



Bryony Walmsley & Associates

Environmental Consultants

Reg No.: 2004/031035/23

CONNECT ST HELENA LTD

DEVELOPMENT OF A WATER QUALITY MONITORING PROGRAMME: PHASE 1 REPORT



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ACKNOWLEDGEMENTS

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David Peters and Patrick Peters drove us to all the water sampling sites and Patrick effortlessly collected all the samples for us. Their patient explanation of the water supply system was much appreciated.

LIST OF ACRONYMS

ANRD	Agricultural and Natural Resources Division
BR	Basil Read
BW&A	Bryony Walmsley & Associates
CSIR	Council for Scientific and Industrial Research
EPO	Environmental Protection Ordinance
EU	European Union
IATA	International Air Transport Association
l	litre
LSI	Langelier Saturation Index
mg	milligrams
mS/m	milliSiemens per metre
ppm	parts per million
RMS	Royal Mail Ship
RSA	Republic of South Africa
SANAS	South African National Accreditation System
SANS	South African National Standards
SHG	St Helena Government
TOR	terms of reference
TWQR	target water quality range
µg	micrograms
WHO	World Health Organisation
WTW	water treatment works

DEVELOPMENT OF A WATER QUALITY MONITORING PROGRAMME FOR CONNECT ST HELENA LTD: PHASE 1 REPORT

1 INTRODUCTION AND BACKGROUND TO THE STUDY

Connect Saint Helena Ltd (Connect) is a commercially operated company owned by the St Helena Government (SHG), responsible for delivering electricity, water and waste water services to the communities of St Helena Island. Up until the formation of the company on 1st April 2013, the provision of utility services was undertaken by SHG.

As one of its core responsibilities, Connect supplies raw and treated water to all communities on the Island from a network of surface water and groundwater resources. Four water treatment works (WTW) supply most of the main settlements on the island. At each of the WTWs, raw water is dosed with chlorine for sterilisation purposes and with permanganate to promote the oxidation-precipitation of soluble iron or manganese. This is an accepted treatment for groundwater or surface water supplies. Permanganate, under normal water treatment conditions, rapidly reacts with iron or manganese, producing a precipitated floc that is removed by coagulation, flocculation and settling, or filtration.

At present, the only water testing facilities on the Island are located at the laboratory of the Jamestown Hospital, which is only accredited to analyse for microbiological parameters. Treated water is routinely tested at this laboratory for the presence of *E. coli*, Enterococci, total colony count and coliform bacteria. Analysis of the chemical make-up of the water thus has to be performed at an off-island laboratory, and as a result of the complicated logistics of this, together with the time taken and the cost, no routine monitoring of the inorganic quality of water supplied by Connect has ever been conducted, although a one-off set of samples was collected from 5 sources in 2015 and send to the Envirotek laboratory in South Africa for analysis.

To rectify this, Connect appointed Bryony Walmsley and Associates (BW&A) on 6th February 2018 to develop a water quality monitoring regime.

2 AIMS AND OBJECTIVES

The aims of the study are as follows:

- Establish seasonal baseline water quality conditions for all water sources used to supply raw and treated water;
- Determine the presence of local sources of pollution;
- On the basis of the baseline conditions, develop a bespoke monitoring programme for Connect;
- Make recommendations regarding the establishment of on-island analytical equipment for ongoing water sample analysis.

3 APPROACH AND METHODOLOGY

3.1 Study approach

Work will be undertaken in a phased manner, with the results of each phase informing the next steps. Phase 1 (the subject of this report) comprised the establishment of the summer-time baseline raw water quality, while Phase 2 will be carried out in winter to collect and analyse samples to establish the winter-time baseline. Phase 2 will also include discussions with the Agricultural and Natural Resources Division (ANRD) to determine potential agricultural pollution sources and sediment sampling if necessary, to detect the presence of persistent organic pollutants such as pesticides. Phase 3 will involve ongoing monitoring and reporting.

3.1.1 Phase 1: summer baseline survey

The activities that have taken place during Phase 1 included:

- Meetings on island with Connect to:
 - Discuss the Environmental Protection Ordinance (EPO) and International Air Transport Association (IATA) requirements and relevance to the Island;
 - Obtain an understanding of the water supply system on the Island, including catchments, dams and reservoirs, reticulation systems;
 - Obtain any water quality data available (and from other sources e.g. Basil Read (BR)).
- Site visits to all main water supply dams, reservoirs, weirs and tanks to obtain first-hand knowledge of:
 - The catchments and land use;
 - State of water holding facilities;
 - Potential locations for monitoring;
 - Visual assessment of water quality – colour, presence of sediment, precipitation, etc.;
- Collection and preparation of water samples for shipment via RMS *St Helena*.
- Analysis and Reporting:
 - Obtain a quotation from CSIR Laboratories in Stellenbosch, South Africa for analysis;
 - Collect water samples from the RMS in Cape Town and deliver to CSIR Laboratories;
 - Analyse the results and present them in a report (this document);
 - Advise Connect on the reagents needed for the Photometer 8000 and whether any other analytical equipment is required.

Between Phase 1 and Phase 2, it is assumed that the Photometer 8000 will be set up at the Hospital Lab for use during Phase 2. It is also assumed that Connect's on-island Environmental Consultant, namely Annina Hayes, will conduct training for the Connect staff on the correct sampling, labelling and sample storage protocols.

3.1.2 Phase 2: winter baseline survey

The activities to be performed in Phase 2 are:

- Meeting with ANRD to understand land use activities within catchments, with particular emphasis placed on use of pesticides and fertilisers, location of piggeries and other intensive

stock farming activities, waste disposal (including septic tanks, sewerage ponds), and any other potential causes of pollution;

- Depending on the findings from the meeting with ANRD, design a sediment sampling programme from selected reservoirs and tanks. The reason for sediment sampling is because pesticides, if they are present, tend to adhere to clay particles in the sediment, rather than existing in the water column;
- Obtaining quotations for sediment analysis, if required;
- Collecting a second set of water samples from the same points as Phase 1, as well as any additional points identified in this report, and sending them for analysis at the Hospital Lab (if Connect's analytical equipment is ready for use);
- Analysis of the water sampling results and compilation of a Phase 2 report;
- Based on the results of the Phase 1 and Phase 2 water analyses, develop a water monitoring programme for Connect, including the following information: monitoring locations; monitoring frequency; sampling protocols; chain of custody procedures; personnel and training required; the parameters to be monitored; data management; data analysis and interpretation in terms of drinking water quality; reporting requirements.

3.1.3 Phase 3: ongoing supervision and review

Phase 3 will comprise ongoing supervision of the sampling programme by Connect's on-Island Environmental Consultant, as well as review and interpretation of the monitoring results and reporting by BW&A. The frequency of sampling and reporting will be determined at the end of Phase 2. BW&A will also prepare an annual report in which all the results of the previous year will be collated, trends identified and interpreted.

3.2 Identification of sampling points

A total of 23 sampling points were identified, 17 of which are current raw water supply sources, 2 were possible future supply sources in Fisher's and Shark's Valleys, and 4 were located at each of the WTWs. Each sampling point has been allocated a letter and number reference, which should be maintained going forward so that sample results can be easily compared. A detailed Sample Log is provided in Appendix A, together with photographs and comments on the sample sites and the physical appearance of the water at each site. The location of each sampling point is shown in Figure 1.

3.3 Sample collection, labelling and transportation

Samples were collected in clean, 1.5 litre plastic bottles. Prior to sample collection, the bottles were rinsed out three times with water from the sampling source. Each sample was labelled and placed in a box with ice blocks and transported under cold conditions on the RMS *St Helena* to Cape Town, South Africa. The samples remained in the ship's chiller until Customs Clearance had been obtained. They were then transported to the CSIR analytical laboratory in Stellenbosch in cooler boxes with ice blocks. The laboratory is accredited under the South African National Accreditation System (SANAS). The samples were delivered with the sampling schedule (Appendix B) which was signed on receipt by the laboratory on 21st February 2018. The sample results were received from the laboratory on 9th March 2017 (Appendix C).

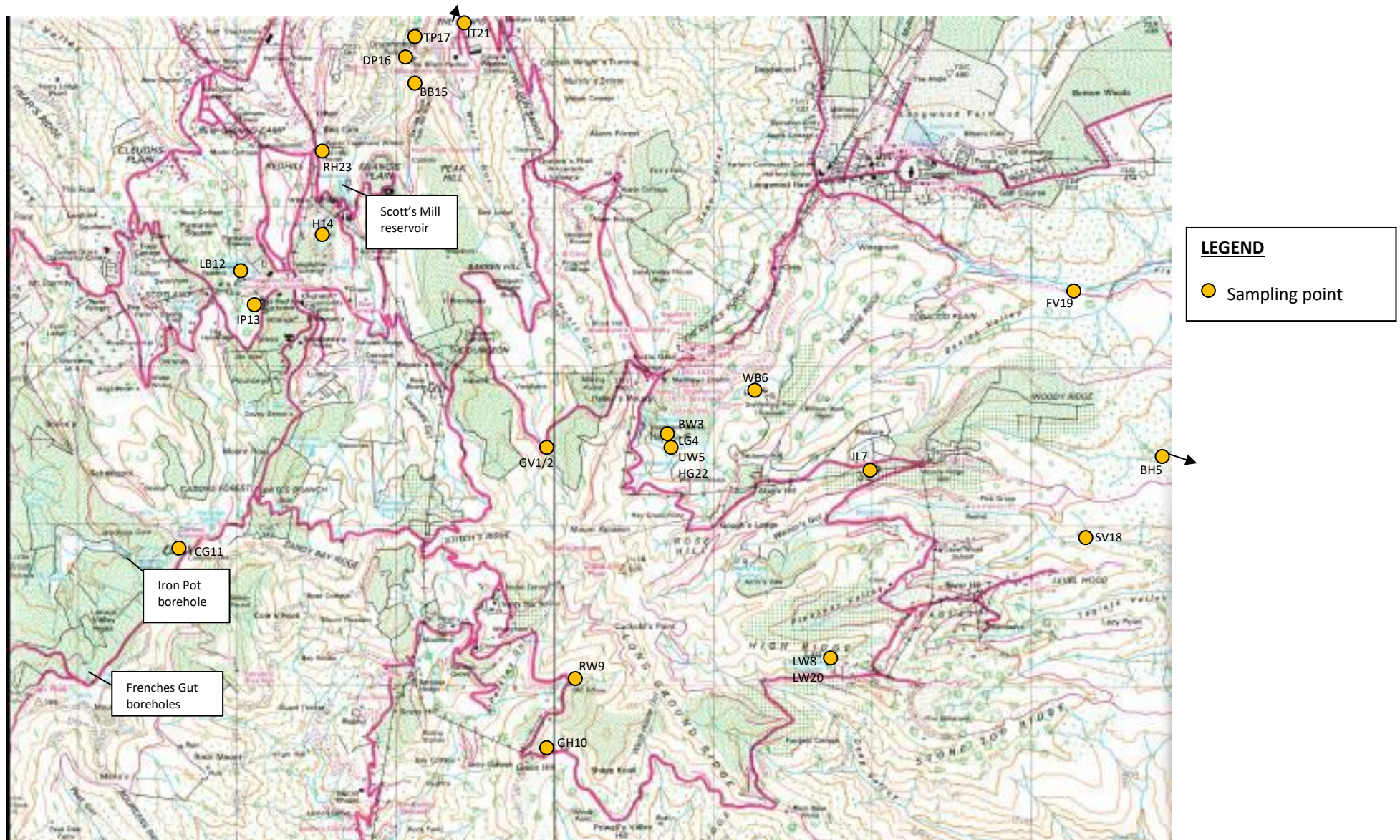


Figure 1: Location of sampling points

3.4 Sample analysis

The determination of which parameters to analyse for was based on the following:

- Schedule III of the Environmental Protection Ordinance (EPO);
- The International Air Transport Association (IATA) requirements for potable water in airports and on aircraft;
- World Health Organisation Guideline Values 2017;
- Elements of concern identified by Basil Read (BR) during routine construction monitoring for the airport project 2013-17;
- The potential risk of pesticide pollution and the relevant analytical capabilities of laboratories in South Africa.

