideal water quality suitable for life time use (multiple generation use) and has no detrimental effects.

Class I: In this range of concentration the key constituent has no detrimental effects on health either in the short or the long term, and is suitable for use for an entire lifetime. This class of water quality is also safe.

Class II: In this range of concentration, health effects may occur with long term use, but in the short term detrimental health effects are either mild or rare. This class is essentially the concentration acceptable for short term or emergency use.

Class III: This is the concentration range where serious health effects may be anticipated, particularly in infants with short term use. The water quality in this class is not suitable for use unless it is treated.

The class guideline categories for the assessment of water for domestic use for the basic key constituents are given in Table 3.

Table 3 Provisional class guideline categories for the assessment of the borehole water for fitness for potable use. Concentrations in mg/*l* unless otherwise indicated.

Constituent	Class 0	Class I	Class II	Class III
Total dissolved salts	0 - 450	450 - 1000	1000 - 2450	> 2450
Electrical,conductivity (mS/m)	0 - 70	70 - 150	150 - 370	> 370
Nitrate plus nitrite as N	0 - 6	6 - 10	10 - 20	> 20
Fluoride	0 - 1.0	1.0 - 1.5	1.5 - 4.0	> 4.0
Sulphate	0 - 200	200 - 400	400 - 600	> 600
Magnesium	0 - 30	30 - 70	70 - 100	> 100
Sodium	0 - 100	100 - 200	200 - 400	> 400
Chloride	0 - 100	100 - 200	200 - 600	> 600
pH (pH units)	6.0 - 9.0	5 - 6 or 9 - 9.5	4 - 5 or 9.5 - 10	< 4 or > 10

The criteria used to classify a borehole in a specific class are as follows:

- If the concentration of any constituent for any sample for a specific borehole falls in Class III, the borehole is classified as a Class III borehole.

- If the concentration of any constituent for any sample for a specific borehole falls in Class II, and none in Class III, the borehole is classified as a Class II borehole.

- The upper value of Class I was used as the cut off value to determine whether a borehole would fall in Class I and also include Class 0 which is the ideal water quality.

7. RESULTS

During the assessment period (January 1994 to October 1995) samples from 1131 boreholes drilled in drought stricken areas were analysed. One hundred and eighty-seven (187) boreholes had conflicting results since the analytical results of two or more samples taken at the same time at the same borehole did not correspond. These boreholes were not taken into account when a statistical analysis of the classification results was made. It was impossible to determine without a doubt to which class the borehole actually belonged. To confirm the classification, resampling of the borehole was requested.

Therefore, 944 boreholes were assessed in terms of their suitability for domestic use. Of the 944 boreholes, spread over several areas in the country,

PROVINCE	NUMBER OF BOREHOLES
Northern Province	450
Northern Cape	104
Western Cape	8
Eastern Cape	25
Kwazulu Natal	296
Mpumalanga	41
North West Province	20
Gauteng	0
Free State	0

According to the classification system, out of the 945 boreholes:

- 45.3% of the boreholes were in Class I
- 28.4% of the boreholes were in Class II
- 26.3% of the boreholes were in Class III.

The results of the provinces are presented in table and graphical format from page 12 onwards.
The raw data for each borehole is listed in Appendix A. The assessment reports provide full macro chemical analysis results for the boreholes, and include constituents not relevant to the health classification *per se* such as calcium (Ca), phosphorus (P), silicon (Si), potassium (K), ammonium (NH_4) and total alkalinity (TAL).

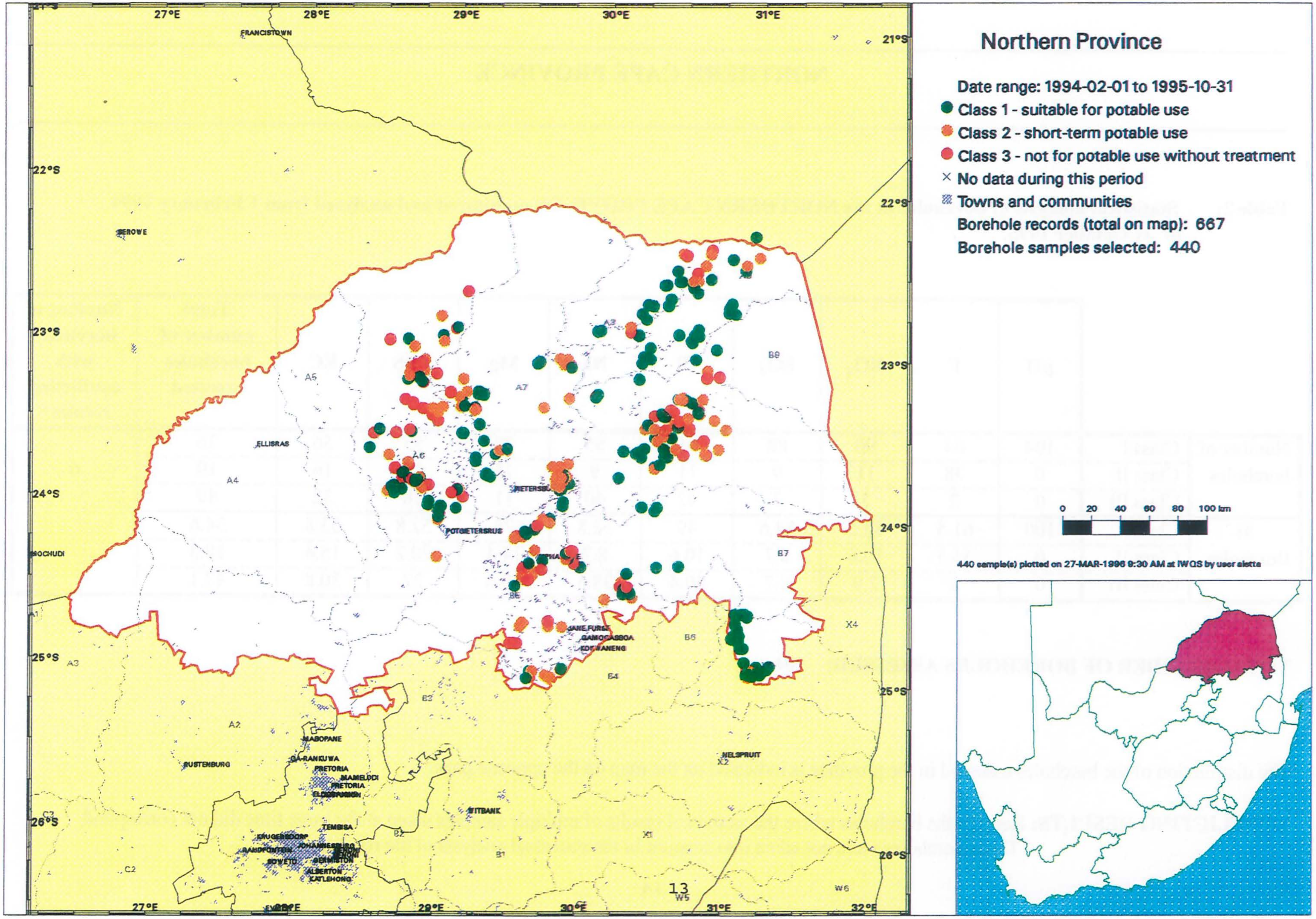
Table 1: **Statistical analysis of boreholes in the NORTHERN PROVINCE monitored and analysed from 1 February 1994 to 31 October 1995.**

