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# February 2022 Ground Water Monitoring Report

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# 1. Introduction

Tetra4 (Pty) Ltd (hereafter referred to as “Tetra4”) is a natural gas production company situated between Welkom and Virginia, within the Free State Province. Tetra4 operates the HDR1-production facility, currently the only production and processing facility, which is connected to two existing production wells. Tetra4 intends to commercially develop the Cluster 1 gas field by extracting gas occurring in fractures, fissures, and faults within the Ventersdorp and Witwatersrand supergroups located at depths of between approximately 380 m to 880 m.

Tetra4 undertakes routine groundwater monitoring on a bi-monthly basis, as per the approved Environmental Management Programme (EMPr) of 2017, to assess whether production activities might influence the prevailing groundwater quality. Activities undertaken by Tetra4 include:

- The drilling of exploration and production boreholes for the extraction of gas.
- The installation of pipelines for the collection and transport of gas.
- The construction of processing facilities (including compression and storage) for the gas as a final product.

This report presents the process and outcome of the bi-monthly groundwater monitoring event conducted between 9 and 10 February 2022. The production operation and associated areas will be developed in a phased approach and as such this monitoring programme is expected to evolve as the phases are implemented. See Figure 1 for a layout map of the monitoring programme at present.

# 2. Background

## 2.1 Geological Setting

In terms of the geological setting the shallow potable aquifers, associated with the Karoo formation, are separated from the deep aquifer systems, associated with the Ventersdorp and Witwatersrand Supergroup Formations, by 30 m thick dolerite sills that extend across the study area as well as 65 m thick Dwyka Tillite. The sills and tillite are expected to have low permeability and to act as vertical barriers to groundwater flow. Unfractured Karoo Supergroup shales found at depths more than 300 m are also expected to act as a horizontal barrier between the deep aquifer systems and the potable shallow aquifers. These zones can yield large volumes of water that is associated with the underground workings of the deep gold mines. The water in the deep aquifers is naturally saline due to their marine depositional history.

## 2.2 Hydrogeological Setting

The following aquifer systems have been identified in the Cluster 1 project area:

**Intergranular or primary aquifers** consisting of alluvium deposits associated with the flood plains of the Sand and Doring Rivers and/ or with the aeolian sands that cover a large portion of the study area. These aquifers comprise of sand and gravel interbedded with clay, calcrete or ferricrete. These aquifers exhibit high porosities, permeabilities and rates of recharge, which makes this aquifer vulnerable to surface sources of

contamination. The primary weathered aquifers are unconfined and typically has a high specific yield - groundwater levels are commonly shallow (<3 m). Alluvial aquifers play an important role in groundwater-surface water interaction, as they are directly connected to the rivers/ streams. The aeolian deposits are unconfined, typically has a high specific yield and form an important recharge mechanism to the underlying fractured and intergranular aquifers.

**Shallow fractured Karoo aquifers** typically occur within the upper 300 m of the geological sequence (± 11-300 mbgl). Below this depth, the fractures tend to close, and the permeability of the rock formations decrease to below viable groundwater abstraction levels. The shallow aquifers in the study area are associated with the Karoo Supergroup sediments as well as with dolerite intrusions. These fractured aquifers are formed because of tectonic forces and to a lesser degree weathering process, which produced a network of fractures in competent sandstone and shales of the Karoo Supergroup sediments. The storage coefficient of these types of aquifers are limited, as little or no decomposition of the rock mass typically takes place due to their arenaceous nature.

**Deep fractured aquifers** occur >300 m below the surface. Below a depth of 300 m, groundwater quality deteriorates, and the permeability of the water-bearing formations decrease by orders of magnitude. As such, these aquifers are not used for water supply or private water use. The deep aquifers are confined. Sedimentary rocks can form higher yielding aquifers, while volcanic formations have very low permeabilities and can act as aquitards or even aquicludes, restricting the vertical movement of groundwater. The deep aquifers are isolated from the shallower Karoo aquifers by the low permeable to impermeable shales of the overlying Ecca Group, the dolerite sill that extends across the study area as well as by the volcanic formations. There is, under natural conditions, very limited natural connection (leakage) between deep and shallow aquifers in this context.

Groundwater level information obtained from monitoring boreholes (monitored on a bi-monthly basis) and private unequipped borehole identified during the baseline assessments and hydrocensus campaigns, indicate that the boreholes can be divided into shallow boreholes that target the shallow weathered aquifer and deeper boreholes that targets the fractured rock aquifer. It is shown that groundwater is generally intersected within the upper 20m of the geological succession, which comprises of weathered material and unconsolidated sediments. Groundwater level data ranges between 1.9 – 26 mbgl. The average depth to groundwater level is ±10.5 m.

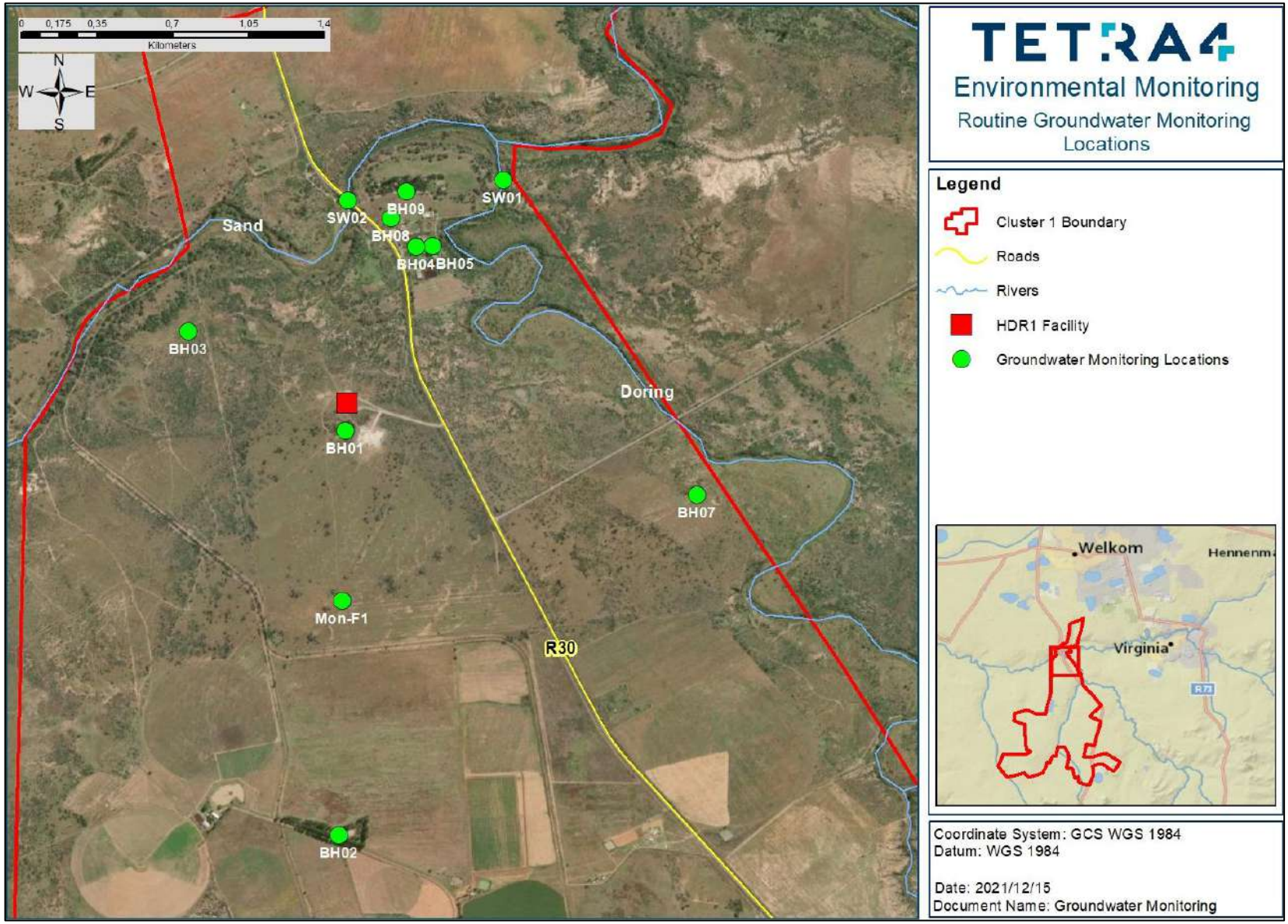



Figure 1: Routine groundwater monitoring locations

# 3. Monitoring Requirements

The groundwater monitoring programme to which this report relates is driven by the following requirements of the Production Right issued by the Petroleum Agency of South Africa (PASA) as well as the 2017 updated EMPr.

- Production Right:
    - The license holder recognises that ground water contamination could materialise from the migration of saline water from the deep to the shallow aquifers and that disposal of wastewater through an injection well where Karoo formations are not properly sealed off could also result in water contamination. Given this, all wastewater is collected and disposed of at a registered facilities. Tetra4 does not undertake any well injections activities. The license holder's proposal to seal off Karoo formations through borehole casing and cementing, and implementing a ground water monitoring programme to prevent the identified impact of saline water migration is deemed to be adequate, and the envisaged impact is of medium significance
    - Surface water resources such as Sand and Vet Rivers with their tributaries, wetlands and pans may be polluted from indirect contamination with wastewater, saline/ produced water, hydrocarbon spillages, etc. The license holder proposes to minimise the impact by channelling contaminated water to primary and secondary lined sumps and keeping drill water in closed circuit on the drilling rig.
    - A continuous environmental monitoring schedule have been agreed with the PASA, which includes monthly internal audits in accordance with the operational commitments in the EMPr, weekly inspections on exploration drilling and an annual EMPr performance assessment.
    - The license holder must undertake a comprehensive baseline assessment of ground and surface water within and adjacent to the proposed production area and results communicated to the Agency before production operations commence on site and continuous monitoring of water chemistry, potential contaminants and static water levels undertaken thereafter. The baseline assessment for HDR1 was done during the months of April and May 2015. Note that the basline sampling for the larger Cluster 1 area has already been completed. Once production within Cluster 1 starts, these sites will be included as part of the bi-monthly monitoring programme.
    - The recommendations of the pre-production Baseline Water Quality Monitoring Report (Dated July 2015) included:
        - On-going bi-monthly monitoring of indicator parameters.
        - Bi-annual monitoring of full monitoring parameters during on-going operations.

        - Bi-annual monitoring of full monitoring parameters for a period ending 1 year following cessation of the production activities (i.e. drilling).
        - A dedicated monitoring borehole is to be drilled and installed for select new production wells.

It should be noted that Tetra4 will be monitoring the full set of parameters on a bi-monthly basis going forward.

- 2017 EMPr:
    - Measure the impacts of gas production on groundwater levels and quality.
    - Detect short- and long-term water level and quality trends.
        - A lowering in groundwater level of more than 10 m will trigger a response.
        - An increase of any of the indicator elements by more than 25 % from baseline conditions will trigger a response.
    - Recognise changes in groundwater characteristics, to enable analysis of their causes and to trigger the appropriate groundwater management response.

# 4. Study Design

## 4.1 Sample Locations

The identification of suitable sample locations was driven primarily by the physical location of the proposed production activities. Sample locations are subsequently identified to achieve the following:

- Utilise available existing water resource sites (including boreholes and surface water features).
- Utilise sites that are practically accessible.
- Utilise sample sites that are representative of the surrounding water uses (i.e. domestic water abstracted from shallow aquifers or surface water features).
- Sample sites identified within ~1 km from the proposed production activities.
- Utilise sample sites that are representative of existing qualities, both upstream and downstream of the proposed production activities.

Figure 1 provides a spatial representation of the current production activities covered under this monitoring programme as well as the location and type of identified monitoring sites monitored during this sampling event. Table 1 provides a brief description of each sample site in terms of location, surrounding land-uses and sample site conditions at the commencement of baseline sampling in 2015. Electrical Conductivity (EC) profiles and a photographic record for each site can be seen in the table of figures, Table 2. EC profiles were created, where possible, for each monitoring site. The EC-profiles, along with the borehole casing depths, are used to determine the depth at which freshwater aquifers are likely to be situated. Changes in EC and temperature below the borehole casing indicates

a change in water characteristics likely attributed to water flow. Changes in EC could be influenced by borehole characteristics, geological formations, pumping equipment etc. EC-profile measurements will be taken bi-annually to account for both the wet and dry seasons in February and August.

When analysing the EC profiles presented in Table 2, the graphs in most cases have relatively stable EC levels at first, which could be indicative of stagnant water that is present in the boreholes. It is therefore assumed that a significant spike in the graph is likely an indication of where flowing/ fresh water enters from the underlying water bearing formation. EC levels tend to stabilise after this first step. In general, flowing fresh water has different EC levels compared to stagnant water, therefore sudden changes in EC levels are indicative of the depth at which the aquifer is situated and the depth at which sampling should be undertaken.

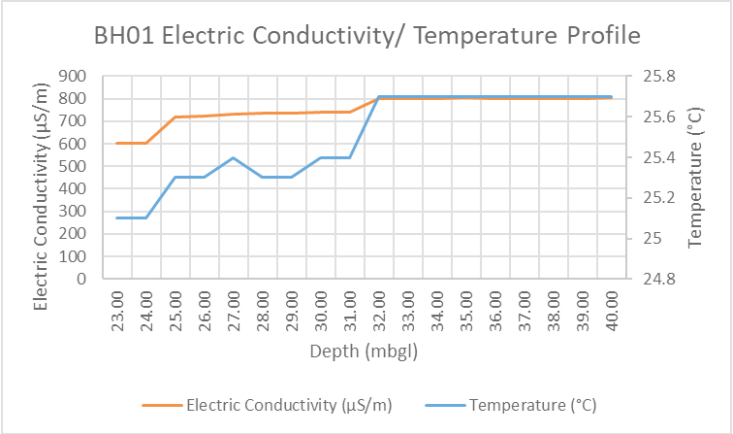
Table 1: Sample site descriptions

| Site | Coordinates (WGS 84) | | Date and Time Sampled | Sample Site Description | Borehole Casing Diameter (m) | Borehole Collar Height (m) | Borehole Casing Depth (mbgl) | Borehole Total Depth (mbgl) | Static Water Level (mbgl) | Sampling Depth (mbgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | | | | | | | | |
| BH01 | -28.127231 | 26.719193 | 2022/02/10 14:56 pm | Un-equipped borehole adjacent to HDR1 which is accessible with the bladder pump. Used in the past for livestock watering. | 0.16 | 0.172 | 30.5 | 38.40 | 23.24 | 34 |
| BH02 | -28.144047 | 26.718938 | 2022/02/10 12:16 pm | Equipped borehole that was used for water supply to the house. Samples were previously collected on surface at the pump outlet tap. Access could not be gained to the pump outlet tap for consecutive sample events. An alternative sampling site (BH10) was thus obtained. BH10 collapsed and is no longer being monitored. However, for this and several previous sampling events, access was granted to the site again. The borehole was unequipped and could be accessed with use of the bladder pump. | 0.16 | 0.20 | N/A | 47.10 | 10.16 | 31 |
| BH03 | -28.123210 | 26.712767 | Not Sampled | This site was originally an un-equipped borehole. Used in the past for livestock watering. The borehole is now equipped with a windmill. The site could not be accessed due to wet roads. | N/A | N/A | N/A | N/A | N/A | N/A |
| BH04 | -28.119499 | 26.722306 | 2022/02/10 08:29 am | Equipped with submersible pump. Site was accessible with the bladder pump for first the two sample events. Thereafter the site was sampled from a JoJo tank outlet. Water is used for domestic purposes. | N/A | N/A | N/A | N/A | N/A | N/A |
| BH05 | -28.119539 | 26.722729 | 2022/02/10 08:36 am | This unequipped site is situated close to BH04. Suspect that it was used for livestock watering. | 0.2 | 0.485 | N/A | 22.55 | 12.77 | 20 |

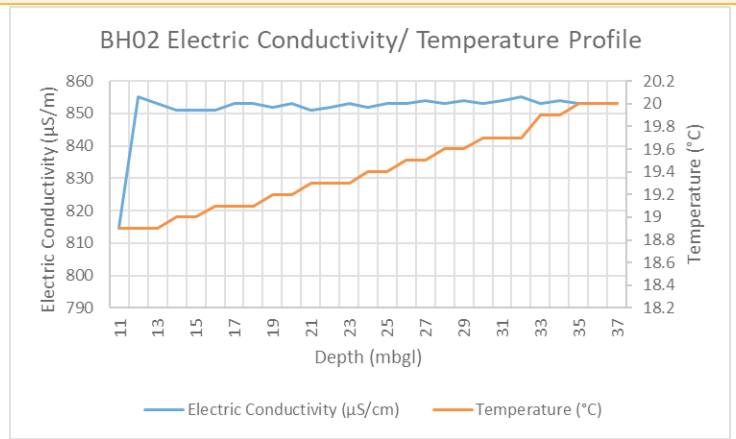
| Site | Coordinates (WGS 84) | | Date and Time Sampled | Sample Site Description | Borehole Casing Diameter (m) | Borehole Collar Height (m) | Borehole Casing Depth (mbgl) | Borehole Total Depth (mbgl) | Static Water Level (mbgl) | Sampling Depth (mbgl) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | | | | | | | | |
| | | | | This site can be accessed with the bladder pump. | | | | | | |
| BH07 | -28.129905 | 26.733792 | 2022/02/09 13:25 pm | Unequipped borehole that is accessible for the bladder pump. Suspect it was used for livestock watering in the past. | 0.16 | 0.135 | 20.02 | 30 | 16.88 | 27 |
| BH08 | -28.118370 | 26.720983 | 2022/02/10 09:46 am | Equipped borehole. Owner says they use a lot of water. They used to run a pivot system. Now they supply their shop and caravan park. | N/A | N/A | N/A | N/A | N/A | N/A |
| BH09 | -28.117312 | 26.721737 | 2022/02/10 10:49 am | Unequipped borehole that is accessible for the bladder pump. | 0.16 | 0.035 | N/A | 42 | 9.45 | 24 |
| Mon-F1 | -28.134285 | 26.719059 | 2022/02/10 16:51 pm | This is an unequipped monitoring borehole that was drilled by Tetra4. This borehole formed part of the Cluster 1 baseline monitoring programme, however, this site has been included as part of the HDR1 monitoring programme, because it is situated close to the south of the HDR1 facility and can act as an upstream reference site. | 0.178 | 0.375 | 40 | 49.625 | 21.25 | 40 |
| SW01 | -28.116835 | 26.725738 | 2022/02/10 10:07 am | Surface water sample in the Doring River. Sample taken just downstream of a weir. The surrounding area is used as a caravan site. | N/A | N/A | N/A | N/A | N/A | N/A |
| SW02 | -28.117652 | 26.719291 | 2022/02/09 14:23 pm | Surface water sample in the Sand River. Sample taken just downstream of a weir under the bridge. Area used for car washing and local rituals. | N/A | N/A | N/A | N/A | N/A | N/A |

Table 2: Sample site photographs with corresponding electric conductivity and temperature profiles

BH01

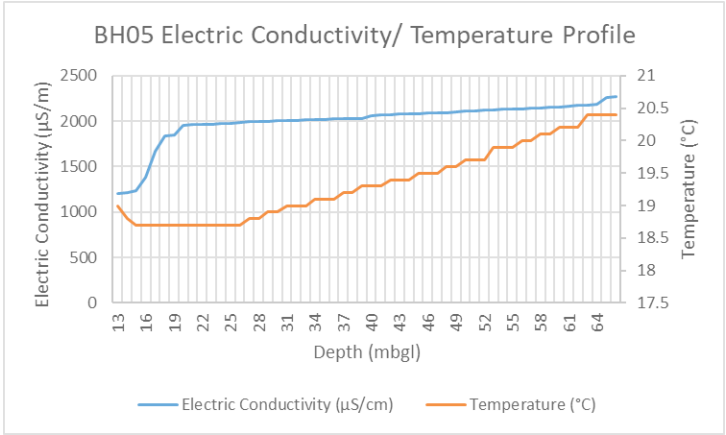



BH02

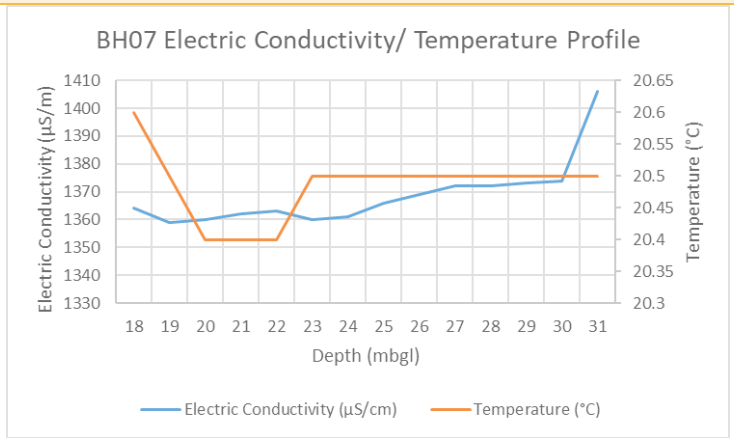



BH03

| | |
|---|---|
| | NA |
| BH04 | |
| | NA |
| BH05 | |


BH05 Electric Conductivity/ Temperature Profile
Electric Conductivity (µS/m)
Temperature (°C)
Depth (mbgl)
Electric Conductivity (µS/cm)
Temperature (°C)

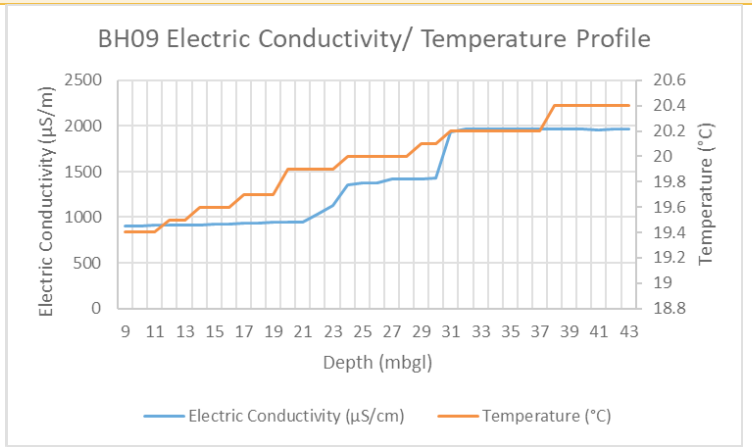
BH07


BH07 Electric Conductivity/ Temperature Profile
Electric Conductivity (µS/m)
Temperature (°C)
Depth (mbgl)
Electric Conductivity (µS/cm)
Temperature (°C)

BH08

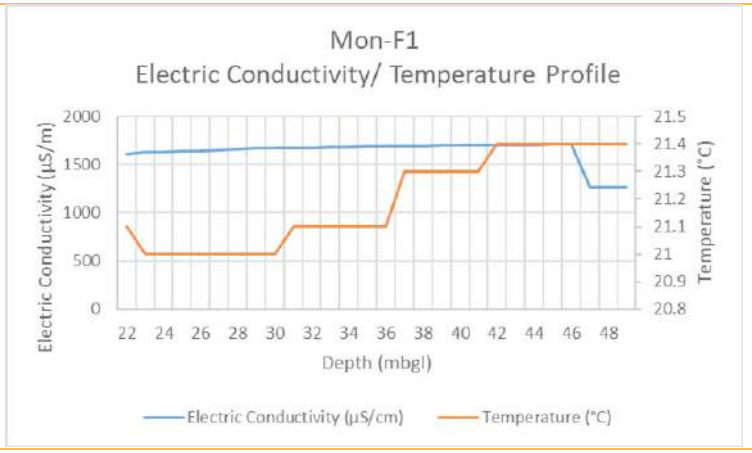
NA

BH09


BH09 Electric Conductivity/ Temperature Profile
Electric Conductivity (µS/m)
2500
2000
1500
1000
500
0
Temperature (°C)
20.6
20.4
20.2
20
19.8
19.6
19.4
19.2
19
18.8
9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43
Depth (mbgl)
Electric Conductivity (µS/cm)
Temperature (°C)

SW01

| | |
|---|---|
| | NA |
| SW02 | |
| | NA |
| Mon-F1 | |


Mon-F1
Electric Conductivity/ Temperature Profile
Electric Conductivity (µS/m)
2000
1500
1000
500
0
Temperature (°C)
21.5
21.4
21.3
21.2
21.1
21
20.9
20.8
22 24 26 28 30 32 34 36 38 40 42 44 46 48
Depth (mbgl)
Electric Conductivity (µS/cm)
Temperature (°C)

## 4.2 Sample Parameters

The selection of parameters to be sampled and analysed depend on the objectives of the sampling. The primary objective of this monitoring programme is to ensure that the proposed production activities do not impact on, or affect, the prevailing groundwater qualities on which existing water users in the area are reliant, and to act as an early alert system designed to identify the potential impact (if any) of production activities. Taking this into account, the parameters to be monitored are driven by:

- Parameters that may be directly attributable to the proposed and/ or current production activities (Appendix A).
- Parameters that are core to the existing water users (e.g. domestic water use, agricultural use).

It should be noted however, that Virginia is surrounded by some of the largest gold fields in the Free State Province and is dominated by extensive historic and current gold mining activities, as well as the production of sulfuric acid from gold ore. The area is also subject to extensive agricultural activities which includes use of chemicals, fertilisers, and pesticides. The above-mentioned activities as well as the exploitation of shallow Karoo aquifers within and surrounding the Cluster1 production right could potentially impact on ground- and surface water quality and static water levels within the area.

The initial baseline and bi-annual monitoring events included a wide selection of parameters to compare long-term results to determine the overall impact (if any) of the activities on surface and groundwater resources, as this relates to domestic use of groundwater, livestock watering and the natural groundwater quality. However, bi-monthly monitoring included only key parameters that may be specific to the production activities. The full spectrum of bi-annual parameters will be monitored on a bi-monthly basis going forward. These are listed in Table 3 below.

Dissolved Methane and Dissolved Ethane were not tested for at groundwater sites which were equipped with either a pump or windmill. These devices introduce bias to the sampling method due to pressure changes and water being stagnant in the pipes or water tanks. Dissolved Methane and Ethane were also not tested for at surface water sites due to these parameters' volatility. Any form of turbulent flow will influence the concentration of Volatile Organic Carbons.

Table 3: Parameters analysed for on a bi-monthly basis

| **Metals** | | | |
|---|---|---|---|
| Calcium | Iron | Magnesium | Potassium |
| Silicon | Sodium | Vanadium | Zinc |
| Aluminium | Arsenic | Barium | Beryllium |
| Boron | Cadmium | Chromium | Cobalt |
| Copper | Lead | Lithium | Manganese |
| Molybdenum | Nickel | Rubidium | Selenium |

| | | | |
|---|---|---|---|
| Silver | Thallium | Titanium | Uranium |
| Antimony | Strontium | Mercury | |
| **Anions** | | | |
| Bromide | Chloride | Fluoride | Nitrate as N and $NO_3$ |
| Nitrite as N and $NO_2$ | | Sulphate | |
| **BTEXMN/ Gasoline Range Organics and Total Petroleum Hydrocarbons** | | | |
| MTBE | TAME | Benzene | Toluene |
| Ethylbenzene | m+p-Xylene | o-Xylene | 1,3,5-Trimethylbenzene |
| 1,2,4-Trimethylbenzene | Naphthalene | TPH GRO C6-C10 | TPH C10-C28 |
| TPH C28-C40 | | TPH C10-C40 Total | |
| **Dissolved Gasses** | | | |
| Dissolved Methane | | Dissolved Ethane | |
| **Polycyclic Aromatic Hydrocarbons** | | | |
| Acenaphthene | Acenaphthylene | Fluorene | Phenanthrene |
| Anthracene | Fluoranthene | Pyrene | Benzo(a)anthracene |
| Chrysene | Benzo(b+k)fluoranthene | Benzo(a)pyrene | Benzo(g,h,i)perylene |
| Dibenz(a,h)anthracene | | Indeno(123-cd)pyrene | |
| **Other** | | | |
| Total Oil and Grease | Total Hardness as $CaCO_3$ | pH | Electric Conductivity |
| Total Dissolved Solids | Dissolved Organic Carbon | Dissolved Inorganic Carbon | P-Alkalinity as $CaCO_3$ |
| M-Alkalinity as $CaCO_3$ | Dissolved Oxygen | Carbonate ($CO_3$) | Bicarbonate ($HCO_3$) |
| Ammonia and Ammoni a as N | | | |

## 4.3 Sampling Procedure

Tetra4 is responsible for the monitoring, assessment and evaluation components of this project. Sample analysis is performed by UIS Organics/ Sediba and X-Lab Earth SANAS accredited Laboratories. Field parameters that are collected using a hand-held probe include: Temperature; Barometric pressure; pH; Oxidation/ Reduction potential; Dissolved Oxygen; Electrical Conductivity; Total Dissolved Solids; Salinity; Seawater Specific Gravity (SSG) and Turbidity.

Surface water samples are collected based on the sample-grab method. Groundwater samples are collected using a low-flow sampling technique with a bladder pump containing a Teflon bladder and Teflon tubing. Low-flow sampling allows for the retrieval of representative samples of water in the formation adjacent to the well screen. Stagnant water above and below the screen are not to be sampled. Purging is an important aspect of groundwater sampling, which aims to remove stagnant water adjacent to the well screen immediately before sampling. Purging allows for the inflow of water from the adjacent formation that is representative of the aquifer conditions for sampling. Micro-purging was the most practical (less time consuming) method of purging chosen for this water sampling programme. Micro-purging (SANS 5667-11:2015) involves the removal of small volumes of water directly adjacent to the well screen to be sampled using a sampling device which causes minimum disturbance to water in the borehole column, in this case a bladder pump. Micro-purging is carried out until the variation in parameters acquired by the hand-held probe, in a closed system, is stable. A minimum of 1 L water is purged.

During sampling, a bladder pump is placed within the screened section or point at which there is a distinct EC deviation, micro-purging takes place, and all water pumped, is monitored for several chemical and physical parameters using a flow through cell and field instrumentation, in a closed system. This sampling method results in improved sample quality, accuracy, precision, and less variability through reducing disturbance to the well and surrounding formation, subsequently reducing mixing, analyte dilution, aeration and degassing. As an alternative, double ball valve Teflon bailers are used to sample unequipped groundwater sites. This tubular device is hooked onto a rope attached to a reel, which is then lowered into the formation adjacent to the well screen (like what would be done for the low-flow Teflon bladder method). This sampling method is only applicable to unequipped sites where access is restricted for the vehicle and bladder pump equipment.

Samples to be analysed for inorganic components are collected in 1 x 500 ml plastic bottle. Samples to be analysed for organic compounds and Total Oil and Grease are collected in 2 x 500 ml glass bottles. Samples to be analysed for dissolved gas, PAH's and BTEXMN and GRO's are collected in 3 x 40 ml glass receptacles with Teflon-lined lids. To prevent compromising analyses for dissolved gasses, the 40 ml glass receptacles are dosed with HCl and no head spaces are included when sampling in the glass bottles or vials. Collected samples are stored and transported in cool boxes and delivered to the laboratory as soon as possible after sampling for processing and analysis.

Static Water Levels (SWL) at the respective groundwater monitoring sites are captured during each sampling event prior to sample collection. A suitable sample depth of each monitoring site has been determined based on the EC-profile and borehole casing depth of each site. Refer to Section 4.1 for a discussion of EC-profile analysis.

# 5. Status of Exploration, Construction and Production Activities

During the months of January and February 2022, production continued at the Compressed Natural Gas (CNG) plant where gas extraction from wells MDR05 and HDR01 occurs. Construction activities are still underway at the Helium and LNG plant, as well as at Compressor Station B. Drilling activities took place at exploration well T4MD006

and was completed during February 2022. Site establishment commenced at exploration well T4MD007.

# 6. Results

In this section the chemical constituents of each site for the current monitoring event were compared with the mean baseline for that parameter at each site and evaluated against the South African National Standards (SANS) and DWAF acceptable South African Water Quality Guidelines. Time-series chemistry data was evaluated for the entire duration of the project. It will be noted if there are any prominent changes in chemical concentrations between the current and previous monitoring event. Static Water Levels (SWL) were also compared to assess if a more than 10 m drop in SWL occurred at any of the unequipped boreholes as per 2017 EMPr requirement.

Further statistical analysis and research was performed on Parameters of Potential Concern (POPC). POPC are chemical parameters which indicated an exceedance of 25 % from the baseline mean or which exceeded the SANS or DWAF water quality standards. Statistical analysis and further investigations should assist in identifying possible causes for certain exceedances.

Refer to Appendix B for the water quality results as obtained from UIS Organics/ Sediba and X-Lab Earth Laboratories.

## 6.1 Site Conditions

The following notes apply for this sampling event:

- The windmill at site BH03 was repaired, however the site was inaccessible due to wet roads and a sample could not be taken.
- The casing depths could not be determined at sites BH05, BH09 and BH02 because the casing depth indicator's magnetic probe was active throughout the total depth at each of these sites. This could be either because of collapses below the casing in the boreholes or rust adhering to the magnetic probe.
- BH01: Rust observed adhering to the pump after sampling.
- BH02: Rust observed adhering to the pump after sampling.
- BH05: The borehole was open/ uncovered. An oily/ black substance adhered to parts of the pump and pipe after sampling this well. Rust observed adhering to the pump after sampling.
- BH07: Rust observed adhering to the pump after sampling. Water in the borehole had an unpleasant smell.
- BH08: The owner could not switch on the pump, because electricity was redirected to operate the fridges at the shop. Stagnant water was left in the pipes and a sample could be taken (the borehole was used to pump water early in the morning). Water was slightly everfescent.
- BH09: Rust was observed adhering to the pump after sampling.

## 6.2 Monitoring Results

Static water levels (SWLs) for accessible groundwater sites over the last year, including the current monitoring event February 2022, are presented in Table 4. The mean, and standard deviation (STDEV) from the mean was calculated for each site measured over the same duration, excluding the current monitoring event's SWLs. These were used to calculate a Coefficient of Variation (CV) for each site over this time. A low CV means that there is a low level of dispersion or high central tendency of the individual measurements around the mean SWL for each site sampled and vice versa. The mean was used as a baseline to which the current monitoring event's SWLs were compared to evaluate if a 10 m difference, which forms part of the 2017 EMPr requirements, exists at any of the sites. A bar graph of the SWLs for each site over the past year can be seen in Figure 2.