Schedule III of the EPO was used as the starting point, but it was found that many of the chemical parameters listed are associated with highly industrialised countries and are therefore irrelevant in the context of St Helena Island which is unlikely to develop iron and steel, petrochemical, pulp and paper, plastics manufacture, heavy metal mines and refineries, and such like in the near future, if ever. The parameters that are usually associated with these industries were thus omitted from the analysis, as shown in Table 1.

On the other hand, some key elements of concern identified during routine sampling by BR are not included on Schedule III, such as calcium, chloride, orthophosphate, sulphate, zinc, conductivity and total alkalinity. All of these can have adverse effects on human health and/or aesthetics (taste) and/or corrosion potential (Table 1). In addition, the IATA Aircraft Handling and Loading Manual requires the drinking water provided to the airport and aircraft to meet certain standards – mostly microbiological and aesthetic (colour, taste, odour, clarity), some of which are also not included in Schedule III of the EPO (see Table 1).

The final consideration in the choice of analysis revolved around whether there is a risk of pesticide or agricultural chemical contamination in any of the water sources. It is planned to hold meetings with the Agricultural and Natural Resources Division (ANRD) during Phase 2 of the work to discuss the land uses in each of the raw water catchments and to determine whether there is any risk from pesticides and/or agricultural chemicals. If there is a potential risk, the nature of the risk will be determined and an appropriate sampling plan developed, which may include sediment sampling as well as water samples. The CSIR laboratory, along with many other labs in South Africa, does not offer pesticide analysis and, depending on the pesticide of concern, samples may have to be sent to the UK for analysis. Thus for Phase 1, no pesticide analyses were included.

Table 1: Determination of analytical requirements

Parameter	Inclusion based on:	Relevant to island (Y/N/?)	Comment
MICROBIOLOGICAL			
Enterococci	Schedule III IATA	Y	Is being routinely analysed at the Hospital Lab
<i>E. coli</i>	Schedule III IATA	Y	Is being routinely analysed at the Hospital Lab
Coliform bacteria	IATA	Y (airport)	Is being routinely analysed at the Hospital Lab
<i>Pseudomonas aeruginosa</i>	IATA	Y (airport)	Reagents being purchased by Hospital Lab
Colony count	IATA WHO	Y (airport)	Is being routinely analysed at the Hospital Lab
<i>Clostridium perfringens</i>	IATA	Y (airport)	Reagents being purchased by Hospital Lab
CHEMICAL			
Acrylamide	Schedule III	N	Used in industrial processes e.g. pulp and paper industry, dyes and plastics, as well as in the treatment of water and waste water. Found in foods cooked at high temperatures
Aluminium	Schedule III	Y	Sources from mining wastes, food additives and antacids
Ammonia	Element of concern	Y	Typically found near septic tanks, sewage treatment works outlets, cattle feedlots
Antimony	Schedule III	N	Found in mining wastes, plumbing materials, manufacturing effluent, landfill leachate
Arsenic	Schedule III	N	Sources from mining wastes, manufacturing processes, heavy industry, pesticides. Previous result: <0.01 mg/l in Longwood tap water
Benzene	Schedule III	N	Used as an industrial solvent in paints, varnishes, lacquer thinners, gasoline. Also used to manufacture chemicals and in industrial process that make resins, adhesives, plastics, etc.
Benzopyrene	Schedule III	N	Is a PAH found in coal tar. Generated by the incomplete combustion of fuel and organic substances
Bicarbonate	Element of concern	Y	A key determinant of corrosion potential
Boron	Schedule III	To be determined	Can occur naturally. Previous result: <0.02 mg/l in Longwood tap water
Bromate	Schedule III	N	Formed in many different ways in municipal drinking water due to the reaction of ozone and bromide and during electrolysis of brine. Sunlight exposure encourages liquid or gaseous

Parameter	Inclusion based on:	Relevant to island (Y/N/?)	Comment
			bromine, which will form bromate in bromide-containing water. Bromide not used by Connect.
Cadmium	Schedule III	N	Can enter water from mining wastes, smelting and refining of metals, manufacturing processes e.g. batteries, coatings and plastics. Previous result: <0.01 mg/l in Longwood tap water
Calcium	Element of concern	Y	Important in determining corrosion potential
Chloride	Element of concern	Y	Rocks and soils on island contain high levels of sodium chloride
Chlorine (residual)	IATA	Y (airport)	Added during water treatment process. Is being routinely analysed by the Hospital Lab
Chromium	Schedule III	N	May enter water from mining activities, tanning/leather industry and other manufacturing processes.
Copper	Schedule III	Y	Can occur in drinking water as a result of mining activities, plumbing, food preparation, pulp, paper and timber industries. Previous result: <0.01 mg/l in Longwood tap water
Cyanide	Schedule III	N	Sources include gold mining, organic chemical industry, iron and steel plants, wastewater treatment plants.
1,2 dichloroethane	Schedule III	N	Used to make vinyl chloride (PVC) pipes and furniture
Epichlorohydrin	Schedule III	N	An organochlorine compound used in the production of epoxy resins.
Fluoride	Schedule III	N	Used in the production of fluorocarbons. Can be artificially added to water but this is not practised on St Helena. Previous result: <0.1 mg/l in Longwood tap water
Iron	Schedule III	Y	Can occur naturally. Sources include plumbing (in presence of corrosion), iron and steel industry, mining, manufacturing. Previous results: 0.09 – 0.13 mg/l at Longwood, Bradleys and airport.
Lead	Schedule III	Y	<i>Depends if there is still lead piping present in plumbing.</i> Otherwise found due to mining and smelting processes, paint. Previous result: <0.01 mg/l in Longwood tap.
Magnesium	Best practice	Y	Standard cation
Manganese	Schedule III	Y	Can occur naturally. Used in metal alloys e.g. stainless steel production.

Parameter	Inclusion based on:	Relevant to island (Y/N/?)	Comment
Nickel	Schedule III	N	Used in food preparation equipment, mobile phones, medical equipment, transport, power generation, mining and smelting. Previous result: 0.01 mg/l in Longwood tap
Nitrate	Schedule III	Y	From fertilisers, waste water, explosives, animal feedlots, etc.
Nitrite	Schedule III	Y	From fertilisers, waste water, explosives, animal feedlots, etc.
Orthophosphate	Possible element of concern	Y	Typically found near septic tanks, sewage treatment works, animal feedlots, etc
Pesticides (including Aldrin, dieldrin, heptachlor, heptachlor epoxide)	Schedule III	To be determined	Occurrence will depend of whether any of these pesticides are used on the Island and where in relation to raw water sources
Total pesticides	Schedule III	To be determined	
PAH	Schedule III	To be determined	Only if fuel sources in catchment areas above water abstraction points.
Selenium	Schedule III	N	Used in the manufacture of electronic and photocopier components, health supplements, glass, pigments, rubber, metal alloys, textiles, petroleum and photographic emulsions and pesticides.
Sodium	Schedule III	Y	Rocks and soils on the Island have high levels of sodium chloride
Sulphate	Element of concern	Y	Elevated levels can have a laxative effect. Can affect corrosion potential. Previous results: 6-15 mg/l in Longwood, Bradleys and airport taps
Tetrachloroethene	Schedule III	N	Used in dry cleaning and textile processing
Tetrachloromethane	Schedule III	N	Used in cleaning industry in Halon-104 firefighting chemicals and in refrigerants
Trichloroethene	Schedule III	N	Used as an industrial solvent
Trihalomethane	Schedule III	N	Forms as a by-product when chlorine is added to drinking water
Vinyl chloride	Schedule III	N	Used in the production of PVC
Zinc	Element of concern - BR	Y	Present in low concentrations. Previous result: 0.11 mg/l in Longwood tap
PHYSICAL			
Colour	Schedule III IATA	Y (airport)	Aesthetic issue
Taste	Schedule III IATA	Y (airport)	Aesthetic issue
Odour	Schedule III IATA	Y (airport)	Aesthetic issue

Parameter	Inclusion based on:	Relevant to island (Y/N/?)	Comment
pH	Best practice IATA	Y (airport)	Standard indicator of water quality
Conductivity	Element of concern	Y	Standard indicator of water salinity and corrosion potential
Turbidity	Schedule III IATA	Y (airport)	Or could use suspended sediment as a surrogate
Total alkalinity as CaCO ₃	Element of concern	Y	Indicator of corrosion
Bicarbonate	Element of concern	Y	Indicator of corrosion

3.5 Sample interpretation

The samples have been interpreted in terms of: quality, compliance with legal standards, health and aesthetic effects, corrosion potential, pollution potential, and where relevant, irrigation use. The methodologies and reference materials used are described below.

3.5.1 Compliance with drinking water standards and guidelines

Schedule III of the St Helena Environmental Protection Ordinance, 2016 lists the standards that need to be complied with for water supplied to consumers. This list (included in Table 1 above) is based on the EU Drinking Water Directive (98/83/EC), which has been revised based on the latest World Health Organisation (WHO) Guideline Values (2017). However there are no EPO, EU or WHO guideline limits for some parameters of concern on St Helena Island and therefore the South African drinking water quality standards set out in SANS 241:2015 have been used for comparative purposes.

3.5.2 Health and aesthetic effects

The South African Water Quality Guidelines for Domestic Use (DWAF, 1996) were used to interpret the health and aesthetic effects of the water used to supply consumers on St Helena Island. These Guidelines were based on the WHO Guidelines for Drinking Water Quality (1984 and 1993), as well as guidelines from Australia, Canada and USA. The most recent WHO Guidelines (2017) were also consulted to ensure that the latest standards for health and aesthetic effects were applied.

Domestic water users can experience a range of impacts as a result of changes in water quality. These may be categorised as follows:

- Health impacts (short-, and long-term);
- Aesthetic impacts, which can include:
 - Changes in water taste, colour and odour;
 - Staining of laundry or domestic appliances;
- Economic impacts such as:
 - Increased cost of treatment;
 - Increased cost of water distribution due to scaling, corrosion, sediment deposition, etc.;
 - Scaling or corrosion of household pipes, fittings and appliances (DWAF, 1996).

The DWAF Guidelines provide a Target Water Quality Range (TWQR), starting with a range of values where no health or aesthetic effects are experienced, through a graduated scale of impacts to a concentration range where severe effects may be experienced. This is a useful guide for the interpretation of impacts and determining significance.

3.5.3 Corrosion potential

There are various measures of corrosion including the Langelier Saturation Index (LSI) and the Ryznar Index. For the purposes of this report, the LSI has been chosen to indicate the potential for corrosion (negative values) or scaling (positive scores). The LSI is calculated based on pH, conductivity or total dissolved solids, calcium and bicarbonate concentrations and water temperature. The latter was set at 20°C for all samples. Bicarbonate analyses were done for all samples (see analysis certificate in Appendix C), but the concentrations in all waters sampled were so low that they are recorded as 0.00 mg/l. The virtual absence of bicarbonate, together with very low calcium concentrations in all samples means that all the water sampled is under-saturated with respect to calcium carbonate (negative scores). Under-saturated water has a tendency to remove existing calcium carbonate protective coatings in pipelines and equipment, and thus there is a risk of serious corrosion. The LSI scores for the treated water samples and the untreated water supplies are provided in the discussion chapter below.

The ideal balance for water is an LSI of 0.0, but any values within the range -0.3 to +0.3 are tolerable in terms of corrosivity and scaling respectively. LSI scores exceeding -0.5 indicate the potential for serious corrosion.

3.5.4 Pollution indicators

The key chemical indicators of pollution from septic tanks, sewage treatment works, fertilised land, animal feedlots and stock concentrations are ammonia, nitrate + nitrite and orthophosphate, while the microbiological indicators include *E. coli*, total coliforms, Enterococci and total plate count. The samples taken as part of this project were only analysed for chemical determinants, because the laboratory at the Jamestown Hospital undertakes routine microbiological analysis of all treated water on the Island.

