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ISO 17025 INAB ACCREDITED TESTING DETAILED IN SCOPE REG NO 150T

AMBIENT WATER MONITORING REPORT

INTEL IRELAND LTD
COLLINSTOWN INDUSTRIAL PARK
LEIXLIP
CO. KILDARE

Annual Monitoring Round, Louisa Spa, August 2019

Report Ref. 26570
TMS Environment Ltd
Issued: 26 March 2020

Approved by: Craig O'Connor **Date: 26 March 2020**

Craig O'Connor
Senior Consultant

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APPENDICES

EXECUTIVE SUMMARY

TMS Environment Ltd has been requested by Intel Ireland Ltd to sample and assess water quality at Louisa Spa Mineral Spring, to comply with the ambient water monitoring requirement specified in the Industrial Emissions Licence for the Intel site (Reg. No. P0207-04). The purpose of the annual sampling is to identify any impact from the Intel facility on water quality at the mineral spring.

TMS personnel collected the water sample on 13th August 2019 from the inlet to the outdoor bath. The sample was analysed at the TMS laboratory and ALS Environmental for the suite of analysis specified in Section C of the licence.

The results show that the water quality continues to show consistently elevated: 1.) temperature, 2.) conductivity, 3.) sodium, and 4.) chloride, and slightly elevated sulphate and potassium. A literature review suggests that groundwater issuing from the spring is old (c. 30,000-40,000 years) and circulates from a depth of c. 1km. Therefore these elevated parameters are to be expected for an old/deep groundwater.

The results also show intermittently elevated: 1.) TOC, 2.) nitrate and 3.) total ammonia, which would not be expected for a deep/anoxic groundwater and most likely originate from mixing with shallow groundwater. Iron and manganese concentrations are significantly higher in the stream coming from the spring, and form deposits along the base of the stream. Elevated iron would be expected in groundwater as the spa well was historically known as a ‘Chalybeate’, a mineral spring rich in iron-salts.

No long-term trends are evident in the monitoring record for most parameters, with concentrations constant about their median values. A slightly decreasing trend is suggested for fluoride, however the rate of decrease is very minor. A slightly increasing trend is also suggested for TOC, however this may only be related to annual variation and the limited sampling frequency.

There is no evidence of any impact from the Intel facility on water quality at the mineral spring over the 22 year monitoring record.

1.0 Introduction & Scope

TMS Environment Ltd (TMS) has been requested by Intel Ireland Ltd (Intel) to sample and assess water quality at Louisa Spa Mineral Spring, to comply with the ambient water monitoring requirement specified in the Industrial Emissions (IE) Licence for the Intel site (Reg. No. P0207-04).

The purpose of the annual sampling is to identify any impact from the Intel facility on water quality at the mineral spring which is located 40m to the east of the eastern site boundary, next to Louisa Bridge on the Royal Canal.

This report presents background information on the history and hydrology of Louisa Spa mineral spring, the sampling results for 2019 and an assessment of the monitoring results gathered to date (1998-2019).

2.0 Background

2.1 History of Louisa Spa

Louisa Spa mineral spring was discovered in 1793 by workmen excavating for the construction of the Royal Canal. The spring water was re-directed to issue from a circular well recessed into the embankment wall, which flows to a shallow hexagonal cistern ('Spa Well' – Photograph 1). The overflow from the spa well was directed via a channel to a stone-lined basin, in the shape of a Roman bath for the purposes of outdoor bathing (Photograph 2). The temperature of the spring was recorded as 75.5°F / 24.2°C (J. Warburton, J. Whitelaw & R. Walsh, 1818, 'History of the City of Dublin' Vol. 2).

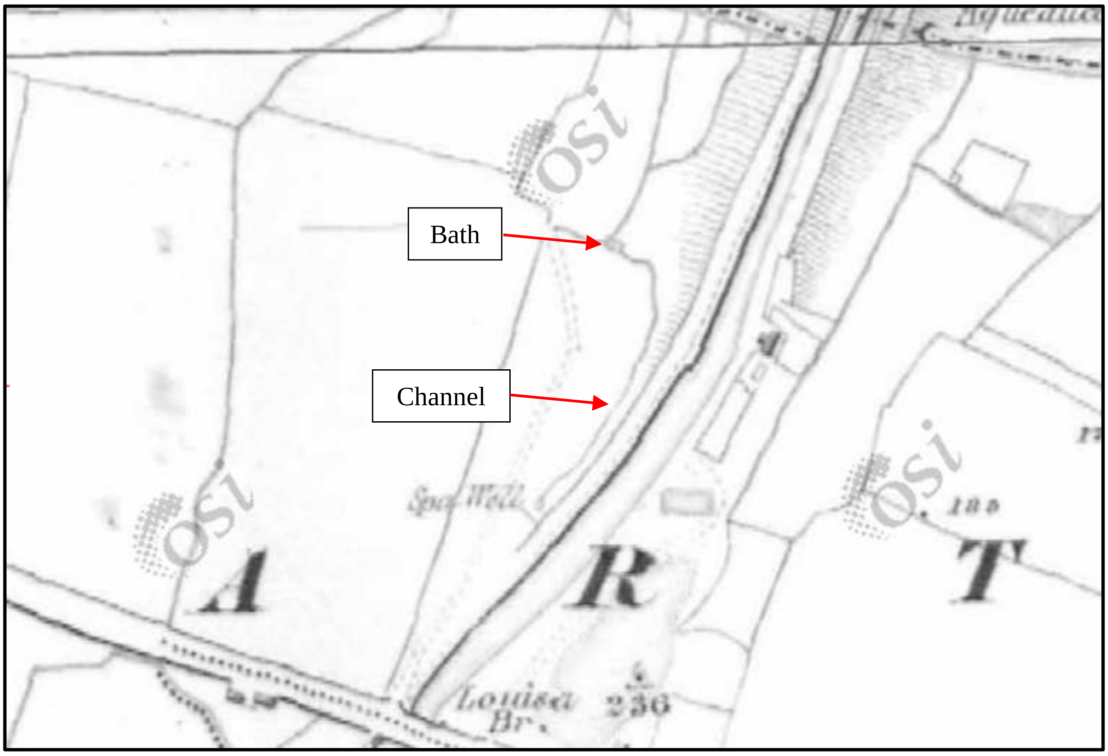


Figure 1: 6" Ordinance Survey map showing Spa Well at Louisa Bridge (1837)

The spa was the rival of Lucan Spa for a time, its popularity was such that the Rt. Hon. Thomas Connolly, on whose land the spring was discovered, intended to build a pump house and hotel, but he died before the work could commence. The spa's popularity eventually declined in the late 19th century.


Photographs 1 & 2: Spa well (c. 1983, GSI) showing original well, hexagonal cistern and overflow, and outdoor Roman-style bath (24th August 2016)

The site fell into disrepair from the 1960s with a thick layer of mud and rubbish accumulating in the bath. Some restoration work was carried out by the Leixlip Boy Scouts and Youth Club in 1975, who uncovering the bath, stone walls and steps, and cleared out the original overflow channel, redirecting the flow of water from the spa well to the bath.

In the late 1990s, the area immediately south of the spa well was used as a halting site during which time the spa well and bath were used as dumping grounds. In 2004, Leixlip Town Council commissioned a report to examine options for the future use of Louisa Spa ('Framework for Future Use Options for Leixlip Spa, Co. Kildare', CAAS Ltd, March 2004), a conservation plan for the site was drawn up in 2009 (Laura Bowen Architects), and restoration work to the bath was carried out in 2010 ('The Leixlip Spa Restoration Project').

The spa well and hexagonal cistern were most recently restored between the 2017 and 2018 monitoring rounds. Up until this time the spa well and cistern were overgrown and flooded. The vegetation was cleared exposing the stonework and the outlet to the cistern was unblocked allowing water to drain freely from the spa well into the cistern and overflow to the channel leading to the outdoor bath (Photograph 3).

For the 2019 monitoring round, the overflow from the cistern was again overgrown and the spa well and cistern flooded (Photograph 4).

Photograph 3: Restored spa well and hexagonal cistern (17th August 2018)

Photograph 4: Current condition of spa well and cistern (13th August 2019)

2.2 Hydrology

The hydrology of Louisa Spa is summarized in Appendix I.

Water from the spa well overflows into the hexagonal cistern, which itself overflows to a covered channel to the northeast, parallel with the base of the Royal Canal embankment. After 50m, the covered channel becomes an open stream, draining to a marsh area which has developed on a landscaped terrace in the overburden (boulder clay). A stream from this marsh area flows past the outdoor bath and over an embankment to another lower marsh area, immediately above the floodplain of the Rye River. The bath is located on a lower landscaped terrace in the overburden and water from this stream is diverted via an underground pipe to the inlet of the bath. The water level in the bath is controlled by a gate valve, the outflow drains to the lower marsh area. The degree of interaction between groundwater and the marsh areas is unknown.

Field measurements of Temperature, Electrical Conductivity and Dissolved Oxygen were collected at various points along the flowpath from the spa well in August 2016 (Appendix I). The warmest water was recorded within the spa well/cistern at 16.6^{o}C (flooded at the time), with water temperature decreasing slowly away from the spa well/cistern downstream. Conductivity decreased slowly away from the spa well/cistern due to slight dilution by rainwater/runoff. Dissolved oxygen was practically absent in the spa well/cistern (7.9% sat.), increasing rapidly along the open stream where significant precipation of iron oxides was seen on the stream bed (orange coating). This is to be expected as the spa well was historically known as a 'Chalybeate', a mineral spring rich in iron-salts. The hydrochemistry of the spring water is discussed in detail in Section 5.0.

Previous assessments by K.T. Cullen & Co. Ltd. (2001), EcoServe (2003) and the Geological Survey of Ireland (2005) incorrectly identified a warm spring and a cold spring at the site when in fact there is only one warm spring: the spa well. The 'cold spring' by the marsh area is just the re-emergence of the surface drainage from the spa well.

The 2018 monitoring round was the first time that the spa well/cistern area was not flooded; a water temperature of 15.5^{o}C was measured at the inlet to the bath, 16.7^{o}C in the stream where it emerges from the covered channel leading from the spa well, and 20.3^{o}C in the spa well itself. This would suggest that the temperatures measured in the past were an underestimate of the actual temperature of groundwater rising in the spa well. In addition, rising gas bubbles were noted in the spa well when the water was disturbed, indicating dissolved gases in groundwater coming out of solution at the source.

2.3 Importance

Louisa Spa mineral spring is important for a number of reasons:

- Louisa Spa is the only warm spring in Ireland located within a designated Special Area of Conservation (SAC), the Rye Water Valley/Carton SAC, and contributes directly to the floral and faunal diversity of the SAC;
- The Geological Survey of Ireland (GSI) identified the warm spring at Louisa Spa as a County Geological Site in 2005. The site is recognized by Kildare County Council as a site of geological importance in the current County Development Plan 2017-2023, and may in the future be designated as a Natural Heritage Area;
- The spa well and bath have architectural/historical value, as the only example of an outdoor spa in the British Isles.