Table 5 presents a summary of the 25 % EMPr upper limit from the mean baseline values for each parameter at each site. The baseline was taken in April/May 2015, and during 2018 for site Mon-F1. These were compared to the current monitoring event, February 2022, results. Values of the current monitoring event highlighted in red indicate chemical constituents that exceeded the 25 % limit from the baseline mean which forms part of the 2017 EMPr requirements. Parameters which were below detection limit at all sites sampled were not included into this table. Also note that not all parameters were sampled for during the baseline. These will not be subject to exceedance determinations. Please see Appendix B for the full laboratory results.

Table 4: Static water level statistics

| | Site | | | | | |
|---|---|---|---|---|---|---|
| **Date** | **BH01** | **BH02** | **BH05** | **BH07** | **BH09** | **Mon-F1** |
| Feb-21 | 23.44 | 10.74 | 12.92 | 17.41 | 9.17 | N/A |
| Apr-21 | 23.40 | 10.90 | 13.15 | 17.43 | 9.35 | 21.04 |
| Jun-21 | 23.40 | 10.86 | 13.15 | 17.33 | 9.35 | 21.06 |
| Aug-21 | 23.40 | 10.86 | 13.15 | 17.33 | 9.35 | 21.06 |
| Sep-21 | 23.35 | N/A | 13.15 | 17.19 | 9.40 | 21.09 |
| Oct-21 | 23.18 | 9.99 | 13.23 | 17.14 | 9.42 | 21.11 |
| Nov-21 | 23.36 | 10.22 | 13.47 | 17.14 | 9.49 | 21.11 |
| Dec-21 | 23.37 | 10.25 | 13.17 | 17.15 | 9.35 | N/A |
| Jan-22 | 23.35 | 10.04 | 12.44 | 17.07 | 8.42 | 21.11 |
| **Mean** | 23.359 | 10.476 | 13.084 | 17.238 | 9.245 | 21.083 |
| **Stdev** | 0.070 | 0.369 | 0.266 | 0.125 | 0.306 | 0.027 |
| **CV %** | 0.299 | 3.519 | 2.032 | 0.725 | 3.312 | 0.129 |
| Feb-22 | 23.328 | 10.010 | 12.475 | 16.975 | 8.325 | 21.150 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Difference between Feb-22 and the mean (m) | 0.031 | 0.466 | 0.609 | 0.263 | 0.920 | -0.067 |

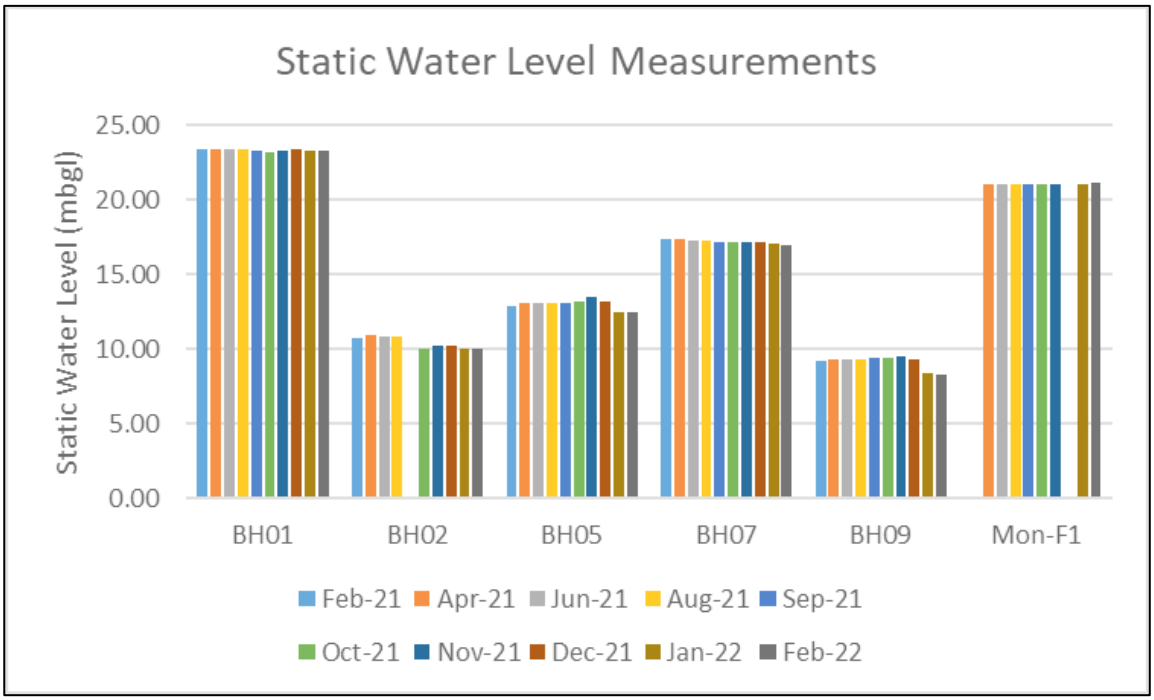



Figure 2: Static water levels for the last year

Table 5: February 2022 monitoring results

| Parameter | Unit | Detection Limit | 25 % EMPr Upper Limit | | | | | | | | | | February 2022 Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | BH01 | BH02 | BH04 | BH05 | BH07 | BH08 | BH09 | Mon-F1 | SW01 | SW02 | BH01 | BH02 | BH04 | BH05 | BH07 | BH08 | BH09 | Mon-F1 | SW01 | SW02 |
| Acenaphthylene | µg/l | 0.1 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | BDL | BDL | BDL | BDL | BDL | BDL | 0.200 | BDL | BDL | BDL |
| Aluminium | mg/l | 0.003 | 0.023 | 0.005 | 0.036 | 0.036 | 0.020 | 0.036 | 0.033 | 0.005 | 0.019 | 0.020 | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.230 | 2.800 |
| Ammonia | mg/l | 0.012 | 0.098 | 0.088 | 1.219 | 0.844 | 0.210 | 0.088 | 0.147 | 0.052 | 0.011 | 0.011 | BDL | 0.035 | 1.200 | 1.100 | 0.071 | BDL | 0.170 | 0.520 | 0.016 | 0.092 |
| Ammonia as N | mg/l | 0.01 | 0.088 | 0.088 | 0.958 | 0.625 | 0.208 | 0.088 | 0.154 | 0.045 | 0.009 | 0.009 | BDL | 0.030 | 1.000 | 0.880 | 0.060 | BDL | 0.140 | 0.430 | 0.010 | 0.080 |
| Barium | mg/l | 0.005 | 0.272 | 0.213 | 0.725 | 1.841 | 0.106 | 0.125 | 0.316 | 0.107 | 0.228 | 0.107 | 0.430 | 0.270 | 0.680 | 0.960 | 0.074 | 0.160 | 0.190 | 0.200 | 0.098 | 0.073 |
| Bicarbonate as CaCO3 | mg/l | 12 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 150.000 | 196.174 | 219.630 | 488.000 | 427.000 | 216.600 | 366.000 | 488.000 | 854.000 | 366.000 | 122.000 | 64.050 | 39.650 |
| Boron | mg/l | 0.002 | 0.331 | 0.075 | 0.159 | 0.069 | 0.015 | 0.081 | 0.378 | 0.556 | 0.142 | 0.086 | 0.058 | 0.029 | 0.210 | 0.090 | 0.023 | 0.080 | 0.610 | 0.190 | 0.044 | 0.025 |
| Bromide | mg/l | 0.1 | 2.591 | 0.350 | 3.009 | 2.738 | 1.494 | 4.794 | 3.919 | 0.244 | 0.165 | 0.303 | 16.00 | 2.900 | 48.00 | 51.00 | 9.200 | 6.500 | 8.300 | 24.00 | 4.700 | 0.800 |
| Calcium | mg/l | 0.5 | 94.063 | 49.688 | 170.000 | 189.375 | 195.938 | 230.313 | 233.438 | 20.895 | 121.366 | 102.150 | 183.0 | 87.00 | 137.0 | 262.0 | 181.0 | 315.0 | 43.00 | 40.00 | 47.00 | 20.00 |
| Chloride | mg/l | 0.05 | 285.313 | 23.750 | 566.875 | 615.938 | 357.188 | 570.938 | 708.438 | 586.506 | 475.932 | 258.122 | 488.0 | 101.0 | 540.0 | 609.0 | 318.0 | 566.0 | 210.0 | 568.0 | 101.0 | 29.00 |
| Chromium | mg/l | 0.002 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.022 | N/A | N/A | 0.013 | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.003 |
| Cobalt | mg/l | 0.0004 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.001 | N/A | N/A | BDL | BDL | BDL | BDL | BDL | 0.002 | BDL | BDL | 0.003 | 0.003 |
| Conductivity in mS/m @ 25°C | mS/m | 0 | 163.500 | 55.938 | 259.438 | 255.031 | 206.313 | 282.313 | 274.188 | 193.326 | 201.208 | 163.954 | 328 | 117.1 | 325 | 398 | 286.1 | 505 | 126.2 | 214.9 | 67.7 | 26.2 |
| Copper | mg/l | 0.0009 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.003 | N/A | N/A | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.002 | 0.001 | BDL | 0.003 | 0.004 |
| Dissolved Inorganic Carbon | mg/l | 0.42 | 50.000 | 33.125 | 64.063 | 44.063 | 73.125 | 48.125 | 48.125 | 1.654 | 31.466 | 37.944 | 74.20 | 56.56 | 56.78 | 53.80 | 82.50 | 51.71 | 35.85 | BDL | 16.26 | BDL |
| Dissolved Methane | mg/l | 0.0068 | 0.062 | 0.048 | N/A | 1.020 | 0.198 | N/A | 0.144 | 0.615 | N/A | N/A | BDL | 0.019 | N/A | 0.140 | 0.024 | N/A | 2.300 | 8.800 | N/A | N/A |
| Dissolved Oxygen | mg/l | 0 | 8.750 | 9.604 | 9.394 | 8.463 | 9.613 | 8.544 | 8.516 | 8.434 | 9.795 | 9.691 | 2.850 | 2.850 | 2.860 | 2.840 | 2.830 | 2.850 | 2.810 | 2.900 | 2.910 | 2.870 |
| Fluoranthene | µg/l | 0.1 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | BDL | BDL | BDL | BDL | BDL | BDL | 0.200 | BDL | BDL | BDL |
| Fluoride | mg/l | 0.05 | 0.656 | 0.147 | 0.500 | 0.406 | 0.531 | 0.625 | 0.938 | 1.205 | 0.374 | 0.246 | 0.060 | BDL | 0.110 | 0.070 | BDL | BDL | 0.880 | 0.120 | 0.060 | 0.090 |
| Iron | mg/l | 0.05 | 0.041 | 0.013 | 0.053 | 0.010 | 0.013 | 0.064 | 0.316 | 0.044 | 0.016 | 0.016 | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.150 | 1.400 |
| Lithium | mg/l | 0.002 | 0.031 | 0.012 | 0.078 | 0.008 | 0.028 | 0.078 | 0.119 | 0.106 | 0.033 | 0.023 | 0.025 | 0.025 | 0.091 | 0.008 | 0.030 | 0.079 | 0.080 | 0.110 | 0.006 | 0.005 |
| Magnesium | mg/l | 0.01 | 35.281 | 16.250 | 69.375 | 70.625 | 108.438 | 116.563 | 74.688 | 14.790 | 60.544 | 45.790 | 69.00 | 27.00 | 56.00 | 80.00 | 91.00 | 121.0 | 9.700 | 6.800 | 22.00 | 7.200 |
| Manganese | mg/l | 0.002 | 0.075 | 0.003 | 1.503 | 3.625 | 0.209 | 0.035 | 0.531 | 0.015 | 0.009 | 0.003 | 0.011 | 0.096 | 1.200 | 5.100 | 0.110 | 0.016 | 0.053 | 0.092 | BDL | 0.015 |
| Methyl Orange (M) Alkalinity as CaCO3 | mg/l | 12 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 193.649 | N/A | N/A | 400.0 | 350.0 | 177.5 | 300.0 | 400.0 | 700.0 | 300.0 | 100.0 | 52.50 | 32.50 |
| Molybdenum | mg/l | 0.001 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | BDL | BDL | BDL | 0.003 | BDL | 0.002 | BDL | BDL | BDL | BDL |

| Parameter | Unit | Detection Limit | 25 % EMPr Upper Limit | | | | | | | | | | February 2022 Results | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | BH01 | BH02 | BH04 | BH05 | BH07 | BH08 | BH09 | Mon-F1 | SW01 | SW02 | BH01 | BH02 | BH04 | BH05 | BH07 | BH08 | BH09 | Mon-F1 | SW01 | SW02 |
| Nickel | mg/l | 0.001 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.002 | N/A | N/A | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.009 | BDL | BDL |
| Nitrate | mg/l | 0.1 | 4.031 | 3.313 | 0.107 | 0.098 | 0.098 | 37.500 | 0.088 | 0.233 | 0.088 | 0.088 | 17.00 | 28.00 | BDL | BDL | BDL | 29.00 | BDL | BDL | 1.500 | 1.300 |
| Nitrate as N | mg/l | 0.03 | 0.647 | 0.750 | 0.088 | 0.088 | 0.088 | 8.469 | 0.088 | 0.064 | 0.027 | 0.027 | 3.800 | 6.400 | BDL | BDL | BDL | 6.600 | BDL | BDL | 0.350 | 0.290 |
| pH in Water at 25°C | N/A | N/A | 9.281 | 8.906 | 9.344 | 8.938 | 8.750 | 9.125 | 9.219 | 10.260 | 10.191 | 10.249 | 7.140 | 7.220 | 7.500 | 7.050 | 6.970 | 7.050 | 7.880 | 8.260 | 7.560 | 7.600 |
| Potassium | mg/l | 0.2 | 1.719 | 6.063 | 3.250 | 2.813 | 1.197 | 7.000 | 5.156 | 5.596 | 12.861 | 16.095 | 3.000 | 9.000 | 4.200 | 3.900 | 2.900 | 12.00 | 1.900 | 2.700 | 6.600 | 7.700 |
| Pyrene | µg/l | 0.1 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | 0.088 | BDL | BDL | BDL | BDL | BDL | BDL | 0.200 | BDL | BDL | BDL |
| Silicon | mg/l | 1 | 18.375 | 19.906 | 20.188 | 15.656 | 27.094 | 17.531 | 9.938 | 1.994 | 1.185 | 0.881 | 23.00 | 15.00 | 18.00 | 16.00 | 25.00 | 15.00 | 7.600 | BDL | 9.100 | 12.00 |
| Sodium | mg/l | 0.5 | 187.188 | 48.438 | 232.813 | 176.875 | 74.688 | 187.813 | 300.938 | 366.225 | 173.089 | 158.748 | 205.0 | 93.00 | 288.0 | 183.0 | 67.00 | 208.0 | 200.0 | 327.0 | 38.00 | 22.00 |
| Strontium | mg/l | 0.0006 | 1.184 | 0.434 | 4.219 | 1.375 | 1.825 | 3.000 | 4.250 | 0.459 | 1.060 | 0.807 | 1.900 | 1.100 | 3.100 | 1.100 | 1.600 | 2.600 | 0.910 | 0.930 | 0.290 | 0.150 |
| Sulphate | mg/l | 0.05 | 56.250 | 30.125 | 62.500 | 55.781 | 70.313 | 245.313 | 131.563 | 3.433 | 149.366 | 240.885 | 39.00 | 43.00 | 43.00 | 44.00 | 48.00 | 246.0 | 23.00 | 0.290 | 27.00 | 24.00 |
| TDS (0.7µm) @ 105ºC | mg/l | 21 | 908.125 | 310.000 | 1588.750 | 1738.125 | 1291.250 | 1959.375 | 1939.375 | 1048.672 | 1329.765 | 1020.008 | 1653 | 676 | 1662 | 2140 | 1511 | 2559 | 697 | 1098 | 437 | 179 |
| Titanium | mg/l | 0.0005 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.001 | N/A | N/A | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.010 | 0.088 |
| Total Hardness as CaCO3 | mg/l | 1.5 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 150.000 | N/A | N/A | 739.0 | 328.0 | 571.0 | 983.0 | 826.0 | 1280 | 147.0 | 127.0 | 207.0 | 80.00 |
| Vanadium | mg/l | 0.0005 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.014 | N/A | N/A | 0.013 | 0.001 | BDL | BDL | BDL | 0.004 | BDL | BDL | 0.009 | 0.008 |
| Zinc | mg/l | 0.05 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.044 | N/A | N/A | 0.540 | BDL | 0.010 | BDL | BDL | 0.180 | BDL | BDL | BDL | BDL |
| Mercury | µg/l | 0.001 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 0.000 | N/A | N/A | BDL | BDL | 0.002 | BDL | 0.006 | BDL | 0.015 | BDL | 0.002 | 0.003 |

## 6.3 South African Water Quality Guidelines

Table 6 indicates the South African National Standard (SANS) thresholds for domestic use which is divided into aesthetic risk and chronic health risks, as well as the DWAF acceptable South African Water Quality Guidelines' target water quality ranges for agricultural and livestock risks. These standards were evaluated against the chemistry data for the current monitoring event, Table 7, at each site. Values marked in:

- red exceeds the threshold for domestic use and poses an aesthetic health risk or operational risk.
- **red and bold exceeds the threshold for domestic use and poses a chronic or acute health risk.**
- underline exceeds the threshold for agricultural use.
- dotted underline exceeds livestock usage thresholds.

Note that at present there are no South African water quality guidelines for many of the parameters which may apply to the exploration and production of petroleum products, in particular dissolved methane concentrations. Thus, only parameters which were measured and are also reflected in the SANS or DWAF standards were evaluated in this section.

High concentration of methane in confined spaces pose explosive risks. Methane can ignite at atmospheric concentrations of between 5 and 15% (Baldasarre et al., 2001). It is however recommended by Baldasarre et al. (2001) that in-line dissolved methane concentrations over 28 mg/l may require mitigation as it could, depending on temperature, pressure, quantity of water pumped and volume of air which the gas exsolves, pose an explosive or flammable risk. Baldasarre et al. (2001) also recommended that methane levels be reduced to below 10 mg/l as per the US Office of Surface Mining Reclamation and Enforcement.

The standard values were obtained from the following references:

- Suitability for drinking water: SANS 241: 2015 Drinking Water (South African Bureau of Standards, 2015).
- Suitability for domestic use: DWAF South African Water Quality Guidelines. Volume 1: Domestic Use.
- Suitability for irrigation: DWAF South African Water Quality Guidelines. Volume 4: Agricultural Use: Irrigation.
- Suitability for livestock water: DWAF South African Water Quality Guidelines. Volume 5: Agricultural Use: Livestock Watering.

Table 6: South African water quality guidelines and standards

| Parameter | Measurement Unit | SANS Aesthetic (A)/ Operational (O) Risk | SANS Chronic (C)/ Acute (A) Risk | DWAF Agricultural Target Range 0 - | DWAF Livestock Target Range 0 - |
|---|---|---|---|---|---|
| Aluminium | mg/l | 0.3 (O) | | 5 | 5 |
| Ammonia | mg/l | 1.5 (A) | | | |
| Arsenic | mg/l | | 0.01 (C) | 0.1 | 1 |
| Barium | mg/l | | 0.7 (C) | | |
| Boron | mg/l | | 2.4 (C) | 5 | 5 |
| Calcium | mg/l | | | 1000 | |
| Chloride | mg/l | 300 (A) | | 100 | 1500 |
| Conductivity in mS/m @ 25°C | mg/l | 170 (A) | | 40 | |
| Dissolved Organic Carbon | mg/l | | 10 (C) | | |
| Fluoride | mg/l | | 1.5 (C) | 2 | 2 |
| Iron | mg/l | 0.3 (A) | 2 (C) | 5 | 10 |
| Lead | mg/l | | 0.01 (C) | 0.2 | 0.1 |
| Manganese | mg/l | 0.1 (A) | 0.4 (C) | 0.02 | 10 |
| Molybdenum | mg/l | | | 0.01 | |
| Nitrate (as NO3) | mg/l | | | | 100 |
| Nitrate as N | mg/l | | 11 (A) | | |

| Parameter | Measurement Unit | SANS Aesthetic (A)/ Operational (O) Risk | SANS Chronic (C)/ Acute (A) Risk | DWAF Agricultural Target Range 0 - | DWAF Livestock Target Range 0 - |
|---|---|---|---|---|---|
| Nitrite as N | mg/l | | 0.9 (A) | | |
| pH in water at 25°C | mg/l | ≤ 5 & 9.7 ≤ (O) | | 8.4 | |
| Sodium | mg/l | 200 (A) | | 70 | 2000 |
| Sulphate | mg/l | 250 (A) | 500 (A) | | 1000 |
| TDS (0.7µm) @ 105ºC | mg/l | 1200 (A) | | 40 | 1000 |
| TSS (0.7µm) @ 105ºC | mg/l | | | 50 | |
| Uranium | mg/l | | 0.03 (C) | 0.01 | |

Table 7: February 2022 results comparisson to water quality standards and guidelines

| Parameter | Unit | BH01 | BH02 | BH04 | BH05 | BH07 | BH08 | BH09 | Mon-F1 | SW01 | SW02 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Aluminium | mg/l | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.230 | 2.800 |
| Ammonia | mg/l | BDL | 0.035 | 1.200 | 1.100 | 0.071 | BDL | 0.170 | 0.520 | 0.016 | 0.092 |
| Arsenic | mg/l | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL |
| Barium | mg/l | 0.430 | 0.270 | 0.680 | **0.960** | 0.074 | 0.160 | 0.190 | 0.200 | 0.098 | 0.073 |
| Boron | mg/l | 0.058 | 0.029 | 0.210 | 0.090 | 0.023 | 0.080 | 0.610 | 0.190 | 0.044 | 0.025 |
| Calcium | mg/l | 183.000 | 87.000 | 137.000 | 262.000 | 181.000 | 315.000 | 43.000 | 40.000 | 47.000 | 20.000 |
| Chloride | mg/l | 488.000 | 101.000 | 540.000 | 609.000 | 318.000 | 566.000 | 210.000 | 568.000 | 101.000 | 29.000 |

| Parameter | Unit | BH01 | BH02 | BH04 | BH05 | BH07 | BH08 | BH09 | Mon-F1 | SW01 | SW02 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Conductivity in mS/m @ 25°C | mS/m | 328.000 | 117.100 | 325.000 | 398.000 | 286.100 | 505.000 | 126.200 | 214.900 | 67.700 | 26.200 |
| Dissolved Organic Carbon | mg/l | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL |
| Fluoride | mg/l | 0.060 | BDL | 0.110 | 0.070 | BDL | BDL | 0.880 | 0.120 | 0.060 | 0.090 |
| Iron | mg/l | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.150 | 1.400 |
| Lead | mg/l | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL |
| Manganese | mg/l | 0.011 | 0.096 | **1.200** | **5.100** | 0.110 | 0.016 | 0.053 | 0.092 | BDL | 0.015 |
| Molybdenum | mg/l | BDL | BDL | BDL | 0.003 | BDL | 0.002 | BDL | BDL | BDL | BDL |
| Nitrate | mg/l | 17.000 | 28.000 | BDL | BDL | BDL | 29.000 | BDL | BDL | 1.500 | 1.300 |
| Nitrate as N | mg/l | 3.800 | 6.400 | BDL | BDL | BDL | 6.600 | BDL | BDL | 0.350 | 0.290 |
| Nitrite as N | mg/l | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL |
| pH in water at 25°C | N/A | 7.140 | 7.220 | 7.500 | 7.050 | 6.970 | 7.050 | 7.880 | 8.260 | 7.560 | 7.600 |
| Sodium | mg/l | 205.000 | 93.000 | 288.000 | 183.000 | 67.000 | 208.000 | 200.000 | 327.000 | 38.000 | 22.000 |
| Sulphate | mg/l | 39.000 | 43.000 | 43.000 | 44.000 | 48.000 | 246.000 | 23.000 | 0.290 | 27.000 | 24.000 |
| TDS (0.7µm) @ 105ºC | mg/l | 1653.000 | 676.000 | 1662.000 | 2140.000 | 1511.000 | 2559.000 | 697.000 | 1098.000 | 437.000 | 179.000 |
| Uranium | mg/l | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL |

## 6.4 Site Chemistry Profiles

### 6.4.1 Piper Diagrams

Piper diagrams are created to plot the percentages of major cation and anions in two separate ternary diagrams. These points are further projected onto a diamond shape in the center of the diagram. This field provides valuable information on the possible water characteristics and water types of each sample in relation with other samples (Sajil Kumar, 2013).

The top end of the diamond shape indicates a permanent hardness of water with chemical characteristics of $Ca^{2+}$ + $Mg^{2+}$ and also $Cl^{-}$ + $SO_4^{2-}$. The right corner of the diamond is indicative of saline water with the constituents $Na^{+}$ + $K^{+}$ and also $Cl^{-}$ + $SO_4^{2-}$. The bottom of the diamond is primarily composed of $Na^{+}$ + $K^{+}$ and also $HCO_3^{-}$ + $CO_3^{2-}$ alkali carbonates. The left corner means that the water sample is rich in $Ca^{2+}$ + $Mg^{2+}$ and also $HCO_3^{-}$, this corner is indicative of temporary hardness (Ghoraba & Khan, 2013).

A piper diagram was drawn comparing ground- and surface water characteristics for sampled sites using the mean baseline results and the results for the February 2022 monitoring event (Figure 3 and Figure 4).

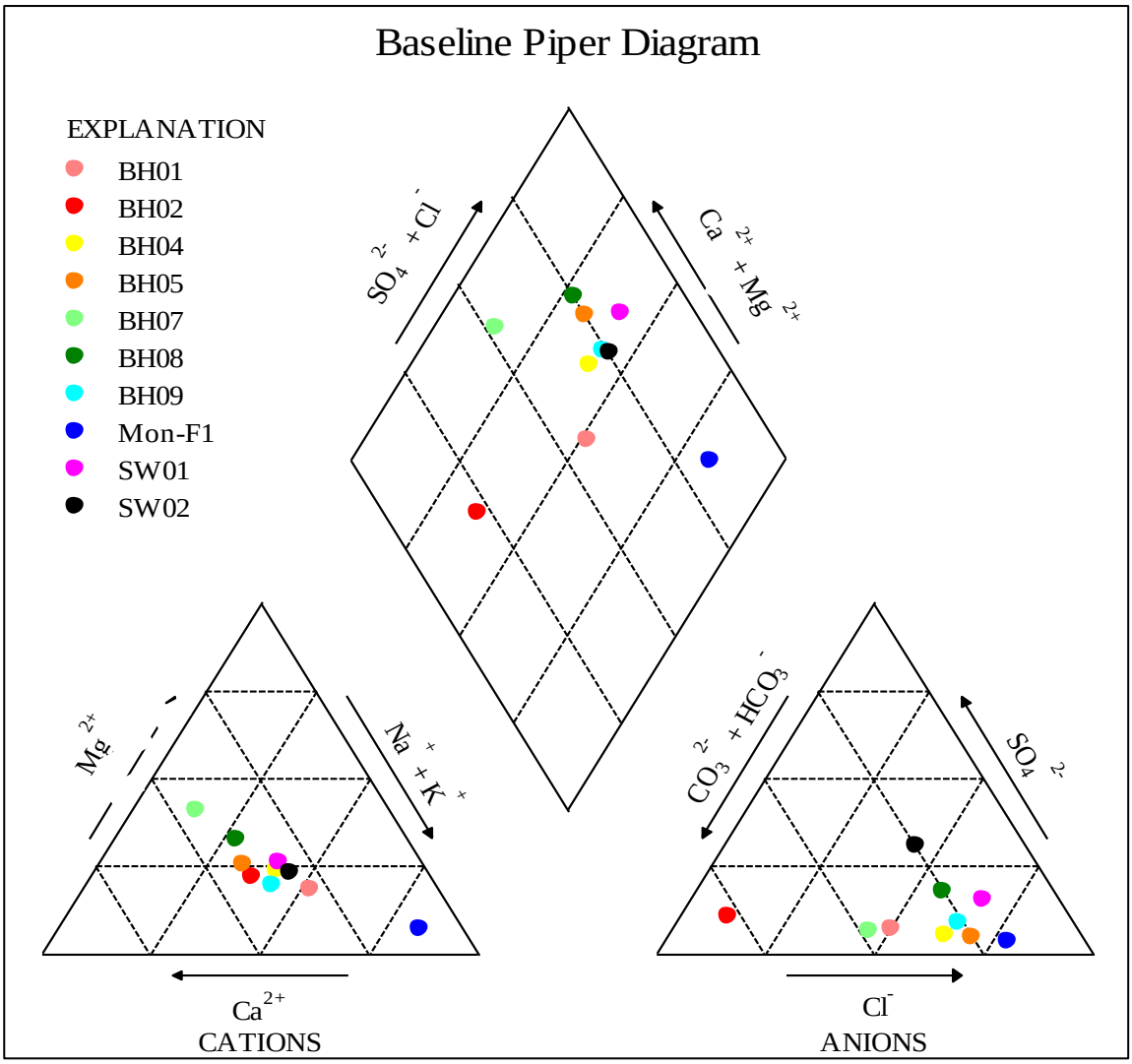



Figure 3: Baseline Piper Diagram

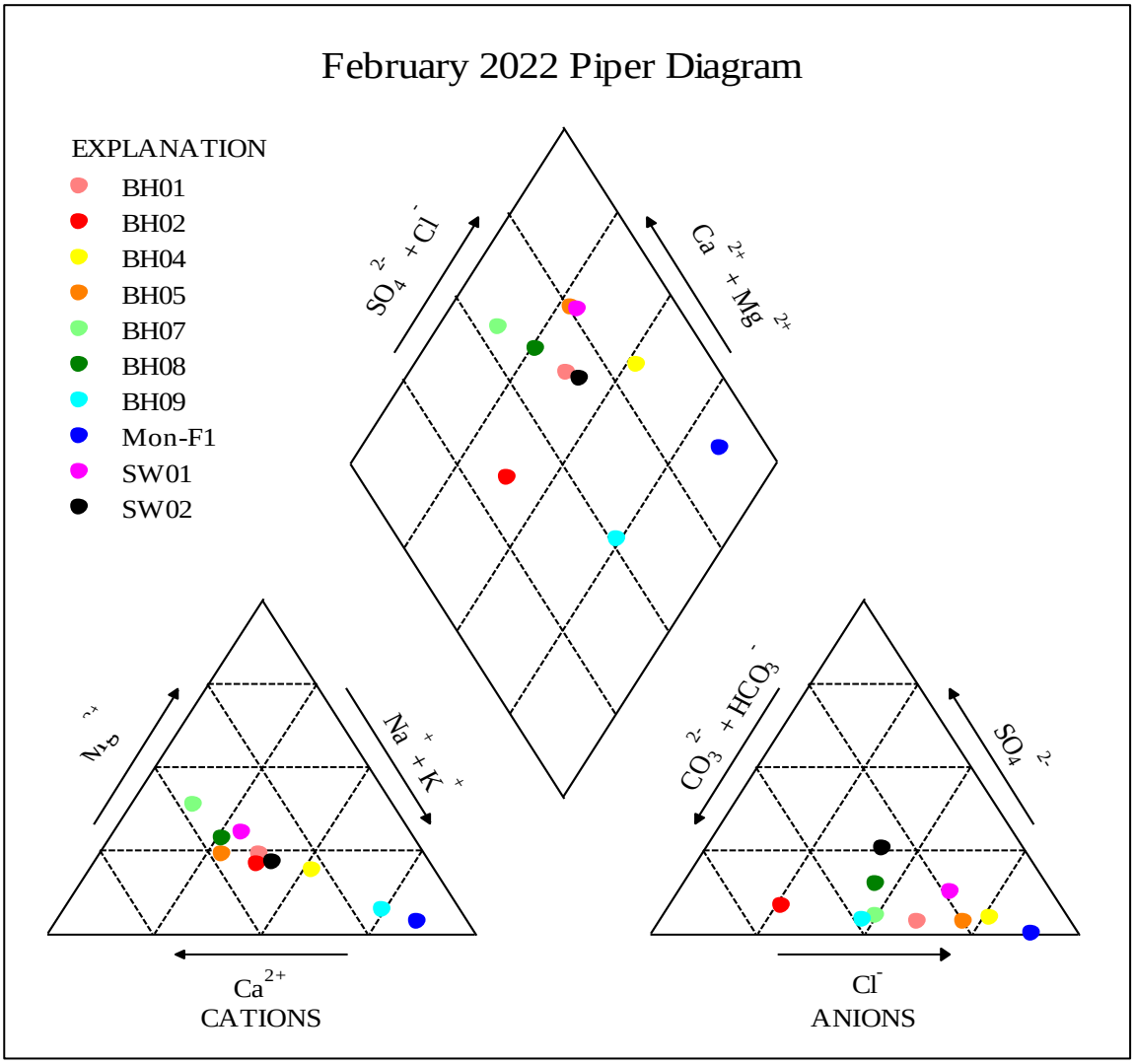



Figure 4: February 2022 Piper Diagram

# 7. Trend- and Statistical Analysis

## 7.1 Parameters of Potential Concern

POPC were identified if they exceeded any of the water quality standards or guidelines in Table 7 or if they exceeded 25 % from the baseline mean for any of the sites sampled in Table 5. The POPC are listed in Table 8 below. These parameters are subject to further trend analysis, statistical analysis and investigation to identify whether any of the Tetra4 exploration, construction or production activities influenced any of the exceedances.

