Report on an Integrated Water Quality Monitoring Programme Conducted in the Town of Delmas

November 2005 to June 2006

water & forestry

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EXECUTIVE SUMMARY

This report summarises the findings of an eight month integrated water quality monitoring programme conducted by the Department of Water Affairs and Forestry (DWAF), Resource Quality Services (RQS) in the town of Delmas, Mpumalanga Province South Africa. Initiation of the intensive integrated water quality monitoring programme was recommended in a report to the Deputy President (DWAF, 2005_c) following a second outbreak of typhoid in September 2005 (the first epidemic occurring in 1993). Work was done on behalf of, and in collaboration with the DWAF Mpumalanga Regional Office. The main aim of the project was to design and implement (on a pilot scale) a programme to generate information needed to holistically manage the quality of the Delmas drinking water supply system.

Information is presented on the fitness for use of water within the Delmas water supply chain. This includes the quality of the surface water component of the supply chain (surface water and effluent discharges) as well as the drinking water component of the supply chain (groundwater, water in the distribution system and at points of end use (taps)). In addition, recommendations and solutions for management of potential water quality risks, as well as guidance on a long-term monitoring plan are given.

The overall microbiological quality classification of water within the supply chain was based on the presence of indicator organisms and determined the suitability for use of the water within the short term. Undesirable physical attributes or unacceptable chemical levels, according to the physico-chemical classification (based on SANS 241: 2005 drinking water standards), determined the fitness for use of the water in the long-term. Some of the physico-chemical variables, free available chlorine and turbidity levels, were also used to indicate the potential for disease causing organisms to be present in the water. These variables were used in concurrence with the overall microbiological quality classification to assess the short term fitness for use of the water in the supply chain. The overall microbiological and physico-chemical quality classification of water within the Delmas water supply chain is presented in Tables B to F below (also see Tables 19 to 27, Chapter 5 Results). A brief discussion of the constituents of concern rendering the water unsuitable for use follows -

E coli detected in the surface water samples indicate that surface water in the Delmas district is faecally polluted. The water is not suitable for recreational activities entailing full body contact. The indicator organism numbers are indicative of the land-use activities taking place adjacent to the water sources. Activities / sources affecting the water quality include run-off from the formal and informal settlements, livestock grazing close to the riverbanks and the discharge (throughout the monitoring period) of wastewater effluents of unacceptable quality.

The microbiological quality of surface water impacted the quality of groundwater in areas where a hydraulic connectivity exits. In particular, microbial indicators detected in surface water, at sampling point S9, reflected in groundwater taken from the A-well field (suspected to be the source of the September 2005 typhoid epidemic). Water at sampling points A3, A4 and A7 in well field A continued to be of an unacceptable quality for drinking without adequate treatment (disinfection). With the exception of the occasional sample, samples taken from other boreholes and water from the reticulation system were of suitable quality for drinking.

Disinfection of the water intended for human consumption needs to be continued on an ongoing basis in order to ensure deactivation of organisms that might be present in the water, as well as to prevent the water quality deteriorating in the reticulation system. Chlorination, as currently used, needs to be adequate and closely monitored to maintain the required free available chlorine levels. Results showed on average the free available chlorine at acceptable concentrations, with occasional under and over dosing. On the other hand, under dosing or breaks in chlorination could result in the outbreak of other diarrhoeal diseases if the untreated water contained pathogenic micro-organisms, on the other hand, over-chlorination could lead to complaints and rejection of the water due to the smell of chlorine, accompanied by health effects such as the irritation of mucous membranes, nausea and vomiting.

Water within the reticulation system was sometimes of unacceptable turbidity. Turbidity in drinking water is undesirable not only for aesthetic reasons, but also because it makes maintaining a positive chlorine residual concentration in the water distribution system difficult. The organic slime generally associated with turbid clay particles can become a hiding place for microbes. Treatment is needed to remove the particles before the water is disinfected. A conventional treatment plant or package plant including processes for flocculation, sedimentation and filtration before disinfection is advised.

Arsenic, which is commonly present in trace concentrations in dolomitic water, was detected in groundwater samples in the B and C-well fields. Low concentrations were also detected in the A-well field, the D-well field and in water in the reticulation system. Consuming the semi-metal in unacceptable quantities in the long term could lead to sensory loss in the peripheral nerves and gastrointestinal symptoms. It is however unlikely that the current concentrations would have already resulted in negative health effects.

According SANS 241: 2005, people should not drink water containing arsenic concentrations exceeding 0,050 mg/L. Water containing arsenic between 0,010 and 0,050 mg/L should not be consumed for longer than a year. While it is difficult to say how long and at what concentration (if any) people have been consuming water containing arsenic, measures to remove the arsenic (or to stop pumping from the affected boreholes) need to be put in place immediately. Groundwater arsenic is often present in the particulate phase, normal treatment processes such as flocculation (preferably with iron salts) and filtration should be capable of removing the arsenic from the groundwater (chlorine disinfection alone will not remove it). Measures to continue monitoring the levels and to identify the source of the arsenic for management purposes must be put in place. As mentioned earlier, the source may be natural or the elevated arsenic concentrations may also occur as a consequence of pollution, e.g. from mining activities or from arsenic containing pesticides in cattle dips. The latter were identified as an activity previously taken place.

In summary, a few recommendations following our intensive integrated water quality monitoring programme are highlighted (see detailed list in text, Chapter 7). While actions to improve / maintain the quality of water supplied to Delmas for drinking (i.e. improved housekeeping at the wastewater pump station (bucket dumpsite), disinfection of the water supplies and the attempts to maintain a positive residual chlorine concentration in the reticulation system) are noted, the following recommendations, some of which have already been suggested in reports following the 1993 and 2005 typhoid outbreaks (South African Institute for Medical Research, University of the Witwatersrand and CSIR, 1994 and DWAF, 2005_c), needs to be addressed urgently:

- Disinfection of water intended for human consumption needs to continue, a positive free available chlorine concentration (between 0.5 – 3.0mg/L) must be present at all times in the reticulation system (pipes and reservoirs).
- Elevated turbidity in the drinking water is an undesirable situation not only for aesthetic reasons, but also because it affects the efficiency of disinfection. Deactivation of microbes may not be successful because the microbes hide in the organic slime generally associated with turbid clay particles. Turbidity also makes maintaining a positive chlorine residual concentration difficult. More treatment to remove the turbidity is needed. A conventional treatment - or package plant comprising flocculation,

sedimentation and filtration should be installed to remove the turbidity particles before the water is disinfected for drinking.

- The conventional treatment or package plant is also urgently needed to remove the arsenic and other constituents occasionally detected in the groundwater.
- A surface water protection management plan must be developed to prevent the surface water affecting the quality of the groundwater negatively. Such a plan could include:
  - Proper sanitation for all – measures should be put in place to phase-out the bucket system still in use by some. Until such time that the bucket system can be eradicated, the municipal collection service needs to improve
  - Adequate refuse removal
  - Effective management of the Waste Water Treatment Works (WWTWs) – put measures in place to ensure that the facilities release into the environment only effluents in compliance with the licence conditions issued by the DWAF, upgrade the facilities when needed, the Town Engineer of Delmas must ensure that adequately qualified staff operate, maintain and manage both WWTWs
  - Controlled areas for cattle grazing at a safe distance from the production boreholes
- It is important to implement and maintain an integrated water quality monitoring programme, based on the design principles described in this document, to ensure that risks associated with the Delmas water supply are identified timeously and that appropriate management actions are taken to ensure that consumers are always supplied with safe drinking water.
- Last but not least, it's foreseen, that even if the groundwater supply capacity is sufficient at present, the current boreholes won't have sufficient quantities of water to satisfy future demands. Alternatives to the current supply will soon be necessary. These alternative supplies could be from additional production boreholes (at least 1 km away from existing boreholes) or the supply can be augmented by water supplied by Rand Water. Due to the nature of the aquifer media, over-abstraction could result in sinkhole development and subsidence in the Delmas aquifer area. Sinkhole formation impacts the waters' turbidity levels, which in turn are associated with other contaminant increases, it affects the efficiency of chlorine disinfection and therefore increases risks to human health.

OVERALL WATER QUALITY CLASSIFICATION

The overall microbiological quality classification of water within the supply chain was based on the presence of indicator organisms and determined the suitability for use of the water within the short term. The physico-chemical classification which reflects undesirable physical attributes or unacceptable levels of chemicals according SANS 241: 2005 for drinking water, determined the fitness for use of the water in the long-term. Free available chlorine and turbidity levels were also used in association with the microbiological classification to determine the suitability for use of the water within the short term.

The colour coded classification system described in Table A was used to assess and present the Delmas water quality data in an easily understandable way.

Table A Colour coded water quality classification system

Class	Colour	Description	Effects
I	Green	Good water quality (Target)	Suitable for use, rare instances of negative effects
II	Yellow	Marginal water quality	Conditionally acceptable. Negative effects may occur in some sensitive groups
III	Red	Poor water quality	Unsuitable for use without treatment. Possible chronic effects.

The overall microbiological and physico-chemical quality classification of *surface water* within the Delmas district is given in Table B. The fitness for use of surface water mainly used for contact recreation and livestock watering was evaluated against the South African Water Quality Guidelines for Recreational and Agricultural Use: Livestock Watering. A summary of the guideline values used are given in Tables 12 and 13, Chapter 4: Information Generation and Dissemination.

Table C summarises the quality classification of *effluents* discharged from the two respective wastewater treatment facilities. The quality of the effluents was evaluated against the licence conditions issued by DWAF on 21 December 2001. Refer to Table 14, Chapter 4 for more detail. Surface water and discharged effluent comprised the ***surface water component*** of the Delmas water supply chain.

The fitness for use of water used for drinking was assessed against the South African National Standard for drinking water (SANS 241: 2005) (Tables 15 and 16, Charter 4). The ***drinking water component*** of the Delmas supply chain consisted *groundwater*, *rural water supply boreholes* under the jurisdiction of the Delmas municipality and water within the *Delmas reticulation system*. Table D summarises the overall microbiological and physico-chemical quality classification of the groundwater, Tables E and F summarises the overall quality classification for the rural water supply boreholes and reticulation system respectively. (Monitoring site descriptions and GPS co-ordinates are given in Tables 1, 4, 5 and 8, Chapter 3: Design of the Delmas Integrated Monitoring Programme).

Classification of the surface water component of supply chain

Table B Overall surface water quality classification

Sample Code	Overall microbiological quality – surface water						
	12 Dec 05	12 Jan 06	13 Feb 06	13 Mar 06	10 Apr 06	22 May 06	21 June 06
S1	Yellow [a]	Red [a + b]	Red [a + b]	Red [b]	Green	Green	Green
S2	Red [a]	Red [a]	Yellow [a]	Red [a]	Green	Green	Green
S3	Red [a]	Site not accesible		Yellow [a]	No flow, samples not taken		
S4	Green	Red [a]	Red [a]	Yellow [a]	Red [b]	Yellow [a + b]	Green
S8	Red [a]	Red [a]	Red [a]	Red [a]	Red [a + b]	Red [a + b]	Red [a + b]
S9	Red [a]	Red [a]	Red [a]	Red [a]	Red [a + b]	Red [a + b]	Red [a + b]
S10	Yellow	Red [a]	Red [a]	Red [a]	Red [a]	Green	Green
S14	Green	Red [a]	Red [a]	Red [a]	Red [a]	Red [a]	Red [a]
S15		Red [a]	Red [a]	Red [a]	Red [a]	Green	Red [a]
S16	Red [a]	Red [a]	Green	Green	Green	Green	Green
S17		Red [a]	Red [a]	Red [a]	No flow, samples not taken		
S20		Red [a]	No flow, samples not taken				
S21			No flow		Green	No flow	
Where a *E coli* b Faecal streptococci							
	Overall physico-chemical quality - surface water						
S1	Green	Green	Green		Green	Green	Green
S2	Green	Green	Green	Green	Green	Green	Yellow [a]
S3	Green	No flow		Green	No flow, samples not taken		
S4	Green	Green	Green	Yellow [a]	Green	Green	Yellow [a]
S8	Green		Green	Green	Green	Green	
S9	Green	Green	Green	Yellow [a]	Green	Green	
S10			Green	Green	Green	Green	
S14	Green	Green	Green	Green	Green	Green	
S15			Green		Green	Green	
S16		Yellow [a]	Green	Green	Green	Green	
S17		Green	Green	Green	No flow, samples not taken		
S20			No flow				
S21			No flow		Green	No flow	
Where a pH							

Table C — Effluent discharge water quality classification

Sample Code	Overall microbiological quality – wastewater effluent						
	12 Dec 05	12 Jan 06	13 Feb 06	13 Mar 06	10 Apr 06	22 May 06	21 June 06
S5	Red	Red	Red	Red	Red	Red	Red
S11	Red	Red	Red	Red	Green	Green	Red
Sample Code	**Overall physico-chemical quality – wastewater effluent**						
	12 Dec 05	12 Jan 06	13 Feb 06	13 Mar 06	10 Apr 06	22 May 06	21 June 06
S5	Red [ii]	Red [ii + v]	Green	Red [iii + v]	Red [ii]	Red [ii]	
S11			Green	Green	Green	Red [iii]	Green

Where i pH; iii NO_3-NO_2

Ii NH_4-N; v PO_4

DRINKING WATER COMPONENT OF SUPPLY CHAIN

Table D — Overall groundwater quality classification

Sample Code	Overall microbiological quality - groundwater									
	07 Dec 05	12 Dec 05	16 Jan 06	17 Jan 06	14 Feb 06	23 Feb 06	13 Mar 06	11 Apr 06	10 May 6	20 June 6
A3	Red	Red			Red		Red	Red	Red	Red
A4	Red	Red	Red		Red		Red	Red	Green	Green
A7	Red	Red	Red		Red		Red	Red	Red	Red
BOT3		Green		Green	Green		Green	Green	Green	Green
BOT4	Green	Green	Green		Green		Green	Green		Green
BOT5	Green	Green		Green	Green		Green	Green	Green	Green
BOT6		Green		Green	Green		Green	Green	Green	Green
BOT8				Green	Green		Green	Green	Green	Green
C1	Green	Green		Green	Green		Green	Green	Green	Green
C2	Green	Green			Green		Green	Green	Green	Green
C3	Green	Green		Green		Green	Green	Green	Green	
C4					Green		Green	Green	Green	Green
D5	Green	Red		Green	Green		Green	Green	Green	Green
D10	Green	Green		Green	Green		Green	Green	Green	Green

Sample Code	Overall physico-chemical quality - groundwater						
	07 Dec 05	12 Dec 05	16 Jan 06	14 Feb 06	13 Mar 06	11 Apr 06	10 May 6	20 June 6
A3		Yellow [be]	Green				Green	Green
A4		Green	Green				Green	Red [d]
A7		Yellow [a]	Green				Green	Green
BOT3		Green					Yellow [d]	Yellow [d]
BOT4		Green	Green					Yellow [d]
BOT5		Green	Green				Green	Green
BOT6		Green					Green	Green
BOT8		Red [c]					Red [c]	Red [c]
C1		Green	Green				Green	Green
C2		Red [d]	Red [d]		Yellow [a]	Red [a]	Red [a, d]	Red [d]
C3		Green	Green				Red [d]	
C4		Green	Green		Red [a]	Red [a]	Red [d]	Red [d]
D5		Green	Green		Green	Red [a]	Green	Red [d]
D10		Green	Yellow [f]				Green	Green

Where a Turbidity; c Fluoride; e Manganese

b NH_4-N; d Arsenic; f Iron

Table E	Overall quality classification of the rural water supply boreholes under the jurisdiction of Delmas Municipality

Sample Code	Overall microbiological quality		
	27 February 2006	11 May 2006	27 June 2006
Arbor		Red	Green
Argent	Green	Green	Green
Dryden	Green	Green	Green
Bambisana	Green	Green	Green
Waaikraal	Red	Green	Green
Droogenfontein	Red	Green	Green
	Overall Physico-chemical quality		
Arbor		Green	Green
Argent		Green	Green
Dryden		Yellow [a]	Yellow [a]
Bambisana		Green	Green
Waaikraal		Yellow [a]	Green
Droogenfontein		Yellow [a]	Yellow [a]

Where	a	NO_3-NO_2

Table F Overall classification of the Delmas reticulation system

Sample Code	Overall microbiological quality																									
	Nov 2005			Dec 2005			Jan	Feb 2006		March 2006				April 2006				May 2006					June 2006			
	15	22	29	6	14	20	31	7	28	7	14	22	28	5	11	18	24	2	9	16	23	30	6	13	20	27
M4	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
T4809_B4	G	G		G	G	G	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G
BN_5092	G	G		G	G	G	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G
B_LS	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
DE_37	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
RS13	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	R	G	G	G	G	G	G	G	G
DE_420	G	G		G	R	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
NPS_5	G	G		G	G	G	G	G		G	G	G	G	G	G	G		G	G	G	G	G	G	G	G	G
NB_3879	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
B_MS	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
	Overall physico-chemical quality																									
M4	G	G	G	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	G	$Y^{c\downarrow}$	G	$Y^{c\uparrow}$	Y^{b}	G	G	G	G	Y^{b}	G	Y^{a}	G	Y^{b}
T4809_B4	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{\downarrow}$	G	G	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	Y^{ac}	$Y^{c\downarrow}$	Y^{cb}	$R^{c\downarrow}$	Y^{a}	Y^{a}	G	Y^{cb}	G	G	G	Y^{b}
BN_5092	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	G	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	Y^{ac}	$Y^{c\downarrow}$	Y^{cb}	$R^{c\downarrow}$	Y^{a}	Y^{a}	G	R^{bd}	G	G	Y^{a}	Y^{b}
B_LS	$R^{c\downarrow}$	$Y^{c\downarrow}$		$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$		$Y^{c\downarrow}$	$Y^{c\downarrow}$	Y^{ac}	Y^{a}	Y^{a}	Y^{a}	G	Y^{b}	$R^{c\downarrow}$	G	G	Y^{a}	Y^{cb}	G	G	G	$R^{c,b}$
DE_37	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$R^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	Y^{ac}	G	$Y^{c\downarrow}$	G	G	Y^{b}	$Y^{c\downarrow}$	G	G	$Y^{c\downarrow}$	Y^{cb}	G	$Y^{c\downarrow}$	$R^{c\downarrow}$	$R^{c,b}$
RS13	G	G	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	G	G	$Y^{c\downarrow}$	$Y^{c\uparrow}$	$Y^{c\uparrow}$	G	$Y^{c\uparrow}$	G	G	G	G	G	G	G	G	G	$Y^{c\uparrow}$	G	$R^{c\downarrow}$
DE_420	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	Y^{ac}	Y^{a}	Y^{a}	Y^{a}	G	Y^{b}	G	$Y^{c\uparrow}$	G	Y^{ac}	R^{b}	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	R^{b}
NPS_5		$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	G	G	G	$R^{c\downarrow}$	Y^{ac}	Y^{a}	Y^{a}	Y^{a}	$Y^{c\uparrow}$		R^{b}	G	G	Y^{ac}	R^{b}	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	$R^{c,b}$
NB_3879	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	G	G	$Y^{c\downarrow}$	G	G	Y^{a}	G	Y^{a}	G	Y^{cb}	G	G	Y^{a}	Y^{a}	Y^{b}	Y^{a}	G	Y^{a}	Y^{b}
B_MS	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	Y^{ac}	Y^{a}	Y^{a}	Y^{a}	G	Y^{b}	$R^{c\downarrow}$	Y^{a}	G	Y^{a}	Y^{cb}	G	G	G	R^{cb}

Where: G - Green Y - Yellow R - Red, and

a - Turbidity
b - Arsenic
c - Residual Chlorine ($^{\downarrow}$ - Under chlorination and $^{\uparrow}$ - Over chlorination)
d - Cadmium and Lead

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1 Background and Purpose of Study

Following the outbreak of another typhoid epidemic during September 2005 in Delmas, Mpumalanga Province South Africa, the Department of Water Affairs and Forestry (DWAF) initiated an intensive follow-up integrated water quality monitoring programme. Work was done by the DWAF directorate, Resource Quality Services (RQS) on behalf of, and in collaboration with the DWAF Mpumalanga Regional Office. The main aim was to design and implement (on a pilot scale) a programme to generate information needed to holistically manage the quality of the Delmas drinking water supply system. Recommendations following the investigation will be taken forward with Delmas municipality as well as Mpumalanga Premier's office (DWAF, 2005_c). Since the 2005 typhoid outbreak was not the first, another epidemic was reported in 1993 (South African Institute for Medical Research, University of the Witwatersrand and CSIR, 1994 and DWAF, 2005_c), actions now needs to be implemented and maintained to ensure that any reoccurrence of the disease is halted (refer to recommendations, Chapter 7).

Water abstracted for drinking purposes are mainly from dolomitic groundwater resources followed by disinfection (chlorination treatment). The quality of groundwater (especially those suspected to have contributed to the cause of the epidemic – namely the A-well field), as well as the quality and potential of surface water to pollute the groundwater, needed investigation. This report summarises the findings of the eight month integrated water quality monitoring programme (November 2005 to June 2006). In addition, recommendations and solutions to manage potential water quality risks, as well as guidance for a long-term monitoring plan, are given.

Subsidiary to the aim, the following objectives were set:

- Determine the overall quality of the water in the Delmas water supply chain. This included determination of the quality of surface water, groundwater, water in the distribution system as well as points of end use (taps)
- Identify the links between the quality of the surface water, groundwater and the treated water supplies
- Identify potential water quality problems (past and present) in the drinking water supply system
- Develop an early warning system
- Report the data and information generated during this study in an easily understandable way to all stakeholders concerned with the supply of safe water to the town of Delmas

Collecting samples and data for the investigation was a joint effort between various directorates of DWAF, namely the Directorate Resource Quality Services; Directorate Hydrological Services, the Directorate Water Services Regulations and Mpumalanga Regional Office. Delmas municipal officers also became involved after receiving the water quality results.

2 Integrated Management of Drinking Water Supplies – The Basics

2.1 Need for integrated management of drinking water supply systems

Water can become contaminated at any point in a drinking water supply system. Effective management therefore requires a clear understanding of the entire drinking water supply system. The system includes everything from the point of water abstraction to the point where the water is used by a consumer.

The best way of consistently ensuring the safety of a drinking water supply is to be continuously aware of possible hazards or risks that may compromise the quality of the water (DWAF 2005_a). Such a holistic risk based management approach requires information on:

- Catchment characteristics (natural characteristics of the surface water and/or groundwater supply systems, as well as land use activities impacting on the quality of the water resources)
- Abstractions and storage dams
- Drinking water treatment systems
- Treated water reservoirs and distribution systems
- Points of end use (taps)

2.2 Need for integrated monitoring programmes

The primary responsibility for providing safe drinking water rests with Water Service Authorities (WSAs). WSAs have a legal responsibility to in terms of regulations of the Water Services Act, Act 108 of 1997 to:

a Monitor the quality of drinking water provided to consumers

b Compare results to national drinking water standards

c Communicate health risks to consumers and appropriate authorities

The need for information to properly manage risks is also recognised in Chapter 14 of the National Water Act (Act 36 of 1998). Depending the situation and information needed, one of the following programmes may be implemented:

- **Catchment monitoring** which includes monitoring of water resources (surface water and groundwater) as well as wastes from land-use activities which could impact the quality of drinking water supplies. Catchment monitoring is necessary to determine if the qualities of water resources (used as raw water supply for potable supplies) are adequately protected, to determine the level of treatment required to supply safe drinking water and to identify possible hazards or risks that could jeopardise the quality of drinking water supplies.

- **Operational process control monitoring** which includes monitoring of the water treatment - and distribution systems. Information gathered during operational process control monitoring triggers short term corrective actions to operational procedures.

- **Drinking water compliance monitoring** to ensure that the drinking water is fit for human use, that drinking water quality management measures to protect public health are working effectively and to assess compliance with regulatory requirements.

2.2.1 Components of monitoring programmes

Monitoring programmes generally consists of three core functions namely (DWAF 2004):

- Data acquisition (consists of sample collection and sample analysis). This function includes the:
  - Selection of adequate and correct sampling sites
  - Identification of the constituents (variables of concern) that need to be sampled for and analysed
  - Determination of the sampling frequency, and
  - Analysis of the samples using standard analytical procedures (where possible, by accredited laboratories)

- Data management and storage. This function requires:
  - A functional data base
  - Capturing data on the data base, and
  - Management of the database

- Information generation and dissemination. This function entails:
  - Abstraction of the data from the data base
  - Data assessment against appropriate assessment criteria for:
    - Operational process control
    - Compliance with water quality guidelines/specifications; licence conditions (e.g. SANS 241: 2005 Drinking Water Specifications; licence conditions for the Waste Water Treatment Works (WWTW); water quality guidelines for other recognised water users, i.e. recreational or agricultural water uses, etc.)
  - Regular reporting of the information to various levels of users needing the information to adequately manage the drinking water supplies. Information users include plant operators, municipal managers, the public and appropriate authorities such as DWAF, DoH, Department of Local Government and Housing, etc.

2.3 Multiple barriers

After identifying risks to the drinking water supply chain, steps to rectify and prevent the hazardous situations need to be put in place (DWAF 2005_a). One of the important preventative strategies that can be followed is to ensure that multiple protective barriers are put in place. This is especially true for the microbiological safety of drinking water supplies. Traditional multiple barriers include:

a Catchment management and source water protection

b Abstraction management

c If so required, treatment of the raw water (i.e. coagulation, sedimentation, filtration and disinfection ensuring adequate disinfection residual)

d Protection and maintenance of the distribution system

e Education of communities in hygienic use of water

3 Design of the Delmas Integrated Monitoring Programme

A Task Team was established to maintain and manage the Delmas Integrated Monitoring Programme. The Task Team consisted of DWAF directorates involved in management of domestic water supplies, representatives of the Municipality of Delmas, the Provincial Department of Health, and Local Government and Housing. Those not able to participate actively as task team members attended Task Team meetings.

The task team jointly designed the water quality monitoring programme according to the components of monitoring programmes described earlier. A sampling schedule was drawn up and responsibilities allocated to each of the Task Team members. Responsibilities included data acquisition, data management and storage, information generation and dissemination. The following sections describe the monitoring programme design:

3.1 Data acquisition

Representative sites were selected for monitoring all components of the water supply system (surface water and groundwater resources, the distribution system and taps at strategic points in the town of Delmas) (Figure 1). Standard sampling protocols were followed (DWAF, 1999). Surface and groundwater samples were taken predominantly monthly, while the distribution network was sampled weekly. All samples were analysed at the accredited laboratories of the Directorate Resource Quality Services, DWAF. The geographic locations of the sampling sites and the constituents of concern in the various components of the water supply system are discussed in more detail in the sections to follow.

3.1.1 Surface water component of the Delmas water supply chain

Monitoring the surface water component of the water supply system was aimed at collecting information for water resources protection purposes. Descriptions of the surface water and effluent discharge sampling sites, as well as GPS co-ordinates, are given in Table 1.

Table 1 Surface water and effluent discharge monitoring points

Sample Code	Feature ID	Point Description	GPS Coordinates
Surface Water			
S1	188608	Witklip Dam, unnamed tributary inflow into town	S 26°09'25. 5" E 28°40'24. 2"
S2	188675	Bronkhorstspruit above Delpark residential area	S 26°08'33. 2" E 28°41'52. 6"
S3	188676	Bronkhorstspruit midway Delpark residential area	S 26°08'09. 5" E 28°42'04. 0"
S4	188678	Unnamed tributary above Delmas Sewage Works	S 26°08'19. 4" E 28°41'09. 3"
S8	188610	Downstream of Delmas Sewage Works Effluent discharge	S 26°08'18. 1" E 28°41'20. 4"
S9	188652	Bronkhorstspruit below Mandela Settlement	S 26°07'14. 2" E 28°42'19. 2"
S10	188730	Bronkhorstspruit at N12 Bridge	S 26°04'50. 9" E 28°42'38. 2"
S12		Bronkhorstspruit above new sewage works	No Access
S13		Bronkhorstspruit below new sewage works	No Access
S14	188729	Leeuspruit upstream of pump station	S 26°06'22. 8" E 28°42'21. 1"

Table 1 Surface water and effluent discharge monitoring points (Continued)

Sample Code	Feature ID	Point Description	GPS Coordinates
Surface Water			
S15	188779	Leeuspruit downstream of pump station before confluence with Bronkhorstspruit	S 26°06'21. 7" E 28°42'26. 4"
S16	188731	Leeuspruit above Botleng new extension	S 26°06'28. 2" E 28°40'43. 2"
S17	188732	Leeuspruit midway Botleng new extension	S 26°06'32. 4" E 28°41'48. 7"
S18	188871	R555 bridge to Springs, unnamed tributary	S 26°09'13. 6" E 28°40'30. 2"
S19	188893	Samuel road bridge, unnamed tributary	S 26°08'56. 4" E 28°40'39. 3"
S20	188869	Vlei road bridge at golf course, unnamed tributary	S 26°08'35. 4" E 28°40'43. 1"
S21	188894	R50 bridge to Leandra, Bronkhorstspruit	S 26°10'41. 1" E 28°42'07. 2"
S22	188895	R50 bridge through town, unnamed tributary	S 26°08'28. 7" E 28°40'53. 0"
Sewage Effluent Discharge			
S5	188680	Witklip Delmas Sewage Works Effluent Discharge	S 26°08'15. 8" E 28°41'11. 8"
S11	188727	Middelburg Botleng Ext 4 STW Effluent Discharge to Bronkhorstspruit	S 26°05'46. 5" E 28°42'52. 0"

The localities of monitoring points in relation to the residential areas of Delmas are given in Figure 1. Sites in the surface water component of the water supply system were selected to include a headwater quality site (reference point of water quality upstream of Delmas, S21 and to an extent S1), sites where the watercourses receive point-source pollution discharges (S5 and S11) and sites representing stretches of watercourses receiving diffuse discharges from the residential areas. Most of the sites are accessible to the residents of Delmas. The water is used for recreational purposes (swimming and fishing) as well as to water livestock kept in the informal settlements. The use of the water to irrigate crops that may be eaten uncooked was minimal.

In addition to the above, surface water monitoring sites were selected in proximity to groundwater extraction points. The latter was done to investigate the potential of the surface water to affect the quality of the groundwater used by residents for drinking after only chlorination. Samples collected at surface water monitoring sites were analysed for the macro-chemical constituents listed in Table 2.

Table 2 Macro-chemical constituents tested for in surface water samples

Macro-chemical constituents		
PH	Total phosphorus as P	Silicon as Si
Kjeldahl Nitrogen as N	Ortho phosphate as P	Calcium as Ca
Ammonia as N	Sulfate as SO_4	Hardness
Nitrate and nitrite as N	Chloride as Cl^-	Total Dissolved Solids (TDS)
Fluoride as F	Potassium as K	Electrical conductivity (EC) at 25°
Alkalinity as $CaCO_3$	Sodium as Na	Magnesium as Mg

To determine the microbiological quality, samples were analysed for total coliforms, *E coli* and faecal streptococci. Faecal streptococci tests were performed to determine the origin (human or animal) of the faecal contamination at vulnerable sites (S1, S3, S4, S8 and S9).

3.1.1.1 Delmas Wastewater Treatment Works (WWTWs)

Sewage effluent discharge samples were collected monthly from the old (S5) and the new (S11) Wastewater Treatment Works (Table 1 and Figure 1). Samples were analysed for most of the constituents stipulated in the licence conditions issued on 21 December 2001 by DWAF. The variables tested for are listed in Table 3. S5 was also analysed for faecal streptococci.

Table 3 Constituents tested for in the WWTWs discharges

Constituents		
pH & Electrical Conductivity (EC)	Chemical Oxygen Demand (COD)	Total coliforms
Nitrate as N	Ortho Phosphate as P	Faecal streptococci
Ammonia as N	Suspended Solids (SS)	*E coli*

3.1.2 Drinking Water Component of the water supply chain

3.1.2.1 Groundwater

Descriptions of the boreholes monitored, along with GPS co-ordinates, are given in Tables 4 and 5 (see also Figure 1). Sites were selected at the boreholes suspected to be the cause of the typhoid epidemic (A-well field), along with other extraction fields for drinking water purposes. Sites were also selected in the outskirts of town where owners of farms and small-holdings extract water for rudimentary supply (rural water supply boreholes) – water extracted from these boreholes do not supplement water in the reticulation system.

Table 4 Groundwater sampling sites

Sample code	Reference code	Feature name	Feature ID	Field	GPS Co-ordinates
A3	MP210	2628BA-432	MFID1000013233	A-Field	S 26°07'09. 8" E 28°42'21. 6"
A4	MP209	2628BA-431	MFID1000013231	A-Field	S 26°07'15. 2" E 28°42'27. 2"
A7	MP200	2628BA-421	MFID1000013209	A-Field	S 26°07'10. 7" E 28°42'15. 4"
BOT3	MP212	2628BA-434	MFID1000013237	B-Field	S 26°06'57. 3" E 28°42'03. 2"
BOT4	MP205	2628BA-427	MFID1000013223	B-Field	S 26°07'08. 5" E 28°41'58. 0"
BOT5	MP203	2628BA-425	MFID1000013219	B-Field	S 26°07'06. 0" E 28°41'38. 1"
BOT6	MP202	2628BA-424	MFID1000013217	B-Field	S 26°07'02. 7" E 28°41'34. 1"
BOT8	MP201	2628BA-422	MFID1000013206	B-Field	S 26°06'33. 1" E 28°41'02. 1"
C1	MP204	2628BA-426	MFID1000013221	C-Field	S 26°08'55. 0" E 28°39'56. 0"
C2	MP211	2628BA-433	MFID1000013235	C-Field	S 26°09'09. 0" E 28°39'50. 0"
C3	MP206	2628BA-428	MFID1000013225	C-Field	S 26°09'20. 6" E 28°40'07. 0"
C4	MP213	2628BA-435	MFID1000013240	C-Field	S 26°09'17. 3" E 28°39'56. 3"
D5	MP208	2628BA-430	MFID1000013229	D-Field	S 26°08'54. 0" E 28°40'24. 1"
D10	MP207	2628BA-429	MFID1000013227	D-Field	S 26°08'45. 6" E 28°44'00. 1"

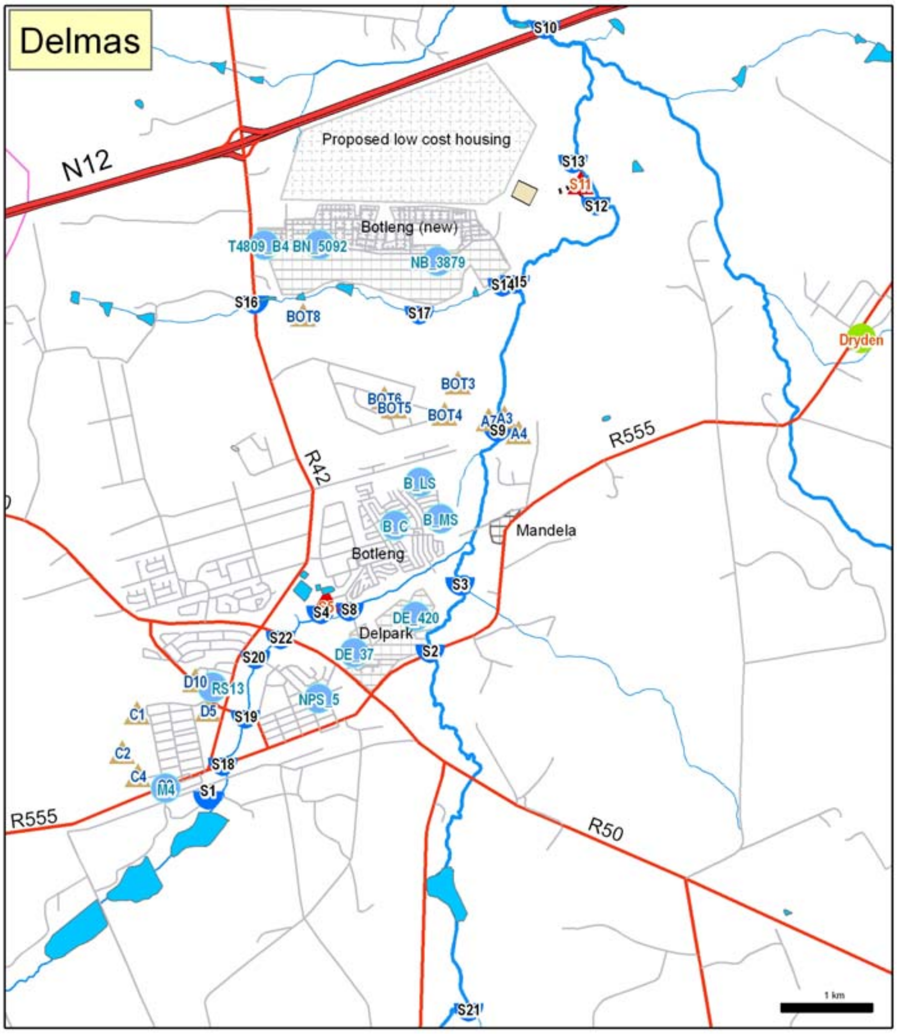

Figure 1: Delmas sampling sites

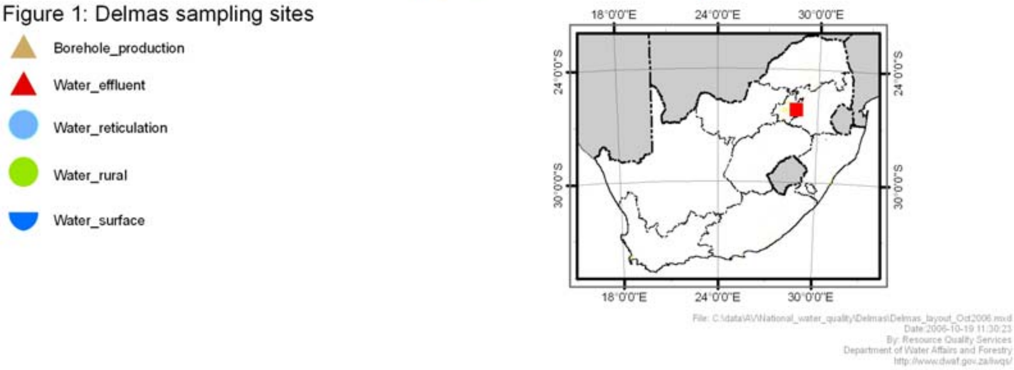

Table 5 Rural water supply boreholes under the jurisdiction of Delmas Municipality

Sample code	Reference	Point Description	GPS Co-ordinates
Arbor	MP229		S 26°02'53. 0" E 28°53'30. 0"
Argent	MP228	5m from the gate of Okhela Primary School	S 26°03'54. 0" E 28°48'41. 0"
Dryden	MP230	About 10m apart from Dryden 2 in the settlements	S 26°06'42. 0" E 28°44'43. 0"
Bambisana	MP225	Modderfontein farm within Bambisana Primary School	S 26°08'26. 0" E 28°32'07. 0"
Waaikraal	MP227	At the vicinity of the settlement.	S 26°00'03. 0" E 28°40'57. 7"
Droogenfontein	MP226	Between gum-trees and the settlement	S 26°12'05. 0" E 28°35'54. 0"

Groundwater macro-chemical analyses are listed in Table 6 and trace metal analyses in Table 7.

Table 6 Macro-chemical constituents analysed for in groundwater

Macro-chemical constituents		
PH	Total phosphorus as P	Silicon as Si
Kjeldahl Nitrogen as N	Ortho phosphate as P	Calcium as Ca
Ammonia as N	Sulfate as SO_4	Hardness
Nitrate and nitrite as N	Chloride as Cl^-	Total Dissolved Solids (TDS)
Fluoride as F	Potassium as K	Electrical conductivity (EC) at 25°
Alkalinity as $CaCO_3$	Sodium as Na	Magnesium as Mg

Table 7 Trace metals analysed for in groundwater

Trace Metals		
Iron as Fe	Zinc as Zn	Arsenic as As
Manganese as Mn	Cadmium as Cd	Copper as Cu
Lead as Pb	Nickel as Ni	Chromium as Cr

To determine the microbiological quality of the groundwater, samples were analysed for total coliforms and *E coli*. A once-off trace metal analysis was also done to determine if the groundwater samples contained any trace metals of concern. After the detection of arsenic in some of the samples, analyses were repeated during May and June 2006.

3.1.2.2 Reticulation System

Water from the boreholes is distributed via a reticulation network after treatment by chlorination at abstraction boreholes. Chlorinated water is either distributed via the networks directly to consumers or after it has been collected in reservoirs. Descriptions for the selected monitoring sites at points of use (taps), together with GPS co-ordinates, are given in Table 8 (see also Figure 1).