3.0 Sampling Methodology

TMS personnel collected the annual water sample from Louisa Spa on 13th August 2019.

Samples collected by K.T. Cullen & Co. Ltd from 1998-2002 were collected from the spa well (exact location not specified). Water samples collected by TMS from 2003-date have been taken from the inlet to the outdoor bath. Further to the discussion on the hydrology of Louisa Spa (Section 2.2), samples will continue to be taken from the inlet to the outdoor bath for continuity of monitoring, however an additional sample will be collected from the spa well (source) for comparison.

Field measurements of temperature, pH and conductivity were made at the time of collection. Water samples for inorganic and trace metals analyses were stored in 1 litre HDPE bottles. Samples for iron, manganese and trace metal analysis were field-filtered with a 0.45µm filter and preserved in the field. Samples were stored in cooler boxes with frozen ice packs and delivered to the laboratory on the same day of collection. A full chain of custody was maintained for all samples.

Samples were analysed at the TMS laboratory, with some analyses subcontracted to ALS Environmental, for the list of parameters indicated in Schedule C of the IE Licence (Figure 2):

C.6.5 ***Ambient Water Monitoring***

Location: Mineral spring at Louisa Bridge

Parameter	Monitoring Frequency	Analysis Method/Technique
pH	Annually	pH electrode/meter
Conductivity	Annually	Conductivity meter
Temperature	Annually	Thermometer
TOC	Annually	Standard Method
Major anions: nitrate, nitrite, chloride, sulphate, fluoride	Annually	Standard Method
Major cations: calcium, magnesium, sodium, potassium, ammonia	Annually	Standard Method
Heavy metals: iron, manganese, copper, tin, chromium, lead, nickel, cobalt	Annually	Atomic absorption/ICP

Figure 2: Ambient Water Monitoring Requirement (IE Licence)

The TMS Environment Ltd laboratory is accredited to ISO 17025. The laboratory registration number is 150T and the current scope of accreditation can be viewed on the Irish National Accreditation Board website www.inab.ie. Accredited tests are marked by an asterisk (*) in front of the parameter name; opinions and interpretations given are not accredited.

4.0 Laboratory Results

The laboratory results for the sample from the outdoor bath ('Bath') and the spa well ('Well') are presented in Appendix II.

5.0 Data Evaluation

5.1 Threshold/Limit Values

A summary of the monitoring results to date is provided in Appendix III.

The monitoring results are compared with the Groundwater Threshold Values (GTVs) from the European Union Environmental Objectives (Groundwater) (Amendment) Regulations 2016 (S.I. No. 366 of 2016), and Drinking Water Parametric Values (PVs) from the European Union (Drinking Water) Regulations 2014 (S.I. No. 122 of 2014).

GTVs are trigger values ('threshold' values) which warn of potential breaches of water quality standards: annual-average results are usually compared with GTVs which are generally set at 75% of water quality standard, usually drinking water, to allow for individual peak concentrations during the year (i.e. if the average is less than the GTV, then individual peak concentrations should be less than the water quality standard).

5.2 Data Presentation

Time series plots of each individual parameter are presented for the complete 22 year monitoring record in Appendix IV.

Time series plots are not generated for nitrite or the trace metals (copper, tin, chromium, lead, nickel, cobalt) due to lack of detections above the laboratory reporting limits. Where a concentration is less than the laboratory reporting limit, half the reporting limit is taken as the representative concentration.

Outliers can significantly affect statistical analyses and interpretations of groundwater monitoring results. There are various graphical/quantitative methods to identify outliers in a dataset (probability plots, Grubbs test, etc.) however these do not justify removing them from the dataset. For the Louisa Spa dataset, identified outliers are only removed if there is a sound justification based on possible field or laboratory error, otherwise outliers are retained.

5.3 Trend Analysis

Trends in time series are evaluated by two methods: a.) test for presence of a monotonic trend (Mann-Kendall test), and b.) moving average trend line.

An Excel program developed by the Finnish Meteorological Institute (MAKESENS) was used to test each time series for the presence of a monotonic trend using the non-parametric Mann-Kendall test. A monotonic increasing (or decreasing) trend means the parameter is consistenly increasing (or decreasing) with time, but the trend may or may not be linear. The Mann-Kendall tests calculates the test statistic Z which is large and positive if there is an increasing trend, and large and negative if there is a decreasing trend; when the value of Z is small, no trend is indicated. MAKESENS calculates the significance for a trend assessment (i.e. trend not significant, trend is 90% significant, trend is 95% significant, trend is 99% significant, and trend is 99.9%

significant). If a significant trend is detected, MAKESENS uses the non-parametric Sen's Method to estimate the slope of a best-fit linear trend line.

A moving average trend line (averaged over 4 periods) is also added to each time series plot in Appendix IV as an indication of the current/ongoing trend; the Mann-Kendall test looks at the entire dataset for a single overall trend, whereas often a time series may exhibit a number of shorter-term trends.

(Note: The sampling frequency of 1 sample/year is not sufficient to identify annual variation, therefore caution is needed interpreting any apparent trend, particularly short-term trends, that might just be related to annual variation.)

5.4 Individual Parameters

pH

pH varies from 7.01 – 8.3 over the monitoring record, within the PVs for drinking water.

A Mann-Kendall test suggests the presence of a monotonic increasing trend, however on closer examination there is a step increase in 2008 from a constant pH of 7.30 (median) to a constant pH of 7.94 (median). This step increase corresponds with a change from field measurements to laboratory measurements of pH and is most likely related to calibration of field instruments. Therefore there is no trend, with values constant about the median, and the suggested monotonic increasing trend is rejected.

Conductivity

Conductivity varies very little over the monitoring record (1,647 – 1,957µS/cm). Conductivities exceed the lower GTV of 800µS/cm but are less than the drinking water PV of 2,750µS/cm (equivalent at 25°C). The time series for conductivity shows no trend about the median value of 1,831µS/cm. Elevated conductivity in water from Louisa Spa is mainly due to the presence of elevated sodium and chloride in solution (see Section 7.0).

Temperature

Temperature varies from 14 – 22.8°C over the monitoring record, with a median value of 16.45°C. There is no GTV or drinking water PV for temperature, but temperature generally ranges from 9 – 11°C for *shallow* groundwater in Ireland. A literature review would suggest that groundwater issuing from the spa well circulates from a depth of c. 1km (see Section 7.0), therefore higher temperatures would be expected.

The moving average trend line on the time series would suggest a slightly decreasing trend, however this is rejected as the variability in temperature is most likely related to surface ponding and warming of water at the flooded cistern before drainage to the outdoor bath where water temperature has historically been recorded.

Total Organic Carbon (TOC)

TOC varies from <0.5 – 42mg/l over the monitoring record, with a median value of 2.8mg/l. There is no GTV or drinking water PV for TOC, but generally TOC ranges up to 3mg/l in shallow groundwater in Ireland. Elevated TOC was detected in 2003 (8.4mg/l), 2013 (12.4mg/l), 2016 (42mg/l) and 2018 (10.7mg/l), and is most likely related to particulate/dissolved organic matter in shallow groundwater mixing with deeper groundwater.

A Mann-Kendall test suggests the presence of a monotonic increasing trend at a 95% significance level, the Sen slope estimate would suggest a constant increase of c. 0.146mg/l per year. This slightly increasing trend may be real or just a result of a larger annual variation than the current monitoring record shows.

Calcium

Calcium varies very little over the monitoring record (101 – 132mg/l). There is no GTV or drinking water PV for calcium, but generally calcium ranges up to 132mg/l in limestone aquifers in Ireland. The time series for calcium shows no trend about the median value of 114mg/l.

Magnesium

Magnesium varies very little over the monitoring record (27 – 37mg/l). There is no GTV or drinking water PV for magnesium, but generally magnesium can range up to 67mg/l in limestone aquifers in Ireland. The concentrations of magnesium mirror that of calcium, and show no trend about the median value of 31mg/l.

Sodium

Sodium ranges from 155 – 300mg/l over the monitoring record, occasionally above the drinking water PV of 200mg/l. Typical sodium concentrations in shallow groundwater in Ireland range up to 37mg/l, therefore sodium levels are considerably elevated compared to typical shallow groundwater. The concentrations of sodium show no trend about the median value of 208mg/l.

Potassium

Potassium ranges from 6.4 – 13mg/l over the monitoring record; there is no GTV or drinking water PV for potassium but generally potassium ranges up to 6mg/l in shallow groundwater in Ireland, therefore potassium levels are slightly elevated compared to typical shallow groundwater. The concentrations of potassium show no trend about the median value of 8.75mg/l.

Nitrate

Nitrate ranges from <0.3 – 15.7mg/l NO_3 over the monitoring record, with a median value of 2.5mg/l, well below the GTV (37.5mg/l) and drinking water PV (50mg/l). Nitrate has been below the laboratory detection limit in several of the annual samples. No trend is interpreted for nitrate, with values constant about the median with short-term elevated concentrations due to annual variations. Nitrate present most likely originates from mixing with shallow groundwater, as nitrate would most likely not be present in deep anoxic groundwater due to denitrification.

Nitrite

Nitrite is more or less absent in the monitoring record, with most analysis results below the laboratory detection limit; very low concentrations were detected on only four occasions at just above the laboratory detection limit, well below the GTV (0.375mg/l NO_2) and drinking water PV (0.5mg/l NO_2).

Chloride

Chloride ranges from 350 – 550mg/l over the monitoring record, with a median value of 450mg/l, above the lower GTV (24mg/l) and drinking water PV (250mg/l). Typical chloride concentrations in shallow groundwater in Ireland range up to 30mg/l in areas close to the coast, therefore chloride levels are considerably elevated compared to typical shallow groundwater. The time series for chloride shows no trend with time, with concentrations constant about the median.

Sulphate

Sulphate ranges from 31 – 75mg/l over the monitoring record, with a median value of 51mg/l, below the GTV (187.5mg/l) and drinking water PV (250mg/l). Typical sulphate concentrations in shallow groundwater in Ireland range up to 37mg/l, therefore sulphate levels are slightly elevated compared to typical shallow groundwater. The concentrations of sulphate show no trend about the median.

Fluoride

Fluoride ranges from 0.26 – 0.57mg/l over the monitoring record, with a median value of 0.445mg/l, well below the drinking water PV (1.5mg/l).

A Mann-Kendall test suggests the presence of a slightly decreasing monotonic trend at a 99% significance level; the Sen slope estimate would suggest a constant decrease of c. 0.01mg/l per year.

Total Ammonia

Total ammonia ranges from <0.01 – 1.6mg/l N over the monitoring record, occasionally above the GTV (0.065mg/l N) and drinking water PV (0.23mg/l N). Total ammonia has been below the laboratory reporting limit in several of the annual samples.