3.5.5 Agricultural use

Some of the water supplied by Connect is used for irrigation of crops and livestock watering. The quality of the water used in agriculture is important in determining its effect on crop production, animal health and performance, as well as the effects on the health of consumers of crop and animal products. Volume 4 of the SA Water Quality Guidelines series (DWAF, 1993) provides target water quality ranges for both irrigation use and livestock drinking and these have been used in this report. The elements of concern used in this report for irrigation and livestock are listed below:

Irrigation use

- Salinity (electrical conductivity)
- Sodicity
- Boron
- Chloride

Livestock watering

- | | |
|--------------------------------------|-------------|
| • Salinity (electrical conductivity) | • Sodium |
| • Chloride | • Lead |
| • Sulphate | • Zinc |
| | • Aluminium |

- | | | |
|------------------|---------------------|-------------|
| • Sodium | • Copper | • Boron |
| • Trace elements | • Calcium | • Iron |
| | • Magnesium | • Manganese |
| | • Nitrate + nitrite | |

4 SAMPLE RESULTS AND INTERPRETATION

Each of the four WTWs on the Island are supplied from one or more sources of water, therefore in order to have operational relevance, the sample results are interpreted and discussed by WTW catchment area. The five sources of untreated water and the two potential future water resources are discussed under separate headings. The results are interpreted on the basis of:

- Compliance with EPO, WHO and EU and South African drinking water quality standards and guidelines;
- Aesthetic and health issues;
- Corrosion potential;
- Pollution indicators; and
- Suitability for agricultural use.

4.1 Red Hill Water Treatment Works: sources and supply

4.1.1 Description of water sources and supply system

The Red Hill WTW is located on top of a ridge just below High Knoll Fort. Water from the following sources is all piped or pumped to Scott's Mill reservoir from where it is pumped up to the Red Hill WTW (Figure 1):

Surface water

- Grape Vine Gut 1 and 2;
- Harpers 1, 2 and 3.

Springs

- Lady's Bath;
- Gent's Bath;
- Callie's spring;
- Fishpond spring;
- Oakbank;
- Osborne's.

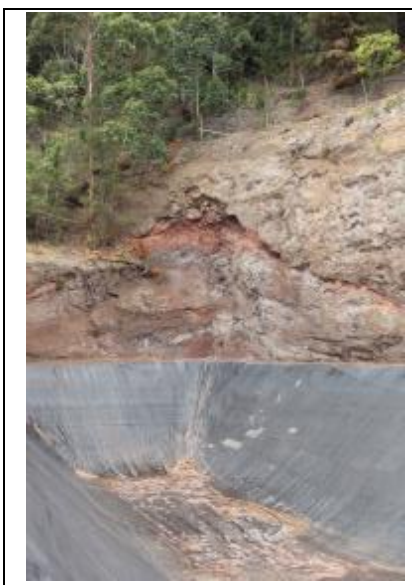
Water can also be pumped to the Red Hill WTW from the Jamestown WTW via Scott's Mill reservoir. Of these sources, samples were only collected from Grape Vine Gut reservoir (GV1 and GV2), Harpers 2 (H14) and Lady's Bath (LB12). A treated water sample was also collected from the sample tap at the Red Hill WTW (RH23) (see Sample Log in Appendix A).

The Grape Vine Gut reservoir is located just below the confluence of two small valleys which drain the northern slopes of Diana's Peak (Figure 1). There is no agricultural development in the catchment above the reservoir and the vegetation is primarily flax, with some exotic tree plantations (Plate 1).

The three Harpers reservoirs are located in a valley immediately to the east of the Red Hill WTW. At the time of sampling, Harpers 1 reservoir was empty to allow repairs to be carried out following a rockfall (Plate 2). The new Harpers 3 reservoir receives water from Oakbank.



**Plate 1: Grape
Vine Gut
catchment**



**Plate 2:
Harpers 1
reservoir**

The Lady's Bath, Callie's and Fishpond springs are all located in Plantation Forest, in the upper reaches of Young's Valley (Figure 1). The area around these springs is densely covered with mature forest, but pasture land is present in the upper reaches of the catchment. Osborne's and Gent's Bath springs are situated in one of the upper tributary valleys high above the Harpers reservoirs. The catchment around the springs is made up of pasture land and flax. Oakbank spring is surrounded by pasture land and mature forest, with its catchment extending towards the Osborne's area.

The Red Hill WTW supplies water to the communities of Half Tree Hollow, Cow Path, Red Hill, New Ground, St Pauls and Francis Plain.

4.1.2 Water chemistry and compliance with water quality standards

The Grape Vine Gut and Harpers water samples are chemically similar, while the Lady's Bath sample is noticeably higher in sodium chloride (Figure 2 and Table 2). The treated water sample (HG23) is clearly influenced in terms of its salinity by the Lady's Bath water and probably other sources not sampled during this monitoring episode.

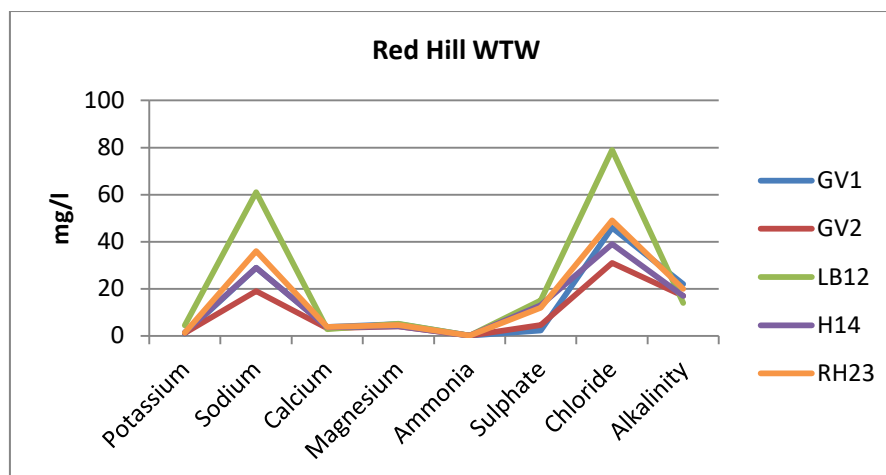


Figure 2: Red Hill WTW water quality: major anions and cations

Table 2: Red Hill WTW water quality results (in mg/l except where indicated)

	EPO/ WHO/ EU drinking water standard	SANS 241:2015	TWQR (no adverse aesthetic or health effects)	GV1	GV2	LB12	H14	RH23
Potassium			0-50	0.9	1.2	4.4	1.5	1.4
Sodium	200	200	0-100	29	19	61	29	36
Calcium			0-32	3.8	3.3	2.8	3.6	3.8
Magnesium			0-30	5	4	5.2	4.1	4.6
Ammonia		1.5	0-1	0.09	0.09	0.08	0.1	0.09
Sulphate		500	0-200	2.3	4.6	15	13	12
Chloride	250	300	0-100	46	31	79	39	49
Alkalinity				22	17	14	17	20
Nitrate + nitrite		11	0-6	<0.1	<0.1	3.4	<0.1	<0.1
Orthophosphate				<0.05	<0.05	0.05	<0.05	<0.05
Conductivity (mS/m)	250	170	0-70	20	15	37	20	23
pH (units)		5-9.7		7.5	7.4	6.6	7	7.4
Aluminium	0.2	0.3	0-0.15	0.02	0.04	<0.01	0.09	0.02
Boron	1	2.4		0.04	0.03	0.06	0.04	0.04
Copper	2	2	0-1	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	0.2	0.3	0-0.1	0.38	0.17	<0.01	0.9	0.05
Lead (µg/l)	10	10	0-10	<0.5	<0.5	20.8	1.6	<0.5
Manganese	0.05	0.1	0-0.05	<0.01	<0.01	0.01	0.09	<0.01
Zinc	5	5	0-3	<0.01	<0.01	0.02	0.03	0.01

Red shading indicates that the value exceeds the drinking water standards; yellow shading indicates where the value exceeds the TWQR for adverse health and aesthetic effects.

The iron concentrations in the GV1 and H14 samples are over the EPO/WHO/EU and SA water quality standards (red shading in Table 2), while the H14 sample exceeds the EPO/WHO/EU Directive for manganese of 0.05 mg/l, but it is just within the SA limit. However, the treated water supplied to

customers from the Red Hill WTW (RH23) is well within the iron and manganese guideline limits. Both iron and manganese occur naturally in the environment and the typical concentration of dissolved iron in unpolluted surface water is in the range of 0.001 to 0.5 mg/l, while for manganese, it can be present up to 0.13 mg/l (DWAF, 1996). Both minerals are present on the Island and it is not thought that these levels have been caused by anthropogenic pollution.

The main issue of concern is the high lead concentration found in the Lady's Bath water. At 20.8 µg/l, this concentration is more than double the EU and SA limit of 10 µg/l (Table 2), however there is sufficient dilution from other sources to ensure that the lead concentration in the treated water supply from the Red Hill WTW (RH23) ***is below the laboratory's detection limits and is therefore safe to drink.***

Lead is rarely present in tap water as a result of its dissolution from natural sources. It is primarily found in drinking-water as a consequence of lead service connections and lead plumbing with a contribution from old high-lead joint solder, leaded brass fixtures and copper alloy fittings, which also contain lead to improve milling characteristics. The amount of lead dissolved from the plumbing system also depends on pH and alkalinity, with soft, acidic water being the most plumbosolvent (WHO, 2017). It was thus postulated that this high concentration could be caused by old lead piping at the spring. This has been investigated and no evidence of lead piping could be found. However, as part of long-term upgrading works envisaged for the site, the old corrugated iron roof and walls surrounding the spring have been removed and the area is now enclosed with steel hand railings.

It is therefore possible that the result is anomalous, even though it was double-checked by the laboratory at the time of analysis. While there is no immediate risk to the public, future monitoring will provide more insight into this issue and inform management decisions going forward.

4.1.3 Health and aesthetic effects

Lead concentrations between 10 – 50 µg/l as found in the Lady's Bath sample, could present a slight risk of behavioural changes and the possibility of neurological impairment especially in children if taken over a long period, especially if there is also exposure to lead from other sources e.g. old lead-based paints, vehicle fumes, etc. Lead concentrations below 10 µg/l, as in the treated water sample RH23, have no adverse health effects (DWAF, 1996).

At values of 0.1 to 0.3 mg/l (as in sample GV2 (shaded orange in Table 2)), the presence of **iron** may have a slight effect on taste and may leave deposits on plumbing, but there will be no adverse health effects. Results in the range of 0.3 to 1.0 mg/l (samples GV1 and H14), will have an adverse effect on taste and could cause plumbing problems. Prolonged use of this water by itself could result in slight adverse health effects in young and iron-sensitive consumers (DWAF, 1996). The presence of iron in the GV1 sample can be seen in the photo in the Sample Log (Appendix A). However, the iron concentration in the treated water sample, RH23, is well within the TWQR for no health and aesthetic effects.

Manganese concentrations below 0.05 mg/l have no adverse health or aesthetic effects, but between 0.05 and 0.1 mg/l (as in sample H14), the water is tolerable to use and has no health

effects, but could cause slight staining of laundry and appliances (DWAF, 1996). Due to the effects of dilution, the manganese level in the treated water from the Red Hill WTW (RH23) is well within the guideline limits. Due to the number of sources contributing to the Harpers reservoir, it may be useful to take samples from some of the other contributing sources to try and determine the source of the manganese.

4.1.4 Corrosion potential

The LSI for the Red Hill WTW treated water is -4.7, indicative of a serious corrosion risk.

4.1.5 Indicators of pollution

None of the samples supplying the Red Hill WTW showed any signs of anthropogenic or agricultural pollution.

4.1.6 Fitness for agricultural use

The water supplying, and being supplied by the Red Hill WTW poses no danger for irrigation use or livestock watering.