Table 8: Reticulation System sampling points

Sample Code	Feature ID	Point Description	GPS Coordinates
M4	188668	Tap Delmas west, Maritz Avenue House no 4	S 26°09'22. 2" E 28°40'07. 3’’
T4809_B4	188664	Tap Botleng Ext 4 Stand 4809	S 26°06'08. 5" E 28°40'47. 0"
BN_5092	188674	New Botleng Ext 4 Stand no 5092 (RDP House)	S 26°06'08. 6" E 28°41'08. 8"
B_LS	188673	Botleng Mandela Informal Settlement Section F Lekalakala Street (communal tap)	S 26°07'33. 1" E 28°41'48. 1"
DE_37	188666	Delpark Ext 1 Carnation Street House no 37	S 26°08'34. 7" E 28°41'22. 1"
RS13	188670	Tap Delmas Strydom street, House no 13	S 26°08'46. 1" E 28°40'26. 0"
DE_420	188672	Tap Delpark Ext 2 House no 420 (Tuckshop)	S 26°08'21. 6" E 28°41'46. 4"
NPS_5	188671	Tap Nesher Private School 5th Street	S 26°08'50. 9" E 28°41'07. 9"
NB_3879	188669	Tap New Botleng Ext 6 Stand no 3878	S 26°06'14. 0" E 28°41'55. 5"
B_MS	188667	Botleng Mandela Informal Settlement Section C Masunyane Street (communal tap)	S 26°07'46. 3" E 28°41'56. 3"
Ad Hoc Reticulation system sampling points			
B_C		Botleng Clinic	S 26° 07' 48.3" E 28° 41' 38.3"

Tables 9 and 10 list the macro-chemical and trace metal constituents tested for in the tap water samples.

Table 9 Macro-chemical constituents analysed for in the reticulation system

Macro-chemical constituents		
PH	Total phosphorus as P	Silicon as Si
Kjeldahl Nitrogen as N	Ortho phosphate as P	Calcium as Ca
Ammonia as N	Sulfate as SO_4	Hardness
Nitrate and nitrite as N	Chloride as Cl^-	Total Dissolved Solids (TDS)
Fluoride as F	Potassium as K	Electrical conductivity (EC) at 25°
Alkalinity as $CaCO_3$	Sodium as Na	Magnesium as Mg

Table 10 Trace metals tested for in the reticulation system

Trace Metals		
Iron as Fe	Zinc as Zn	Arsenic as As
Manganese as Mn	Cadmium as Cd	Copper as Cu
Lead as Pb	Nickel as Ni	Chromium as Cr

To determine the microbiological quality, total coliforms (TC), *E coli* and Standard Plate Count (SPC) analyses were done.

4 Information Generation and Dissemination

4.1 Data management and storage

Data generated during the investigation were stored and managed on DWAF's database, Water Management System (WMS).

4.2 Data interpretation

A colour coded classification system was used to assess and present the water quality data in an easily understandable way. A description of the classification system is given in Table 11.

Table 11 Colour coded water quality classification system

Class	Colour	Description	Effects
I	Green	Good water quality (Target)	Suitable for use, rare instances of negative effects
II	Yellow	Marginal water quality	Conditionally acceptable. Negative effects may occur in some sensitive groups
III	Red	Poor water quality	Unsuitable for use without treatment. Possible chronic effects.

4.2.1 Surface water

Surface water in the Delmas vicinity is mainly used for contact recreation, i.e. swimming and fishing, as well as for watering cattle, pigs and other livestock. The quality of the surface water was therefore evaluated against the South African Water Quality Guidelines for Recreational - and Agricultural Use: Livestock Watering (DWAF 1996$_a$ and $_b$). A summary of the guideline values used is given in Tables 12 and 13.

Table 12 Water quality requirements for surface water as adapted from the South African Water Quality Guidelines for Recreational Use

Determinant	Unit	Class I	Class II	Class III
Microbiological requirements				
E coli	counts/100mL	0 - 200	200 - 4 000	>400
Faecal coliforms	counts/100mL	0 - 600	600 - 2 000	>2 000
Faecal streptococci	counts/100mL	0 - 60	60 - 100	>100
Chemical requirement				
PH	pH units	6.5 - 8.5	Between 5.0 - 6.5 or 8.5-9.0	Between 0 - 5.0 or >9.0

Table 13 Chemical quality requirements for surface water as adapted from the South African Water Quality Guidelines for Agricultural Use: Livestock watering

Determinant	Unit	Class I	Class II	Class III
Chemical requirements – macro-determinant				
Total Dissolved Solids	mg/L	0 - 1 000	1 000 - 3 000	>3 000
Calcium as Ca	mg/L	0 - 1 000	1 000 -2 000	>2 000
Chloride as Cl^- (health)	mg/L	0 - 3 000	3 000 - 4 000	>4 000
Fluoride as F^- (health)	mg/L	0 - 2	2 - 6	>6
Magnesium as Mg	mg/L	0 - 500	500 - 1 000	>1 000
Nitrate as NO_3	mg/L	0 - 100	100 - 200	>200
Sodium as Na	mg/L	0 - 2 000	2 000 - 2 500	>2 500
Sulfate as SO^{2-}_4	mg/L	0 - 1 000	1 000 - 1 500	>1 500
Zinc as Zn	mg/L	0 - 20	20 - 40	>40
Chemical requirements – micro-determinant				
Aluminium as Al	mg/L	0 - 5	5 - 10	>10
Arsenic as As	mg/L	0 - 1.0	1.0 - 1.5	>1.5
Boron as B	mg/L	0 - 5	5 - 50	>50
Cadmium as Cd	mg/L	0 - 0.01	0.01 - 0.02	>0.02
Chromium (VI) as Cr	mg/L	0 - 1	1 - 2	>2
Cobalt as Co	mg/L	0 - 1	1 - 2	>2
Copper as Cu	mg/L	0 - 1	1 - 2	>2
Iron as Fe	mg/L	0 - 10	10 - 50	>50
Lead as Pb	mg/L	0 - 0.1	0.1 - 0.2	>0.2
Manganese as Mn	mg/L	0 - 10	10 - 50	>50
Mercury as Hg	mg/L	0 - 1	1 - 6	>6
Molybdenum	mg/L	0 - 0.01	0.01 - 0.02	>0.02
Nickel as Ni	mg/L	0 - 1	2 - 5	>5
Selenium as Se	µg/L	0 - 50	50 - 75	>75
Vanadium as V	mg/L	0 - 1	1 - 2	>2

4.2.2 WWTW Effluent

The quality of effluents was evaluated against the licence conditions issued for the treatment facilities by DWAF on 21 December 2001 (Table 14). Both facilities need to release effluents with ammonia and orthophosphate concentrations not exceeding 10mg/L. The colour red, when used to indicate the quality of the discharged effluent, implied per sample failure to adhere to the licence conditions.

Table 14 Licence conditions for Delmas WWTW

Constituents	Regulatory limit concentration
PH	5.50 - 9.50
Electrical Conductivity (EC)	70.0 mS/m above intake to a maximum of 150mS/m
Nitrate as N	15.0 mg/L
Ammonia as N	10.0 mg/L (after 5 years of this licence, 3mg/L)
Chemical Oxygen Demand (COD)	75.0 mg/L after removal of algae
Faecal coliforms	0cfu /100mL
Ortho Phosphate as P	10.0 mg/L (1.00 mg/L after 5 years of this licence)
Suspended Solids (SS)	25 mg/L

4.2.3 Domestic water supply system

The quality of water used for drinking was assessed against SANS 241: 2005. Water in all the boreholes and reticulation system needs to comply with the microbiological requirements given in Table 15, as well as the physical, organoleptic and chemical requirements listed in Table 16.

Table 15 Microbiological safety requirements for drinking water (SANS 241:2005)

1	2	3	4	5
Determinant	**Unit**	**Allowable compliance contribution [a]**		
		95 % of sample, min	**4 % of samples, max**	**1 % of sample, max**
E coli [b]	count/100mL	Not detected	Not detected	1
Thermotolerant (faecal) coliform bacteria [c]	count/100mL	Not detected	1	10

[a] The allowable compliance contribution shall be at least 95 % of the limits indicated in the column 3, with a maximum of 4 % and 1 %, respectively, to the limits indicated in column 4 and 5. The objective of disinfection should, nevertheless, be to attain 100 % compliance to the limits indicated in column 3.

[b] Definitive, preferred indicator of faecal pollution.

[c] Indicator of unacceptable microbial water quality, could be tested instead of *E coli* but is not the preferred indicator of faecal pollution. Also provides information on treatment efficiency and after growth in distribution networks.

Table 16 Physical, organoleptic and chemical requirements for drinking water (SANS 241:2005)

1	2	3	4	5
Determinant	**Unit**	**Class I (recommended operational limit)**	**Class II (max. allowable operational limit)**	**Class II water consumption period [a], max.**
Physical and organoleptic requirements				
Colour (aesthetic)	mg/L Pt	<20	20 - 50	No limit [b]
Conductivity at 25°C (aesthetic)	mS/m	<150	150 - 370	7 years
Dissolved solids (aesthetic)	mg/L	<1 000	1 000 – 2 400	7 years
Odour (aesthetic)	TON	<5	5-10	No limit [b]
pH value at 25°C (aesthetic/operational)	pH units	5.0 - 9.5	4.0 - 10.0	No limit [c]
Taste (aesthetic)	FTN	<5	5 - 10	No limit
Turbidity (aesthetic/operational/indirect health)	NTU	<1	1 - 5	No limit [d]
Chemical requirements – macro-determinant				
Ammonia as N (operational)	mg/L	<1.0	1.0 - 2.0	No limit [d]
Calcium as Ca (aesthetic / operational)	mg/L	<150	150 - 300	7 years
Chloride as Cl^- (aesthetic)	mg/L	<200	200 - 600	7 years
Fluoride as F^- (health)	mg/L	<1.0	1.0 - 1.5	1 year
Magnesium as Mg (aesthetic/health)	mg/L	<70	70 - 100	7 years
(Nitrate and nitrite) as N (health)	mg/L	<10	10 - 20	7 years
Potassium as K (operational/health)	mg/L	<50	50 - 100	7 years
Sodium as Na (aesthetic/health)	mg/L	<200	200 - 400	7 years
Sulfate as SO^{2-}_4	mg/L	<400	400 - 600	7 years
Zinc as Zn (aesthetic/health)	mg/L	<5.0	5.0 - 10	1 year

Table 16 Physical, organoleptic and chemical requirements for drinking water (SANS 241:2005) (Continued)

1	2	3	4	5
Determinant	**Unit**	**Class I (recommended operational limit)**	**Class II (max. allowable operational limit)**	**Class II water consumption period [a], max.**
Chemical requirements – micro-determinant				
Aluminium as Al (health)	µg/L	<300	300 - 500	1 year
Antimony as Sb (health)	µg/L	<10	10 - 50	1 year
Arsenic as As (health)	µg/L	<10	10 - 50	1 year
Cadmium as Cd (health)	µg/L	<5	5 - 10	6 months
Total Chromium as Cr (health)	µg/L	<100	100 - 500	3 months
Cobalt as Co (health)	µg/L	<500	500 – 1 000	1 year
Copper as Cu (health)	µg/L	<1 000	1 000 – 2 000	1 year
Cyanide (recoverable) as CN^- (health)	µg/L	<50	50 - 70	1 week
Iron as Fe (aesthetic/operational)	µg/L	<200	200 – 2 000	7 years[b]
Lead as Pb (health)	µg/L	<20	20 - 50	3 months
Manganese as Mn (aesthetic)	µg/L	<100	100 – 1 000	1 year
Mercury as Hg (health)	µg/L	<1	1 – 5	3 months
Nickel as Ni (health)	µg/L	<150	150 - 350	1 year
Selenium as Se (health)	µg/L	<20	20 - 50	1 year
Vanadium as V (health)	µg/L	<200	200 - 500	1 year
Chemical requirement – organic determinant				
Dissolved organic carbon as C (aesthetic)	mg/L	<10	10 - 20	3 months[e]
Total trihalomethanes (health)	µg/L	<200	200 - 300	10 years[f]
Phenols (aesthetic/health)	µg/L	<10	10 - 70	No limit[b]

a The limits for the consumption of class II water are based on the consumption of 2L of water per day by a person of mass 70 kg over a period of 70 years. Columns 4 and 5 shall be applied together.

b The limits given are based on aesthetic aspects.

c No primary health effect – low pH values can result in structural problems in the distribution system.

d These values can indicate process efficiency and risks associated with pathogens.

e When dissolved organic carbon is deemed of natural origin, the consumption period can be extended.

f This is a suggested value because trihalomethanes have not been proved to have any effect on human health.

Treated domestic water supplies should also be evaluated to identify exceedance of alert levels given in Table 17. Free available (residual) chlorine is the free chlorine concentration remaining 30 minutes after breakpoint disinfection of water with chlorine. Residual chlorine is an indication of the efficacy of the disinfection process. Absence of free available chlorine means that either the water was not treated with chlorine, or that insufficient chlorine was used for disinfection. If the untreated water contained pathogenic micro-organisms, the risk of microbiological infection might still exist. A too high concentration of chlorine, on the other hand might irritate the mucous membranes and cause nausea or vomiting.

Table 17 Operational water quality alert values (SANS 241:2005)

Determinant	Unit	Alert level
Residual chlorine	mg/L	< 0.5
Heterotrophic plate count	count/100mL	5 000

[a] Dependent on network characteristics and chlorine demand. A residual of 0.5 mg/L applies to the waterworks final water. The appropriate level in a distribution system is 0.2 mg/L. Where other disinfectants are used, appropriate alert levels should be selected.

The project team proposed the SANS241: 2005 guideline for residual chlorine be elaborated upon to also assess the suitability for use of water within the distribution network against over chlorination of water supplies. Guidelines proposed by the project team to assess the efficiency of chlorination of water in the distribution system are given in Table 18.

Table 18 Free available chlorine requirements proposed by the project team

Class	Concentration mg/L	Description	Effects
III (Red)	0 – <0.2	Poor water quality	Disinfection inadequate, health risk may exist
II (Yellow)	0.2 – <0.5	Marginal	Slight risk of infection
I (Green)	0.5 – 3.0	Good	Disinfection adequate water microbially safe
II (Yellow)	>3.0 – <5.0	Marginal	Antiseptic taste but water safe
III (Red)	>5.0	Poor	Strong antiseptic taste and risk of mucous membrane irritation

5 Results

The results of an overall assessment of the microbiological quality of the surface water, WWTW effluent, groundwater as well as the quality of the water in the reticulation system are given in Tables 19 to 24, Figures 2 and 3. The overall microbiological water quality classification can be used to determine the suitability for use of the water within the immediate timeframe (hours to days). Water not fit for use, in terms of the microbiological quality, puts users at risk of contracting water-related diseases shortly after consuming the water. Under favourable conditions outbreaks, often associated with diarrhoea, may occur within hours to days after communities have consumed the water.

Tables 25 to 29, Figures 4 and 5 reflect the overall physico-chemical quality of water sampled during the Delmas investigation. This classification of the quality of the Delmas water is based on the fitness for use of the physico-chemical characteristics of the water. Chemical constituents differ from microbiological contaminants in that they do not usually cause acute health effects (unless large quantities are consumed), but cause chronic diseases after the ingestion of small quantities over extended periods. Small quantities of some chemicals ingested over years may increase risks of contracting certain cancers.

Some of the physico-chemical variables, free available chlorine and turbidity, were also used to evaluate the microbial quality and thus indicate the potential for disease causing organisms to be present in the water. These variables were used in conjunction with the overall microbial classification to assess the fitness for use of the water within the short term.

To serve as an early warning system, the worst water quality class observed during the assessment period dictated the overall quality class for each monitoring site on a particular sampling date. Data (Appendices B, C, D and E) were compared to the water quality requirements (per water category) given in Tables 12 – 18. For better understanding, the constituent(s) rendering the water unsuitable for use are indicated in the overall water quality tables to follow. Those variables considered to pose the greatest risk to human health, are also presented graphically in Figures 9 to 53, Appendix A.

5.1 Microbial results

The overall classification of the microbiological quality of the Delmas waters is given in Tables 19 to 24 and Figures 2 and 3. *E coli* and faecal streptococci concentrations were used to determine the suitability for use of the surface water, while only the *E coli* concentrations dictated the fitness for use of all the other water categories.

5.1.1 Surface water component of supply chain

Table 19 Overall surface water microbiological quality classification

Sample Code	Overall microbiological quality – surface water						
	12 Dec 05	12 Jan 06	13 Feb 06	13 Mar 06	10 Apr 06	22 May 06	21 June 06
S1	Yellow [a]	Red [a + b]	Red [a + b]	Red [b]	Green	**Green**	**Green**
S2	Red [a]	Red [a]	Yellow [a]	Red [a]	Green	**Green**	**Green**
S3	Red [a]	Site not accesible		Yellow [a]	No flow, samples not taken		
S4	Green	Red [a]	Red [a]	Yellow [a]	Red [b]	Yellow [a + b]	Green
S8	Red [a]	Red [a]	Red [a]	Red [a]	Red [a + b]	Red [a + b]	Red [a + b]

Where a *E coli*
b Faecal streptococci

Table 19 Overall surface water microbiological quality classification

Sample Code	Overall microbiological quality – surface water						
	12 Dec 05	12 Jan 06	13 Feb 06	13 Mar 06	10 Apr 06	22 May 06	21 June 06
S9	Red [a]	Red [a]	Red [a]	Red [a]	Red [a + b]	Red [a + b]	Red [a + b]
S10	Yellow	Red [a]	Red [a]	Red [a]	Red [a]	Green	Green
S12	Site not accessible during monitoring period – no sample taken						
S13	Site not accessible during monitoring period – no sample taken						
S14	Green	Red [a]	Red [a]	Red [a]	Red [a]	Red [a]	Red [a]
S15		Red [a]	Red [a]	Red [a]	Red [a]	Green	Red [a]
S16	Red [a]	Red [a]	Green	Green	Green	Green	Green
S17		Red [a]	Red [a]	Red [a]	No flow, samples not taken		
S18	No flow, samples not taken						
S19	No flow, samples not taken						
S20		Red [a]	No flow, samples not taken				
S21			No flow		Green	No flow	
S22	No flow, samples not taken						

Where a *E coli*
b Faecal streptococci

Table 20 Effluent discharge microbial water quality classification

Sample Code	Overall microbiological quality – discharged effluent						
	12 Dec 05	12 Jan 06	13 Feb 06	13 Mar 06	10 Apr 06	22 May 06	21 June 06
S5	Red	Red	Red	Red	Red	Red	Red
S11	Red	Red	Red	Red	Green	Green	Red

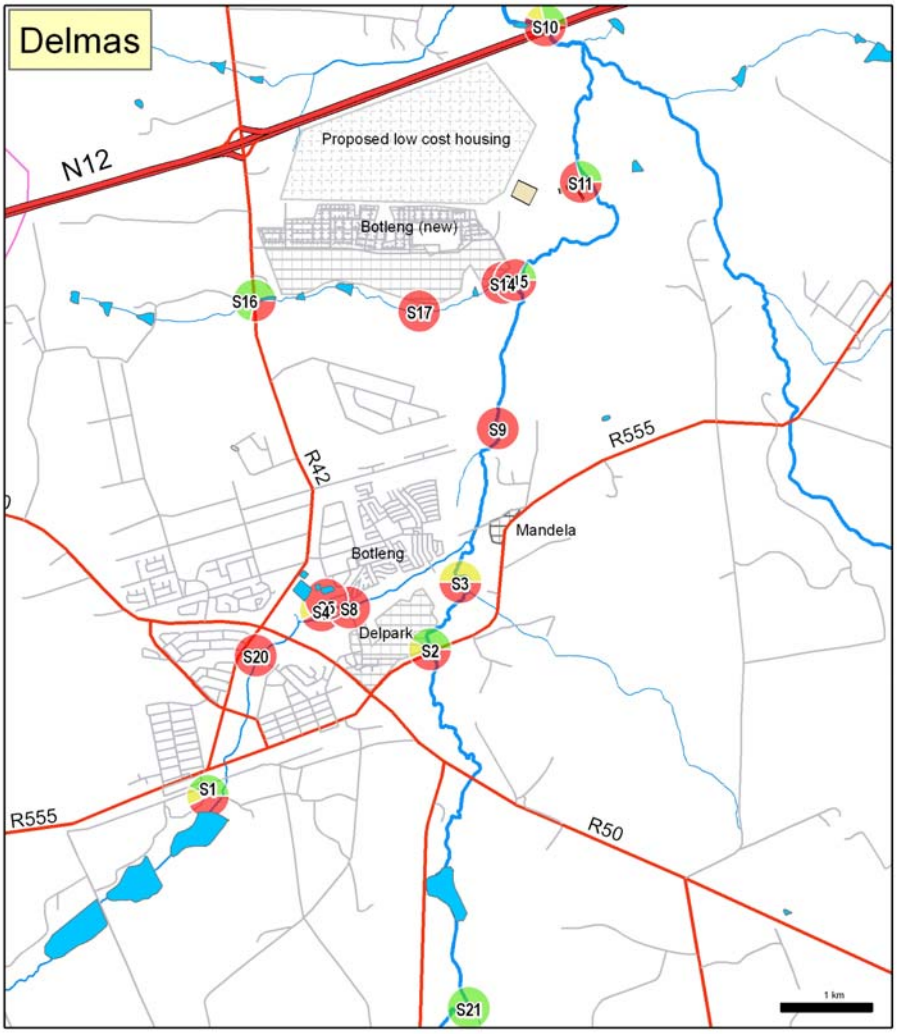

Figure 2: Overall microbial water quality classification - surface water

Symbols represent the proportion of time during the sampling period that the water quality fell into the "Good", "Fair" and "Poor" categories.
The labels on each symbol represent the water quality variables that are a problem.
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5.1.2 Drinking water component of supply chain

Table 21 Overall groundwater microbiological quality classification

Sample Code	Overall microbiological quality - groundwater									
	07 Dec 05	12 Dec 05	16 Jan 06	17 Jan 06	14 Feb 06	23 Feb 06	13 Mar 06	11 Apr 06	10 May 6	20 June 6
A3	Red	Red			Red		Red	Red	Red	Red
A4	Red	Red	Red		Red		Red	Red	Green	Green
A7	Red	Red	Red		Red		Red	Red	Red	Red
BOT3		Green		Green	Green		Green	Green	Green	Green
BOT4	Green	Green	Green		Green		Green	Green		Green
BOT5	Green	Green		Green	Green		Green	Green	Green	Green
BOT6		Green		Green	Green		Green	Green	Green	Green
BOT8				Green	Green		Green	Green	Green	Green
C1	Green	Green		Green	Green		Green	Green	Green	Green
C2	Green	Green			Green		Green	Green	Green	Green
C3	Green	Green		Green		Green	Green	Green	Green	
C4					Green		Green	Green	Green	Green
D5	Green	Red		Green	Green		Green	Green	Green	Green
D10	Green	Green		Green	Green		Green	Green	Green	Green

Table 22 Overall microbial quality classification of the rural water supply boreholes under the jurisdiction of Delmas Municipality

Sample Code	Overall microbiological quality – rural boreholes		
	27 February 2006	11 May 2006	27 June 2006
Arbor		Red	Green
Argent	Green	Green	Green
Dryden	Green	Green	Green
Bambisana	Green	Green	Green
Waaikraal	Red	Green	Green
Droogenfontein	Red	Green	Green

Table 23 Overall microbiological classification of the Delmas reticulation system

Sample Code	Overall Microbiological Quality – reticulation system																									
	Nov 2005			Dec 2005			Jan	Feb 2006		March 2006				April 2006				May 2006					June 2006			
	15	22	29	6	14	20	31	7	28	7	14	22	28	5	11	18	24	2	9	16	23	30	6	13	20	27
M4	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
T4809_B4	G	G		G	G	G	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G
BN_5092	G	G		G	G	G	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G
B_LS	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
DE_37	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
RS13	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	R	G	G	G	G	G	G	G	G
DE_420	G	G		G	R	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
NPS_5	G	G		G	G	G	G	G		G	G	G	G	G	G	G		G	G	G	G	G	G	G	G	G
NB_3879	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
B_MS	G	G		G	G	G	G	G		G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G

Where: G - Green
Y - Yellow
R - Red

Table 24 Microbial classification of an ad hoc reticulation system sample

Sample Code	Monitoring Point Description	Overall quality 14 March 2006
B_C	Botleng Clinic	Red

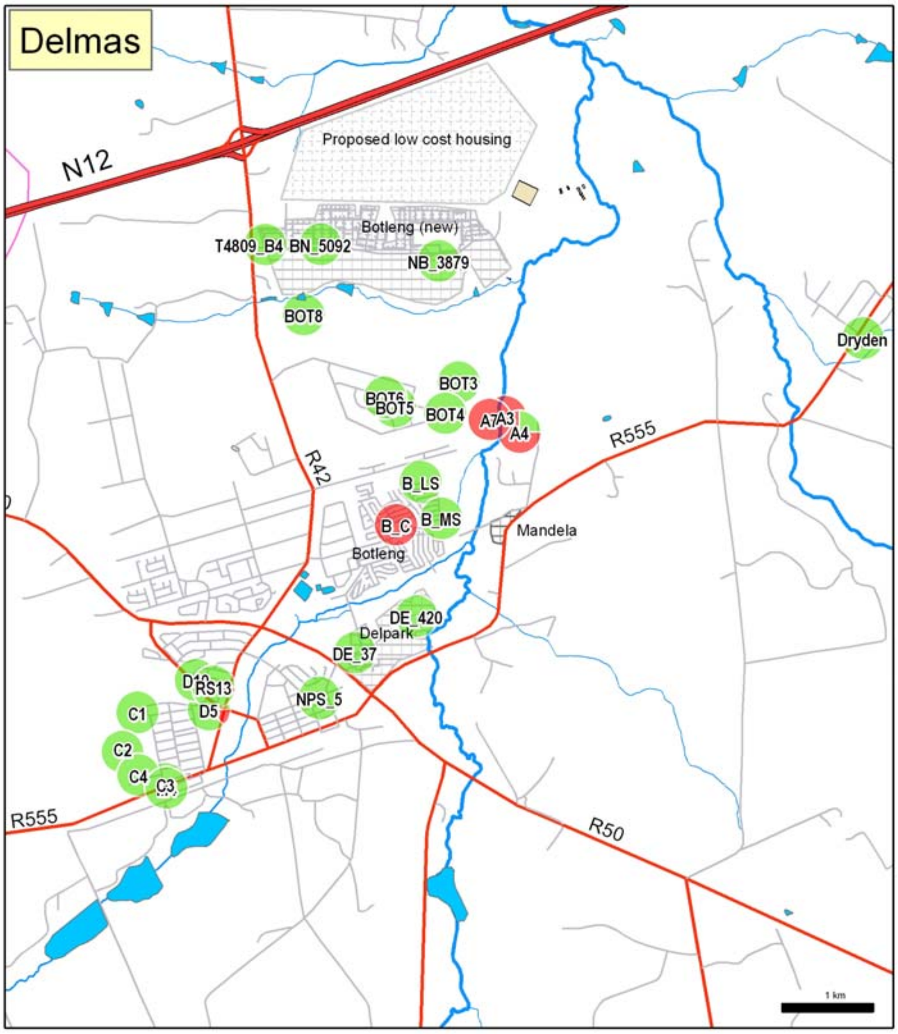

Figure 3: Overall microbial water quality classification - drinking water

Symbols represent the proportion of time during the sampling period that the water quality fell into the "Good", "Fair" and "Poor" categories.
The labels on each symbol represent the water quality variables that are a problem.
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5.2 Chemical results

The overall classification of the physico-chemical quality of the Delmas waters is given in Tables 25 to 29, as well as Figure 4 and 5.

5.2.1 Surface water component of supply chain

Table 25 Overall surface water physico-chemical quality classification

Sample Code	Overall Physico-chemical Quality - surface water						
	12 Dec 05	**12 Jan 06**	**13 Feb 06**	**13 Mar 06**	**10 Apr 06**	**22 May 06**	**21 June 06**
S1	Green	Green	Green		Green	**Green**	Green
S2	Green	Green	Green	Green	Green	Green	Yellow [a]
S3	Green	No flow		Green	No flow, samples not taken		
S4	Green	Green	Green	Yellow [a]	Green	Green	Yellow [a]
S8	Green		Green	Green	Green	Green	
S9	Green	Green	Green	Yellow [a]	Green	Green	
S10			Green	Green	Green	Green	
S12	Site not accessible during monitoring period – no samples taken						
S13	Site not accessible during monitoring period – no samples taken						
S14	Green	Green	Green	Green	Green	Green	
S15			Green		Green	Green	
S16		Yellow [a]	Green	Green	Green	Green	
S17		Green	Green	Green	No flow, samples not taken		
S18	No flow, samples not taken						
S19	No flow, samples not taken						
S20			No flow				
S21			No flow		Green	No flow	
S22	No flow, samples not taken						

Where a pH

Table 26 Effluent discharge physico-chemical quality classification

Sample Code	Overall Physico-chemical Quality - discharged effluent						
	12 Dec 05	12 Jan 06	13 Feb 06	13 Mar 06	10 Apr 06	22 May 06	21 June 06
S5	Red [ii]	Red [ii + v]	Green	Red [iii + v]	Red [ii]	Red [ii]	
S11			Green	Green	Green	Red [iii]	Green

Where i pH; ii NH_4-N; iii NO_3-NO_2; v PO_4

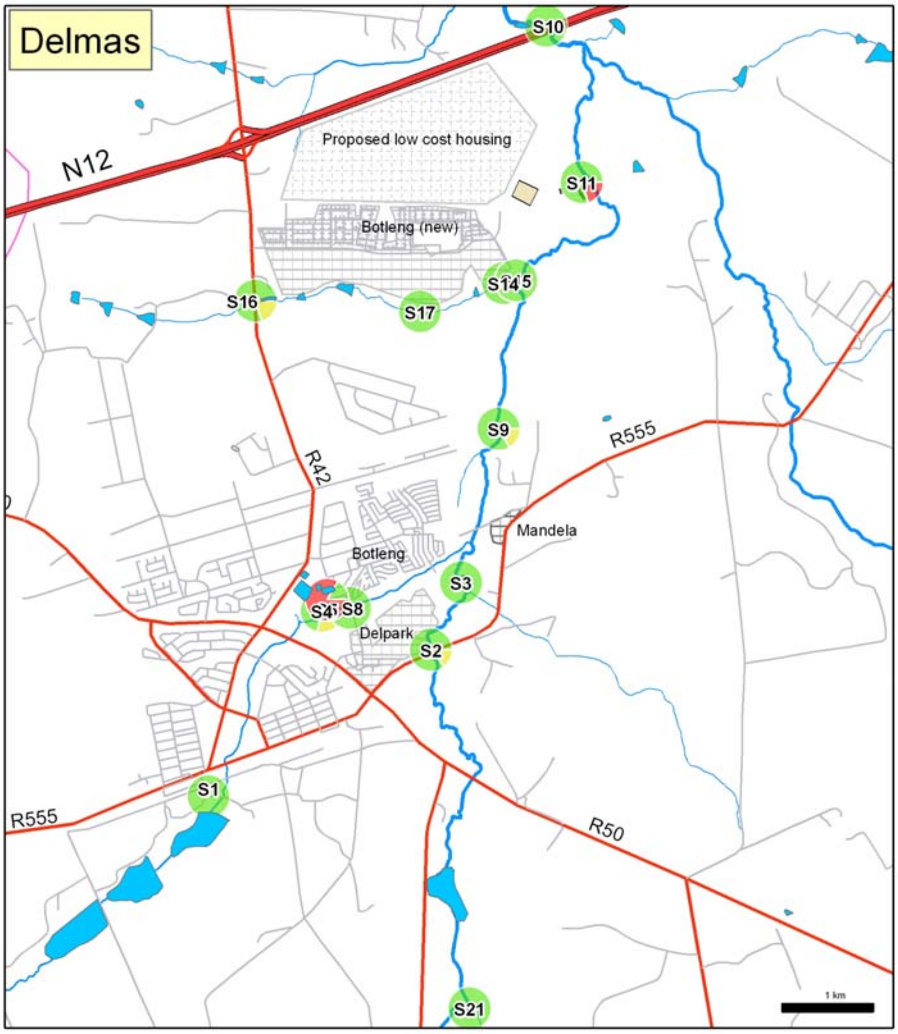

Figure 4: Overall physico-chemical water quality classification - surface water

GOOD_
FAIR_
POOR_

Symbols represent the proportion of time during the sampling period that the water quality fell into the "Good", "Fair" and "Poor" categories.
The labels on each symbol represent the water quality variables that are a problem.
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5.2.2 Drinking water component of supply chain

Table 27 Overall physico-chemical quality classification of Delmas groundwater

Sample code	Overall Physico-chemical Quality - groundwater							
	07 Dec 05	12 Dec 05	16 Jan 06	14 Feb 06	13 Mar 06	11 Apr 06	10 May 06	20 June 06
A3		Yellow [b, e]	Green				Green	Green
A4		Green	Green				Green	Red [d]
A7		Yellow [a]	Green				Green	Green
BOT3		Green					Yellow [d]	Yellow [d]
BOT4		Green	Green					Yellow [d]
BOT5		Green	Green				Green	Green
BOT6		Green					Green	Green
BOT8		Red [c]					Red [c]	Red [c]
C1		Green	Green				Green	Green
C2		Red [d]	Red [d]		Yellow [a]	Red [a]	Red [a, d]	Red [d]
C3		Green	Green				Red [d]	
C4		Green	Green		Red [a]	Red [a]	Red [d]	Red [d]
D5		Green	Green		Green	Red [a]	Green	Red [d]
D10		Green	Yellow [f]				Green	Green

Where a Turbidity c Fluoride e Manganese
b NH_4-N d Arsenic f Iron

Some of the red classified samples showed arsenic concentrations exceeding the recommended drinking water quality standards proposed in SANS 241: 2005. Many spectrometric emission lines however interfere with the detection of arsenic in water - a decision was therefore taken to re-sample and verify the presence of arsenic in the Delmas water. Samples were again taken on 2 October 2006 in the C-well field from monitoring sites C1, C2, C3 and C4.

Arsenic presence was confirmed by triple checking for three (3) different emission lines by ICP, including wavelength scanning and background correction. Results of previous analyses were confirmed when arsenic was again detected in the C-well field boreholes (results given below). The detection of the arsenic in the filtered samples, also confirms that the arsenic is present in colloidal solution. Flocculation techniques will therefore be effective in removing the arsenic to concentrations not harmful to human health.

Table 27a Re-tested arsenic concentrations (Note that Class II (marginal) is 10-50µm/L (Table 16)

Sample site	Arsenic (µg/L) at the measured wavelength (nm)		
	As nm wavelength 188.98	As nm wavelength 193.70	As nm wavelength 197.20
C1	7	9	8
C2	291	296	274
C3	45	55	58
C4	73	52	83

Table 28 Overall physico-chemical quality classification of the rural water supply boreholes under the jurisdiction of Delmas Municipality

Sample code	Overall Physico-chemical Quality - rural boreholes		
	27 February 2006	11 May 2006	27 June 2006
Arbor		Green	Green
Argent		Green	Green
Dryden		Yellow [a]	Yellow [a]
Bambisana		Green	Green
Waaikraal		Yellow [a]	Green
Droogenfontein		Yellow [a]	Yellow [a]

Where a NO_3-NO_2

Table 29 Overall physico-chemical quality classification of the Delmas reticulation system

Sample Code	Overall Physico-chemical quality																								
	Nov 2005			Dec 2005			Jan	Feb 2006		March 2006				April 2006				May 2006					June 2006			
	15	22	29	6	14	20	31	7	28	7	14	22	28	5	11	18	24	2	9	16	23	30	6	13	20	27
M4	G	G	G	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	G	$Y^{c\downarrow}$	G	$Y^{c\uparrow}$	Y^{b}	G	G	G	G	Y^{b}	G	Y^{a}	G	Y^{b}
T4809_B4	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{\downarrow}$	G	G	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	Y^{ac}	$Y^{c\downarrow}$	Y^{cb}	$R^{c\downarrow}$	Y^{a}	Y^{a}	G	Y^{cb}	G	G	G	Y^{b}
BN_5092	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	G	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	Y^{ac}	$Y^{c\downarrow}$	Y^{cb}	$R^{c\downarrow}$	Y^{a}	Y^{a}	G	R^{bd}	G	G	Y^{a}	Y^{b}
B_LS	$R^{c\downarrow}$	$Y^{c\downarrow}$		$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$		$Y^{c\downarrow}$	$Y^{c\downarrow}$	Y^{ac}	Y^{a}	Y^{a}	Y^{a}	G	Y^{b}	$R^{c\downarrow}$	G	G	Y^{a}	Y^{cb}	G	G	G	$R^{c,b}$
DE_37	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$R^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	Y^{ac}	G	$Y^{c\downarrow}$	G	G	Y^{b}	$Y^{c\downarrow}$	G	G	$Y^{c\downarrow}$	Y^{cb}	G	$Y^{c\downarrow}$	$R^{c\downarrow}$	$R^{c,b}$
RS13	G	G	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	G	G	$Y^{c\downarrow}$	$Y^{c\uparrow}$	$Y^{c\uparrow}$	G	$Y^{c\uparrow}$	G	G	G	G	G	G	G	G	G	$Y^{c\uparrow}$	G	$R^{c\downarrow}$
DE_420	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	Y^{ac}	Y^{a}	Y^{a}	Y^{a}	G	Y^{b}	G	$Y^{c\uparrow}$	G	Y^{ac}	R^{b}	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	R^{b}
NPS_5		$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	G	G	G	$R^{c\downarrow}$	Y^{ac}	Y^{a}	Y^{a}	Y^{a}	$Y^{c\uparrow}$		R^{b}	G	G	Y^{ac}	R^{b}	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	$R^{c,b}$
NB_3879	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	$Y^{c\downarrow}$	$Y^{c\downarrow}$	G	G	G	$Y^{c\downarrow}$	G	G	Y^{a}	G	Y^{a}	G	Y^{cb}	G	G	Y^{a}	Y^{a}	Y^{b}	Y^{a}	G	Y^{a}	Y^{b}
B_MS	$R^{c\downarrow}$	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	$Y^{c\downarrow}$	G	$R^{c\downarrow}$	$Y^{c\downarrow}$	Y^{ac}	Y^{a}	Y^{a}	Y^{a}	G	Y^{b}	$R^{c\downarrow}$	Y^{a}	G	Y^{a}	Y^{cb}	G	G	G	R^{cb}

Where:
G - Green
Y - Yellow
R - Red, and

a - Turbidity
b - Arsenic
c - Residual Chlorine ($^{\downarrow}$ - Under chlorination and $^{\uparrow}$ - Over chlorination)
d - Cadmium and Lead

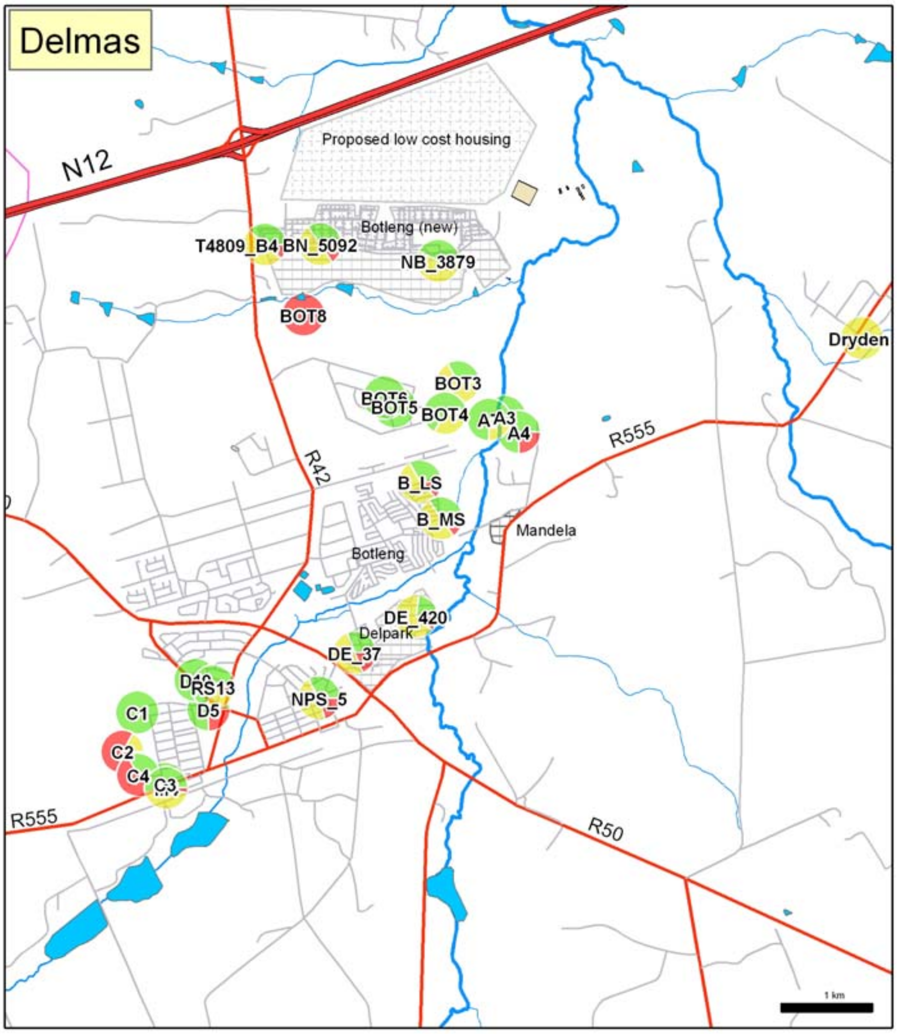

Figure 5: Overall physico-chemical water quality classification - drinking water

GOOD_
FAIR_
POOR_

Symbols represent the proportion of time during the sampling period that the water quality fell into the "Good", "Fair" and "Poor" categories.
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6 Discussion

6.1 Sample collection and analysis

As with most new monitoring programmes, some logistical problems were experienced at the beginning of the Delmas water quality monitoring project. Making sure that all understood when and where they need to take samples, following appropriate methods during sampling as well as arranging for transport where some of the problems experienced. Good project management however surmounted most problems and good cooperation was established between the various Task Team members. Other reasons for not always taking samples according the agreed upon schedule included:

a. No flow in the tributaries implied that surface water samples at S3, S17, S20, and S21 could often not be taken.

b. During the January and February sampling trips, samples were not taken at S3 because the municipality was busy upgrading the only access to S3.

c. Sampling points S12 and S13 (upstream and downstream of the new WWTW) were not accessible during the study period; the impact of the WWTW on the Bronkhorstspruit system could thus not be assessed.

d. Out of order production borehole pumps resulted in no collection of groundwater samples (pumps were not working on 12 January 2006 at A3 and on 10 May 2006 at BOT4).