The concentrations of total ammonia show no trend about the median of 0.08mg/l N, calculated using half the reporting limit where concentrations were below the laboratory reporting limit. The low levels of total ammonia occasionally detected most likely originate from mixing with shallow groundwater, as ammonium would most likely not be present in old/deep groundwaters.

Iron

Iron in water from the bath inlet ranges from <5 – 520µg/l over the monitoring record, occasionally above the drinking water PV (200µg/l). Iron has been below the laboratory reporting limit in several of the annual samples. No trend is interpreted for iron at this location, with occasionally elevated concentrations occurring due to a larger annual variation than the current monitoring record shows.

The return visit in September 2017 to re-sample the stream and bath for total iron and manganese showed elevated total iron (1.81mg/l) and manganese (0.119mg/l) in the stream, with lower total iron (<0.23mg/l) and manganese (0.025mg/l) in the inlet to the bath, showing that the iron and manganese is precipitating out of solution between the emergence of the stream and the bath. This was noted in the 2016 monitoring report, with evidence of iron oxides deposited on the stream bed as the stream water is oxygenated. This elevated iron content is more representative of the mineral spring/spa well, which was historically know as a 'Chalybeate' (see Section 2.2).

Manganese

Manganese in water from the bath inlet ranges from <5 – 74µg/l over the monitoring record, occasionally above the drinking water PV (50µg/l). Manganese has been below the laboratory reporting limit in several of the annual samples. Manganese concentrations tend to mirror iron concentrations, with no trend apparent from the time series plot and occasionally elevated concentrations due to a larger annual variation than the current monitoring record shows.

Manganese in the stream sample in 2017 was 24µg/l (filtered), slightly higher than the concentration detected in the bath inlet water (<7µg/l). This concentration is lower than reality as it does not include what has precipitated out of solution in transit to the laboratory.

Trace Metals

Six trace metals (copper, tin, chromium, lead, nickel, cobalt) have been analysed in the annual samples. Lead and cobalt have never been detected above the laboratory reporting limit; copper, chromium, nickel and tin have only been detected a few times at low concentrations close to the laboratory reporting limit (Appendix III).

6.0 Discussion

The Intel monitoring record for Louisa Spa to date consists of grab samples collected once a year at the outdoor bath.

Recent work by Blake et al. (2016) [1] involved the installation of a temperature-conductivity datalogger at Louisa Spa for a continuous monitoring period of two years. The exact location of the datalogger was not specified however it was likely to have been installed in the flooded spa well/cistern. The results are shown in Figure 3.

[1] Blake, S. et al. (2016), 'Compositional multivariate statistical analysis of thermal groundwater provenance: A hydrogeochemical case study from Ireland', Applied Geochemistry, 75, 171-188.

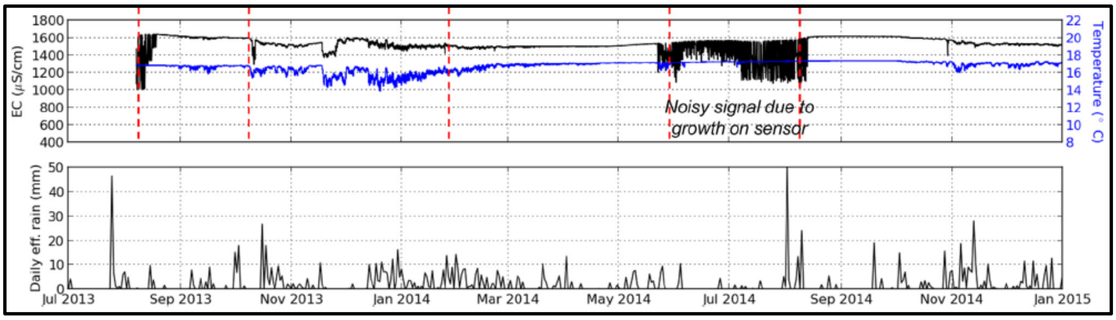


Figure 3: Continuous monitoring record of temperature and conductivity at Louisa Spa (Blake et al., 2016)

This continuous record shows that temperature and conductivity within the flooded spa well/cistern remained relatively constant throughout the year, with a slight seasonal decrease in winter related to rainfall/runoff. This agrees with the Intel monitoring record although the Intel monitoring record would suggest a slightly higher median conductivity (specific conductance) of 1,831µS/cm downstream at the bath, assuming the reference temperature used by Blake et al. was 25°C.

Monitoring of the spa well itself would result in higher temperatures and conductivities than recorded in either the Intel monitoring record or Blake et al. (2016), as demonstrated by the 2016 monitoring round (Appendix I) and the 2019 monitoring round (Table 1):

	Spa Well	Cistern	Emergent Stream	Outdoor Bath
Temperature (°C)	16.8	16.0	15.8	15.7
Conductivity (µS/cm @25°C)	1,914	1,893	1,772	1,756
pH	8.31	8.11	7.86	7.62

Table 1: Changes in physical parameters away from the spa well source (13th August 2019)

Going forward, an additional sample will be collected in each monitoring round from the spa well (source), for comparison with the downstream bath which has been sampled in most of the historic sampling rounds.

7.0 Conclusions

- Water quality at Louisa Spa (as measured at the bath inlet) continues to show consistently elevated temperature, conductivity, sodium and chloride, and slightly elevated sulphate and potassium, related to the natural hydrochemistry of groundwater issuing from the spa well upstream;

- Intermittently elevated TOC, nitrate and total ammonia are most likely related to mixing with shallow groundwater before emergence at the spa well, as these parameters are not likely not be present in old/deep groundwaters. Intermittently elevated iron and manganese monitored at the bath inlet are lower than actual concentrations in groundwater issuing at the spa well due to rapid precipitation of iron/manganese in the stream feeding the bath. Elevated iron would be expected in groundwater as the spa well was historically known as a ‘Chalybeate’, a mineral spring rich in iron-salts;

- A literature review would suggest that the groundwater issuing from the spa well is old (c. 30,000-40,000 years) [2] and circulates from a depth of c. 1km. Therefore the elevated temperature, conductivity, sodium and chloride would be expected for an old/deep groundwater;

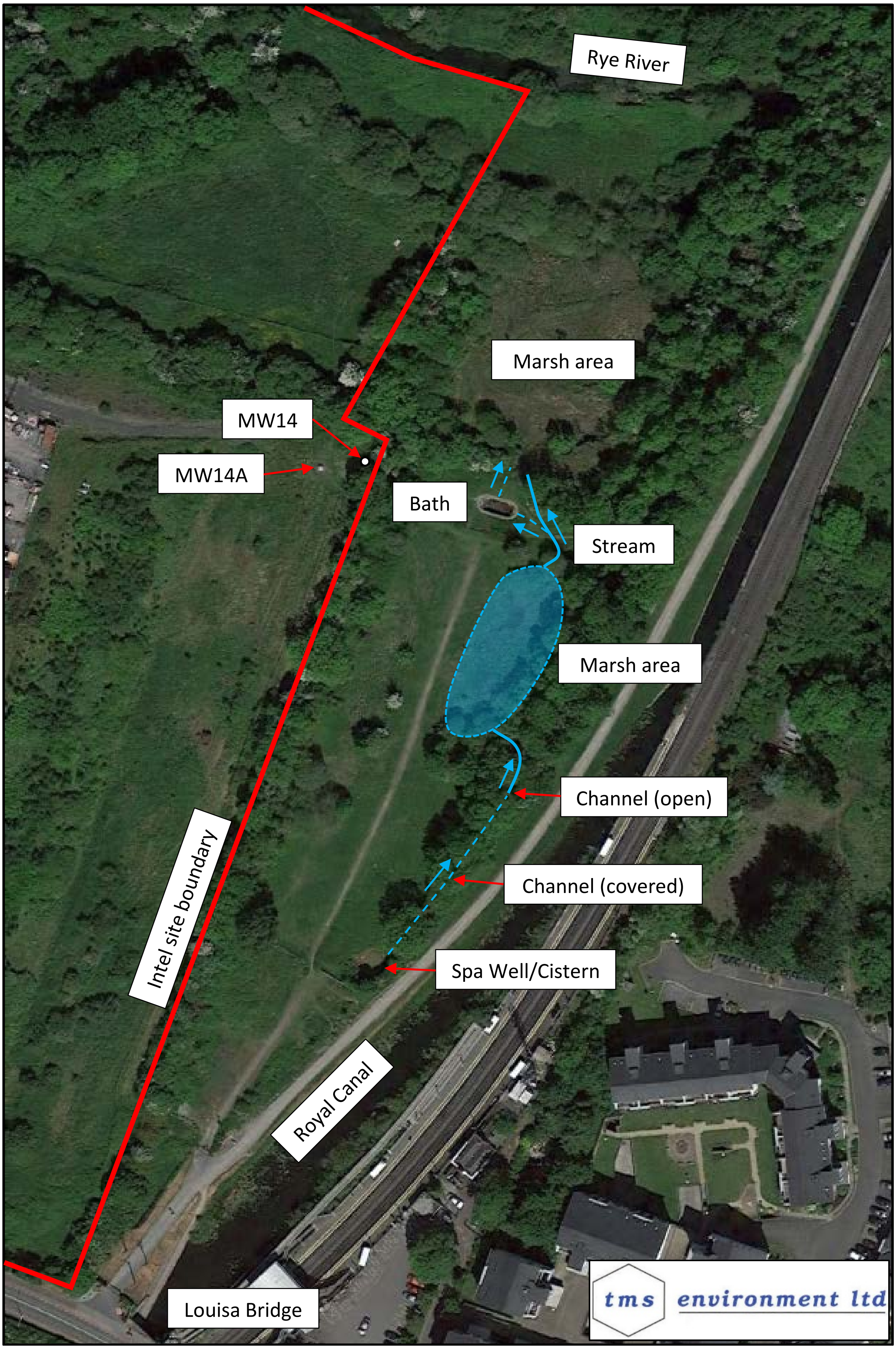
- No long-term trends are evident in the monitoring record for most parameters, with concentrations relatively constant about their median values. A slightly decreasing trend is suggested for fluoride, however the rate of decrease is very minor. A slightly increasing trend is also suggested for TOC, however this may only be related to annual variation and the limited sampling frequency;

- There is no evidence of any impact from the Intel facility on water quality at the mineral spring over the 22 year monitoring record to date.