Table 8: Identified parameters of potential concern

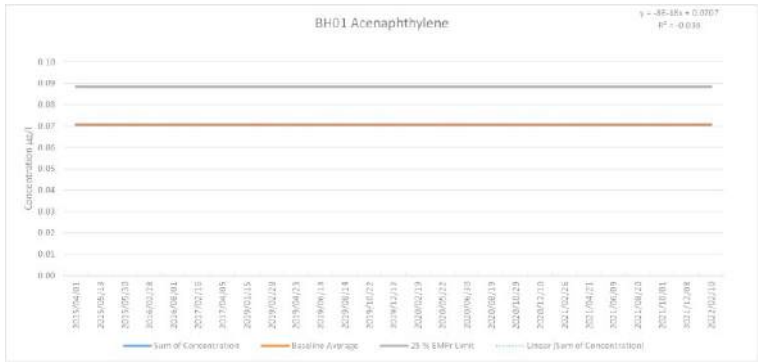
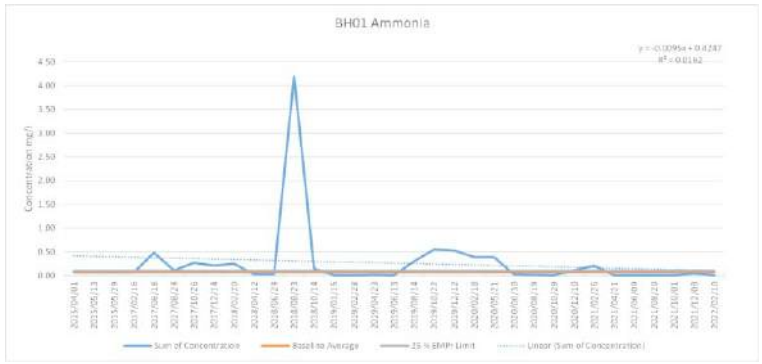
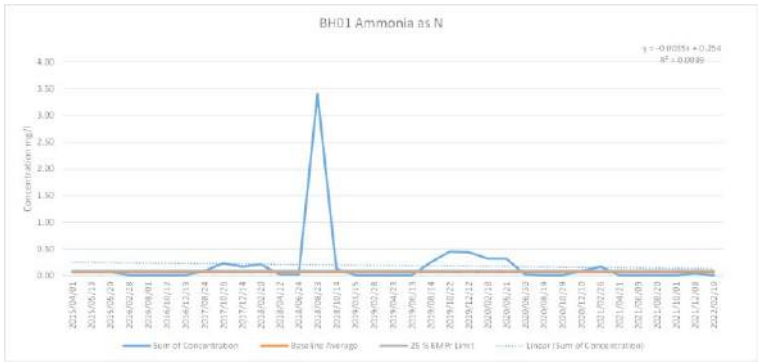
| Metals | | | |
|---|---|---|---|
| Aluminium | Barium | Boron | Calcium |
| Iron | Lithium | Magnesium | Manganese |
| Molybdenum | Nickel | Potassium | Silicon |
| Sodium | | Strontium | |

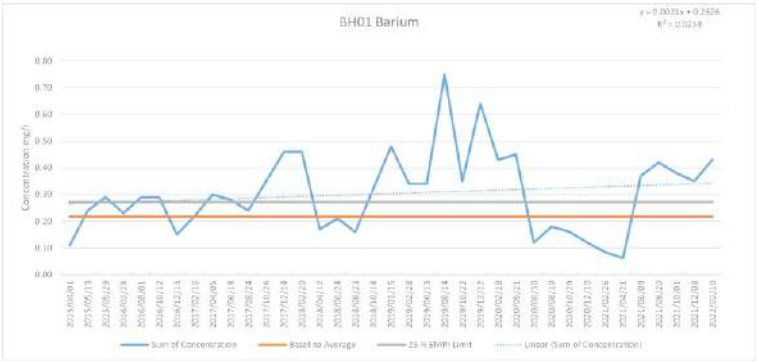
| | | | |
|---|---|---|---|
| **Anions** | | | |
| Bromide | Chloride | Nitrate as N and $NO_3$ | Sulphate |
| **Dissolved Gasses** | | | |
| Dissolved Methane | | | |
| **Polycyclic Aromatic Hydrocarbons** | | | |
| Acenaphthylene | Fluoranthene | Pyrene | |
| **Other** | | | |
| Ammonia as $NH_3$ and N | Dissolved Inorganic Carbon | Electric Conductivity | Total Dissolved Solids |

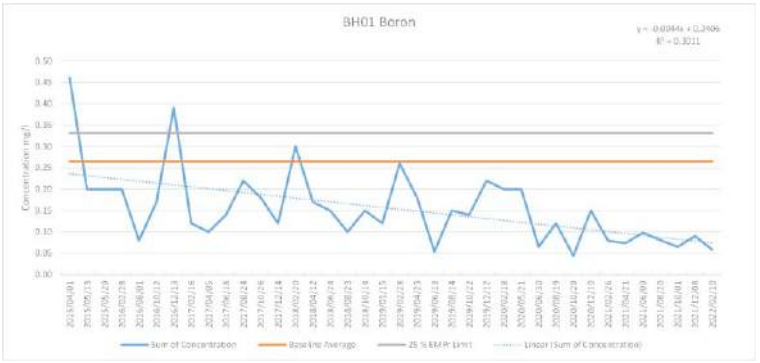
## 7.2 Concentration Trends of POPC

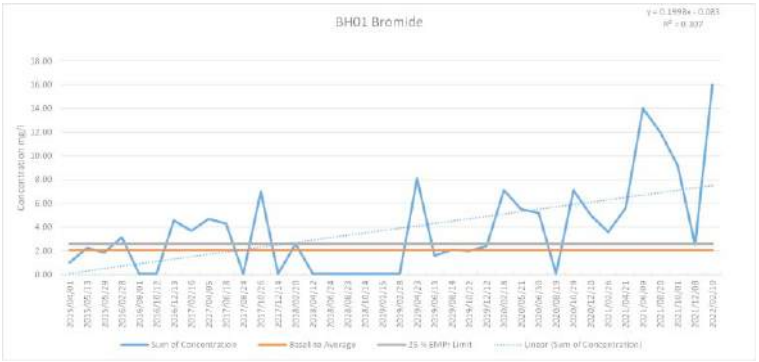
The table of figures, Table 9, presents the concentration trends of key parameters observed at chosen sites BH01, BH02, BH05, BH07, BH09 and Mon-F1. BH01 was chosen as it is the closest site to the HDR1 facility. If any immediate changes near the facility occurs, it is expected to show up here. BH07 was chosen as it is situated upstream (topographically) from the HDR1 facility. BH02 and Mon-F1 was included as these sites seems more suited as an upstream reference than BH07, although due to sampling constraints at BH02 in the past leading to a gap in information, this site will only be reported on starting from June 2018. Upstream sites could act as references as no change in water quality is expected at these locations with regards to production activities. BH05 and BH09 are situated downstream from the HDR1 facility and any changes to the water quality that could occur due to production are expected to show up here. BH03 could not be sampled during the February 2022 monitoring event and will thus not be displayed in this section. Data from April/ May 2015 and February 2018 to December 2018 for Mon-F1 through to the current monitoring event were included. These graphs aim to determine in a qualitative manner whether a trend exists, or if any outliers exist for the identified POPCs during the current monitoring event.

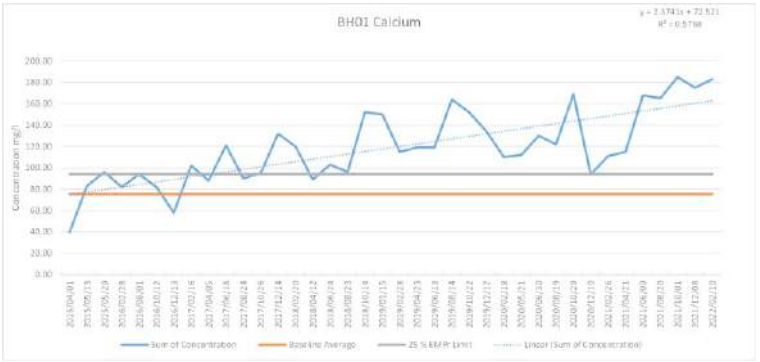
Table 9: Time-series chemistry graphs of identified POPCs

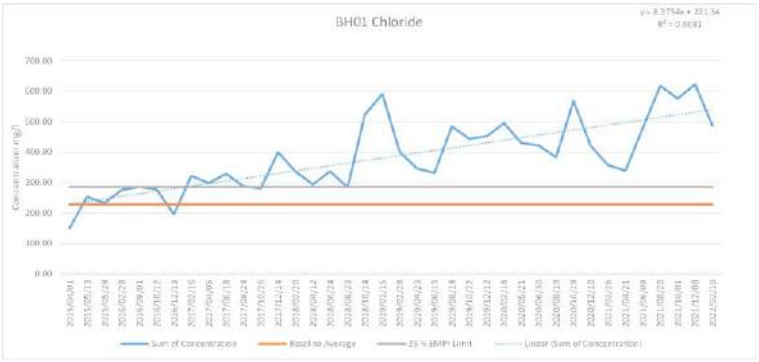
| BH01 | |
|---|---|
|  | |
|  |  |

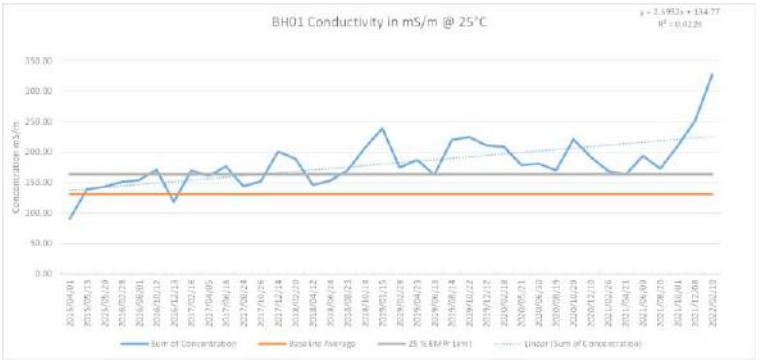

BH01 Barium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

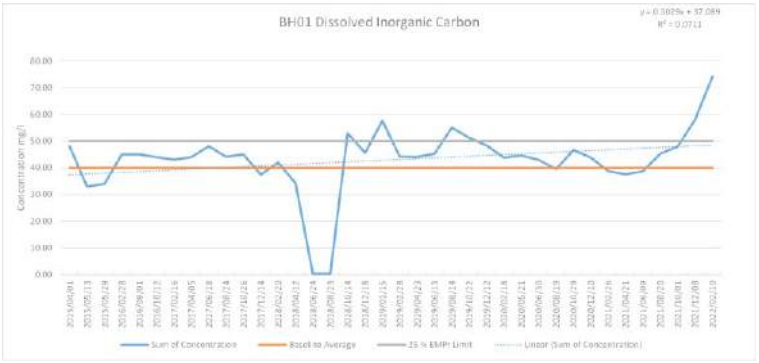

BH01 Boron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

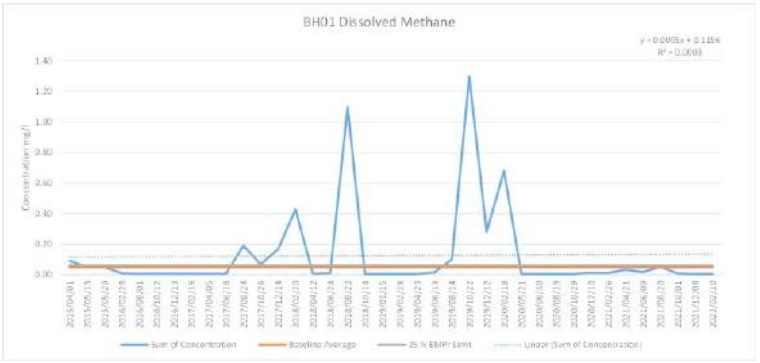

BH01 Bromide
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

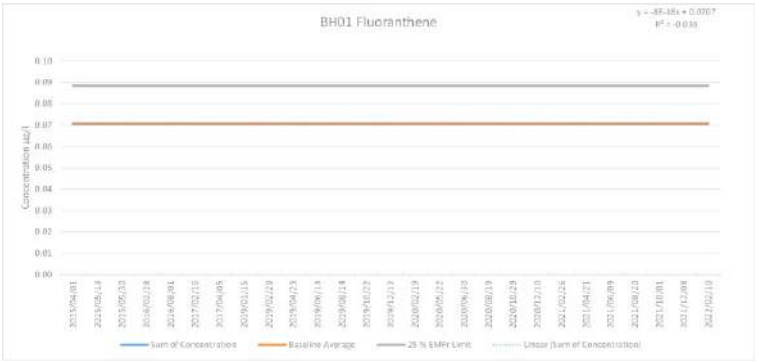

BH01 Calcium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

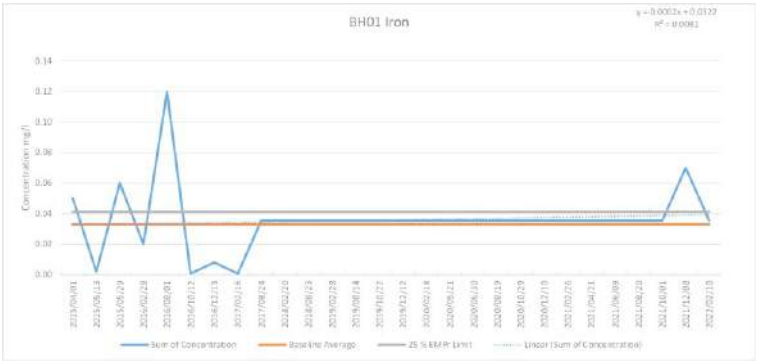

BH01 Chloride
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

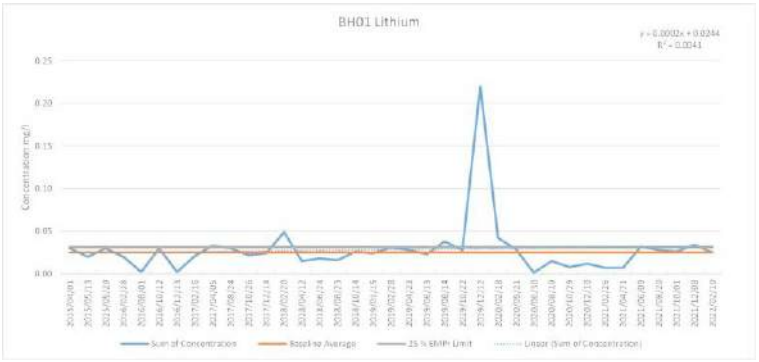

BH01 Conductivity in mS/m @ 25°C
Concentration mS/m
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

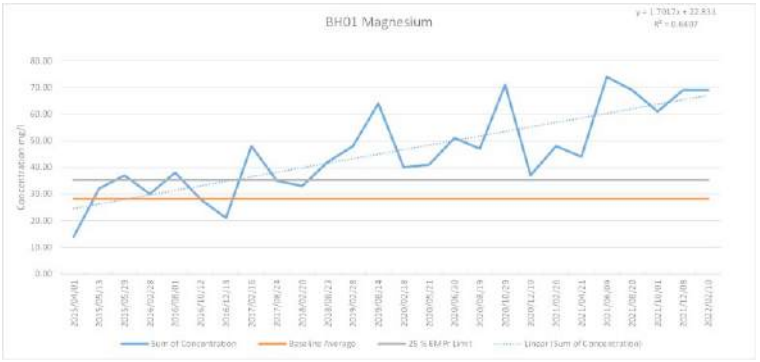

BH01 Dissolved Inorganic Carbon
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

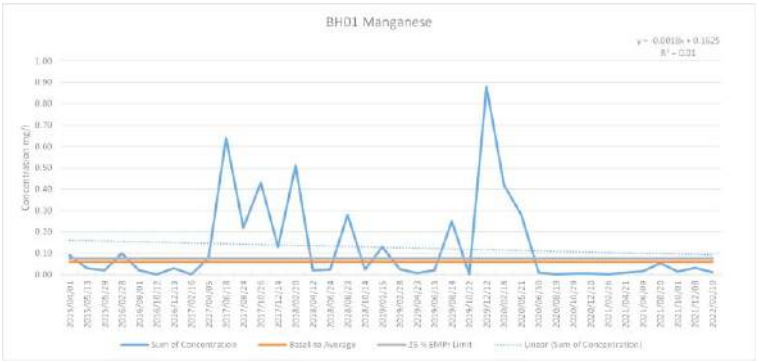

BH01 Dissolved Methane
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

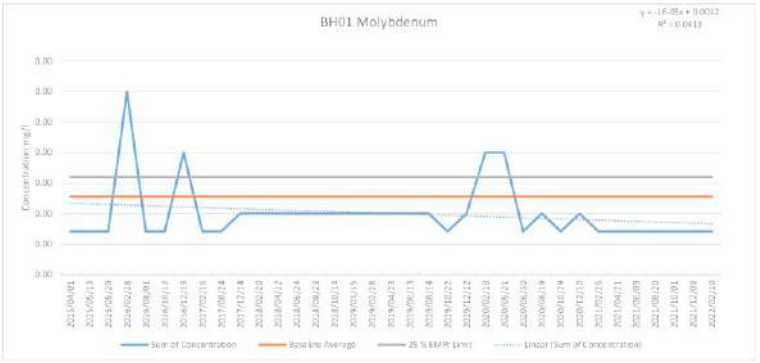

BH01 Fluoranthene
Concentration µg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

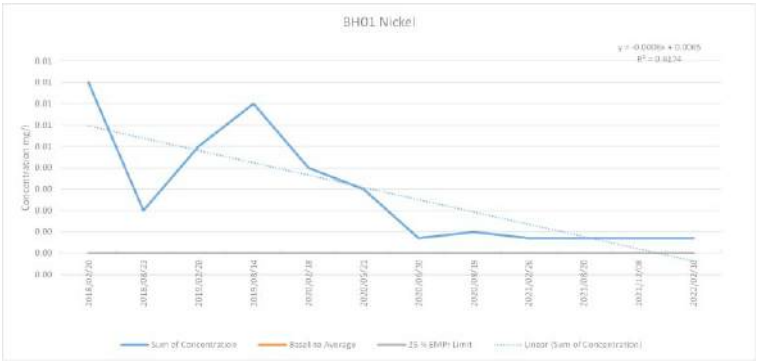

BH01 Iron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

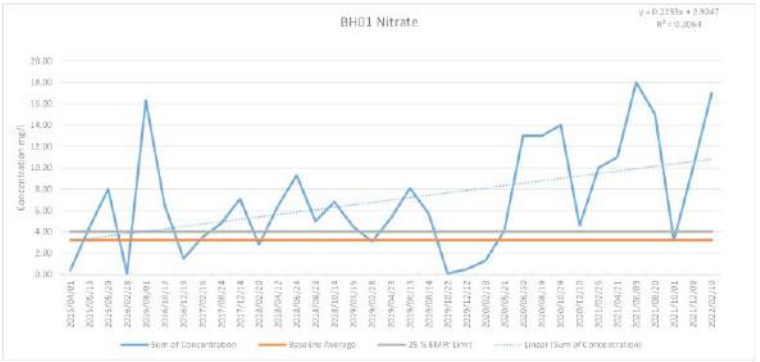

BH01 Lithium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

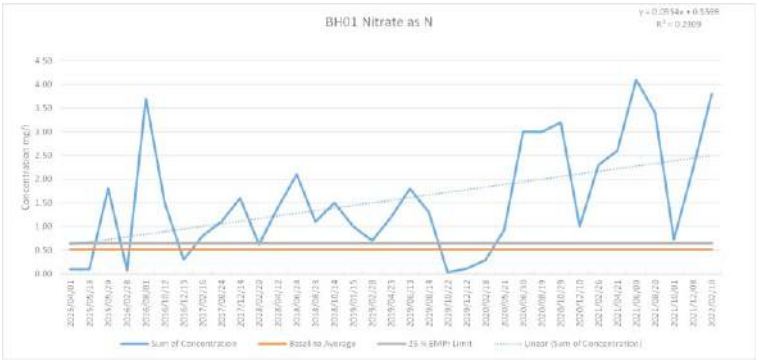

BH01 Magnesium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

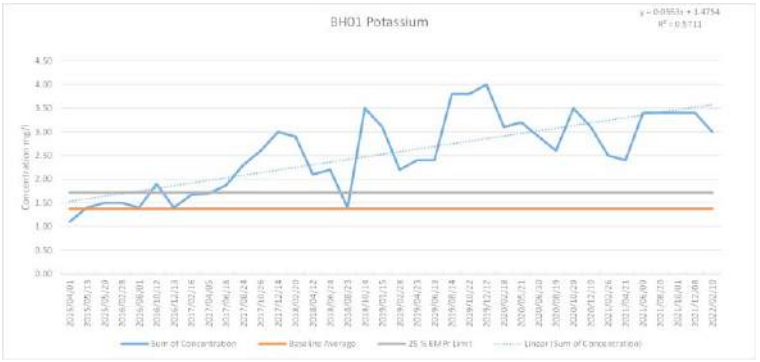

BH01 Manganese
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

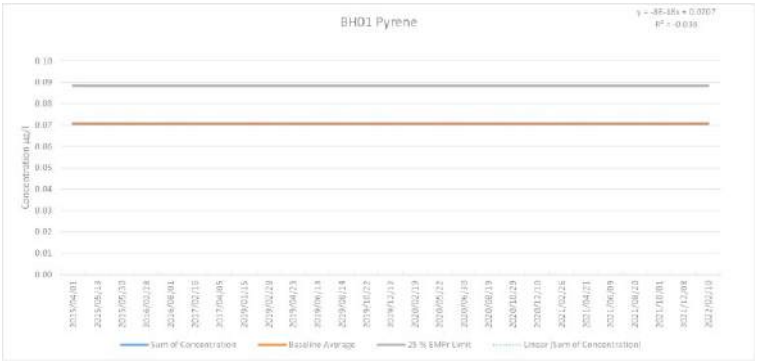

BH01 Molybdenum
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

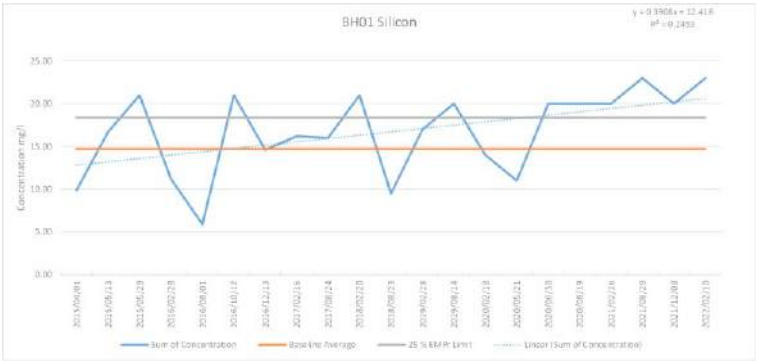

BH01 Nickel
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

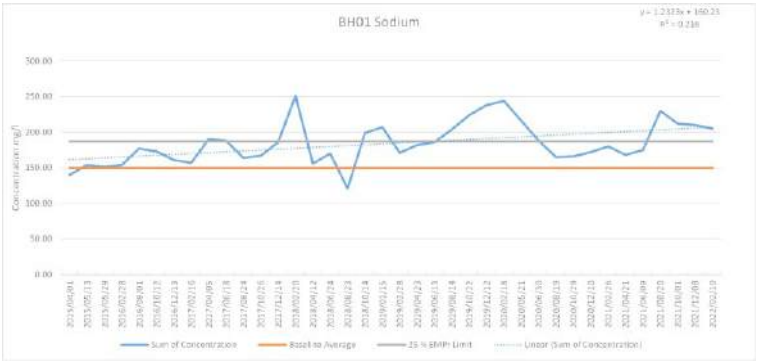

BH01 Nitrate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

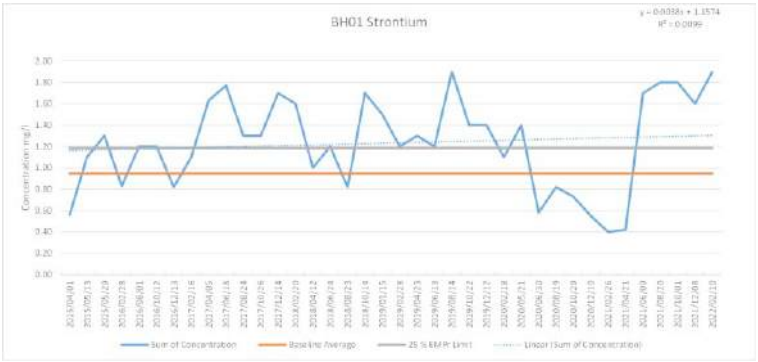

BH01 Nitrate as N
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

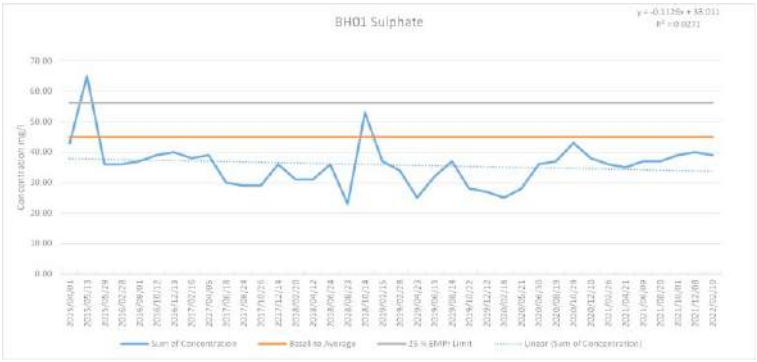

BH01 Potassium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

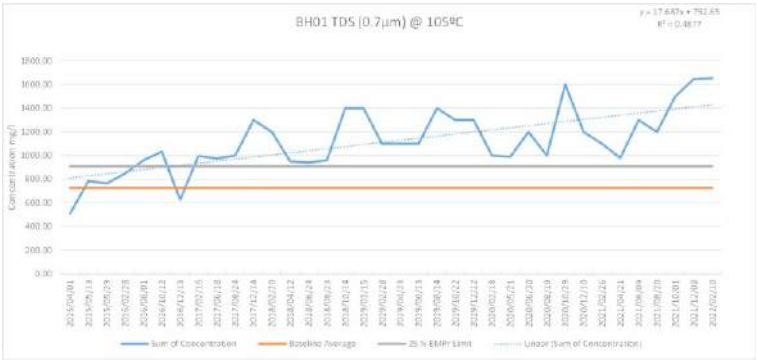

BH01 Pyrene
Concentration µg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

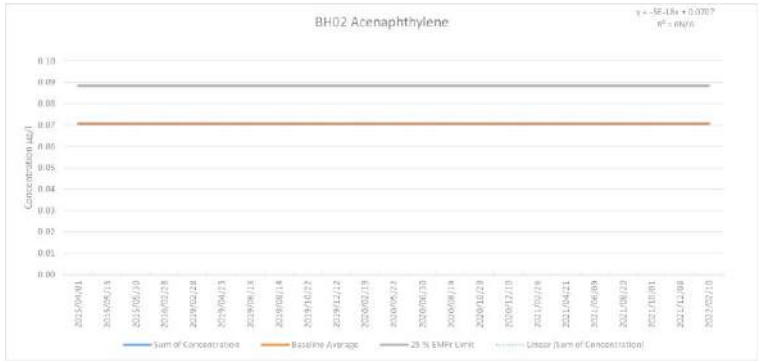
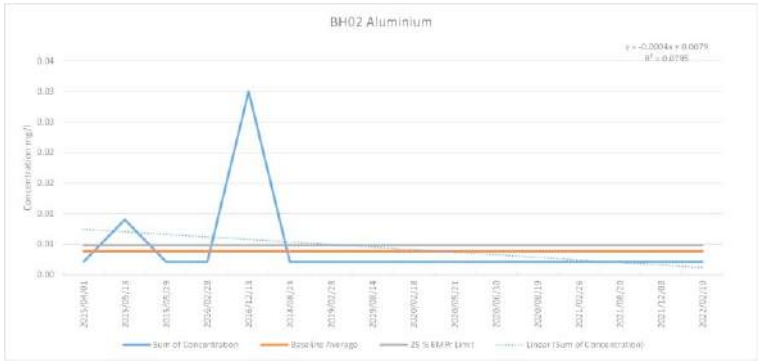
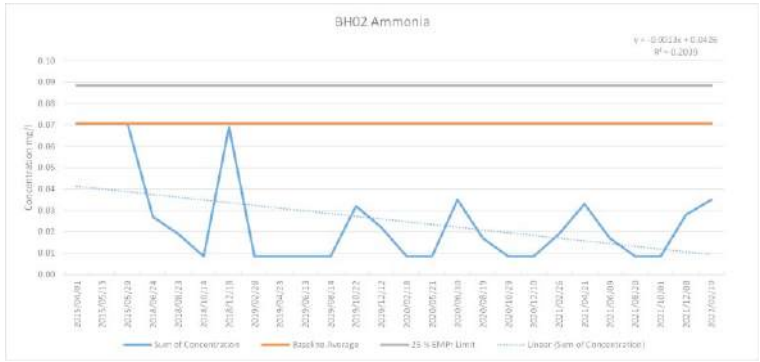
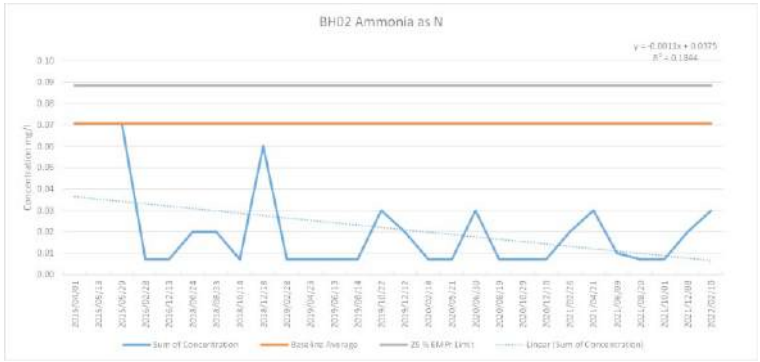

BH01 Silicon
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

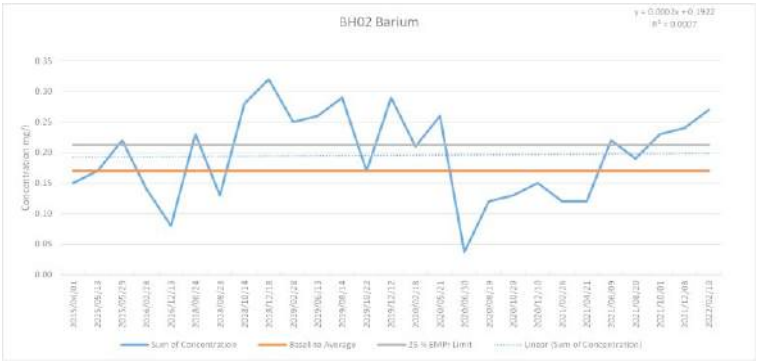

BH01 Sodium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

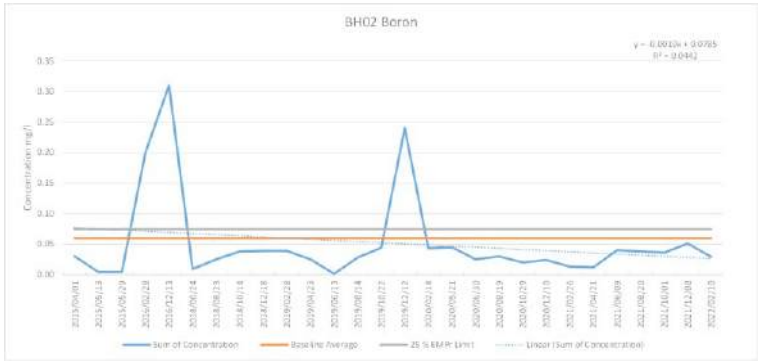

BH01 Strontium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)


BH01 Sulphate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)


BH01 TDS (0.7µm) @ 105ºC
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

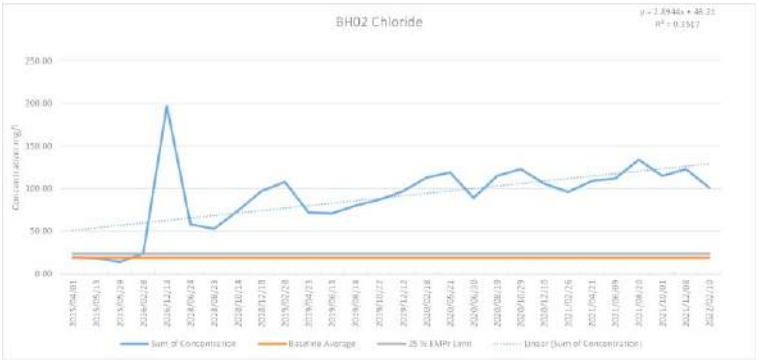
| BH02 | |
|---|---|
|  BH02 Acenaphthylene |  BH02 Aluminium |
|  BH02 Ammonia |  BH02 Ammonia as N |