6.2 Interpretation of analytical results

6.2.1 Surface Water

S1 at Witklip dam

The water quality, with respect to bacteriological contamination, improved during the assessment period from poor to acceptable levels. The cessation of pumping return water flows from the sewage works to the Witklip dam most likely brought about the improvement, good rains during the later period of the monitoring programme also assisted in diluting the contamination.

The chemical quality of water in the Witklip Dam was throughout the monitoring period acceptable for livestock watering and recreational use.

S2 above Delpark and S3 midway through Delpark

Microbiological constituents exceeded the recommended water quality guidelines during rainy periods, acceptable results were generally observed in the dry season. During the rain season, runoff may have flushed land-deposited faecal matter of animal and / or human origin into this unnamed tributary of the Bronkhorstspruit (the land adjacent to the monitoring site is used for livestock grazing). An acceptable chemical water quality was observed.

No samples were taken at S3 during January and February 2006 when road upgrading work by the municipality resulted in no access to the site. The impact of the Mandela informal settlement close to the banks of the tributary is reflected at this site. The limited results obtained however showed that the water was faecally polluted (unacceptable levels of micro organisms). On completion of road maintenance work, monitoring needs to continue because residents from the informal settlement may use this water for various purposes.

S4 above Delmas sewage works

Flow is marginal, above this point no flow was observed for most of the monitoring period - the tributary was considered non-perennial. No significant flow-through occurred from the Witklip Dam.

The chemical quality of the water was, in terms of recreation and livestock watering, well within acceptable limits. The microbial quality deteriorated during wet periods to unacceptable limits.

At S8 and further below to S9 (downstream of the old Delmas sewage works)

S4 and S8 are in one system, but flow was always observed at S8. The high flows can be attributed to the effluent discharges from Delmas sewage works. The impact of the effluent discharges is also evident in the comparable higher *E coli* counts detected at S5, S8 and not at S4. S4 sometimes had *E coli* counts of acceptable levels compared to the unacceptable levels always detected at S8. The *E coli* levels showed that the non-perennial system did not have the capacity to assimilate the poor water quality discharges from the wastewater treatment works, the water is unsuitable for recreation or livestock watering.

S10 in the Bronkhorstspruit downstream of Delmas

Water quality at this point reflected the impact of Delmas on the Bronkhorstspruit. The water course could not assimilate all the discharges received upstream. In terms of microbiological quality, the water was unsuitable for recreation and watering of livestock. Similar to most of the other surface water sampling sites, the chemical quality was acceptable.

S12 and S13 (above and below the new WWTW)

The sites were not accessible during the monitoring period. The impact of the new WWTW on the Bronkhorstspruit system was not determined during this study.

S14 above pump station and below Mandela informal settlements

Unacceptable levels of *E coli* were detected for most of the monitoring period. The high counts may be attributed to impacts from informal settlements, poor sanitation and livestock grazing. People should be advised not to use the water for recreational purposes and livestock should not drink the water. The water was of an acceptable chemical quality.

S15 downstream of S14

Although still showing relatively high *E coli* counts, *E coli* were detected in lower levels at this site. The resource showed an ability to assimilate the faecal microbiological pollution loads between S14 and S15. This capacity to reduce the contamination could be due to: (i) the filtering effect by riparian and in-stream vegetation, (ii) the slow water movement which increases residence time and thus increases exposure of micro-organisms to UV and as a consequence, micro-organism die-off, and (iii) the hydraulic connectivity which increases the dilution affect after increasing the groundwater base-flow.

S16 above Botleng new extension

Unacceptable *E coli* levels were detected during the rain season when runoff could have flushed land deposited faecal material into the water. The water quality was good (acceptable / green class) during the dry period, the quality was then indicative of a reference water quality.

S17 midway Botleng new extension (downstream of S16)

High *E coli* counts caused the water to be of poor microbiological quality. The microbiological contamination most likely reflects the impacts caused by the informal settlements, poor sanitation, livestock grazing and livestock watering. The water was of acceptable chemical quality.

S20 (bridge to Leandra, Bronkhorstspruit) and S21 (bridge through town, unnamed tributary)

No flow in the tributaries implied that samples were only taken once at both sites. The data was too little to formulate a meaningful picture of the water quality at the two sites.

S5 Delmas sewage works effluent discharge point

The continued non-compliance of the old sewage works has a detrimental effect on the water quality measured at S8 and S9, high counts of *E coli* were detected in samples taken at the two sites. Pollution of the surface water resources could affect groundwater in the hydrologically connected well fields A and B (main sources of water supply to Delmas community).

The effluent of the new sewage works (S11)

The quality gradually improved from poor to good from the beginning of the 8-month monitoring period. Generally the new system operating with newer technology performed better than the overloaded “old” Delmas wastewater treatment works. Future plans by the municipality to relocate approximately 1000 households from other informal settlements in the vicinity of Delmas, to an area close to Botleng new extension, would however require review of the infrastructure capacity of the Botleng sewage works.

The existing landfill site situated in the Botleng extension area is another issue of concern. Joint regulatory auditing functions at landfill sites, implies that DWAF is responsible for ensuring that groundwater and surface water at landfill sites comply with permit conditions. The location of the current landfill site, roughly 300m from the Bronkhorstspruit, is cause for concern. Runoff from the site has the potential to pollute surface and groundwater resources. Continuous monitoring of sites S12 and S13 therefore needs to be included in any future monitoring programme.

6.2.2 Groundwater

A-well Field - (Well field assumed to be linked to the outbreak of the typhoid epidemic)

Production Borehole A3

E coli counts were consistently high in all samples analysed. Water in A3 was classified as unacceptable for use throughout the monitoring period - the water was unfit for domestic use without adequate treatment. *E coli* counts were higher during the rainy season than during the dryer period, the latter indicates a hydraulic connectivity between the surface and groundwater. This sense of hydraulic connectivity is evident when looking at the results determined at S9 (the surface water monitoring site) which correlated to some extent with the microbial quality of the groundwater determined at A3.

The chemical quality of the water was generally good and classified as safe for use.

Production Borehole A4

In terms of microbial quality, the water showed some improvement over the monitoring period – from December 2005 to April 2006, the water was unfit for domestic use without disinfection, while water collected in May to June 2006 was fit for domestic use (these samples were classified in the green class). The microbial water quality improvement could also be indicative of a hydraulic connection between surface and groundwater; the improvement occurred during the dryer months when little water from the surface infiltrated. The water was in general of good chemical quality.

Production Borehole A7

The microbial water quality was in the red class (unacceptable for use), while the chemical quality was in the green class (safe for domestic use) throughout the monitoring period. The microbial quality rendered A7 unfit for domestic use without proper disinfection.

The microbial pollution in the boreholes in A-well field seems to originate from the poor quality of the surface water, the quick response of the groundwater levels to rainfall supports this conclusion (GCS, 2006).

B-well Field

Production boreholes BOT3, BOT4, BOT5, BOT6 and BOT8

As expected from protected dolomitic aquifers, the water in the production boreholes was generally of good microbial and chemical quality. Occasionally, unacceptable concentrations of arsenic were detected in BOT3 and BOT4 (June 2006). Testing for arsenic should be routinely done in terms of SANS 241: 2005, after detecting the arsenic in some samples, care should be taken to ensure that tests are definitely done to optimally manage the situation. Care should also be taken to analyse the samples with a method sensitive enough to detect (if any) the arsenic. People should be advised not to drink water containing arsenic, treatment should be put in place to remove the unacceptable quantities arsenic before distribution (also refer to recommendations). BOT8 contained fluoride concentrations slightly above the maximum allowable limit.

C-well Field

The microbial quality of the production boreholes C1, C2, C3 and C4 was good throughout the assessment period, no *E coli* were detected in any of the samples. The macro-chemical quality was also generally good and in the green class. Unacceptably high arsenic concentrations were however found in C2 (0.219 – 0.318 mg/L), C3 (0.095 mg/L) and C4 (0.073mg/L). Arsenic is commonly found in trace concentrations in dolomitic water, concentrations greater than 0.050 mg/L renders the water unfit for drinking purposes without treatment. Groundwater arsenic is often present in the particulate phase, a conventional treatment plant or package plant consisting flocculation and filtration processes will be sufficient to remove the arsenic from the water.

People should be advised not to drink water containing particulates because the particulates can contain unacceptable levels of trace metals such as iron, manganese and arsenic. The detection of unacceptably high levels of arsenic in these boreholes once again demonstrates the importance to test at least once, before the water is used for drinking, for the presence of trace metals in the water.

D-well Field

Production Boreholes D5 and D10 were assessed. Minimal *E coli* were detected in some of the samples. The microbial quality of both sites could be classified in the green class. Although both sites have a good macro-chemical quality, D5 contained elevated arsenic levels (0.081 mg/L). Water of D5 needs treatment before use for drinking purposes.

6.2.3 Rural Water Supply Boreholes under the jurisdiction of Delmas Municipality

Six boreholes were monitored during the months of February, May and June 2006.

Arbor borehole

Unacceptably high levels of *E coli* were detected in May. A sample taken in June contained no *E coli.* This indicates that the borehole is vulnerable in terms of faecal pollution and that the people using the water should be encouraged to disinfect the water before using it for drinking purposes. The chemical quality was fit for human consumption.

Argent borehole

The water quality was safe for drinking throughout the assessment period, both microbially and chemically.

Dryden borehole

The water, although chemically and microbially safe for drinking water purposes, contained slightly elevated nitrate-nitrite concentrations. It is possible that some land-use activities, for example the close proximity of pit latrines or livestock roaming the area surrounding the water, could be the cause of the elevated nitrate concentrations. Attention should therefore be given to adequate protection of the borehole.

Bambisa Borehole

The water was fit for human use, both microbially and chemically.

Waaikraal Borehole

E coli were detected once; the water was thus generally safe for domestic use. The chemical quality of the water is generally good. One of the samples taken on 11 May 2006 contained slightly elevated nitrate-nitrite concentrations.

Droogenfontein Borehole

E coli were detected in the sample collected on 27 February 2006, the rest of the samples were microbially in the green class. It is recommended that this water be disinfected before use for drinking water purposes. Fairly high nitrate-nitrite concentrations were detected and the water may pose a slight risk for bottle-fed babies.

6.2.4 Reticulation System

Samples were taken at ten points in the reticulation system namely at:

M4, T4809-B4; BN_5092; B_LS; DE_37; RS13, DE_420; NPS_5; NB_3879; B_MS.

E coli were detected twice, once in a sample taken at DE_420 and once at RS13. Generally the water was microbially safe for domestic use. Caution with use is however needed because the residual chlorine concentrations were in many instances found to be low or absent. In addition, Standard Plate Count results sometimes indicated a deterioration of the microbial quality in the distribution system. Elevated turbidity levels (found in a significant number of the samples) or stagnant sections in the reticulation system could be the cause of the bacterial re-growth and development of biofilms in the distribution system. Increased organism numbers require more chlorine for disinfection. Current levels of free available chlorine may not be enough to de-activate any opportunistic pathogens present in the distribution system; this could become a health risk.

Although the chemical quality was generally deemed in the green class, ELEVATED arsenic concentrations were detected in some samples. Specifically, arsenic was detected in:

- M4
- BN_5092
- B_LS
- DE_420
- DE_37
- NPS_5
- NB_3879

Elevated arsenic levels could cause chronic health problems such as characteristic skin lesions or chronic diarrhoea. The levels of arsenic found in the tap water are not acceptable and the water should be treated to remove the arsenic before being released into the distribution system for drinking and other domestic uses.

Botleng Clinic

The clinic was not monitored as part of this investigation because the site is routinely monitored by the Department of Health. An ad-hoc sample was however taken on 14 March 2006 after receiving a complaint that the water was turbid and of an unacceptable aesthetic quality. The analytical test showed high *E coli* counts (110 cfu/100mL). The water posed a health risk to consumers on the day of sampling. Since immuno-compromised people may use the clinic daily, it is recommended that monitoring continue at the clinic and any other place which might be visited by sensitive users (i.e. schools and hospitals). The residual chlorine levels should, at least be checked every day at this point to ensure that the water is properly disinfected.

6.2.5 Time series graphs to indicate downstream changes in water quality

Geometric mean *E coli* concentrations were used to illustrate the downstream changes in microbiological quality of water sources within the Delmas district. The quality of sites within the three water courses (Figure 1) was plotted respectively in Figure 6, 7 and 8.

Figure 6 illustrates the downstream changes in microbiological quality of the “bigger” tributary, the Bronkhorstspruit, measured at S2, S3 and S9. Geometric *E coli* means of the last monitoring sites in the other two tributaries confluencing with the Bronkhorstspruit is also plotted on Figure 6. This was done to illustrate, in spatial relation to the Bronkhorstspruit sites, the impact water from the other tributaries might have on the water quality of the Bronkhorstspruit (represented by S8 and S11). Geometric mean *E coli* levels determined at S11, the downstream site receiving discharges from the new wastewater treatment works, was plotted to show how the effluent could impact the downstream quality of the Bronkhorstspruit. Geometric mean *E coli* concentrations of boreholes in the vicinity of the surface water sampling sites were also plotted to illustrate the hydrologic connectivity alluded to while discussing the results. Water quality guidelines are indicated for using the surface water for recreational purposes, as well as for assessing the fitness for use of the borehole for drinking.

Figure 7 and 8 illustrate the water qualities in the other two tributaries monitored in Delmas. A similar approach to the above was followed, sources believed to influence the quality of the tributary are indicated as well as boreholes in the vicinity.

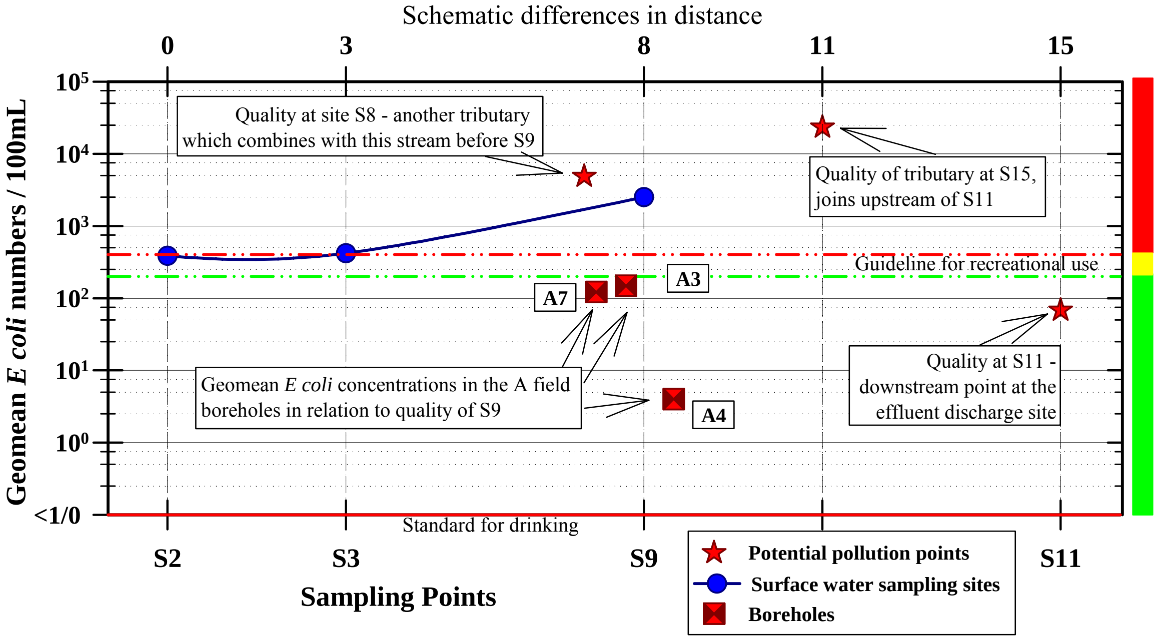

FIGURE 6: Schematic representation of the downstream changes in the geometric mean *E coli* concentrations in the stream with sampling sites S2, S3 & S9

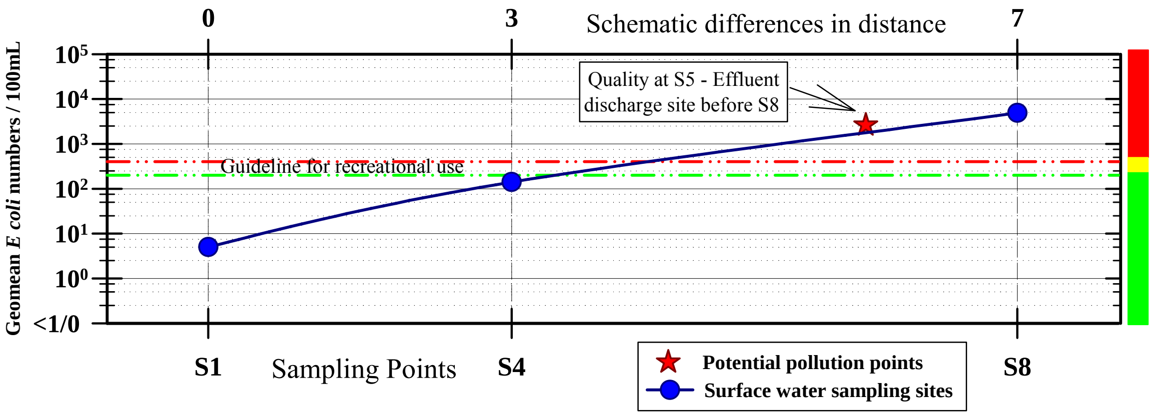

FIGURE 7: Representation of water quality in the stream ending at S8

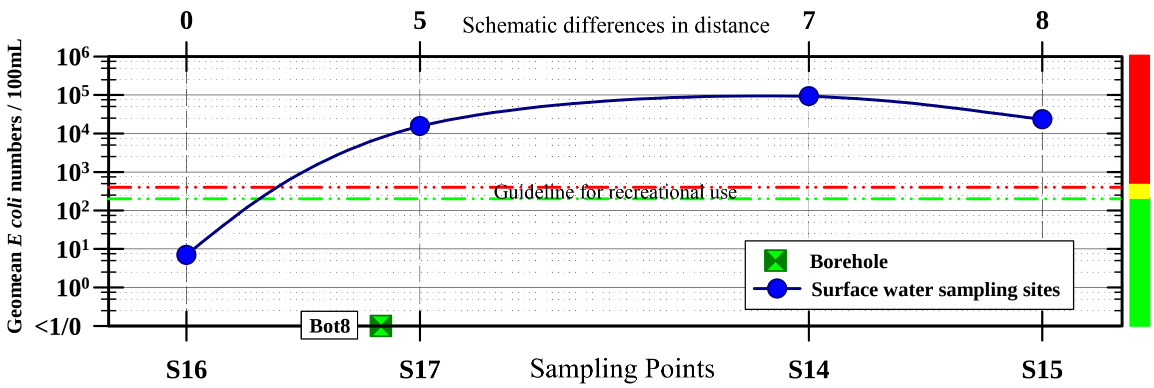

FIGURE 8: Representation of water quality in the stream ending at S15

7 Recommendations

7.1 Integrated management of the Delmas drinking water supply system

Risks associated with the quality of drinking water supplies can only be appropriately addressed if an integrated water quality management approach is followed. The following problems (hazards) identified at the end of the intensive monitoring programme need to be addressed in future management approaches:

- **Inadequate protection of surface water resources:** A link is suspected between the microbiological quality of the surface water and that of the groundwater. The link exists especially in the vicinity of sampling point S9 and the boreholes in the A-well field. Land use activities, such as cattle roaming in the vicinity of the A production boreholes, as well as rain-induced run-off from the formal and informal settlements, all contribute to the surface water being unacceptably contaminated by faecal matter from human and animal origin. It is thus important to develop a management plan to protect the surface water but which would also ultimately lead to the protection of the A-well field boreholes. The plan should include:
  - Proper sanitation for all
  - Adequate refuse removal
  - Effective management of the Waste Water Treatment Works (WWTWs)
  - Controlled areas for cattle grazing at a safe distance from the production boreholes.
- **Overload of the Delmas Wastewater Treatment Works:** Continuous non-compliance of the “old” Delmas WWTW with licence conditions was shown to affect the quality of the surface water resources downstream of the discharge point (refer to the water quality of S8 and S9). Suspecting a hydraulic connection between the surface and groundwater, it is likely that the groundwater may absorb the high *E coli* counts discharged into the surface water via the effluent from the sewage treatment works. The latter is a definite possibility if sinkholes form due to over-abstraction.

  The new WWTW on the Bronkhorstspruit system, operating with newer technology, performed better that the old WWTW. Loads to the system may however increase if the municipality proceeds with plans to relocate some residents (approximately 1000 households) from the existing Mandela informal settlement to an area in the vicinity of new Botleng. Review of the infrastructure capacity of the facility would then be needed to ensure that it continues to cope adequately with the increased loads.

  The municipality is advised to upgrade the old WWTW, and equally important, to ensure that all staff are trained and qualified to operate, maintain and manage both the old and the new WWTWs.

  Previous investigations also showed that spillages occurred repeatedly at the sewage pumping stations (at the Botleng Ext 4 WWTW and at the sewage disposal site for the bucket system). A maintenance program needs to be implemented, and if possible, a back-up system needs to be in place to ensure that spillages do not reach the surface water or infiltrate the groundwater.
- **Groundwater contamination:** Time series data from the National Groundwater Data Base showed that groundwater in the Delmas area is sensitive to rainfall events which equate to high recharge rates. It also means that the aquifer is quite vulnerable to surface

contamination (GCS, 2006). Once polluted, the quality of the groundwater will remain impacted for long periods of time. Microbes remain viable for decades in groundwater - this could result in long-term human health risks unless the water is properly treated before use for drinking. It is very important to adequately protect the groundwater production boreholes by ensuring that they are properly sealed and fenced off.

The existing landfill site in the Botleng extension area is another issue of concern. Due to its proximity to Bronkhorstspruit, roughly 300m away, the landfill site has the potential not only to pollute the surface water directly through surface run-off, but also to pollute the groundwater through base-flow conditions. The situation needs continuous monitoring. Sites S12 and S13 need to be included in any future monitoring programme.

- **Breaks in disinfection (chlorination):** Currently water abstracted from the boreholes is chlorinated before distribution. Any break in chlorination could result in another diarrhoeal-disease outbreak if people then continue to drink water from any of the potentially contaminated boreholes without other intervention. It is of the utmost importance to ensure, at all times, an adequate free residual chlorine concentration in the reticulation system.
- **Turbidity in the water:** The presence of unacceptable levels of turbidity in some of the water pumped from the boreholes, e.g. from the A-well field, is an undesirable situation not only for aesthetic reasons, but also because it affects the efficiency of disinfection. Microbes may not be deactivated because they hide in the organic slime generally associated with turbid clay particles. Turbidity also makes maintaining a positive chlorine residual concentration in the distribution system difficult. Processes such as flocculation and sedimentation are needed to remove the turbidity particles before the water is disinfected for drinking.
- **Regular cleaning of reservoirs and distribution pipes:** Particles still present in the potable water supply inevitably settle to the bottom of the reservoirs. Procedures need to be in place to ensure regular cleaning of all storage tanks to ovoid the risk of distributing the turbid bottom water to residents for consumption. Although originally safe for human consumption, the stagnant bottom water may now constitute a health risk especially if microbes started multiplying in the biofilms which usually form at the bottom of reservoirs. Practices should also be in place to routinely flush the entire distribution system – the latter minimises the formation of biofilm in pipes and removes water from potentially inactive (stagnant) corners.
- **Arsenic in the B, C and D-well fields and at the point of use:** Arsenic is commonly present in trace concentrations in dolomitic water. Unacceptable concentrations for drinking were however detected in water from some of the boreholes. According to the SANS 241: 2005 drinking water specification, water containing arsenic concentrations between 0.010 and 0.050 mg/L should not be consumed for more than 1 year. Arsenic concentrations greater than 0.050 mg/L are not fit for drinking purposes without treatment. The arsenic detected in the water needs to be removed before people continue to consume the water. Groundwater arsenic is often present in the particulate phase, conventional or package treatment facilities consisting of treatment processes such as flocculation (preferably with iron salts) and filtration should be capable of removing the arsenic from the groundwater.
- **Fluoride in the B-well field at Bot8:** Water containing fluoride concentrations exceeding the optimum level (more than 0.7 and less than 3mg/L) may cause teeth discolouration when ingested during the teeth formation years (DWAF, 1998). Ingesting

concentrations exceeding 3mg/L can damage the skeleton, causing a hardening of the bones and making them brittle. The slightly elevated fluoride concentrations detected at Bot8 currently only pose the risk that it may discolour the teeth of some individuals, the situation however, needs to be monitored to detect increases in concentrations before a health risk develops.

- Nitrate in the rural water supply boreholes: Slightly elevated concentrations of nitrate were sporadically detected in samples taken from Dryden, Waaikraal and Droogenfontein. Nitrates is associated with many land-use activities, monitoring should continue and management options put in place if the concentrations increases.

- **The bucket system:** A direct link exists between diarrhoeal disease incidence, hygienic practices and the efficacy of sanitation services to deal with night soil. Good sanitation practices are therefore just as important as water disinfection to prevent the occurrence of diseases. The bucket system should be phased out as soon as practically possible – determining the impact of the bucket system on the quality of the water sources would dictate the urgency with which the system needs to be phased out.

  Until such time that the bucket system can be eradicated completely, the municipal collection service should be improved through upgrading the collection equipment and increasing the number of staff on the collection team. An improved service within the growing informal settlement is needed to avoid cases where residents dump the contents of their buckets into or close to water resources.

- **Inadequate monitoring of the water supply system:** Continuous monitoring for both operational process control purposes and compliance-assessment with drinking water standards is important to gather information needed to effectively manage any drinking water supply system. Sampling should be frequent enough to detect a loss of process control and timely enough to enable the implementation of corrective actions before a significant drinking water quality failure occurs. Testing regularly for indicators used during this investigation will provide sufficient information to properly manage the quality of water within Delmas. The use of more specific molecular techniques such as PCR to detect pathogens not detected by methods used for indicators could further strengthen the data-base needed to optimally manage the Delmas drinking water supply chain.

- **Over-abstraction leading to groundwater instability:** Due to the nature of the aquifer media, the likelihood of sinkhole development and subsidence exists in the Delmas aquifer area (GCS, 2006). To date, only one sinkhole has been identified near borehole A1 (the sinkhole has been backfilled). A potential exits for more sinkholes and subsidence if the abstraction volume continues to increase. Sinkhole formation increase water turbidity, which in turn is associated with other contaminant increases and increased risks to human health.

  Perennial abstraction patterns should be considered and if needed implemented to better manage extraction volumes needed by all water users (domestic use and irrigation).

- **Insufficient water supply:** Insufficient supply due to breakdown in service delivery or insufficient reticulation to all, can force community members to use alternative sources such as river or dam water. It is also foreseen that, even if the groundwater supply capacity is sufficient, the current boreholes will be insufficient to satisfy future demands (GCS, 2006). Alternatives to the current supply will soon be necessary. These alternative supplies could be from additional production boreholes (at least 1 km away from existing boreholes) or water supplied by Rand Water (GCS, 2006).

Means should be put in place to regularly inform residents about the risks associated with the use of water (drinking and other domestic uses) from other sources than the treated water supply, i.e. from stagnant pools, farm dams, streams, etc.

- **Role of carriers in disease transmission:** A reservoir for microbes is always present in some or other niche in the environment. Both humans and animals can be carriers of microbes, microbes which multiply under favourable conditions and eventually cause diseases. In many cases, the carrier itself does not become ill but only transmits, under unhygienic conditions, the pathogen to other healthy individuals. Unless good hygiene is practised by all water users, and care is taken with sanitation measures, people in Delmas may still be at risk for another outbreak of gastrointestinal disease.

7.2 Installation of a conventional water treatment system

Previously the groundwater resources used for drinking water supplies in Delmas was assumed clean and safe for use without any treatment. This intensive monitoring programme has confirmed that this is not the case and that the groundwater (including the water from the B, C and D-well fields) should not be used for drinking without prior treatment. Conventional processes should at least be used to remove microbial contaminants, as well as the arsenic and fluoride found in some of the production boreholes. The treatment processes should include:

- Coagulation
- Flocculation
- Sedimentation
- Filtration and
- Disinfection

7.3 Proposed design for a future monitoring programme

It is proposed that Delmas municipality implements the following monitoring design (the latter based on the information and experience obtained during the monitoring programme operated from November 2005 to June 2006):

7.3.1 Data acquisition

Information regarding the location of appropriate sampling sites (in order of priority, A being the highest priority), sampling frequency (for operational and compliance purposes) as well as constituents of concern are summarised in Table 30. Additional sites should also be identified and included at high risk areas. A high risk area is any area frequently visited by people (schools, hospitals and clinics) or sites particularly vulnerable to pollution, i.e. wastewater pumping stations.

Table 30 Information regarding the data acquisition function of a proposed monitoring programme for Delmas municipality

Sampling site location		**Sampling frequency**		**Constituents of concern**	
Site code	Priority	Operational	Compliance	Operational	Compliance
Surface water *					
S1	A	Not Applicable	Monthly	Not Applicable	Microbial (Table 12) & Macro-chemical (Table 12 & 13)
S3	A	“	“	“	“
S4	A	“	“	“	“

Table 30 Information regarding the data acquisition function of a proposed monitoring programme for Delmas municipality (Continued)

Sampling site location		**Sampling frequency**		**Constituents of concern**	
Site code	Priority	Operational	Compliance	Operational	Compliance
S8	A	“	“	“	“
S9	A	“	“	“	“
S12	A	“	“	“	“
S13	A	“	“	“	“
S14	A	“	“	“	“
S16	A	“	“	“	“
S17	A	“	“	“	“
S2	B	“	“	“	“
S15	B	“	“	“	“
S10	C	“	“	“	“
S18	C	“	“	“	“
S19	C	“	“	“	“
S20	C	“	“	“	“
S21	C	“	“	“	“
S22	C	“	“	“	“
Effluent Discharge**					
S5	A	Daily	Weekly	Turbidity and Chlorine	Licence Conditions
S11	A	Daily	Weekly	“	“
Groundwater***					
A3	A	Monthly	Monthly	Turbidity	SANS 241
A4	A	“	“	“	“
A7	A	“	“	“	“
BOT3	A	“	“	“	“
BOT4	A	“	“	“	“
BOT5	A	“	“	“	“
BOT8	A	“	“	“	“
C1	A	“	“	“	“
C2	A	“	“	“	“
C3	A	“	“	“	“
C4	A	“	“	“	“
D5	A	“	“	“	“
D10	A	“	“	“	“
				“	“
Rural boreholes****					
MP 229	A	Monthly	Monthly	Turbidity	SANS 241
MP228	A	“	“	“	“
MP 230	A	“	“	“	“
MP 225	A	“	“	“	“
MP 227	A	“	“	“	“
Mp226	A	“	“	“	“
Reticulation system*****					
M4	A	Daily	Weekly	Turbidity and chlorine residual	TC+ and HPC++ and SANS 241
T4809-B4	A	“	“	“	“
BN_5092	A	“	“	“	“
B_LS	A	“	“	“	“
DE_37	A	“	“	“	“
RS13	A	“	“	“	“
DE_420	A	“	“	“	“
NPS_5	A	“	“	“	“
NB_3879	A	“	“	“	“
B_MS	A	“	“	“	“
Botleng Clinic	A	“	“	“	“

For detailed monitoring point description and GPS co-ordinates, refer to tables:
* & ** Table 1, *** Table 4, **** Table 5, **** Table 8
+ TC = Total coliforms, ++ HPC = Heterotrophic Plate Count

7.3.2 Data Management and Storage

Currently all monitoring data collected by Delmas Municipality is kept in MS-Excel format. A more suitable database should be considered especially if the monitoring programme is going to accumulate more data over a long period of time. The Chief Directorate: Water Services of the DWAF is recommending the use of an Electronic Water Quality Management System (eWQMS) as a suitable database. Water Services, DWAF can be contacted for more information on eWQMS.

> At the time of writing the document, Mr Leonardo Manus at Water Services could be contacted at +27(0)12 336 6583 / 6839

According to DWAF, eWQMS can be used (DWAF, 2005_b):

- Submission of drinking water quality monitoring programme details and water quality data
- Assessment and interpretation of drinking water quality data, including comparison of results against SANS 241 Drinking Water Specification
- Tabular, graphical and spatial summary presentations of drinking water quality data

7.3.3 Information Generation and Dissemination

A system of regular reporting, both internal and external, is required and important to ensure that the responsible people receive information needed to make informed decisions on the operation and management of the water supply system. Reporting publicly on drinking water quality performance ensures a high level of transparency and public accountability. The following Drinking Water Quality Management Reports are recommended (DWAF, 2005_a):

1. Monthly report (Operational monitoring report) - A summary report of the compliance of the quality of the water in the total water supply system with suitable criteria (see tables in Appendices A, B, and C as examples)
2. Quarterly report (Consultative report) - This report should be submitted to the Consultative Audit Teams of DWAF on a quarterly basis to determine required regulatory intervention, assess progress with achieving drinking water quality compliance
3. Annual Report (Stakeholder information report) - This report should summarise the drinking water quality performance over the preceding year against numerical guideline values and regulatory requirements. The report should be made available to consumers, regulatory authorities and stakeholders (See tables 18 to 28, figures 1 to 53 as well as Figures 2 to 5 as examples).

7.4 Resource implications for a functional monitoring programme

Effective operation of an integrated water quality monitoring programme is largely dependent on adequate resources including:

A fully competent and committed staff component consisting of:

- o A monitoring programme manager to oversee the total integrated monitoring programme (including data acquisition, data management and storage, as well as information generation and dissemination) on a day to day basis, ensure that the quality control measures are in place and to take care of any functional problems that may arise. This person would also be responsible to ensure that the information generated by the programme is communicated at appropriate frequencies to all stakeholders (e.g. operational information on a daily basis, compliance monthly, quarterly, annual etc.)

- Trained samplers to collect the samples
- Trained laboratory staff to do the required chemical, physical and microbiological analyses
- A data manager able to interpret the results and to generate the various reports

Adequate infrastructure including:

- Reliable transport to collect samples
- A functional laboratory to analyse the samples for operational purposes and to asses compliance (preferably an accredited lab)
- Computer hardware and software to handle data storage and to generate the required information

8 References

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DWAF 1996_b South African Water Quality Guidelines (Second Edition). Volume 5: Agricultural Use: Livestock Watering. Pretoria.

DWAF 1998 Quality of Domestic Water Supplies. Volume 1: Assessment Guide (2^{nd} Ed). Water Research Commission and Department of Health, Pretoria.

DWAF 2000 Quality of Domestic Water Supplies. Volume 2: Sampling Guide (1st Ed). Water Research Commission and Department of Health, Pretoria.

DWAF 2005_a Drinking Water Quality Framework of South Africa

DWAF 2005_b Drinking Water Quality Management Guide for Water Services Authorities

DWAF 2005_c Summarised report to the Deputy President on the outbreak of Typhoid and Diarrhoea in Delmas, Mpumalanga. 29 September 2005

DWAF 2004 Strategic Framework for National Water Resource Quality Monitoring Programmes by DC Grobler and M Ntsaba. Report No. N/0000/REQ0204. ISBN 0-621-35069-9. Resource Quality Services, DWAF, Pretoria, South Africa

GCS 2006 Groundwater Management Plan for Delmas Municipal Council Report No: 2005.08.399

Republic of South Africa (1998). Act No. 36: National Water Act. Govt Notice No. 19182. Vol. 398. Office of the President, Pretoria.