4.2 **Hutt's Gate Water Treatment Works: sources and supplies**

4.2.1 Description of water sources and supply system

The Hutt's Gate WTW is located in the centre of the Island in the settlement of Hutt's Gate. It is currently supplied by a network of surface water sources, springs and one borehole. Water is also often pumped from the Grape Vine Gut reservoir (samples GV1 and GV2, see section 4.1 above). As part of Connect's drought mitigation strategy, a transfer system has been installed from two boreholes in Fisher's Valley and infrastructure is also in place to obtain water from Shark's Valley and Borehole 5 in Dry Gut if required. Water from the latter two sources is pumped up to the Fisher's Valley pump station balancing tank, and thence to the Hutt's Gate WTW (Figure 1).

Surface water

- Upper and Lower Legg's Gut;
- Fig Tree Gut;
- Grape Vine Gut (when needed);
- Shark's Valley (when needed).

Springs

- Upper Wells;
- Lower (Bottom) Wells;
- Jimmy Lots (in future).

Groundwater

- Willowbank;
- Fisher's Valley (when needed);
- Borehole 5 (when needed).

The Legg's Gut, Fig Tree Gut, Upper and Lower Wells and Willowbank sources are all located in the upper tributaries of the Shark's Valley catchment draining the north-eastern slopes of Diana's Peak (Figure 1). The Fisher's Valley, Shark's Valley and Borehole 5 sources are located in the mid-valley reaches on the dry eastern side of the Island (Figure 1).

The catchment area above the Hutt's Gate WTW is characterised by flax, while the area around the WTW is mainly pasture land, with some exotic forestry plantations and dense forest in the valley (Plate 3). Further east, the landscape becomes drier and the vegetation in the mid-valley sections of

Shark's, Fisher's and Dry Gut valleys is typified by bare ground, low scrub and some invasive woodland, especially along the water courses (Plate 4). Some wetlands are present along the broad floor of Fisher's Valley close to the location of the boreholes (see photo in Sample Log). Some arable agriculture is practised in Fisher's Valley (Longwood, Tobacco Plain) and Shark's Valley (below Levelwood and Silver Hill).



Plate 3: Vegetation around the Willowbank borehole



Plate 4: Typical vegetation cover in Shark's Valley. Note dense infestation of wild mango in the watercourse

Water from the Hutt's Gate WTW supplies the following communities: Alarm Forest, Hutt's Gate, Longwood, Bottom Woods and Deadwood.

4.2.2 Water chemistry and compliance with water quality standards

The water from Legg's Gut (LG4), Upper and Lower (Bottom) Wells (UW5, BW3) is chemically the same with respect to cations, anions and dissolved metals, while the Willowbank borehole water (WB6) has significantly higher levels of sodium chloride salts and lower iron, as might be expected in a groundwater sample (Figure 3 and Table 3). This is confirmed by the results of the sample taken in 2015. Since water from the Willowbank borehole is pumped on a daily basis to cover the deficit of water abstracted from the springs feeding the Hutt's Gate WTW, it is unsurprising that the treated water from the Hutt's gate WTW is very similar to the Willowbank water quality (Figure 3).

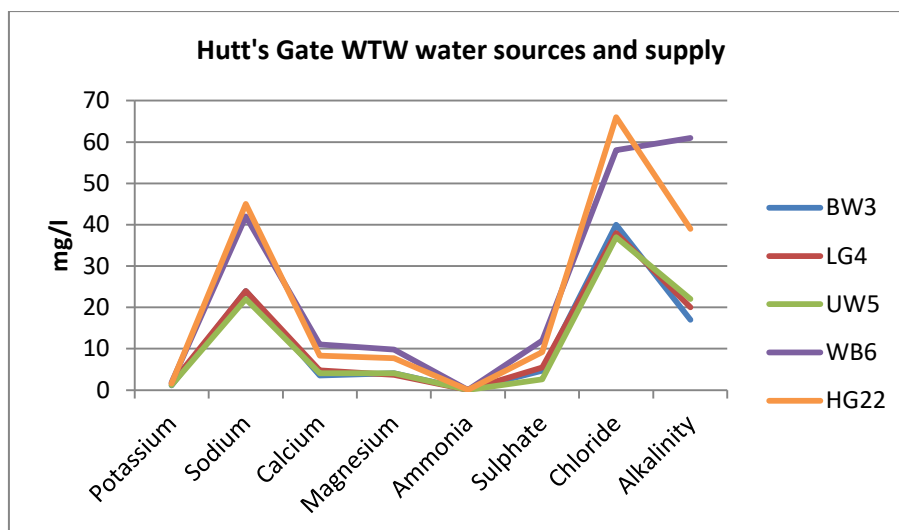


Figure 3: Hutt's Gate WTW water quality: major anions and cations

Table 3: Hutt's Gate WTW water quality results (in mg/l except where indicated)

	EPO/ WHO/ EU drinking water standard	SANS 241:2015	TWQR (no adverse aesthetic or health effects)	BW3	LG4	UW5	WB6	HG22
Potassium			0-50	1.1	1.6	1.2	1.8	1.6
Sodium		200	0-100	24	24	22	42	45
Calcium			0-32	3.5	4.8	4.1	11	8.3
Magnesium			0-30	4.1	3.7	4.1	9.8	7.7
Ammonia		1.5	0-1	0.09	0.08	0.07	0.08	0.06
Sulphate		500	0-200	4.7	5.5	2.6	12	9.2
Chloride	250	300	0-100	40	38	37	58	66
Alkalinity				17	20	22	61	39
Nitrate + nitrite		11	0-6	<0.1	<0.1	<0.1	0.4	0.1
Orthophosphate				<0.05	<0.05	0.06	0.12	0.05
Conductivity (mS/m)	250	170	0-70	19	18	18	34	32
pH (units)		5-9.7		6.9	7.3	7.3	7.4	7.7
Aluminium	0.2	0.3	0-0.15	0.06	0.02	0.02	<0.01	0.03
Boron	1	2.4		0.04	0.03	0.03	0.05	0.04
Copper	2	2	0-1	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	0.2	0.3	0-0.1	0.46	0.22	0.63	0.04	0.12
Lead (µg/l)	10	10	0-10	<0.5	<0.5	<0.5	<0.5	<0.5
Manganese	0.05	0.1	0-0.05	0.02	<0.01	0.02	0.03	<0.01
Zinc	5	5	0-3	<0.01	<0.01	<0.01	<0.01	0.02

Red shading indicates that the value exceeds the drinking water standards; yellow shading indicates where the value exceeds the TWQR for adverse health and aesthetic effects.

The Upper Wells (UW5) and Lower Wells (BW3) samples significantly exceed the guideline limits for **iron**, while the Legg's Gut (LG4) sample exceeds the EPO, WHO and EU limit of 0.2 mg/l, but is within the SA limit (highlighted in red in Table 3). The evidence of the high iron content can be seen below the Lower (Bottom) Wells and Legg's Gut pipe outlets at the Hutt's Gate reservoir (see photos in Sample Log). However, the treated water supplied to customers is within the guideline limit for potable water for iron.

4.2.3 Health and aesthetic effects

The iron concentration in the Willowbank water (WB6) will have no adverse health or aesthetic effects, but the Legg's Gut (LG4) and treated water (HG22) could have a slight metallic taste and there is a small risk of iron deposition on plumbing, as the iron concentrations fall in the range 0.1 to 0.3 mg/l (Table 3). The iron present in the Upper and Lower Wells water (UW5 and BW3) will give it a distinct taste and deposits on plumbing are likely, however there are no adverse health effects at this concentration (0.3 to 1.0 mg/l).

4.2.4 Corrosion potential

The LSI for the Hutt's Gate WTW treated water is -4.1, indicative of a serious corrosion risk.

4.2.5 Indicators of pollution

None of the samples supplying the Hutt's Gate WTW showed any signs of anthropogenic or agricultural pollution (Table 3).

4.2.6 Fitness for agricultural use

The water from all the sources described above can be used for irrigation and livestock use without any adverse effects.

4.3 **Levelwood Water Treatment Works: sources and supply**

4.3.1 Description of water sources and supply system

The Levelwood WTW is currently only supplied with water being gravity fed from Deep Valley to a reservoir at the WTW (Figure 1 and Plate 5), but it is possible that water from the Jimmy Lot's spring could be pumped to the Levelwood WTW in future. The Levelwood WTW is situated in the south-east of the Island on a ridge between Deep Valley and Pleasant Valley (Figure 1). Deep Valley has its origins high up on the south-east flank of Diana's Peak and the vegetation in the upper catchment is dominated by flax. The middle section of the valley around the WTW is largely covered with exotic plantations.



Plate 5: Levelwood reservoir, with the WTW located below the green tanks.

Treated water from the Levelwood WTW supplies the communities of Silver Hill, Levelwood and Sandy Bay.

4.3.2 Water chemistry and compliance with water quality standards

Given that there is only once source of water entering the WTW (LW8), it would be expected that the treated water (LW20) would have a similar chemical signature, but sodium, chloride and iron are all noticeably higher in the treated water sample (Figure 4 and Table 4).

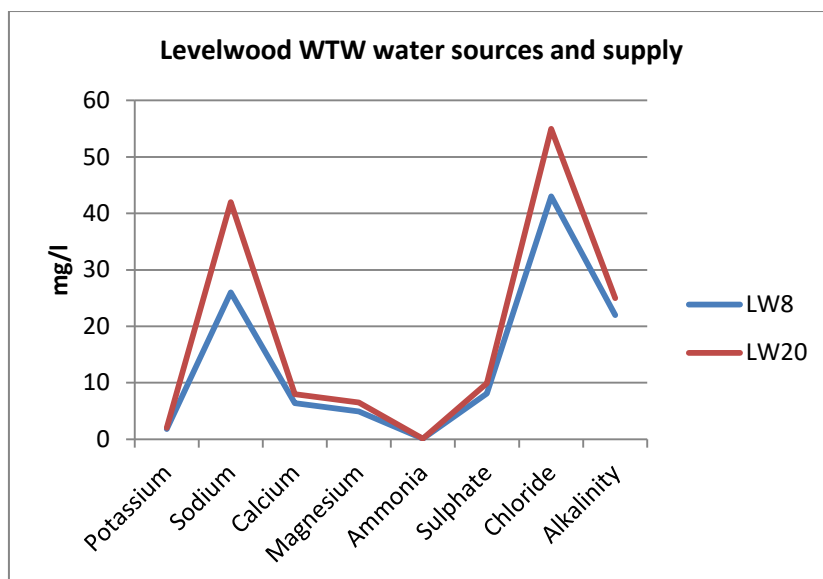


Figure 4: Levelwood WTW water quality: major anions and cations

Table 4: Levelwood WTW water quality results (in mg/l except where indicated)

	EU/ WHO /EU Drinking water standard	SANS 241:2015	TWQR (no adverse aesthetic or health effects)	LW8	LW20
Potassium			0-50	1.8	2
Sodium		200	0-100	26	42
Calcium			0-32	6.4	8
Magnesium			0-30	4.9	6.5
Ammonia		1.5	0-1	0.08	0.09
Sulphate		500	0-200	8.1	9.9
Chloride	250	300	0-100	43	55
Alkalinity				22	25
Nitrate + nitrite		11	0-6	<0.1	<0.1
Orthophosphate				0.1	0.1
Conductivity (mS/m)	250	170	0-70	21	26
pH (units)		5-9.7		7.5	7.4
Aluminium	0.2	0.3	0-0.15	0.07	0.05
Boron	1	2.4		0.04	0.04
Copper	2	2	0-1	<0.01	<0.01
Iron	0.2	0.3	0-0.1	0.15	0.24
Lead (µg/l)	10	10	0-10	<0.5	0.6
Manganese	0.05	0.1	0-0.05	<0.01	<0.01
Zinc	5	5	0-3	<0.01	0.04

Red shading indicates that the value exceeds the drinking water standards; yellow shading indicates where the value exceeds the TWQR for adverse health and aesthetic effects.

The **iron** content in the treated water is over the EPO/WHO/EU recommended guideline limit of 0.2 mg/l, but within the SA standard of 0.3 mg/l (Table 4).