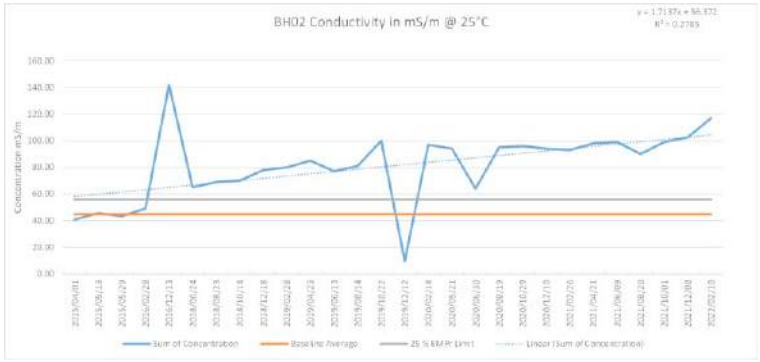

BH02 Barium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

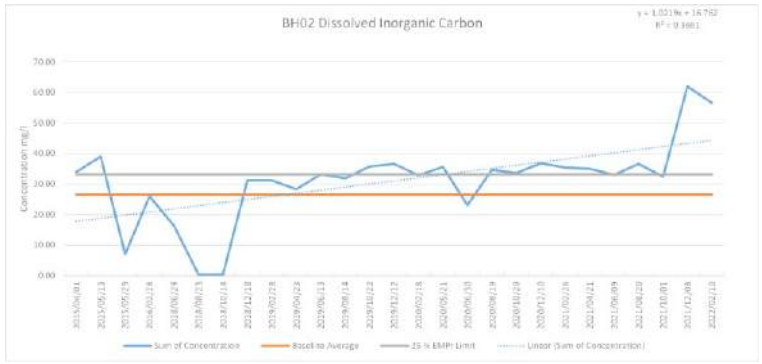

BH02 Boron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

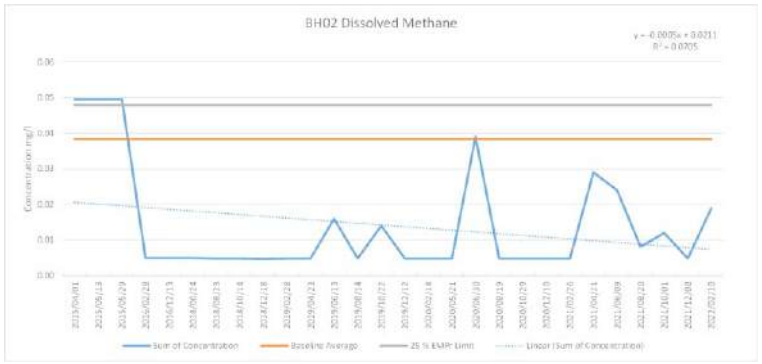
BH02 Bromide
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

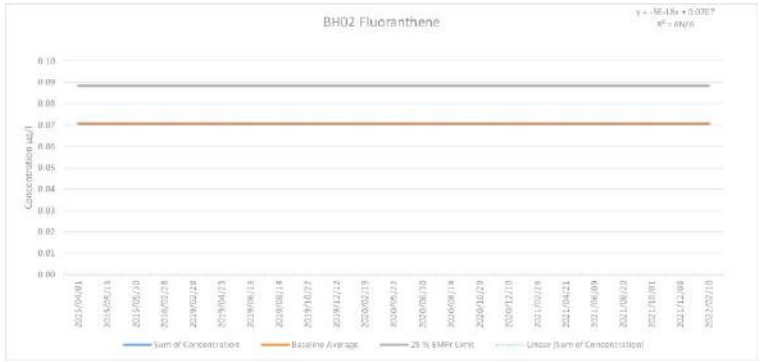
BH02 Calcium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)


BH02 Chloride
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

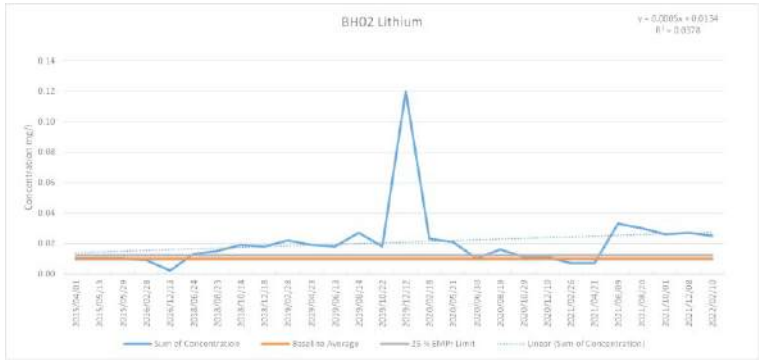

BH02 Conductivity in mS/m @ 25°C
Concentration mS/m
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

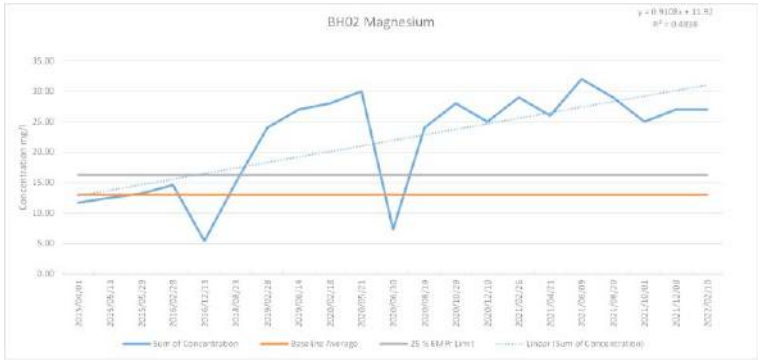

BH02 Dissolved Inorganic Carbon
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

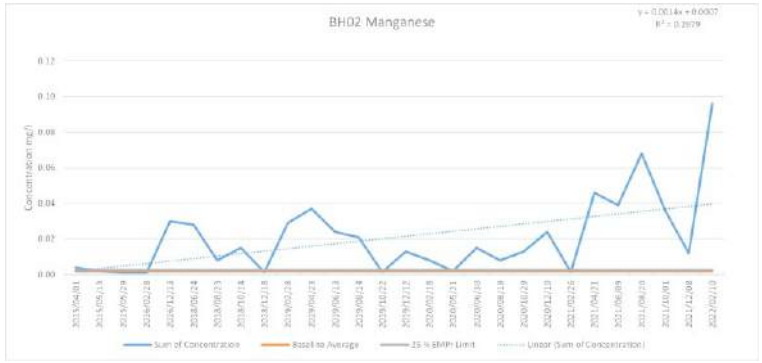

BH02 Dissolved Methane
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

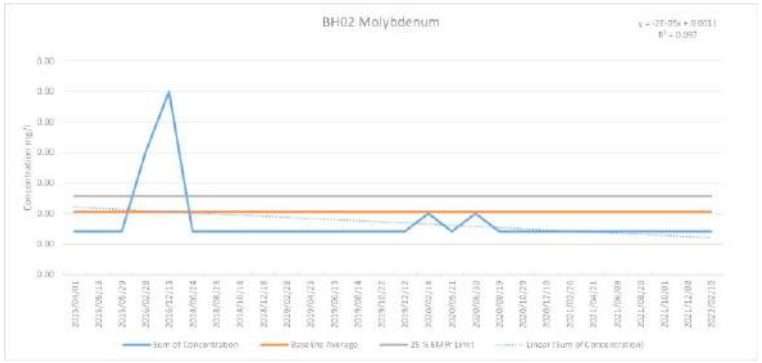

BH02 Fluoranthene
Concentration µg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

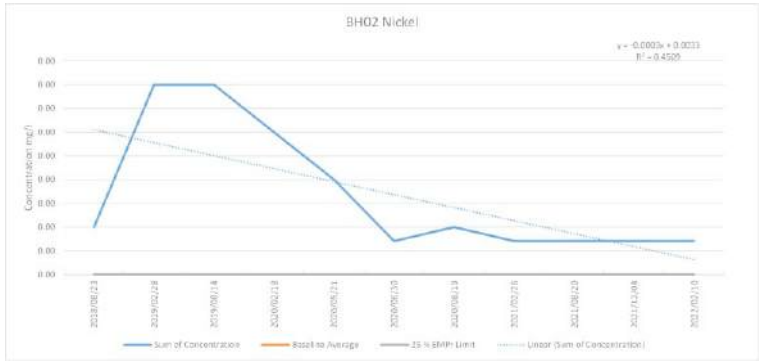
BH02 Iron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

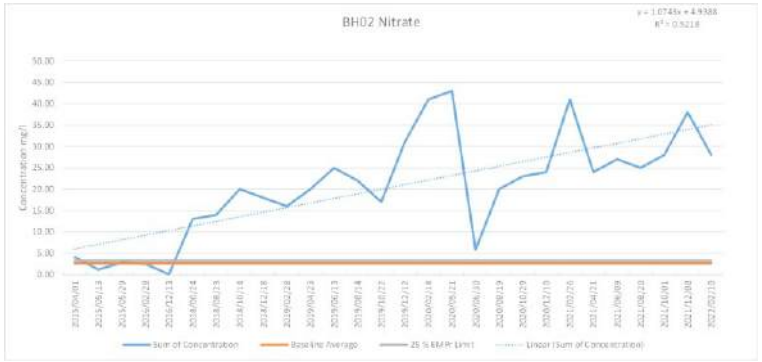

BH02 Lithium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

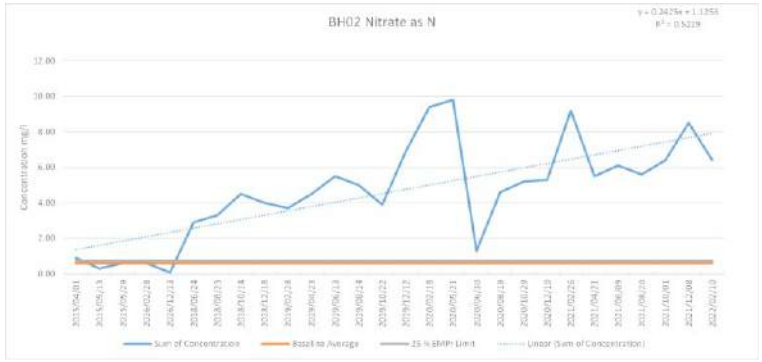

BH02 Magnesium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPC Limit
Linear (Sum of Concentration)

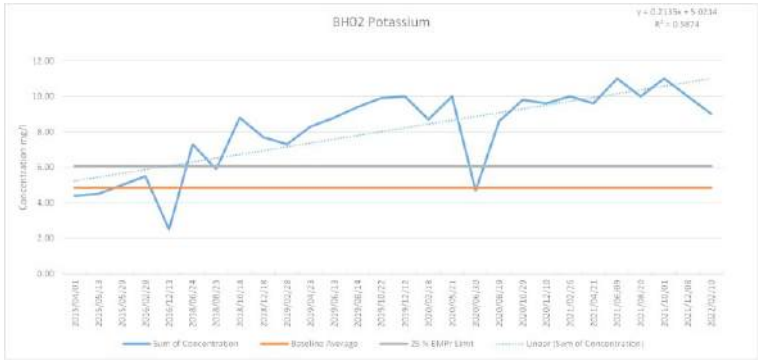

BH02 Manganese
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

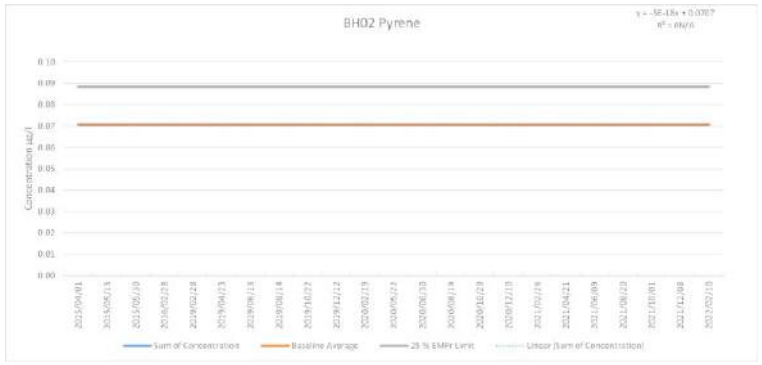

BH02 Molybdenum
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

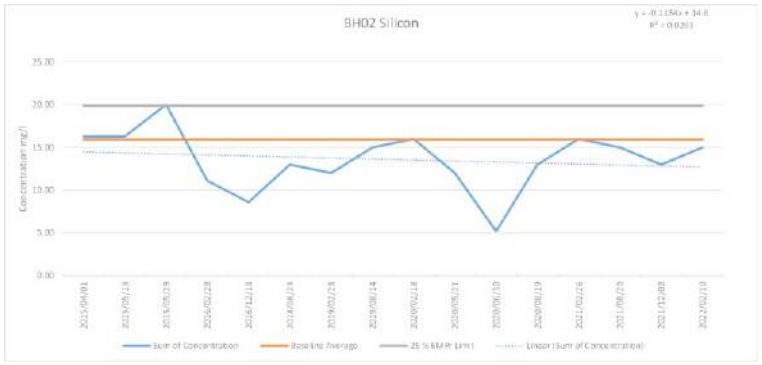

BH02 Nickel
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

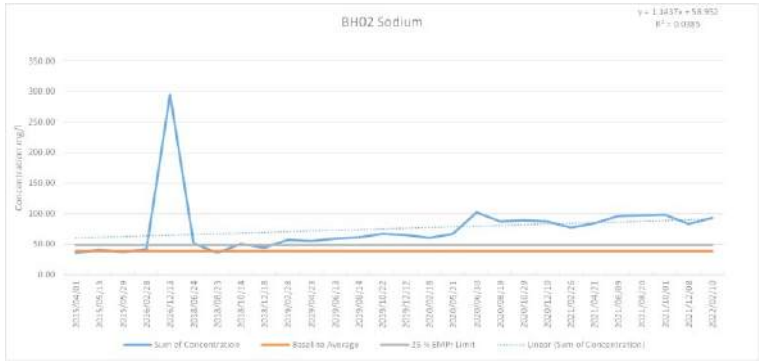

BH02 Nitrate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

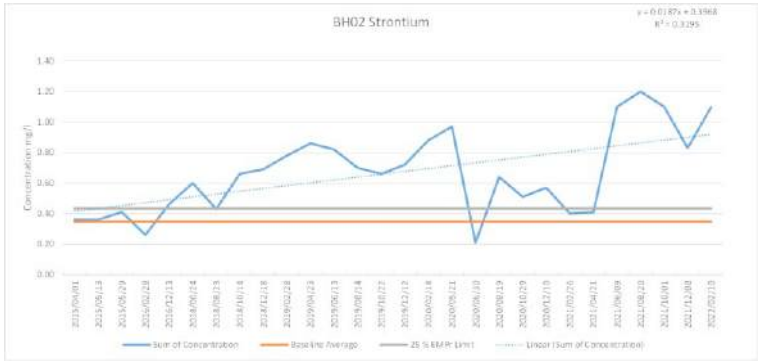

BH02 Nitrate as N
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

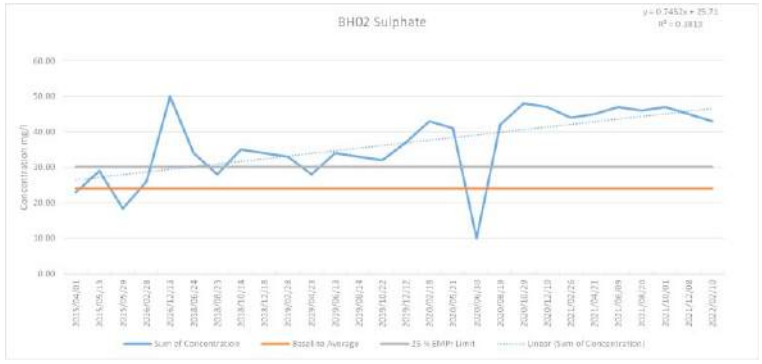

BH02 Potassium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % BMP Limit
Linear (Sum of Concentration)

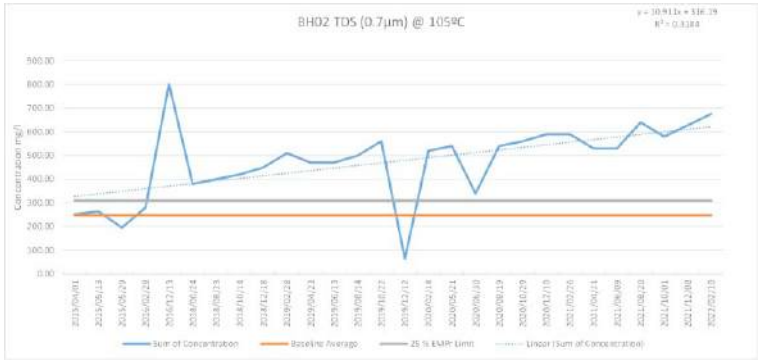

BH02 Pyrene
Concentration µg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

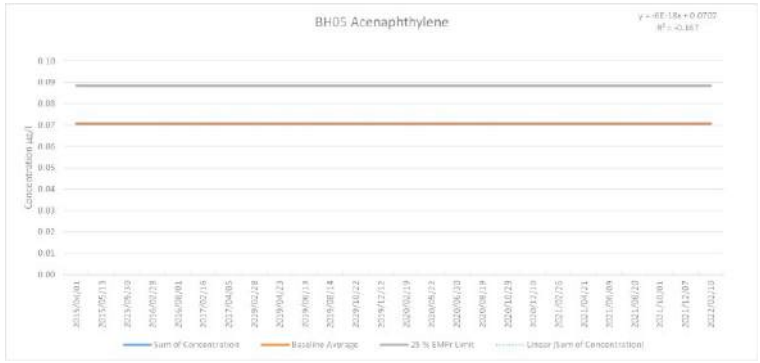
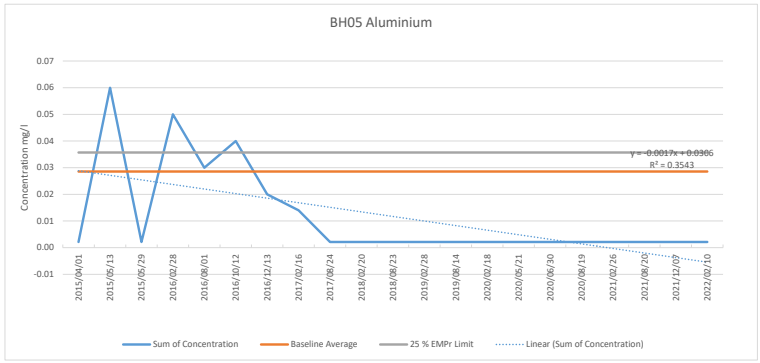
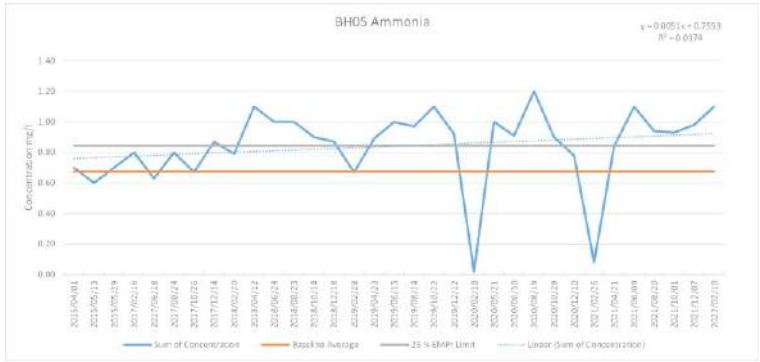

BH02 Silicon
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

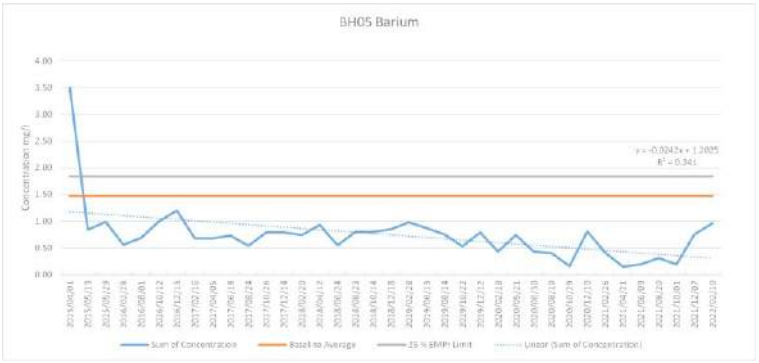

BH02 Sodium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

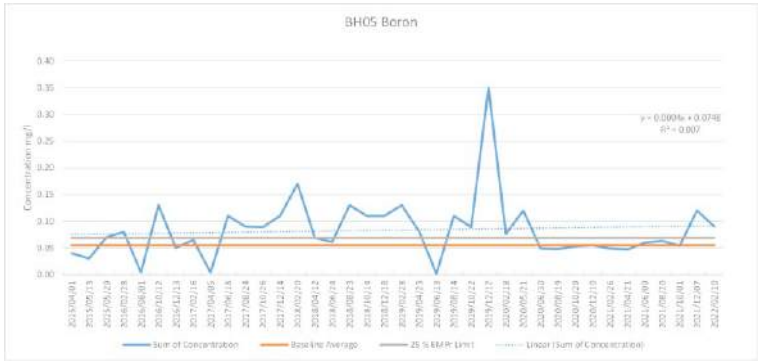

BH02 Strontium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

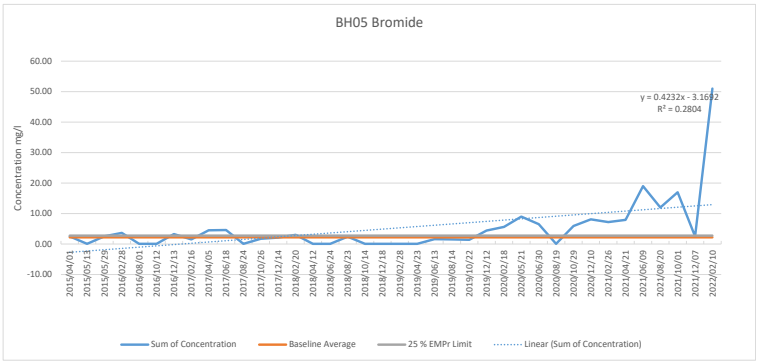

BH02 Sulphate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

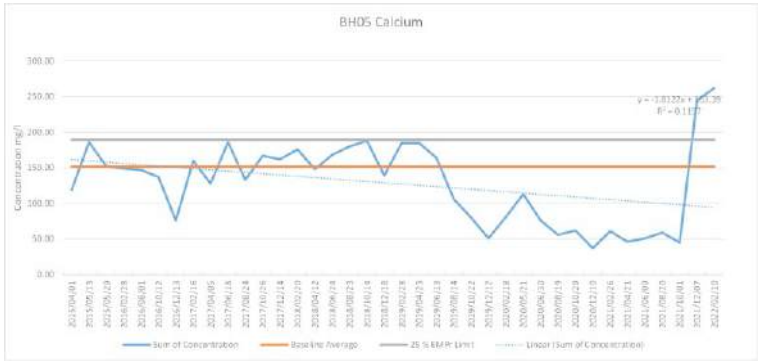

BH02 TDS (0.7µm) @ 105ºC
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

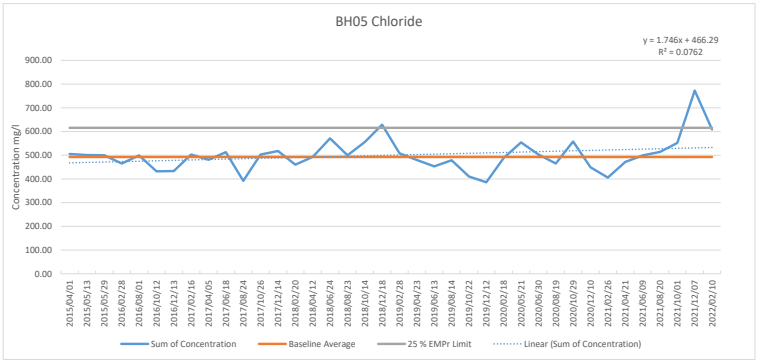
| BH05 | |
|---|---|
|  BH05 Acenaphthylene<br>Concentration µg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPr Limit<br>Linear (Sum of Concentration) |  BH05 Aluminium<br>Concentration mg/l<br>y = -0.0017x + 0.0386<br>R² = 0.3543<br>Sum of Concentration<br>Baseline Average<br>25 % EMPr Limit<br>Linear (Sum of Concentration) |
|  BH05 Ammonia<br>y = 0.0051x + 0.7553<br>R² = 0.0374<br>Concentration mg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPr Limit<br>Linear (Sum of Concentration) | BH05 Ammonia as N<br>Concentration mg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPr Limit<br>Linear (Sum of Concentration) |

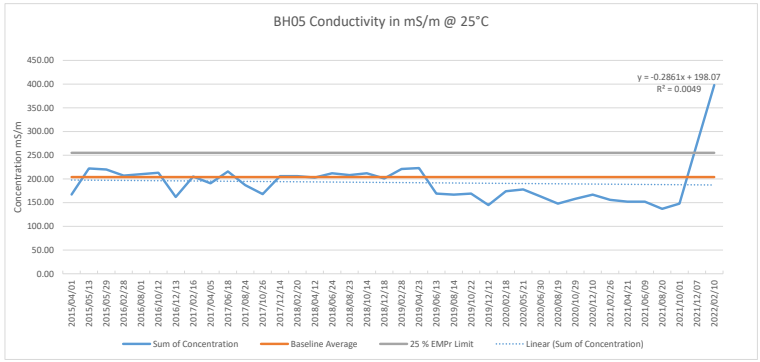

BH05 Barium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

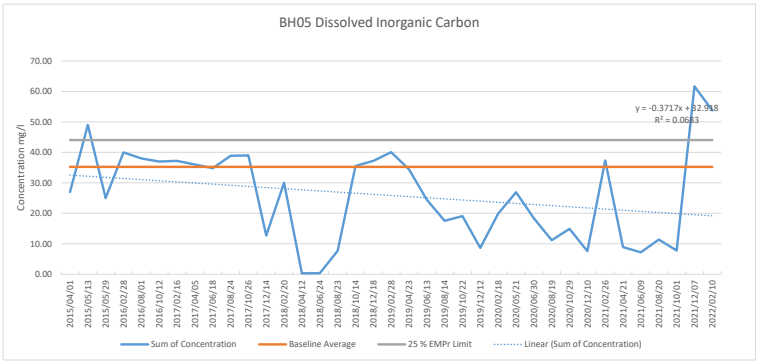

BH05 Boron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

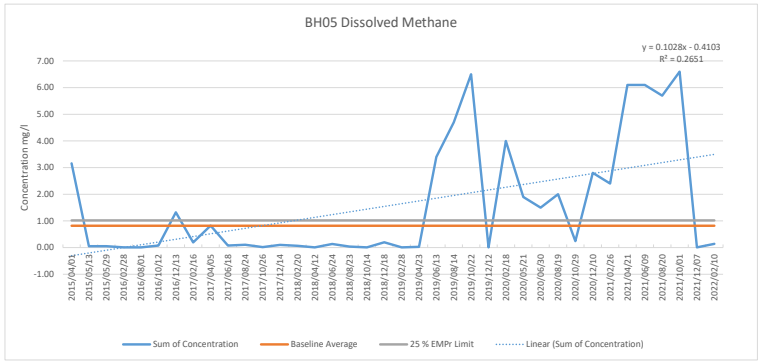

BH05 Bromide
Concentration mg/l
y = 0.4232x - 3.1692
R² = 0.2804
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

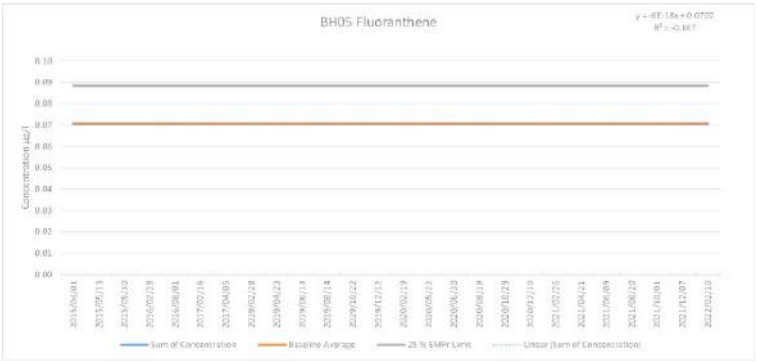

BH05 Calcium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

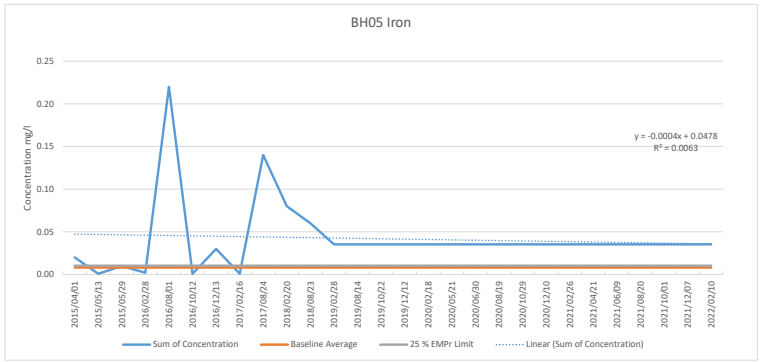

BH05 Chloride
Concentration mg/l
y = 1.746x + 466.29
R² = 0.0762
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

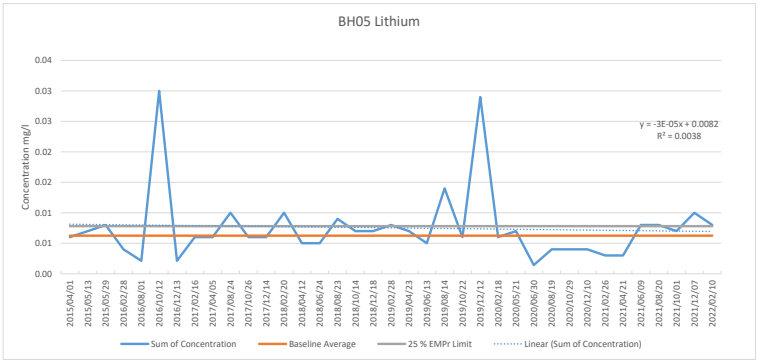

BH05 Conductivity in mS/m @ 25°C
Concentration mS/m
y = -0.2861x + 198.07
R² = 0.0049
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

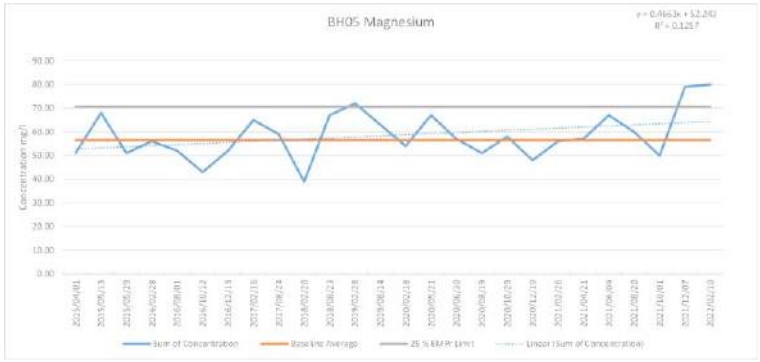

BH05 Dissolved Inorganic Carbon
Concentration mg/l
y = -0.3717x + 82.918
R² = 0.0633
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

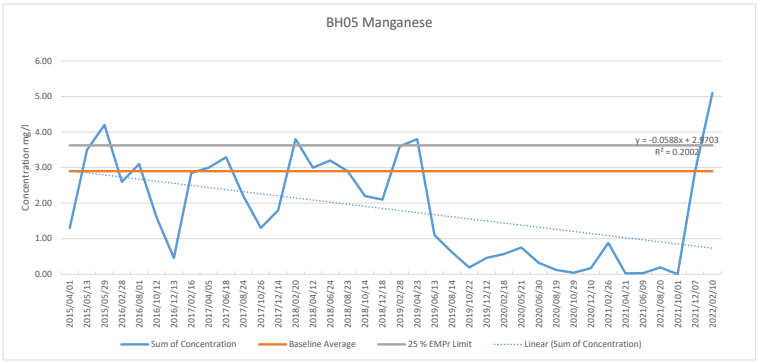

BH05 Dissolved Methane
Concentration mg/l
y = 0.1028x - 0.4103
R² = 0.2651
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

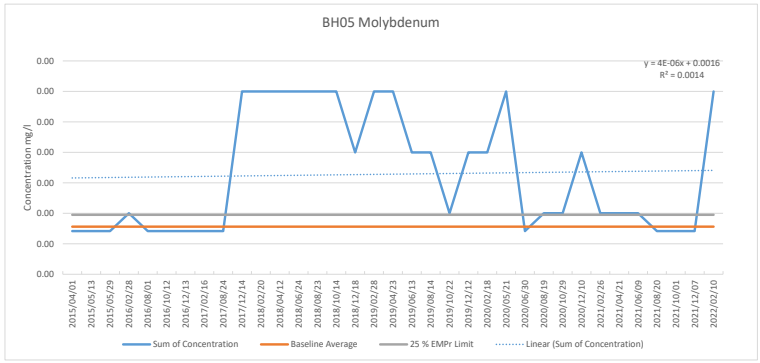

BH05 Fluoranthene

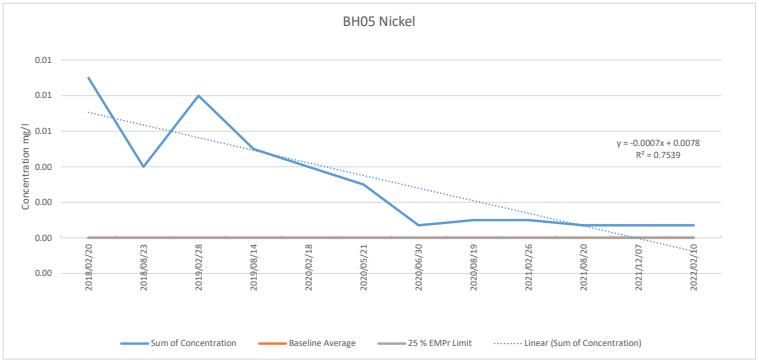

BH05 Iron
Concentration mg/l
y = -0.0004x + 0.0478
R² = 0.0063
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

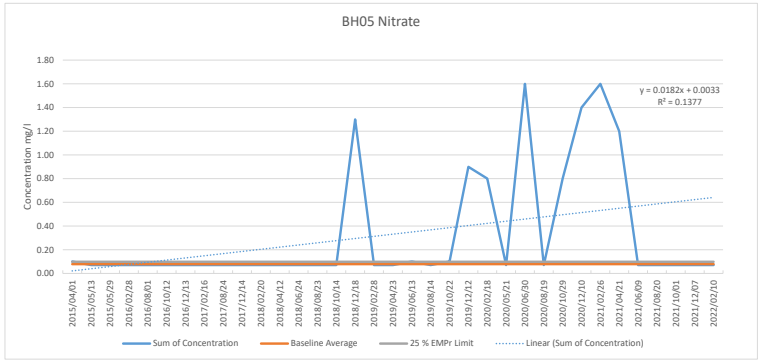

BH05 Lithium
Concentration mg/l
y = -3E-05x + 0.0082
R² = 0.0038
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