SANS 241: 2005 South African National Standard, Drinking Water. Edition 6 ICS 13.060.20; ISBN 0-626-17752-9

The South African Institute for Medical Research, the University of the Witwatersrand and the Division of Water Technology (CSIR) 1994 Investigation into the *Salmonella typhi* epidemic at Delmas , November – December 1993

APPENDIX A

Water Quality Variables of Concern Plotted Against Applicable Water-Use Quality Guidelines

Delmas surface water

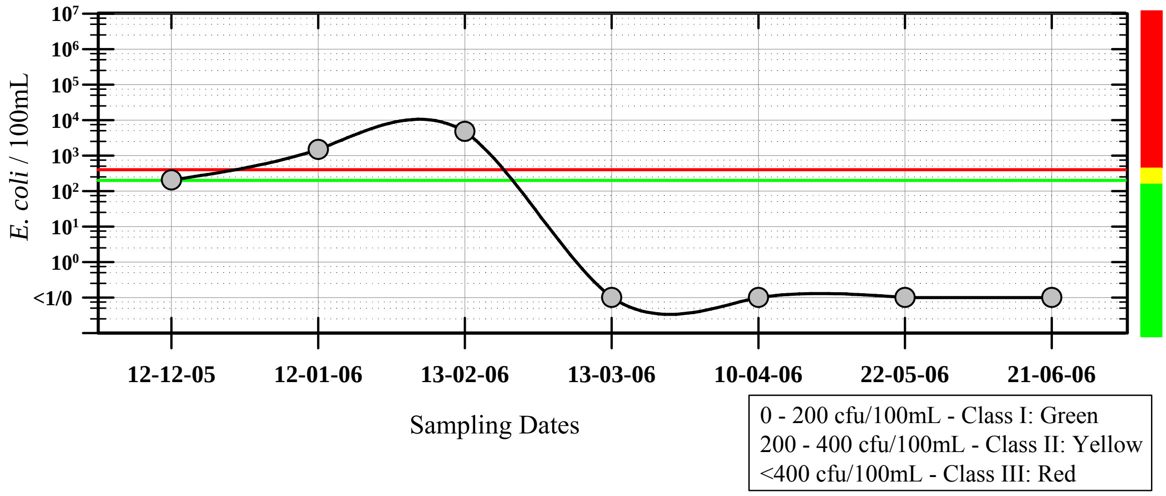


FIGURE 9: Water quality at S1 plotted against the SA water quality guidelines for recreational use

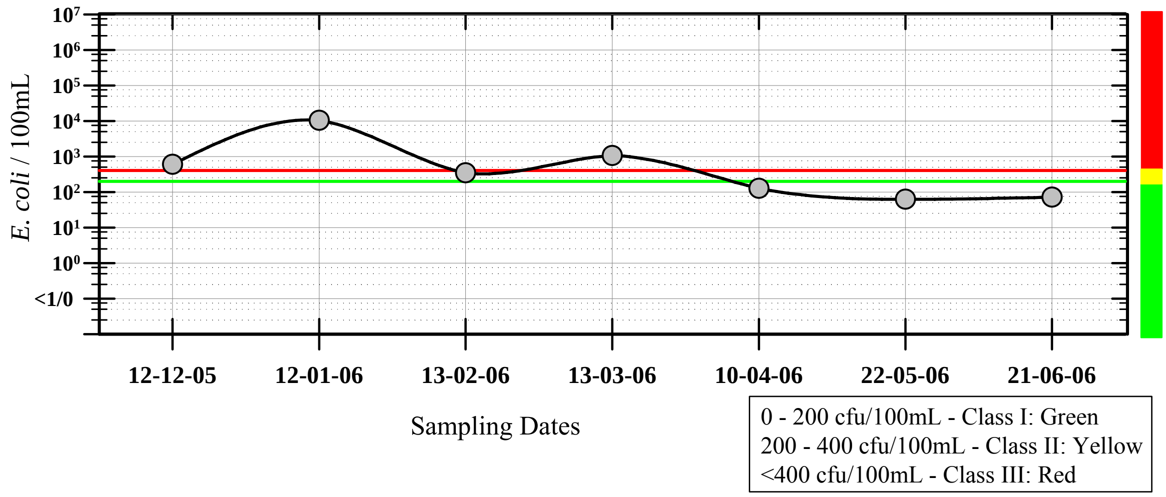


FIGURE 10: Water quality at S2 plotted against the SA water quality guidelines for recreational use

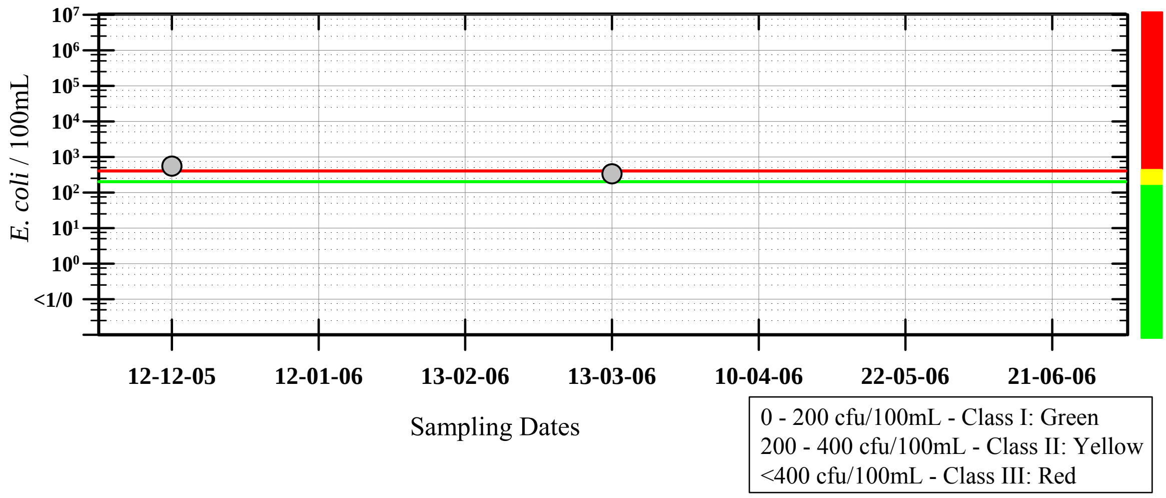


FIGURE 11: Water quality at S3 plotted against the SA water quality guidelines for recreational use

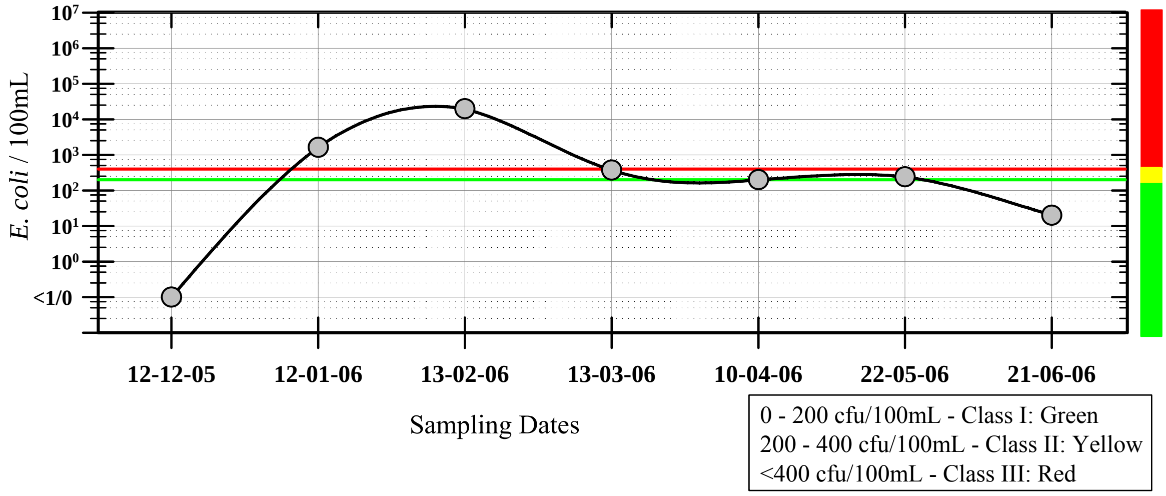


FIGURE 12: Water quality at S4 plotted against the SA water quality guidelines for recreational use

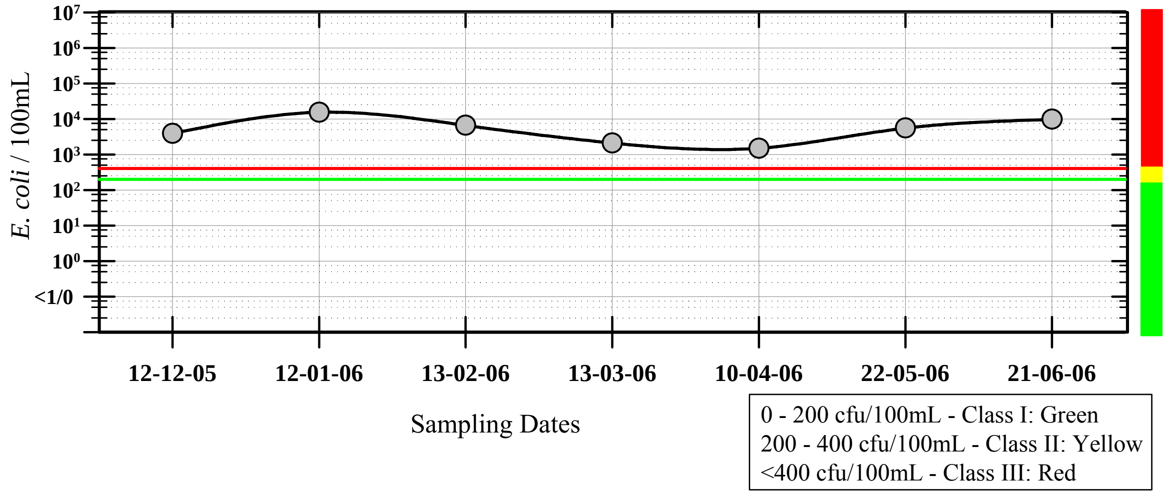


FIGURE 13: Water quality at S8 plotted against the SA water quality guidelines for recreational use

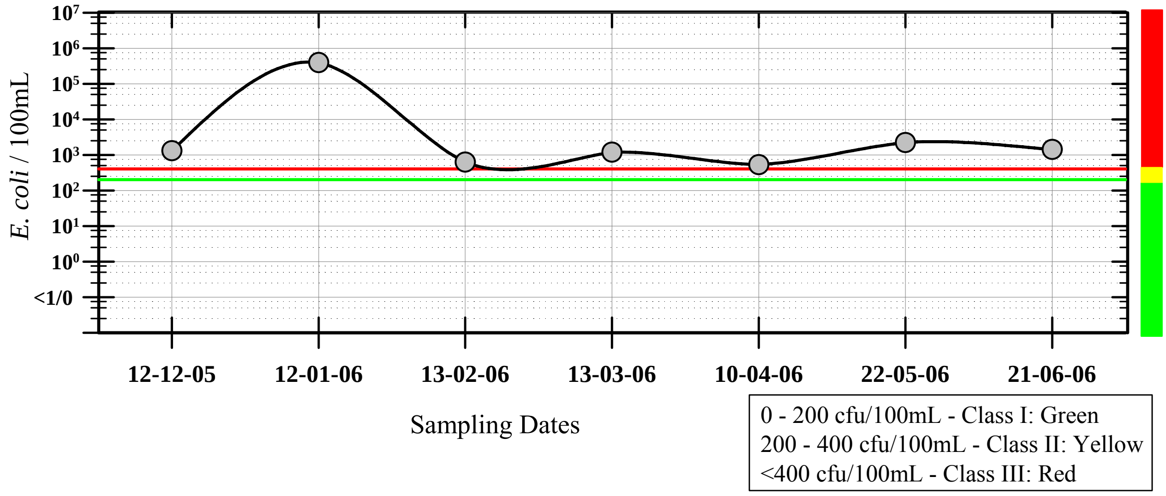


FIGURE 14: Water quality at S9 plotted against the SA water quality guidelines for recreational use

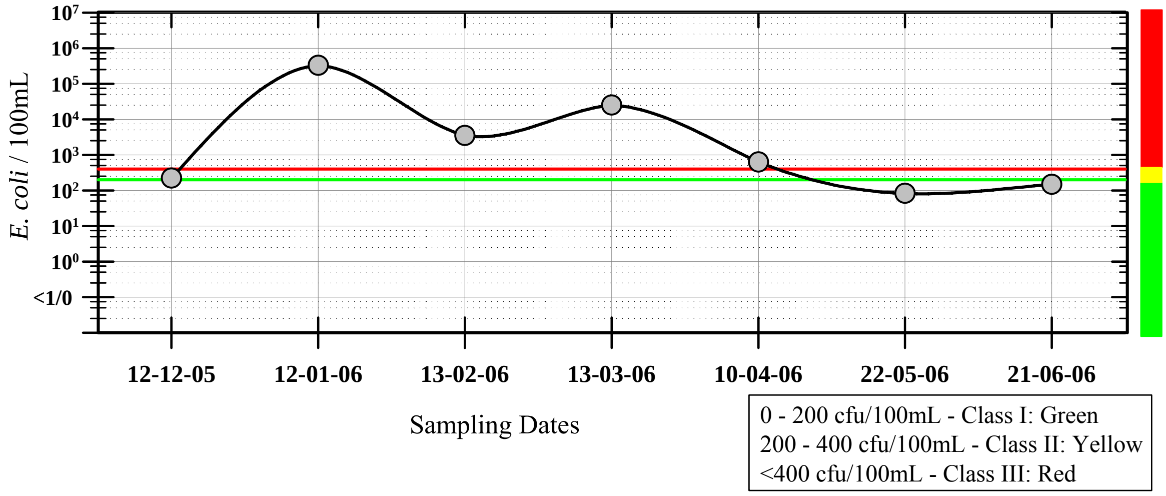


FIGURE 15: Water quality at S10 plotted against the SA water quality guidelines for recreational use

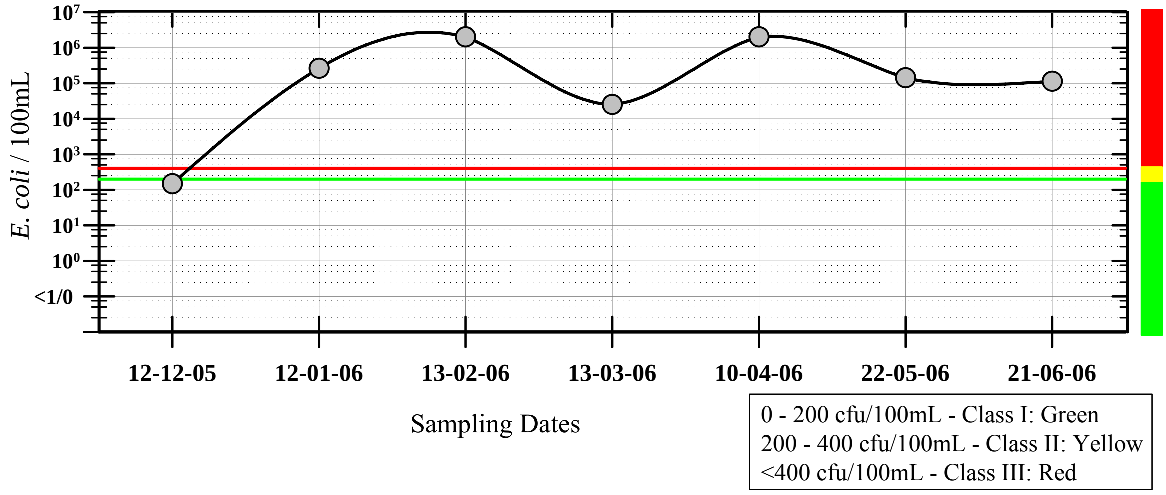


FIGURE 16: Water quality at S14 plotted against the SA water quality guidelines for recreational use

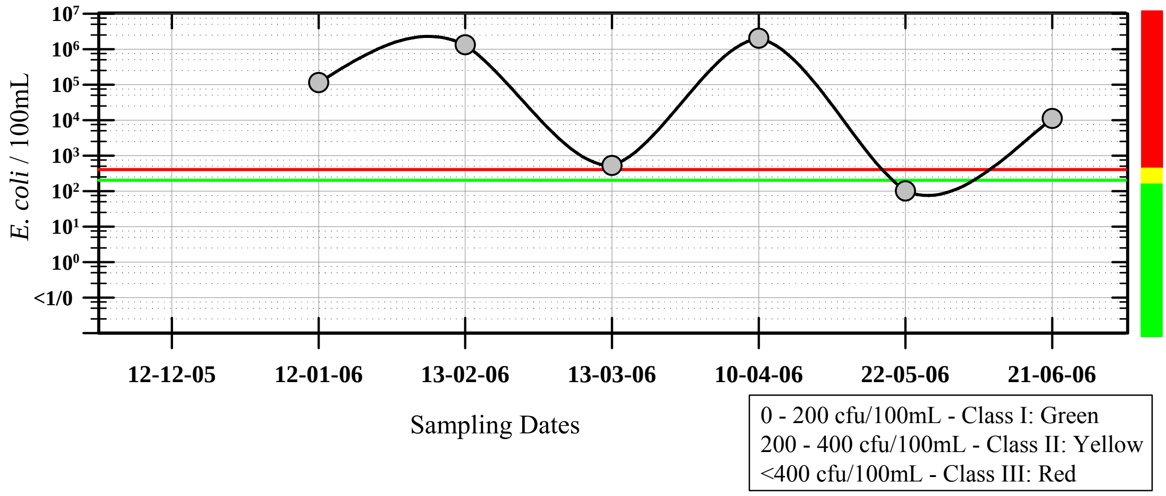


FIGURE 17: Water quality at S15 plotted against the SA water quality guidelines for recreational use

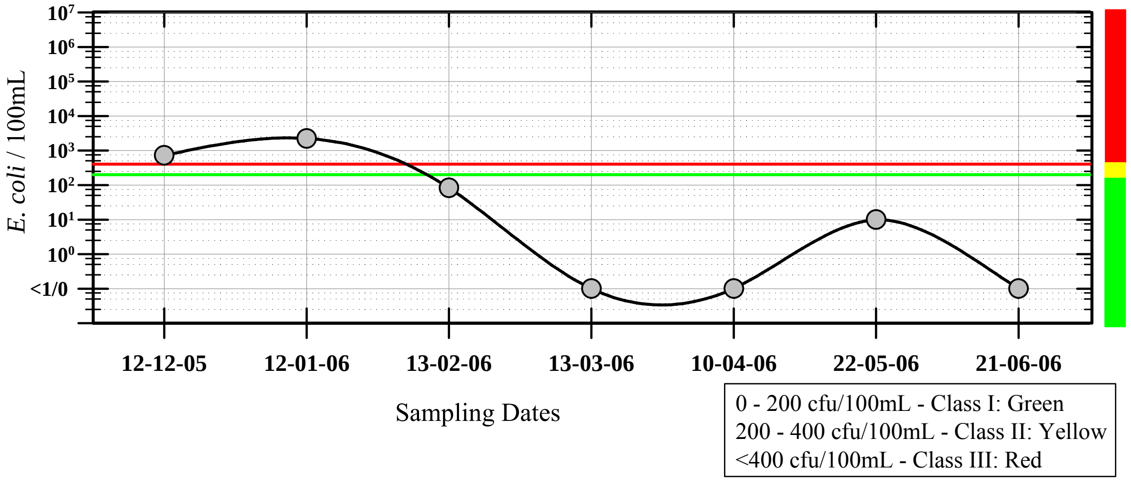


FIGURE 18: Water quality at S16 plotted against the SA water quality guidelines for recreational use

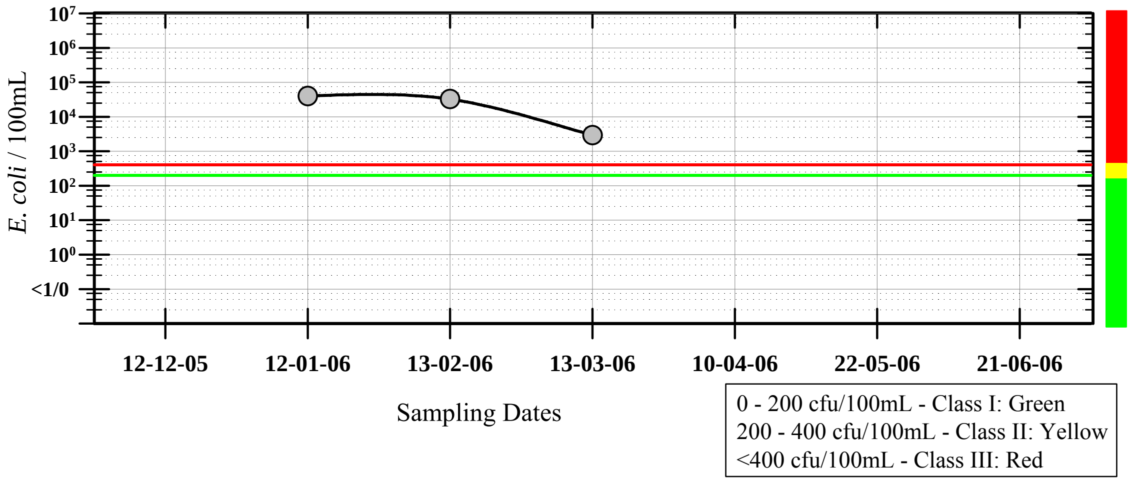


FIGURE 19: Water quality at S17 plotted against the SA water quality guidelines for recreational use

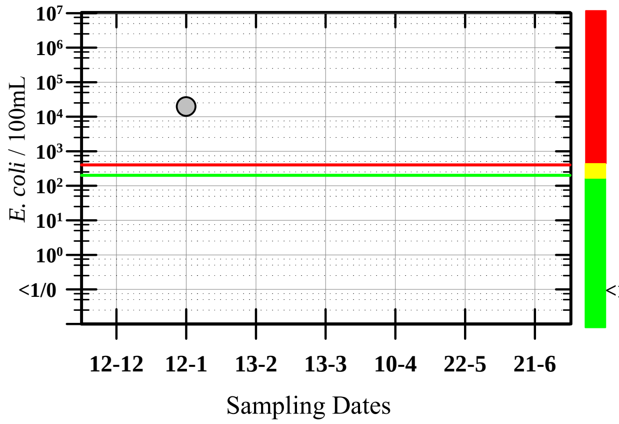


FIGURE 20: Water quality at S20

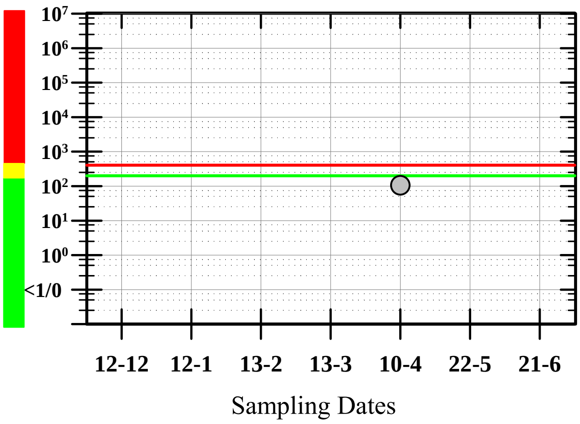


FIGURE 21: Water quality at S21

Discharged effluent

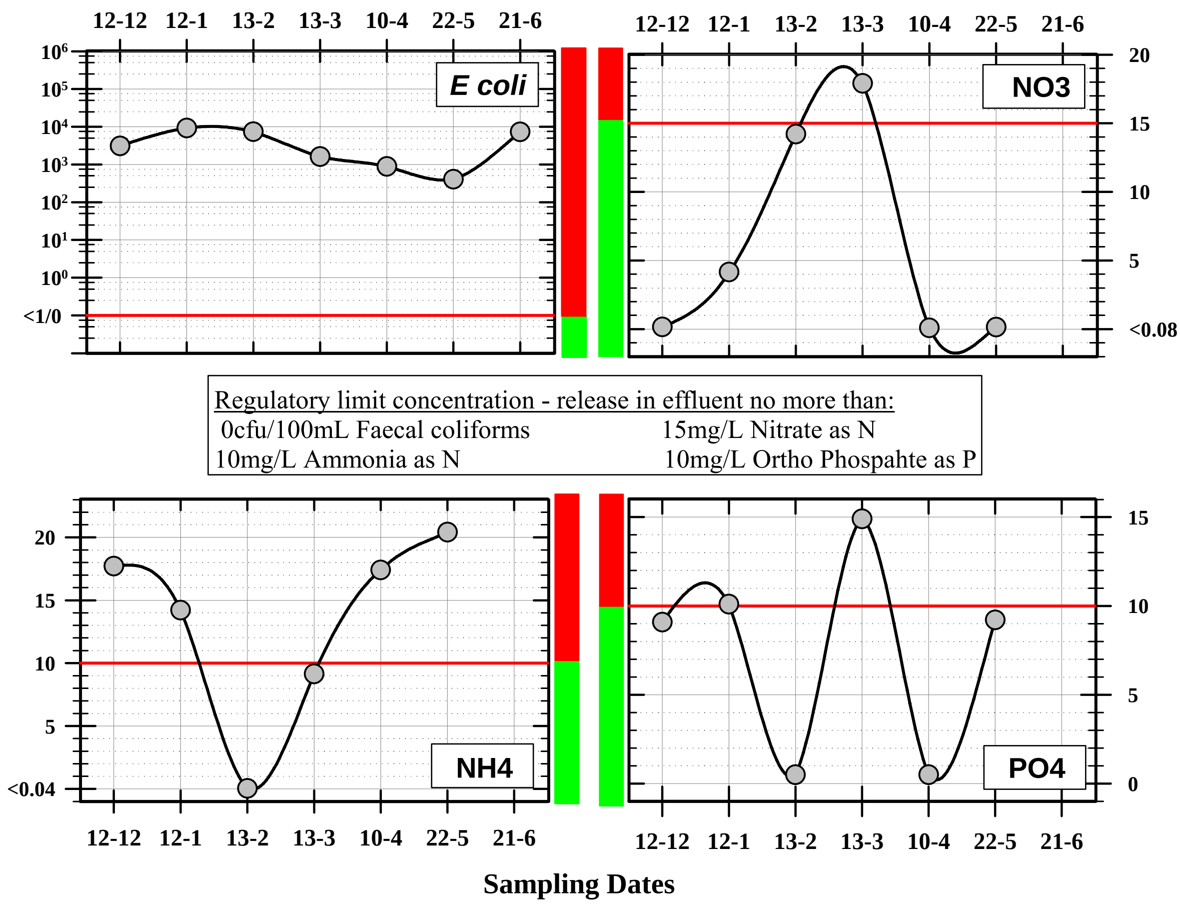


FIGURE 22: Water quality at S5 for the period 2005 to 2006 measured against licence conditions for wastewater treatment works in Delmas

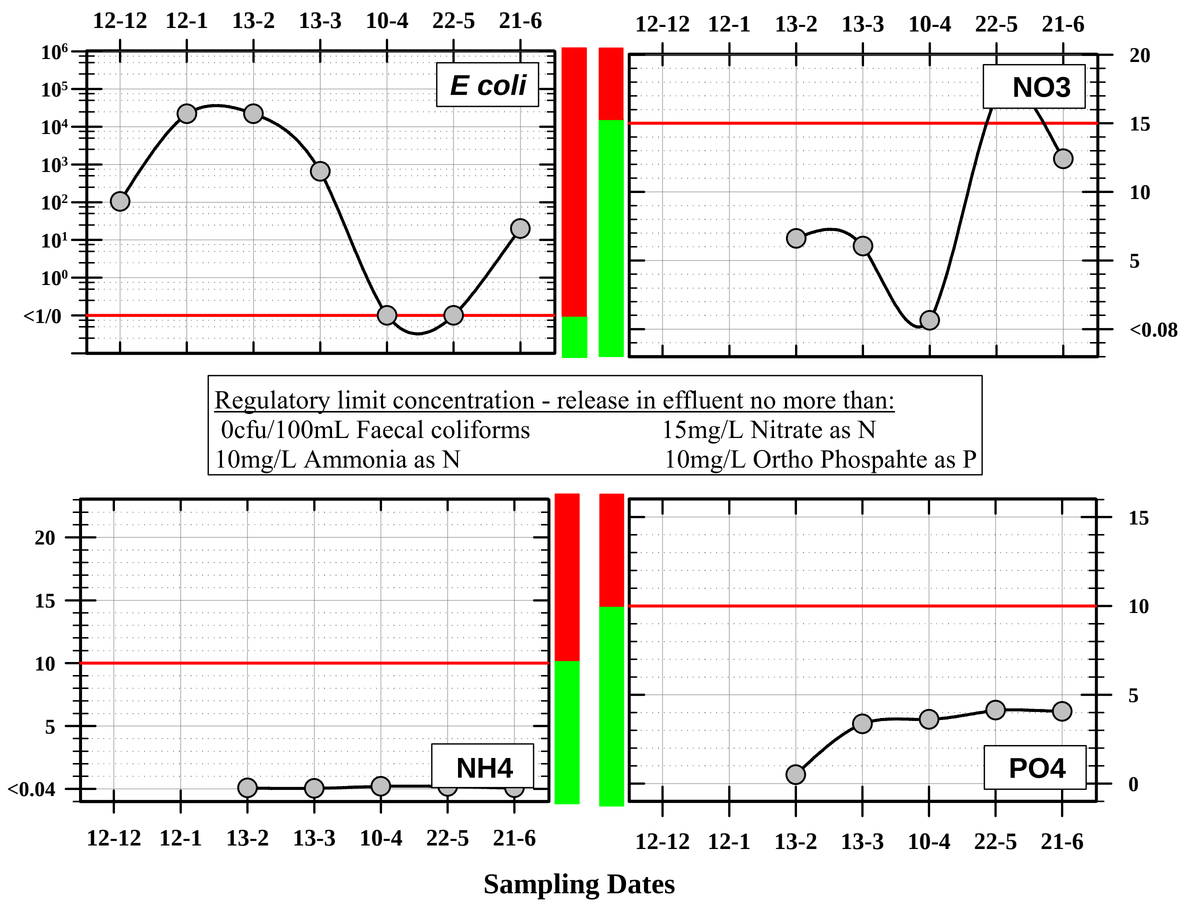
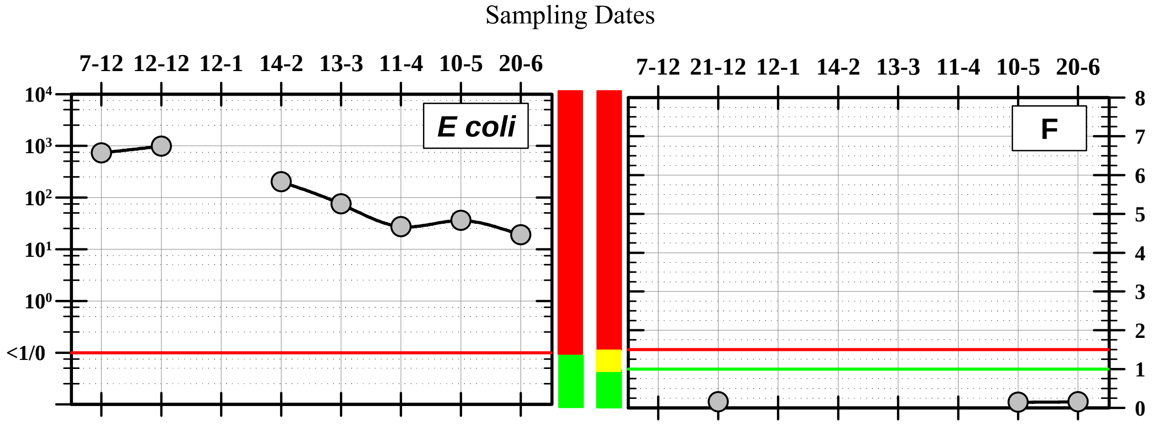


FIGURE 23: Water quality at S11 for the period 2005 to 2006 measured against licence conditions for wastewater treatment works in Delmas

Groundwater



<u>Drinking water quality requirements as specified in SANS 241:2005:</u>
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

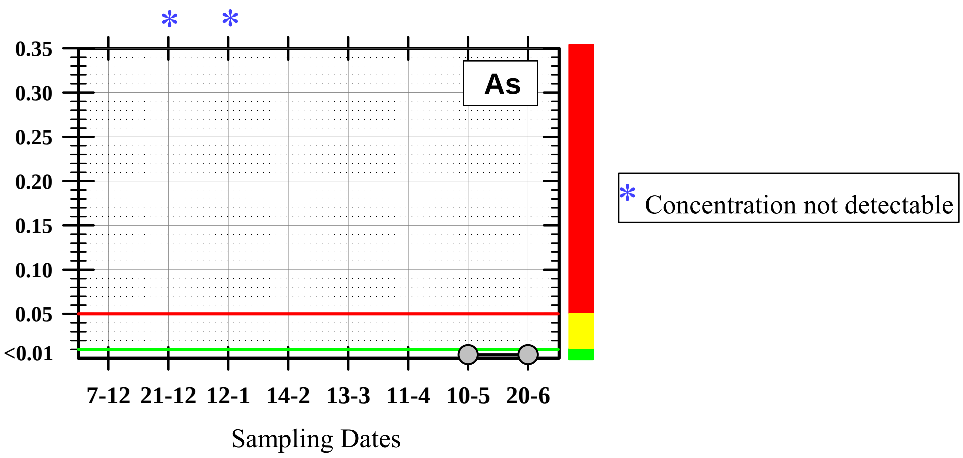
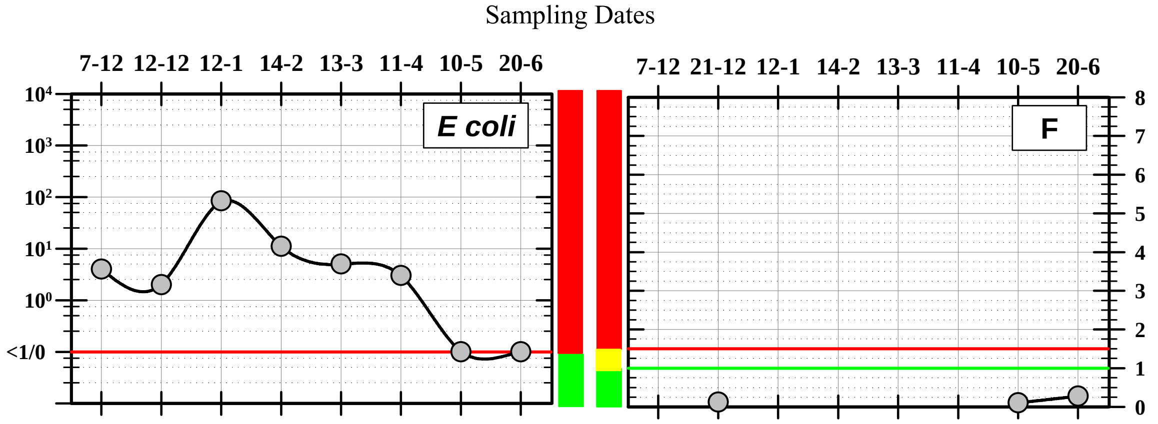


FIGURE 24: Water quality at A3 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

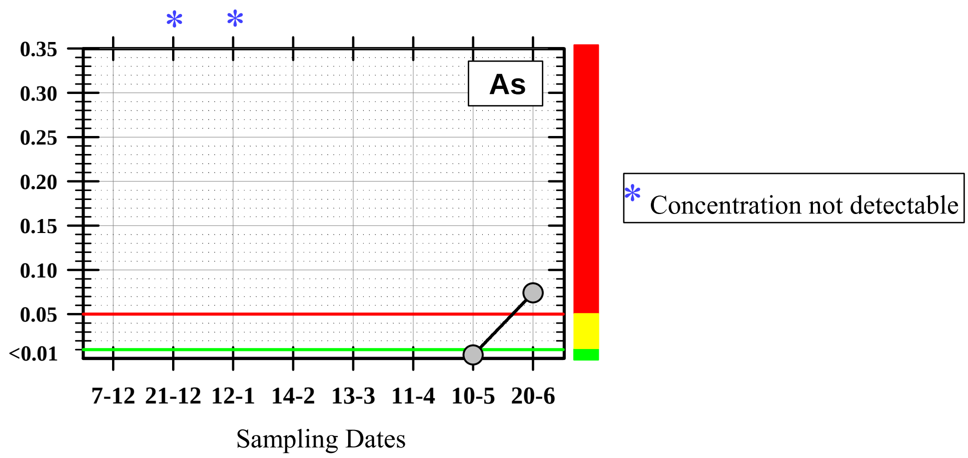
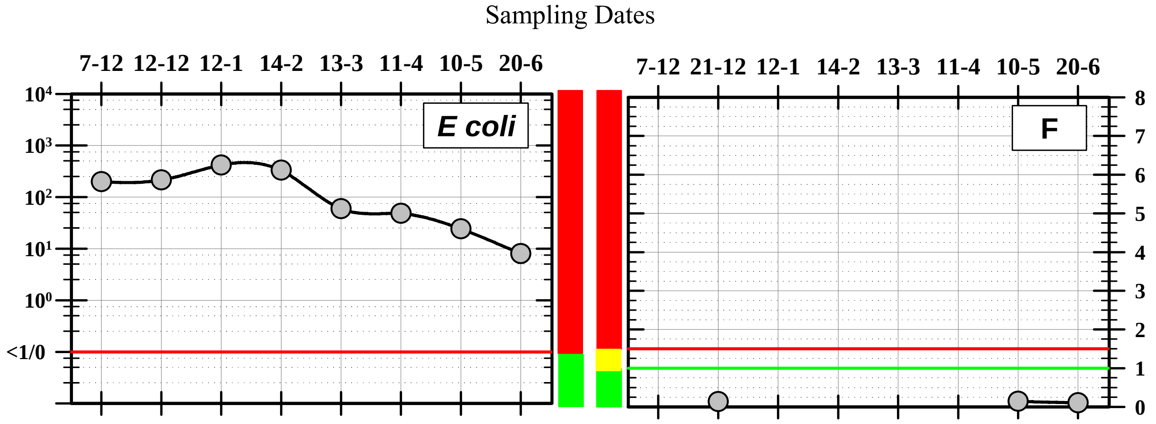


FIGURE 25: Water quality at A4 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

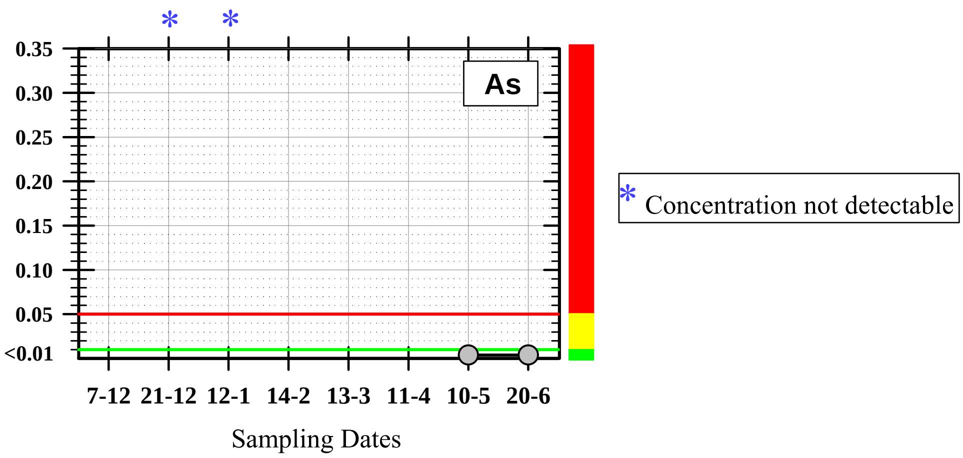
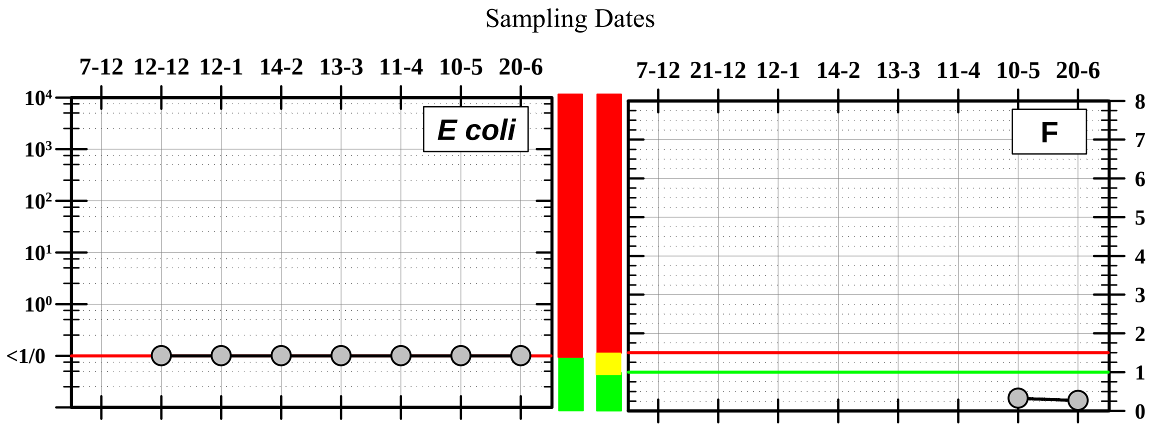


FIGURE 26: Water quality at A7 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



<u>Drinking water quality requirements as specified in SANS 241:2005:</u>
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

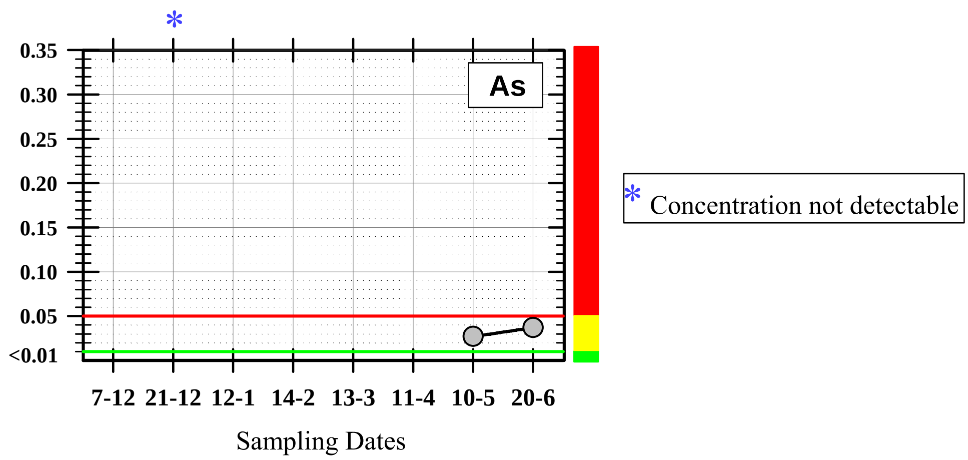
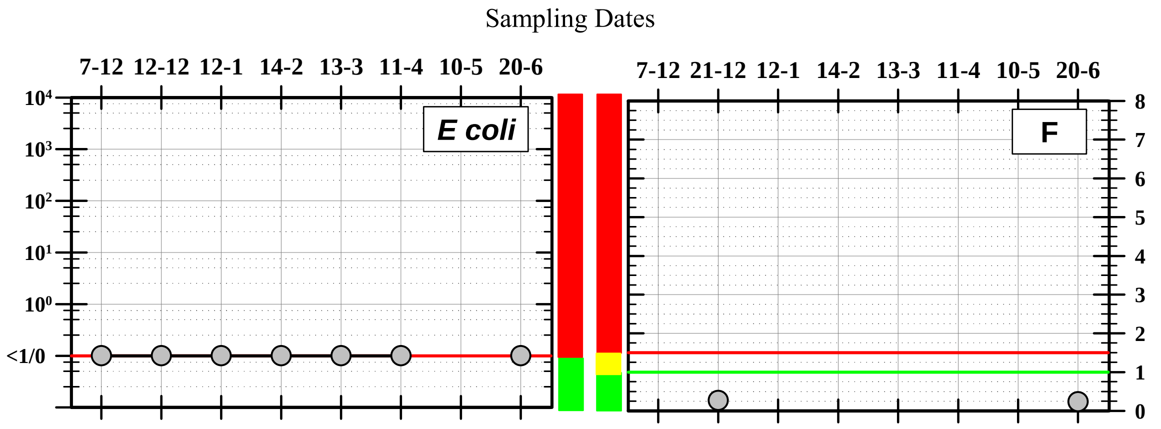


FIGURE 27: Water quality at Bot3 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