4.3.3 Health and aesthetic effects

Iron concentrations in the range 0.1 to 0.3 mg/l, as found in the Levelwood water, will give the water a very slight metallic taste and possibly cause iron staining and deposition on plumbing. However there are no adverse health effects associated with this level of iron.

4.3.4 Corrosion potential

The LSI for the Levelwood WTW treated water is -4.3, indicative of a serious corrosion risk.

4.3.5 Indicators of pollution

The water from Deep Valley which supplies the Levelwood WTW does not show any signs of anthropogenic or agricultural pollution (Table 4).

4.3.6 Fitness for agricultural use

The water supplied by the Levelwood WTW is suitable for livestock watering and irrigation.

4.4 **Jamestown Water Treatment Works: sources and supply**

4.4.1 Description of water sources and supply system

The Jamestown WTW (also known as Chubb's Spring) is supplied from four springs in the valley upstream of the plant: Black Bridge (BB15), Drummond's Point (DP16), Tom Peters (TP17) (Figure 1) and the Hambess spring (not sampled). The Jamestown WTW can also receive water via gravity feed from the Scott's Mill reservoir below the Red Hill WTW.

The catchment above the springs is severely disturbed with residential areas, roads, the Prince Andrew School and playing fields, Harper's reservoirs and associated water supply infrastructure, intensive agriculture (open and in tunnels), dense forest, rough scrubby vegetation and bare mountain slopes (Plate 6).



Plate 6: Catchment above Jamestown WTW supply springs showing Prince Andrew school and playing fields, pasture land and plantations



Plate 7: Jamestown WTW (black tank on lower right of photo), showing valley where Black Bridge, Drummond's Point and Tom Peters springs are located

The Jamestown WTW is located on the edge of The Briars residential area and it supplies this suburb, as well as Jamestown and Rupert's Valley (Plate 7).

4.4.2 Water chemistry and compliance with water quality standards

The water from the Black Bridge (BB15) and Tom Peters (TP17) springs is chemically similar in terms of the major cations and anions (Figure 5 and Table 5), but Black Bridge has a high iron concentration (0.61 mg/l) which exceeds the EPO/WHO/EU limit of 0.2 mg/l. This in turn seems to impact the iron concentration in the treated water from the WTW, which at 0.16 mg/l is higher than the other waters supplying this plant. Black Bridge water also has elevated aluminium, which again has an impact on the overall water quality of the treated sample (Table 5).

The water from the Drummond Point spring (DP16) is somewhat different and reflects a different geochemical provenance with elevated sodium chloride salts, and thus a high electrical conductivity (Figure 5 and Table 5). None of these values are over the prescribed limits, but they exceed the TWQR for no aesthetic or health effects (see section 4.4.3 below).

The Drummond Point water clearly has an impact on the overall quality of the treated water (JT21), which shows elevated chloride levels compared to other sampled water sources.

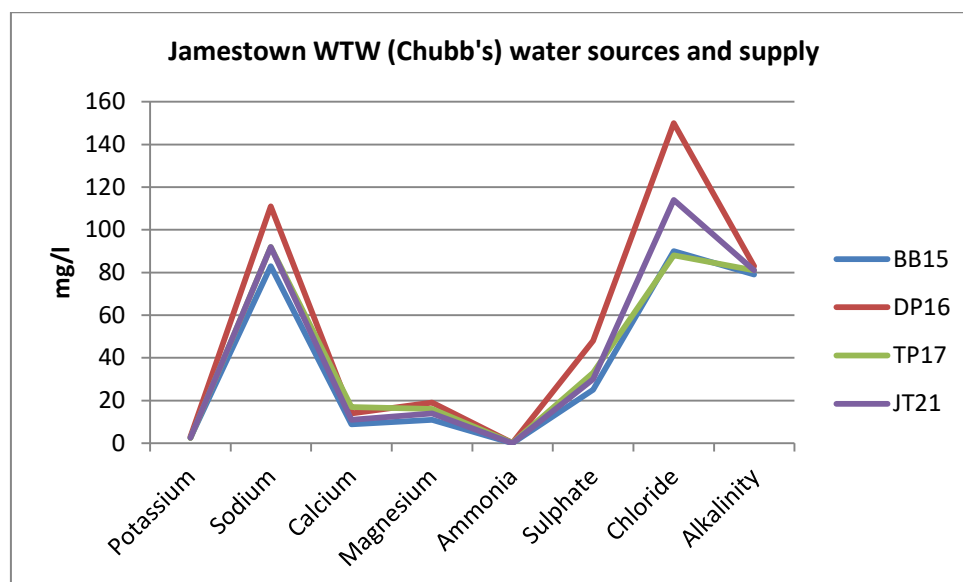


Figure 5: Jamestown WTW water quality: major anions and cations

Table 5: Jamestown WTW water quality results (in mg/l except where indicated)

	EPO/ WHO/ EU drinking water standard	SANS 241:2015	TWQR (no adverse aesthetic or health effects)	BB15	DP16	TP17	JT21
Potassium			0-50	2.6	3	2.4	2.5
Sodium		200	0-100	83	111	92	92
Calcium			0-32	8.8	14	17	11
Magnesium			0-30	11	19	16	14
Ammonia		1.5	0-1	0.08	0.09	0.09	0.07
Sulphate		500	0-200	25	48	33	30

	EPO/ WHO/ EU drinking water standard	SANS 241:2015	TWQR (no adverse aesthetic or health effects)	BB15	DP16	TP17	JT21
Chloride	250	300	0-100	90	150	88	114
Alkalinity				79	83	81	81
Nitrate + nitrite		11	0-6	<0.1	0.6	0.6	0.3
Orthophosphate				0.18	0.13	0.15	0.14
Conductivity (mS/m)	250	170	0-70	50	74	52	58
pH (units)		5-9.7		8	7.8	7.8	7.9
Aluminium	0.2	0.3	0-0.15	0.18	<0.01	0.03	0.08
Boron	1	2.4		0.12	0.1	0.07	0.1
Copper	2	2	0-1	<0.01	<0.01	<0.01	<0.01
Iron	0.2	0.3	0-0.1	0.61	<0.01	<0.01	0.16
Lead (µg/l)	10	10	0-10	<0.5	<0.5	<0.5	<0.5
Manganese	0.05	0.1	0-0.05	<0.01	<0.01	<0.01	<0.01
Zinc	5	5	0-3	<0.01	<0.01	<0.01	0.03

Red shading indicates that the value exceeds the drinking water standards; yellow shading indicates where the value exceeds the TWQR for adverse health and aesthetic effects.

4.4.3 Health and aesthetic effects

The Drummonds Point sample (DP16) has a **sodium** concentration of 111 mg/l which may make the water taste faintly salty.

Chloride levels in the range 100-200 mg/l, as found in DP16 and the treated water (JT21), do not have any adverse health or aesthetic (taste) effects, but values over 50 mg/l (all samples), together with a high conductivity are indicative of a serious potential for corrosion (see s 4.4.4 below).

Conductivity levels higher than 45 mS/m as evident in all samples may give the water a slightly salty taste, but there are otherwise no adverse effects.

The **aluminium** concentration in the Black Bridge water (BB15) is just within the EPO/WHO/EU drinking water guideline limit of 0.2 mg/l, but it could have a noticeable impact on water colour, especially in the presence of iron, as is the case with this water source. Although intake of aluminium from this source alone could exceed the 5% dietary guideline (DWAF, 1996), the concentration of aluminium in the treated water from this plant (JT21) is well within the TWQR for no aesthetic or health effects.

As noted above, the Black Bridge sample (BB15) has an **iron** concentration of 0.61 mg/l which will cause an impact on taste and possible deposition on plumbing, but no adverse health effects. The iron concentration in the final treated water is 0.16 mg/l which could result in a very slight effect on taste (JT21).

4.4.4 Corrosion potential

The LSI for the Jamestown WTW treated water is -3.8, indicative of a serious corrosion risk, primarily due to the contribution of water with elevated sodium chloride from the Drummond Point source (Table 5). Water from the Jamestown WTW supplies Rupert's Valley where the new Bulk Fuel Facilities (BFI) for the Island and airport are being constructed. One of the main concerns of the design engineers and fuel management contractor is the level of chloride in the treated water supply they use in the firefighting systems for the fuel facilities. A chloride concentration of less than 50 mg/l would be optimal, but less than 100 mg/l could be tolerated. It is recommended that consideration needs to be given to the water supply operating system to see if the contribution of water from Drummond Point could be reduced, or greater dilution could be achieved for the Rupert's valley supply.

4.4.5 Indicators of pollution

The water from the Jamestown WTW does not show any signs of anthropogenic or agricultural pollution (Table 5).

4.4.6 Fitness for agricultural use

The sources to and water supplied from the Jamestown WTW are categorised as Class II water for irrigation, in terms of salinity, chloride and sodium. A small reduction in yield can be expected in salt-sensitive crops. It is therefore recommended that farmers use a low frequency drip or flood irrigation system and avoid foliar sprays. The water is suitable for livestock.

4.5 **Untreated water supplies**

4.5.1 Jimmy Lots

Water is fed by gravity from the Jimmy Lots spring in Warren's Gut to a tank next to the road near Woody Ridge (Figure 1). Warren's Gut flows off one of the east-facing slopes of Diana's Peak and the catchment is mostly under flax. The water is used for irrigation in Longwood and on Tobacco Plain (Plate 8), however, there are plans to pump water from the Jimmy Lots spring to either the Hutt's Gate or Levelwood WTWs in future.



Plate 8: View of the Longwood agricultural area from the Jimmy Lots tank near Woody Ridge

The water is good quality, with no sign of any anthropogenic pollution, except for a high iron content (0.8 mg/l), which exceeds the guideline limits for drinking water on the grounds that it will impart a

distinctly metallic taste to the water and cause problems with plumbing (Table 6 and Figure 6). However, there would be no adverse health effects at this concentration.

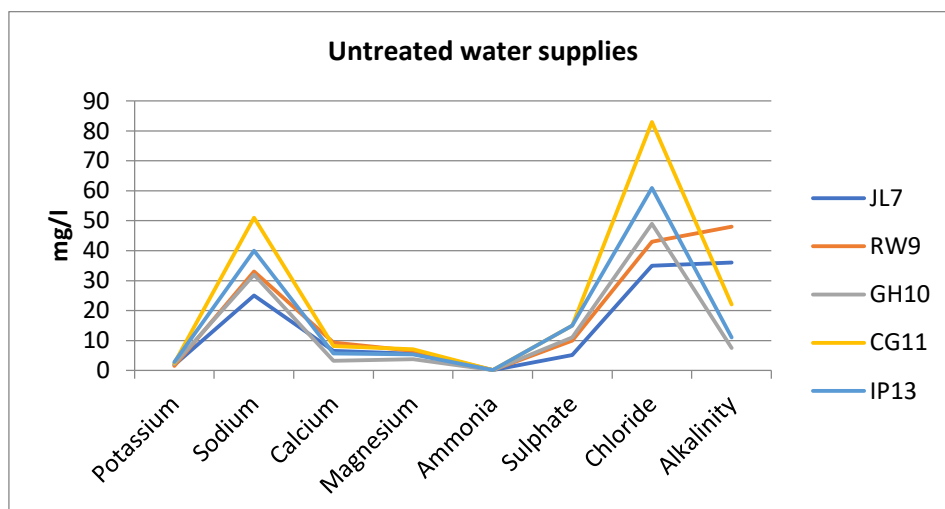


Figure 6: Untreated water sources: major anions and cations

Table 6: Water quality of untreated supplies (in mg/l except where stated)

	EPO/ WHO/ EU drinking water standard	SANS 241:2015	TWQR (no adverse aesthetic or health effects)	JL7	RW9	GH10	CG11	IP13
Potassium			0-50	1.8	1.5	2.1	2.5	2.8
Sodium		200	0-100	25	33	32	51	40
Calcium			0-32	6.5	9.3	3.2	8.1	5.7
Magnesium			0-30	5.6	6.5	3.7	7.1	5.3
Ammonia		1.5	0-1	0.09	0.08	0.08	0.08	0.06
Sulphate		500	0-200	5.1	10	11	15	15
Chloride	250	300	0-100	35	43	49	83	61
Alkalinity				36	48	7.5	22	11
Nitrate + nitrite		11	0-6	<0.1	<0.1	<0.1	0.4	1.4
Orthophosphate				0.07	0.13	0.1	0.08	0.08
Conductivity (mS/m)	250	170	0-70	20	26	22	36	28
pH (units)		5-9.7		7.6	7.9	6.9	7.4	7
Aluminium	0.2	0.3	0-0.15	0.03	0.02	0.07	<0.01	<0.01
Boron	1	2.4		0.03	0.04	0.04	0.07	0.07
Copper	2	2	0-1	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	0.2	0.3	0-0.1	0.8	0.04	0.07	<0.01	<0.01
Lead (µg/l)	10	10	0-10	<0.5	<0.5	<0.5	<0.5	4
Manganese	0.05	0.1	0-0.05	<0.01	<0.01	<0.01	<0.01	0.17
Zinc	5	5	0-3	<0.01	<0.01	<0.01	0.04	0.02

Red shading indicates that the value exceeds the drinking water standards; yellow shading indicates where the value exceeds the TWQR for adverse health and aesthetic effects.