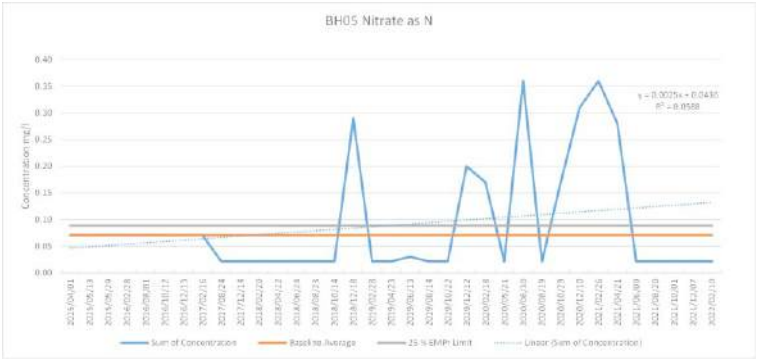

BH05 Magnesium

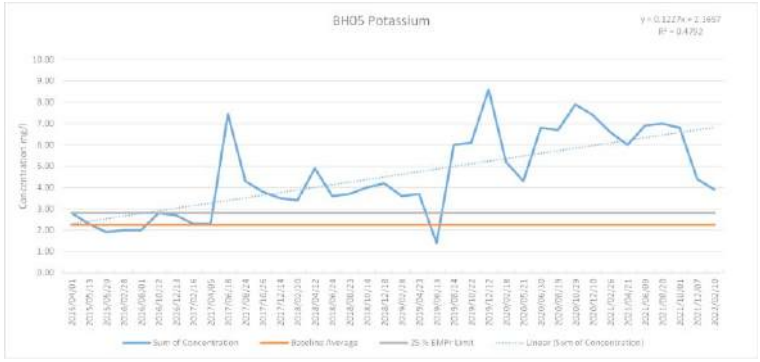

BH05 Manganese
Concentration mg/l
y = -0.0588x + 2.9703
R² = 0.2002
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

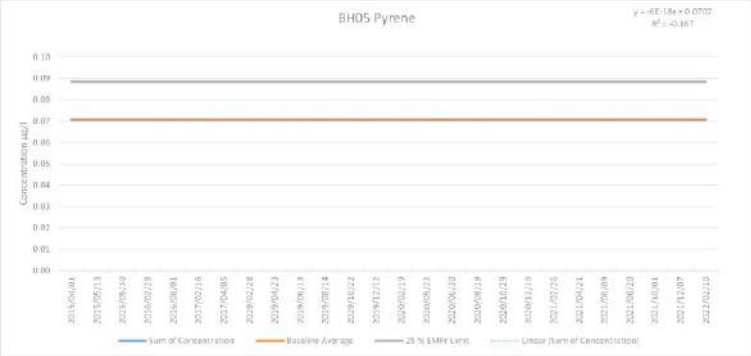

BH05 Molybdenum
Concentration mg/l
y = 4E-06x + 0.0016
R² = 0.0014
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

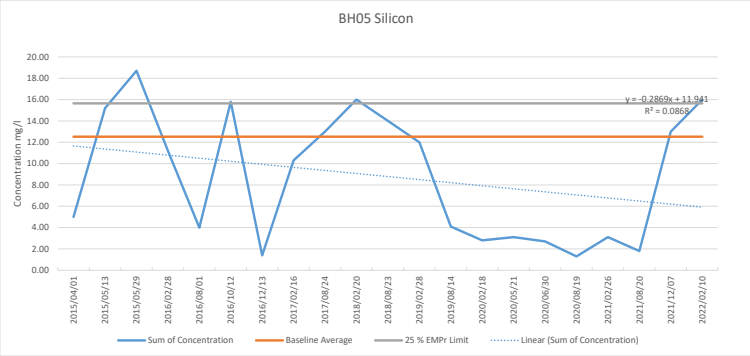

BH05 Nickel
Concentration mg/l
y = -0.0007x + 0.0078
R² = 0.7539
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

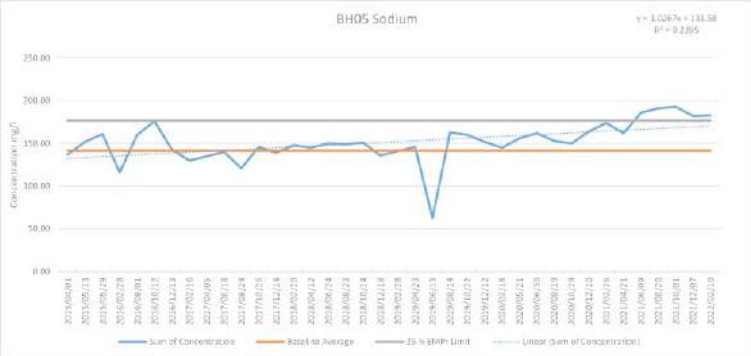

BH05 Nitrate
Concentration mg/l
y = 0.0182x + 0.0033
R² = 0.1377
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

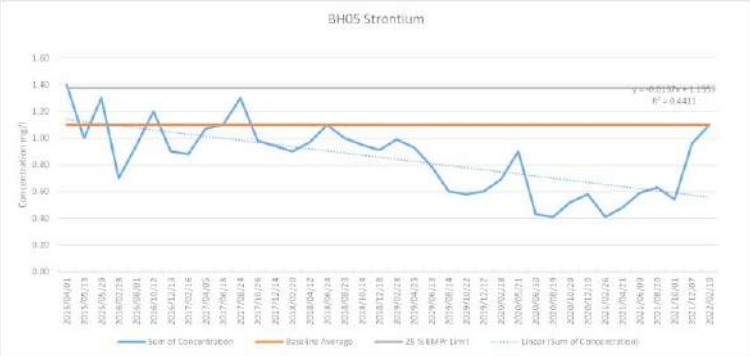

BH05 Nitrate as N

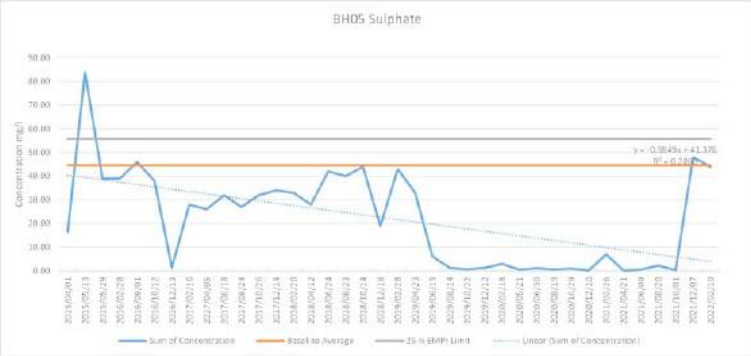

BH05 Potassium

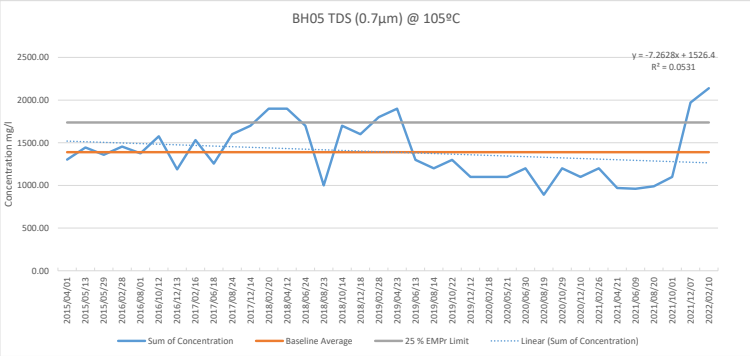

BH05 Pyrene
Concentration µg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

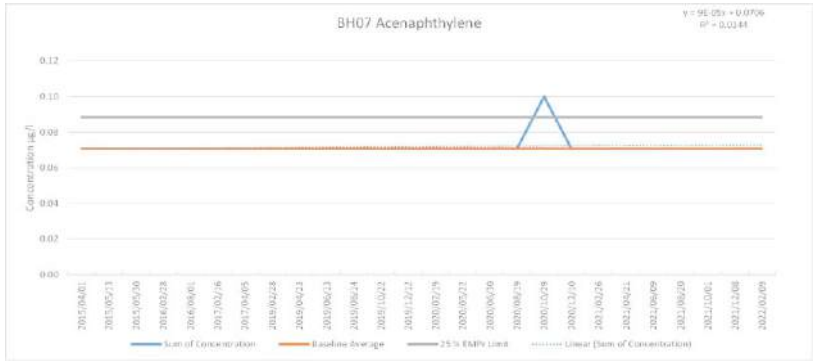
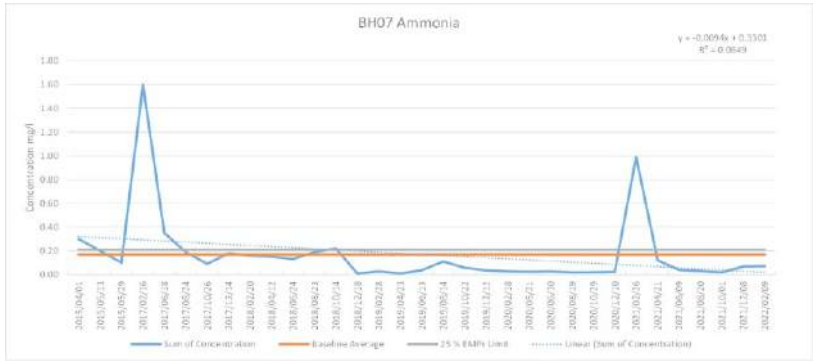
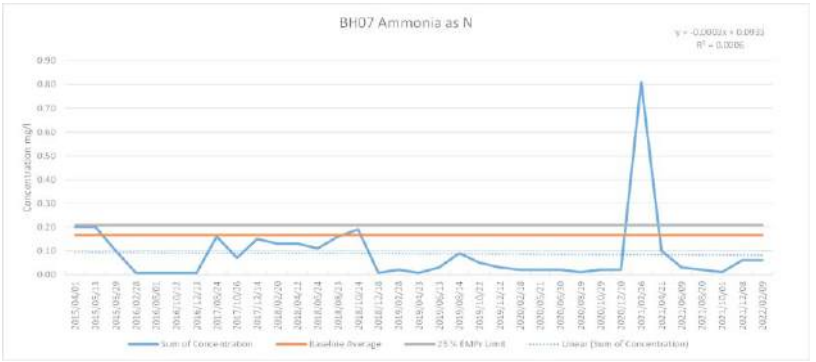

BH05 Silicon
Concentration mg/l
y = -0.2869x + 11.941
R² = 0.0868
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

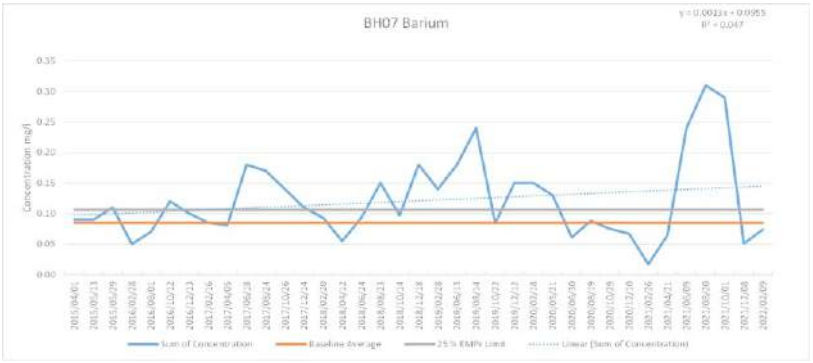

BH05 Sodium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

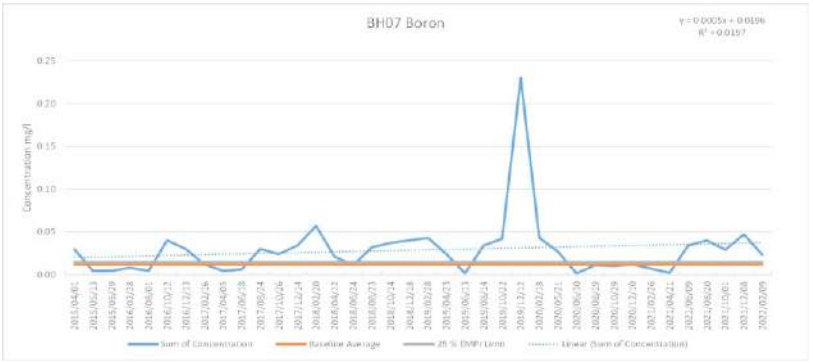

BH05 Strontium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

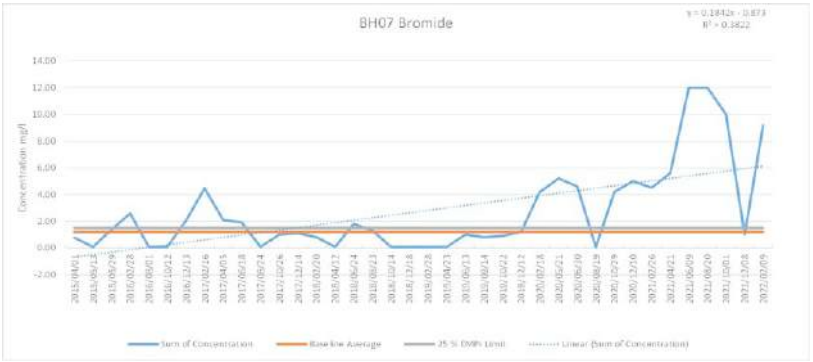

BH05 Sulphate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

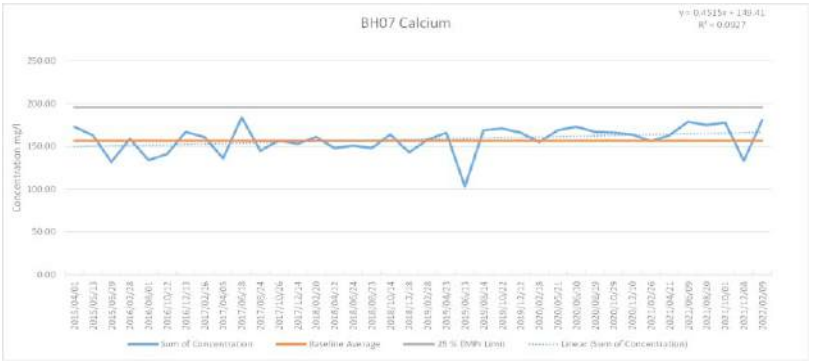

BH05 TDS (0.7µm) @ 105ºC
Concentration mg/l
y = -7.2628x + 1526.4
R² = 0.0531
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

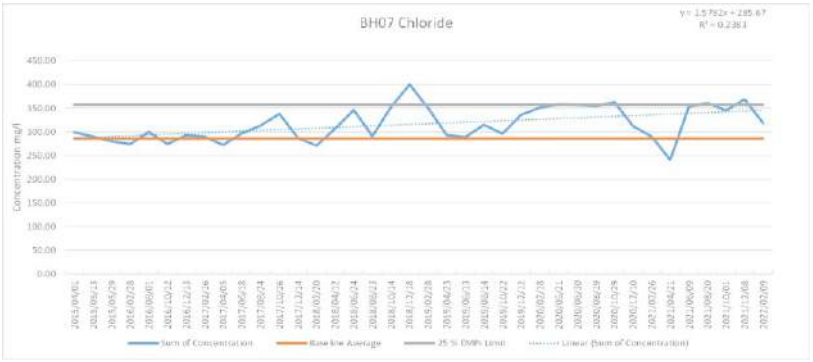
| BH07 | |
|---|---|
|  BH07 Acenaphthylene<br>Concentration µg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPs Limit<br>Linear (Sum of Concentration) | BH07 Aluminium<br>Concentration mg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPs Limit<br>Linear (Sum of Concentration) |
|  BH07 Ammonia<br>Concentration mg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPs Limit<br>Linear (Sum of Concentration) |  BH07 Ammonia as N<br>Concentration mg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPs Limit<br>Linear (Sum of Concentration) |

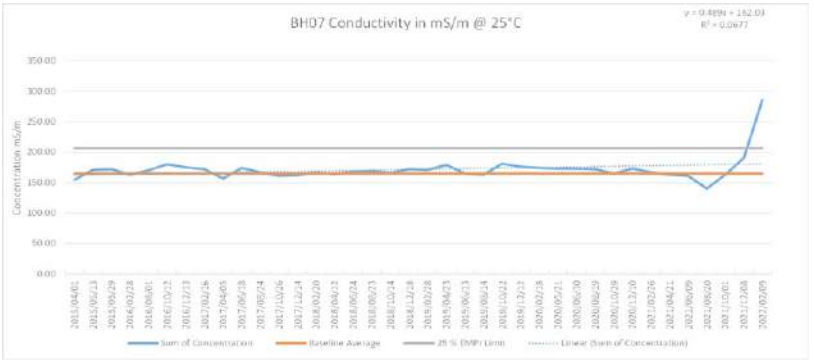

BH07 Barium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

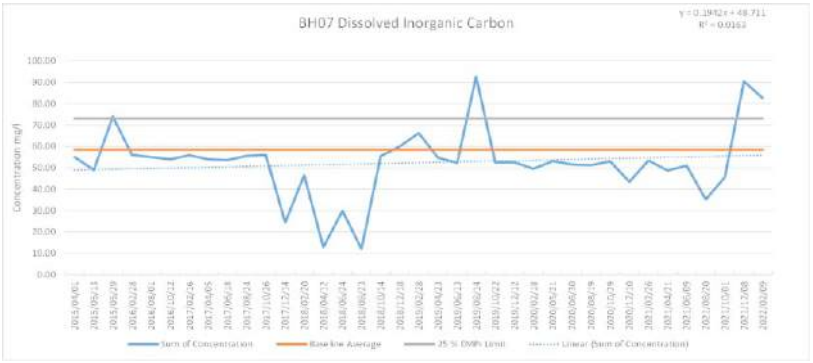

BH07 Boron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

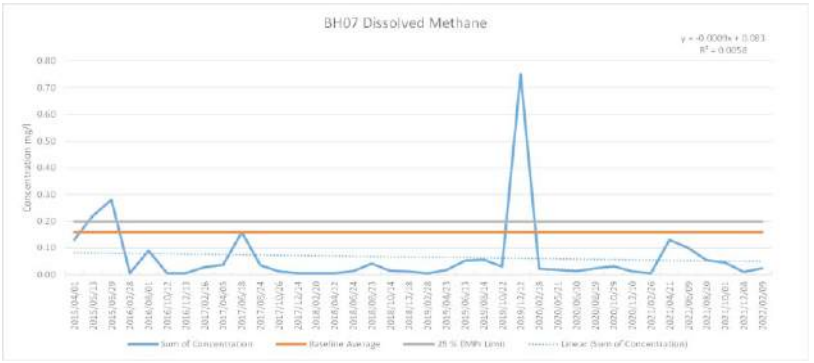

BH07 Bromide
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

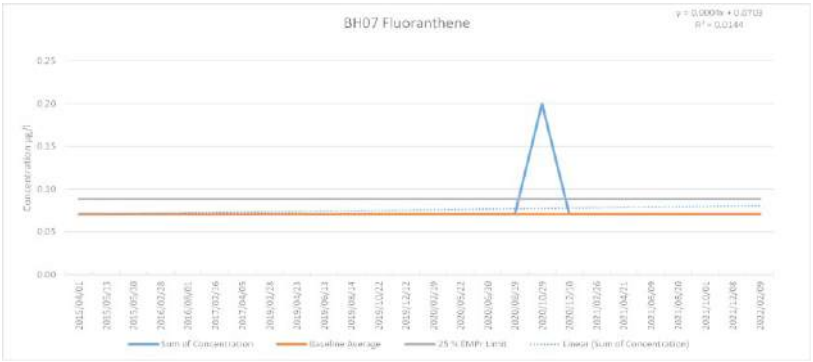

BH07 Calcium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

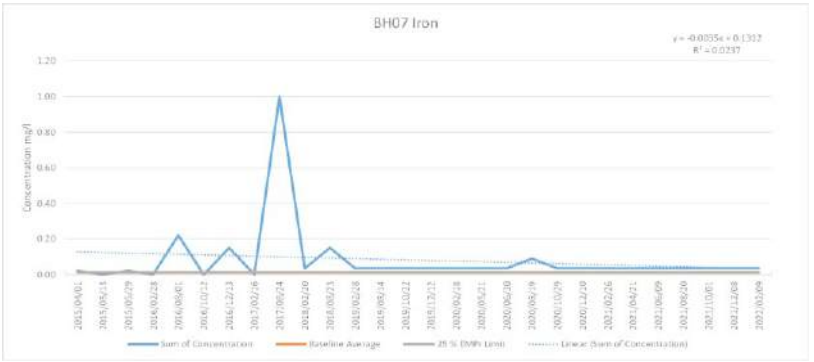

BH07 Chloride
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

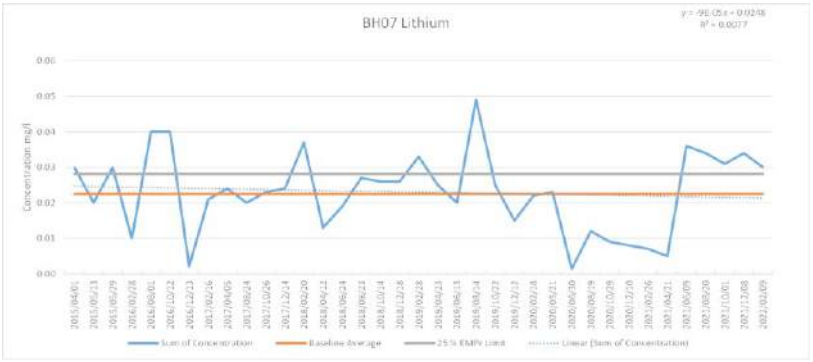

BH07 Conductivity in mS/m @ 25°C
Concentration mS/m
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

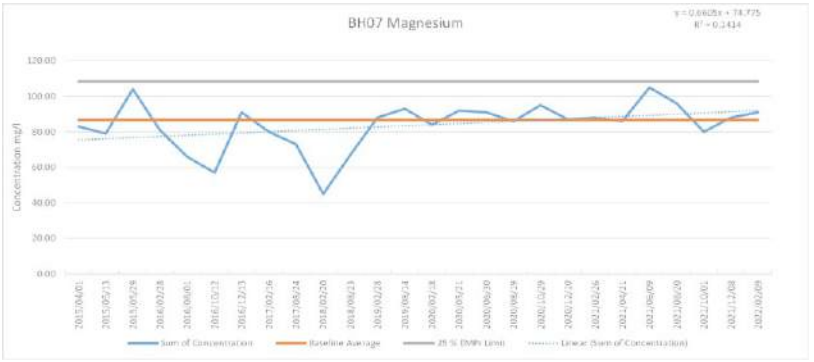

BH07 Dissolved Inorganic Carbon
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

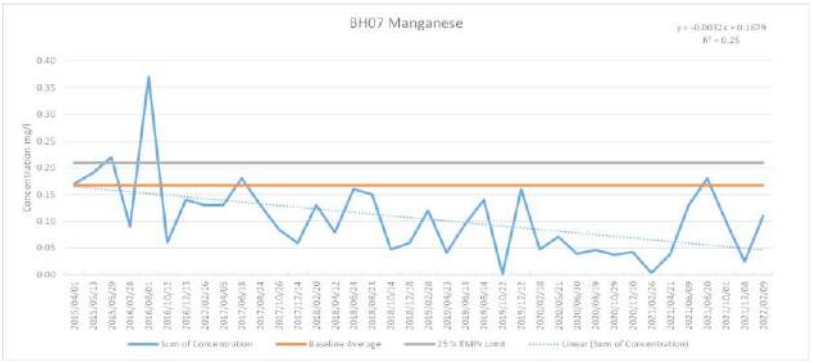

BH07 Dissolved Methane
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

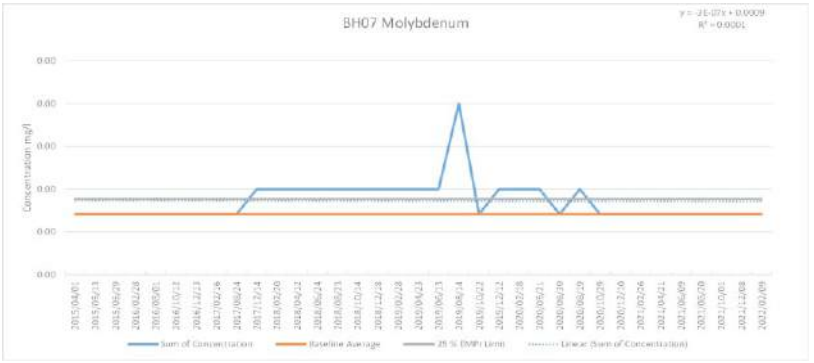

BH07 Fluoranthene
Concentration µg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

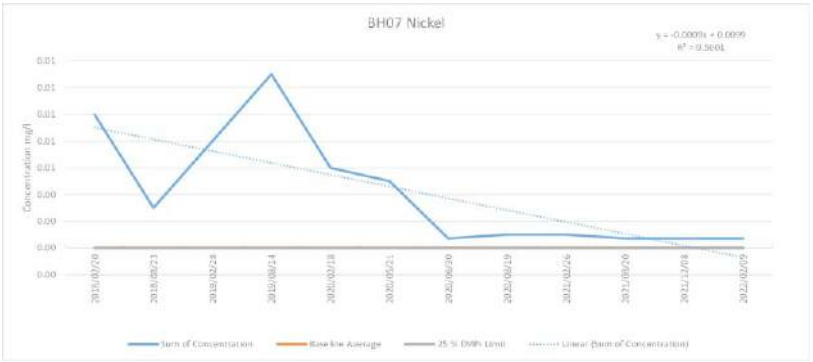

BH07 Iron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

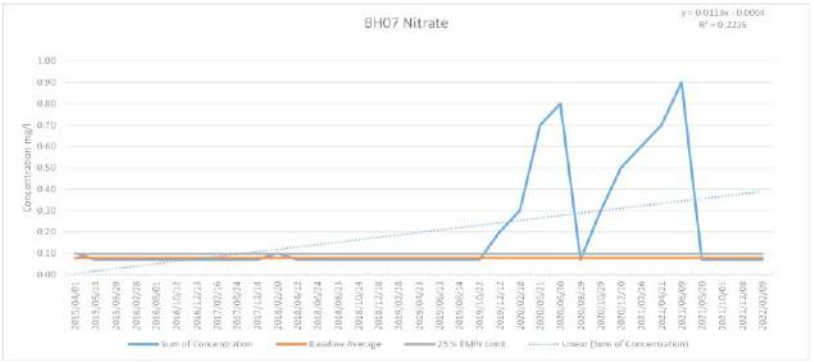

BH07 Lithium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

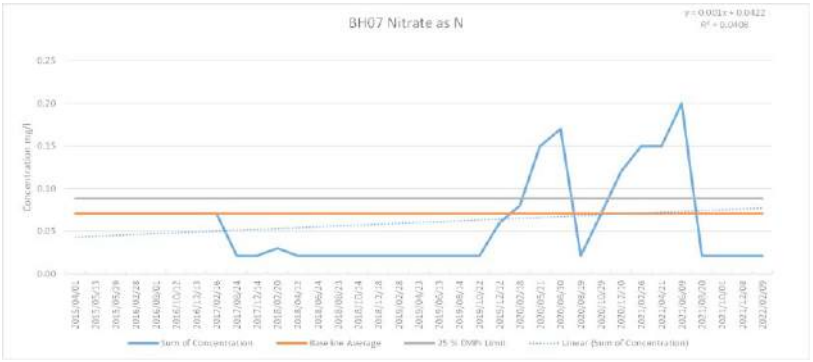

BH07 Magnesium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

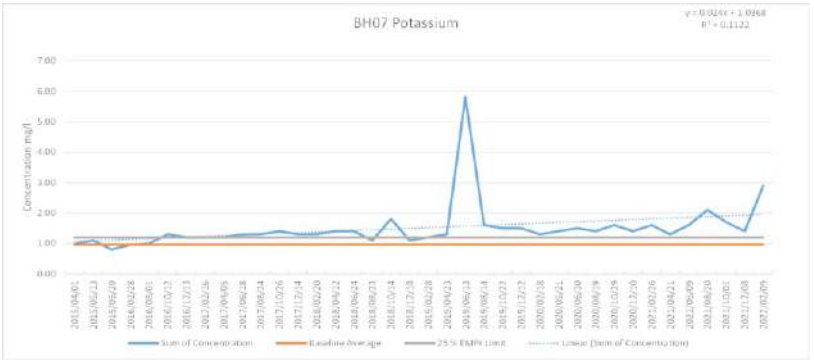

BH07 Manganese
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPc Limit
Linear (Sum of Concentration)

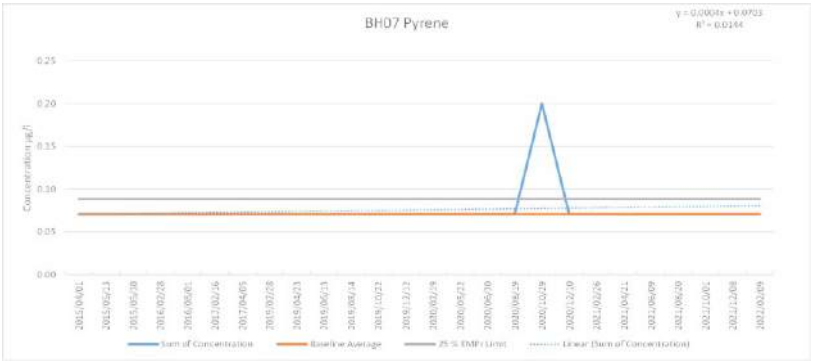

BH07 Molybdenum
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPc Limit
Linear (Sum of Concentration)

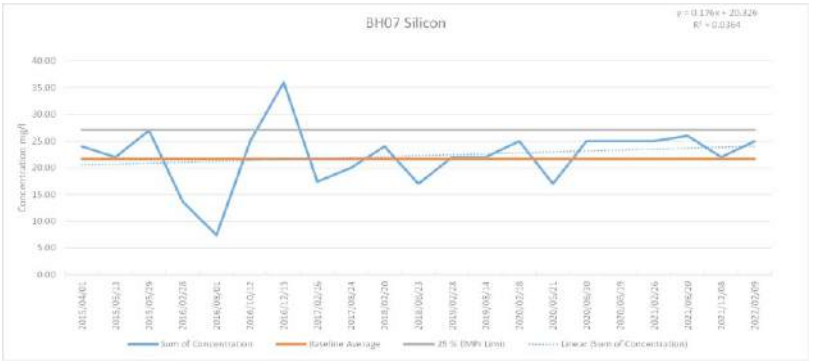

BH07 Nickel
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPc Limit
Linear (Sum of Concentration)

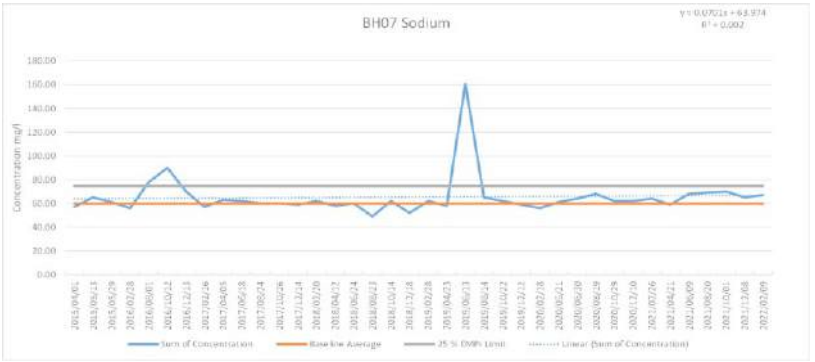

BH07 Nitrate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPc Limit
Linear (Sum of Concentration)

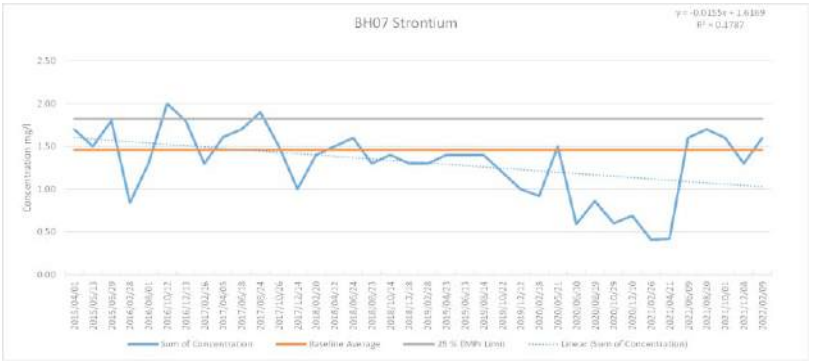

BH07 Nitrate as N
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPc Limit
Linear (Sum of Concentration)

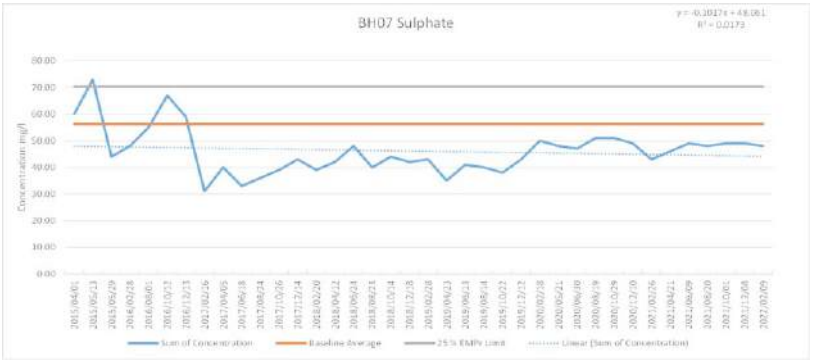

BH07 Potassium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPc Limit
Linear (Sum of Concentration)