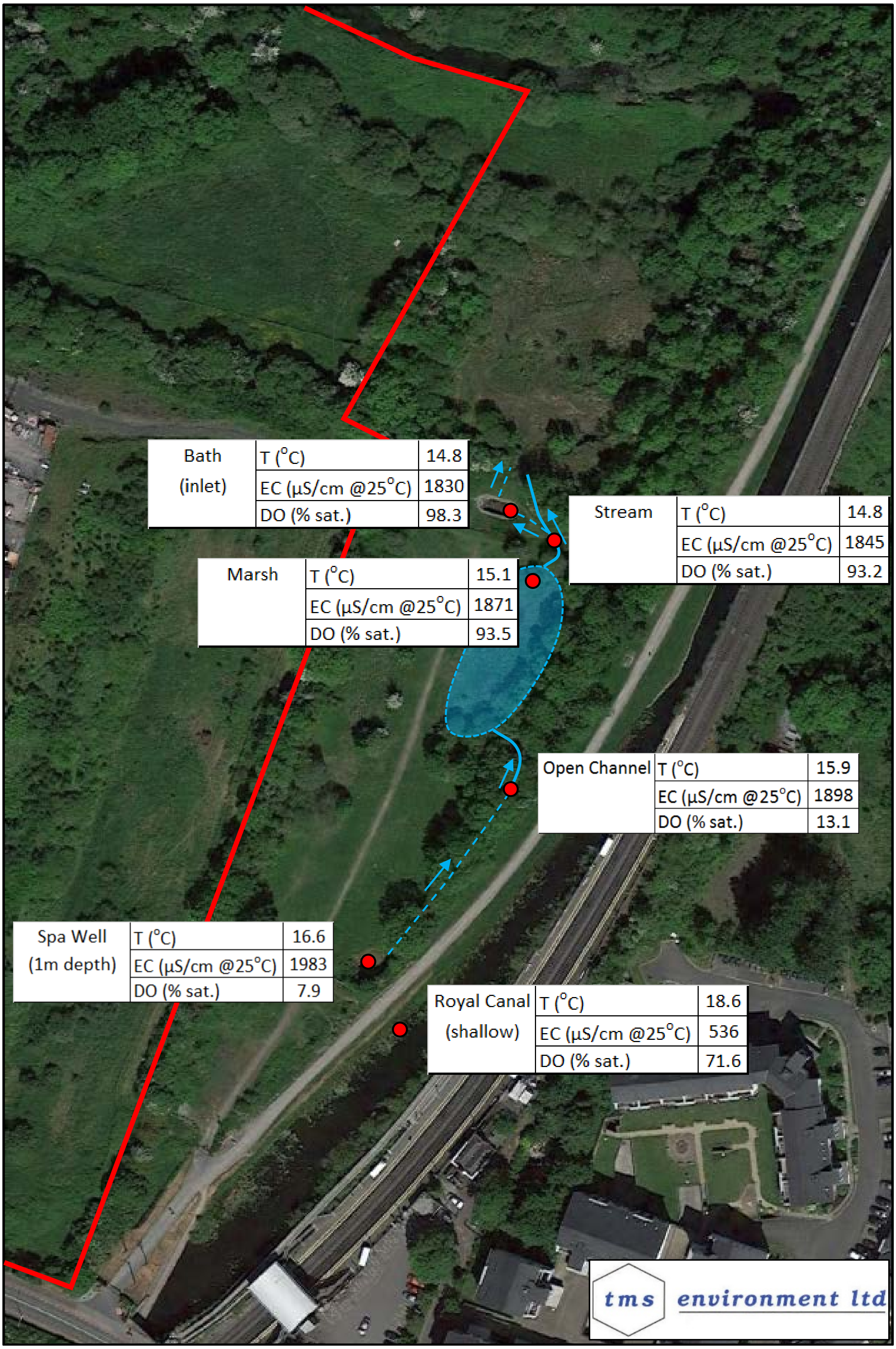
[2] Burdon, D.J., Burns, D.J. & Peel, S. (1983), ‘Geothermal energy investigations in Ireland’, Proceedings of the Third International Seminar on the Results of EC Geothermal Energy Research, Munich 1983, 350-360.

APPENDIX I

Louisa Spa Mineral Spring - Maps



Appendix I: Louisa Spa Mineral Spring – Hydrology



Appendix I: Louisa Spa Mineral Spring – Field Hydrochemistry (24th August 2016)

APPENDIX II

Laboratory Results

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ISO 17025 INAB ACCREDITED TESTING DETAILED IN SCOPE REG NO.150T

Confidential Laboratory Test Report

Client: Intel Ireland Ltd
Collinstown Industrial Park
Leixlip
Co. Kildare

F.T.A.O.: Ronan Kearney
Commencement Date: 13 August 2019
Completion Date: 05 December 2019
Report Date: 07 January 2020

TMS Environment Ref: 26570

Sample Type: Surface Water

TEST RESULTS

Parameter	26570-1 Well	26570-2 Bath	Units	Methodology	Test Procedure Ref
pH*	8.31	7.62	-	pH Meter	QP-SITE-6001
Conductivity*	1914	1756	µS/cm @ 25ºC	Conductivity Meter	QP-SITE-6001
Temperature	16.8	15.7	ºC	Conductivity Meter	QP-SITE-6001
TOC	2.1	2.9	mg/l	Spectrophotometry	QP-CHEM-2071
DOC	3.9	4.1	mg/l	Spectrophotometry	QP-CHEM-2071
Major Cations:					
Calcium**	119	118	mg/l	Note 1	Note 1
Magnesium**	31.2	31.1	mg/l	Note 1	Note 1
Sodium**	213	211	mg/l	Note 1	Note 1
Potassium**	10.7	10.6	mg/l	Note 1	Note 1
Major Anions:					
Chloride***	425	370	mg/l	Titration	QP-CHEM-2035
Sulphate***	55.8	55.7	mg/l	Turbidimetry	QP-CHEM-2050
Nitrate	2.35	1.97	mg/l NO_3	Ion Selective Electrode	QP-CHEM-2043
Other:					
Total Alkalinity***	254	250	mg/l $CaCO_3$	Titration	QP-CHEM-2012
Ortho Phosphate***	< 0.02	< 0.02	mg/ P l	Spectrophotometry	QP-CHEM-2040
Total Ammonia	0.15	0.16	mg/l N	Spectrophotometry	QP-CHEM-2037
Nitrite	0.018	0.021	mg/l NO_2	Spectrophotometry	QP-CHEM-2087

Fluoride* **	0.23	0.26	mg/l	Ion Selective Electrode	QP-CHEM-2036
Iron (filtered)**	0.47	0.4	mg/l	Note 1	Note 1
Manganese (filtered)**	0.063	0.066	mg/l	Note 1	Note 1

Trace Metals (filtered):

Chromium**	< 0.002	< 0.002	mg/l	Note 1	Note 1
Cobalt**	< 0.002	< 0.002	mg/l	Note 1	Note 1
Copper**	< 0.009	< 0.009	mg/l	Note 1	Note 1
Lead**	< 0.006	< 0.006	mg/l	Note 1	Note 1
Nickel**	< 0.003	< 0.003	mg/l	Note 1	Note 1
Tin**	< 0.007	< 0.007	mg/l	Note 1	Note 1

*On-site Accredited Test
**Subcontracted Accredited Test
***In-house Accredited Test
Note 1: Analysis subcontracted to ALS Environmental

Prepared By: Peter Smith **Date:** 07 Jan 2020
Peter Smith
Laboratory Analyst

Approved By: Imelda Shanahan **Date:** 07 January 2020
Dr. Imelda Shanahan
Technical Manager

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APPENDIX III

Summary of Monitoring Results (1998-2019)

Appendix III: Summary of Monitoring Results (1998-2019)

Parameter	Units	15/04/98	15/08/99	15/05/00	15/12/01	15/05/02	07/04/03	28/04/04	12/04/05	10/10/06	23/04/07	23/07/08	11/08/09	16/08/10	26/08/11	29/08/12	19/08/13	27/08/14	25/08/15	24/08/16	16/08/17	17/08/18	13/08/19	Groundwater Threshold Values	Drinking Water Parametric Values
pH	-	7.3	7.5	7.3	7.2	8	7.36	7.28	7.41	7.01	7.3	8	8.03	7.85	7.62	7.8	8	8.3	7.7	7.88	8.15	8.2	7.62	-	≥6.5 and ≤9.5
Conductivity	µS/cm @25°C	1720	1720	1720	1894	1858	1837[1]	1921[1]	1882[1]	1797[1]	1086[1]	1762[1]	1856	1831	1834	1805[1]	1957	1764[1]	1647	1830	1906	1868[4]	1756	800 - 1875	2750[3]
Temperature	°C	-	16	20	20.1	19.8	15.8	16.5	17.2	17.1	15	22.8	18.5	16.7	14	16.4	16.5	17.7	15.2	14.8	15.2	15.5	15.7	-	-
Total Organic Carbon	mg/l	1.7[2]	0.7[2]	0.5[2]	2	4	8.4	-	<0.5	1.4	2.8	2.8	3	0.8	4	3.9	12.4	1.4	3.2	42	1.8	10.7	2.9	-	No abnormal change
Calcium	mg/l	120	100	115	114	110.1	215	169	119	114	65	125	115	116	110	132	108	110	101	104	108	119	118	-	-
Magnesium	mg/l	32	30	33	30.56	31.44	56	50	30	32	23	31	29	37	31	35	28.5	28.6	26.7	27	28.2	31.5	31.1	-	-
Sodium	mg/l	230	205	190	300	232.5	180	282	222	208	90	210	229	240	183	155	195	199	175	177	181	211	211	-	200
Potassium	mg/l	8.7	12	13	7.3	8.3	34.5	8.2	8.8	8	8.1	13	8.4	10	<1	6.4	8.11	10.6	8.51	9.82	9.9	12.2	10.6	-	-
Nitrate	mg/l NO_3	<2	<5	<5	0.5	<0.3	<1	<5	<1	14	4.3	6.33	1.53	6.97	3.9	15.7	2.82	3.87	<1	<1	3.16	<1	8.7	37.5	50
Nitrite	mg/l NO_2	<0.01	<0.01	<0.01	<0.05	<0.05	<0.016	<0.016	<0.016	<0.016	0.016	<0.016	<0.065	0.076	<0.02	<0.082	<0.082	<0.082	<0.082	<0.263	0.026	0.007	0.069	0.375	0.5
Chloride	mg/l	438	450	460	46	390	471	350	31	550	485	435	535	468	406	406.2	490	450	77.7	392	414	460	370	24 - 187.5	250
Sulphate	mg/l	59	51	48	75	54	65	55	56	105	58	44	50.5	17.33	41.23	49	50	43.3	31.2	50.1	52.6	54.1	55.7	187.5	250
Fluoride	mg/l	0.45	0.65	0.21	0.57	0.56	0.49	0.08	0.44	0.19	0.43	0.5	0.39	0.465	0.425	0.456	0.436	0.471	0.37	0.34	0.49	0.31	0.26	-	1.5
Total Ammonia	mg/l N	0.18	0.23	<0.05	-	1.6	0.5	<0.02	0.08	0.152	0.14	<0.01	0.012	0.011	<0.19	<0.27	<0.06	<0.06	0.08	<0.41	<0.02	0.02	0.16	0.065 - 0.175	0.23
Iron (filtered)	µg/l	500	<10	520	10	1	3	<50	370	450	320	<5	<5	<5	<5	<5	<230	<230	<230	<230	<230	<230	400	-	200
Manganese (filtered)	µg/l	70	<10	60	<50	25	48	<50	54	50	70	<5	<5	<5	<5	<5	74	25	<7	30	<7	<7	66	-	50
Copper (filtered)	µg/l	<10	<10	<10	<50	<5	2	<50	<10	-	<10	<50	<50	<50	<50	<50	<9	<9	<9	<9	<9	<9	<9	-	2000
Tin (filtered)	µg/l	<50	<50	<50	<500	<5	<2	<50	<10	< 10	<10	<10	<10	<10	<50	<50	<7	<7	<7	<7	17	8	<7	-	-
Chromium (filtered)	µg/l	<10	<10	<10	<50	<1	3	<50	<10	<5	<5	<5	<5	<5	<5	<5	<2	<2	<2	<2	<2	<2	<2	37.5	50
Lead (filtered)	µg/l	<50	<50	<50	<50	<5	<0.5	<50	<5	<10	<10	<10	<10	<10	<10	<10	<6	<6	<6	<6	<6	<6	<6	7.5	10
Nickel (filtered)	µg/l	30	<10	<10	<10	<10	<0.6	<50	<10	<10	<20	<20	<20	<20	<20	<20	<3	<3	<3	<3	3	<3	<3	-	20
Cobalt (filtered)	µg/l	<10	<10	<10	-	<1	<0.1	<50	<10	<5	<10	<10	<10	<10	<10	<10	<2	<2	<2	<2	<2	<2	<2	-	-