		pH	F	NO_3	SO_4	Cl	Na	Mg	TDS	EC	Total number of boreholes assessed	Number of boreholes with conflicting results *
Number of boreholes	Class I	449	392	332	449	364	400	407	327	357	233	97
	Class II	1	47	64	1	67	39	35	114	84	136	
	Class III	0	11	54	0	19	11	8	9	9	81	
% Boreholes	Class I	99.8	87.1	73.8	99.8	80.9	88.9	90.4	72.7	79.3	51.8	
	Class II	0.2	10.4	14.2	0.2	14.9	8.6	7.8	25.3	18.7	30.2	
	Class III	0	2.5	12	0	4.2	2.5	1.8	2	2	18	

TOTAL NUMBER OF BOREHOLES ASSESSED: 450

The distribution of the boreholes assessed in the province is indicated on the map on the opposite page.

CONFLICTING RESULTS: Refer to the boreholes where the analytical results of multiple samples taken at the same time did not correspond. These boreholes were not taken into account in the statistical analysis of the results.


Northern Province
Date range: 1994-02-01 to 1995-10-31
Class 1 - suitable for potable use
Class 2 - short-term potable use
Class 3 - not for potable use without treatment
No data during this period
Towns and communities
Borehole records (total on map): 667
Borehole samples selected: 440
0 20 40 60 80 100 km
440 sample(s) plotted on 27-MAR-1996 9:30 AM at IWQS by user aletta
27°E
28°E
29°E
30°E
31°E
32°E
21°S
22°S
23°S
24°S
25°S
26°S
FRANCISTOWN
SEROWE
ELLISRAS
POTGIETERSRUS
PIETERSBURG
MOCHUDI
RUSTENBURG
MABOPANE
GA-RANKUWA
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SOWETO
ALBERTON
KATLEHONG
NELSPRUIT
JANE FURSE
A4
A5
A6
A7
A9
B9
B7
B6
B4
B3
A2
A3
X4
X2
X1
B1
B2
C2
W6

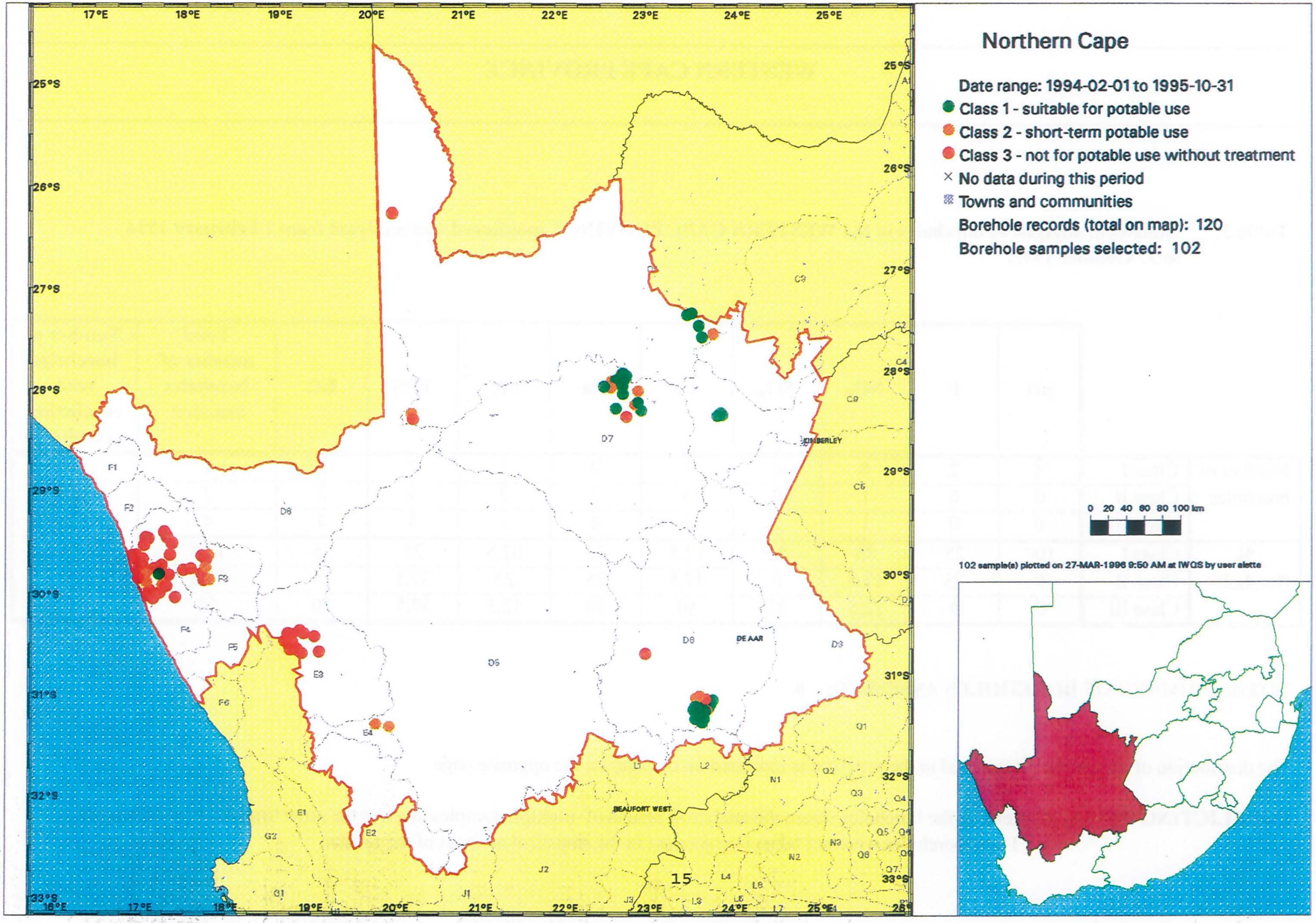
Table 2: **Statistical analysis of boreholes in the NORTHERN CAPE PROVINCE monitored and analysed from 1 February 1994 to 31 October 1995.**

