CatchmentCARE
Community Actions for Resilient Ecosystems

# Sampling and Analysis of Groundwater at selected locations on the island of Ireland

## Derg Catchment Hydrochemistry Report

UK Research and Innovation/British Geological Survey
Author: F. Papageorgiou & B. Anders & L. Foley, CDM Smith

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# Section 1 Introduction

## 1.1 Background

The British Geological Survey (BGS) appointed CDM Smith Ireland Ltd (CDM Smith) to undertake a programme of groundwater monitoring at locations across the Derg catchment. This work was completed as part of the CatchmentCARE project.

Six monitoring events were carried out between November 2020 and August 2022:

- November 2020
- May 2021
- October 2021
- March 2022
- June 2022
- August 2022

Six monitoring wells were sampled during each monitoring event with a total of 36 samples collected over the two-year monitoring period.

This report presents the fundamental hydrochemical characteristics of the Derg catchment based on the six monitoring events. The hydrochemistry across the catchment is summarised, an initial assessment of the water types is provided and as preliminary assessment of potential anthropogenic pressures in the catchment is presented.

## 1.2 Site Background

The Derg catchment straddles the border between the Republic of Ireland and Northern Ireland (Figure 1). Two wells are located at each of three locations: Derg Inlet works, Derg Lagoons and Corgary Trout Hatchery, totalling six wells.

From the Corine 2018 Landcover dataset, landuse in the east of the Derg catchment is principally agricultural pastures, with some areas of natural vegetation and some discontinuous urban fabrics (Corine Landcover 2018). Peat bogs, coniferous forest and mixed forests become prevalent in the west.

The bedrock comprises metasediments (psammitic & pelitic schist, phyllite, marble, amphibolite, and diamictite) and some (shallow marine) sandstone, mudstone and conglomerate in the south (GSI Map Viewer; GSNI GeoIndex).

Subsoils across the Derg catchment are largely variable sandstone and shale derived till with bedrock at or close to surface (GSI Map Viewer; UK Soil Observatory). Some sandstone derived till, alluvium and glacio fluvial and glaciolacustrine sand and gravel are present in the east. Peat becomes prevalent in the west. Soils are largely Stagnosols and Podzols with minor cambisols in the east of the catchment. The west is largely occupied with histosols and stagnosols.

The soils are poorly drained to the west (EPAMaps, data available for Republic of Ireland only). The aquifer across the catchment is largely Pl (Poor Aquifer - Bedrock which is generally unproductive except for local zones with limited potential productivity fracture flow) (EPAMaps; GSNI GeoIndex). The Derg catchment aquifer vulnerability is generally "extreme" (ROI)" and "most extreme" (NI) with some smaller areas of "moderate" (EPAMaps; GSNI GeoIndex).