Notes:

All samples to date collected from inlet to Roman-style outdoor bath, except for 1998-2002 (collected from spa well)

Shaded cells indicate results exceeding the Groundwater Threshold Value or Drinking Water Parametric Value

< Denotes less than the laboratory reporting limit

1. Corrected from 20°C to 25°C assuming 2% change/°C

2. Measured as Non-Purgeable Organic Carbon

3. Equivalent Conductivity at 25°C assuming 2% change/°C

4. Laboratory measurement (error with field reading)

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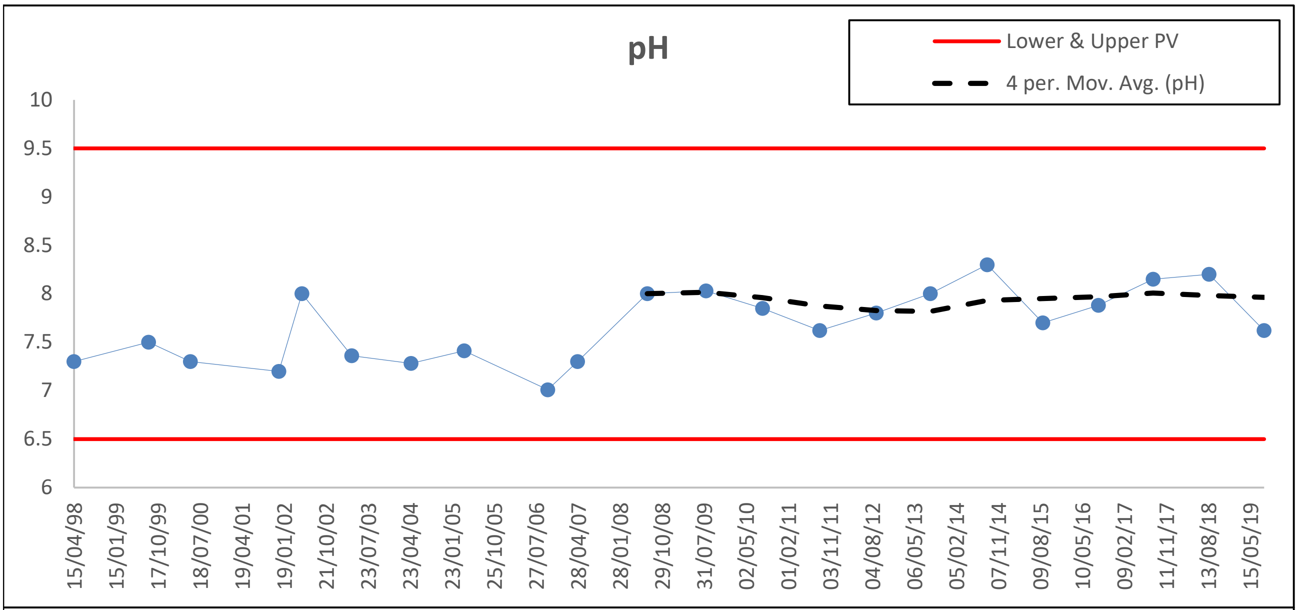
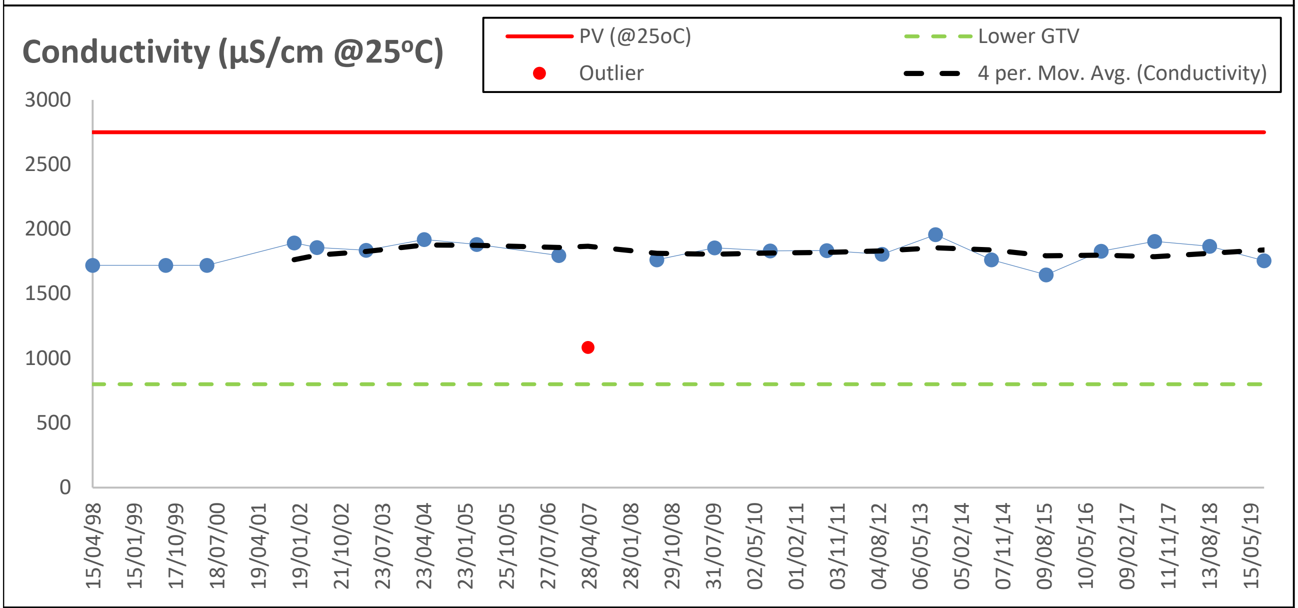
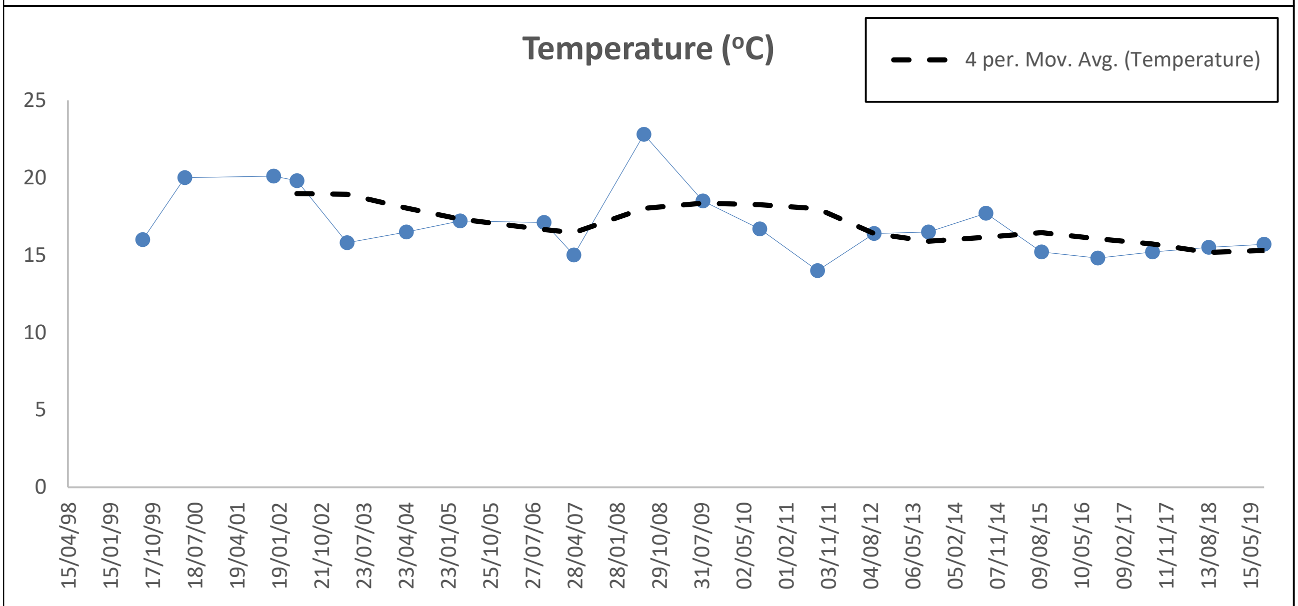
APPENDIX IV

Graphed Monitoring Results (1998-2019)

Appendix IV: Graphed Monitoring Results (1998-2019)