		pH	F	NO_3	SO_4	Cl	Na	Mg	TDS	EC	Total number of boreholes assessed	Number of boreholes with conflicting results *
Number of boreholes	Class I	104	64	90	88	51	55	78	55	56	36	6
	Class II	0	38	11	9	11	9	15	21	16	19	
	Class III	0	2	3	7	42	40	11	28	32	49	
% Boreholes	Class I	100	61.5	86.5	84.6	49	52.8	75	52.8	53.8	34.6	
	Class II	0	36.5	10.6	8.7	10.6	8.7	14.4	20.2	15.4	18.3	
	Class III	0	2	2.9	6.7	40.4	38.5	10.6	27	30.8	47.1	

TOTAL NUMBER OF BOREHOLES ASSESSED: 104

The distribution of the boreholes assessed in the province is indicated on the map on the opposite page.

CONFLICTING RESULTS: Refer to the boreholes where the analytical results of multiple samples taken at the same time did not correspond. These boreholes were not taken into account in the statistical analysis of the results.


Northern Cape
Date range: 1994-02-01 to 1995-10-31
Class 1 - suitable for potable use
Class 2 - short-term potable use
Class 3 - not for potable use without treatment
No data during this period
Towns and communities
Borehole records (total on map): 120
Borehole samples selected: 102
0 20 40 60 80 100 km
102 sample(s) plotted on 27-MAR-1996 9:50 AM at IWQS by user aletta
KIMBERLEY
DE AAR
BEAUFORT WEST
17°E
18°E
19°E
20°E
21°E
22°E
23°E
24°E
25°E
25°S
26°S
27°S
28°S
29°S
30°S
31°S
32°S
33°S

WESTERN CAPE PROVINCE

Table 3: Statistical analysis of boreholes in the WESTERN CAPE PROVINCE monitored and analysed from 1 February 1994 to 31 October 1995.

		pH	F	NO_3	SO_4	Cl	Na	Mg	TDS	EC	Total number of boreholes assessed	Number of boreholes with conflicting results *
Number of boreholes	Class I	8	2	6	6	1	2	5	2	2	1	
	Class II	0	6	1	0	3	2	2	3	2	3	5
	Class III	0	0	1	2	4	4	1	3	4	4	
% Boreholes	Class I	100	25	75	75	12.5	25	62.5	25	25	12.5	
	Class II	0	75	12.5	0	37.5	25	25	37.5	25	37.5	
	Class III	0	0	12.5	25	50	50	12.5	37.5	50	50	

TOTAL NUMBER OF BOREHOLES ASSESSED: 8

The distribution of the boreholes assessed in the province is indicated on the map on the opposite page

CONFLICTING RESULTS: Refer to the boreholes where the analytical results of multiple samples taken at the same time did not correspond. These boreholes were not taken into account in the statistical analysis of the results.