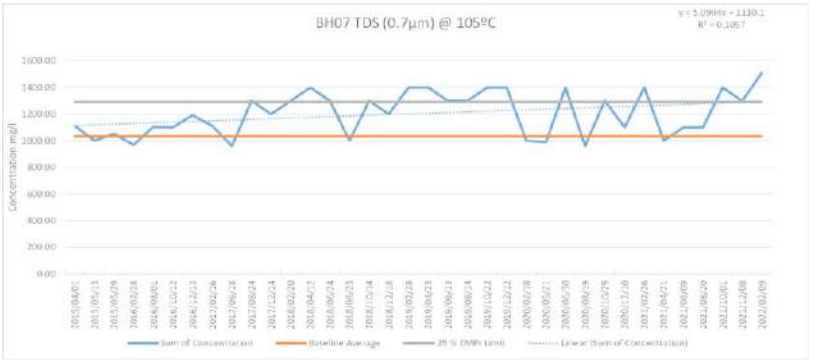

BH07 Pyrene
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

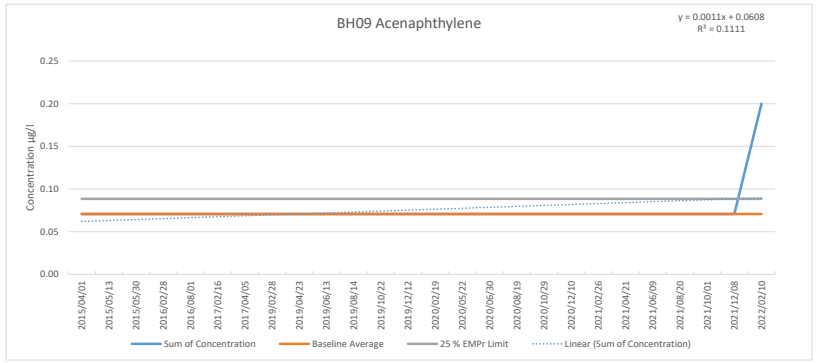
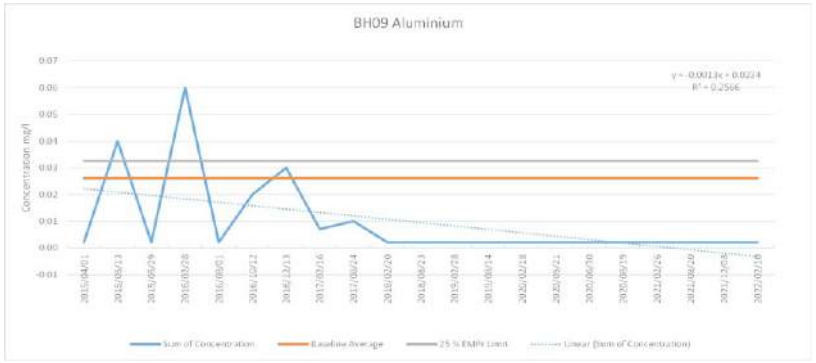
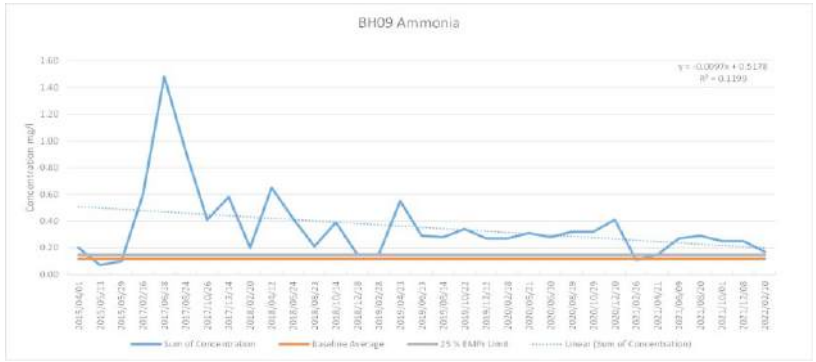
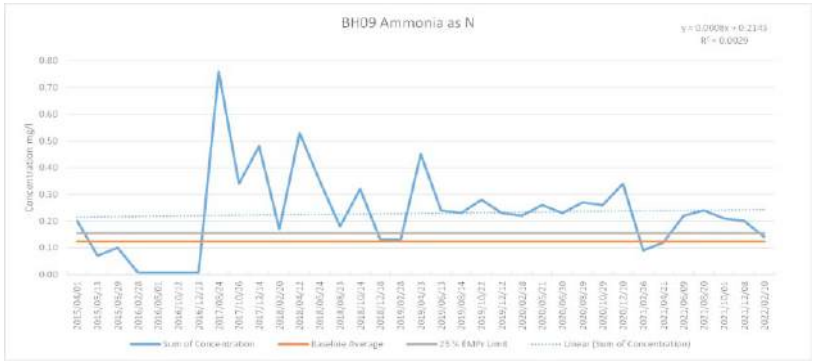

BH07 Silicon
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

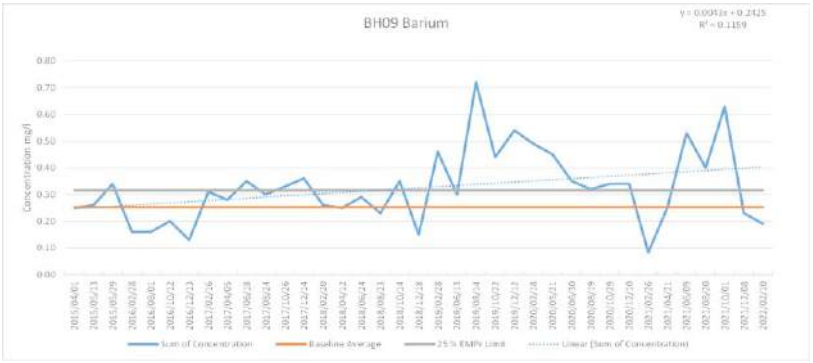

BH07 Sodium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

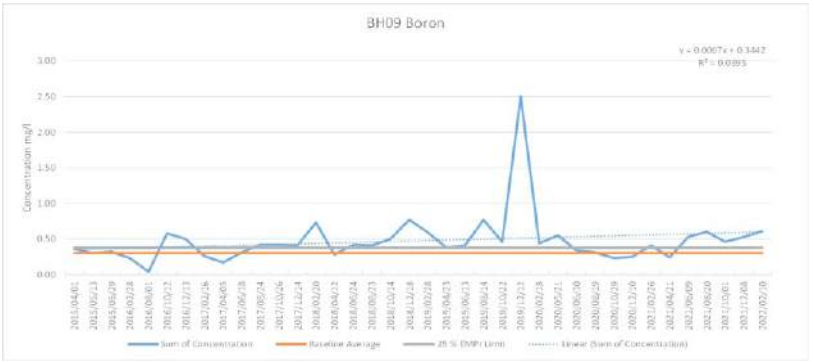

BH07 Strontium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

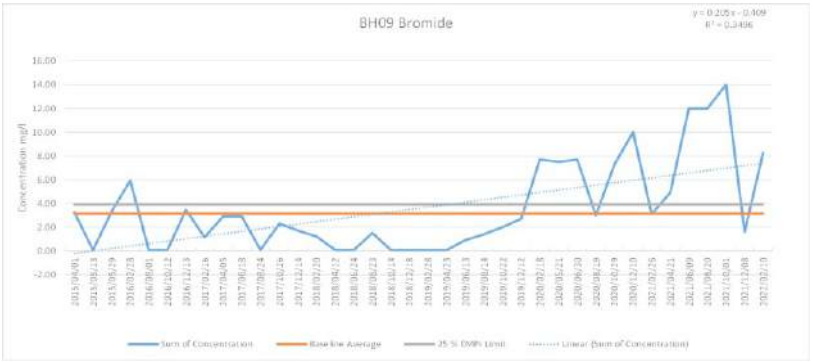

BH07 Sulphate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

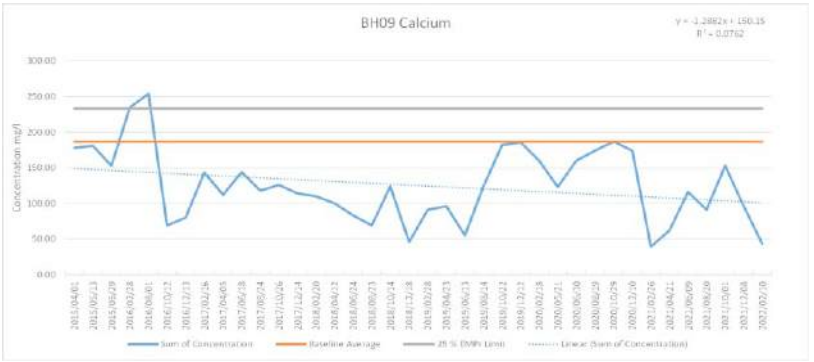

BH07 TDS (0.7µm) @ 105ºC
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

| BH09 | |
|---|---|
|  BH09 Acenaphthylene<br>y = 0.0011x + 0.0608<br>R² = 0.1111<br>Concentration µg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPr Limit<br>Linear (Sum of Concentration) |  BH09 Aluminium<br>Concentration mg/l |
|  BH09 Ammonia<br>Concentration mg/l |  BH09 Ammonia as N<br>Concentration mg/l |

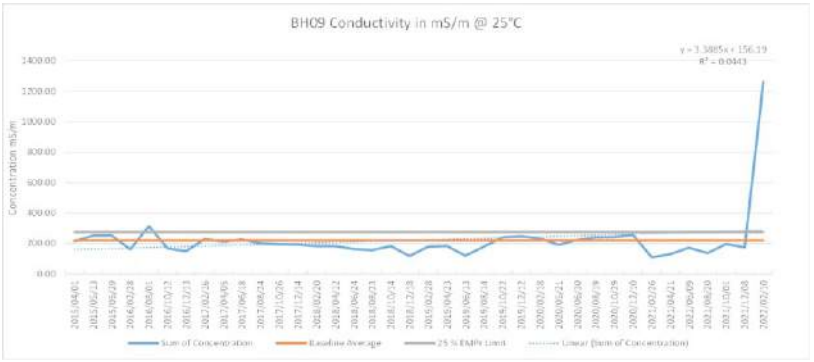

BH09 Barium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

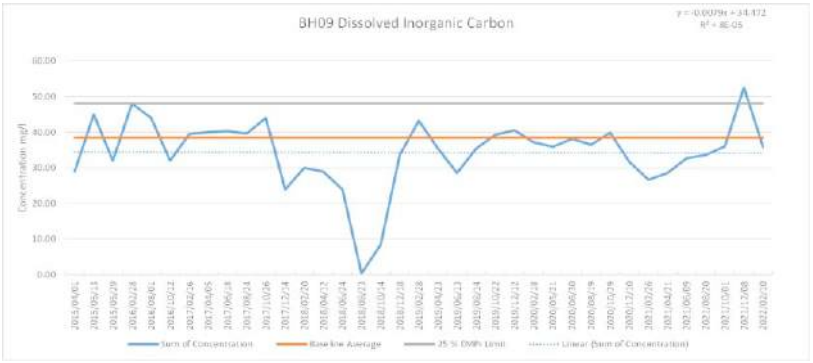

BH09 Boron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

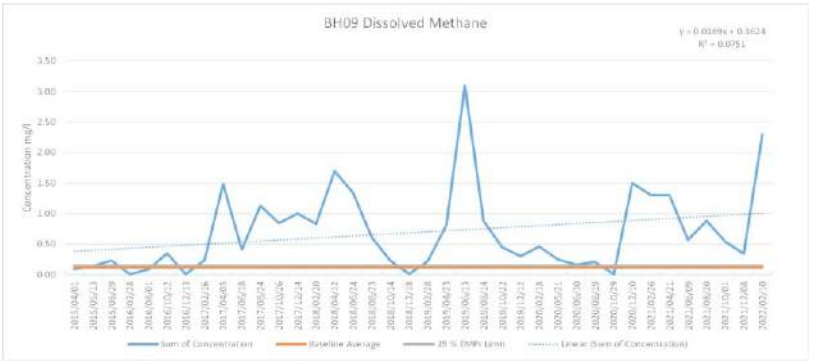

BH09 Bromide
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

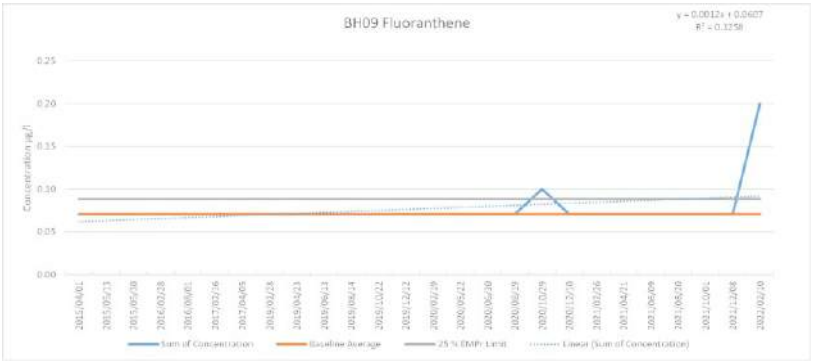

BH09 Calcium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

BH09 Chloride
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

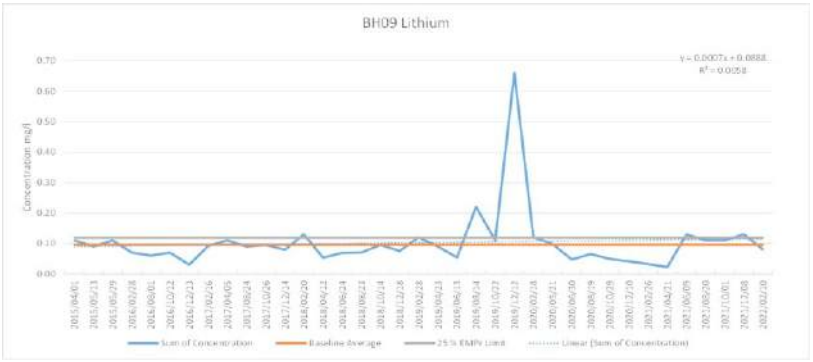

BH09 Conductivity in mS/m @ 25°C
Concentration mS/m
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

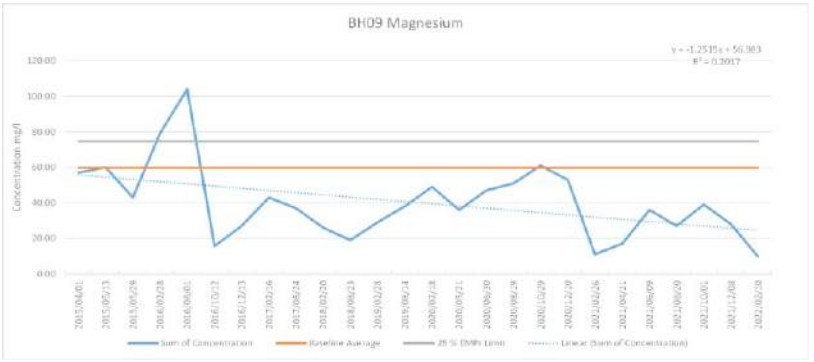

BH09 Dissolved Inorganic Carbon
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

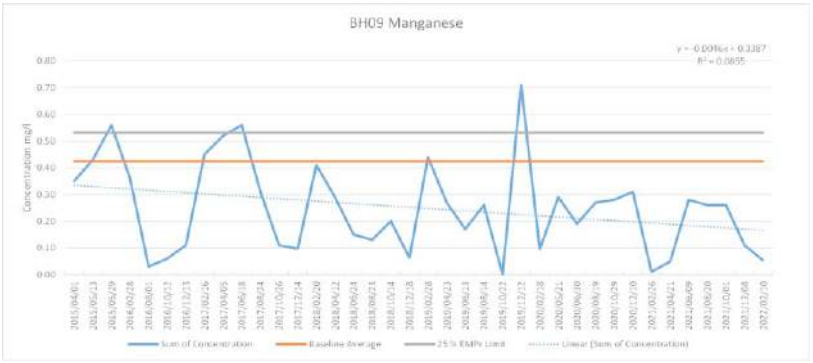

BH09 Dissolved Methane
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

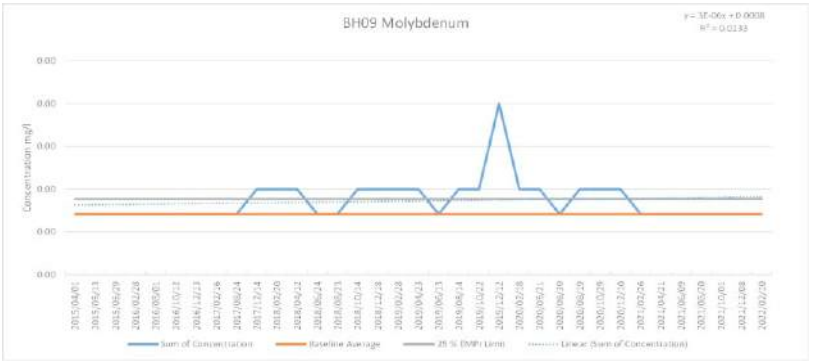

BH09 Fluoranthene
Concentration µg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

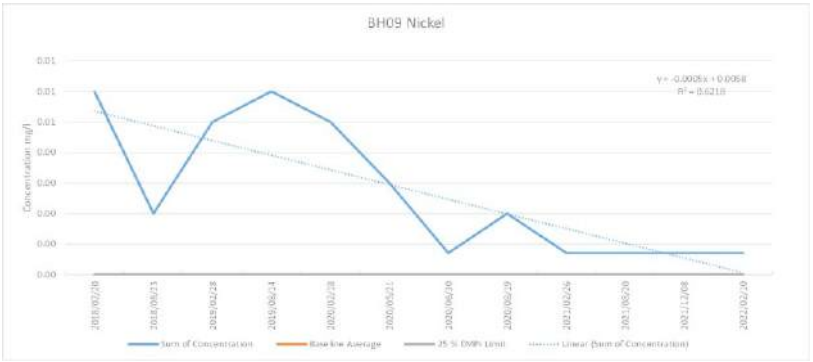
BH09 Iron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

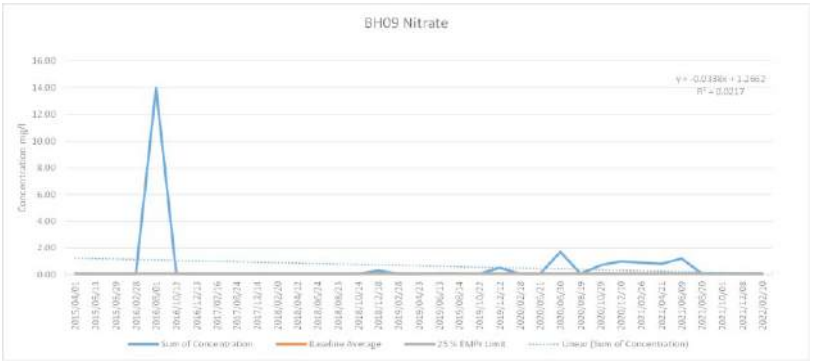

BH09 Lithium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

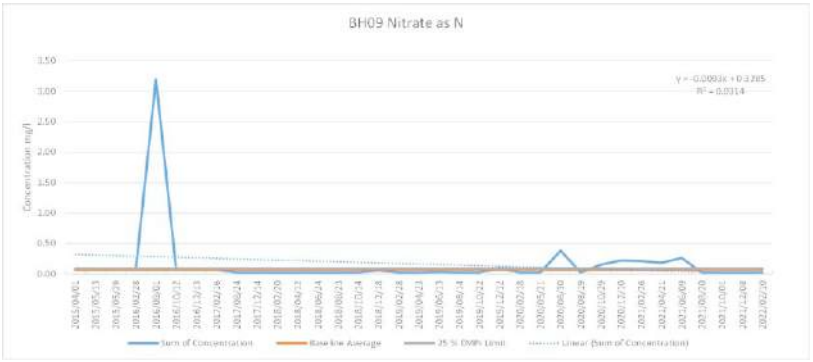

BH09 Magnesium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

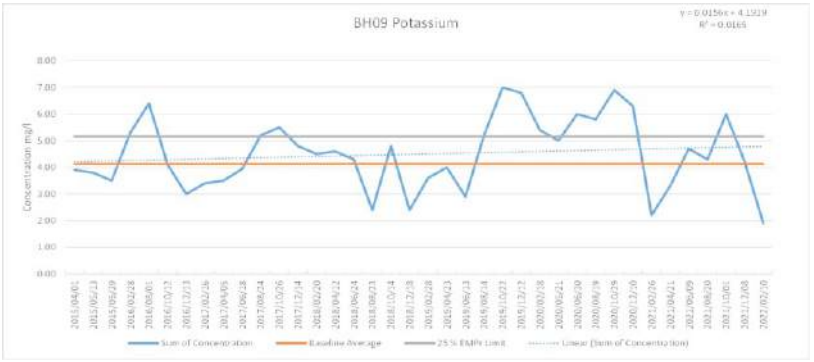

BH09 Manganese
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

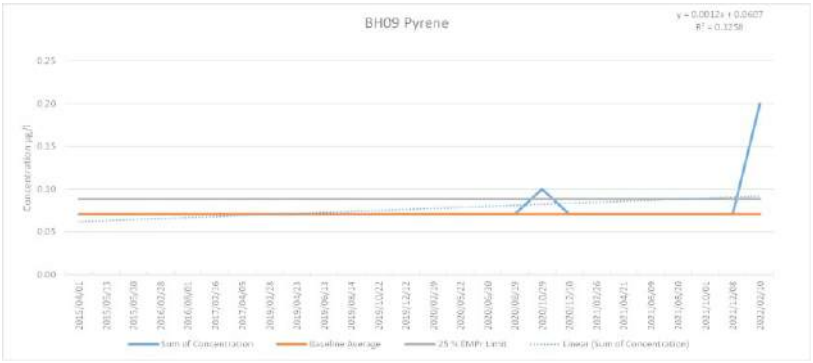

BH09 Molybdenum
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)


BH09 Nickel
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

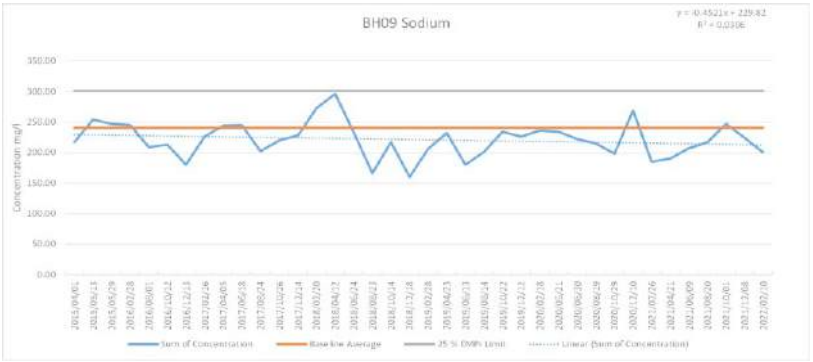

BH09 Nitrate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

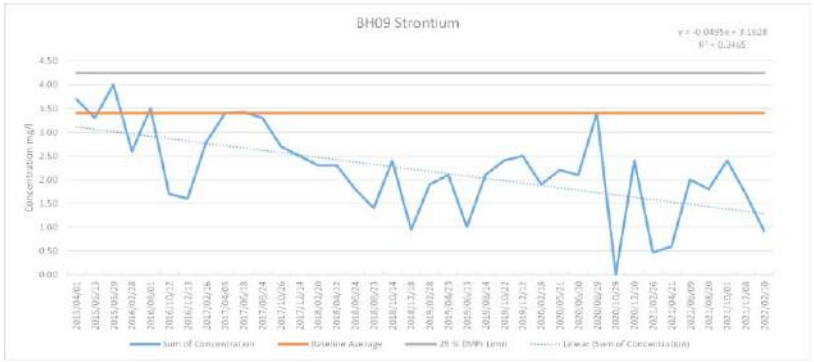

BH09 Nitrate as N
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

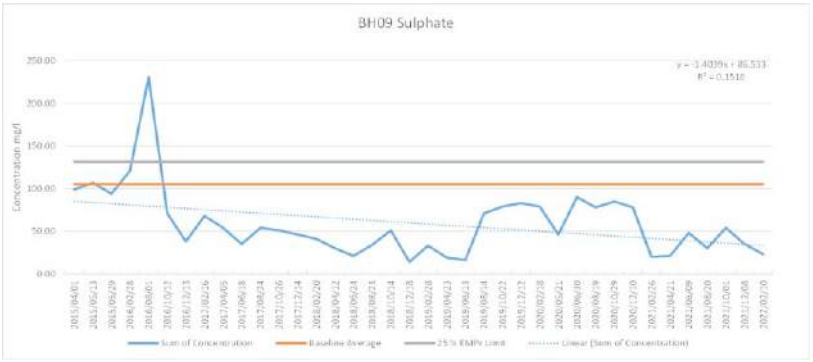

BH09 Potassium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPs Limit
Linear (Sum of Concentration)

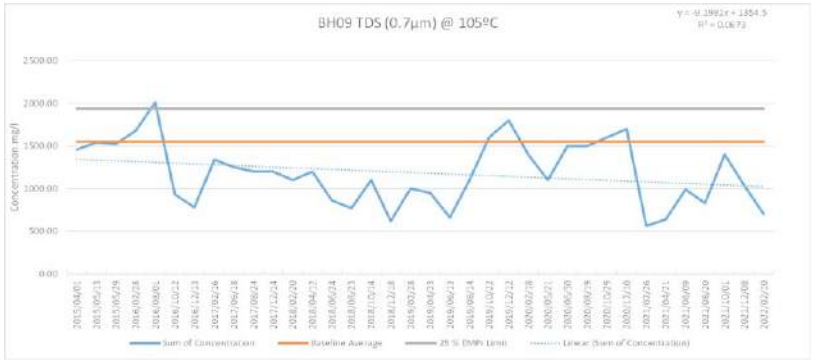

BH09 Pyrene
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

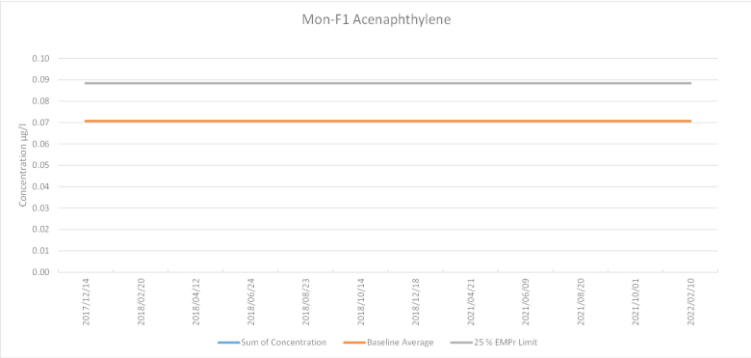
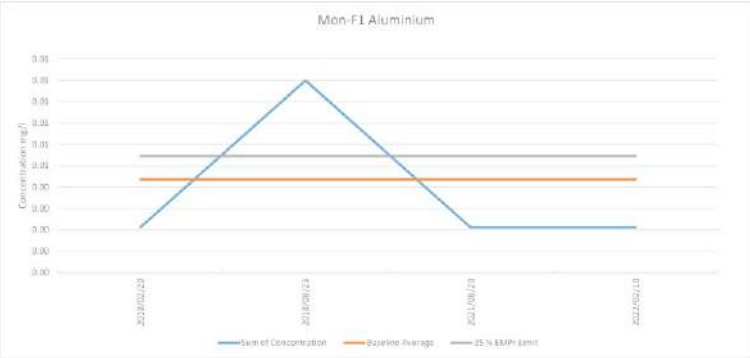
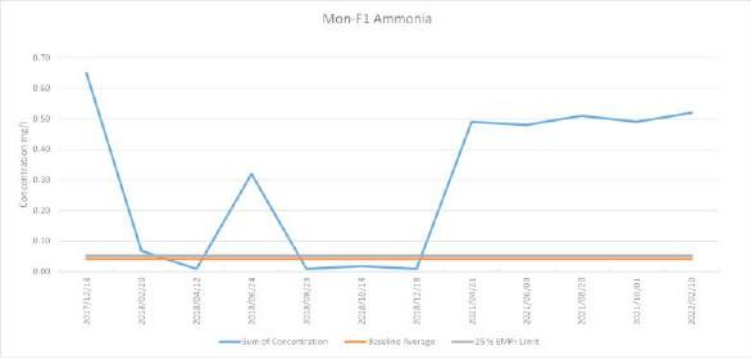
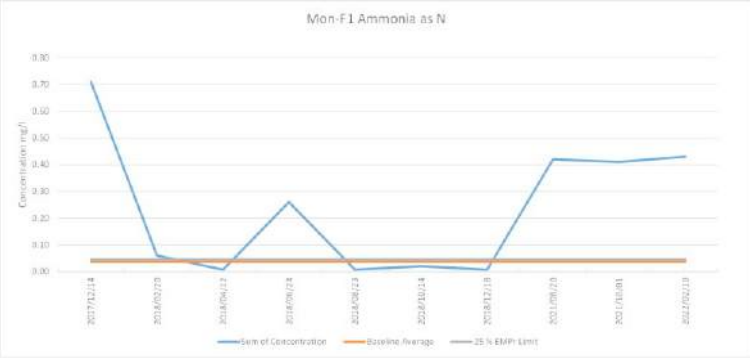
BH09 Silicon
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

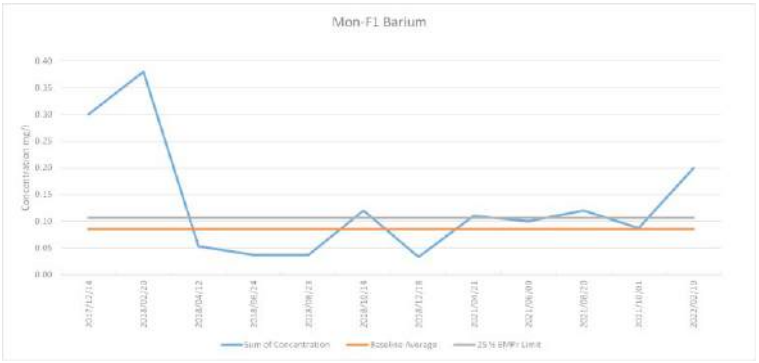

BH09 Sodium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

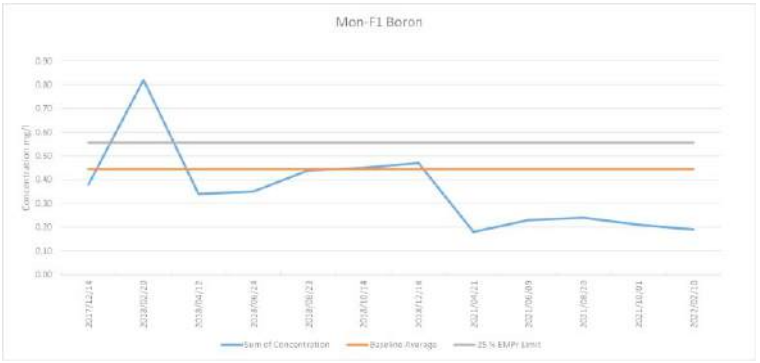

BH09 Strontium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

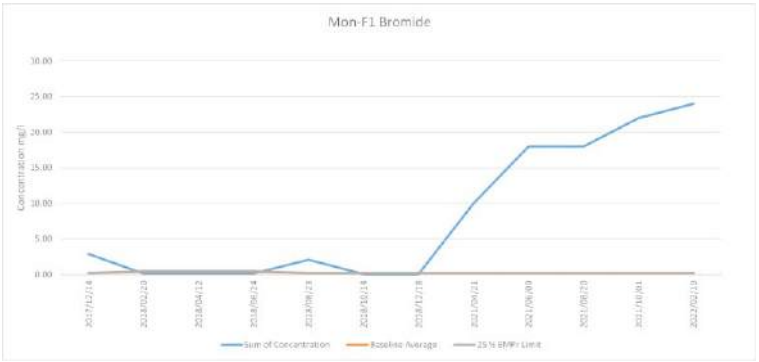

BH09 Sulphate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

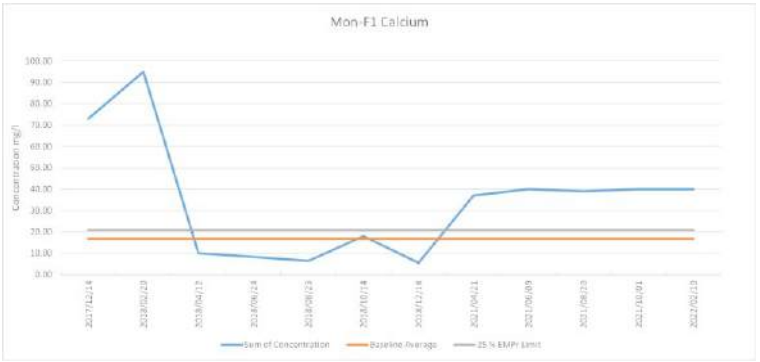

BH09 TDS (0.7µm) @ 105ºC
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit
Linear (Sum of Concentration)

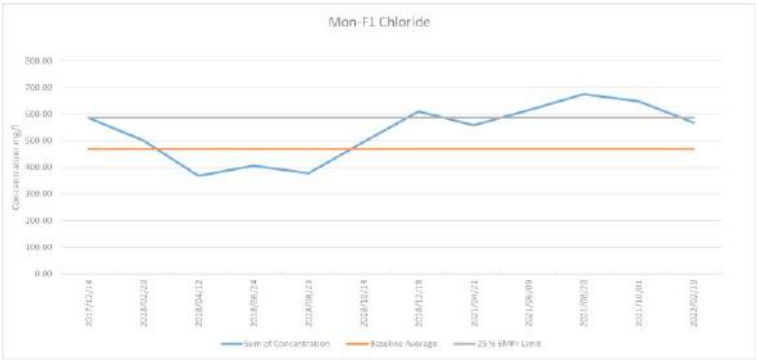
| Mon-F1 | |
|---|---|
|  Mon-F1 Acenaphthylene<br>Concentration µg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPr Limit |  Mon-F1 Aluminium<br>Concentration mg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPr Limit |
|  Mon-F1 Ammonia<br>Concentration mg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPr Limit |  Mon-F1 Ammonia as N<br>Concentration mg/l<br>Sum of Concentration<br>Baseline Average<br>25 % EMPr Limit |