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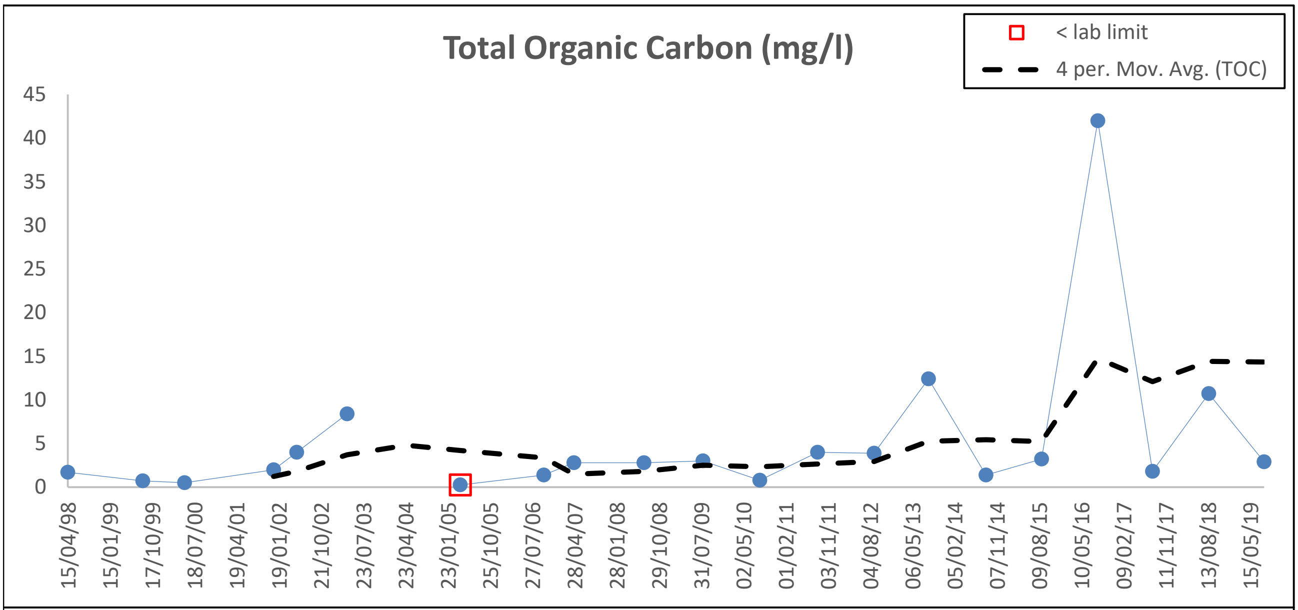

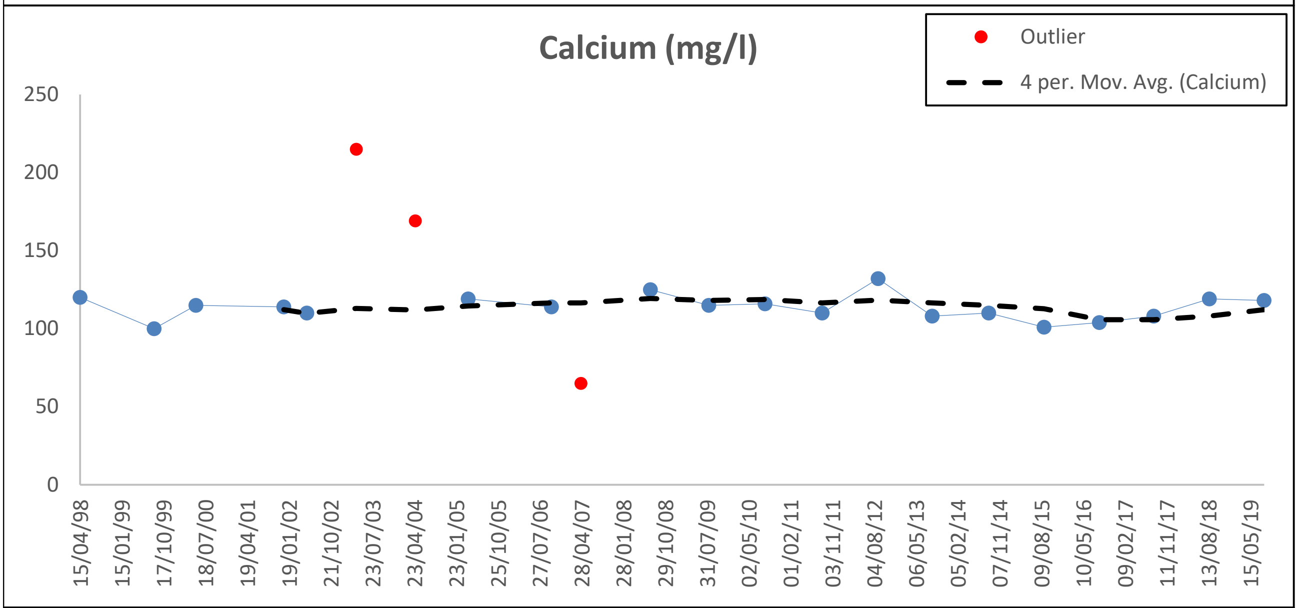

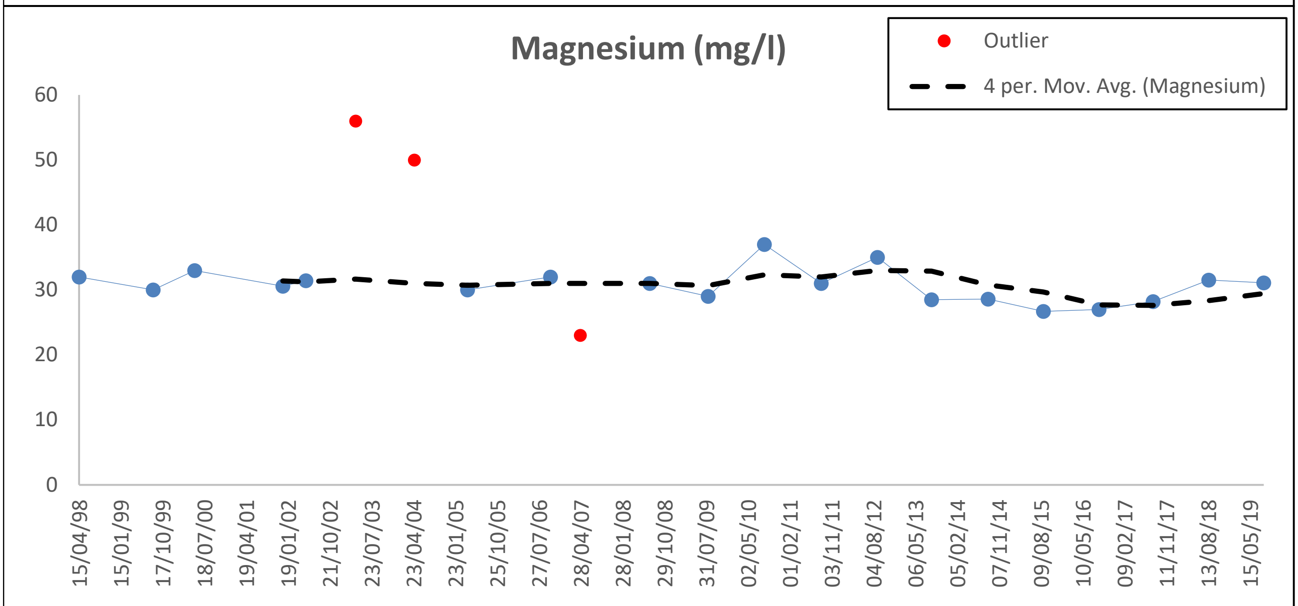

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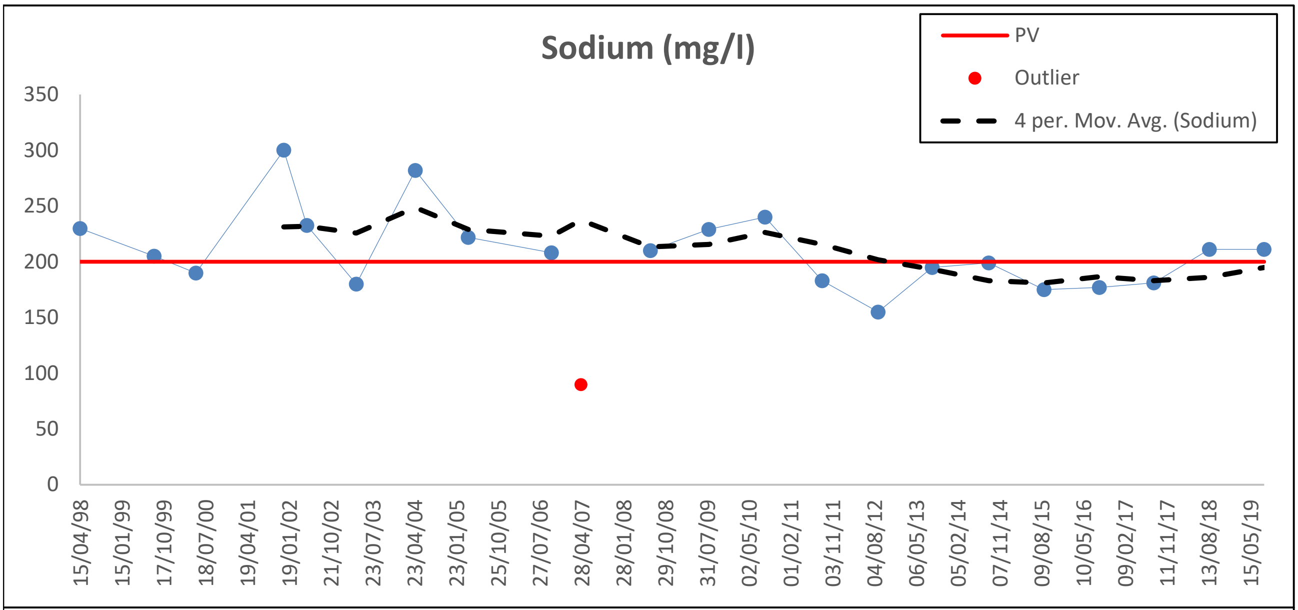