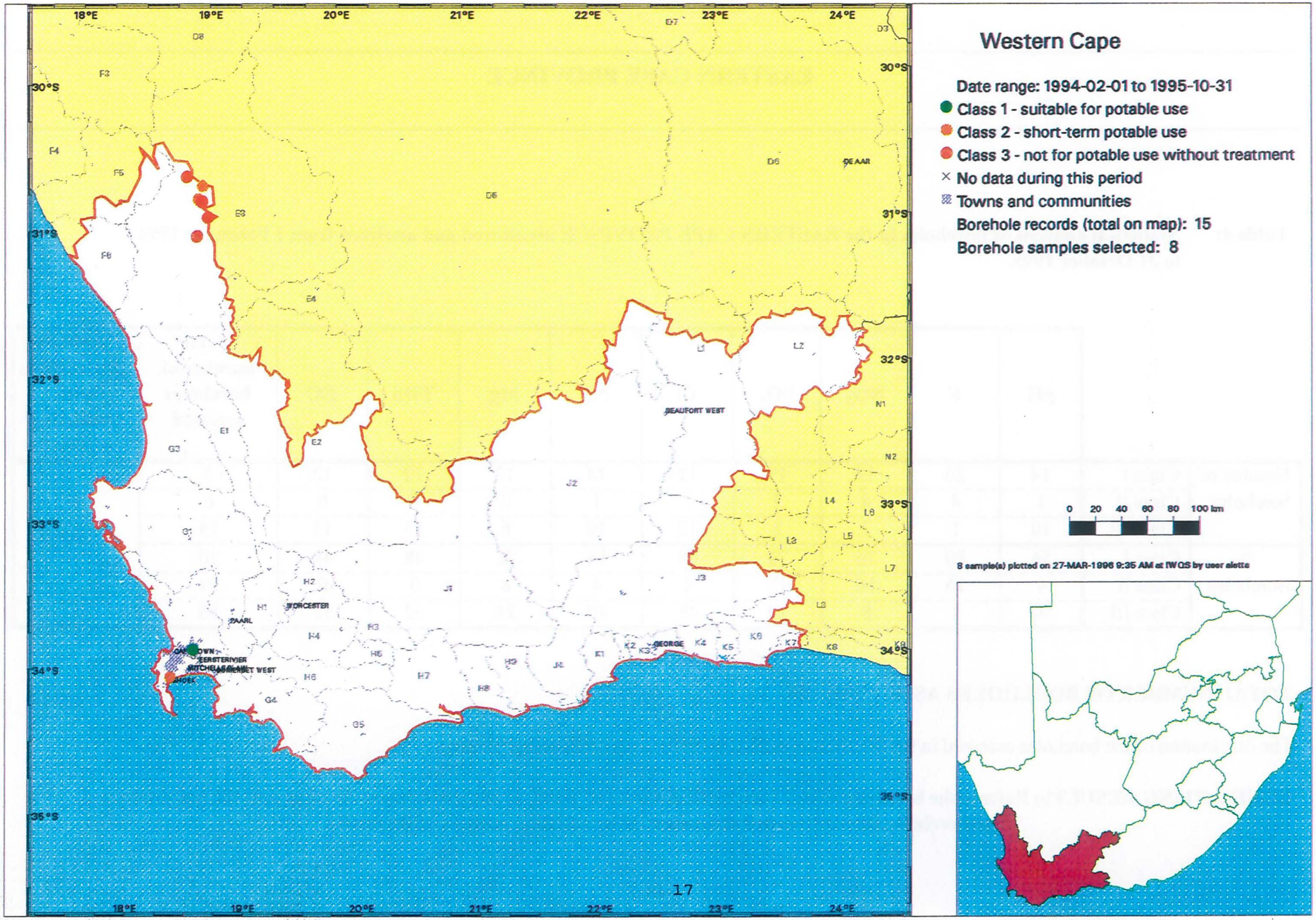

Western Cape
Date range: 1994-02-01 to 1995-10-31
Class 1 - suitable for potable use
Class 2 - short-term potable use
Class 3 - not for potable use without treatment
No data during this period
Towns and communities
Borehole records (total on map): 15
Borehole samples selected: 8
0 20 40 60 80 100 km
8 sample(s) plotted on 27-MAR-1996 9:35 AM at IWQS by user aletta
18°E
19°E
20°E
21°E
22°E
23°E
24°E
30°S
31°S
32°S
33°S
34°S
35°S
BEAUFORT WEST
DE AAR
WORCESTER
PAARL
GEORGE
EERSTERIVIER

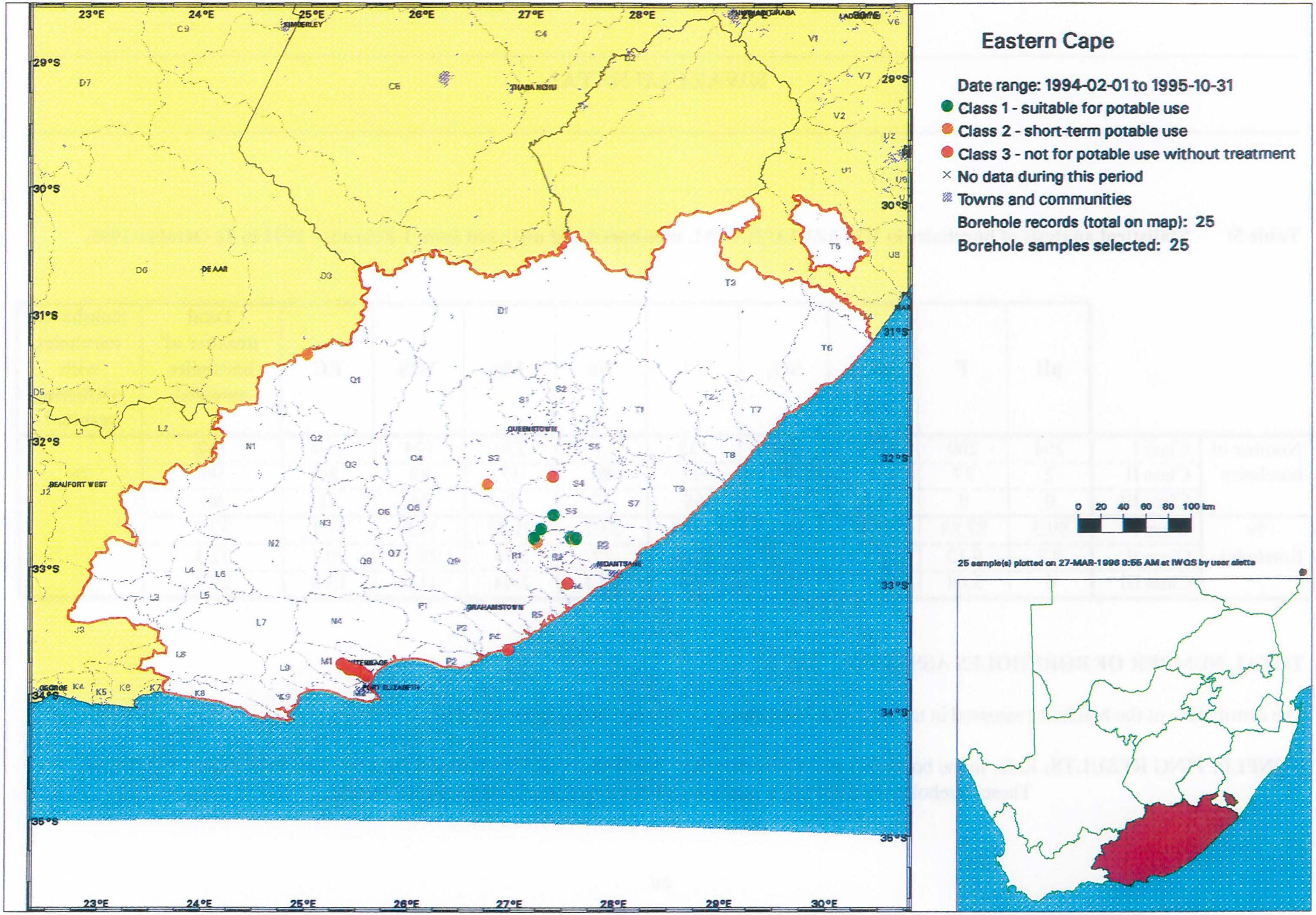
Table 4: **Statistical analysis of boreholes in the EASTERN CAPE PROVINCE monitored and analysed from 1 February 1994 to 31 October 1995.**

		pH	F	NO_3	SO_4	Cl	Na	Mg	TDS	EC	Total number of boreholes assessed	Number of boreholes with conflicting results *
Number of boreholes	Class I	14	20	19	19	12	14	17	12	12	5	0
	Class II	1	4	4	3	1	1	2	0	0	6	
	Class III	10	1	2	3	12	10	6	13	13	14	
% Boreholes	Class I	56	80	76	76	48	56	68	48	48	20	
	Class II	4	16	16	12	4	4	8	0	0	24	
	Class III	40	4	8	12	48	40	24	52	52	56	

TOTAL NUMBER OF BOREHOLES ASSESSED: 25

The distribution of the boreholes assessed in the province is indicated on the map on the opposite page.