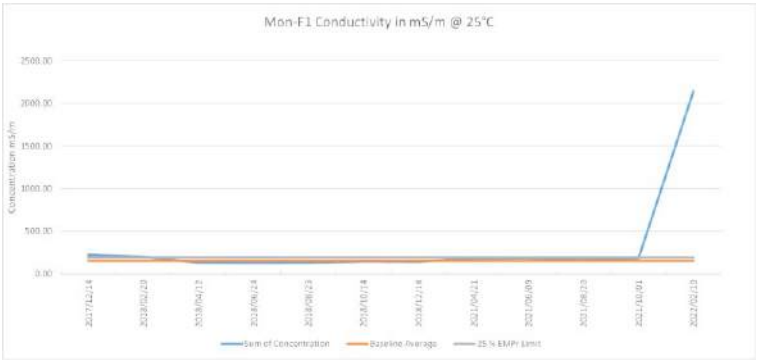

Mon-F1 Barium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit

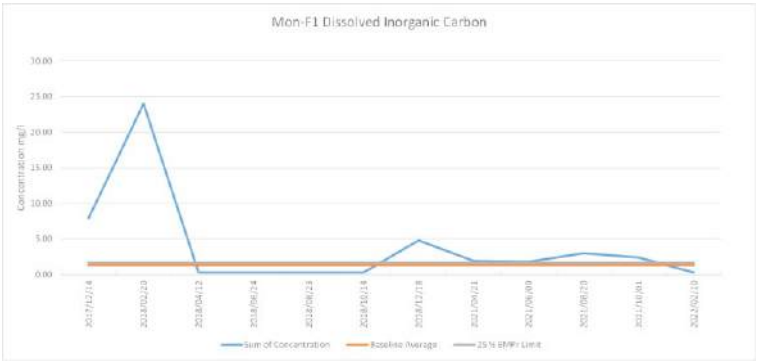

Mon-F1 Boron
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit

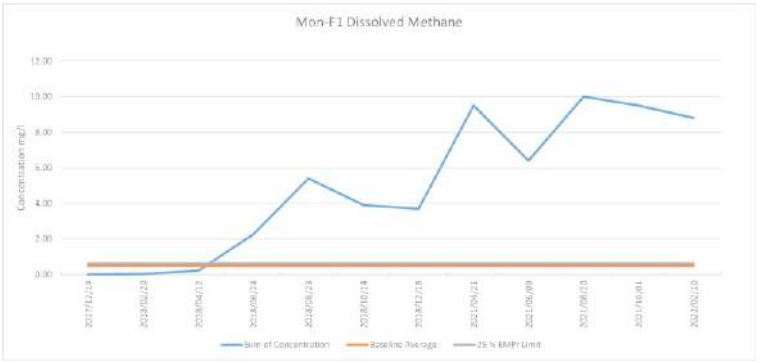

Mon-F1 Bromide
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit

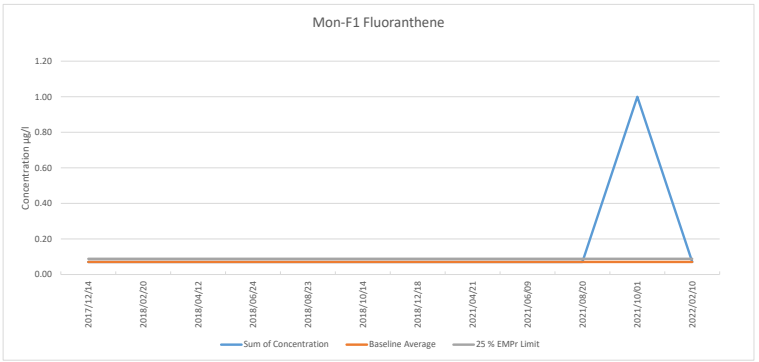

Mon-F1 Calcium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit

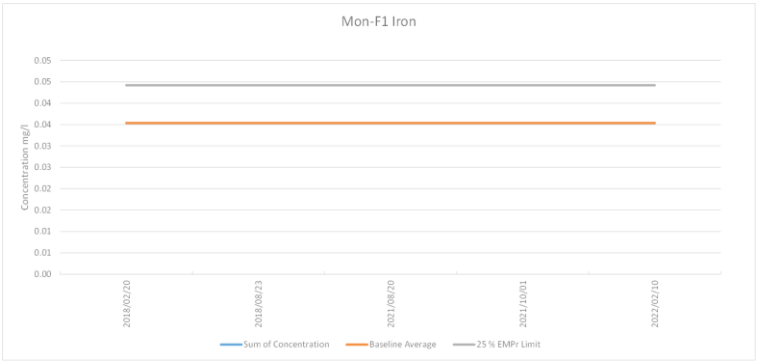

Mon-F1 Chloride
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit

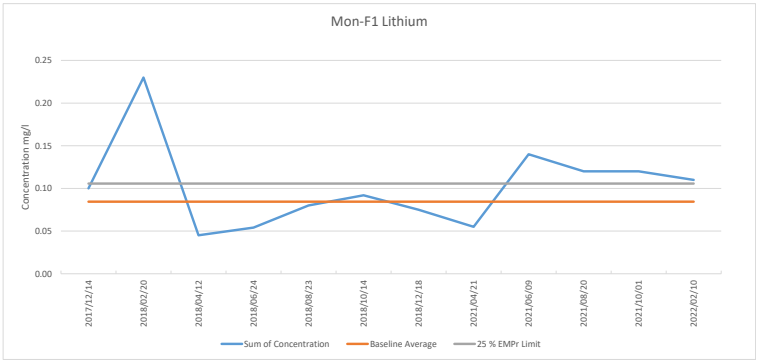

Mon-F1 Conductivity in mS/m @ 25°C
Concentration mS/m
Sum of Concentration
Baseline Average
25 % EMPr Limit

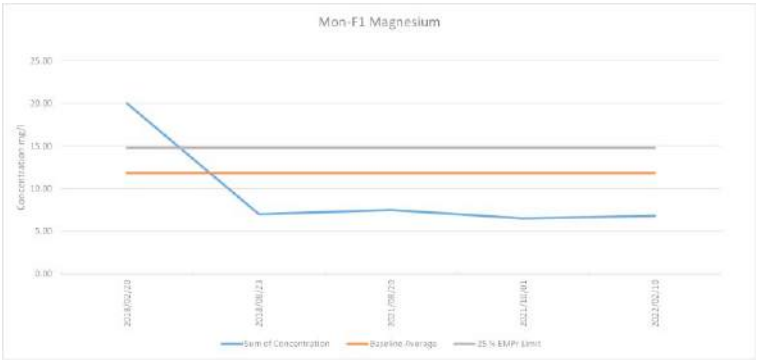

Mon-F1 Dissolved Inorganic Carbon
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit

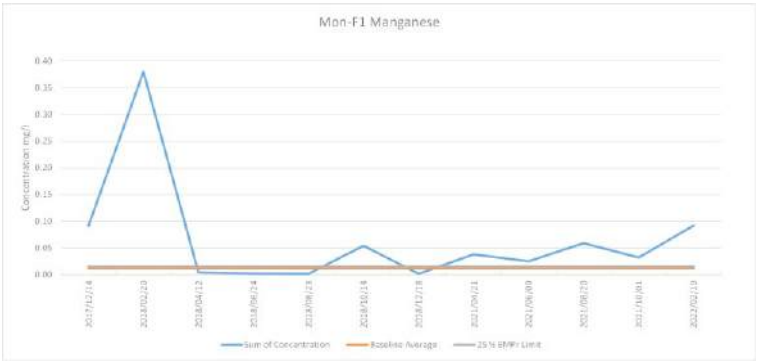

Mon-F1 Dissolved Methane
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit

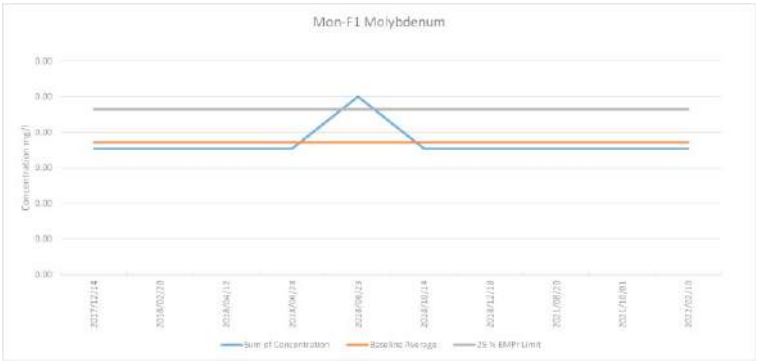

Mon-F1 Fluoranthene
Concentration µg/l
1.20
1.00
0.80
0.60
0.40
0.20
0.00
2017/12/14
2018/02/20
2018/04/12
2018/06/24
2018/08/23
2018/10/14
2018/12/18
2021/04/21
2021/06/09
2021/08/20
2021/10/01
2022/02/10
Sum of Concentration
Baseline Average
25 % EMPr Limit

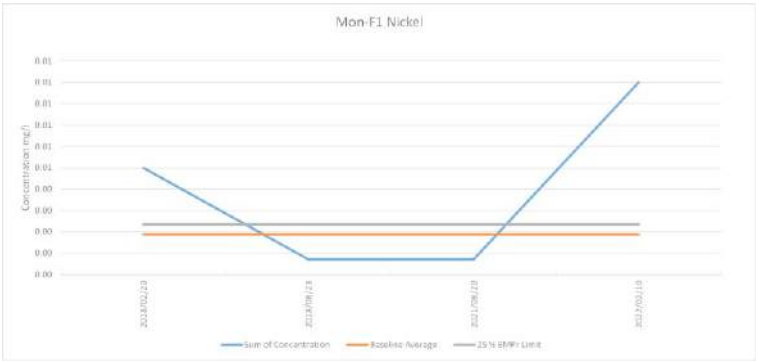

Mon-F1 Iron
Concentration mg/l
0.05
0.05
0.04
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
2018/02/20
2018/08/23
2021/08/20
2021/10/01
2022/02/10
Sum of Concentration
Baseline Average
25 % EMPr Limit

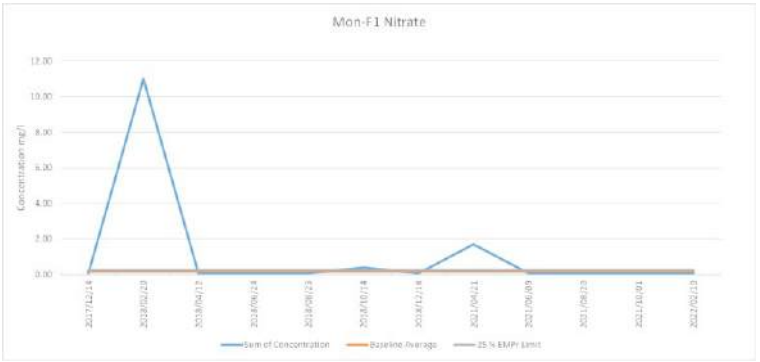

Mon-F1 Lithium
Concentration mg/l
0.25
0.20
0.15
0.10
0.05
0.00
2017/12/14
2018/02/20
2018/04/12
2018/06/24
2018/08/23
2018/10/14
2018/12/18
2021/04/21
2021/06/09
2021/08/20
2021/10/01
2022/02/10
Sum of Concentration
Baseline Average
25 % EMPr Limit

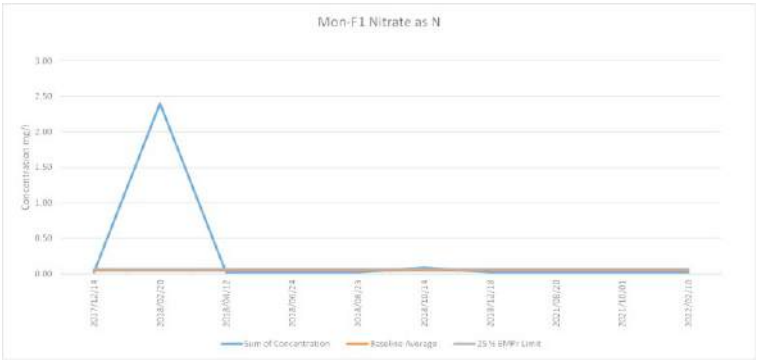

Mon-F1 Magnesium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPr Limit

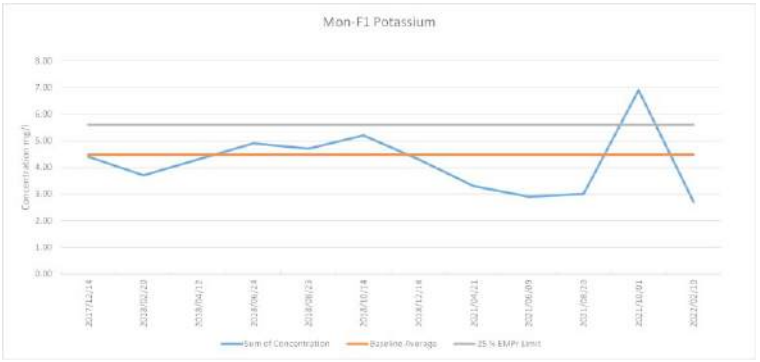

Mon-F1 Manganese
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPV Limit

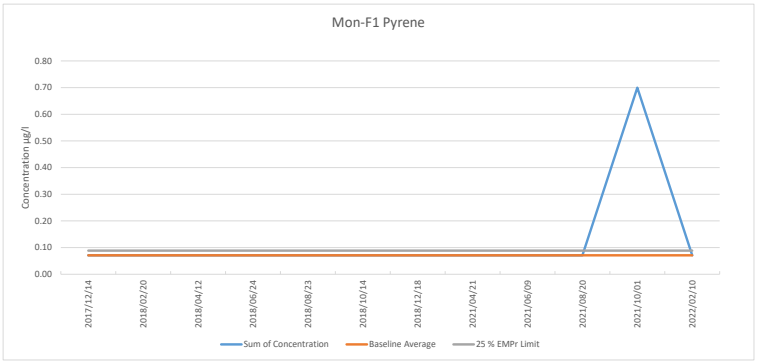

Mon-F1 Molybdenum
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPV Limit


Mon-F1 Nickel
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPV Limit

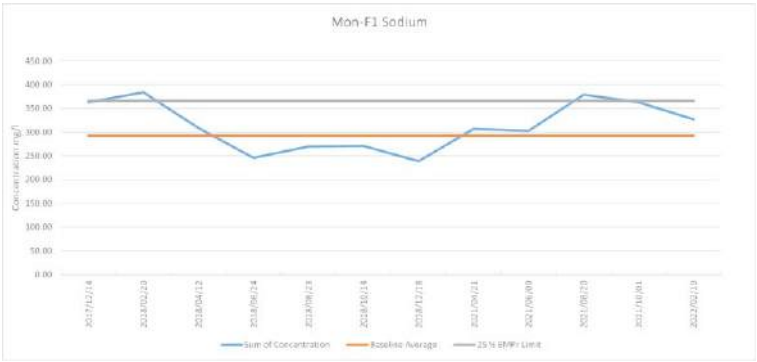

Mon-F1 Nitrate
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPV Limit


Mon-F1 Nitrate as N
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPV Limit

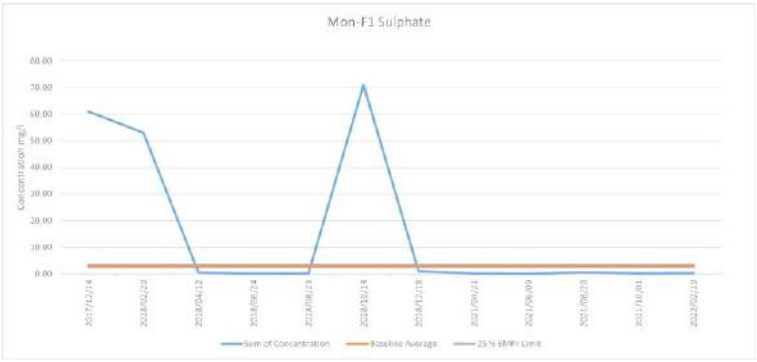

Mon-F1 Potassium
Concentration mg/l
Sum of Concentration
Baseline Average
25 % EMPV Limit


Mon-F1 Pyrene
Concentration µg/l
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2017/12/14
2018/02/20
2018/04/12
2018/06/24
2018/08/23
2018/10/14
2018/12/18
2021/04/21
2021/06/09
2021/08/20
2021/10/01
2022/02/10
Sum of Concentration
Baseline Average
25 % EMPr Limit

Mon-F1 Silicon


Mon-F1 Sodium

Mon-F1 Strontium


Mon-F1 Sulphate

Mon-F1 TDS (0.7µm) @ 105ºC

## 7.3 Regression Analysis

Regresion analysis was performed on all the POPC for each site sampled. Regression analysis was done to evaluate whether any increasing or decreasing trends exist over time for any of the identified POPC at any of the sites and to determine the significance of these trends. Regresion analysis was performed over the entire span of the monitoring programme as well as over the past year of monitoring, in an attempt to identify any emerging trends early on.

The skewness for every range of time-series chemistry results for each POPC at each site sampled was first evaluated. If the data was considered skew (more than 1 or less than -1), the data was log transformed before regression analysis was conducted.

The hypothesis for identifying significant trends is as follows:

$H_0$ (null hypothesis): No significant trend exists

$H_1$ (alternative hypothesis): A significant trend exists

The null hypothesis will be rejected if a high coefficient of determination ($R^2$) value of 0.5 or higher and an f-value of 5 % (0.05) or less is obtained from the regression analysis, and a significant trend will be assumed. The $R^2$ value is an indication of how well the data fits the regression model. The f-value is an indication of the propability that the null hypothesis for the model is correct, where a low f-value indicates that the propablity of obtaining the test results under the null hypothesis is unliekly.

If any significant trends exist at any of the POPC, these will be further investigated to attempt and identify possible causes for these trends. Please note that the identification of a significant trend in this model does not indicate cause or effect of the trend. Table 10 depicts the $R^2$ and f-values over all time and annually for each parameter at each site sampled.

Table 10: Regression analysis statistics

| Parameter | Statistic | BH01 | | BH02 | | BH04 | | BH05 | | BH07 | | BH08 | | BH09 | | Mon-F1 | | SW01 | | SW02 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual |
| Aluminium | F-Value | 0.767 | 0.563 | 0.766 | 0.563 | 0.906 | 0.563 | 0.340 | 0.563 | 0.331 | 0.563 | 0.240 | 0.563 | 0.157 | 0.563 | 0.511 | 0.000 | 0.693 | 0.074 | 0.242 | 0.000 |
| | $R^2$ | 0.005 | 0.090 | 0.007 | 0.090 | 0.001 | 0.090 | 0.048 | 0.090 | 0.050 | 0.090 | 0.072 | 0.090 | 0.102 | 0.090 | 0.239 | 0.000 | 0.011 | 0.590 | 0.090 | 0.000 |
| Ammonia | F-Value | 0.060 | 0.445 | 0.008 | 0.681 | 0.000 | 0.685 | 0.000 | 0.341 | 0.004 | 0.690 | 0.014 | 0.913 | 0.803 | 0.971 | 0.033 | 0.001 | 0.029 | 0.959 | 0.001 | 0.886 |
| | $R^2$ | 0.109 | 0.152 | 0.257 | 0.047 | 0.000 | 0.045 | 0.000 | 0.226 | 0.237 | 0.044 | 0.187 | 0.003 | 0.002 | 0.000 | 0.378 | 0.961 | 0.227 | 0.001 | 0.461 | 0.006 |
| Ammonia as N | F-Value | 0.531 | 0.445 | 0.041 | 0.739 | 0.000 | 0.685 | 0.000 | 0.496 | 0.542 | 0.755 | 0.219 | 0.907 | 0.140 | 0.987 | 0.241 | 0.000 | 0.003 | 0.897 | 0.000 | 0.891 |
| | $R^2$ | 0.012 | 0.152 | 0.151 | 0.031 | 0.000 | 0.045 | 0.000 | 0.123 | 0.011 | 0.027 | 0.048 | 0.004 | 0.065 | 0.000 | 0.167 | 0.990 | 0.303 | 0.005 | 0.512 | 0.005 |
| Barium | F-Value | 0.325 | 0.148 | 0.592 | 0.030 | 0.242 | 0.219 | 0.000 | 0.014 | 0.796 | 0.625 | 0.655 | 0.229 | 0.040 | 0.518 | 0.718 | 0.060 | 0.737 | 0.594 | 0.073 | 0.930 |
| | $R^2$ | 0.028 | 0.444 | 0.012 | 0.731 | 0.040 | 0.346 | 0.364 | 0.815 | 0.002 | 0.065 | 0.006 | 0.335 | 0.115 | 0.111 | 0.014 | 0.630 | 0.005 | 0.077 | 0.128 | 0.002 |
| Boron | F-Value | 0.000 | 0.390 | 0.672 | 0.367 | 0.217 | 0.226 | 0.389 | 0.000 | 0.356 | 0.241 | 0.857 | 0.000 | 0.057 | 0.145 | 0.000 | 0.008 | 0.154 | 0.000 | 0.204 | 0.370 |
| | $R^2$ | 0.347 | 0.189 | 0.007 | 0.205 | 0.043 | 0.339 | 0.021 | 0.000 | 0.024 | 0.321 | 0.001 | 0.000 | 0.097 | 0.450 | 0.722 | 0.860 | 0.079 | 0.000 | 0.064 | 0.203 |
| Bromide | F-Value | 0.032 | 0.767 | 0.028 | 0.932 | 0.023 | 0.864 | 0.006 | 0.714 | 0.005 | 0.576 | 0.040 | 0.500 | 0.006 | 0.764 | 0.000 | 0.006 | 0.001 | 0.551 | 0.004 | 0.402 |
| | $R^2$ | 0.122 | 0.025 | 0.172 | 0.002 | 0.140 | 0.008 | 0.192 | 0.037 | 0.201 | 0.085 | 0.115 | 0.121 | 0.192 | 0.025 | 0.897 | 0.872 | 0.361 | 0.096 | 0.297 | 0.180 |
| Calcium | F-Value | 0.000 | 0.077 | 0.000 | 0.806 | 0.030 | 0.959 | 0.036 | 0.032 | 1.000 | 0.000 | 0.000 | 0.853 | 0.070 | 0.737 | 0.282 | 0.001 | 0.126 | 0.194 | 0.718 | 0.167 |
| | $R^2$ | 0.573 | 0.583 | 0.588 | 0.017 | 0.128 | 0.001 | 0.116 | 0.724 | 0.000 | 0.000 | 0.498 | 0.010 | 0.088 | 0.031 | 0.115 | 0.950 | 0.091 | 0.378 | 0.005 | 0.415 |
| Chloride | F-Value | 0.000 | 0.262 | 0.000 | 0.835 | 0.000 | 0.970 | 0.163 | 0.064 | 0.002 | 0.370 | 0.000 | 0.891 | 0.201 | 0.931 | 0.020 | 0.961 | 0.119 | 0.452 | 0.915 | 0.153 |
| | $R^2$ | 0.612 | 0.299 | 0.406 | 0.012 | 0.392 | 0.000 | 0.053 | 0.616 | 0.240 | 0.203 | 0.406 | 0.005 | 0.045 | 0.002 | 0.432 | 0.001 | 0.094 | 0.147 | 0.000 | 0.437 |
| | F-Value | 0.053 | 0.000 | 0.015 | 0.060 | 0.082 | 0.000 | 0.108 | 0.046 | 0.576 | 0.107 | 0.004 | 0.000 | 0.818 | 0.000 | 0.876 | 0.030 | 0.080 | 0.605 | 0.008 | 0.272 |

| Parameter | Statistic | BH01 | | BH02 | | BH04 | | BH05 | | BH07 | | BH08 | | BH09 | | Mon-F1 | | SW01 | | SW02 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual |
| Dissolved Inorganic Carbon | $R^2$ | 0.100 | 0.000 | 0.216 | 0.627 | 0.089 | 0.000 | 0.072 | 0.673 | 0.009 | 0.518 | 0.228 | 0.000 | 0.002 | 0.000 | 0.003 | 0.732 | 0.117 | 0.073 | 0.247 | 0.288 |
| Dissolved Methane | F-Value | 0.575 | 0.000 | 0.141 | 0.223 | 0.000 | 0.000 | 0.013 | 0.046 | 0.635 | 0.006 | 0.000 | 0.000 | 0.457 | 0.000 | 0.000 | 0.334 | 0.000 | 0.000 | 0.000 | 0.000 |
| | $R^2$ | 0.009 | 0.000 | 0.082 | 0.341 | 0.000 | 0.000 | 0.158 | 0.670 | 0.006 | 0.881 | 0.000 | 0.000 | 0.015 | 0.000 | 0.856 | 0.305 | 0.000 | 0.000 | 0.000 | 0.000 |
| Iron | F-Value | 0.166 | 0.000 | 0.024 | 0.000 | 0.895 | 0.000 | 0.081 | 0.000 | 0.083 | 0.685 | 0.380 | 0.685 | 0.001 | 0.000 | 0.638 | 0.000 | 0.141 | 0.062 | 0.000 | 0.000 |
| | $R^2$ | 0.072 | 0.000 | 0.219 | 0.000 | 0.001 | 0.000 | 0.112 | 0.000 | 0.111 | 0.045 | 0.030 | 0.045 | 0.366 | 0.000 | 0.083 | 0.000 | 0.100 | 0.623 | 0.604 | 0.000 |
| Lithium | F-Value | 0.832 | 0.000 | 0.026 | 0.310 | 0.002 | 0.000 | 0.848 | 0.144 | 0.591 | 0.297 | 0.402 | 0.324 | 0.885 | 0.335 | 0.510 | 0.316 | 0.311 | 0.735 | 0.578 | 0.264 |
| | $R^2$ | 0.001 | 0.000 | 0.176 | 0.252 | 0.243 | 0.000 | 0.001 | 0.452 | 0.008 | 0.264 | 0.021 | 0.240 | 0.001 | 0.231 | 0.045 | 0.247 | 0.041 | 0.032 | 0.013 | 0.296 |
| Magnesium | F-Value | 0.000 | 0.319 | 0.000 | 0.567 | 0.046 | 0.719 | 0.108 | 0.174 | 0.000 | 0.633 | 0.000 | 0.900 | 0.048 | 0.592 | 0.206 | 0.000 | 0.155 | 0.220 | 0.714 | 0.217 |
| | $R^2$ | 0.602 | 0.244 | 0.573 | 0.089 | 0.162 | 0.036 | 0.104 | 0.405 | 0.000 | 0.063 | 0.487 | 0.004 | 0.154 | 0.078 | 0.464 | 0.000 | 0.104 | 0.345 | 0.007 | 0.349 |
| Manganese | F-Value | 0.259 | 0.776 | 0.004 | 0.583 | 0.029 | 0.503 | 0.004 | 0.029 | 0.001 | 0.958 | 0.814 | 0.382 | 0.054 | 0.607 | 0.365 | 0.079 | 0.283 | 0.000 | 0.315 | 0.768 |
| | $R^2$ | 0.035 | 0.023 | 0.274 | 0.081 | 0.129 | 0.119 | 0.204 | 0.735 | 0.249 | 0.001 | 0.002 | 0.194 | 0.100 | 0.072 | 0.083 | 0.579 | 0.046 | 0.000 | 0.040 | 0.024 |
| Molybdenum | F-Value | 0.534 | 0.685 | 0.764 | 0.685 | 0.947 | 0.685 | 0.466 | 0.245 | 0.788 | 0.685 | 0.250 | 0.000 | 0.277 | 0.685 | 0.627 | 0.000 | 0.010 | 0.000 | 0.030 | 0.000 |
| | $R^2$ | 0.012 | 0.045 | 0.004 | 0.045 | 0.000 | 0.045 | 0.016 | 0.316 | 0.002 | 0.045 | 0.041 | 0.000 | 0.036 | 0.045 | 0.031 | 0.000 | 0.248 | 0.000 | 0.181 | 0.000 |
| Nickel | F-Value | 0.001 | 0.308 | 0.031 | 0.308 | 0.006 | 0.308 | 0.000 | 0.316 | 0.002 | 0.316 | 0.027 | 0.259 | 0.005 | 0.308 | 0.676 | 0.000 | 0.250 | 0.968 | 0.005 | 0.155 |
| | $R^2$ | 0.659 | 0.254 | 0.421 | 0.254 | 0.582 | 0.254 | 0.790 | 0.247 | 0.639 | 0.247 | 0.403 | 0.302 | 0.560 | 0.254 | 0.105 | 0.000 | 0.184 | 0.000 | 0.704 | 0.434 |
| Nitrate | F-Value | 0.010 | 0.957 | 0.000 | 0.225 | 0.603 | 0.000 | 0.132 | 0.000 | 0.053 | 0.000 | 0.023 | 0.937 | 0.000 | 0.685 | 0.542 | 0.000 | 0.002 | 0.897 | 0.000 | 0.319 |
| | $R^2$ | 0.185 | 0.001 | 0.601 | 0.340 | 0.009 | 0.000 | 0.067 | 0.000 | 0.108 | 0.000 | 0.152 | 0.002 | 0.000 | 0.045 | 0.038 | 0.000 | 0.337 | 0.005 | 0.523 | 0.244 |

| Parameter | Statistic | BH01 | | BH02 | | BH04 | | BH05 | | BH07 | | BH08 | | BH09 | | Mon-F1 | | SW01 | | SW02 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual |
| Nitrate as N | F-Value | 0.005 | 0.893 | 0.000 | 0.211 | 0.848 | 0.175 | 0.991 | 0.175 | 0.853 | 0.047 | 0.015 | 0.929 | 0.000 | 0.000 | 0.721 | 0.000 | 0.003 | 0.884 | 0.000 | 0.331 |
| | $R^2$ | 0.214 | 0.005 | 0.602 | 0.356 | 0.001 | 0.403 | 0.000 | 0.403 | 0.001 | 0.670 | 0.170 | 0.002 | 0.404 | 0.000 | 0.017 | 0.000 | 0.317 | 0.006 | 0.512 | 0.234 |
| Potassium | F-Value | 0.000 | 0.476 | 0.000 | 0.447 | 0.000 | 0.567 | 0.000 | 0.098 | 0.334 | 0.000 | 0.000 | 0.760 | 0.413 | 0.553 | 0.373 | 0.830 | 0.016 | 0.266 | 0.044 | 0.254 |
| | $R^2$ | 0.583 | 0.134 | 0.669 | 0.151 | 0.707 | 0.088 | 0.480 | 0.535 | 0.026 | 0.000 | 0.728 | 0.026 | 0.019 | 0.095 | 0.080 | 0.013 | 0.211 | 0.294 | 0.152 | 0.307 |
| Silicon | F-Value | 0.039 | 0.184 | 0.445 | 0.197 | 0.716 | 0.392 | 0.144 | 0.059 | 0.471 | 0.524 | 0.145 | 0.668 | 0.821 | 0.185 | 0.346 | 0.000 | 0.034 | 0.116 | 0.000 | 0.074 |
| | $R^2$ | 0.206 | 0.391 | 0.042 | 0.375 | 0.008 | 0.187 | 0.109 | 0.633 | 0.028 | 0.108 | 0.108 | 0.051 | 0.003 | 0.390 | 0.428 | 0.000 | 0.266 | 0.501 | 0.602 | 0.590 |
| Sodium | F-Value | 0.002 | 0.188 | 0.002 | 0.944 | 0.000 | 0.544 | 0.000 | 0.685 | 0.612 | 0.000 | 0.000 | 0.716 | 0.251 | 0.550 | 0.372 | 0.559 | 0.688 | 0.000 | 0.987 | 0.137 |
| | $R^2$ | 0.230 | 0.386 | 0.314 | 0.001 | 0.509 | 0.099 | 0.000 | 0.045 | 0.007 | 0.000 | 0.434 | 0.037 | 0.036 | 0.096 | 0.080 | 0.125 | 0.007 | 0.000 | 0.000 | 0.463 |
| Strontium | F-Value | 0.508 | 0.149 | 0.001 | 0.374 | 0.390 | 0.191 | 0.000 | 0.018 | 0.008 | 0.285 | 0.330 | 0.162 | 0.000 | 0.911 | 0.970 | 0.290 | 0.501 | 0.693 | 0.646 | 0.410 |
| | $R^2$ | 0.012 | 0.443 | 0.352 | 0.200 | 0.021 | 0.382 | 0.447 | 0.792 | 0.179 | 0.275 | 0.027 | 0.424 | 0.370 | 0.004 | 0.000 | 0.353 | 0.018 | 0.043 | 0.009 | 0.174 |
| Sulphate | F-Value | 0.309 | 0.020 | 0.001 | 0.241 | 0.128 | 0.924 | 0.000 | 0.039 | 0.562 | 0.346 | 0.003 | 0.511 | 0.017 | 0.888 | 0.058 | 0.328 | 0.591 | 0.213 | 0.345 | 0.145 |
| | $R^2$ | 0.029 | 0.777 | 0.354 | 0.321 | 0.065 | 0.003 | 0.298 | 0.694 | 0.009 | 0.221 | 0.222 | 0.115 | 0.148 | 0.006 | 0.315 | 0.236 | 0.012 | 0.354 | 0.036 | 0.449 |
| TDS (0.7µm) @ 105ºC | F-Value | 0.000 | 0.009 | 0.001 | 0.022 | 0.000 | 0.340 | 0.232 | 0.018 | 0.035 | 0.012 | 0.000 | 0.413 | 0.088 | 0.791 | 0.350 | 0.003 | 0.214 | 0.393 | 0.787 | 0.111 |
| | $R^2$ | 0.514 | 0.845 | 0.329 | 0.770 | 0.429 | 0.226 | 0.042 | 0.788 | 0.124 | 0.825 | 0.449 | 0.172 | 0.083 | 0.020 | 0.110 | 0.910 | 0.064 | 0.186 | 0.003 | 0.509 |
| Acenaphthylene | F-Value | 0.000 | 0.685 | 0.000 | 0.685 | 0.000 | 0.685 | 0.000 | 0.685 | 0.530 | 0.000 | 0.000 | 0.685 | 0.223 | 0.000 | 0.000 | 0.567 | 0.000 | 0.685 | 0.000 | 0.685 |
| | $R^2$ | 0.000 | 0.045 | 0.000 | 0.045 | 0.000 | 0.045 | 0.000 | 0.045 | 0.017 | 0.000 | 0.000 | 0.045 | 0.061 | 0.000 | 0.000 | 0.088 | 0.000 | 0.045 | 0.000 | 0.045 |
| | F-Value | 0.000 | 0.685 | 0.000 | 0.685 | 0.000 | 0.685 | 0.000 | 0.685 | 0.530 | 0.000 | 0.000 | 0.685 | 0.645 | 0.000 | 0.000 | 0.567 | 0.000 | 0.685 | 0.000 | 0.685 |

| Parameter | Statistic | BH01 | | BH02 | | BH04 | | BH05 | | BH07 | | BH08 | | BH09 | | Mon-F1 | | SW01 | | SW02 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual | All-Time | Annual |
| Fluoranthene | $R^2$ | 0.000 | 0.045 | 0.000 | 0.045 | 0.000 | 0.045 | 0.000 | 0.045 | 0.017 | 0.000 | 0.000 | 0.045 | 0.009 | 0.000 | 0.000 | 0.088 | 0.000 | 0.045 | 0.000 | 0.045 |
| Pyrene | F-Value | 0.000 | 0.685 | 0.000 | 0.685 | 0.000 | 0.685 | 0.000 | 0.685 | 0.530 | 0.000 | 0.000 | 0.685 | 0.645 | 0.000 | 0.238 | 0.000 | 0.000 | 0.685 | 0.000 | 0.685 |
| | $R^2$ | 0.000 | 0.045 | 0.000 | 0.045 | 0.000 | 0.045 | 0.000 | 0.045 | 0.017 | 0.000 | 0.000 | 0.045 | 0.009 | 0.000 | 0.136 | 0.000 | 0.000 | 0.045 | 0.000 | 0.045 |
| Conductivity in mS/m @ 25°C | F-Value | 0.000 | 0.010 | 0.004 | 0.131 | 0.000 | 0.041 | 0.000 | 0.039 | 1.000 | 0.000 | 0.001 | 0.028 | 1.000 | 0.000 | 0.000 | 0.044 | 0.271 | 0.233 | 0.722 | 0.120 |
| | $R^2$ | 0.468 | 0.840 | 0.284 | 0.474 | 0.434 | 0.6 | 0.000 | 0.605 | 0.000 | 0.000 | 0.292 | 0.741 | 0.000 | 0.000 | 0.000 | 0.678 | 0.048 | 0.330 | 0.005 | 0.493 |

# 8. Discussion

## 8.1 Static Water Levels

Low CV values as calculated for each site over the last year, indicate that the SWLs for each site measured have a high central tendency around the mean or a low level of dispersion, indicating that the SWL has not changed much over this time at any of the sites. When comparing the mean SWLs for each site to that of the current monitoring event, it was clear that water level at these sites, except for Mon-F1, have slightly risen. The area has been subject to a lot of rain during the past months. The largest increase in SWL from the mean was seen at sites BH09 with 0.92 m.