The water is suitable for irrigation with low concentrations of the main salts: sodium and chloride. Iron, at the levels present, is not toxic to plants.

The corrosion potential is serious, with a LSI of -4.2.

4.5.2 Rockwater

The Rockwater spring is found in one of the small lower tributaries of Mount Pleasant (Figure 1). There was very little flow at the time of sampling and the water in the small weir contained green algae (see photo in Sample Log). The catchment valley is densely vegetated (Plate 9). Raw water from this source supplies the western parts of Sandy Bay, where it is used for irrigation and domestic use.



**Plate 9: The overgrown
Rockwater catchment**

In spite of the presence of some algae, the quality of water from this source is good and it is compliant with the drinking water guidelines, with no adverse aesthetic or health effects (Figure 6 and Table 6). No signs of pollution are evident and the water is suitable for all crops and livestock watering. However, there is a serious risk of corrosion, with an LSI of -3.8.

4.5.3 Green Hill

Water is piped via gravity from Wash's Gut to a holding tank at Green Hill, where sample GH10 was collected. Wash's Gut forms one of the upper tributaries of Powell's Valley draining the southern slopes of Diana's Peak (Figure 1). The catchment area is mostly covered with flax, but there is some arable and pasture land. Water from this source supplies the Green Hill area (Plate 10).

The water quality is good and complies with all the drinking water standards and it does not have any adverse aesthetic or health effects (Table 6 and Figure 6). There is no evidence of nutrient pollution and the water is suitable for agriculture. However, it has a very high LSI of -5.2, which indicates a serious corrosion potential.



Plate 10: View of the Green Hill area

4.5.4 Frenches Gut boreholes and Cason's Gate (CG11)

Two boreholes have been developed in Frenches Gut at the upper end of Lemon Valley on the west side of the Island (Figure 1). The boreholes are located 100 m apart in pastureland, with one being a vertical hole to 30 m; the other is an artesian source accessed via a horizontal hole (Plates 11 and 12). Raw water from this source is supplied to the communities of Blue Hill, Head O'Wain, Burnt Rock, Horse Pasture and Thompson's Wood, as well as to the public tap at the Cason's Gate parking area (where the sample was collected).



Plate 11: The outlet of the horizontal borehole in Frenches Gut. Note oily film on the water surface



Plate 12: Pastureland surrounding the Frenches Gut boreholes

The quality of water is good and complies with all the drinking water guidelines, but slightly higher sodium and chloride values suggest that the water is in contact with saline volcanic rocks (Figure 6 and Table 6). The water presents no adverse health or aesthetic effects and is suitable for agriculture, although very salt sensitive plants may be slightly affected. The 2018 results compare favourably with the results obtained in 2015, except for zinc which is higher (but still within limits) and bicarbonate.

During sample collection, a film of hydrocarbons was evident on the surface of pools lying below the borehole outlet (Plate 11). The source of this is unknown and could be from servicing the boreholes; it is unlikely that the water itself is polluted.

The corrosion potential for this water is serious with a LSI of -5.2.

4.5.5 Iron Pot

The Iron Pot borehole is located in one of the upper tributaries of Lemon Valley, just below Cason's Gate (Figure 1). Water is pumped from this borehole to a holding tank near Cason's (Gold Mine Tank), from where raw water is supplied to High Point, St Pauls and Blueman's Field. Land use around the borehole comprises pasture and forestry plantations.

In the sample analysed at the CSIR in 2018, manganese exceeds the allowable EPO/WHO/EU and SA limits at 0.17 mg/l (Table 6). At this level, the water is tolerable taste-wise, but could cause slight staining of laundry and plumbing. No health effects are expected. It is likely that the source of the manganese is natural, rather than anthropogenic at the concentrations found here. Indeed, the 2015 sample analysis showed a much lower manganese concentration at 0.05 mg/l, but in all other respects the 2015 and 2018 results were similar. The water is fit to use for agriculture, but there is a serious risk of corrosion – the LSI for the Iron Pot water is -5.9.

4.6 **Potential future water sources**

4.6.1 Description of water sources

Borehole 5, Shark's and Fisher's Valleys have been identified as potential future water supply sources.

Borehole 5 was drilled in Dry Gut by Basil Read in 2012 as part of the programme to find sufficient water to use to compact the Dry Gut rockfill for the airport runway extension. The borehole yields a constant supply of good quality water and has thus been retained by Connect to provide water in times of drought (Plate 13). The water in the borehole must emanate from high up on Diana's Peak and flow rapidly towards the borehole because the quality of the water is far superior to any of the other boreholes drilled close by in Dry Gut. However, the quality is susceptible to long contact with the underlying geology, showing a marked increase in salinity when pumping stops for a few days. The water quality thus improves with increased pumping.

The Shark's Valley water abstraction point is located near Levelwood (Figure 1). Shark's Valley has quite a large catchment, draining the eastern slopes of Diana's peak. The main tributaries include Warren's Gut, Pleasant Valley and Taglate Valley. Catchment land use and vegetative cover comprises flax on the upper slopes of the mountain, with extensive agricultural land (arable and pasture), plantations and alien vegetation on the mid-slopes. Further downstream the valley slopes are largely bare or support sparse scrubby plants, while the river valley is choked with wild mango (Plate 4). The settlements of Woody Ridge, Silver Hill and Levelwood are situated in this catchment.

Fisher's Valley is a large catchment draining the eastern side of the Island, with tributaries rising high on the eastern slopes of Diana's Peak. The main tributary is Beale's Valley. The upper catchment,

above the Hutt's Gate WTW is largely composed of flax and some plantations. As one moves away from the higher slopes, agriculture (pasture and arable) becomes quite dominant in the landscape, which in turn merges into Crown wastes and sparsely vegetated slopes as one moves downstream (Plate 14). The two boreholes in Fisher's valley lie upstream of Cook's Bridge, in pasture land upstream of the wetland area (Figure 1).



Plate 13: Connect collecting Borehole 5 water at the Fire Water tank in February 2017 as part of the drought relief strategy



Plate 14: Typical vegetation in Fisher's Valley

A pump station and balancing tank are located next to the boreholes in Fisher's Valley to pump water from these boreholes up to the Hutt's Gate WTW and/or Longwood Reservoirs in times of drought. Direct pipelines have also been laid from the Borehole 5 holding tank (Airport Fire Tank) and Shark's Valley to allow water to be pumped up to the Fisher's Valley balancing tank during drought periods.

4.6.2 Water chemistry and compliance with drinking water standards

Borehole 5 water complies with all the drinking water standards when it is being pumped on a regular basis as mentioned above. If it is allowed to stay in contact with the underlying geology for a few days, it becomes noticeably saltier and unfit to drink.

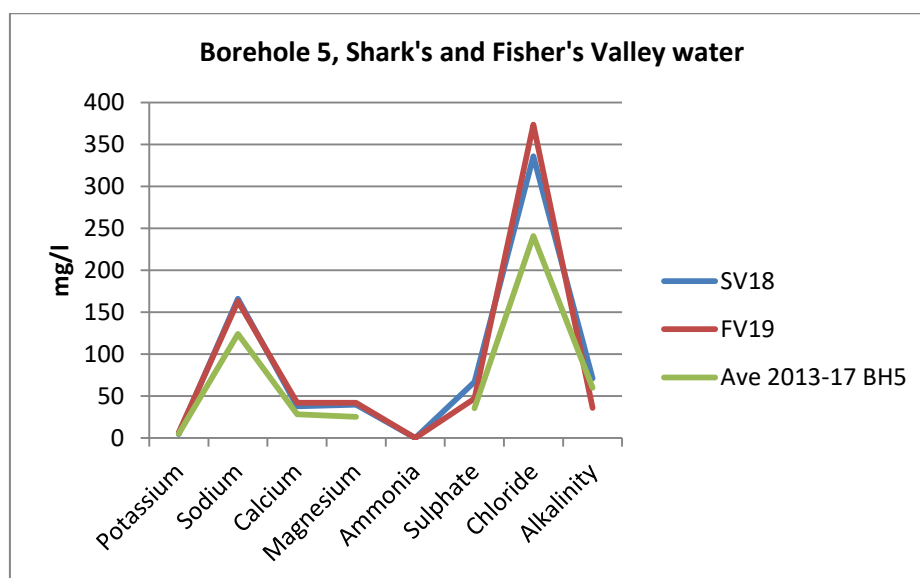


Figure 7: Shark's and Fisher's Valleys water quality: major anions and cations

Table 7: Water quality results for Shark's and Fisher's Valleys (all results in mg/l except where shown)

	EPO/ WHO/ EU drinking water standard	SANS 241:2015	TWQR (no adverse aesthetic or health effects)	SV18	FV19	Ave 2013-18 BH5
Potassium			0-50	4.6	6.7	4.9
Sodium		200	0-100	166	163	124
Calcium			0-32	38	42	28.3
Magnesium			0-30	40	42	25.3
Ammonia		1.5	0-1	0.1	0.09	Nd
Sulphate		500	0-200	67	47	35.8
Chloride	250	300	0-100	336	374	241
Alkalinity				71	36	60
Nitrate + nitrite		11	0-6	1	4.9	3.6
Orthophosphate				0.12	0.15	Nd
Conductivity (mS/m)	250	170	0-70	132	136	106
pH (units)		5-9.7		8	7.3	7.8
Aluminium	0.2	0.3	0-0.15	0.03	0.02	Nd
Boron	1	2.4		0.11	0.09	Nd
Copper	2	2	0-1	<0.01	<0.01	Nd
Iron	0.2	0.3	0-0.1	<0.01	<0.01	Nd
Lead (µg/l)	10	10	0-10	<0.5	<0.5	Nd
Manganese	0.05	0.1	0-0.05	<0.01	<0.01	Nd
Zinc	5	5	0-3	<0.01	<0.01	Nd

Nd: not determined

Red shading indicates that the value exceeds the drinking water standards; yellow shading indicates where the value exceeds the TWQR for adverse health and aesthetic effects.

The water chemistry from Sharks' and Fisher's Valleys is very similar as shown in Figure 7 and Table 7. The water quality is noticeably poorer than any of the other sampled sources, with very high chloride and elevated sodium, calcium and magnesium. This is confirmed by the results of the 2015 sample taken from Fisher's Valley boreholes. The presence of these salts means that the electrical conductivity is also elevated (Figure 7 and Table 7). This is fairly typical of groundwater and surface water on the eastern side of the Island and is indicative of the underlying geology and highly saline soils found in this part of the Island.

The chloride values over 300 mg/l do not comply with the drinking water standards, and while the other elevated elements do comply, they are at levels where aesthetic effects may be observed.