CONFLICTING RESULTS: Refer to the boreholes where the analytical results of multiple samples taken at the same time did not correspond. These boreholes were not taken into account in the statistical analysis of the results.


Eastern Cape
Date range: 1994-02-01 to 1995-10-31
Class 1 - suitable for potable use
Class 2 - short-term potable use
Class 3 - not for potable use without treatment
No data during this period
Towns and communities
Borehole records (total on map): 25
Borehole samples selected: 25
0 20 40 60 80 100 km
25 sample(s) plotted on 27-MAR-1996 9:55 AM at IWQS by user aletta
23°E
24°E
25°E
26°E
27°E
28°E
29°E
30°E
29°S
30°S
31°S
32°S
33°S
34°S
35°S
36°S
KIMBERLEY
THABA NCHU
DE AAR
BEAUFORT WEST
QUEENSTOWN
GRAHAMSTOWN
MDANTSANE
UITENHAGE
PORT ELIZABETH
GEORGE

KWAZULU NATAL

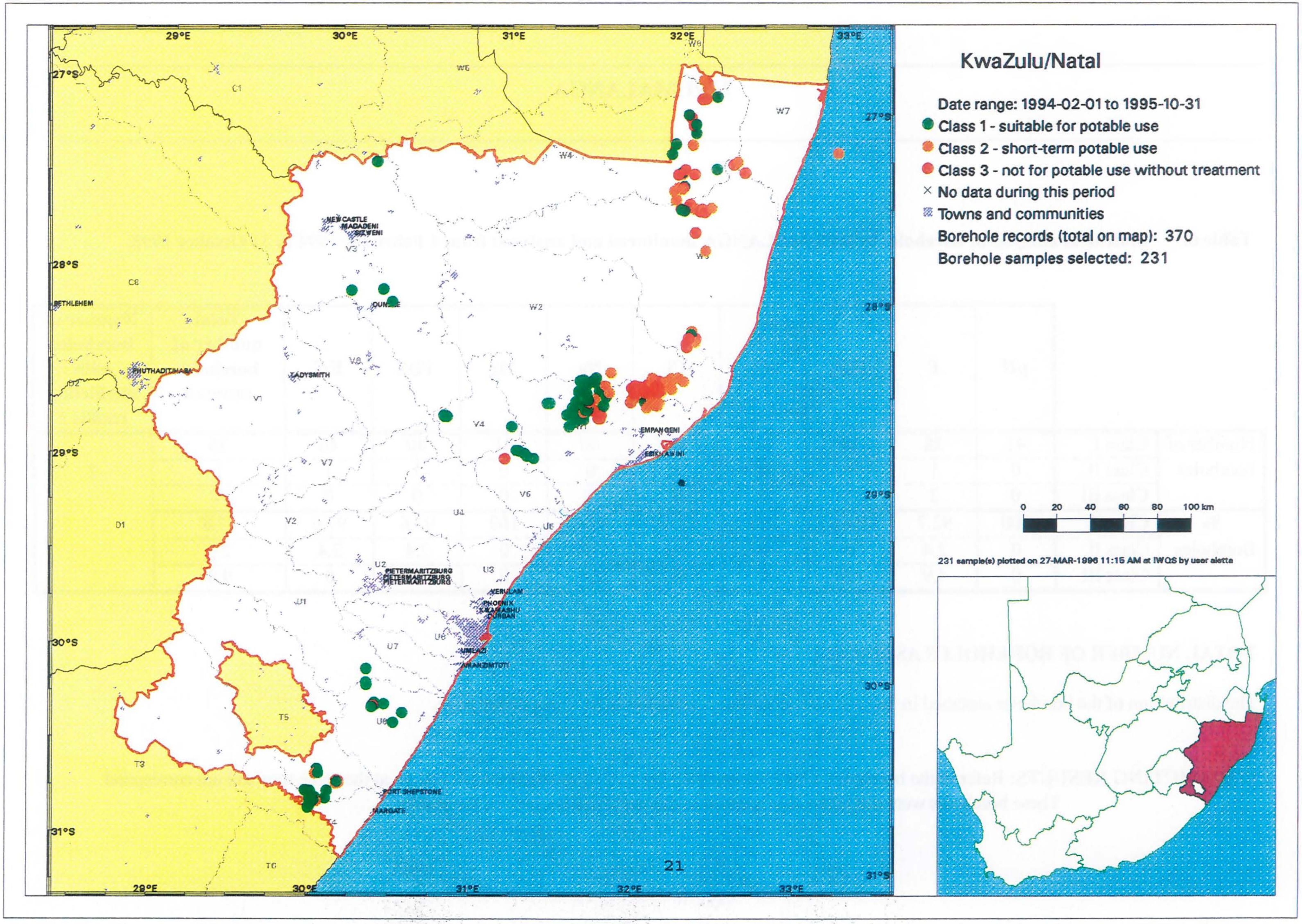
Table 5: Statistical analysis of boreholes in KWAZULU NATAL monitored and analysed from 1 February 1994 to 31 October 1995.

		pH	F	NO_3	SO_4	Cl	Na	Mg	TDS	EC	Total number of boreholes assessed	Number of boreholes with conflicting results *
Number of boreholes	Class I	294	260	275	291	132	159	270	174	169	112	76
	Class II	2	27	4	3	96	80	17	88	86	96	
	Class III	0	9	17	2	68	57	9	34	41	88	
% Boreholes	Class I	99.3	87.84	92.9	98.3	44.6	53.7	91.22	58.8	57.1	37.9	
	Class II	0.7	9.12	1.4	1.0	32.4	27	5.74	29.7	29.1	32.4	
	Class III	0	3.04	5.7	0.7	23	19.3	3.04	11.5	13.8	29.7	

TOTAL NUMBER OF BOREHOLES ASSESSED: 296

The distribution of the boreholes assessed in the province is indicated on the map on the opposite page.