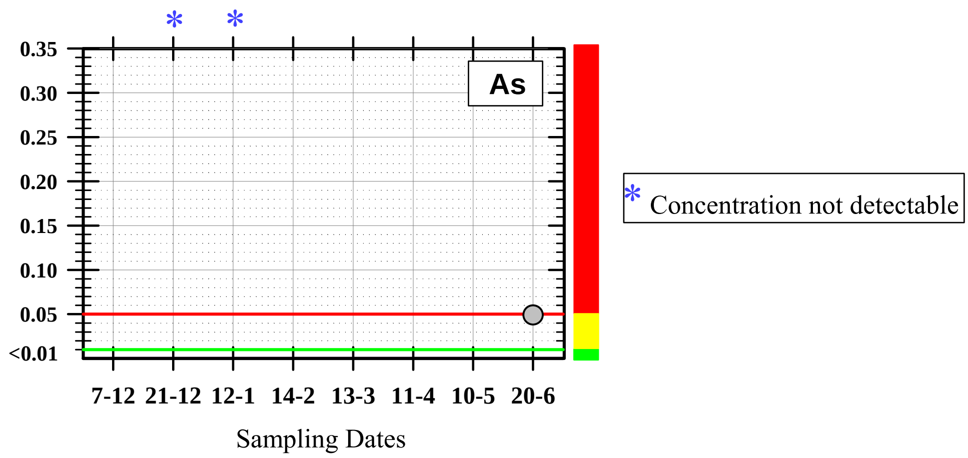
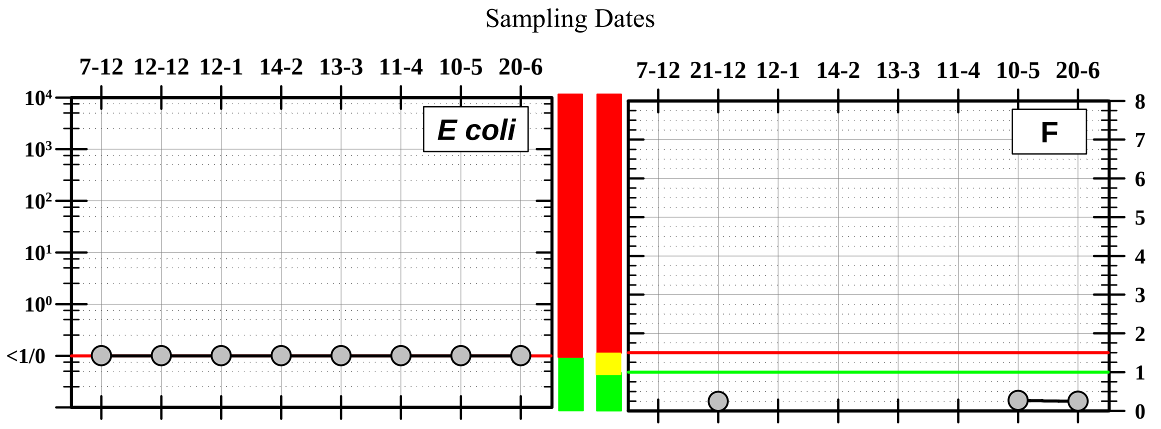


FIGURE 28: Water quality at Bot4 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



<u>Drinking water quality requirements as specified in SANS 241:2005:</u>
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

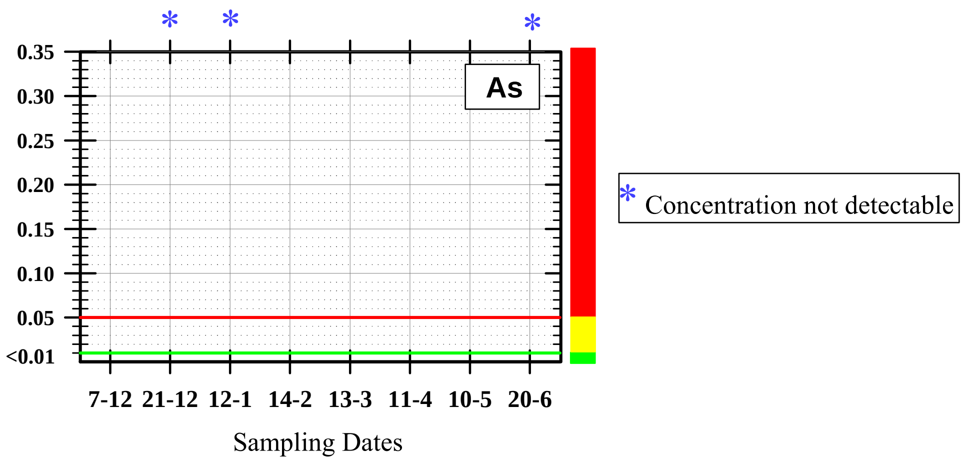
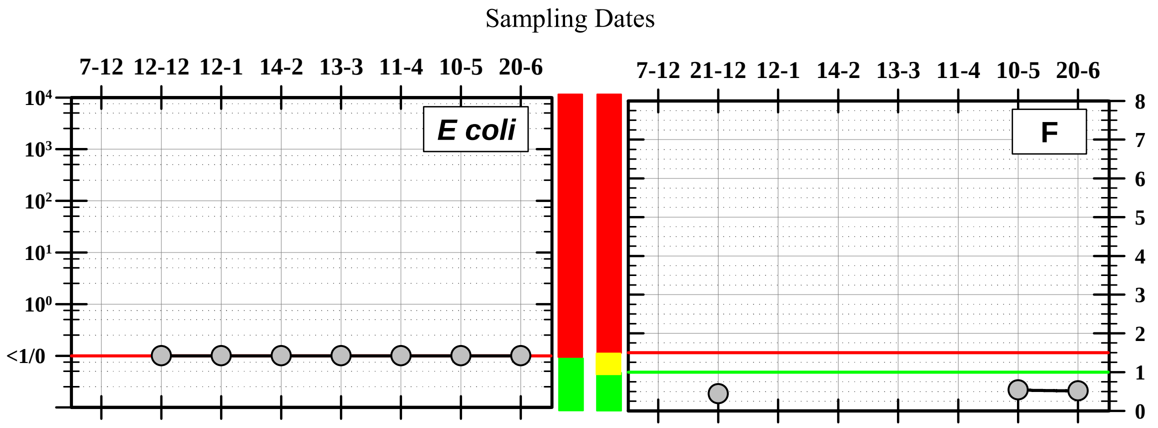


FIGURE 29: Water quality at Bot5 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



<u>Drinking water quality requirements as specified in SANS 241:2005:</u>
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

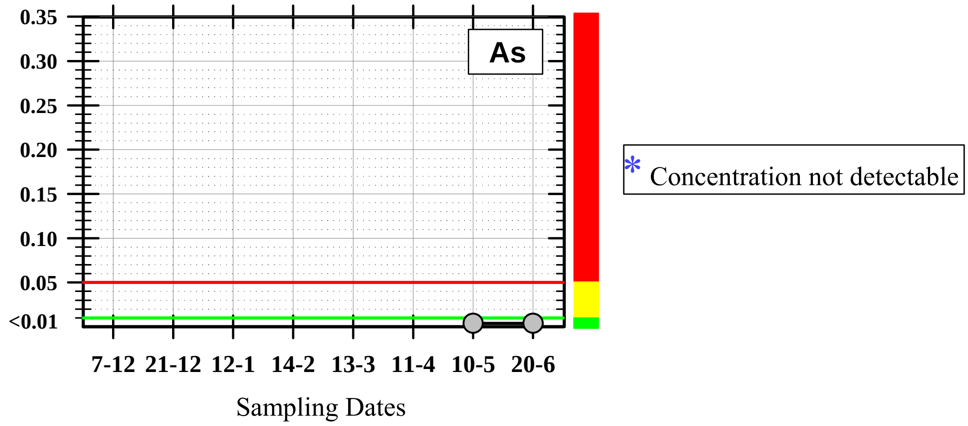
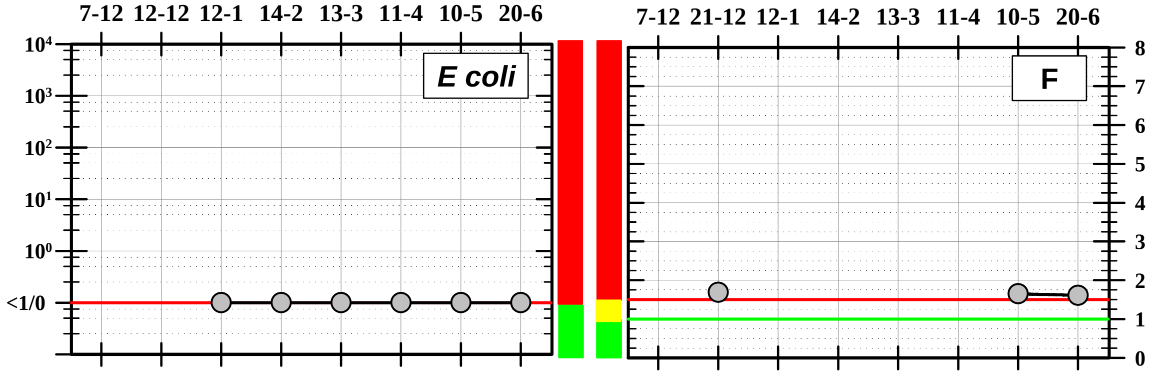
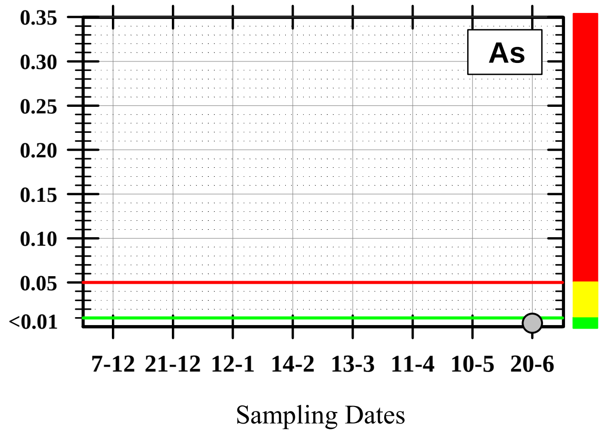


FIGURE 30: Water quality at Bot6 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005

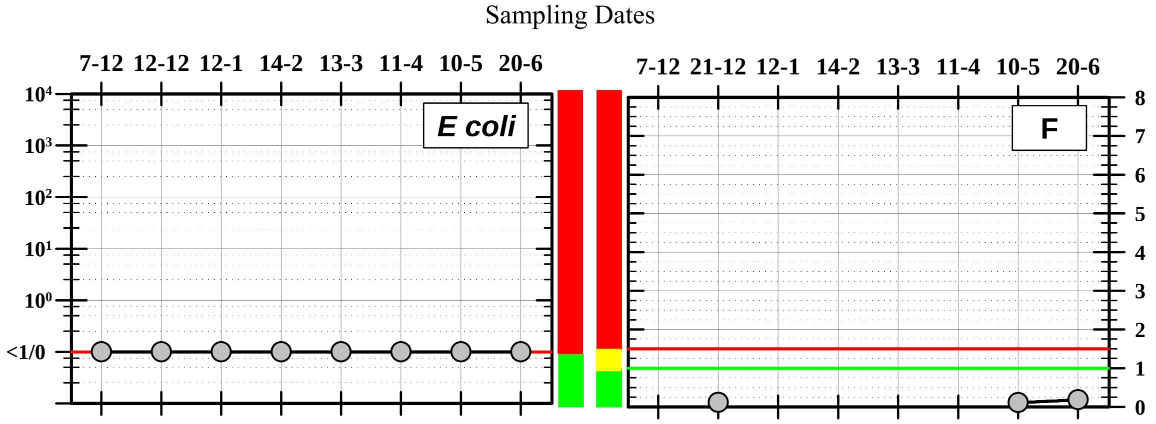


Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year



* Concentration not detectable

FIGURE 31: Water quality at Bot8 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

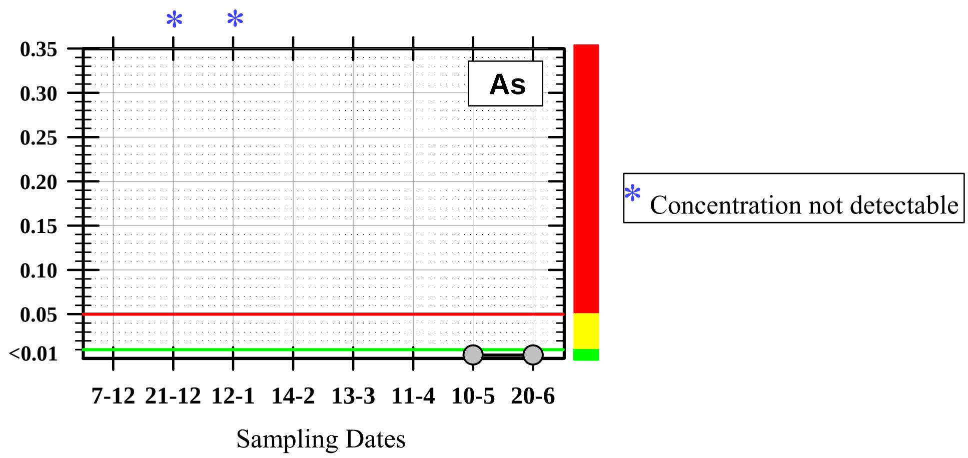
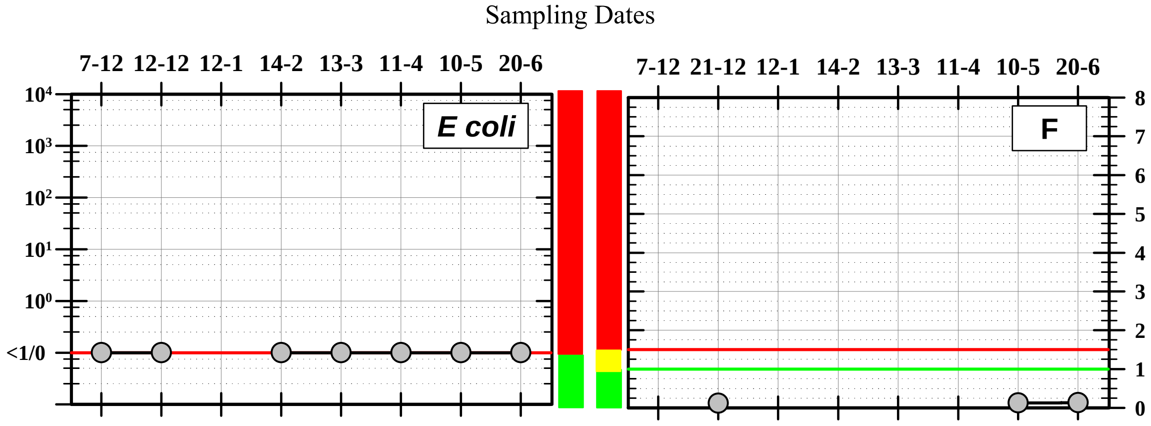


FIGURE 32: Water quality at C1 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

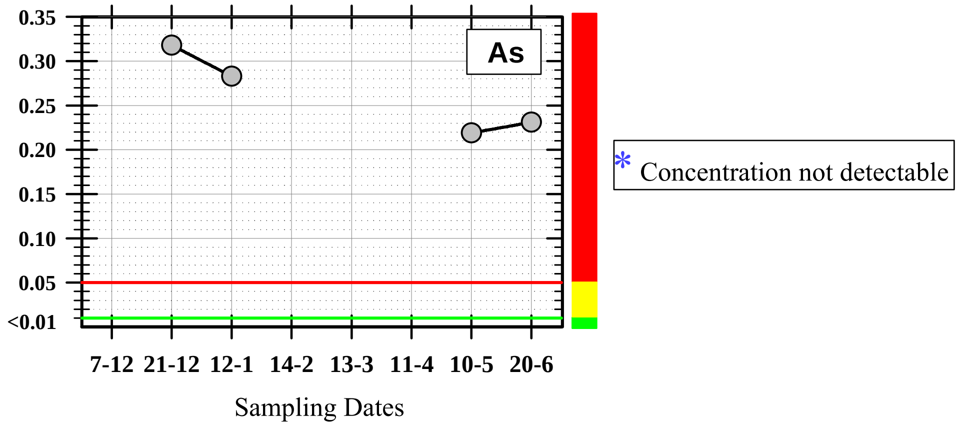
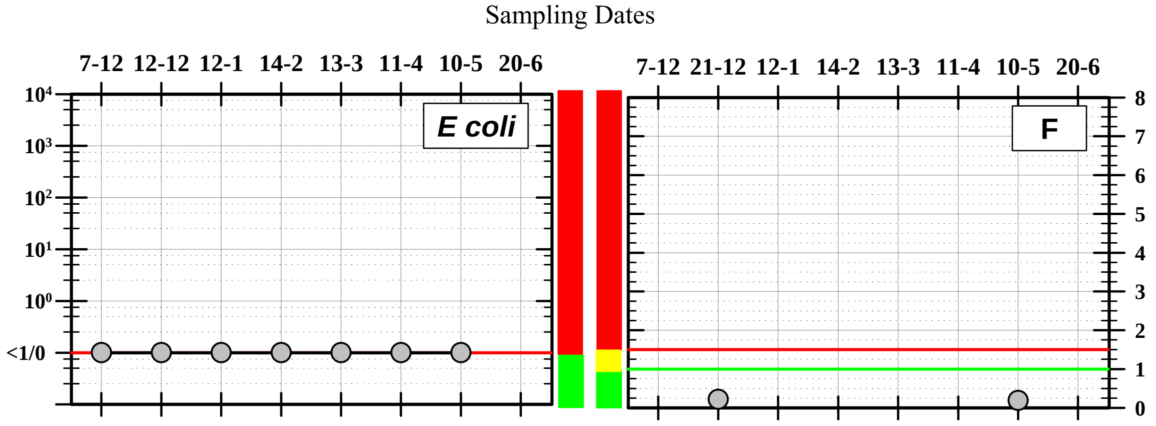


FIGURE 33: Water quality at C2 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



<u>Drinking water quality requirements as specified in SANS 241:2005:</u>
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

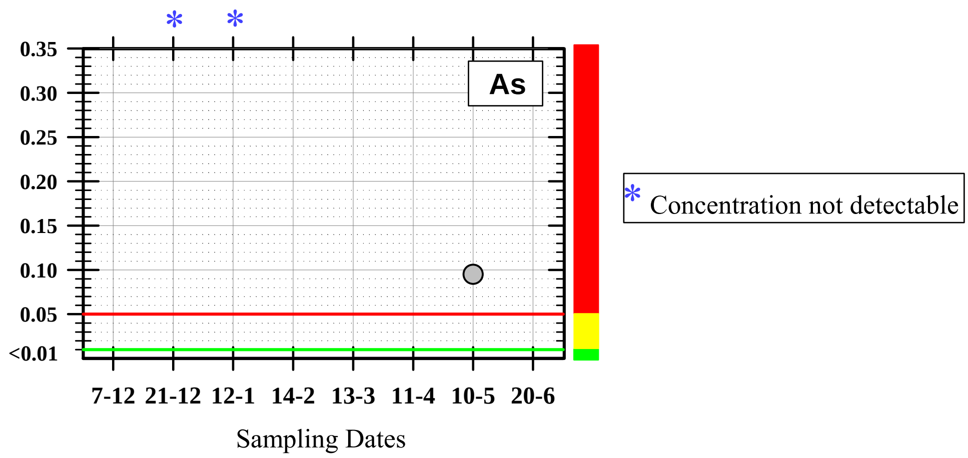
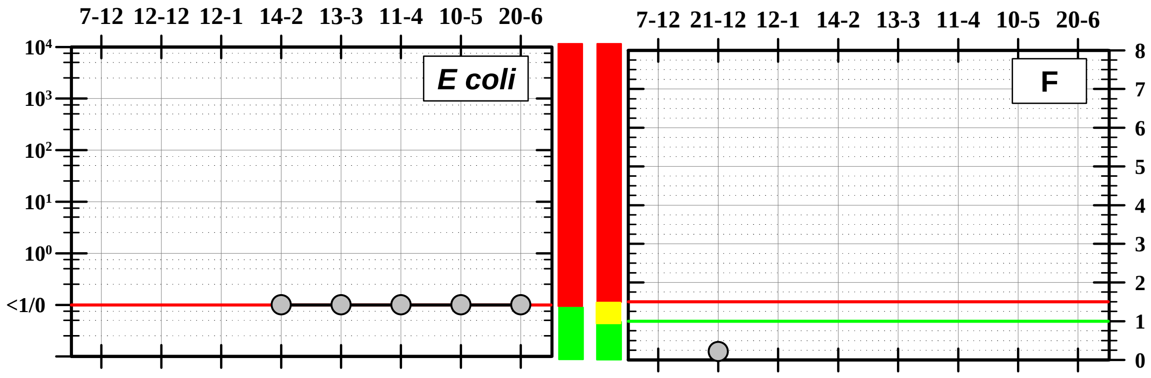
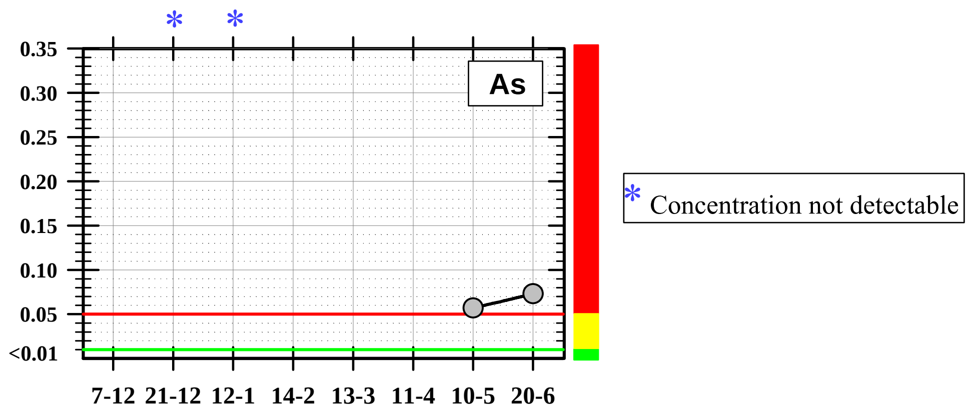


FIGURE 34: Water quality at C3 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005

Sampling Dates

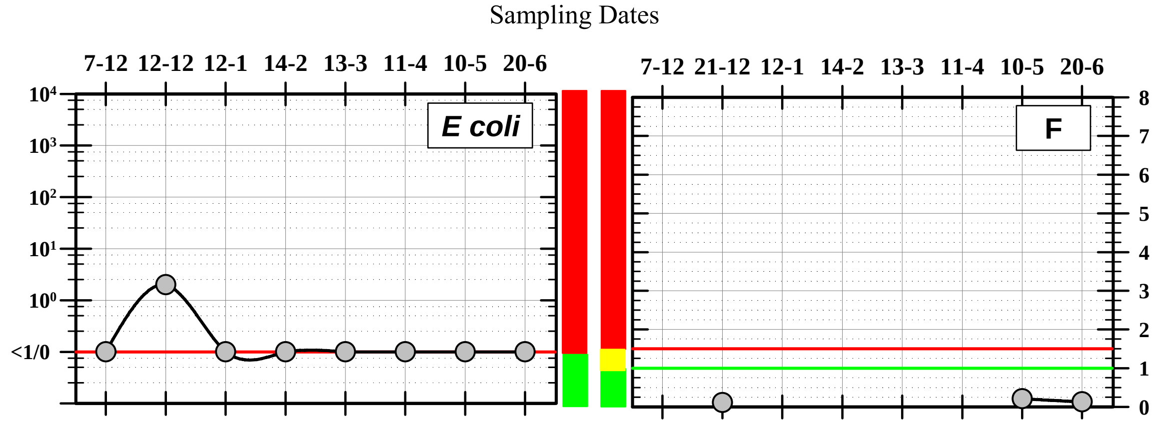


Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year



Sampling Dates

FIGURE 35: Water quality at C4 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

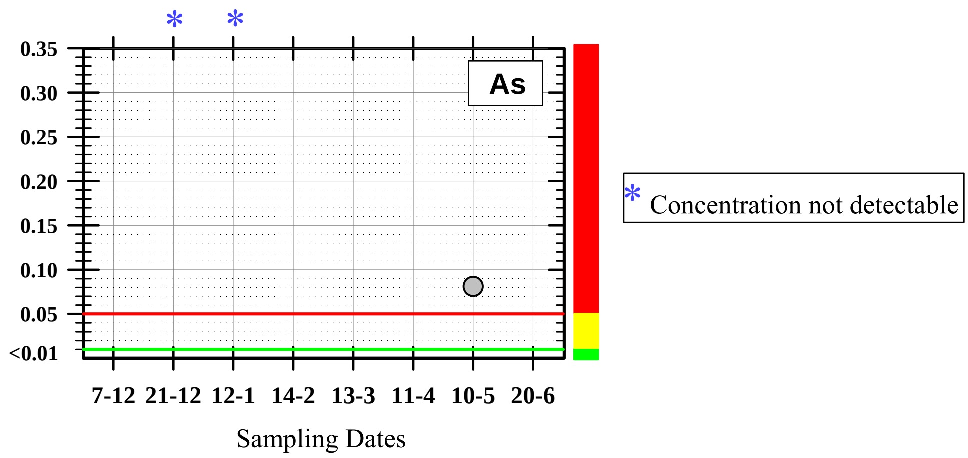
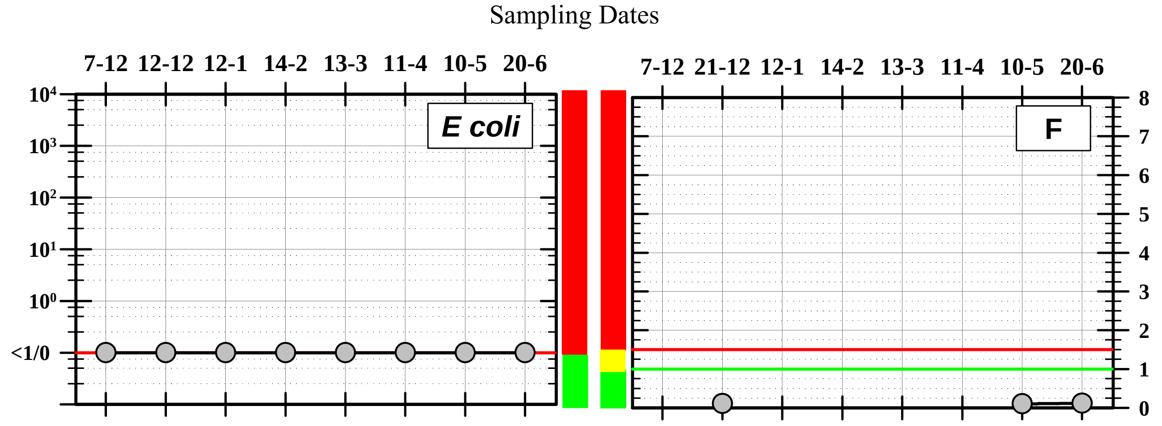


FIGURE 36: Water quality at D5 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)
Fluoride as F: <1mg/L recommended operational limit; max allowed 1.0 - 1.5mg/L for 1 year
Arsenic as As: <0.01mg/L recommended operational limit; max allowed 0.01 - 0.05mg/L for 1 year

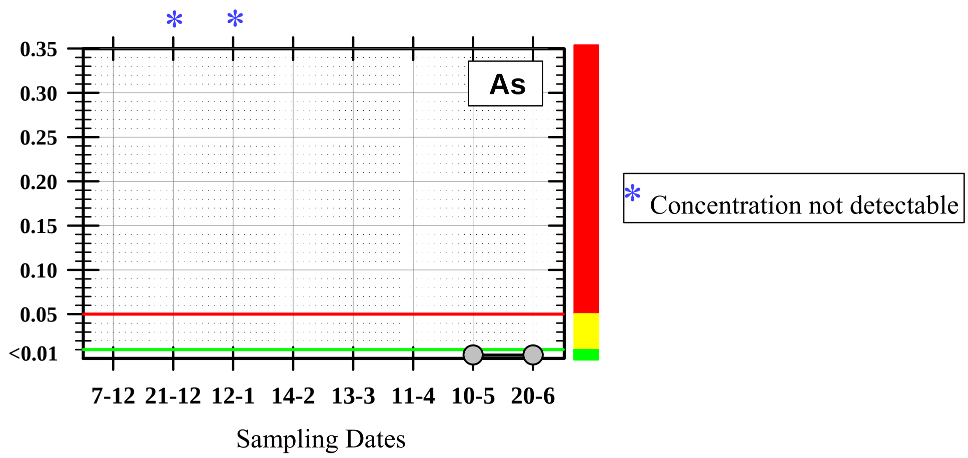


FIGURE 37: Water quality at D10 for the period 2005 to 2006 measured against drinking water requirements specified in SANS 241:2005

Rural water supply boreholes

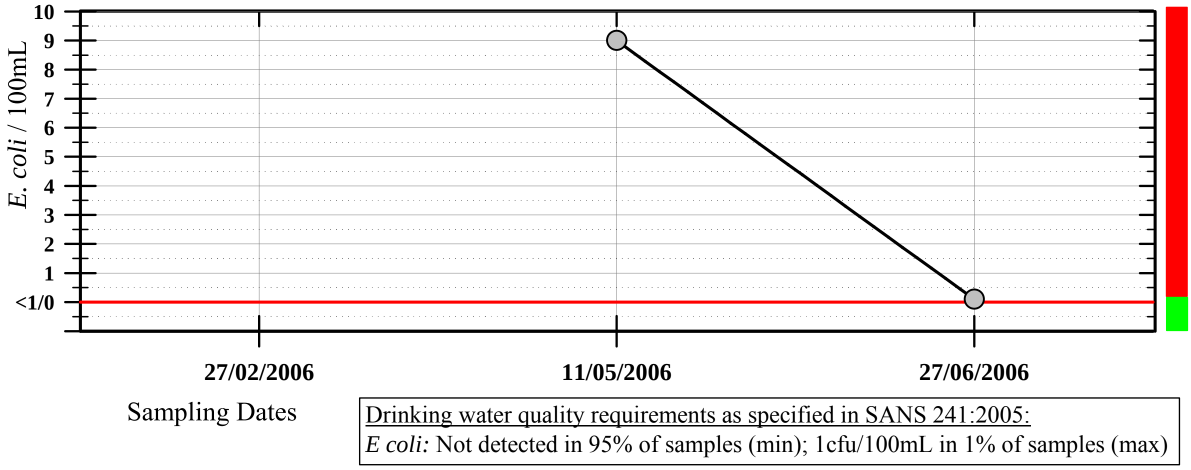


FIGURE 38: Water quality at ARBOR, rural water supply borehole plotted against SANS 241:2005

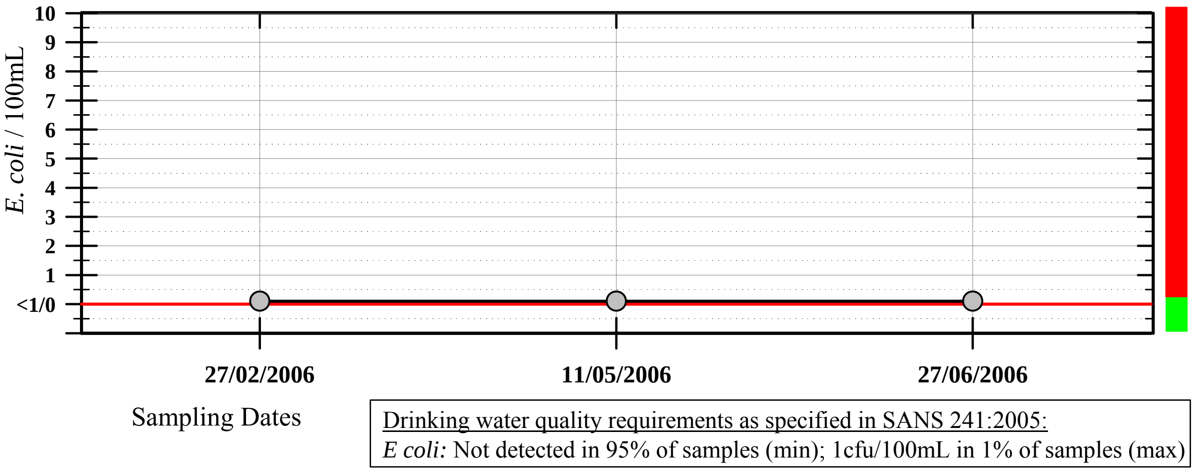


FIGURE 39: Water quality at ARGENT, rural water supply borehole plotted against SANS 241:2005

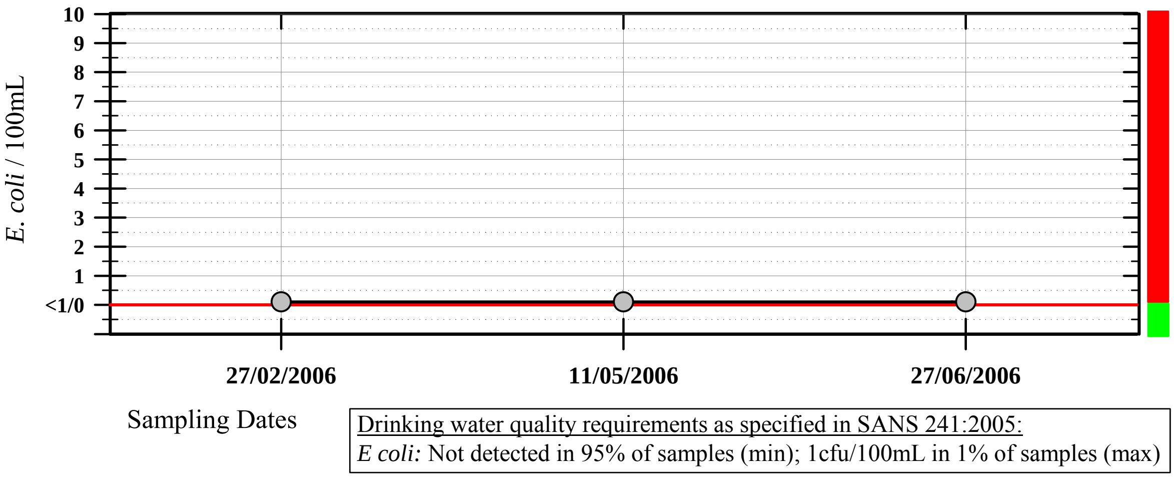
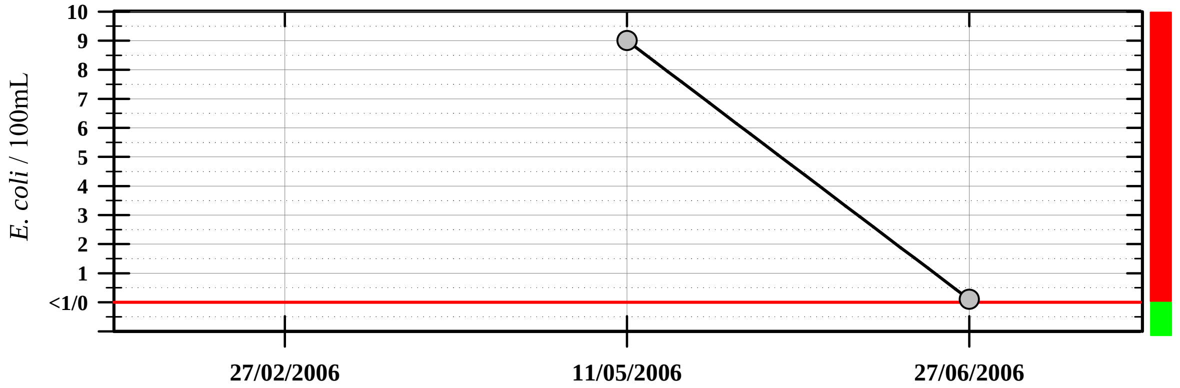


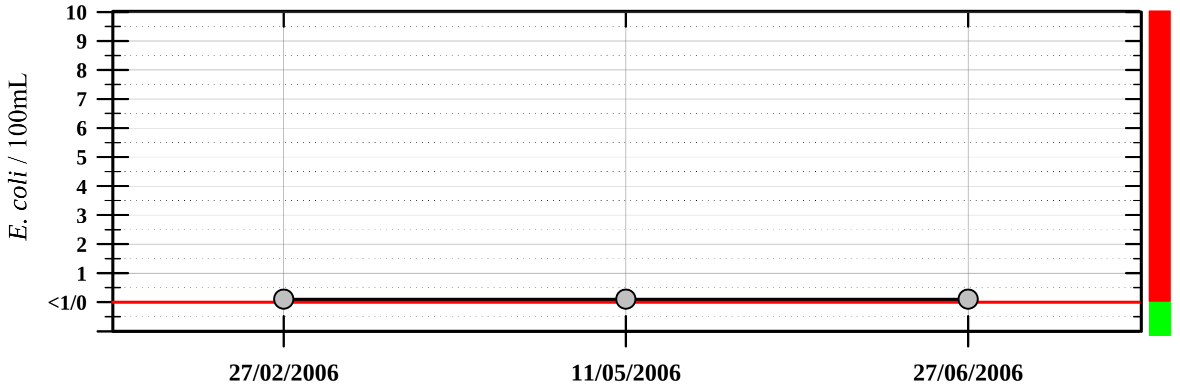
FIGURE 40: Water quality at DRYDEN, rural water supply borehole plotted against SANS 241:2005



Sampling Dates

Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

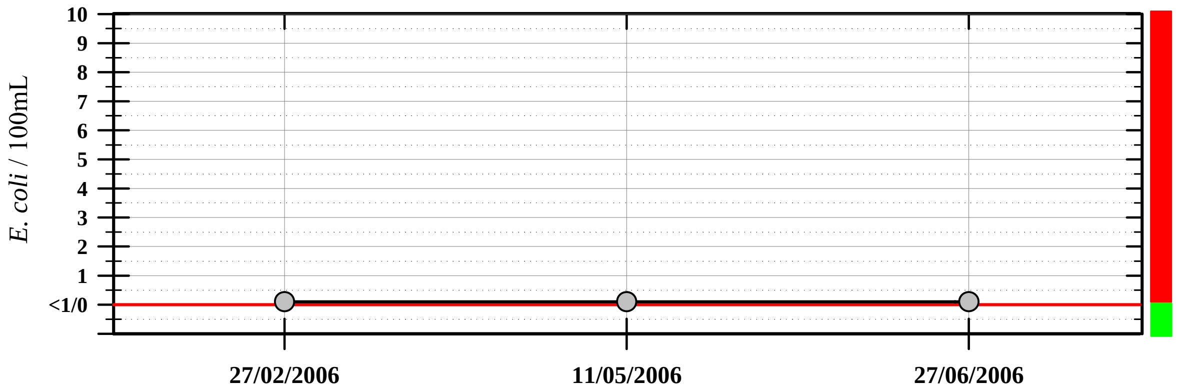
FIGURE 41: Water quality at BAMBISANA, rural water supply borehole plotted against SANS 241:2005



Sampling Dates

Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

FIGURE 42: Water quality at WAAIKRAAL, rural water supply borehole plotted against SANS 241:2005

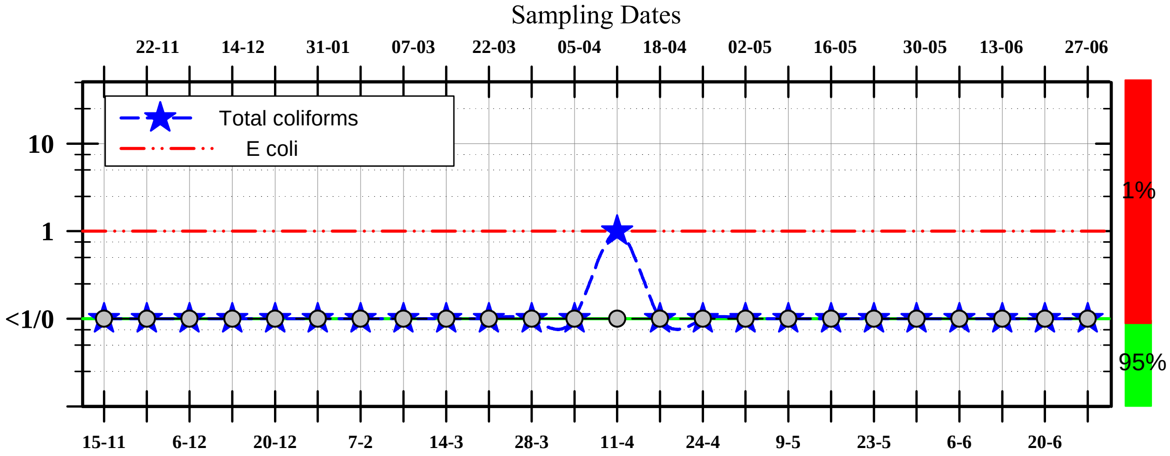


Sampling Dates

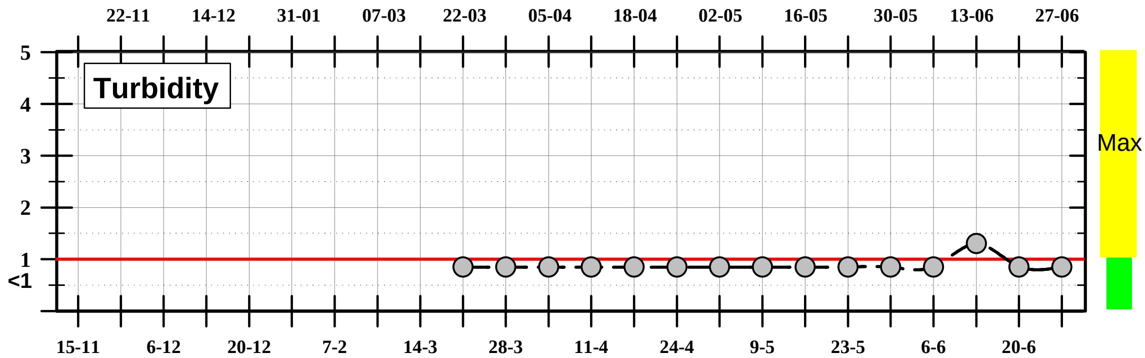
Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

FIGURE 43: Water quality at DROOGENFONTEIN, rural water supply borehole plotted against SANS 241:2005