4.6.3 Health and aesthetic effects

Sodium values higher than 100 mg/l and chloride over 300 mg/l will give the water a slight salty taste. Calcium and magnesium exceed the TWQR of 0-32 and 0-30 mg/l respectively, which could result in scaling and inhibit soap lathering, but no adverse health impacts would be expected.

4.6.4 Corrosion potential

The corrosion potential is high for all three sources of water with LSIs of -2.8, -4.2 and -4.9 for Borehole 5, Shark's Valley and Fisher's Valley respectively.

4.6.5 Indicators of pollution

There are no signs of nutrient enrichment from septic tanks or agriculture in either water sample.

4.6.6 Fitness for agricultural use

The high concentrations of sodium, chloride and the high conductivity of all three water sources indicate that this water is classed as Class III or IV for irrigation purposes. Even moderately salt-tolerant crops grown using this water could have a reduced yield and water application should be by drip or flood irrigation, rather than foliar sprays. The water is suitable for livestock drinking without any adverse effects.

5 CONCLUSIONS

Generally the water quality supplied to consumers on St Helena Island is good, with only lead, iron and manganese exceeding the specified guideline limits for some of the current sources of water. The lead concentration in the Lady's Bath spring water is a concern as it could cause behavioural changes and neurological impairment in small children if consumed over a period of time, especially if they are also in contact with other sources of lead, such as old lead-based paints and leaded petrol fumes. However, the relatively small contribution of the Lady's Bath spring to the overall supply to the Red Hill WTW means that the lead concentration in the treated water supplied to the public ***is well within the prescribed limits.***

There are non-compliant levels of iron in the Grape Vine Gut 1, Harpers 14, Upper and Lower (Bottom) Wells, Legg's Gut, Levelwood WTW, Black Bridge and Jimmy Lots samples, but only the Levelwood WTW water is supplied directly to consumers for drinking water. This water will have a slight metallic taste and may cause staining on plumbing (Figure 8). However, at the levels found on the Island, the iron concentrations will have no adverse effects on health, irrigated crops or livestock.

Manganese levels are non-compliant in two samples: Harpers 2 reservoir and Iron Pot. In both cases the source is likely to be natural and there would be no adverse health effects at these levels. The main impact will be on taste (minor) and possible staining of laundry.

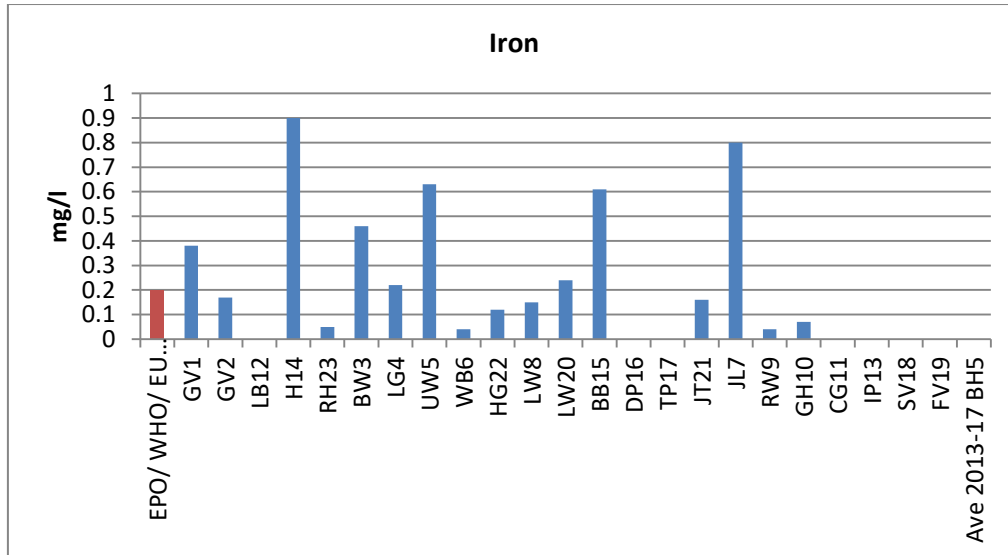


Figure 8: Iron concentrations in all water samples compared to the guideline limit for drinking water

The conductivity of all samples is within the target water quality range of 0-170 mS/m, but the levels are over the aesthetic limit of no adverse effects of 70 mS/m in the Drummond Point (DP16) source and the potential new supplies in Fisher's and Shark's Valleys and Borehole 5 (Figure 9). The salinity is caused by natural sodium chloride salts found in the volcanic rocks and soils of the Island, especially on the dry eastern side. However, the salinity levels of these samples should give no cause for concern for drinking water quality, but may have an impact on irrigated crops. All the WTWs are compliant with regard to sodium, chloride and conductivity levels.

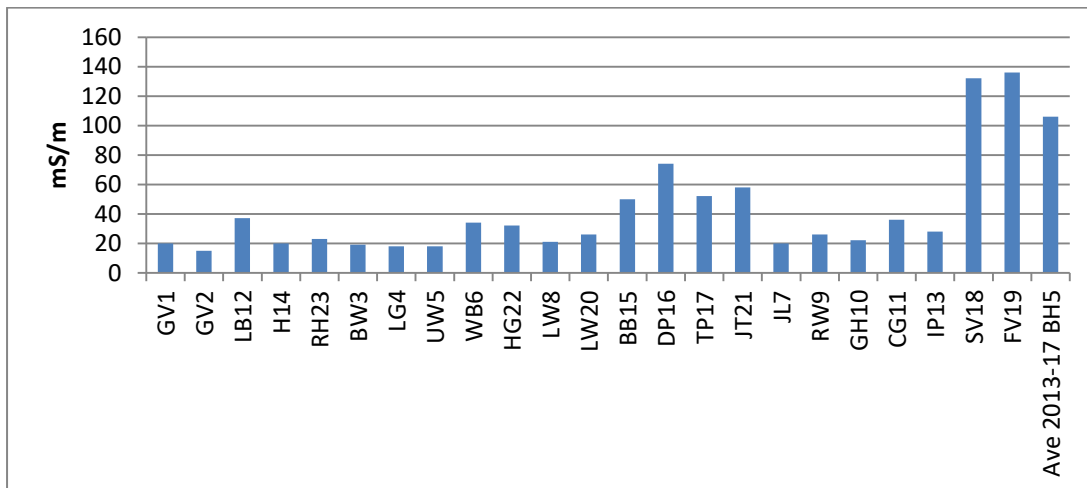


Figure 9: Conductivity of all samples

The pH of all samples analysed fell within the specified range for drinking water of 5 – 9.7 as shown in Figure 10. The lowest pH was encountered in Lady's Bath (LB12) at 6.6 and the highest (8.0) was found in Black Bridge (BB15) and Shark's Valley (SV18).

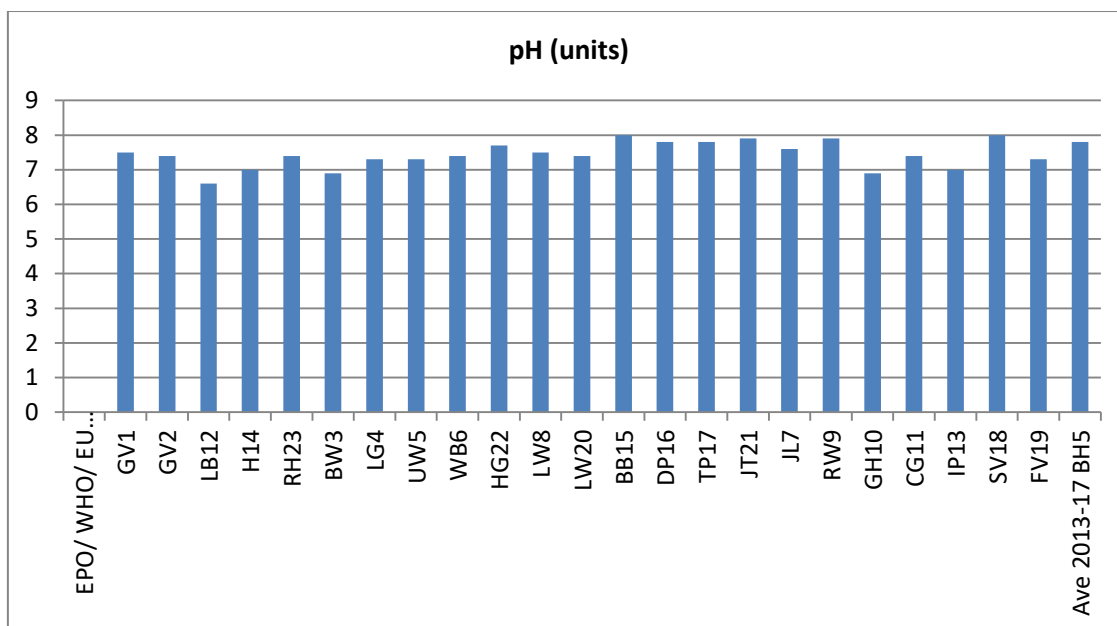


Figure 10: pH of all water analysed.

All of the water sources analysed had very low calcium and bicarbonate, except for the Shark's and Fisher's Valley sources. Very low calcium and bicarbonate, in combination with relatively high sodium and chloride salinity will result in water that is under-saturated with calcium carbonate, thus exposing metal pipes, fixtures and fittings to serious corrosion. The Langelier Saturation Index results for the water supplied directly to consumers are shown in Table 8 below. As mentioned in section 3.5.3, the ideal value where water is chemically balanced is 0.0, but any values between -0.3 and +0.3 indicate that the water is tolerable in terms of corrosion and scaling respectively. Values over -0.5 indicate that serious corrosion could occur.

Table 8: Langelier Saturation Index scores for all water supplied to customers

Water source	LSI
Red Hill WTW	-4.7
Hutt's Gate WTW	-4.1
Levelwood WTW	-4.3
Jamestown WTW	-3.8
Jimmy Lots	-4.2
Rockwater	-3.8
Green Hill	-3.8
Frenches Gut boreholes	-5.2
Iron Pot	-5.9
Shark's Valley	-4.2
Fishers' Valley	-4.9
Borehole 5	-2.8

None of the samples collected appeared to contain high levels of sediment; a few contained slight amounts of organic material, as noted in the sample log, and most were clear in colour.

6 RECOMMENDATIONS

Several recommendations arise from this report relating to the immediate actions that need to be taken, the Phase 2 study and the purchase of reagents for the analytical equipment.

6.1 Immediate actions

Following receipt of the sample results, Connect was alerted to the high concentration of lead in the Lady's Bath spring water (LB12) and an investigation was launched to determine whether any lead pipes, old lead joint solders, or leaded brass and copper alloy fittings were present at the spring. None were found, but all old roof sheeting has been removed and a metal fence has been erected as part of planned maintenance works. This water must be sampled as part of the Phase 2 study (see below) to determine whether the result obtained during the February 2018 sampling exercise is anomalous or not. The result will determine the management actions that might need to be taken.

Some evidence of hydrocarbon pollution was observed in small puddles just below the Frenches Gut horizontal borehole. The source of this contamination needs to be investigated and any hydrocarbon leaks from pumps need to be repaired.

The high chloride level in the water supplied to Rupert's Valley from the Jamestown WTW is of concern to the BR design engineers and the fuel management contractor. Chloride concentrations over 100 mg/l could increase the risk of corrosion in the firewater tanks and fittings at the Bulk Fuel Installation in upper Rupert's and at the Bayside facility. This analysis indicates that the water from the Drummond Point source has a chloride concentration over 100 mg/l, which is influencing the overall quality of the Jamestown WTW treated water. It is recommended that various options be considered to reduce the contribution of water from the Drummond Point source to improve the quality of water with respect to chloride supplied to Rupert's Valley.

It is recommended that an investigation is carried out as to why the treated water from the Levelwood WTW has a higher salinity than the source of the incoming water. The results from the next sampling exercise will confirm this finding.

6.2 Phase 2 study

Based on the findings of this Phase 1 study, the phase 2 approach, as described in s. 3.1.2, should proceed as planned in August/September 2018. However, it is recommended that samples should be taken from the following sources in addition to the 23 samples collected during Phase 1: Harpers 1 and 3 (if full), the Oakbank, Osborne's, Gent's Bath, Callie's and Fish Pond springs (if accessible).