CONFLICTING RESULTS: Refer to the boreholes where the analytical results of multiple samples taken at the same time did not correspond. These boreholes were not taken into account in the statistical analysis of the results.


KwaZulu/Natal
Date range: 1994-02-01 to 1995-10-31
Class 1 - suitable for potable use
Class 2 - short-term potable use
Class 3 - not for potable use without treatment
No data during this period
Towns and communities
Borehole records (total on map): 370
Borehole samples selected: 231
0 20 40 60 80 100 km
231 sample(s) plotted on 27-MAR-1996 11:15 AM at IWQS by user aletta
29°E
30°E
31°E
32°E
33°E
27°S
28°S
29°S
30°S
31°S
NEWCASTLE
MADADENI
BETHLEHEM
PHUTHADITJHABA
LADYSMITH
EMPANGENI
ESIKHAWINI
PIETERMARITZBURG
VERULAM
PHOENIX
DURBAN
UMLAZI
AMANZIMTOTI
PORT SHEPSTONE
MARGATE

MPUMALANGA

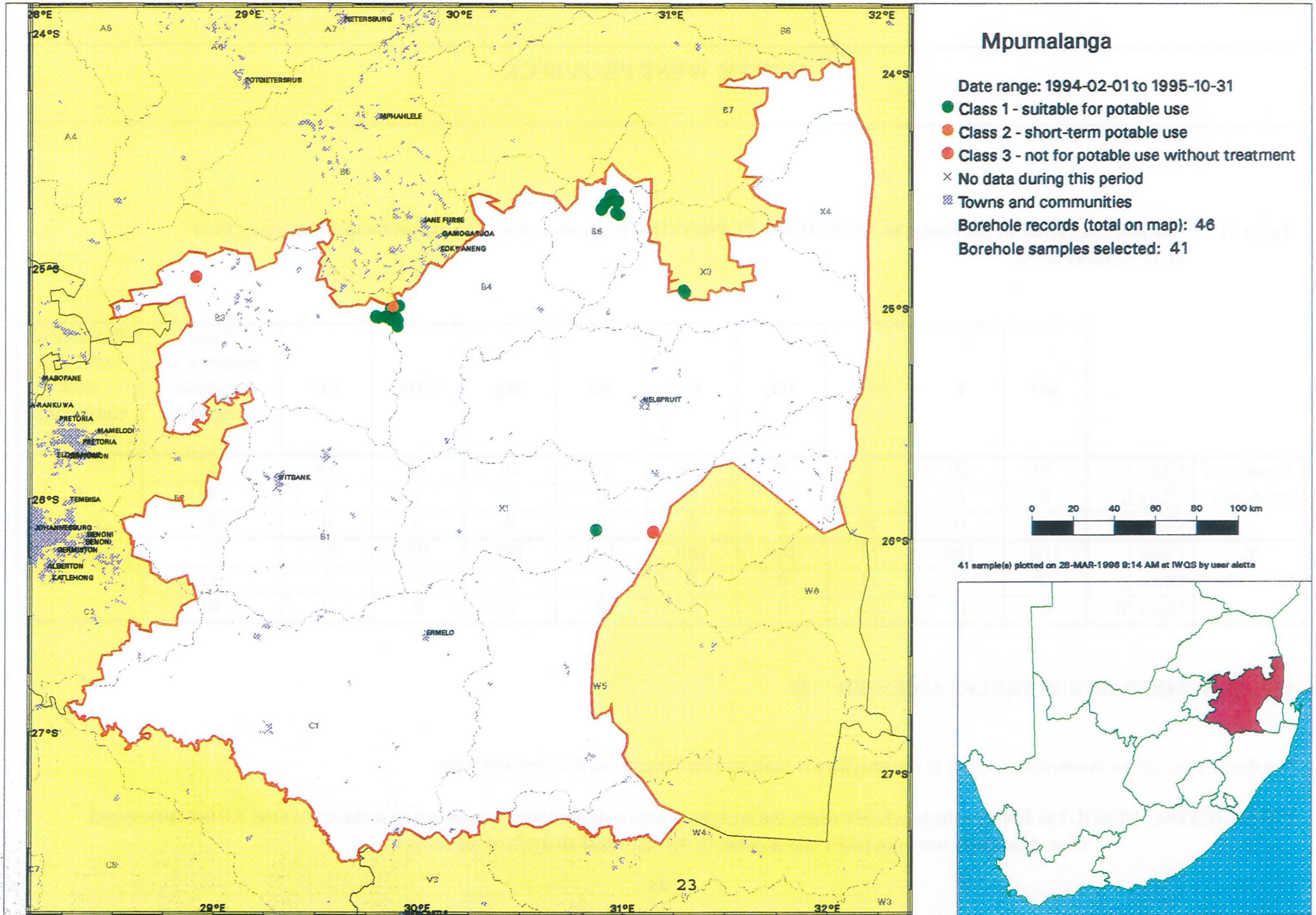
Table 6: Statistical analysis of boreholes in MPUMALANGA monitored and analysed from 1 February 1994 to 31 October 1995.

		pH	F	NO_3	SO_4	Cl	Na	Mg	TDS	EC	Total number of boreholes assessed	Number of boreholes with conflicting results *
Number of boreholes	Class I	41	38	39	41	40	40	41	40	40	36	2
	Class II	0	1	0	0	1	0	0	1	1	1	
	Class III	0	2	2	0	0	1	0	0	0	4	
% Boreholes	Class I	100	92.7	95.1	100	97.6	97.6	100	97.6	97.6	87.8	
	Class II	0	2.4	0	0	2.4	0	0	2.4	2.4	2.4	
	Class III	0	4.9	4.9	0	0	2.4	0	0	0	9.8	

TOTAL NUMBER OF BOREHOLES ASSESSED: 41

The distribution of the boreholes assessed in the province is indicated on the map on the opposite page.

CONFLICTING RESULTS: Refer to the boreholes where the analytical results of multiple samples taken at the same time did not correspond. These boreholes were not taken into account in the statistical analysis of the results.