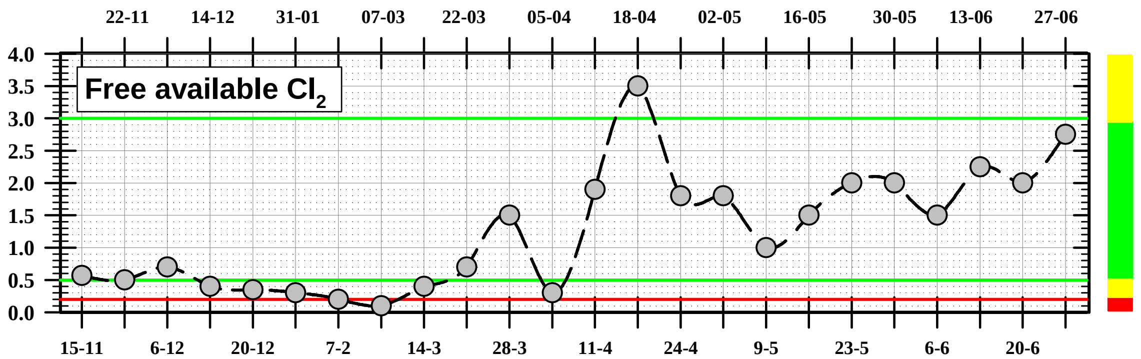
Delmas reticulation system water



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)



Drinking water quality requirements as specified in SANS 241:2005:
Turbidity: <1NTU recommended operational limit; max allowed 1- 5NTU



Operational guide for free available Chlorine ($Cl2_2$) proposed by project team:
0.5 - 3. 0 : Class I Green
0.2 - 0.5 and 3.0 - 5.0 : Class II Yellow
0 - 0.2 and >5.0 : Class III Red

FIGURE 44: Water quality at M4 (Tap Delmas west, Maritz laan House no.4) for the period 2005 to 2006 plotted against SANS 241:2005

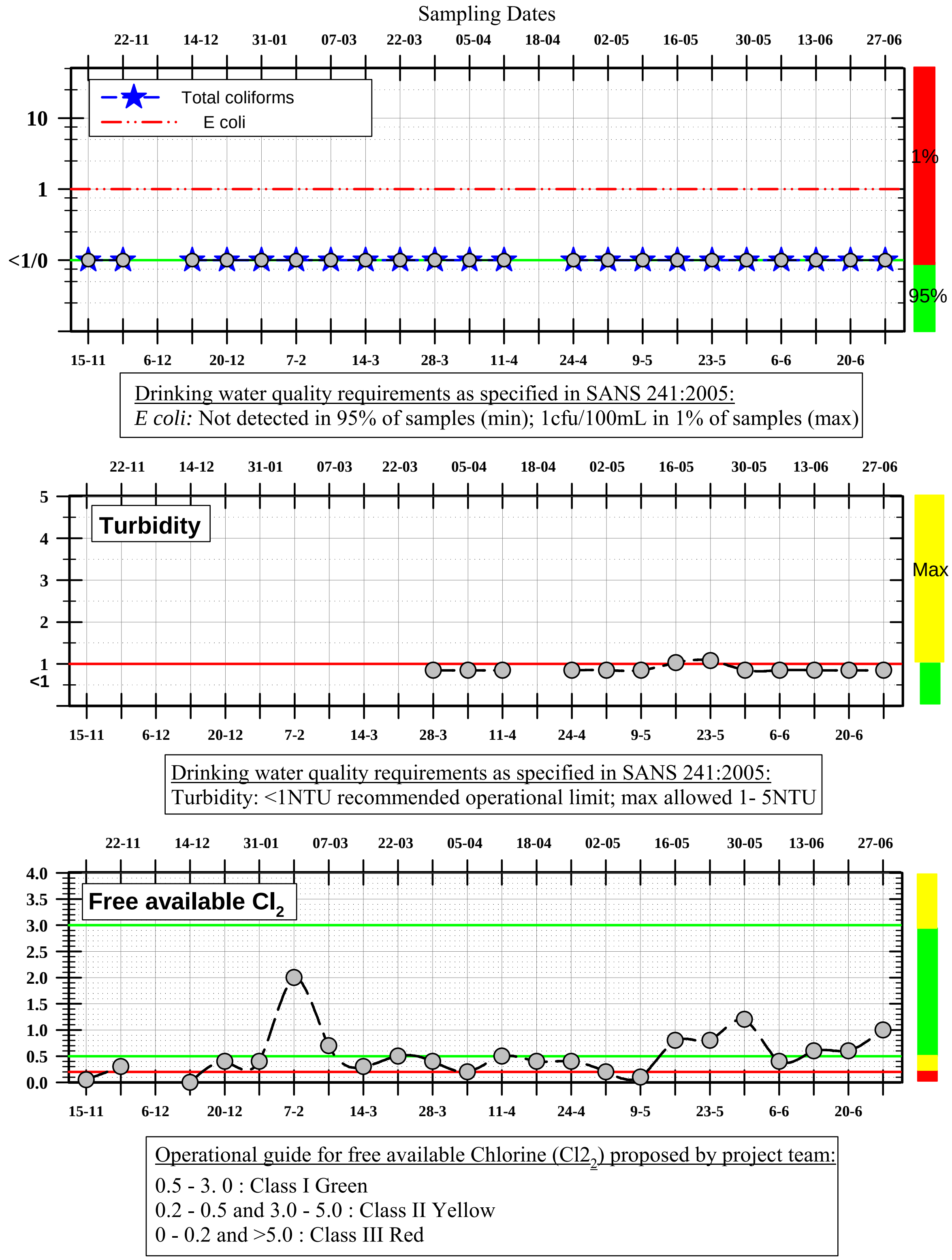
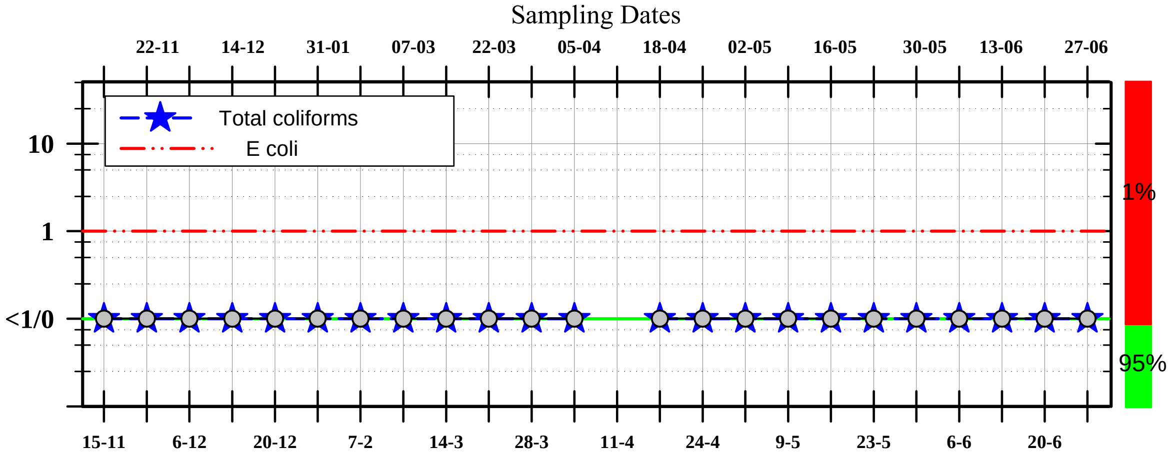
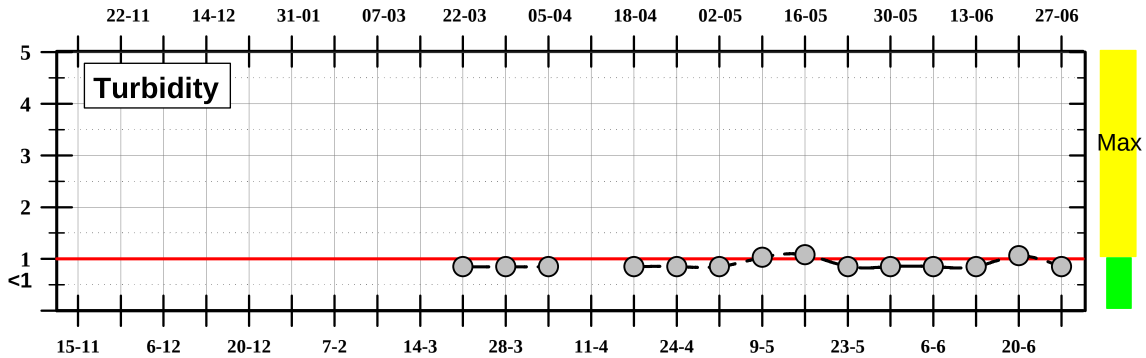


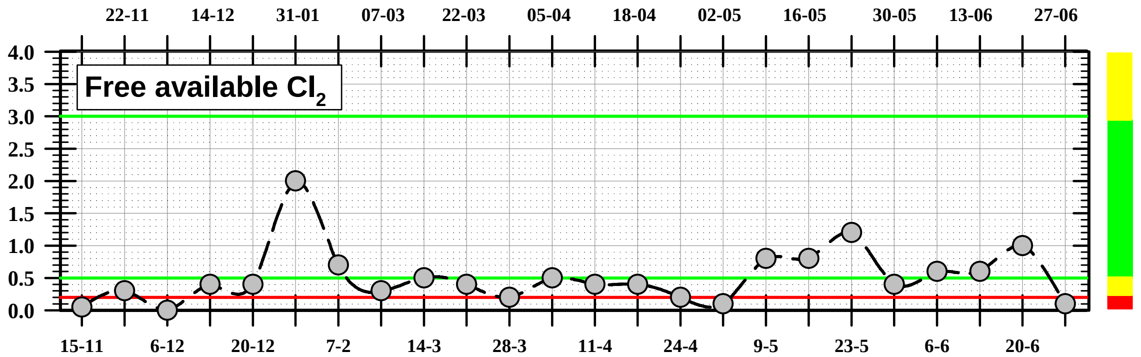
FIGURE 45: Water quality at T4809_B4 (Tap Botleng Ext 4 Stand 4809) for the period 2005 to 2006 plotted against SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

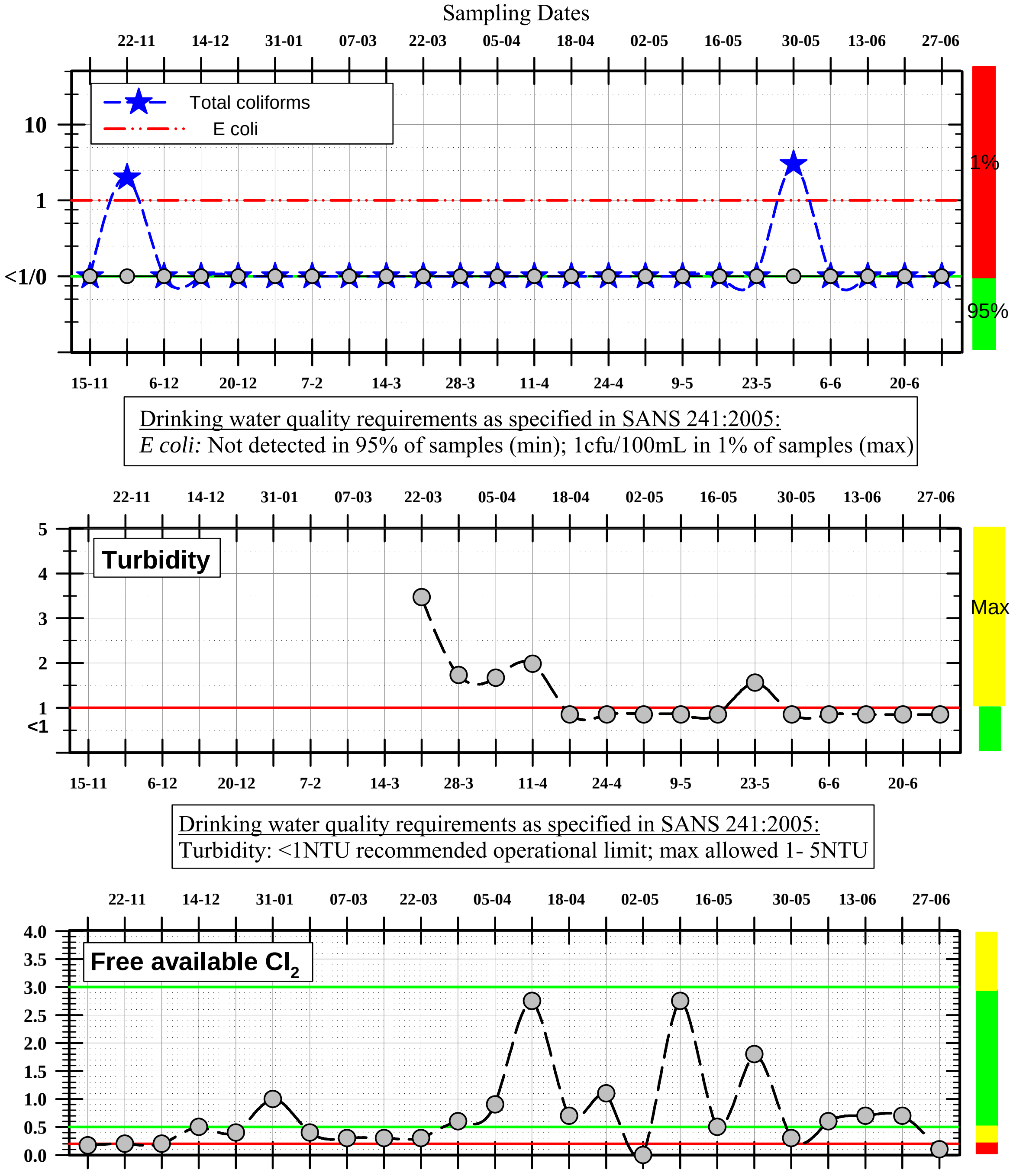


Drinking water quality requirements as specified in SANS 241:2005:
Turbidity: <1NTU recommended operational limit; max allowed 1- 5NTU



Operational guide for free available Chlorine ($Cl2_2$) proposed by project team:
0.5 - 3. 0 : Class I Green
0.2 - 0.5 and 3.0 - 5.0 : Class II Yellow
0 - 0.2 and >5.0 : Class III Red

FIGURE 46: Water quality at BN_5092 (New Botleng Ext. 4 Stand # 5092) for the period 2005 to 2006 plotted against SANS 241:2005

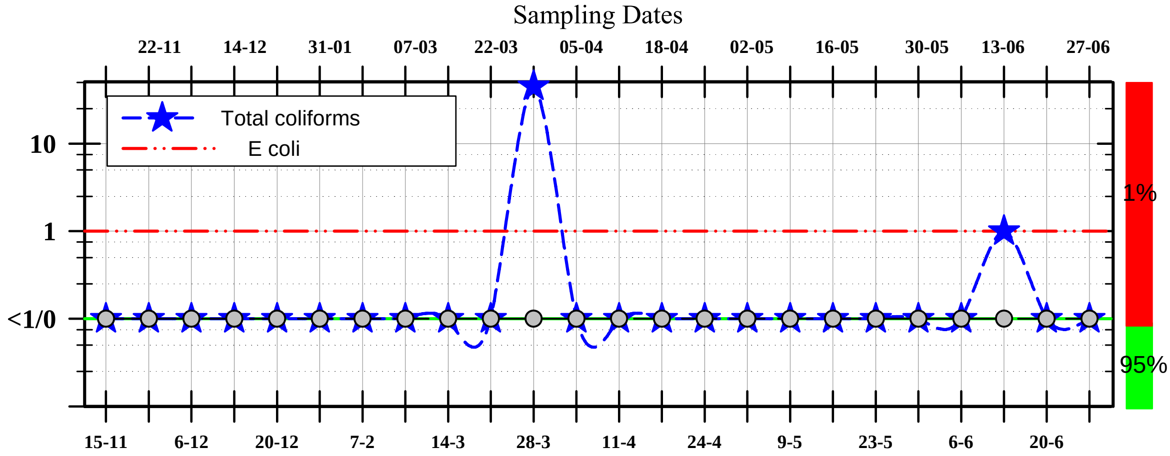


Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

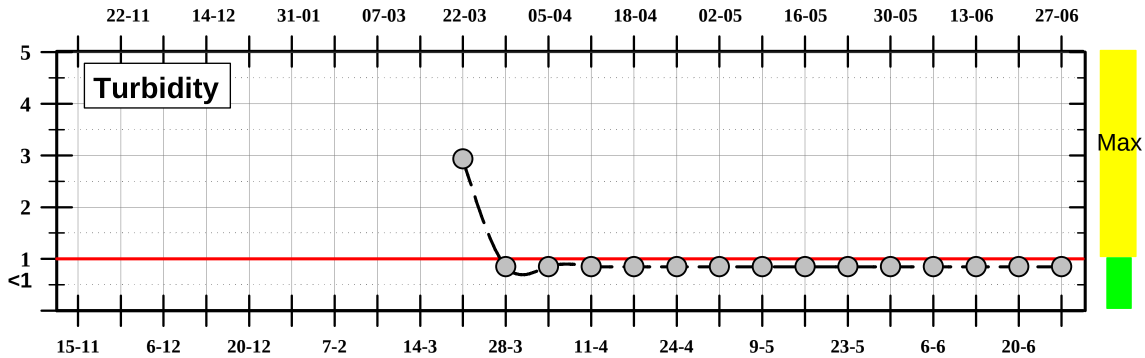
Drinking water quality requirements as specified in SANS 241:2005:
Turbidity: <1NTU recommended operational limit; max allowed 1- 5NTU

Operational guide for free available Chlorine ($Cl2_2$) proposed by project team:
0.5 - 3. 0 : Class I Green
0.2 - 0.5 and 3.0 - 5.0 : Class II Yellow
0 - 0.2 and >5.0 : Class III Red

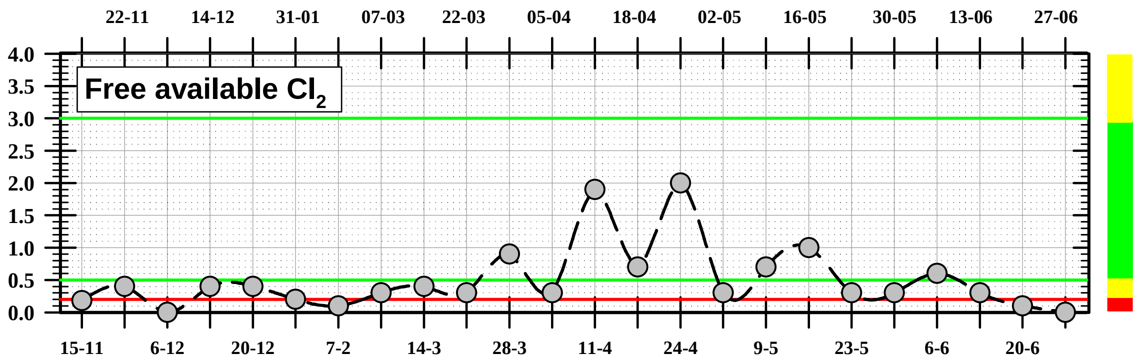
FIGURE 47: Water quality at B_LS (Botleng Mandela Informal Settlement Section F Lekalakala Street) for the period 2005 to 2006 plotted against SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

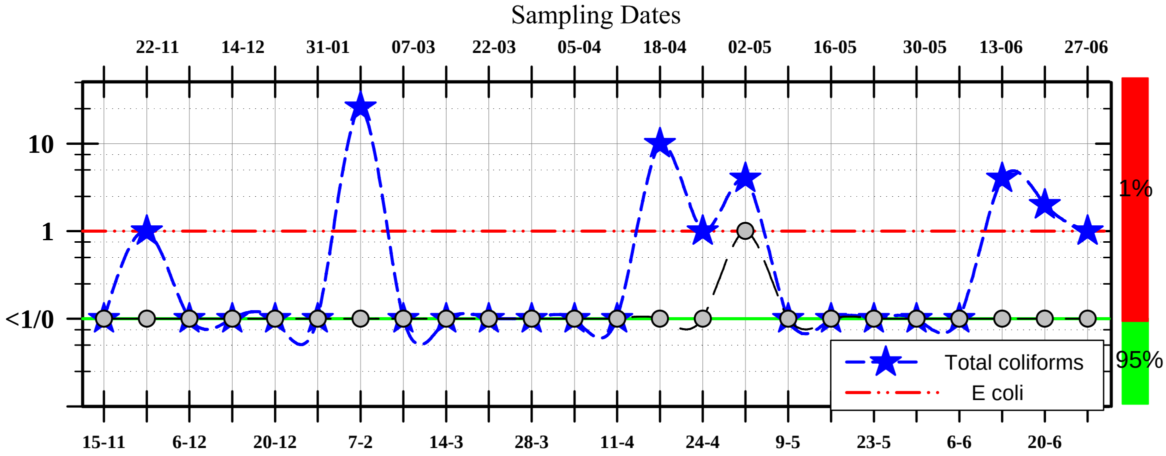


Drinking water quality requirements as specified in SANS 241:2005:
Turbidity: <1NTU recommended operational limit; max allowed 1- 5NTU

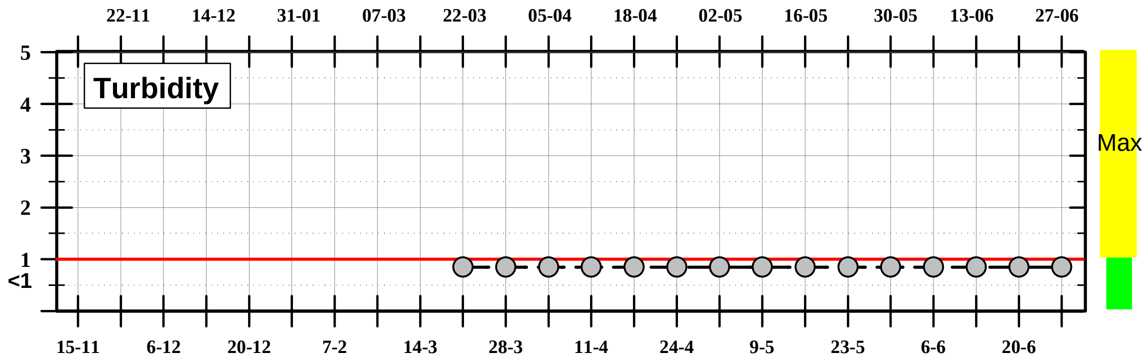


Operational guide for free available Chlorine ($Cl2_2$) proposed by project team:
0.5 - 3. 0 : Class I Green
0.2 - 0.5 and 3.0 - 5.0 : Class II Yellow
0 - 0.2 and >5.0 : Class III Red

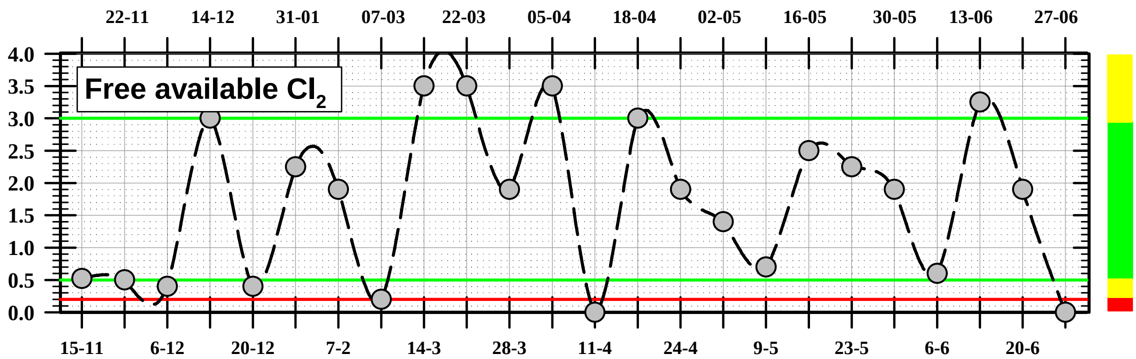
FIGURE 48: Water quality at DE_37 (Delpark Ext. 1 Carnation Street House # 37) for the period 2005 to 2006 plotted against SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

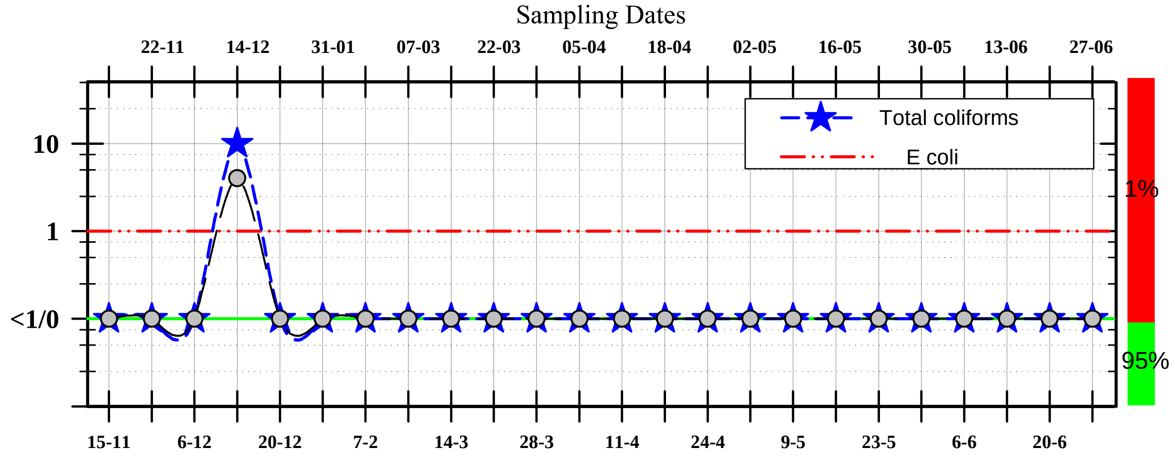


Drinking water quality requirements as specified in SANS 241:2005:
Turbidity: <1NTU recommended operational limit; max allowed 1- 5NTU

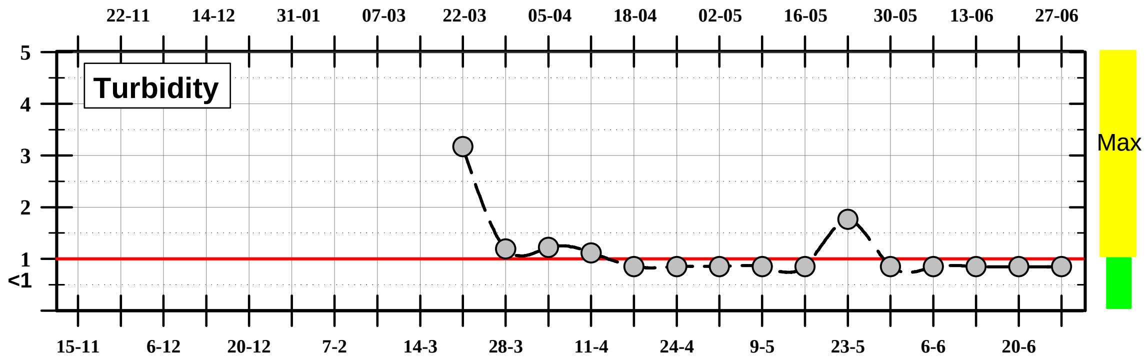


Operational guide for free available Chlorine ($Cl2_2$) proposed by project team:
0.5 - 3. 0 : Class I Green
0.2 - 0.5 and 3.0 - 5.0 : Class II Yellow
0 - 0.2 and >5.0 : Class III Red

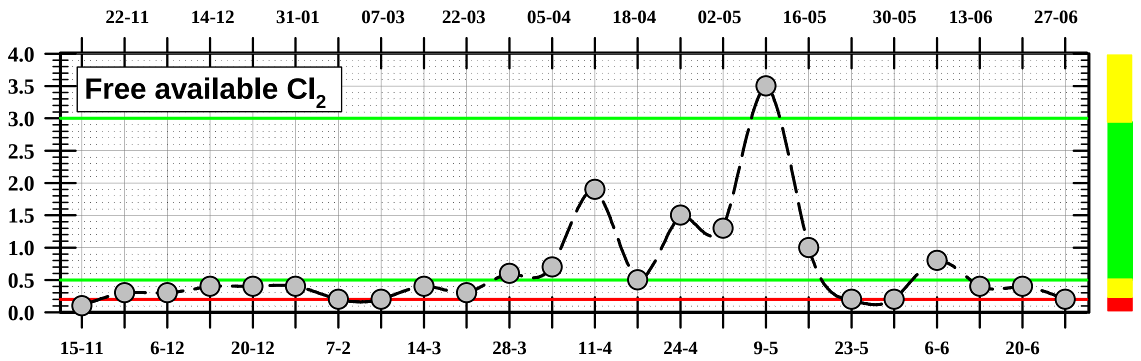
FIGURE 49: Water quality at RS13 (Tap Delmas Strydom street, House no. 13) for the period 2005 to 2006 plotted against SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

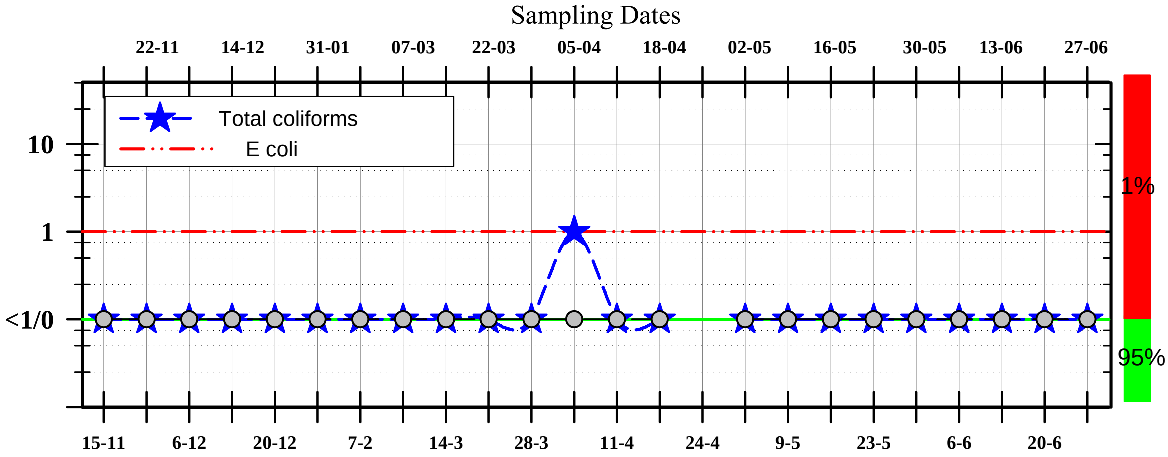


Drinking water quality requirements as specified in SANS 241:2005:
Turbidity: <1NTU recommended operational limit; max allowed 1- 5NTU

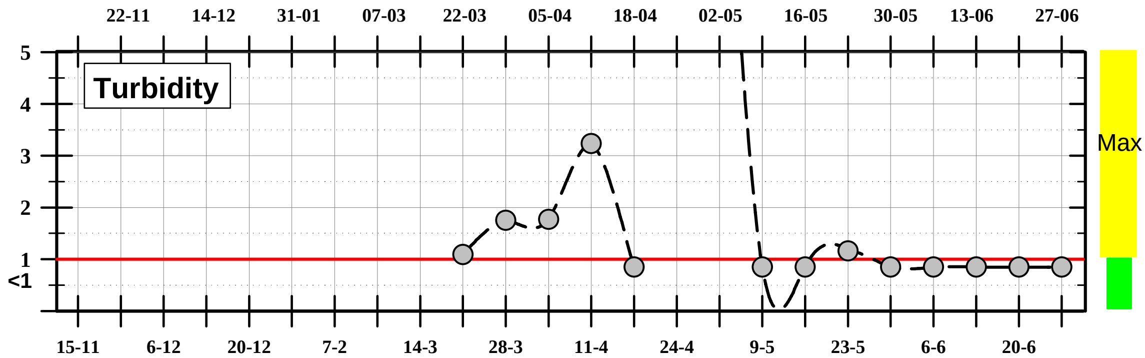


Operational guide for free available Chlorine ($Cl2_2$) proposed by project team:
0.5 - 3. 0 : Class I Green
0.2 - 0.5 and 3.0 - 5.0 : Class II Yellow
0 - 0.2 and >5.0 : Class III Red

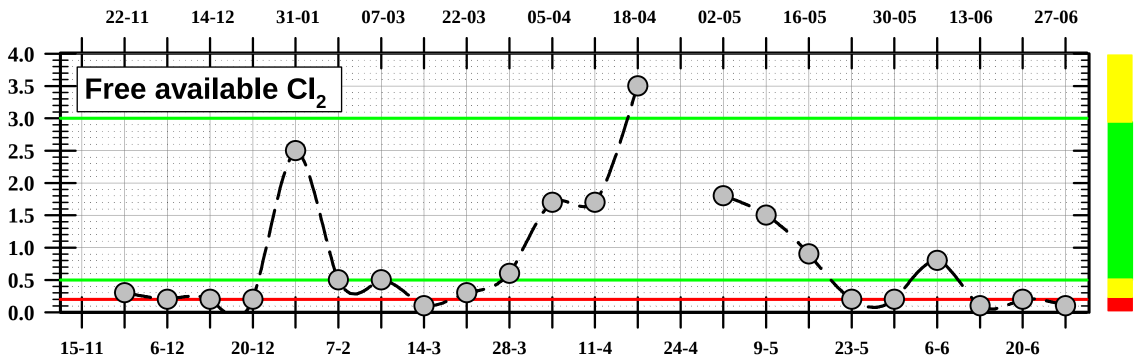
FIGURE 50: Water quality at DE_420 (Tap Delpark Ext. 2 House 420 (Tuckshop)) for the period 2005 to 2006 plotted against SANS 241:2005



<u>Drinking water quality requirements as specified in SANS 241:2005:</u>
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

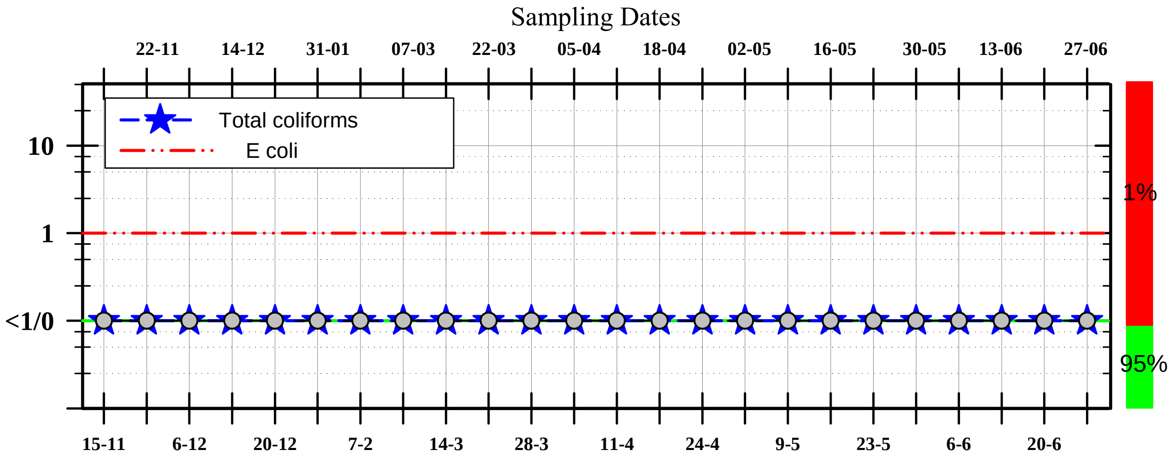


<u>Drinking water quality requirements as specified in SANS 241:2005:</u>
Turbidity: <1NTU recommended operational limit; max allowed 1- 5NTU

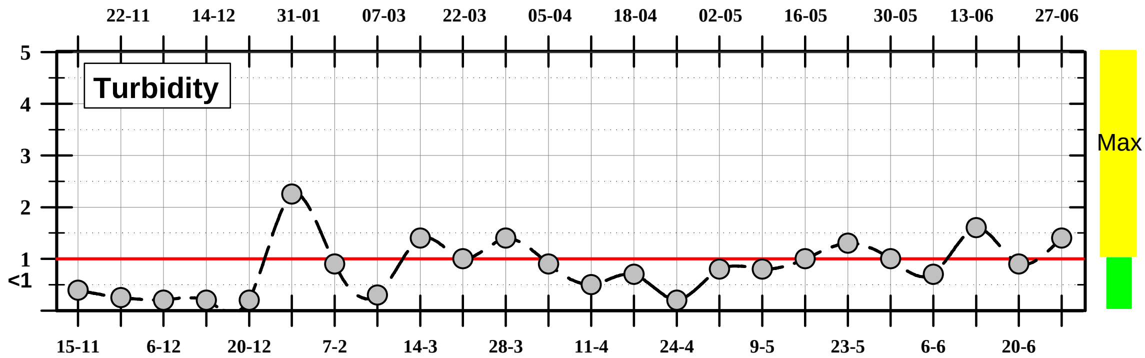


<u>Operational guide for free available Chlorine ($Cl2_2$) proposed by project team:</u>
0.5 - 3. 0 : Class I Green
0.2 - 0.5 and 3.0 - 5.0 : Class II Yellow
0 - 0.2 and >5.0 : Class III Red

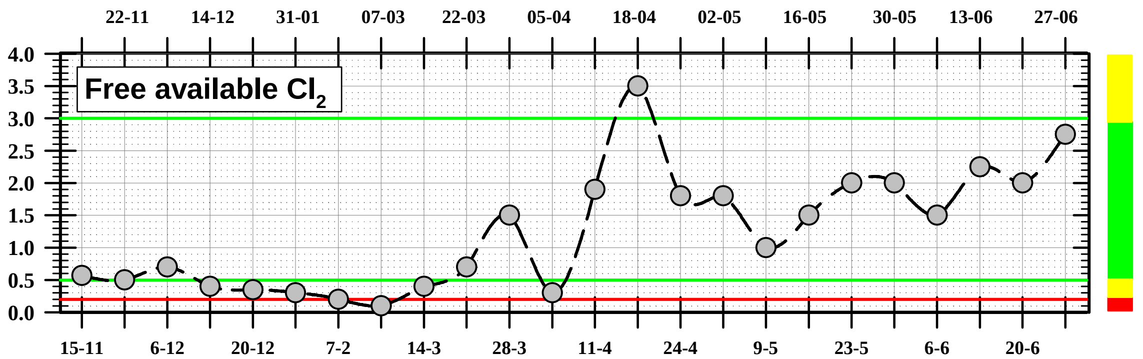
FIGURE 51: Water quality at NPS_5 (Tap Nesher Private School 5th Street) for the period 2005 to 2006 plotted against SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)

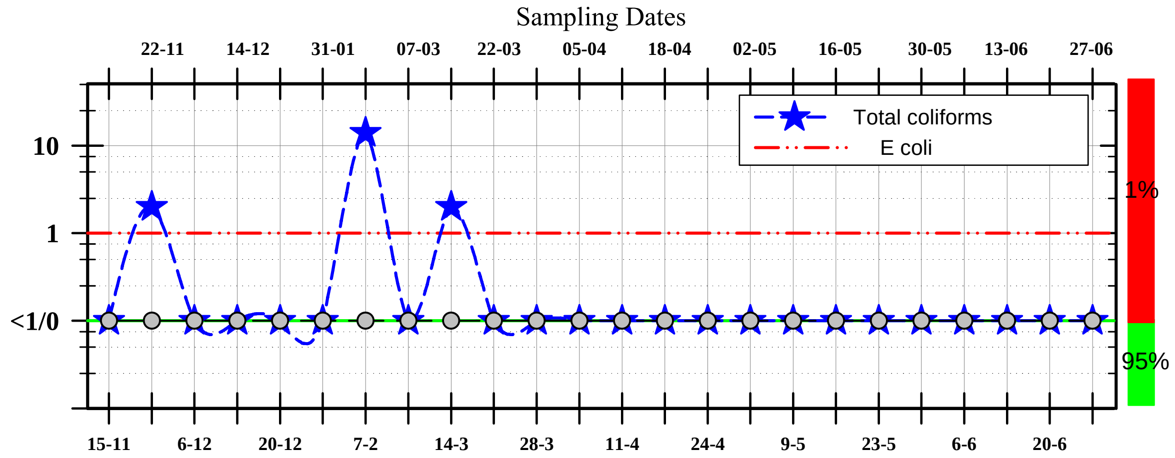


Drinking water quality requirements as specified in SANS 241:2005:
Turbidity: <1NTU recommended operational limit; max allowed 1- 5NTU

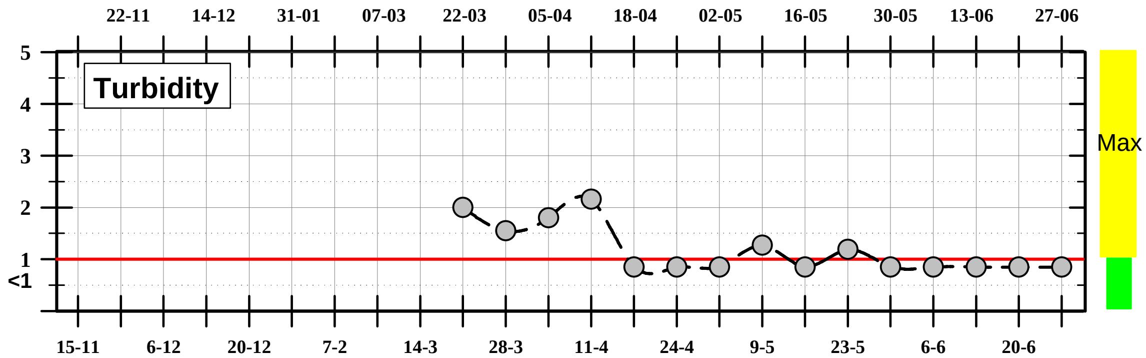


Operational guide for free available Chlorine ($Cl2_2$) proposed by project team:
0.5 - 3. 0 : Class I Green
0.2 - 0.5 and 3.0 - 5.0 : Class II Yellow
0 - 0.2 and >5.0 : Class III Red