Copper, boron and zinc could be dropped from the analyses as all of the samples were well within the prescribed limits.

6.3 Analytical equipment

Connect has a Palintest Photometer 8000 analytical instrument, but no reagents at present. Table 9 shows the main elements of concern, the range found during this sampling episode and the reagent range available for the photometer. There are, however, some key determinants such as pH, conductivity, calcium and sodium which cannot be analysed with a photometer. For these elements, it is recommended that a Hach HQ440d multi-parameter benchtop meter (or similar) should be purchased together with the relevant probes.

Table 9: Reagents required for the Palintest Photometer 8000 instrument



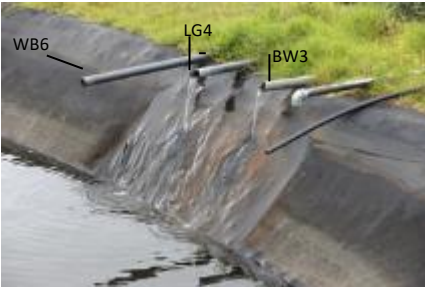
Water quality parameter	Range found on Island	Recommended reagent range (as per instrument manual)
Aluminium	<0.01 – 0.18	0 – 0.5
Ammonia	0.06 – 0.1	0 – 1
Bicarbonate	<0.01	0 - 12
Boron	0.3 – 0.12	0 – 2.5
Chloride	31 - 374	0 – 50,000
Copper	<0.01	0 – 5
Iron	<0.01 – 0.9	0 – 5
Lead	<0.5 – 20.8	??
Magnesium	3.7 - 42	??
Manganese	<0.01 – 0.17	0 – 0.03 (is there a reagent for a larger range?)
Nitrate + nitrite	<0.1 – 3.6	0 – 20
Potassium	0.9 – 6.7	0 - 100
Orthophosphate	<0.05 – 0.18	0 – 1.3
Sulphate	0 - 67	0 - 200
Zinc	<0.01 – 0.04	0 – 4
Total alkalinity	0 - 83	0 - 500



It is strongly recommended that these reagents are purchased as soon as possible so that future analyses can be done on-Island.

REFERENCES



- DWAF (1996). South African Water Quality Guidelines. Volume 1: Domestic Use. 2nd Edition. Department of Water Affairs and Forestry, Pretoria.
- DWAF (1993). South African Water Quality Guidelines. Volume 4: Agricultural Use. 2nd Edition. Department of Water Affairs and Forestry, Pretoria.
- Environmental Protection Ordinance (2016). St Helena Island.
- WHO (1984). Volume 2: Health Criteria and Other Supporting Information. World Health Organisation, Geneva.
- WHO (1993). Guidelines for Drinking Water Quality. 2nd Edition, Volume 1: Recommendations. World Health Organisation, Geneva.
- WHO (2015). Drinking Water Quality Guidelines. World Health Organisation, Geneva.



SAMPLE LOG

Sample location	Sample Code and Number	Type of water	Photo	Comments
Grape Vine Gut reservoir inflow pipe 1	GV1	Surface		Pipe 1 (GV1) is on the left (looking towards pipes); Note iron (orange) precipitation below Pipe 1, with less below Pipe 2 on right; Colour: clear Sediment: slight Supplies Red Hill WTW
Grape Vine Gut reservoir inflow pipe 2 (right)	GV2	Surface		Collecting sample from Pipe 2 (GV2); Colour: clear Sediment: more than GV1 Supplies Red Hill WTW
Hutt's Gate reservoir inflow pipe 1 from Lower (Bottom) Wells	BW3	Surface		BW3 (third pipe from left); Iron precipitation below pipe; Colour: pale yellow Sediment: slight Supplies Hutt's Gate WTW
Hutts Gate reservoir inflow pipe 2 from Upper and Lower Legg's Gut	LG4	Surface		LG4 (second pipe from left); Slight iron (orange) precipitation; Colour: very pale yellow Sediment: very slight Supplies Hutt's Gate WTW

Hutt's Gate raw water tank inflow pipe from Upper Wells	UW5	Surface and springs		<p>Colour: very pale yellow</p> <p>Sediment: none visible</p> <p>Supplies Hutt's Gate WTW</p>
Willowbank borehole holding tank	WB6	Groundwater		<p>Willowbank borehole pump;</p> <p>Water pumped to Hutt's Gate reservoir;</p> <p>Colour: clear</p> <p>Sediment: none visible</p> <p>Supplies Hutt's Gate WTW</p>



Jimmy Lots tank overflow pipe	JL7	Spring		<p>Water fed by gravity from Jimmy Lots spring in Warren's Gut; Untreated water used for irrigation only in Longwood and Tobacco Plain; Colour: clear Sediment: very slight Could be pumped to Hutt's Gate or Levelwood WTW in future;</p>
Levelwood reservoir inflow pipe	LW8	Surface		<p>Water gravity fed from Deep Valley to Levelwood reservoir (LW8); Colour: pale yellow Sediment: very slight Supplies the Levelwood WTW</p>

Inflow pipe to tank at Rockwater	RW9	Spring		<p>Rockwater weir with algae (green) and iron precipitation (orange);</p> <p>Very low flow, sample taken from tank;</p> <p>Provides raw water to western parts of Sandy Bay where used for irrigation and domestic use;</p> <p>Colour: clear</p> <p>Sediment: moderate</p>
Inflow pipe from Wash's Gut to Green Hill tank	GH10	Spring		<p>Water from Wash's Gut is fed by gravity to the Green Hill reservoir (GH10);</p> <p>Supplies untreated water to the Green Hill area;</p> <p>Colour: very pale yellow</p> <p>Sediment: slight</p>

Tap at Cason's Gate fed from Frenches Gut boreholes	CG11	Groundwater		<p>The tap at Cason's Gate parking area is fed from 2 boreholes in Frenches Gut (upper Lemon Valley);</p> <p>Boreholes supply Blue Hill, Head O'Wain, Burnt Rock, Horse Pasture, Thompson's Wood with untreated water;</p> <p>Boreholes 100m apart;</p> <p>One drilled to 30 m; the other is artesian (horizontal hole);</p> <p>Colour: clear</p> <p>Sediment: very slight</p>
Perkin's Gut	Not sampled	Surface	No photo	Supplies untreated water to parts of Sandy Bay
Wrangham's Sping	Not sampled	Surface	No photo	Supplies untreated water to the upper parts of Sandy Bay
Inflow pipe to weir at Lady's Bath	LB12	Spring		<p>Surface water from Lady's Bath spring is fed by gravity to Red Hill WTW;</p> <p>Sample collected from tank due to low flow;</p> <p>Colour: clear</p> <p>Sediment: none visible</p>
Raw water tank pumped from Iron Pot borehole	IP13	Groundwater	No photo of tank due to rain	<p>Water pumped from Iron Pot borehole in upper Lemon valley near Cason's Gate to tank near Cason's (Gold Mine Tank);</p> <p>Provides raw water to High Point, Blueman's Field and St Pauls</p> <p>Colour: clear</p> <p>Sediment: none visible</p>

Outflow pipe from stilling dam above Harpers 2	H14	Surface		Stilling dam above the Harpers 2 reservoir; Water pumped from Harpers reservoirs (1, 2 and 3) to Red Hill WTW; Colour: slightly cloudy grey Sediment: very slight
Small weir outflow at Black Bridge	BB15	Surface		Stream upstream of Jamestown WTW; Gravity fed to Jamestown WTW at Chubb's Spring; Colour: pale yellow Sediment: very little
Small weir outflow at Drummond's Point	DP16	Surface and spring		Stream upstream of Jamestown WTW; Gravity fed to Jamestown WTW at Chubb' Spring; Colour: clear Sediment: slight

Inflow pipe to tank from Tom Peters spring	TP17	Spring		Spring in same valley as samples BB15 and DP16 above; Gravity feed to Jamestown WTW at Chubb' Spring; Colour: clear Sediment: very slight
Lower Shark's Valley	SV18	Surface		Pipe outlet in lower Shark's Valley; Note the entire valley is overgrown with wild mango; In times of drought, water is pumped to the pump station in Fisher's Valley and thence to the Hutt's Gate WTW.

Borehole holding tank in Fisher's Valley	FV19	Groundwater		2 boreholes in Fisher's Valley; Pump station and balancing tank receives water from Shark's Valley and Borehole 5 and pumps to Hutt's Gate WTW in times of drought.
Borehole 5	BR results	Groundwater		Borehole in Dry Gut; Pumped to Firewater tank for use at airport. In times of drought can be pumped to the Fisher's Valley balancing tank and thence to Hutt's Gate WTW; Colour: clear Sediment: none
Levelwood WTW sampling tap	LW20	Treated potable water		Supplies the communities of: Silver Hill, Levelwood and Sandy Bay
Jamestown WTW (Chubbs) sampling tap	JT21	Treated potable water		Supplies the communities of: Jamestown, The Briars, Rupert's Valley
Hutt's Gate WTW sampling tap	HG22	Treated potable water		Supplies the communities of: Longwood, Bottom Woods, Airport, Deadwood, Alarm Forest, Hutt's Gate
Red Hill WTW sampling tap	RH23	Treated potable water		Supplies the communities of: Half Tree Hollow, Cow Path, Red Hill;

APPENDIX B
SAMPLE SCHEDULE

WATER SAMPLE ANALYSIS: CONNECT

Date samples collected: 2nd February 2018
 Samples collected by: Patrick (Connect)
 Received by: B Walmsley via Zedcore Reefer on RMS St Helena
 Date received: 19th February 2018
 Date delivered to laboratory: 19th February 2018
 Delivered by: B Walmsley
 Name of laboratory: CSIR Laboratory, Stellenbosch
 Sample preservation: in cooler box with freezer blocks or fridge

CSIR Quotation No: SALQ 03103
 Connect PO No: 103297

Description on bottle	Location	Type of water	Sample size
Grape Vine 1	Grape Vine reservoir inflow pipe 1	Surface	2 litres
Grape Vine 2	Grape Vine reservoir inflow pipe 2	Surface	2 litres
Bottom Wells 3	Hutts Gate reservoir inflow pipe 1	Surface	2 litres
Leggs Gut 4	Hutts Gate reservoir inflow pipe 2	Surface	2 litres
Upper Wells 5	Hutts gate raw water tank inflow pipe	Surface and springs	2 litres
Willowbank 6	Willowbank borehole holding tank	Groundwater	2 litres
Jimmy Lots 7	Jimmy Lots tank overflow pipe	Surface	2 litres
Levelwood 8	Levelwood reservoir inflow pipe	Surface	2 litres
Rockwater 9	Inflow pipe to small weir	Surface	2 litres
Green Hill 10	Inflow pipe from Wash's Gut to Green Hill tank	Surface	2 litres
Cason's Gate 11	Tap fed from French's Gut boreholes	Groundwater	2 litres
Lady Bath 12	Inflow pipe to weir	Surface	2 litres
Iron Pot 13	Raw water tank pumped from Iron Pot borehole	Groundwater	2 litres
Harpers 14	Outflow pipe from stilling dam above Harpers 2	Surface	2 litres
Black Bridge 15	Small weir outflow	Surface	2 litres
Drummond's Point 16	Small weir outflow	Surface and spring	2 litres
Tom Peters 17	Inflow pipe to tank from Tom Peters spring	Spring	2 litres
Shark's Valley 18	Lower Shark's Valley	Surface	2 litres
Fisher's Valley 19	Borehole holding tank	Groundwater	2 litres
Levelwood WTW 20	WTW sampling tap	Treated potable water	2 litres
Jamestown WTW 21	WTW sampling tap	Treated potable water	2 litres
Hutt's gate WTW 22	WTW sampling tap	Treated potable water	2 litres
Redhill WTW 23	WTW sampling tap	Treated potable water	2 litres

Received by: Dragon Adonis

Signed: 

Date: 21/02/18

APPENDIX C
RESULTS CERTIFICATE