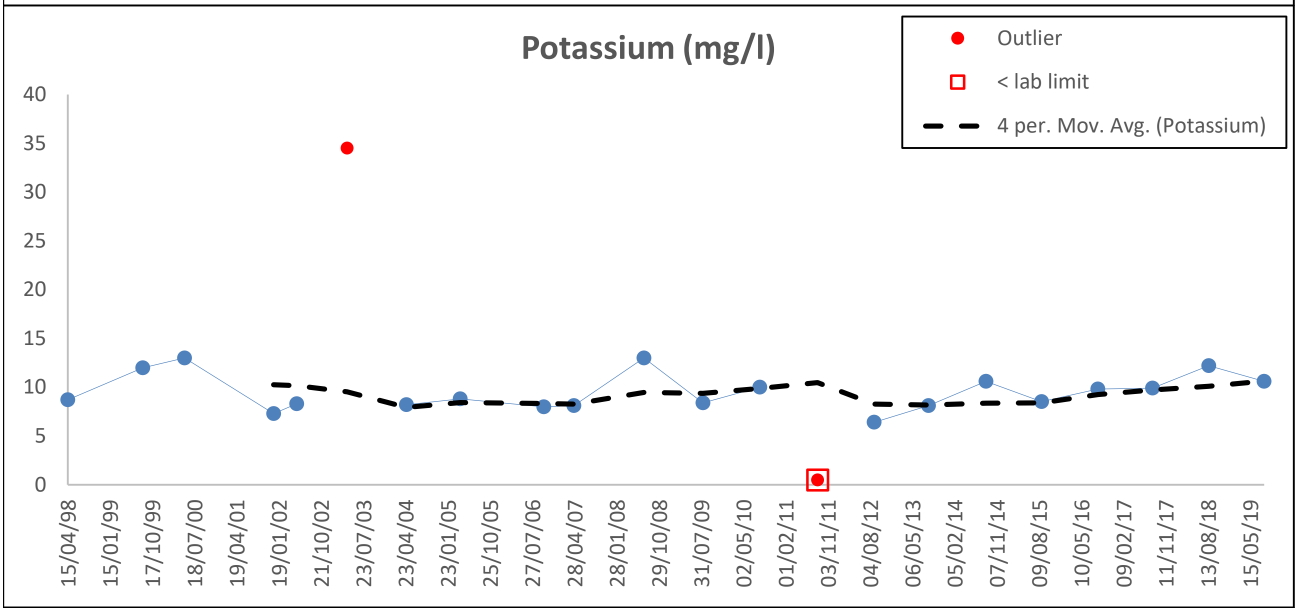

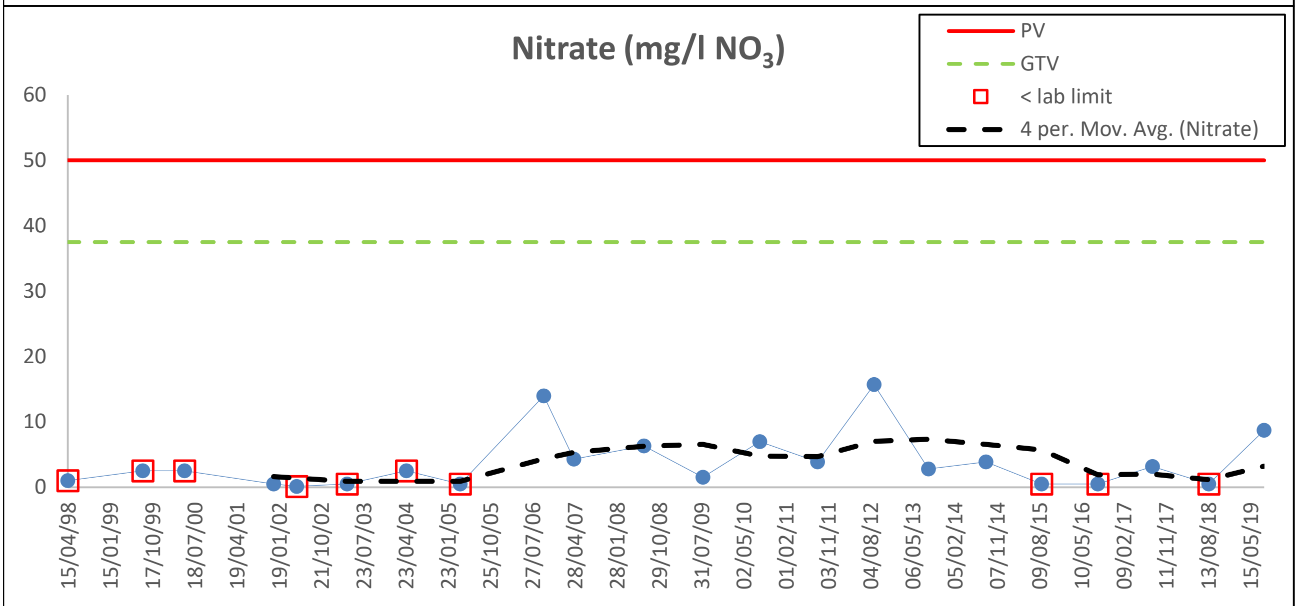

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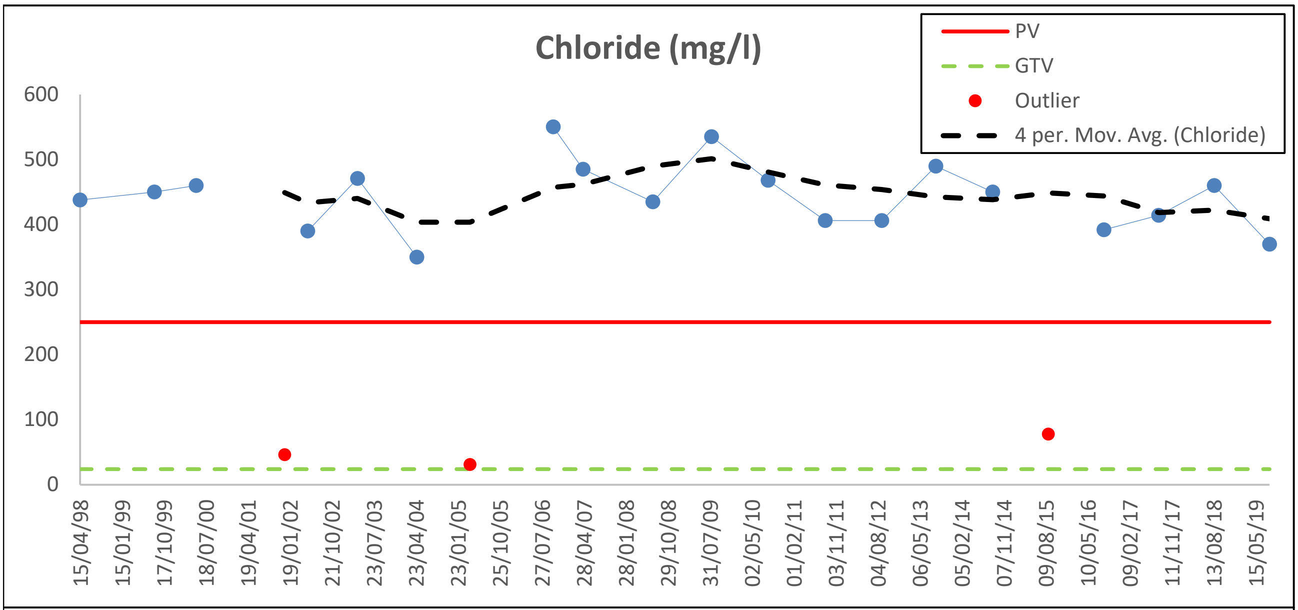