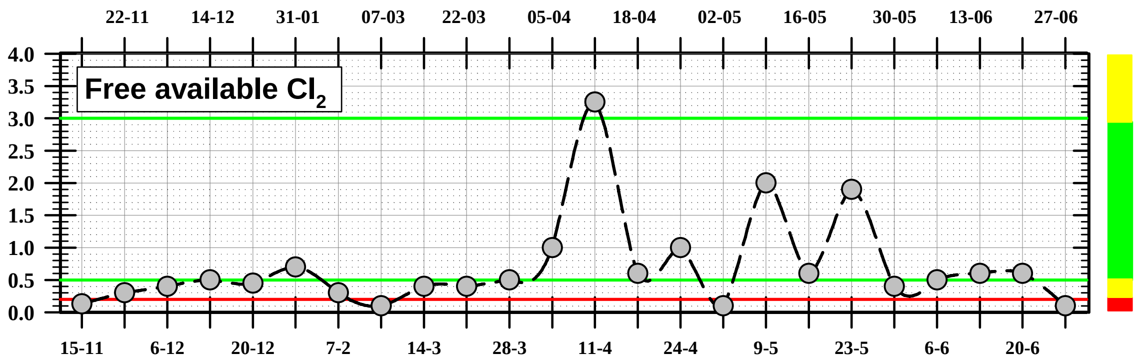
FIGURE 52: Water quality at NB_3879 (Tap New Botleng Ext. 6 Stand # 3878) for the period 2005 to 2006 plotted against SANS 241:2005



Drinking water quality requirements as specified in SANS 241:2005:
E coli: Not detected in 95% of samples (min); 1cfu/100mL in 1% of samples (max)



Drinking water quality requirements as specified in SANS 241:2005:
Turbidity: <1NTU recommended operational limit; max allowed 1- 5NTU



Operational guide for free available Chlorine ($Cl2_2$) proposed by project team:
0.5 - 3. 0 : Class I Green
0.2 - 0.5 and 3.0 - 5.0 : Class II Yellow
0 - 0.2 and >5.0 : Class III Red

FIGURE 53: Water quality at B_MS (Botleng Mandela Informal Settlement Section C Masunyane Street) for the period 2005 to 2006 plotted against SANS 241:2005

Note

The following variables, for the different water categories, were interpreted against the following guidelines:

1 Appendix B: Surface water quality results

pH; *E coli* and Faecal Streptococci : South African Water Quality Guidelines for Recreational Use (DWAF, 1996[a])

TDS; Nitrate (NO_3); Fluoride (F); Calcium (Ca); Sodium (Na); Sulfate (SO_4); Chloride (Cl) and Magnesium (Mg) : South African Water Quality Guidelines for Livestock watering (DWAF, 1996[b])

2 Appendix C: Discharged effluent quality results

pH, Electrical conductivity (EC); *E. coli*; Ammonia (NH_4); Nitrate (NO_3-NO_2) and Ortho Phosphate (PO_4) : Licence conditions for Delmas WWTW's

3 Appendix D: Groundwater quality results

pH; Electrical conductivity (EC); Turbidity; *E. coli*; Ammonia (NH_4); Potassium (K); Nitrate (NO_3-NO_2); Fluoride (F); Calcium (Ca); Sodium (Na); Sulphate (SO_4); Chloride (Cl); Magnesium (Mg); Chromium; Iron: Manganese; Nickel; Copper; Zinc; Arsenic; Cadmium and Lead : SANS 241:2005

4 Appendix E: Reticulation system water quality results

pH; Electrical conductivity (EC); Turbidity; *E. coli*; Ammonia (NH_4); Potassium (K); Nitrate (NO_3-NO_2); Fluoride (F); Calcium (Ca); Sodium (Na); Sulphate (SO_4); Chloride (Cl); Magnesium (Mg); Chromium; Iron; Manganese; Nickel; Copper; Zinc; Arsenic; Cadmium and Lead : SANS 241:2005

Residual chlorine (Cl_2) : Guideline proposed by project team

APPENDIX B

Surface Water Quality Results

S1 – WITKLIP DAM							
Sampling Date	Physical Constituents				Microbiological Constituents		
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Faecal Streptococci (count/100mL)
12/12/2005	7.61	89	581		8 454 500	205	
12/01/2006	7.70	73	479		4 106 000	1 480	
13/02/2006	8.04	52	339			4 790	
13/03/2006	No results				141 360	<1	160
10/04/2006	7.72	31	203	1.19	51 720	<1	18
22/05/2006	7.28	34	218	5.51	6 510	<1	6
21/06/2006	8.16	33	215	1.20	746	<1	4

Major Inorganic Compounds (mg/L)														
Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005			84.8	<0.08	0.293	2.96	205	39.8		1.707	62.5	71.4	94.1	20.5	184
12/01/2006	0.08	4.90	75.5	0.83	0.198	2.98	188	30.2	3.65	0.105	51.4	52.9	68.0	15.9	141
13/02/2006	0.74	3.77	50.6	<0.08	0.268	6.17	120	20.2	1.58	0.489	29.2	50.4	46.3	12.6	102
13/03/2006	No results														
10/04/2006	<0.04	1.52	17.0	<0.08	0.344	6.83	96	19.0	1.32	1.082	10.9	16.1	15.9	10.2	98
22/05/2006	0.37	2.52	17.4	0.10	0.368	5.78	111	17.3	1.37	0.987	11.5	11.9	16.0	11.2	97
21/06/2006	0.06	1.23	18.5	0.13	0.371	4.02	133	21.7	1.47	0.917	11.3	7.05	15.7	13.6	110

S2 – BRONKHORST RIVER ABOVE DELPARK RESIDENTIAL AREA						
Sampling Date	**Physical Constituents**				**Microbiological Constituents**	
	pH (pH units)	**EC (mS/m)**	**TDS (mg/L)**	**TURB (NTU)**	**Total Coliforms (MPN/100mL)**	***E. coli* (MPN/100mL)**
12/12/2005	8.34	54	350		19 608	598
12/01/2006	8.12	54	352		19 608	10 344
13/02/2006	7.99	36	237		28 272	346
13/03/2006	8.05	42	276		39 726	1 058
10/04/2006	7.93	45	289	2.08	10 344	126
22/05/2006	8.21	51	331	3.29	6 510	62
21/06/2006	8.52	51	332	<1	9 783	71

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005	0.07	0.377	1.72	0.614	0.108		199	47.5	0.085	0.046	15.0	27.8	24.4	30.3	243
12/01/2006	<0.04	0.311	2.41	0.376	<0.1		207	49.1	0.075	0.035	14.5	29.6	27.4	28.7	208
13/02/2006	0.16		6.56	0.777	0.218	8.20	133	25.1		0.205	11.4	18.1	17.7	17.0	132
13/03/2006	<0.04	0.616	7.94	0.739	0.251	8.86	166	37.3	0.091	0.043	14.9	16.8	14.3	21.7	208
10/04/2006	0.14	0.626	3.23	1.495	0.252	8.05	170	40.6	0.089	0.062	14.7	35.5	19.7	24.3	220
22/05/2006	<0.04	0.303	1.46	2.807	0.179	5.35	199	41.5	0.054	0.031	14.1	21.8	19.8	26.8	233
21/06/2006	<0.04		1.80	3.030	0.154	5.41	198	48.9		0.013	14.2	23.7	17.4	28.2	238

S3 – BRONKHORSTSPRUIT MIDWAY DELPARK RESIDENTIAL AREA					
Sampling Date	Physical Constituents			Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
12/12/2005	7.93	60	388	8 704	538
12/01/2006	Site not accessible, municipality working on road				
13/02/2006	Site not accessible, municipality working on road				
13/03/2006	8.37	43	277	12 442	327
10/04/2006	No flow				
22/05/2006	No flow				
21/06/2006	No flow				

Major Inorganic Compounds															
Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005	0.072		1.08	0.081	0.162	8.15	230	43.0		0.074	15.9	22.9	29.2	34.8	250
12/01/2006	Site not accessible														
13/02/2006	Site not accessible														
13/03/2006	<0.04	0.633	8.20	0.362	0.314	9.00	172	35.6	0.12	0.048	15.4	14.3	14.0	23.4	205
10/04/2006	No flow														
22/05/2006	No flow														
21/06/2006	No flow														

S4 – UNNAMED TRIBUTARY ABOVE DELMAS SEWAGE WORKS							
Sampling Date	Physical Constituents				Microbiological Constituents		
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Faecal Streptococci (count/100mL)
12/12/2005	7.75	114	740		17 230	<1	
12/01/2006	7.96	67	435		34 480	1 618	
13/02/2006	6.99	106	686		1 986 280	19 608	
13/03/2006	8.54	85	554		64 880	374	
10/04/2006	8.01	79	516	15.4	68 670	200	790
22/05/2006	8.36	77	499	10.9	21 661	239	92
21/06/2006	8.78	89	580	26.3	72 700	20	41

Major Inorganic Compounds (mg/L)															
Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005	0.57		14.8	<0.08	0.250	12.0	482	95.5		0.184	7.5	<4	109.3	56.4	463
12/01/2006	<0.04	0.949	8.1	<0.08	0.157	6.8	196	53.1	0.287	0.046	35.9	71.0	50.6	27.8	247
13/02/2006	0.08	3.703	75.8	41.01	0.187	15.7	141	44.6	24.103	0.484	68.9	70.3	84.9	34.9	157
13/03/2006	0.05	2.328	12.7	1.16	0.178	9.2	312	64.8	3.654	1.094	52.1	26.5	78.9	47.6	386
10/04/2006	0.24	0.903	8.2	0.24	0.186	7.0	273	66.7	0.796	0.560	51.7	34.5	86.0	39.7	360
22/05/2006	0.14	0.744	5.6	0.78	0.233	5.4	263	51.3	0.495	0.369	52.9	34.1	80.1	36.0	299
21/06/2006	0.59	1.730	11.5	1.81	0.180	5.1	308	63.5	1.870	0.824	67.1	37.1	82.7	42.7	334

S8 – DOWNSTREAM OF DELMAS SEWAGE WORKS EFFLUENT DISCHARGE							
Sampling Date	Physical Constituents				Microbiological Constituents		
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Faecal Streptococci (count/100mL)
12/12/2005	8.15	100	651		22 397	3 912	
12/01/2006					307 600	15 402	
13/02/2006	7.62	74	481			6 564	
13/03/2006	7.65	95	616		34 657	2 108	
10/04/2006	8.12	84	543	1.1	25 993	1 476	1900
22/05/2006	7.54	86	560	16.0	21 430	5 510	4 200
21/06/2006				12.2	15 531	9 768	6 200

Major Inorganic Compounds (mg/L)															
Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4 (mg/L)	Na (mg/L)	SO_4 (mg/L)	Cl^- (mg/L)	Mg (mg/L)	Hardness (mg/L)
12/12/2005	8.16		106.4	0.083	0.187	9.1	320	35.3		6.99	62.3	35.9	77.1	25.5	202
12/01/2006															
13/02/2006	7.46		76.9	0.200	0.235	7.5	238	29.4		9.73	35.6	25.4	47.6	20.3	157
13/03/2006	6.72	15.66	96.9	9.491	0.169	10.4	232	39.1	10.4	8.71	50.1	28.3	64.8	27.8	231
10/04/2006	<0.04	1.01	92.9	2.801	0.213	8.9	235	36.1	8.3	6.92	51.1	34.7	65.9	26.3	215
22/05/2006	10.21	18.02	89.7	0.933	0.198	7.9	246	37.9	6.2	4.95	48.9	42.4	57.6	25.2	215
21/06/2006															

S9 – BRONKHORSTSPRUIT BELOW MANDELA SETTLEMENT							
Sampling Date	**Physical Constituents**				**Microbiological Constituents**		
	pH (pH units)	**EC (mS/m)**	**TDS (mg/L)**	**TURB (NTU)**	**Total Coliforms (MPN/100mL)**	***E. coli* (MPN/100mL)**	**Faecal Streptococci (count/100mL)**
12/12/2005	8.23	100	652		92 080	1 296	
12/01/2006	7.66	57	371		770 100	392 726	
13/02/2006	8.06	56	365		28 272	618	
13/03/2006	8.62	72	469		39 726	1 182	
10/04/2006	8.09	73	471	2.65	39 726	530	960
22/05/2006	8.25	75	488	2.94	30 760	2 212	870
21/06/2006				<1	25 993	1 406	240

Major Inorganic Compounds (mg/L)															
Sampling Date	**NH_4-N**	**Kjeldahl Nitrogen**	**K**	**NO_3-NO_2**	**F**	**Si**	**TAL**	**Ca**	**Total P**	**PO_4**	**Na**	**SO_4**	**Cl^-**	**Mg**	**Hardness**
12/12/2005	9.15		105.6	1.357	0.218	9.73	353	38.2		10.86	64.4	27.2	76.4	27.7	209
12/01/2006	1.89	3.57	46.6	0.546	0.248	6.67	165	24.7	2.80	0.49	29.1	28.3	42.1	14.8	134
13/02/2006	2.71		43.1	0.747	0.237	8.06	177	29.7		4.84	22.4	37.2	31.6	18.6	151
13/03/2006	2.75	2.98	61.0	1.436	0.210	9.49	254	38.7	4.51	4.10	38.6	23.1	47.8	27.3	227
10/04/2006	0.65	1.98	57.9	2.549	0.230	7.62	236	40.9	2.97	2.95	39.1	33.4	50.9	26.4	229
22/05/2006	0.41	1.45	66.2	5.371	0.202	5.81	247	34.7	3.76	3.18	41.7	41.7	50.1	27.3	215
21/06/2006															

S10 – BRONKHORSTSPRUIT AT N12 BRIDGE						
Sampling Date	**Physical Constituents**				**Microbiological Constituents**	
	pH (pH units)	**EC (mS/m)**	**TDS (mg/L)**	**TURB (NTU)**	**Total Coliforms (MPN/100mL)**	***E. coli* (MPN/100mL)**
12/12/2005					11 588	220
12/01/2006					2 014 000	328 200
13/02/2006	7.85	44	284		54 750	3 500
13/03/2006	7.27	59	380		>24 192	>24 192
10/04/2006	7.94	52	335	1.25	7 430	630
22/05/2006	7.97	63	406	3.73	4 718	82
21/06/2006				<1	4 494	148

Major Inorganic Compounds (mg/L)															
Sampling Date	**NH_4-N**	**Kjeldahl Nitrogen**	**K**	**NO_3-NO_2**	**F**	**Si**	**TAL**	**Ca**	**Total P**	**PO_4**	**Na**	**SO_4**	**Cl^-**	**Mg**	**Hardness**
12/12/2005															
12/01/2006															
13/02/2006	0.15	1.36	22.3	2.20	0.258	8.14	122	25.4	2.94	0.49	19.7	31.1	26.3	17.1	134
13/03/2006	10.88	13.67	7.8	0.87	0.349	8.11	146	34.4	2.88	1.34	26.6	17.8	33.6	24.2	202
10/04/2006	0.07	0.96	22.6	3.03	0.314	6.88	147	30.3	1.89	1.60	25.0	28.6	30.9	19.8	171
22/05/2006	0.10	1.00	36.5	7.36	0.288	4.61	177	36.2	3.05	2.55	36.8	32.9	42.0	24.1	206
21/06/2006															

S14 – LEEUSPRUIT UPSTREAM OF PUMP STATION						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
12/12/2005	7.58	21	136		10 344	147
12/01/2006	7.84	22	145		2 419 170	259 500
13/02/2006	7.76	43	278		4 106 000	1 986 280
13/03/2006	7.80	79	514		>24 192	>24 192
10/04/2006	7.11	43	281	2.53	7 270 000	1 986 280
22/05/2006	7.71	36	234	2.38	727 000	141 360
21/06/2006				2.69	313 000	111 985

Major Inorganic Compounds (mg/L)															
Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005	0.39	1.17	4.68	1.07	0.233	3.48	46	17.8	0.210	0.074	6.3	28.7	9.2	6.2	70
12/01/2006	0.43		4.37	1.17	0.286	3.67	54	21.6		0.081	7.5	25.4	9.5	6.7	81
13/02/2006	1.99	7.11	6.28	<0.08	0.332	5.96	139	28.6	0.848	0.433	19.1	20.2	25.3	15.1	133
13/03/2006	34.27		11.12	<0.08	0.376	7.91	282	32.6	3.604	1.795	34.2	37.2	46.1	25.1	199
10/04/2006	<0.04	12.45	7.06	<0.08	0.370	6.16	171	28.7	1.701	1.657	25.9	30.0	32.9	15.6	149
22/05/2006	3.46	6.40	3.87	0.12	0.268	4.29	114	25.1	0.657	0.315	14.9	12.3	19.3	13.6	130
21/06/2006															

S15 – LEEUSPRUIT DOWNSTREAM OF PUMP STATION BEFORE CONFLUENCE WITH BRONKHORSTSPRUIT						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
12/12/2005						
12/01/2006					146 700	111 985
13/02/2006	7.32	43	280		5 794 000	1 299 650
13/03/2006					10 950	518
10/04/2006	7.13	53	344	2.14	2 419 170	1 986 200
22/05/2006	7.55	35	227	2.83	12 010	100
21/06/2006				<1	39 726	10 950

Major Inorganic Compounds (mg/L)															
Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005															
12/01/2006															
13/02/2006	4.45		6.39	<0.08	0.337	5.54	146	29.9		0.279	20.0	25.4	28.2	14.7	135
13/03/2006															
10/04/2006	8.29	14.20	8.55	0.31	0.363	5.97	168	28.2	2.589	1.346	24.6	12.8	33.6	16.3	150
22/05/2006	2.71	4.69	3.63	0.11	0.279	3.96	109	19.5	0.523	0.212	15.4	10.3	20.3	11.9	107
21/06/2006															

S16 – LEEUSPRUIT ABOVE BOTLENG NEW EXTENSION

Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
12/12/2005					39 726	720
12/01/2006	6.24	18	116		98 040	2 212
13/02/2006	7.84	13	85		19 608	82
13/03/2006	7.49	20	127		1 220	<1
10/04/2006	7.55	14	91	201.00	4 718	<1
22/05/2006	7.50	11	69	2.35	275	10
21/06/2006				<1	697	<1

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005															
12/01/2006	0.17	0.439	4.30	0.13	<0.1	2.53	<8	9.05	0.262	0.118	8.7	49.4	8.6	8.7	58
13/02/2006	0.04	0.728	1.46	<0.08	0.195	2.48	21	4.85	0.028	0.026	9.6	9.6	16.4	3.6	27
13/03/2006	<0.04	0.562	0.97	<0.08	0.169	3.54	53	10.60	0.228	0.049	13.6	<4	19.3	8.6	65
10/04/2006	<0.04	0.487	1.92	0.15	0.171	3.33	24	5.52	0.194	0.034	9.9	8.7	18.1	4.1	33
22/05/2006	0.20	0.387	3.11	<0.08	0.138	2.50	<8	3.16	0.142	0.028	8.9	<4	16.4	2.4	19
21/06/2006															

S17– LEEUSPRUIT MIDWAY BOTLENG NEW EXTENSION						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
12/12/2005						
12/01/2006	7.56	19	124		980 400	39 726
13/02/2006	7.66	34	220		517 200	32 550
13/03/2006	7.71	48	309		51 720	2 900
10/04/2006	No flow, sample not taken					
22/05/2006	No flow, sample not taken					
21/06/2006	No flow, sample not taken					

Major Inorganic Compounds (mg/L)															
Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005															
12/01/2006	0.057	0.82	6.25	0.53	0.172	3.88	27	14.2	0.187	0.068	6.1	31.0	8.3	3.9	52
13/02/2006	0.612	1.76	7.61	<0.08	0.301	5.18	101	26.4	0.112	0.040	14.7	19.2	21.3	9.7	105
13/03/2006	2.363	3.90	18.07	0.11	0.440	2.72	169	41.9	0.162	0.093	16.2	10.3	29.8	14.8	210
10/04/2006	No flow, sample not taken														
22/05/2006	No flow, sample not taken														
21/06/2006	No flow, sample not taken														

S20 – VLEI ROAD BRIDGE AT GOLF COURSE, UNMAED TRIBUTARY						
Sampling Date	**Physical Constituents**				**Microbiological Constituents**	
	pH (pH units)	**EC (mS/m)**	**TDS (mg/L)**	**TURB (NTU)**	**Total Coliforms (MPN/100mL)**	***E. coli* (MPN/100mL)**
12/12/2005						
12/01/2006					687 900	19 363
13/02/2006	No flow, sample not taken					
13/03/2006	No flow, sample not taken					
10/04/2006	No flow, sample not taken					
22/05/2006	No flow, sample not taken					
21/06/2006	No flow, sample not taken					

Major Inorganic Compounds (mg/L)															
Sampling Date	**NH_4-N**	**Kjeldahl Nitrogen**	**K**	**NO_3-NO_2**	**F**	**Si**	**TAL**	**Ca**	**Total P**	**PO_4**	**Na**	**SO_4**	**Cl^-**	**Mg**	**Hardness**
12/12/2005															
12/01/2006															
13/02/2006	No flow, sample not taken														
13/03/2006	No flow, sample not taken														
10/04/2006	No flow, sample not taken														
22/05/2006	No flow, sample not taken														
21/06/2006	No flow, sample not taken														

S21 – R50 BRIDGE TO LEANDRA , BRONKHORSTSPRUIT						
Sampling Date	**Physical Constituents**				**Microbiological Constituents**	
	pH (pH units)	**EC (mS/m)**	**TDS (mg/L)**	**TURB (NTU)**	**Total Coliforms (MPN/100mL)**	***E. coli* (MPN/100mL)**
12/12/2005						
12/01/2006						
13/02/2006	No flow, sample not taken					
13/03/2006	No flow, sample not taken					
10/04/2006	7.78	36.1	235	1.25	3 578	104
22/05/2006	No flow, sample not taken					
21/06/2006	No flow, sample not taken					

Major Inorganic Compounds (mg/L)														
Sampling Date	**NH_4-N**	**Kjeldahl Nitrogen**	**K**	**NO_3-NO_2**	**F**	**Si**	**TAL**	**Ca**	**Total P**	**PO_4**	**Na**	**SO_4**	**Cl^-**	**Mg**	**Hardness**
12/12/2005															
12/01/2006															
13/02/2006	No flow, sample not taken														
13/03/2006	No flow, sample not taken														
10/04/2006	<0.04	0.724	7.17	0.083	0.339	6.22	138	22.2	0.156	0.142	16.3	6.3	11.4	16.9	125
22/05/2006	No flow, sample not taken														
21/06/2006	No flow, sample not taken														

APPENDIX C

Discharged Effluent Quality Results

S5 – WITKLIP DELMAS SEWAGE WORKS EFFLUENT DISCHARGE

Sampling Date	Physical Constituents				Microbiological Constituents		
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Faecal Streptococci (count/100mL)
12/12/2005	8.13	105	685		461 100	3 100	
12/01/2006	8.11	105	685		173 287	9 222	
13/02/2006	7.50	86	557		120 331	7 308	
13/03/2006	7.14	103	670		27 550	1 610	
10/04/2006	8.03	100	650	2.32	7 746	882	3000
22/05/2006		100	651	5.23	16 328	406	153
21/06/2006				3.87	31 061	7 270	1 900

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005	17.7		111	0.15	0.184	9.71	348	35.5		9.08	62.3	42.2	78.3	26.4	197
12/01/2006	14.2	16.2	108	4.15	0.162	8.88	268	29.9	12.2	10.05	55.7	38.0	70.8	21.3	162
13/02/2006	<0.04	1.6	110	14.22		8.88	217	30.2	14.0	0.49	50.9	26.0	62.7	24.0	174
13/03/2006	9.1	27.7	109	17.88	0.175	11.65	199	38.6		14.91	53.1	31.4	67.5	27.7	228
10/04/2006	17.4	20.4	112	<0.08	0.340	9.81	349	39.5	9.9	0.49	60.0	41.8	80.6	27.1	210
22/05/2006	20.4	31.4	113	0.14	0.206	9.09	376	35.3	9.5	9.21	57.6	37.1	65.3	23.9	187
21/06/2006															

S11 – MIDDELBURG BOTKLENG EXTENSION SEWATE TREATMENT WORKS (STW) EFFLUENT DISCHARGE TO BRONKHORSTSPRUIT						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
12/12/2005					1 596	104
12/01/2006					2 413 500	21 950
13/02/2006	8.03	50	319		2 413 500	21 950
13/03/2006	7.38	57	373		8 704	656
10/04/2006	7.77	54	352	1.49	<1	<1
22/05/2006	7.64	54	350	4.54	5 470	<1
21/06/2006	8.08	52	337	3.01	82	20

Major Inorganic Compounds (mg/L)															
Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
12/12/2005															
12/01/2006															
13/02/2006	0.07	0.655	8.29	6.60	0.337	7.47	113	26.3	3.44	0.49	31.6	39.3	35.6	20.7	151
13/03/2006	<0.04	1.114	9.85	6.03	0.380	8.48	139	34.0	4.02	3.36	39.2	40.8	43.5	25.4	204
10/04/2006	0.20	0.598	9.99	0.63	0.404	7.93	112	32.7	3.81	3.61	35.1	37.0	44.1	22.5	174
22/05/2006	0.19	1.244	8.60	16.85	0.456	7.62	82	26.7	4.83	4.11	35.8	25.6	41.0	20.1	150
21/06/2006	0.07	0.891	8.03	12.40	0.530	8.33	103	28.5	5.08	4.05	32.0	33.9	39.2	21.8	161

APPENDIX D

Groundwater Quality Results

A3 – PRODUCTION BOREHOLE IN A-FIELD						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					3 106	727
12/12/2005	8.36	67	433	<1	3 466	980
16/01/2006	Sample not taken					
14/02/2006					201	201
13/03/2006					548	75
11/04/2006					201	27
10/05/2006	8.55	61	398		201	36
20/06/2006	8.08	59	380		130	19

Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K (mg/L)	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	1.47	46.2	0.234	0.153	7.39	227	41.5	3.50	36.0	20.5	48.9	24.0	202
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	0.24	27.5	0.965	0.141	9.00	203	32.4	0.50	28.5	17.5	37.9	23.8	179
20/06/2006	<0.04	28.4	1.350	0.152	7.03	215	38.2	1.26	27.5	21.7	33.0	23.5	192

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.453	0.02	<0.011	0.072	See note	See note	See note
12/01/2006	<0.005	<0.012	0.001	0.012	<0.011	<0.002	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.001	<0.002	0.002	0.003	<0.004	0.001	<0.004
20/06/2006	0.04	<0.012	0.023	<0.002	0.05	0.069	<0.004	0.001	<0.004

Note: Concentration mot detected with analytical method use, method not sensitive enough

A4 – PRODUCTION BOREHOLE IN A-FIELD						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					38	4
12/12/2005	8.36	30	192	<1	10	2
16/01/2006					185	84
14/02/2006					74	11
13/03/2006					>24 192	5
11/04/2006					24	3
10/05/2006	8.37	31	201		2	<1
20/06/2006	7.97	30	194		<1	<1

Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na (mg/L)	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	<0.04	5.11	1.34	0.123	5.90	112	24.4	0.101	8.5	<4	11.6	14.0	118
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	<0.04	7.06	1.34	<0.1	6.37	114	22.5	0.128	9.7	<4	14.2	15.5	120
20/06/2006	<0.04	6.10	1.39	0.274	6.11	121	23.6	0.093	9.1	6.2	11.9	14.6	119

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.001	<0.008	<0.011	<0.003	See note	See note	See note
12/01/2006	<0.005	<0.012	0.001	0.016	<0.011	<0.003	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.001	<0.012	0.001	0.008	<0.004	0.001	<0.004
20/06/2006	0.002	<0.012	0.001	<0.012	0.013	0.074	0.074	0.001	<0.004

Note: Concentration mot detected with analytical method use, method not sensitive enough

A7 – PRODUCTION BOREHOLE IN A-FIELD						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					2 407	198
12/12/2005	8.12	56	364	1.1	2 559	214
16/01/2006					2 100	417
14/02/2006					402	330
13/03/2006					461	59
11/04/2006					478	48
10/05/2006	8.50	48	312		218	24
20/06/2006	8.12	44	286		83	8

Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	0.71	31.65	0.89	0.131	7.23	193	38.2	2.19	25.1	14.6	33.3	22.1	186
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	<0.04	7.51	2.82	0.139	8.59	157	32.3	0.34	13.8	17.6	21.9	22.3	172
20/06/2006	<0.04	9.91	3.27	<0.1	7.15	171	39.8	0.357	12.4	14.0	19.0	22.4	192

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.041	<0.008	<0.011	<0.003	See note	See note	See note
12/01/2006	<0.005	0.097	0.001	0.013	<0.011	0.71	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.013	<0.012	0.001	0.003	<0.004	0.001	<0.004
20/06/2006	0.007	0.089	0.002	<0.012	0.001	0.007	<0.004	0.001	<0.004

Note: Concentration mot detected with analytical method use, method not sensitive enough

BOT3 – PRODUCTION BOREHOLE IN B-FIELD					
Sampling Date	Physical Constituents			Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					
12/12/2005				<1	<1
17/01/2006				<1	<1
14/02/2006				58	<1
13/03/2006				3	<1
11/04/2006				9	<1
10/05/2006	7.75	51	331	<1	<1
20/06/2006	8.17	46	302	<1	<1

Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005													
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	0.210	4.86	0.094	0.324	7.67	167	32.6	0.262	15.6	29.6	23.7	27.2	193
20/06/2006	0.155	6.68	0.126	0.264	7.65	174	34.9	0.271	13.9	32.2	19.2	26.3	195

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.001	<0.008	<0.011	<0.003	See note	See note	See note
12/01/2006									
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.093	<0.012	0.001	0.016	0.027	0.001	<0.004
20/06/2006	0.003	0.019	0.072	<0.012	0.003	0.041	0.037	0.001	<0.004

Note: Concentration mot detected with analytical method use, method not sensitive enough

BOT4 – PRODUCTION BOREHOLE IN B-FIELD						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					<1	<1
12/12/2005	8.24	43	278	<1	<1	<1
16/01/2006					<1	<1
14/02/2006					<1	<1
13/03/2006					6	<1
11/04/2006					<1	<1
10/05/2006	Sample not taken, pump not working					
20/06/2006	8.15	44	284		<1	<1

Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	0.044	2.08	0.086	0.266	7.56	152	33.1	0.029	9.0	34.4	15.5	26.2	190
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	Sample not taken, pump not working												
20/06/2006	0.065	2.89	0.096	0.232	7.52	166	34.4	0.09	9.2	36.3	16.5	28.6	204

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	0.02	0.029	0.024	<0.011	<0.003	See note	See note	See note
12/01/2006	<0.005	<0.012	0.001	0.009	<0.011	<0.003	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006									
20/06/2006	0.003	0.018	0.079	<0.012	0.016	0.069	0.049	0.001	<0.004

Note: Concentration mot detected with analytical method use, method not sensitive enough

BOT5 – PRODUCTION BOREHOLE IN B-FIELD

Sampling Date	Physical Constituents: pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Microbiological Constituents: Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					<1	<1
12/12/2005	8.16	42	271	<1	<1	<1
17/01/2006					<1	<1
14/02/2006					<1	<1
13/03/2006					<1	<1
11/04/2006					<1	<1
10/05/2006	8.02	39	255		<1	<1
20/06/2006	8.43	41	268		9	<1

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	0.06	1.45	<0.08	0.241	7.09	133	32.1	0.023	8.0	43.3	16.2	26.4	189
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	<0.04	1.26	<0.08	0.266	7.39	132	29.7	0.033	9.0	39.4	13.2	25.1	178
20/06/2006	<0.04	1.50	<0.08	0.246	7.24	141	32.4	0.014	7.5	45.5	15.7	27.1	192

Trace Metals (mg/L)

Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.001	<0.008	<0.011	<0.003	See note	See note	See note
12/01/2006	<0.005	<0.012	0.001	0.015	<0.011	<0.003	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006									
20/06/2006	0.011	<0.012	0.001	<0.008	<0.011	0.029	See note	See note	See note

Note: Concentration mot detected with analytical method use, method not sensitive enough

BOT6 – PRODUCTION BOREHOLE IN B-FIELD						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005						
12/12/2005	8.32	26	166	<1	<12	<1
17/01/2006					<1	<1
14/02/2006					<1	<1
13/03/2006				<1	<1	<1
11/04/2006				<1	<1	<1
10/05/2006	8.31	30	260	<1	<1	<1
20/06/2006	8.26	25	164	<1	<1	<1

Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	<0.04	1.16	0.147	0.437	7.44	106	20.1	0.05	9.1	9.1	6.2	12.0	99.8
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	<0.04	0.88	0.098	0.536	8.35	106	19.3	0.018	10.4	10.0	6.2	14.3	107
20/06/2006	<0.04	1.10	0.151	0.511	7.54	107	19.3	<0.011	9.1	12.8	8.0	13.2	103

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005									
12/01/2006									
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.001	<0.012	0.001	0.032	<0.004	0.001	<0.004
20/06/2006	0.003	<0.012	0.006	<0.012	0.001	0.013	<0.004	0.001	<0.004

BOT8 – PRODUCTION BOREHOLE IN B-FIELD

Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005						
12/12/2005	8.26	29	186	<1		
17/01/2006					<1	<1
14/02/2006					<1	<1
13/03/2006					<1	<1
11/04/2006					1	<1
10/05/2006	7.87	32	205		<1	<1
20/06/2006	8.01	29	189		<1	<1

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	0.114	1.17	<0.08	1.69	6.66	111	18.0	0.053	27.2	4.6	12.4	8.5	80
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	<0.04	1.46	<0.08	1.65	6.57	109	20.5	0.021	30.6	8.2	16.9	8.8	88
20/06/2006	0.097	1.12	0.086	1.61	7.34	120	16.0	<0.011	28.3	5.6	13.4	8.9	76

Trace Metals (mg/L)

Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005									
12/01/2006									
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006									
20/06/2006	0.002	<0.012	0.053	<0.012	0.038	0.570	<0.004	0.001	<0.004

C1 – PRODUCTION BOREHOLE IN C-FIELD						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					1	<1
12/12/2005	8.35	33	271	<1	3	<1
17/01/2006					<1	<1
14/02/2006					<1	<1
13/03/2006				<1	1	<1
11/04/2006				<1	<1	<1
10/05/2006	8.29	36	231	<1	1	<1
20/06/2006	8.51	32	205	<1	1	<1

Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	<0.04	1.46	0.188	0.114	7.61	141	26.1	0.012	6.7	10.1	0.3	21.4	153
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	<0.04	1.54	0.131	0.105	8.14	140	22.8	0.02	6.2	13.5	5.1	21.5	145
20/06/2006	<0.04	1.33	0.190	0.181	7.77	145	25.1	<0.011	5.9	11.2	6.4	21.1	150

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	0.047	0.019	0.029	<0.011	<0.003	See note	See note	See note
12/01/2006	<0.005	<0.012	0.001	0.07	<0.011	0.878	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.005	<0.012	0.003	0.012	<0.004	0.001	<0.004
20/06/2006	0.003	0.021	0.012	<0.012	0.012	0.033	<0.004	0.001	<0.004

Note: Concentration mot detected with analytical method use, method not sensitive enough

C2 – PRODUCTION BOREHOLE IN C-FIELD						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					<1	<1
12/12/2005	8.34	48	309	2	<1	<1
17/01/2006						
14/02/2006					3	<1
13/03/2006				3	3	<1
11/04/2006				11	11	<1
10/05/2006	8.39	46	304	36	36	<1
20/06/2006	8.40	42	276	<1	1	<1

Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4 (mg/L)	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	0.04	1.79	<0.08	0.116	6.94	158	37.9	0.017	11.9	46.4	20.7	29.7	217
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	<0.04	1.82	<0.08	0.126	7.35	149	30.8	0.027	12.2	39.5	18.9	28.3	193
20/06/2006	<0.04	1.62	<0.08	0.130	7.21	155	32.6	<0.011	11.3	37.4	16.5	26.4	190

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.001	<0.008	<0.011	<0.003	0.318	See note	See note
12/01/2006	<0.005	0.057	0.001	0.02	<0.011	<0.003	0.283	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.001	<0.012	0.001	0.004	0.219	0.001	<0.004
20/06/2006	0.002	<0.012	0.001	<0.012	0.004	0.117	0.231	0.001	<0.004

Note: Concentration mot detected with analytical method use, method not sensitive enough

C3 – PRODUCTION BOREHOLE IN C-FIELD

Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					1	<1
12/12/2005	8.42	61	395	<1	<1	<1
17/01/2006					<1	<1
23/02/2006					<1	<1
13/03/2006					<1	<1
11/04/2006					<1	<1
10/05/2006	8.54	67	432		<1	<1
20/06/2006	Sample not taken, pump not working					

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	0.055	1.97	0.41	0.214	7.59	180	46.8	0.077	29.2	44.8	53.8	32.1	249
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	0.082	4.08	<0.08	0.188	8.20	192	41.6	0.026	28.5	56.4	60.8	36.3	254
20/06/2006	Sample not taken, pump not working												

Trace Metals (mg/L)

Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.001	<0.008	<0.011	0.031	See note	See note	See note
12/01/2006	<0.005	<0.012	0.001	0.028	<0.011	<0.003	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.001	<0.012	0.001	0.004	0.095	0.001	<0.004
20/06/2006	Sample not taken, pump not working								

Note: Concentration mot detected with analytical method use, method not sensitive enough

C4 – PRODUCTION BOREHOLE IN C-FIELD

Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005						
12/12/2005	8.17	66	426	<1		
17/01/2006						
14/02/2006					62	<1
13/03/2006				49	49	<1
11/04/2006				201	201	<1
10/05/2006				<1	1	<1
20/06/2006	8.22	64	415	<1	<1	<1

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	0.093	2.37	0.129	0.209	7.4	185	49.1	0.023	31.6	56.0	56.9	34.4	264
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006													
20/06/2006	0.045	1.88	0.748	0.177	8.0	205	50.3	<0.011	23.8	47.3	45.0	35.6	272

Trace Metals (mg/L)

Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.001	0.028	<0.011	<0.003	See note	See note	See note
12/01/2006	<0.005	<0.012	0.001	<0.008	<0.011	0.093	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.001	<0.012	0.004	0.021	0.057	0.001	<0.004
20/06/2006	0.006	0.035	0.039	<0.012	0.045	0.081	0.073	0.001	<0.004

Note: Concentration mot detected with analytical method use, method not sensitive enough

D5 – PRODUCTION BOREHOLE IN D-FIELD

Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					<1	<1
12/12/2005	8.23	57	371	<1	10	2
17/01/2006					<1	<1
14/02/2006					5	<1
13/03/2006				<1	<1	<1
11/04/2006				11	11	<1
10/05/2006	8.52	46	296	<1	<1	<1
20/06/2006	8.30	57	370	<1	<1	<1

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4 (mg/L)	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	<0.04	2.00	1.54	0.107	10.3	217	46.7	<0.011	10.0	33.7	22.4	39.9	281
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	0.04	1.36	0.82	0.207	8.71	154	32.6	0.026	8.7	31.0	17.3	26.1	254
20/06/2006	<0.04	1.88	1.28	0.126	9.96	233	45.2	<0.011	8.0	41.7	17.1	43.0	290

Trace Metals (mg/L)

Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.001	0.016	0.025	0.425	See note	See note	See note
12/01/2006	<0.005	0.047	0.001	0.023	<0.011	<0.003	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.001	<0.012	0.001	0.007	0.081	0.001	<0.004
20/06/2006									

Note: Concentration mot detected with analytical method use, method not sensitive enough

D10 – PRODUCTION BOREHOLE IN D-FIELD						
Sampling Date	Physical Constituents				Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
07/12/2005					<1	<1
12/12/2005	8.66	51	330	<1	<1	<1
17/01/2006					<1	<1
14/02/2006					<1	<1
13/03/2006					2	<1
11/04/2006					8	<1
10/05/2006	8.55	55	367		1	<1
20/06/2006	8.55	53	344		2	<1

Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F	Si	TAL	Ca	PO_4	Na	SO_4	Cl^-	Mg	Hardness
07/12/2005													
21/12/2005	<0.04	1.37	5.70	0.109	11.1	208	57.0	0.013	6.2	11.6	12.4	28.3	259
12/01/2006													
14/02/2006													
13/03/2006													
11/04/2006													
10/05/2006	<0.04	1.14	4.87	<0.1	11.7	217	48.7	0.016	5.9	22.2	13.7	30.5	247
20/06/2006	<0.04	1.23	4.51	0.115	11.3	224	59.8	<0.011	6.5	17.4	13.4	30.6	273