## 8.2 Site Chemistry Profiles

Piper diagrams are useful tools for characterising water types with the purpose of comparing different sites or change of water chemistry in sites over time within a proposed area. Sites might even be grouped within an area according to similar chemical characteristics as observed within these diagrams, this is especially useful for areas with a lot of sites. Furthermore, these diagram can be used to distinguish between dominant acids, alkalies and alkaline earths per site (see Figure 5 below).

| Cations | | Reciprocal of combining weight | Anions | | Reciprocal of combining weight |
|---|---|---|---|---|---|
| Alkaline earths | **Calcium ($Ca^{2+}$)** | 0.0499 | Weak acids | **Bicarbonate ($HCO_3^-$)** | 0.01639 |
| | Barium ($Ba^{2+}$) | 0.01456 | | Carbonate ($CO_3^{2-}$) | 0.03333 |
| | Strontium ($Sr^{2+}$) | 0.02282 | | Tetraborate ($B_4O_7^{2-}$) | 0.01288 |
| | **Magnesium ($Mg^{2+}$)** | 0.08224 | | Orthophosphate ($PO_4^{3-}$) | 0.03157 |
| Alkalies | **Sodium ($Na^+$)** | 0.04348 | Strong acids | **Sulphate ($SO_4^{2-}$)** | 0.02082 |
| | Potassium ($K^+$) | 0.02558 | | **Chloride ($Cl^-$)** | 0.0282 |
| | Caesium ($Cs^+$) | 0.00752 | | Iodide ($I^-$) | 0.00788 |
| | Rubidium ($Rb^+$) | 0.0117 | | Bromide ($Br^-$) | 0.01251 |
| | Lithium ($Li^+$) | 0.14409 | | Fluoride ($F^-$) | 0.05263 |
| | Ammonium ($NH4^+$) | 0.05543 | | Nitrate ($NO_3^-$) | 0.01613 |
| | | | | Nitrite ($NO_2^-$) | 0.02174 |

Figure 5: Major and Minor Constituents of Natural Water (Piper, 1994)

When analysing the baseline Piper diagram in Figure 3, site Mon-F1 can be described as having a Na-Cl dominant water type and site BH02 can be described as Mg-$HCO_3$ dominant. Water at all other sites can be described as mixed. All the sites except BH07, SW02 and BH02 could be described as dominated by strong acids, more specifically $Cl^-$. Sites BH07 and SW02 have no dominant acids. Site BH02 was dominated by weak acids ($HCO_3^-$). No cation was dominant at any of these sites, except for Mon-F1 ($Na^+$ and $K^+$ dominant), and all the sites had low $SO_4^{2-}$ concentrations. In general alkaline earths exceeded alkalies (except for site Mon-F1), however Sodium concentration at all the sites were high.

When analysing the February 2022 Piper diagram (Figure 4), slight changes in water chemistry exists at most sites over time, in general the water types and characteristics are the same. The most prominent changes were noted at site BH09. Although still

described as a mixed water type, $Cl^-$ is no longer a dominant acid, and alkalies exceeded alkaline earths (specifically $Na^+$ and $K^+$)- previously there were no dominant cations at this site. The effect of heavy rainfall prior to sampling could have affected these changes at site BH09 as it is situated close to the sand and Doring Rivers and groundwater surface water interactions are expected between these sites. Site BH01 is dominated by the strong acid $Cl^-$ and site BH08 was dominated by $Cl^-$ but can now be described by a mix between acids.

Previous studies by Christian et al. (2016), Molofsky et al. (2013), McPhillips et al. (2014) and Drage and Kennedy (2014) all show a strong correlation of elevated methane levels in Na-CL and Na-$HCO_3$ dominated water types. The association of elevated methane levels with water dominated by sodium types in boreholes suggest that boreholes with elevated methane levels may be influenced by sodium bearing rocks, longer water-rock interactions or the interaction with deeper more saline aquifers (Drage & Kennedy, 2014). Alvarez et al. (2016) further explains that low Nitrate in Sodium rich water are strong predictors in the natural occurrence of high Methane concentrations.

## 8.3 Parameters of Potential Concern

This section aims to discuss any trends or correlations identified in terms of the POPCs as in Table 8.

### 8.3.1 Aluminium

Aluminum was identified as a POPC, because the 25 % limit from the mean baseline concentration was exceeded at surface water sites SW01 and SW02 only. Site SW02 poses an aesthetic risk to domestic users with regards to the aluminium concentration. When analysing the time-series chemistry for these sites, Figure 6 and Figure 7 below, it is evident that there was a spike in aluminum concentrations at both sites during the December 2022 event. During this monitoring event however, the concentration at site SW01 lowered and at sit SW02 increased notably.

It should be noted that site SW01 is located within the Doring River and site SW02 is located downstream of where the Doring and Sand Rivers merge. The higher Aluminium concentration at site SW02 could have either originated upstream in the Doring River or because of local contamination at the sampling location. This location is subject to various sources of pollution such as local rituals, fishing, washing of clothes and cars. It is recommended that an additional surface water monitoring site be added to the monitoring programme within the Sand River upstream of where the two rivers merge. The additional monitoring site should assist in identifying any possible sources of pollution detected downstream.

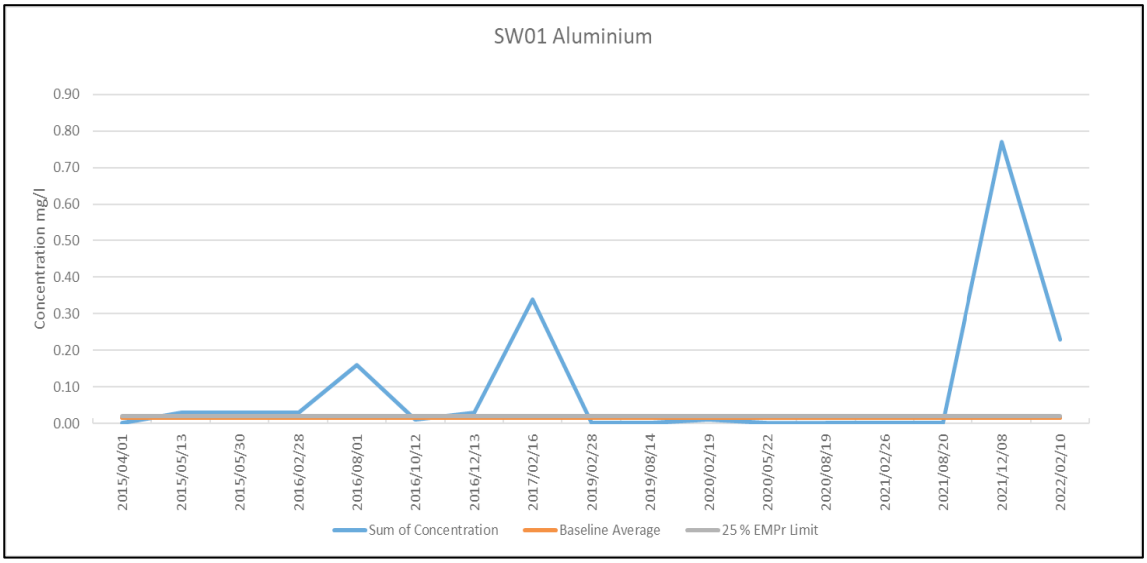



Figure 6: Site SW01 Aluminium time-series chemistry

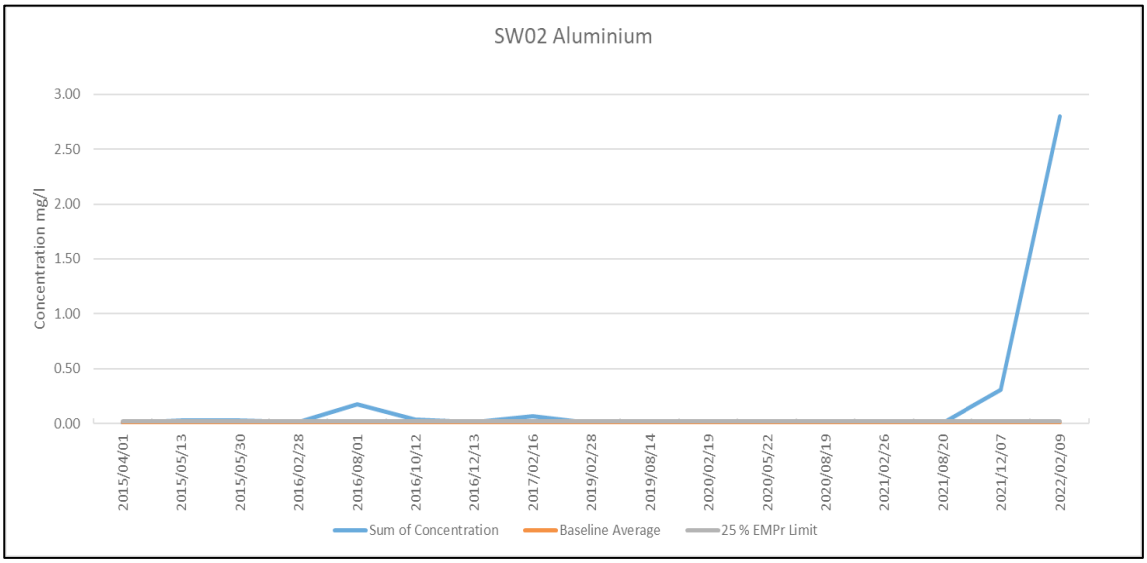



Figure 7: Site SW02 Aluminium time-series chemistry

When conducting further analysis, the following correlations with Aluminium were noted:

Table 11: Aluminium correlations at sites SW01 and SW02

| Parameter | Aluminium Correlations | |
|---|---|---|
| | SW01 | SW02 |
| Iron | +High | +Very High |
| Titanium | +Very High | +Very High |
| Silicon | +Moderate | +High |

The region received a lot of rainfall and runoff from surrounding areas. Runoff from agricultural fields could potentially enrich surface water sources with Alkalies and Alkaline Earths (Magnesium, Calcium, Potassium, Sodium, etc.), these could in turn lead to single displacement reactions (the alkalies/ alkaline earth metals are more reactive than aluminium and can displace aluminium from its salts).

Fluoride tends to form complexes with aluminium, and can keep aluminium in solution at a neutral pH, however, no correlation could be found between Fluoride and Aluminium at these sites.

### 8.3.2 Ammonia and Ammonia as N

Ammonia exceeded 25 % from the mean baseline concentration at downstream sites BH05 and BH09, upstream site Mon-F1 and at surface water sites SW01 and SW02. Ammonia as N exceeded 25 % from the mean baseline concentration at downstream sites BH04 and BH05, upstream site Mon-F1 and at surface water sites SW01 and SW02. None of the SANS/ DWAF water quality guidelines were breached at any of the sites.

Site Mon-F1 had a consitent Ammonia as $NH_3$ and N concentration over the last year. Site SW02 indicated a significant increasing trend since the start of monitoring. When analysing the time-series chemistry graph at site SW02, the Ammonia trend seems sporadic in nature (upward spikes, rather than a steadily increasing trend).

Ammonia in water can occur as a result of organic decomposition in anaerobic conditions (such as groundwater), contamination with organic wastes or runoff from agricultural lands as a result of certain fertilizer application.

Site BH05 is situated close to pig- and cattle pens. Decomposing animal waste could seap into the shallow aquifer and contaminate the groundwater. With the large quantity of rainfall in the area, agricultural runoff could have lead to increased Ammonia in the surface water sites (SW01 and SW02). Site BH09 is situated close to the surface water sites and interconnectivity between these sites are expected.

### 8.3.3 Barium

Downstream site BH01 and BH08 and upstream sites BH02 and Mon-F1 exceeded the 25 % limit from the baseline mean cocnetrations for Barium. Downstream site BH05 poses a chronic health risk to domestic users. Site BH02 indicated a statistical significant increasing trend over the past year, however over all-time there is no statistical significant trend. This is also apparent when visually inspecting the time-series chemistry graph for Barium at site BH02. The Barium concentration during Februaruary 2022 at BH02 was below the maximum recorded at this site, and is expected to lower in coming months.

Only site BH05 showed a significant increasing trend throughout the last year, however, the Barium concentration during February 2022 at this site was still below the baseline mean.

### 8.3.4 Boron

Downstream sites BH04, BH05 and BH09 and upstream site BH07 exceeded 25 % from the mean baseline concentration for Boron. Regression analysis indicated that none of the above-mentioned sites indicated a statistical significant increasing trend annually or over all time.

When conducting correlation analysis between the above-mentioned sites for Boron (Table 12), it was clear that high correlation exists between most of these sites for Boron, including the surface water sites- indicating possible interconnectivity.

Table 12: Boron correlation analysis

| | BH04 | BH05 | BH07 | BH09 | SW01 | SW02 |
|---|---|---|---|---|---|---|
| **BH04** | 1.00 | | | | | |
| **BH05** | 0.63 | 1.00 | | | | |
| **BH07** | 0.51 | 0.88 | 1.00 | | | |
| **BH09** | 0.53 | 0.87 | 0.95 | 1.00 | | |
| **SW01** | 0.43 | 0.62 | 0.60 | 0.63 | 1.00 | |
| **SW02** | 0.27 | 0.74 | 0.76 | 0.76 | 0.69 | 1.00 |

Boron can be associated with saline conditions and once in solution it tends to accumulate during evaporation of water/ lowering of the water table in areas with arid conditions.

### 8.3.5 Bromide

All sites exceeded the 25 % limit from the mean baseline concentration for Bromide. When analysing the time-series chemistry data, sites BH01, BH04, BH05 and Mon-F1 had the highest concentration yet for Bromide at these sites. Only site Mon-F1 indicated a significant increasing trend annually and over all time.

Bromide had an increase at all sites sample when compared to the previous sampling event. This together with the correlation analysis conducted for Bromide between sampled sites (Table 13), indicate possible interconnectiveness between these sites as well as a more regional occurrence of Bromide increases rather than only local. Pump tests and Isotope analysis is underway and could assist in determining the origin of much higher Bromide concentrations at sites BH04 and BH05.

Table 13: Bromide Correlation Analysis

| | BH01 | BH02 | BH04 | BH05 | BH07 | BH08 | BH09 | Mon-F1 | SW01 | SW02 |
|---|---|---|---|---|---|---|---|---|---|---|
| **BH01** | 1.00 | | | | | | | | | |
| **BH02** | 0.75 | 1.00 | | | | | | | | |
| **BH04** | 0.82 | 0.67 | 1.00 | | | | | | | |
| **BH05** | 0.79 | 0.63 | 0.99 | 1.00 | | | | | | |
| **BH07** | 0.84 | 0.79 | 0.79 | 0.73 | 1.00 | | | | | |
| **BH08** | 0.41 | 0.70 | 0.15 | 0.13 | 0.26 | 1.00 | | | | |
| **BH09** | 0.77 | 0.74 | 0.68 | 0.63 | 0.90 | 0.33 | 1.00 | | | |
| **Mon-F1** | 0.95 | 0.96 | 0.89 | 0.84 | 0.95 | 0.82 | 0.94 | 1.00 | | |
| **SW01** | 0.68 | 0.59 | 0.49 | 0.40 | 0.87 | 0.84 | 0.81 | 0.09 | 1.00 | |
| **SW02** | 0.56 | 0.45 | 0.34 | 0.26 | 0.68 | 0.75 | 0.70 | -0.35 | 0.85 | 1.00 |

### 8.3.6 Calcium

Downstream sites BH01, BH05 and BH08 and upstream sites BH02 and Mon-F1 exceeded the 25 % limit from the mean baseline concentration for Calcium. Sites BH01 and BH02 indicated a significant increasing trend over all time. Site BH05 indicated a significant increasing trend over the past year only, and reached the highest Calcium concentration at this site yet. Calcium concentrations at site Mon-F1 were stagnant since April 2021. Calcium can originate as lime in agricultural fields and make its way through to the shallow water table after rainfall events. Natural water rock interactions could also influence the Calcium concentration in groundwater.

### 8.3.7 Chloride

Only downstream site BH01 and upstream site BH02 exceeded the 25 % limit from the mean for Chloride. All sites except the surface water sites, BH02 and BH09 pose an aesthetic risk to domestic users and all sites except the surface water site SW02 also pose an agricultural risk to crops sensitive to chloride.

Only site BH01 indicated a significant increasing trend over all time for Chloride. Chloride had a decrease in concentration at all sites, except SW01, when compared to the previous sampling event.

Chloride is highly soluble, and tends to accumulate once in solution. This conservative constituent does not readilty react with other chemicals and is not chemically altered as it travels underground. This is in-line with trends seen at most of the groundwater sites (with the exception of site BH09, which may be influenced by surface water ingress). Agricultural activities is believed to have a high impact on the chloride concentrations in the groundwater in the area. Surface water sites are suspected to have lower Chloride concentrations due to heavy rainfall in the area prior to sampling, which could indicate dilution. It is expected that the Chloride concentration will rise again at the surface water sites as the water level lowers.

### 8.3.8 Electric Conductivity

All sites except downstream site BH09 and surface water sites SW01 and SW02 exceeded the 25 % limit from the mean for Electric Conductivity. Sites BH01, BH04, BH05, BH07, BH08 and Mon-F1 pose an aesthetic risk to domestic users. All sites except SW02 pose an agricultural risk with regards to Electric Conductivity.

Sites BH01, BH04, BH05, BH08 and Mon-F1 indicated significant increasing trends for Conductivity over the past year. When analysing time-series chemistry data, all sites except BH09 had a notable increase in conductivity when compared to previous sampling events. This parameter has a linear relationship and is dependant on the amount of Total Dissolved Solids in water.

### 8.3.9 Dissolved Inorganic Carbon

Downstream sites BH01, BH05 and BH08 and upstream sites BH02 and BH07 exceeded the 25 % limit from the mean for Dissolved Inorganic Carbon. Of these site BH01 indicated a significant increasing trend and BH05 and Mon-F1 indicated significant

downward trends over the past year. Additionally, sites BH02, BH07 and BH08 had a decline in Dissolved Inorganic Carbon concentration since the previous sampling event.

### 8.3.10 Dissolved Methane

Only downstream site BH09 and upstream site Mon-F1 exceeded the 25% limit from the baseline mean for Dissolved Methane. Of these two only site Mon-F1 indicated a significant increasing trend over the entire sampling period, however the Dissolved Methane concentration have been decreasing when compared to the previous two sampling events.

### 8.3.11 Iron

Only surface water sites SW01 and SW02 exceeded the 25% limit from the mean baseline for Iron, which was below detection limit at the time. Only site SW02 poses an aesthetic risk to domestic users with regards to Iron. Site SW02 indicated a significant increasing trend over all time for iron.

It should be noted that site SW01 is located within the Doring River and site SW02 is located downstream of where the Doring and Sand Rivers merge. Iron followed the same trend as Aluminium at these sites. The higher Iron concentration at site SW02 could have either originated upstream in the Doring River or because of local contamination at the sampling location. This location is subject to various sources of pollution such as local rituals, fishing, washing of clothes and cars. It is recommended that an additional surface water monitoring site be added to the monitoring programme within the Sand River upstream of where the two rivers merge. The additional monitoring site should assist in identifying any possible sources of pollution detected downstream.

### 8.3.12 Lithium

Downstream sites BH04, BH05 and BH08 and upstream sites BH02, BH07 and Mon-F1 exceeded the 25% limit from the mean baseline for Lithium. No significant trends or concerns were identified when analysing the time-series chemistry data for any of these sites.

### 8.3.13 Magnesium

Magnesium exceeded the 25 % limit from the baseline mean at downstream sites BH01, BH05 and BH08 and at upstream site BH02. Only sites BH01 and BH02 indicated significant increasing trends in Magnesium concentration over the entire sampling period.

As expected, at most of these sites, Magnesium had high to very high positive correlations with Calcium, Chloride, Potassium and Sodium. Water rock interactions over time could lead to increases in Magnesium concentration. Use of agricultural fertilizer can also contribute to Magnesium in groundwater.

### 8.3.14 Manganese

Downstream site BH05, upstream sites BH02 and Mon-F1 and site SW02 exceeded the 25 % limit from the baseline mean for Manganese. Sites BH04 and BH05 pose chronic health risks to domestic users. These sites along with BH02, BH07, BH09 and Mon-F1 pose an agricultural risk with regards to Managanese. Only site BH05 indicated a

statistical significant increasing trend over the past year. This site, along with site BH02, recorded the highest Managanese concentration for these sites yet.

Elevated Managnese concentrations can occur under anaerobic conditions (dissolution can occur when dissolved oxygen is not present) where Managnese has been introduced (either through sediment/ rocks in the aquifer or through external contamination).

### 8.3.15 Molybdenum

Downstream sites BH05 and BH08 exceeded the 25 % limit from the baseline mean for Molybdenum. No statistical significant trends exist at any of these sites.

### 8.3.16 Nickel

Only upstream site Mon-F1 exceeded the 25 % limit from the baseline mean for Nickel. It should be noted however that Nickel was only analysed for twice a year since the start of monitoring. The limited monitoring for this parameter, occurring only twice a year, could lead to unreliable regression results. No reason for concern with regards to Nickel exists at this time. All parameters that have been measured on a bi-annual basis, will be included as part of the bi-monthly analysis going forward.

### 8.3.17 Nitrate and Nitrate as N

Upstream site BH02 and downstream site BH01 as well as surface water sites SW01 and SW02 all exceeded the 25 % limit from the baseline mean of Nitrate and Nitrate as N. Of these, BH07 indicated a significant decreasing trend and sites BH02 and SW02 indicated an all time significant increasing trend, however the concentrations were lower than the previous monitoring event at all these sites.

Nitrate is the end product when oxidation of Ammonia or Nitrite occurs. Nitrates are highly soluble, and can be associated with the breakdown of organic material (animal/ vegetable debris and excrement) and eutrophic conditions. Nitrate in shallow groundwater sources can also be associated with agricultural activities.

### 8.3.18 Potassium

Potassium exceeded the 25 % limit from the baseline mean at downstream sites BH01, BH04, BH05, BH08 and at upstream sites BH02 and BH07. Sites BH01, BH02, BH04 and BH08 all indicated significant increasing trends sover the entire monitoring period, however, no significant increasing trends were identified over the last year. All sites, except for BH07, had a decrease in Potassium concentration when compared to the previous monitoring event.

Potassium is ubiquitous in nature and will always be associated with certain anions in water, in this case, Chloride, Nitrate and Sulphate respectively at the sampled sites described above. Potassium also had a high correlation with Sodium at these sites, which is expected as Potassium is found in association with Soidum in many minerals.

### 8.3.19 Silicon

Downstream sites BH01 and BH05 and surface water sites SW01 and SW02 exceeded the 25 % limit from the baseline mean for Silicon. Only site SW02 indicated a statistical significant increasing trend over all time, and has also recorded the highest silicon concentration for this site yet.

It is recommended that an additional surface water monitoring site be added to the monitoring programme within the Sand River upstream of where the Sand and Doring Rivers merge. The additional monitoring site should assist to identify whether higher concentrations in certain parameters are as a result of upstream sources or localized contaminiation.

### 8.3.20 Sodium

Upstream site BH02 and downstream sites BH01, BH04, BH05 and BH08 all exceeded the 25 % limit from the baseline mean for Sodium. Sites BH01, BH04, BH08, BH09 and Mon-F1 pose an aesthetic risk to domestic users. All sites except BH07 and the surface water sites pose an agricultural risk with regards to Sodium concentrations. Of the above-metioned sites, only site BH04 indicated a significant increasing trend over all time.

As with Potassium, Sodium is ubiquitous in the environment, and usually occurs as Sodium-Chloride and sometimes as Sodium-Sulphate, -Bicarbonate or -Nitrate. The sites mentioned above mostly have a moderate to high Chloride and Sodium correlation.

### 8.3.21 Strontium

Upstream sites BH02 and Mon-F1 and downstream site BH01 exceeded the 25 % limit from the baseline mean for Strontium. No statistical significant trends exist at any of these sites.

### 8.3.22 Sulphate

Upstream site BH02 and downstream site BH08 both exceeded the 25 % limit from the baseline mean. None of these sites indicated any significant trends.

Sulphate tends to form salts with highly soluble cations such as Potassium, Sodium, Calcium, Magnesium and Ammonia. This is further exacerbated by the moderate to high correlation between Sulphate and these cations at sites BH02 and BH08. Sulphate occurs in nature through the dissolution of Sulphate minerals, and tend to accumulate over time as a result of its solubility. However, none of these sites had statistical significant increasing trends.

Sulphate in water can also originate from anthropogenic activities such as discharge of effluent or from acid mine drainage. The farms in the area are old, and leakages from pit latrines can possibly contaminate the groundwater.

### 8.3.23 Total Dissolved Solids

All sites except downstream site BH09 and surface water sites SW01 and SW02 exceeded the 25 % limit from the mean for Total Dissolved Solids. Sites BH01, BH04, BH05, BH07 and BH08 pose both an aesthetical risk to domestic users as well as a livestock risk. All sites pose an agricultural risk with regards to Total Dissolved Solids.

Of the above-mentioned sites, BH01, BH05 and BH07 indicated statistical significant increasing trends over the last year. BH01 also had indicated a statistical significant increasing trend since the start of the monitoring programme. When analysing the time-series chemistry data, BH05 had the highest concentration of Total Dissolved Solids at this site yet. The same applies for upstream site BH07.

### 8.3.24 Polycyclic Aromatic Hydrocarbons

Polycylcic Aromatic Hydrocarbons Acenaphthylene, Fluoranthene and Pyrene (isomere of Fluoranthene) were detected at downstream site BH09 only. These PAHs can form throught the incomplete combustion of organic compounds, such as fuel. The samples taken at this site were likely contaminated with the above-mentioned PAHs because of a diesel generator used to pump the samples. The generator has been sent in for repairs and maintenance after the site visit. These PAHs are not expected to appear again at this site during the next sampling event.

# 9. Conclusion

The chemical character of groundwater can be altered due to a variety of influences. These can be natural: minerals and gases reacting with the water in its relatively slow natural passage through sediments and rocks and the interaction of lower lying and deeper aquifers, or anthropogenic causes. The possibility of surface (rivers and streams) and groundwater interactions in lower lying areas also exist. Pollution from these surface water sources could potentially pollute groundwater. The time-series chemistry data, as well as the Piper Diagrams indicate that small variations in the chemical character of the groundwater in the area exist over time and space, although no evidence exist that these changes fall outside of the naturally occurring variations (inclusive of extensive mining and agricultural activities surrounding the monitoring sites).

Some parameters did exceed the 25 % limit from the mean for this monitoring event at certain sites. These parameters were: Aluminium, Barium, Boron, Calcium, Iron, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Potassium, Silicon, Sodium, Strontium, Bromide, Chloride, Nitrate, Sulphate, Dissolved Methane, Ammonia, Dissolved Inorganic Carbon, Electric Conductivity and Total Dissolved Solids. High standard deviation values of the mean baseline for some of these parameters mean that there is high variability (low central tendency) of the data points around the mean for the parameters at each respective site. High standard deviation could possibly be attributed to the limited baseline data taken over a short period, leading to lowered reliability of the baseline mean. High standard deviation could also hint on the natural volatility of these chemical parameters as the variation is high over a short sampling period for the baseline study. Some PAHs were identified at site BH09. However, the presence of these PAHs is expected to be because of contamination from the diesel generator used to pump samples to the surface. The generator has been sent in for repairs and maintenance.

Some of the POPCs at some of the sites showed statistical significant increasing trends since the start of the monitoring programme and over the past year as per Table 10. Most notably Electric Conductivity at sites BH01, BH04, BH05, BH08 and Mon-F1. Electric Conductivity is closely correlated to the amount of Total Dissolved in water, which is expected to slowly increase over time in aquifers due to their confined nature. Although no statistical significant increases at site BH04 and BH05 for Bromide was observed, this parameter had a big increase during the February 2022 monitoring event at these sites. Istope analysis and pump tests which are underway could assist in identifying possible reasons for these increases.

Water in the area is naturally saline – previous studies showed that Sodium/ Chloride dominated water types have a strong correlation with elevated methane concentrations.

Alvarez et al. (2016) further highlights the above by identifying that low Nitrate and Sulphate in Sodium rich water are strong predictors in the natural occurrence of high Methane concentrations. However, the Methane concentrations at all sites sampled are lower than in previous months.

Health concerns associated with chemical determinants of drinking water differs from that of microbial contamination, as chemical determinants can cause adverse health effects after prolonged periods of exposure. None of the sites included in this monitoring programme have water suitable for drinking (either health or aesthetic effects exist). The standard microbial, physical, aesthetic and chemical determinant thresholds as presented in SANS 241-1:2015 provides a numerical limit for certain parameters, which if met, could prevent the health of consumers from deteriorating over prolonged exposure. These standards are set to be protective of the general population over a lifetime of consumption and to ensure that water quality is preserved for future generations. Parameters that exceeded either SANS 241-1:2015 limits and/or DWAF water quality guidelines at certain sites for this monitoring event include: Aluminium, Barium, Chloride, Electric Conductivity, Iron, Manganese, Sodium and Total Dissolved Solids.

# 10. Recommendations

The following recommendations apply:

- The baseline study for Cluster1 has been completed. It is recommended that when production for Cluster1 commences that the HDR1 and Cluster1 monitoring programs be combined and integrated as one monitoring program.
- The monitoring data indicates that there are certain sites which have parameters which exceed the acceptable drinking water thresholds. In instances where these boreholes are being used for domestic purposes it would be advisable for Tetra4 to inform the relevant landowners/ users.
- Isotope fingerprinting to determine age, origin and pathways of water and pump tests to identify aquifer specific parameters.
- An additional surface water monitoring site be added to the monitoring programme within the Sand River upstream of where the Sand and Doring Rivers merge. The additional monitoring site should assist in identifying any possible sources of pollution detected downstream.

# 11. References

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## Appendix A- Production Associated Parameters

The following chemical parameters can be associated with production activities. It should be noted that some of these parameters can also occur in nature.

| Parameters associated with production activities | |
|---|---|
| Dissolved Methane | Ammonia ($NH_4$) |
| Polycyclic Aromatic Hydrocarbons | Uranium (U) |
| Boron (Bo) | Total hardness/Alkalinity |
| Dissolved Organic Carbon (DOC) | Rubidium (Rb) |
| Total Petroleum Hydrocarbons (TPH) | Arsenic (As) |
| Total Suspended Solids (TSS) | Total Dissolved Solids (TDS) |
| Lead (Pb) | Dissolved Ethane |
| Soap, Oil and Grease | Sulphate ($SO_4$) |
| Diesel Range Organics (DRO's) | Lithium (Li) |
| Dissolved Inorganic Carbon (DIC) | Gasoline Range Organics (GRO's) |

## Appendix B- Laboratory Results