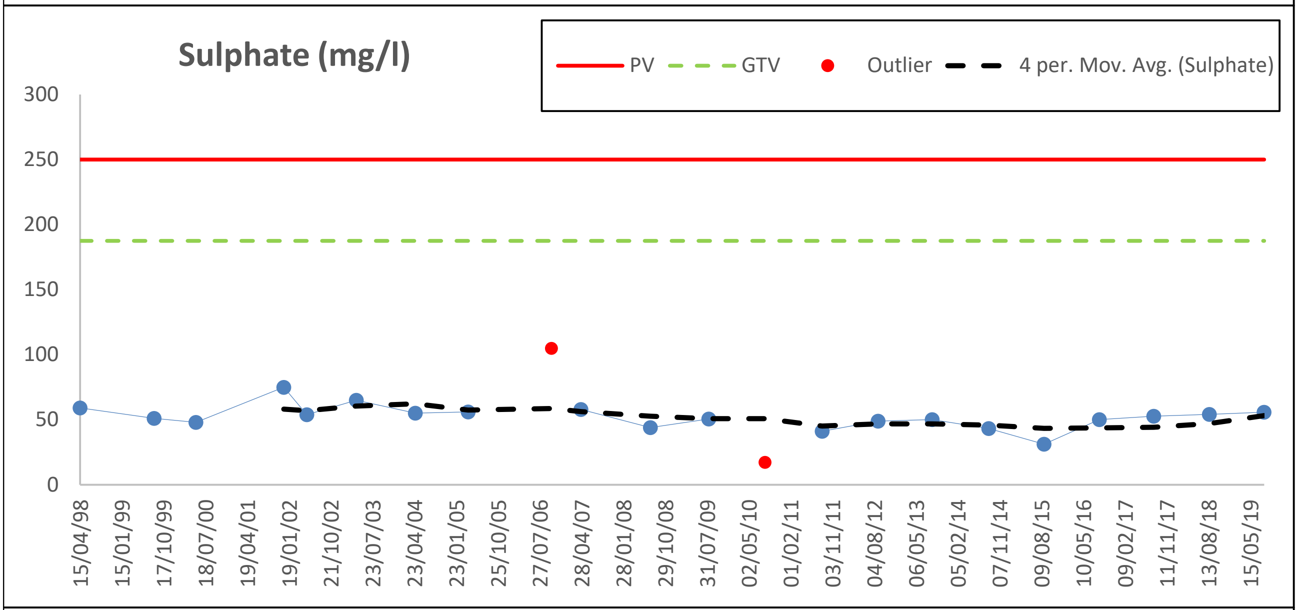

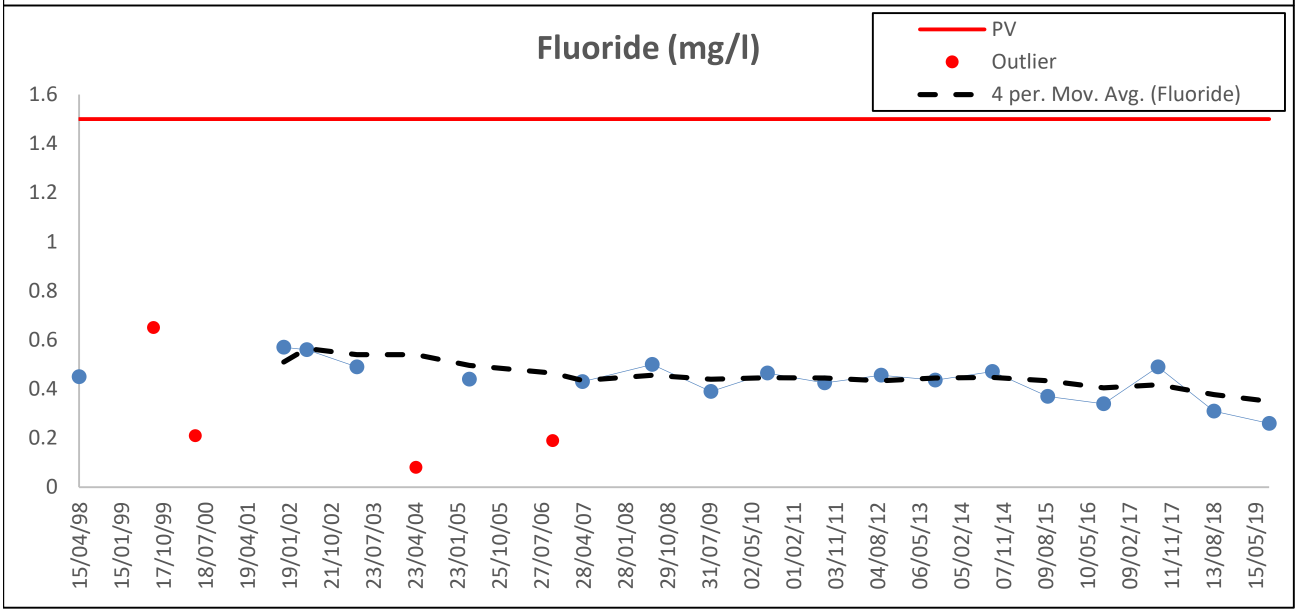

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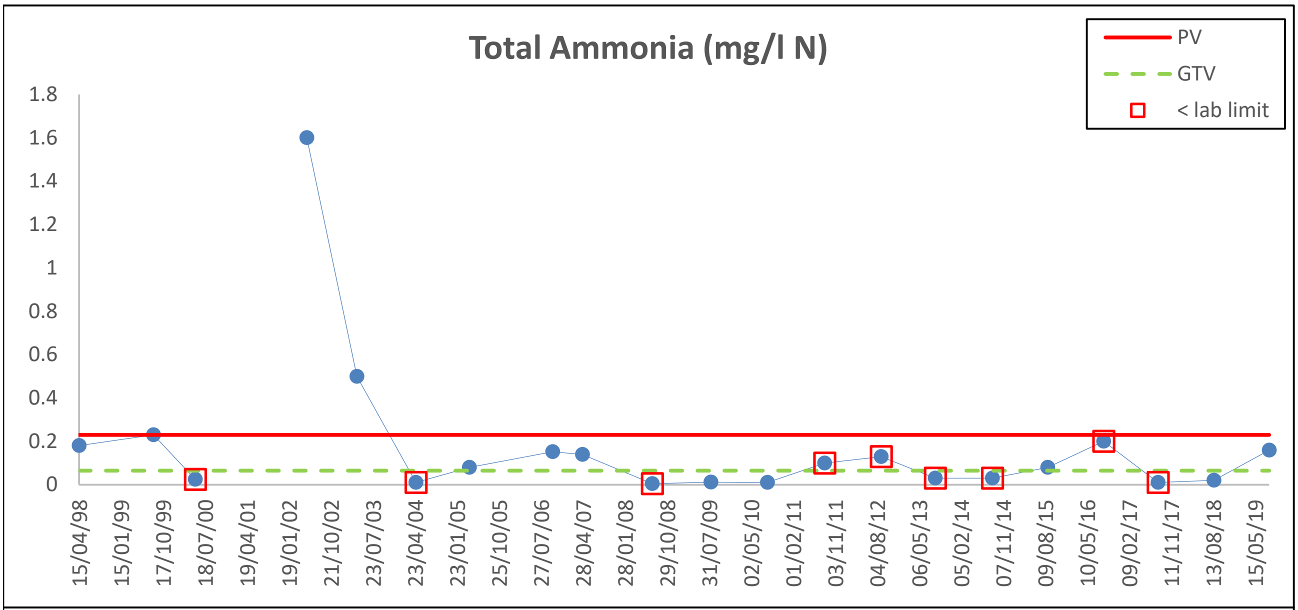

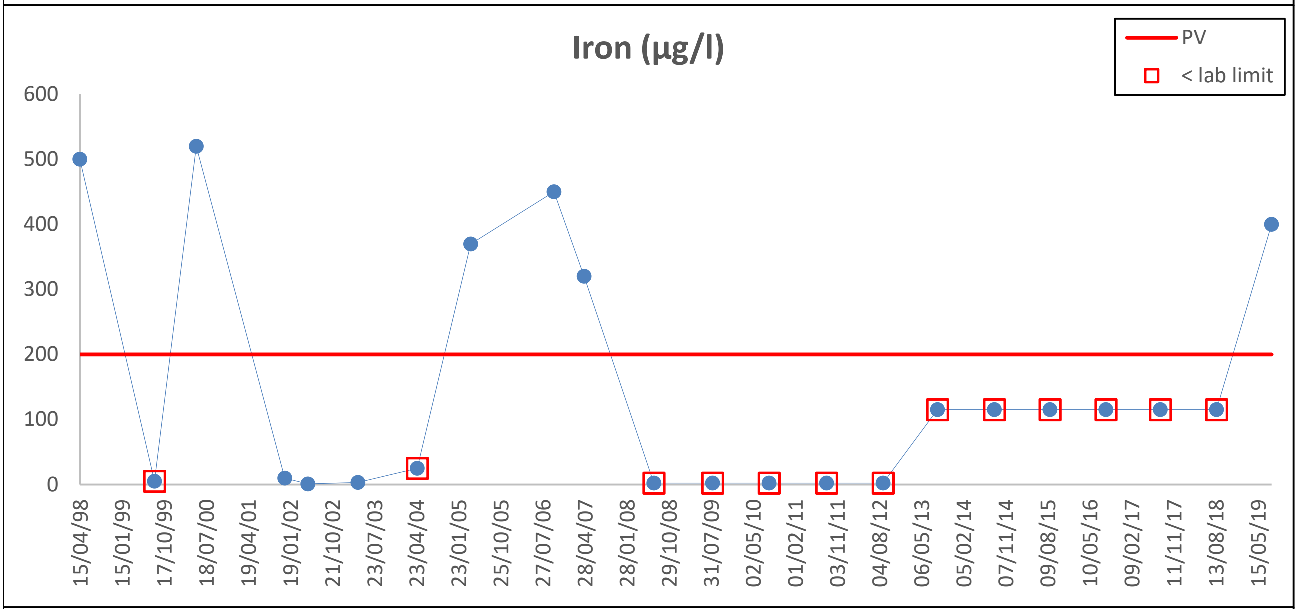

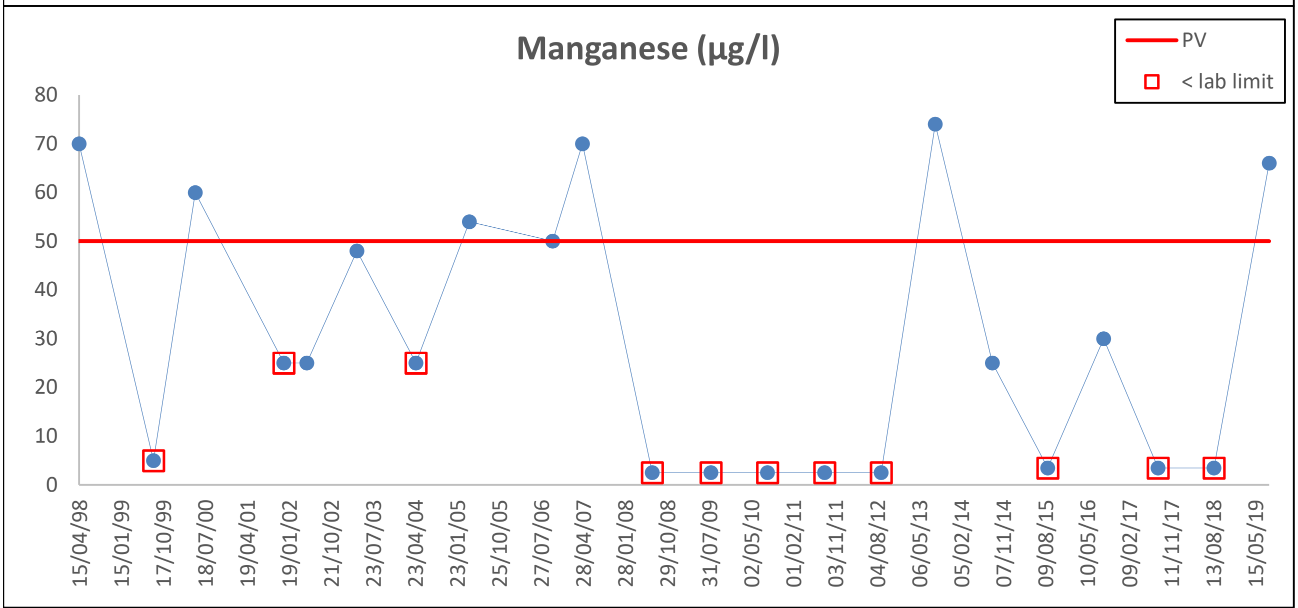

APPENDIX V

Trend Analysis Summary

Appendix V: Trend Analysis Summary

Time Series	First Year	Last Year	n	Mann-Kendall test			Sen Slope Estimate	Time Series Analysis			
				Z Statistic	Significance	Comment		Median	Range	Interpreted Trend	Comment
pH	1998	2019	22	2.80	99%	Monotonic increasing trend (rejected)	-	7.94*	7.62 - 8.3*	No trend	Step increase in 2008 corresponds with change from field to lab measurement, *statistics from 2008 onwards
Conductivity (µS/cm @25^{o}C)	1998	2019	21	0.24	-	-	-	1831	1647 - 1957	No trend	1 outlier removed (2007)
Temperature (^{o}C)	1999	2019	21	-2.21	95%	Monotonic decreasing trend (rejected)	-	16.45	14 - 22.8	No trend	Apparent decreasing trend is most likely related to ponding/warming at the cistern and not the spring source
TOC (mg/l)	1998	2019	21	2.12	95%	Monotonic increasing trend	0.146	2.8	<0.5 - 42	Increasing trend*	*Apparent increasing trend may not be real, related to annual variation and limited sampling frequency?
Calcium (mg/l)	1998	2019	19	-0.67	-	-	-	114	101 - 132	No trend	3 outliers removed (2003, 2004, 2007)
Magnesium (mg/l)	1998	2019	20	-1.51	-	-	-	31	26.7 - 37	No trend	3 outliers removed (2003, 2004, 2007)
Sodium (mg/l)	1998	2019	21	-1.63	-	-	-	208	155 - 300	No trend	1 outlier removed (2007)
Potassium (mg/l)	1998	2019	20	0.94	-	-	-	8.75	6.4 - 13	No trend	2 outliers removed (2003, 2011)
Nitrate (mg/l NO_3)	1998	2019	22	1.03	-	-	-	2.5	<0.3 - 15.7	No trend	
Chloride (mg/l)	1998	2019	19	-0.63	-	-	-	450	350 - 550	No trend	3 outliers removed (2001, 2005, 2015)
Sulphate (mg/l)	1998	2019	20	-1.33	-	-	-	51.8	31.2 - 75	-	2 outliers removed (2006, 2010)
Fluoride (mg/l)	1998	2019	18	-2.77	99%	Monotonic decreasing trend	-0.010	0.445	0.26 - 0.57	Decreasing trend	4 outliers removed (1999, 2000, 2004, 2006)
Total Ammonia (mg/l N)	1998	2019	21	-1.15	-	-	-	0.08	<0.01 - 1.6	No trend	Half the reporting limit assumed where values below laboratory reporting limit
Iron (µg/l)	1998	2019	22	0.20	-	-	-	115	<5 - 520	No trend	Half the reporting limit assumed where values below laboratory reporting limit
Manganese (µg/l)	1998	2019	22	-0.86	-	-	-	25	<5 - 74	No trend	Half the reporting limit assumed where values below laboratory reporting limit

Notes:
1. Time series not generated for Nitrite and the 6 No. trace metals as most results were below the laboratory reporting limits

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