Mpumalanga
Date range: 1994-02-01 to 1995-10-31
Class 1 - suitable for potable use
Class 2 - short-term potable use
Class 3 - not for potable use without treatment
No data during this period
Towns and communities
Borehole records (total on map): 46
Borehole samples selected: 41
0 20 40 60 80 100 km
41 sample(s) plotted on 28-MAR-1996 9:14 AM at IWQS by user aletta
28°E
29°E
30°E
31°E
32°E
24°S
25°S
26°S
27°S
PIETERSBURG
POTGIETERSRUS
MPHAHLELE
JANE FURSE
KOKWANENG
NELSPRUIT
WITBANK
ERMELO
MABOPANE
PRETORIA
MAMELODI
TEMBISA
JOHANNESBURG
BENONI
GERMISTON
ALBERTON
KATLEHONG
A4
A5
A6
A7
B3
B4
B5
B6
B7
B8
B1
X1
X2
X3
X4
W4
W5
W6
W3
V3
C1
C2
C5
C7

NORTH WEST PROVINCE

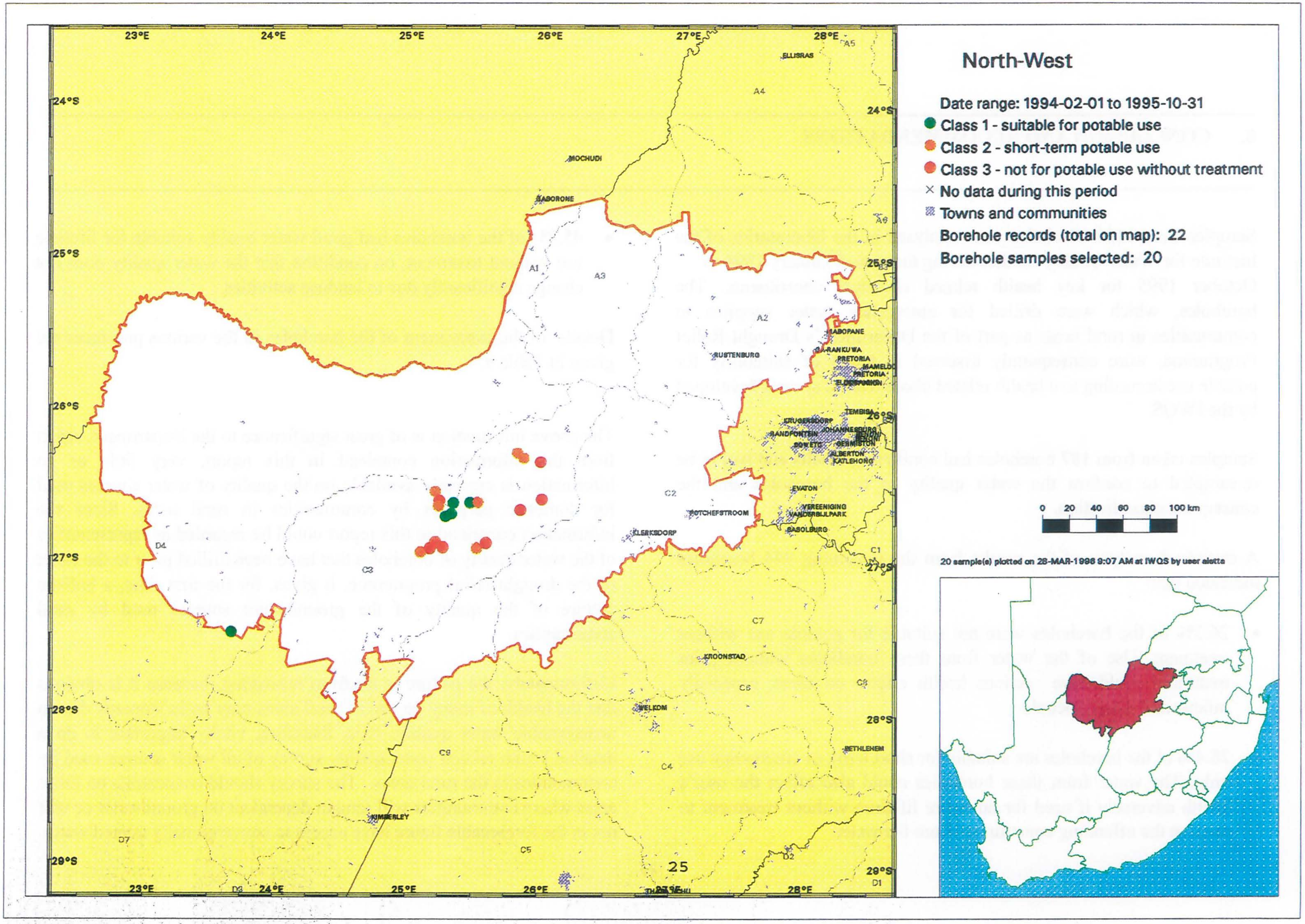
Table 7: Statistical analysis of boreholes in NORTH WEST PROVINCE monitored and analysed from 1 February 1994 to 31 October 1995.

		pH	F	NO_3	SO_4	Cl	Na	Mg	TDS	EC	Total number of boreholes assessed	Number of boreholes with conflicting results *
Number of boreholes	Class I	20	20	5	20	20	20	20	19	19	5	1
	Class II	0	0	7	0	0	0	0	1	1	7	
	Class III	0	0	8	0	0	0	0	0	0	8	
% Boreholes	Class I	100	100	25	100	100	100	100	95	95	25	
	Class II	0	0	35	0	0	0	0	5	5	35	
	Class III	0	0	40	0	0	0	0	0	0	40	

TOTAL NUMBER OF BOREHOLES ASSESSED: 20

The distribution of the boreholes assessed in the province is indicated on the map on the opposite page.

CONFLICTING RESULTS: Refer to the boreholes where the analytical results of multiple samples taken at the same time did not correspond. These boreholes were not taken into account in the statistical analysis of the results.