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
07/12/2005									
21/12/2005	<0.005	<0.012	0.001	<0.008	<0.011	<0.003	See note	See note	See note
12/01/2006	<0.005	0.328	0.001	0.017	<0.011	<0.003	See note	See note	See note
14/02/2006									
13/03/2006									
11/04/2006									
10/05/2006	0.001	<0.012	0.001	<0.012	0.001	0.002	<0.004	0.001	<0.004
20/06/2006	0.005	<0.012	0.015	<0.012	0.006	0.019	<0.004	0.001	<0.004

Note: Concentration mot detected with analytical method use, method not sensitive enough

DETAILED MICROBIOLOGICAL AND CHEMICAL CONSTITUENTS FOR RURAL WATER SUPPLY BOREHOLES UNDER THE JURISDICTION OF DELMAS MUNICIPALITY

ARBOR

Sampling Date	Physical Constituents			Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
27/02/2006					
11/05/2006	6.6	66	454	4 405	9
27/06/2006	6.6	54	370	74	<1

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	Kjeldahl Nitrogen	TAL	K	NO_3-NO_2	F	Si	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
14/02/2006															
11/05/2006	<0.04	<0.05	26	6.8	7.2	<0.1	10.3	60	<0.010	0.011	11	268	7	37	302
27/06/2006	<0.04	0.10	22	7.4	6.6	<0.1	12.6	49	0.045	0.014	13	209	6	30	246

Trace Metals (mg/L)

Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
14/02/2006									
11/05/2006	0.005	0.022	0.048	0.017	0.012	0.032		<0.001	<0.004
27/06/2006	0.006	0.027	0.097	<0.012	0.003	0.128	<0.004	<0.001	0.004

ARGENT – 5 METRES FROM THE GATE OF OKHELA PRIMARY SCHOOL					
Sampling Date	Physical Constituents			Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
27/02/2006				88	<1
11/05/2006	6.7	7	46	210	<1
27/06/2006	7.4	7	38	16	<1

Major Inorganic Compounds (mg/L)															
Sampling Date	NH_4-N	Kjeldahl Nitrogen	TAL	K	NO_3-NO_2	F	Si	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
14/02/2006															
11/05/2006	<0.04	0.09	12	1.9	3.05	<0.1	5.4	2	<0.010	0.017	3	<4	5	2	13
27/06/2006	<0.04	0.11	<8	1.6	3.16	<0.1	6.1	3	0.025	0.014	3	<4	4	2	16

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
14/02/2006									
11/05/2006	0.004	0.017	0.017	<0.012	0.002	0.032		<0.001	<0.004
27/06/2006	0.005	0.070	0.055	<0.012	0.018	0.224	<0.004	<0.001	<0.004

DRYDEN – ABOUT 10 METRES APART FROM DRYDEN 2 IN THE SETTLEMENT					
Sampling Date	Physical Constituents			Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
27/02/2006				10	<1
11/05/2006	6.6	26	137	<1	<1
27/06/2006	6.3	24	139	<1	<1

Major Inorganic Compounds (mg/L)															
Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
14/02/2006															
11/05/2006	0.05	0.10	1.6	11.55	<0.1	5.1	18	12	<0.010	0.017	6	13	20	11	75
27/06/2006	0.09	0.16	1.3	11.02	<0.1	5.3	19	12	0.018	0.011	6	15	20	12	79

Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
14/02/2006									
11/05/2006	0.005	0.056	0.086	<0.012	0.012	3.533		<0.001	<0.004
27/06/2006	0.005	0.070	0.055	<0.012	0.018	0.224	<0.004	<0.001	<0.004

BAMBISANA – MODDERFONTEIN FARM WITHIN BAMBISANA PRIMARY SCHOOL

Sampling Date	Physical Constituents			Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
27/02/2006				19	<1
11/05/2006	8.4	63	399	<1	<1
27/06/2006	8.6	55	391	4	<1

Major Inorganic Compounds (mg/L)

Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
14/02/2006															
11/05/2006	0.15	0.14	5.4	0.11	0.5	15.1	169	54	0.029	0.022	22	9	79	23	230
27/06/2006	0.07	0.15	4.1	0.20	0.5	17.3	162	54	0.029	0.017	24	9	79	22	225

Trace Metals (mg/L)

Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
14/02/2006									
11/05/2006	0.006	0.027	0.097	<0.012	0.003	0.128		<0.001	0.004
27/06/2006	0.006	0.027	0.097	<0.012	0.003	0.128	<0.004	<0.001	0.004

WAAIKRAAL – AT THE VICINITY OF THE SETTLEMENT

Sampling Date	Physical Constituents			Microbiological Constituents	
	pH (pH units)	EC (mS/m)	TDS (mg/L)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
27/02/2006				14	1
11/05/2006	8.3	42	265	36	<1
27/06/2006	8.3	69	519	61	<1

Major Inorganic Compounds

Sampling Date	NH_4-N	Kjeldahl Nitrogen	K	NO_3-NO_2	F	Si	TAL	Ca	Total P	PO_4	Na	SO_4	Cl^-	Mg	Hardness
14/02/2006															
11/05/2006	<0.04	0.10	0.4	10.3	0.1	18.2	185	61	<0.010	0.021	15	39	69	43	329
27/06/2006	<0.04	0.07	0.4	6.9	0.1	20.2	194	67	0.031	0.015	17	34	88	45	353

Trace Metals (mg/L)

Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
14/02/2006									
11/05/2006	0.004	0.017	0.017	<0.012	0.002	0.032		<0.001	<0.004
27/06/2006	0.006	0.056	0.086	<0.012	0.012	3.533	<0.004	<0.001	<0.004

DROOGENFONTEIN – BETWEEN GUM-TREES AND THE SETLLEMENT					
Sampling Date	**Physical Constituents**			**Microbiological Constituents**	
	pH (pH units)	**EC (mS/m)**	**TDS (mg/L)**	**Total Coliforms (MPN/100mL)**	***E. coli* (MPN/100mL)**
27/02/2006				866	5
11/05/2006	7.1	42	265	21	<1
27/06/2006	7.1	39	259	326	<1

Major Inorganic Compounds (mg/L)															
Sampling Date	**NH_4-N**	**Kjeldahl Nitrogen**	**K**	**NO_3-NO_2**	**F**	**Si**	**TAL**	**Ca**	**Total P**	**PO_4(**	**Na**	**SO_4**	**Cl^-**	**Mg**	**Hardness**
14/02/2006															
11/05/2006	<0.04	0.07	3.4	17.4	0.2	28.6	75	31	0.020	0.012	12	5	30	15	139
27/06/2006	<0.04	0.10	3.8	16.8	0.1	33.0	69	33	0.020	0.012	13	7	28	17	152

Trace Metals (mg/L)									
Sampling Date	**Chromium**	**Iron**	**Manganese**	**Nickel**	**Copper**	**Zinc**	**Arsenic**	**Cadmium**	**Lead**
14/02/2006									
11/05/2006	0.018	0.023	0.001	<0.012	0.009	0.109		<0.001	0.004
27/06/2006	0.005	0.022	0.048	0.017	0.012	0.032	<0.004	<0.001	<0.004

APPENDIX E

Reticulation System Water Quality Results

M4 – TAP DELMAS WEST, MARITZ LAAN HOUSE NUMBER 4								
Sampling Date	Physical Constituents				Microbiological Constituents			
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Residual Cl_2 (mg/L)	Standard Plate Count (MPN/1mL)
15/11/2005					<1	<1	0.6	0
22/11/2005					<1	<1	0.5	1
29/11/2005	8.29	59	386					
06/12/2005					<1	<1	0.7	0
14/12/2005					<1	<1	0.4	0
20/12/2005					<1	<1	0.4	5
31/01/2006	8.04	43	276		<1	<1	0.3	0
07/02/2006	8.26	50	326		<1	<1	0.2	33
28/02/2006								
07/03/2006					<1	<1	0.1	7
14/03/2006					<1	<1	0.4	1
22/03/2006				<1	<1	<1	0.7	1
28/03/2006	8.50	38	247	<1	<1	<1	1.5	1
05/04/2006				<1	<1	<1	0.3	0
11/04/2006				<1	1	<1	1.9	0
18/04/2006				<1	<1	<1	>3.5	1
24/04/2006	7.98	56	361	<1	<1	<1	1.8	0
02/05/2006				<1	<1	<1	1.8	1
09/05/2006				<1	<1	<1	1.0	0
16/05/2006				<1	<1	<1	1.5	0
23/05/2006				<1	<1	<1	2.0	3
30/05/2006	8.19	54	354	<1	<1	<1	2.0	2
06/06/2006				<1	<1	<1	1.5	6
13/06/2006				1.3	<1	<1	2.3	2
20/06/2006				<1	<1	<1	2.0	0
27/06/2006	8.30	55	356	<1	<1	<1	2.8	1

M4 – TAP DELMAS WEST, MARITZ LAAN HOUSE NUMBER 4													
Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F^-	Silicon	TAL	Calcium	PO_4	Na	SO_4	Cl^-	Mg	Hardness
29/11/2006	<0.04	2.21	0.48	0.15	6.80	175	43.6	0.183	23.0	42.9	42.4	33.1	245
31/01/2006	0.16	2.56	0.33	0.17	6.85	148	32.7	<0.011	13.9	24.7	21.7	21.9	172
28/02/2006	<0.04	2.25	0.57	0.22	7.50	179	40.9	0.024	14.5	32.6	25.1	28.0	217
28/03/2006	<0.04	1.31	0.42	0.17	8.50	152	30.4	0.019	7.5	13.4	8.5	21.8	166
24/04/2006	<0.04	1.41	4.08	0.11	10.5	210	57.4	0.021	7.8	24.1	15.6	36.8	282
30/05/2006	<0.04	0.30	4.52	0.12	10.7	216	60.2	0.017	7.0	28.0	17.0	36.3	300
27/06/2006	<0.04	1.82	3.58	0.14	10.5	230	51.1	0.060	7.6	51.5	19.0	33.9	267

M4 – TAP DELMAS WEST, MARITZ LAAN HOUSE NUMBER 4									
Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
24/04/2006	0.01	0.066	0.023	<0.012	0.003	0.008	0.023	0.001	<0.004
30/05/2006	0.01	<0.012	0.001	<0.012	0.004	0.008	0.011	0.002	<0.004
27/06/2006	0.01	0.038	0.001	<0.012	0.005	0.011	0.036	0.003	<0.004

T4809_B4 – TAP BOTLENG EXTENSION 4 STAND NUMBER 4809 (RDP HOUSE)								
Sampling Date	Physical Constituents				Microbiological Constituents			
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Residual Cl_2 (mg/L)	Standard Plate Count (MPN/1mL)
15/11/2005					<1	<1	0.1	31
22/11/2005					<1	<1	0.3	6
29/11/2005	8.36	47	302					
06/12/2005					<1	<1	0.0	21
14/12/2005					<1	<1	0.4	44
20/12/2005					<1	<1	0.4	0
31/01/2006	8.28	47	306		<1	<1	2.0	0
07/02/2006					<1	<1	0.7	6
28/02/2006	8.41	47	303					
07/03/2006					<1	<1	0.3	1
14/03/2006					<1	<1	0.5	1
22/03/2006				<1	<1	<1	0.4	0
28/03/2006	8.48	48	311	<1	<1	<1	0.2	1
05/04/2006				<1	<1	<1	0.5	0
11/04/2006				1.09	Sample rejected by lab		0.4	Sample rejected
18/04/2006				<1	<1	<1	0.4	0
24/04/2006	7.95	43	281	<1	<1	<1	0.2	4
02/05/2006				<1	<1	<1	0.1	103
09/05/2006				1.03	<1	<1	0.8	1
16/05/2006				1.08	<1	<1	0.8	0
23/05/2006				<1	<1	<1	1.2	3
30/05/2006	8.14	42	272	<1	<1	<1	0.4	0
06/06/2006				<1	<1	<1	0.6	2
13/06/2006				<1	<1	<1	0.6	0
20/06/2006				<1	<1	<1	1.0	1
27/06/2006	8.17	43	280	<1	<1	<1	0.1	3

T4809_B4 – TAP BOTLENG EXTENSION 4 STAND NUMBER 4809 (RDP HOUSE)													
Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F^-	Silicon	TAL	Calcium	PO_4	Na	SO_4	Cl^-	Mg	Hardness
29/11/2006	0.07	5.90	0.09	0.49	8.00	158	31.4	0.114	17.3	30.2	21.8	25.5	183
31/01/2006	<0.04	5.32	0.12	0.44	7.63	164	33.6	0.167	15.8	35.2	23.8	27.2	196
28/02/2006	<0.04	6.71	0.09	0.65	7.24	161	32.3	0.236	18.8	28.2	25.5	24.0	179
28/03/2006	0.05	6.50	0.09	0.70	7.90	159	31.0	0.216	18.9	25.7	23.3	23.5	174
24/04/2006	0.11	5.91	0.11	0.58	7.03	149	33.7	0.174	18.6	25.6	19.5	22.5	177
30/05/2006	<0.04	4.95	<0.08	0.71	7.34	155	33.3	0.162	19.1	28.3	22.0	23.3	179
27/06/2006	<0.04	5.28	0.07	0.64	7.44	156	32.4	0.194	20.2	27.7	24.8	22.4	173

T4809_B4 – TAP BOTLENG EXTENSION 4 STAND NUMBER 4809 (RDP HOUSE)									
Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
24/04/2006	0.009	0.037	0.023	<0.012	0.002	0.011	0.017	0.001	<0.004
30/05/2006	0.001	<0.012	0.001	<0.012	0.005	0.007	0.020	0.001	<0.004
27/06/2006	0.002	<0.012	0.002	<0.012	0.003	0.013	0.026	0.001	<0.004

BN_5092 – TAP BOTLENG EXTENSION 4 STAND NUMBER 5092 (RDP HOUSE)								
Sampling Date	**Physical Constituents**				**Microbiological Constituents**			
	pH (pH units)	**EC (mS/m)**	**TDS (mg/L)**	**TURB (NTU)**	**Total Coliforms (MPN/100mL)**	***E. coli* (MPN/100mL)**	**Residual Cl_2 (mg/L)**	**Standard Plate Count (MPN/1mL)**
15/11/2005					<1	<1	0.1	31
22/11/2005					<1	<1	0.3	6
29/11/2005	8.36	47	302					
06/12/2005					<1	<1	0.0	21
14/12/2005					<1	<1	0.4	44
20/12/2005					<1	<1	0.4	0
31/01/2006	8.28	47	306		<1	<1	2.0	0
07/02/2006					<1	<1	0.7	6
28/02/2006	8.41	47	303					
07/03/2006					<1	<1	0.3	1
14/03/2006					<1	<1	0.5	1
22/03/2006				<1	<1	<1	0.4	0
28/03/2006	8.49	48	311	<1	<1	<1	0.2	1
05/04/2006				<1	<1	<1	0.5	0
11/04/2006				1.09	Sample rejected by lab		0.4	Sample rejected
18/04/2006				<1	<1	<1	0.4	0
24/04/2006	8.22	38	245	<1	<1	<1	0.2	4
02/05/2006				<1	<1	<1	0.1	103
09/05/2006				1.03	<1	<1	0.8	1
16/05/2006				1.08	<1	<1	0.8	0
23/05/2006				<1	<1	<1	1.2	3
30/05/2006	8.28	40	260	<1	<1	<1	0.4	0
06/06/2006				<1	<1	<1	0.6	2
13/06/2006				<1	<1	<1	0.6	0
20/06/2006				1.06	<1	<1	1.0	1
27/06/2006	7.76	43	281	<1	<1	<1	0.1	3

BN_5092 – TAP BOTLENG EXTENSION 4 STAND NUMBER 5092 (RDP HOUSE)													
Major Inorganic Compounds (mg/L)													
Sampling Date	**NH_4-N**	**K**	**NO_3-NO_2**	**F^-**	**Silicon**	**TAL**	**Calcium**	**PO_4**	**Na**	**SO_4**	**Cl^-**	**Mg**	**Hardness**
29/11/2006	0.07	5.90	0.09	0.489	8.00	158	31.4	0.114	17.3	30.2	21.8	25.5	183
31/01/2006	<0.04	5.32	0.12	0.441	7.63	164	33.6	0.167	15.7	35.2	23.8	27.2	196
28/02/2006	<0.04	6.71	0.09	0.648	7.24	161	32.3	0.236	18.8	28.2	25.5	24.0	179
28/03/2006	0.05	6.50	0.09	0.704	7.90	159	31.0	0.216	18.9	25.7	23.3	23.5	174
24/04/2006	<0.04	3.82	<0.08	0.411	7.20	128	30.8	0.073	12.9	26.5	15.2	21.7	166
30/05/2006	0.42	3.61	0.11	0.642	6.91	136	30.3	0.113	16.0	29.3	20.1	21.4	164
27/06/2006	<0.04	3.02	0.95	0.418	8.17	146	34.0	0.098	13.5	34.1	19.8	24.9	187

BN_5092 – TAP BOTLENG EXTENSION 4 STAND NUMBER 5092 (RDP HOUSE)									
Trace Metals (mg/L)									
Sampling Date	**Chromium**	**Iron**	**Manganese**	**Nickel**	**Copper**	**Zinc**	**Arsenic**	**Cadmium**	**Lead**
24/04/2006	0.010	0.042	0.005	<0.012	0.004	0.011	0.022	0.001	<0.004
30/05/2006	0.007	<0.012	0.001	0.035	<0.011	<0.003	<0.205	<0.010	<0.107
27/06/2006	0.003	<0.012	0.001	<0.012	0.002	0.006	0.035	0.001	<0.004

B_LS – BOTLENG MANDELA INFORMAL SETTLEMENT SECTION F LEKALAKALA STREET (COMMUNAL TAP)								
Sampling Date	Physical Constituents				Microbiological Constituents			
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Residual Cl_2 (mg/L)	Standard Plate Count (MPN/1mL)
15/11/2005					<1	<1	0.2	3
22/11/2005					2	<1	0.2	13
29/11/2005								
06/12/2005					<1	<1	0.2	7
14/12/2005					<1	<1	0.5	12
20/12/2005					<1	<1	0.4	6
31/01/2006	8.01	43	279		<1	<1	1.0	0
07/02/2006	8.30	51	328		<1	<1	0.4	1
28/02/2006								
07/03/2006					<1	<1	0.3	16
14/03/2006					<1	<1	0.3	1
22/03/2006				3.47	<1	<1	0.3	1
28/03/2006	8.09	42	270	1.73	<1	<1	0.6	0
05/04/2006				1.67	<1	<1	0.9	0
11/04/2006				1.98	<1	<1	2.8	0
18/04/2006				<1	<1	<1	0.7	2
24/04/2006	8.01	52	339	<1	<1	<1	1.1	0
02/05/2006				<1	<1	<1	0.0	0
09/05/2006				<1	<1	<1	2.8	0
16/05/2006				<1	<1	<1	0.5	0
23/05/2006				1.56	<1	<1	1.8	0
30/05/2006	8.09	45	293	<1	3	<1	0.3	1
06/06/2006				<1	<1	<1	0.6	4
13/06/2006				<1	<1	<1	0.7	1
20/06/2006				<1	<1	<1	0.7	1
27/06/2006	8.20	50	326	<1	<1	<1	0.1	0

B_LS – BOTLENG MANDELA INFORMAL SETTLEMENT SECTION F LEKALAKALA STREET (COMMUNAL TAP)													
Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F^-	Silicon	TAL	Calcium	PO_4	Na	SO_4	Cl^-	Mg	Hardness
29/11/2006													
31/01/2006	<0.04	13.5	0.96	0.185	7.04	151	29.7	0.645	15.5	17.9	24.5	17.8	148
28/02/2006	<0.04	18.1	1.29	0.204	7.23	180	37.1	0.814	19.3	16.3	32.3	22.6	186
28/03/2006	0.04	10.0	0.95	0.292	8.03	140	30.1	0.370	147.6	16.3	18.7	18.3	151
24/04/2006	<0.04	1.6	0.54	0.218	7.54	153	35.4	0.054	18.4	23.0	34.9	27.8	203
30/05/2006	<0.04	6.4	0.76	0.164	7.42	166	36.8	0.189	15.6	27.5	24.4	25.0	195
27/06/2006	<0.04	2.6	0.47	0.175	7.70	165	38.2	0.092	14.8	60.3	29.8	29.7	218

B_LS – BOTLENG MANDELA INFORMAL SETTLEMENT SECTION F LEKALAKALA STREET (COMMUNAL TAP)									
Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
24/04/2006	0.009	0.037	0.001	<0.012	0.001	0.007	0.041	0.001	<0.004
30/05/2006	0.001	<0.012	0.001	<0.012	0.003	0.005	0.034	0.001	<0.004
27/06/2006	0.004	<0.012	0.001	<0.012	0.003	0.008	0.073	0.001	<0.004

DE_37 – DELPARK EXTENSION 1 CARNATION STREET HOUSE NUMBER 37								
Sampling Date	Physical Constituents				Microbiological Constituents			
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Residual Cl_2 (mg/L)	Standard Plate Count (MPN/1mL)
15/11/2005					<1	<1	0.2	10
22/11/2005					<1	<1	0.4	13
29/11/2005	8.18	54	348					
06/12/2005					<1	<1	0.0	4
14/12/2005					<1	<1	0.4	9
20/12/2005					<1	<1	0.4	1
31/01/2006	8.29	35	229		<1	<1	0.2	0
07/02/2006					<1	<1	0.1	5
28/02/2006	8.19	50	326					
07/03/2006					<1	<1	0.3	2
14/03/2006					<1	<1	0.4	6
22/03/2006				2.93	<1	<1	0.3	0
28/03/2006	8.19	39	255	<1	45	<1	0.9	6
05/04/2006				<1	<1	<1	0.3	2
11/04/2006				<1	<1	<1	1.9	0
18/04/2006				<1	<1	<1	0.7	2
24/04/2006	8.04	53	343	<1	<1	<1	2.0	0
02/05/2006				<1	<1	<1	0.3	0
09/05/2006				<1	<1	<1	0.7	1
16/05/2006				<1	<1	<1	1.0	0
23/05/2006				<1	<1	<1	0.3	3
30/05/2006	8.26	45	294	<1	<1	<1	0.3	0
06/06/2006				<1	<1	<1	0.6	6
13/06/2006				<1	1	<1	0.3	0
20/06/2006				<1	<1	<1	0.1	3
27/06/2006	8.12	57	372	<1	<1	<1	0.0	1

DE_37 – DELPARK EXTENSION 1 CARNATION STREET HOUSE NUMBER 37													
Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F^-	Silicon	TAL	Calcium	PO_4	Na	SO_4	Cl^-	Mg	Hardness
29/11/2006	0.33	13.6	1.09	0.149	8.03	174	38.5	0.797	20.1	22.0	31.7	25.9	203
31/01/2006	<0.04	2.6	0.61	0.176	6.60	127	26.8	0.067	9.6	25.3	15.0	17.5	139
28/02/2006	<0.04	2.5	0.53	0.224	7.58	181	41.4	0.067	13.7	33.2	24.3	27.9	218
28/03/2006	<0.04	6.2	0.50	0.232	8.12	154	30.5	0.141	10.9	14.4	11.1	19.6	156
24/04/2006	<0.04	3.8	0.63	0.162	7.29	170	42.2	0.094	19.0	34.2	33.9	29.1	225
30/05/2006	<0.04	2.8	0.40	0.165	7.26	166	38.1	0.048	14.0	26.6	27.0	27.5	208
27/06/2006	<0.04	2.1	0.43	0.215	7.64	177	45.4	0.035	18.8	50.6	39.5	33.4	251

DE_37 – DELPARK EXTENSION 1 CARNATION STREET HOUSE NUMBER 37									
Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
24/04/2006	0.011	0.041	0.003	<0.012	0.005	0.024	0.040	0.001	<0.004
30/05/2006	0.001	<0.012	0.001	<0.012	0.001	0.011	0.049	0.001	<0.004
27/06/2006	0.005	<0.012	0.004	<0.012	0.005	0.020	0.097	0.001	<0.004

RS13 – TAP DELMAS STRYDOM STREET HOUSE NUMBER 13								
Sampling Date	Physical Constituents				Microbiological Constituents			
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Residual Cl_2 (mg/L)	Standard Plate Count (MPN/1mL)
15/11/2005					<1	<1	0.5	0
22/11/2005					1	<1	0.5	1
29/11/2005	8.13	54	350					
06/12/2005					<1	<1	0.4	0
14/12/2005					<1	<1	3.0	0
20/12/2005					<1	<1	0.4	0
31/01/2006	8.34	56	361		<1	<1	2.3	0
07/02/2006					26	<1	1.9	0
28/02/2006	8.40	58	378					
07/03/2006					<1	<1	0.2	18
14/03/2006					<1	<1	3.5	7
22/03/2006				<1	<1	<1	>3.5	0
28/03/2006	8.62	59	383	<1	<1	<1	1.9	1
05/04/2006				<1	<1	<1	3.5	0
11/04/2006				<1	<1	<1	0.0	1.6
18/04/2006				<1	10	<1	3.0	0
24/04/2006	8.08	54	347	<1	1	<1	1.9	1
02/05/2006				<1	4	1	1.4	2
09/05/2006				<1	<1	<1	0.7	11
16/05/2006				<1	<1	<1	2.5	1
23/05/2006				<1	<1	<1	2.3	15
30/05/2006	8.12	54	350	<1	<1	<1	1.9	4
06/06/2006				<1	<1	<1	0.6	4
13/06/2006				<1	4	<1	3.3	0
20/06/2006				<1	2	<1	1.9	0
27/06/2006	8.32	55	356	<1	1	<1	0.0	1

RS13 – TAP DELMAS STRYDOM STREET HOUSE NUMBER 13													
Major Inorganic Compounds (mg/L)													
Sampling Date	**NH_4-N**	**K**	**NO_3-NO_2**	**F^-**	**Silicon**	**TAL**	**Calcium**	**PO_4**	**Na**	**SO_4**	**Cl^-**	**Mg**	**Hardness**
29/11/2006	<0.04	1.54	5.22	<0.1	12.4	209	56.3	0.035	6.2	16.5	12.3	30.8	267
31/01/2006	<0.04	1.52	5.33	0.123	11.3	224	58.0	0.013	6.4	15.2	15.3	31.4	274
28/02/2006	<0.04	1.56	5.30	0.165	11.1	223	63.7	0.021	7.7	16.7	20.3	30.9	286
28/03/2006	0.21	1.32	5.16	0.177	12.1	228	61.9	0.017	6.7	18.1	15.1	32.0	286
24/04/2006	<0.04	1.14	5.11	0.104	10.6	206	49.7	0.036	6.0	17.9	15.5	29.3	245
30/05/2006	<0.04	0.83	5.39	0.121	11.9	213	64.7	0.019	6.6	16.6	16.6	33.6	300
27/06/2006	<0.04	1.52	4.45	0.214	11.2	230	59.1	0.017	5.5	17.0	152	31.4	277

RS13 – TAP DELMAS STRYDOM STREET HOUSE NUMBER 13									
Trace Metals (mg/L)									
Sampling Date	**Chromium**	**Iron**	**Manganese**	**Nickel**	**Copper**	**Zinc**	**Arsenic**	**Cadmium**	**Lead**
24/04/2006	0.011	0.044	0.003	<0.012	0.002	0.003	<0.004	0.001	<0.004
30/05/2006	0.001	<0.012	0.001	<0.012	0.017	0.011	<0.004	0.001	<0.004
27/06/2006	0.003	0.020	0.001	<0.012	0.005	0.007	<0.004	0.001	<0.004

DE_420 – TAP DELPARK EXTENSION 2 HOUSE NUMBER 420 (TUCKSHOP)								
Sampling Date	Physical Constituents				Microbiological Constituents			
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Residual Cl_2 (mg/L)	Standard Plate Count (MPN/1mL)
15/11/2005					<1	<1	0.1	22
22/11/2005					<1	<1	0.3	11
29/11/2005	8.21	53	346					
06/12/2005					<1	<1	0.3	0
14/12/2005					10	4	0.4	9
20/12/2005					<1	<1	0.4	10
31/01/2006	8.10	35	228		<1	<1	0.4	0
07/02/2006					<1	<1	0.2	2
28/02/2006	7.90	51	331					
07/03/2006					<1	<1	0.2	15
14/03/2006					<1	<1	0.4	2
22/03/2006				3.17	<1	<1	0.3	1
28/03/2006	8.37	41	264	1.19	<1	<1	0.6	1
05/04/2006				1.22	<1	<1	0.7	1
11/04/2006				1.11	<1	<1	1.9	0
18/04/2006				<1	<1	<1	0.5	2
24/04/2006	7.87	50	326	<1	<1	<1	1.5	0
02/05/2006				<1	<1	<1	1.3	1
09/05/2006				<1	<1	<1	>3.5	0
16/05/2006				<1	<1	<1	1.0	1
23/05/2006				1.76	<1	<1	0.2	3
30/05/2006	8.11	43	277	<1	<1	<1	0.2	0
06/06/2006				<1	<1	<1	0.8	3
13/06/2006				<1	<1	<1	0.4	2
20/06/2006				<1	<1	<1	0.4	1
27/06/2006	8.27	49	320	<1	<1	<1	0.2	1

DE_420 – TAP DELPARK EXTENSION 2 HOUSE NUMBER 420 (TUCKSHOP)													
Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F^-	Silicon	TAL	Calcium	PO_4	Na	SO_4	Cl^-	Mg	Hardness
29/11/2006	0.54	23.7	1.32	0.143	7.83	172	33.5	1.330	21.7	19.8	32.1	23.4	180
31/01/2006	<0.04	3.7	0.60	0.183	6.53	121	26.8	0.065	9.7	22.5	15.5	18.4	145
28/02/2006	<0.04	15.5	1.33	0.197	7.38	180	38.0	0.736	18.4	19.9	30.9	24.0	194
28/03/2006	0.05	9.1	0.89	0.257	8.03	143	28.8	0.304	13.7	14.7	17.2	19.2	151
24/04/2006	<0.04	6.6	1.11	0.145	7.52	160	41.0	0.166	17.9	24.8	29.5	26.1	210
30/05/2006	<0.04	2.7	0.39	0.156	7.23	155	35.7	0.318	13.2	32.9	20.6	24.8	191
27/06/2006	<0.04	2.8	0.59	0.224	7.76	165	37.2	0.047	15.5	34.7	29.1	29.0	212

DE_420 – TAP DELPARK EXTENSION 2 HOUSE NUMBER 420 (TUCKSHOP)									
Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
24/04/2006	0.010	0.039	0.002	<0.012	0.004	0.024	0.038	0.001	<0.004
30/05/2006	0.001	<0.012	0.001	<0.012	0.003	0.011	0.060	0.001	<0.004
27/06/2006	0.003	0.019	0.002	<0.012	0.005	0.019	0.062	0.001	<0.004

NPS_5 – TAP NESHER PRIVATE SCHOOL FIFTH STREET								
Sampling Date	Physical Constituents				Microbiological Constituents			
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Residual Cl_2 (mg/L)	Standard Plate Count (MPN/1mL)
15/11/2005					<1	<1		4
22/11/2005					<1	<1	0.3	7
29/11/2005	8.25	54	350					
06/12/2005					<1	<1	0.2	7
14/12/2005					<1	<1	0.2	1
20/12/2005					<1	<1	0.2	2
31/01/2006	8.02	49	320		<1	<1	2.5	0
07/02/2006					<1	<1	0.5	2
28/02/2006	8.36	51	333					
07/03/2006					<1	<1	0.5	3
14/03/2006					<1	<1	0.1	1
22/03/2006				1.09	<1	<1	0.3	0
28/03/2006	8.29	55	358	1.75	<1	<1	0.6	1
05/04/2006				1.77	1	<1	1.7	0
11/04/2006				3.23	<1	<1	1.7	0
18/04/2006	8.12	45	289	<1	<1	<1	>3.5	1
24/04/2006	Sample not taken due to maintenance							
02/05/2006				11.50	<1	<1	1.8	3
09/05/2006				<1	<1	<1	1.5	1
16/05/2006				<1	<1	<1	0.9	2
23/05/2006				1.16	<1	<1	0.2	21
30/05/2006	8.14	45	293	<1	<1	<1	0.2	0
06/06/2006				<1	<1	<1	0.8	7
13/06/2006				<1	<1	<1	0.1	16
20/06/2006				<1	<1	<1	0.2	21
27/06/2006	8.12	53	342	<1	<1	<1	0.1	1

NPS_5 – TAP NESHER PRIVATE SCHOOL FIFTH STREET													
Major Inorganic Compounds (mg/L)													
Sampling Date	**NH_4-N**	**K**	**NO_3-NO_2**	**F^-**	**Silicon**	**TAL**	**Calcium**	**PO_4**	**Na**	**SO_4**	**Cl^-**	**Mg**	**Hardness**
29/11/2006	0.66	27.50	1.47	0.149	7.72	175	33.2	1.600	22.5	16.9	33.0	21.8	173
31/01/2006	<0.04	2.35	1.14	0.121	9.09	192	36.8	0.045	8.9	32.7	18.1	30.4	217
28/02/2006	<0.04	3.00	0.76	0.221	7.96	179	40.7	0.025	14.5	27.9	25.8	30.8	229
28/03/2006	<0.04	3.24	0.83	0.185	9.23	191	39.2	0.066	14.2	31.3	25.3	32.6	232
24/04/2006	<0.04	10.40	1.58	0.162	7.03	157	37.9	0.469	16.5	16.1	25.4	21.2	207
30/05/2006	<0.04	2.97	0.50	0.161	7.08	164	37.2	0.161	14.4	29.7	25.3	28.0	208
27/06/2006	<0.04	2.06	0.59	0.180	7.72	173	38.6	0.023	15.2	49.2	30.5	31.6	227

NPS_5 – TAP NESHER PRIVATE SCHOOL FIFTH STREET									
Trace Metals (mg/L)									
Sampling Date	**Chromium**	**Iron**	**Manganese**	**Nickel**	**Copper**	**Zinc**	**Arsenic**	**Cadmium**	**Lead**
24/04/2006	0.011	0.045	0.003	<0.012	0.006	0.037	0.007	0.001	<0.004
30/05/2006	0.001	0.054	0.002	<0.012	0.003	0.065	0.073	0.001	<0.004
27/06/2006	0.004	<0.012	0.001	<0.012	0.008	1.456	0.068	0.001	<0.004

NB_3879 – TAP NEW BOTLENG EXTENSION 6 STAND NUMBER 3879								
Sampling Date	Physical Constituents				Microbiological Constituents			
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Residual Cl_2 (mg/L)	Standard Plate Count (MPN/1mL)
15/11/2005					<1	<1	0.4	1
22/11/2005					<1	<1	0.3	1
29/11/2005	8.18	40	256					
06/12/2005					<1	<1	0.2	0
14/12/2005					<1	<1	0.2	0
20/12/2005					<1	<1	0.2	17
31/01/2006	8.10	47	306		<1	<1	2.3	0
07/02/2006					<1	<1	0.9	0
28/02/2006	8.15	40	259					
07/03/2006					<1	<1	0.3	0
14/03/2006					<1	<1	1.4	0
22/03/2006				<1	<1	<1	1.0	0
28/03/2006	8.48	46	298	1.04	<1	<1	1.4	0
05/04/2006				<1	<1	<1	0.9	0
11/04/2006				1.58	<1	<1	0.5	0
18/04/2006				<1	<1	<1	0.7	1
24/04/2006	8.01	38	246	<1	<1	<1	0.2	6
02/05/2006				<1	<1	<1	0.8	1
09/05/2006				<1	<1	<1	0.8	1
16/05/2006				1.70	<1	<1	1.0	0
23/05/2006				1.41	<1	<1	1.3	0
30/05/2006	8.12	40	261	<1	<1	<1	1.0	0
06/06/2006				1.12	<1	<1	0.7	4
13/06/2006				<1	<1	<1	1.6	0
20/06/2006				1.19	<1	<1	0.9	31
27/06/2006	8.17	42	275	<1	<1	<1	1.4	0

NB_3879 – TAP NEW BOTLENG EXTENSION 6 STAND NUMBER 3879													
Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F^-	Silicon	TAL	Calcium	PO_4	Na	SO_4	Cl^-	Mg	Hardness
29/11/2006	<0.04	2.33	<0.08	0.330	6.73	129	28.6	0.027	9.7	31.1	14.7	24.0	170
31/01/2006	<0.04	5.22	0.09	0.484	7.62	168	33.9	0.139	15.6	30.7	24.8	25.9	191
28/02/2006	<0.04	4.64	0.12	0.662	7.32	142	28.2	0.116	16.4	22.4	19.4	21.0	157
28/03/2006	<0.04	3.32	<0.08	0.427	7.88	148	33.9	0.072	12.3	34.1	20.2	24.9	187
24/04/2006	<0.04	3.26	<0.08	0.424	7.30	134	32.1	0.056	12.8	26.1	15.2	21.8	170
30/05/2006	<0.04	4.50	0.11	0.626	7.35	149	30.4	0.131	17.3	28.4	20.5	21.9	166
27/06/2006	<0.04	2.73	0.13	0.427	7.57	143	30.1	0.104	12.3	41.3	20.3	25.2	179

NB_3879 – TAP NEW BOTLENG EXTENSION 6 STAND NUMBER 3879									
Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
24/04/2006	0.009	0.036	0.001	<0.012	0.001	0.004	0.019	0.001	0.005
30/05/2006	0.001	<0.012	0.001	<0.012	0.006	0.007	0.015	0.001	<0.004
27/06/2006	0.003	<0.012	0.001	<0.012	0.004	0.011	0.049	0.001	<0.004

B_MS – BOTLENG MANDELA INFORMAL SETTLEMENT SECTION C MASUNYANE STREET (COMMUNAL TAP)								
Sampling Date	Physical Constituents				Microbiological Constituents			
	pH (pH units)	EC (mS/m)	TDS (mg/L)	TURB (NTU)	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)	Residual Cl_2 (mg/L)	Standard Plate Count (MPN/1mL)
15/11/2005					<1	<1	0.1	5
22/11/2005					2	<1	0.3	82
29/11/2005	7.98	54	352					
06/12/2005					<1	<1	0.4	6
14/12/2005					<1	<1	0.5	6
20/12/2005					<1	<1	0.5	5
31/01/2006	7.99	41	265		<1	<1	0.7	0
07/02/2006					14	<1	0.3	4
28/02/2006	8.28	55	354					
07/03/2006					<1	<1	0.1	9
14/03/2006					2	<1	0.4	2
22/03/2006				2.00	<1	<1	0.4	1
28/03/2006	8.30	40	260	1.55	<1	<1	0.5	0
05/04/2006				1.80	<1	<1	1.0	6
11/04/2006				2.16	<1	<1	3.3	0
18/04/2006				<1	<1	<1	0.6	1
24/04/2006	8.26	51	330	<1	<1	<1	1.0	14
02/05/2006				<1	<1	<1	0.1	1
09/05/2006				1.27	<1	<1	2.0	1
16/05/2006				<1	<1	<1	0.6	1
23/05/2006				1.19	<1	<1	1.9	4
30/05/2006	8.07	45	291	<1	<1	<1	0.4	0
06/06/2006				<1	<1	<1	0.5	1
13/06/2006				<1	<1	<1	0.6	0
20/06/2006				<1	<1	<1	0.6	1
27/06/2006	8.14	51	334	<1	<1	<1	0.1	1

B_MS – BOTLENG MANDELA INFORMAL SETTLEMENT SECTION C MASUNYANE STREET (COMMUNAL TAP)													
Major Inorganic Compounds (mg/L)													
Sampling Date	NH_4-N	K	NO_3-NO_2	F^-	Silicon	TAL	Calcium	PO_4	Na	SO_4	Cl^-	Mg	Hardness
29/11/2006	0.62	26.0	1.46	0.144	6.38	172	34.1	1.494	22.3	15.8	33.5	22.3	177
31/01/2006	<0.04	8.2	1.17	0.182	7.05	140	32.3	0.278	13.1	19.3	21.5	20.2	164
28/02/2006	<0.04	4.8	1.14	0.224	7.68	181	43.7	0.114	17.7	34.3	33.9	28.6	227
28/03/2006	<0.04	9.1	0.86	0.303	8.10	141	29.7	0.338	14.1	14.9	16.6	18.0	148
24/04/2006	<0.04	2.4	0.60	0.160	7.32	163	41.5	0.057	17.6	42.7	30.6	29.5	225
30/05/2006	<0.04	6.5	0.96	0.163	7.29	166	38.8	0.266	15.1	21.0	23.7	24.9	199
27/06/2006	<0.04	2.7	0.48	0.180	7.71	165	37.2	0.071	15.5	50.8	31.1	29.7	215

B_MS – BOTLENG MANDELA INFORMAL SETTLEMENT SECTION C MASUNYANE STREET (COMMUNAL TAP)									
Trace Metals (mg/L)									
Sampling Date	Chromium	Iron	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
24/04/2006	0.009	0.037	0.002	<0.012	0.002	0.012	0.050	0.001	<0.004
30/05/2006	0.001	0.024	0.001	<0.012	0.002	0.007	0.031	0.001	<0.004
27/06/2006	0.004	<0.012	0.003	<0.012	0.004	0.008	0.080	0.001	<0.004

MICROBIOLOGICAL RESULTS FOR AN AD HOC SAMPLE COLLECTED AT THE DELMAS RETICULATION SYSTEM

BOTLENG CLINIC		
Sampling Date	Microbiological Constituents	
	Total Coliforms (MPN/100mL)	*E. coli* (MPN/100mL)
14/03/2006	703	110