North-West
Date range: 1994-02-01 to 1995-10-31
Class 1 - suitable for potable use
Class 2 - short-term potable use
Class 3 - not for potable use without treatment
No data during this period
Towns and communities
Borehole records (total on map): 22
Borehole samples selected: 20
0 20 40 60 80 100 km
20 sample(s) plotted on 28-MAR-1996 9:07 AM at IWQS by user aletta
23°E
24°E
25°E
26°E
27°E
28°E
24°S
25°S
26°S
27°S
28°S
29°S
ELLISRAS
MOCHUDI
GABORONE
RUSTENBURG
PRETORIA
JOHANNESBURG
SOWETO
VEREENIGING
VANDERBIJLPARK
SASOLBURG
POTCHEFSTROOM
KLERKSDORP
KROONSTAD
WELKOM
BETHLEHEM
KIMBERLEY

8. CONCLUSION AND RECOMMENDATIONS

Samples from 1131 boreholes were analysed in the laboratories of the Institute for Water Quality Studies during the period January 1994 to October 1995 for key health related chemical constituents. The boreholes, which were drilled for emergency water supplies to communities in rural areas as part of the Department's Drought Relief Programme, were consequently assessed in terms of suitability for potable use according to a health related classification system developed by the IWQS.

Samples taken from 187 boreholes had conflicting results and had to be re-sampled to confirm the water quality of the boreholes and the consequent classification.

A statistical analysis of the results from the remaining 944 boreholes indicated that:

- 26.3% of the boreholes were not suitable for potable use without treatment. Use of the water from these boreholes without prior treatment could have serious health effects on users, especially infants and elderly people.

- 28.4% of the boreholes are suitable for short term, or emergency use only. The water from these boreholes could also affect the user's health adversely if used for an entire lifetime without treatment to remove the offending constituents from the water.

- 45.3% of the boreholes had good water quality suitable for lifetime use without treatment, on condition that the water quality does not change significantly due to landuse activities.

Details of the assessment of the boreholes in the various provinces are given in Table 9.

The above information is of great significance to the Department. Apart from the information contained in this report, very little or no information is currently available on the quality of water sources used for domestic purposes by communities in rural areas. Since the information contained in this report could be regarded as representative of the water quality of boreholes that have been drilled prior to the onset of the drought relief programme, it gives, for the first time, a holistic picture of the quality of the groundwater sources used by rural communities.

Unfortunately, the picture is far from reassuring, because it is obvious that the health of many people in rural areas may be in jeopardy due to unacceptable water quality. It is, therefore, vitally important to do a detailed health related water quality survey of all water sources used by communities in the rural areas. The survey should concentrate on those areas where communities will remain dependent on groundwater or will not in the foreseeable future have access to conventionally treated water.

Such a survey will provide reliable baseline information which is essential for the effective design on ongoing water quality monitoring programmes to ensure that communities are supplied with clean potable water. It will also be valuable for planning purposes because it will provide information on water quality problems that cannot be detected by surveys based entirely on macro chemical constituents such as TDS. The information is also essential to make rationale decisions with regard to corrective actions to deal with these water quality problems in the short, medium and long term.

Water of almost any quality can be treated, at a cost, to make it fit for domestic use. However, it is important to obtain detailed and reliable information on the water quality of a particular source since water can only be treated cost effectively if the quality problems and the characteristics of the water source are known.

A survey based on the classification system described in this report will, in addition, provide information in a format that can be communicated to the communities. Information on the quality of their water resources can play an important role in motivating communities to become involved in the operation and maintenance of local water supply schemes as well as to protect the water resources from pollution for their own well being.

There are however, a number of issues that were not addressed in the Drought Relief Programme which should be attended to in future community water supply programmes.

Much more attention should be given to the water quality aspects during the planning stages of water supply projects. Quality assurance of the information is only possible if correct and standardised sampling, transport as well as analytical and data processing procedures are followed. Insufficient quality control especially in terms of sampling and sample handling procedures may be the main reason for the many conflicting results. It is therefore crucial to involve the Institute for Water Quality Studies right from the start in future projects.

It is not possible to make conclusive statements on the safety of the boreholes for drinking water purposes without information on the microbiological and trace metal quality of the water. These parameters must in future be included in water quality monitoring programmes of community water supplies.

Sustainable use of the source is only possible if the causes of poor water quality are known and properly managed. Water quality surveys should be conducted in such a way that information on landuse activities and other factors that may affect the quality of the water are obtained simultaneously.

In conclusion, results from this assessment indicated that a significant percentage of the boreholes drilled for emergency water supply had poor water quality and are not suitable for drinking purposes. For this reason, the boreholes were not equipped even though, in some cases, the other factors were favourable for development. These boreholes may be utilised in future if the correct treatment is applied. Reliable information is, therefore, a key factor in the sustained utilisation of water resources for community water supply. The design and operation of effective water quality monitoring programme is, however, a complex issue and reliable information can only be produced if the programmes are well structured and tight quality control is exercised.

Table 4: Summary of water quality constituents causing Class II and III boreholes in each province

PROVINCE	Class I	Class II	Class III	Comments
Northern Province	51.8 %	30.2 %	18 %	Boreholes classified as class III were due to elevated nitrate concentrations.
		TDS, EC, NO_3, Cl	NO_3	Class II boreholes were due to high TDS(EC), nitrate and chloride concentrations.
Northern Cape Province	34.6 %	18.3 %	47.1 %	Class III boreholes were due to elevated sodium and chloride concentrations.
		F	Cl, Na	Class II boreholes were due to elevated fluoride concentration.
Western Cape Province	12.5 %	37.5 %	50 %	Class III boreholes were due to elevated chloride and sodium concentrations
		F, Cl	Cl, Na	Class II boreholes were due to elevated fluoride and chloride concentrations.
Eastern Cape Province	20 %	24 %	56 %	Class III boreholes were due to elevated chloride, sodium and TDS(EC) and low pH
		F, NO_3	pH, Cl, Na, TDS, EC	Class II boreholes were due to elevated fluoride and nitrate concentrations.
Kwazulu Natal	37.9 %	32.4 %	29.7 %	Class III boreholes were due to elevated chloride, sodium and TDS(EC)
		Cl, Na, TDS, EC	Cl, Na, TDS, EC	Class II boreholes were due to elevated chloride, sodium and TDS(EC)
Mpumalanga	87.8 %	2.4 %	9.8 %	Class III boreholes were due to elevated nitrate, sodium and fluoride concentrations.
		F, Cl	F, NO_3, Na	Class II boreholes were due to elevated fluoride and chloride concentrations.
North West Province	25 %	35 %	40 %	Boreholes classified as class III were due to elevated nitrate concentrations.
		NO_3	NO_3	Class II boreholes were due to elevated nitrate concentrations.

9. REFERENCES

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