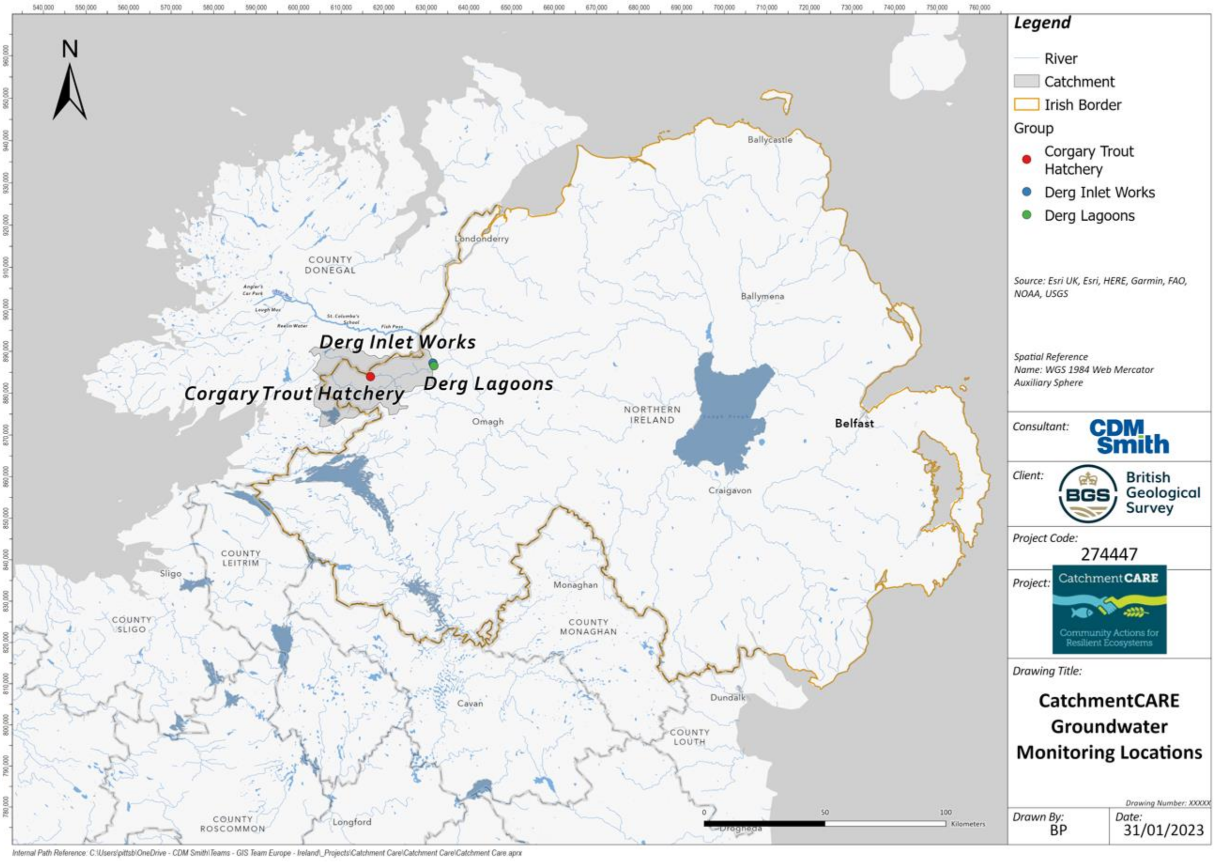


**Figure 1: Derg Catchment and Monitoring Group Locations**

**Table 1 Bedrock Geology and Associated General Mineralogy**

| Location | Bedrock Geology (GSNI 1:250,000) | General mineral composition |
|---|---|---|
| East catchment (Derg Lagoons & Derg Inlet Works) | Neoproterozoic Limestone within the Claudy Formation. | Limestone: Predominantly calcite ($CaCO_3$).<br>Also containing:<br>Psammite: silicon, potassium, sodium, aluminium, barium and iron.<br>Microgabbro: calcium, sodium, aluminium, titanium, silicate.<br>Quartzite: quartz (quartz 88-98%), iron, silicate. |
| West catchment (Corgary Trout Hatchery) | Neoproterozoic Epidotic Psammite within the Lough Mourne Grit formation and near the boundary of a Palaeogene Microgabbro dike | Psammite: quartz (silicon), feldspar (potassium, sodium, silicon, aluminium, barium) and mica (silica, aluminium, potassium, iron).<br>Microgabbro: calcium, iron sodium, aluminium, titanium, silicate. |

# Section 2 Methodology

## 2.1 Field Sampling Method

Groundwater samples were collected using either the low-flow technique or fixed volume technique. Ground water purging and sampling was carried out using pumps as follows:

- Bladder pump (low flow purge and sample method);
- Peristaltic pump (low flow purge and sample method); or
- Suction pump (fixed volume purge).

Groundwater levels were measured at all wells prior to pumping using a portable electronic water level meter and the initial static water level was recorded.

Field water quality parameters (temperature, pH, oxidation-reduction potential (ORP), conductivity and dissolved oxygen (DO)) were measured at all wells.

For low flow monitoring, the field water quality parameters were monitored in the field during low-flow purging using a flow-through cell to minimise oxidation by the atmosphere. Purging continued until the water quality indicator parameters stabilised (pH < ± 0.1; specific electrical conductivity < 3%; temperature < ± 0.1 ° C). The water level was measured throughout the purging process to monitor drawdown. The field data were recorded in a Survey123 Groundwater Purging and Sampling Survey digital form using a handheld portable electronic device every approximately three-five minutes during the purging process. After the well was purged and stable parameters measured, the flow was reduced for low-flow sample collection (500 ml / minute).

Fixed volume purging was carried out by purging three times volume of the complete water column in the well. The well was then allowed to recharge before sampling using either the peristaltic pump or suction pump.

All samples for trace metal analyses were filtered in the field using a 0.45-micron membrane filter before filling bottles containing nitric acid preservative. New bottles supplied by the laboratories were used for sample collection.

## 2.2 Laboratory Analysis

Analysis of water samples was undertaken by McQuillan Environmental, Antrim, Northern Ireland, United Kingdom and Element Materials Technology (Element), Deeside, United Kingdom. Both laboratories are accredited by the United Kingdom Accreditation Service (UKAS) in accordance with ISO/IEC 17025:2005.

Water samples were either collected by a courier on the day of sampling (McQuillan Environmental) or dispatch by DHL to Element in UK.

The laboratory monitored parameters fall into three groups:

1. Inorganic parameters: 52 parameters, including metals, major anions and cations, macronutrients (nitrogen and phosphorus species), physico-chemical parameters (analysed by McQuillan Environmental);

2. Organic parameters: up to 81 parameters, including pesticides and herbicides (analysed by Element); and

3. Microbial parameters: *E. coli*, total coliforms and *Clostridium Perfringens* (analysed by McQuillan Environmental).

# Section 3 Data Quality and Usability Evaluation

## 3.1 Introduction

Laboratory data quality and usability were assessed using data quality indicators (DQIs). Data "usability" means that the data are acceptable to use for their intended purpose and associated evaluations. The DQIs for assessing data are expressed in terms of precision and accuracy. These DQIs provide a mechanism to evaluate and measure laboratory data quality throughout the project. The definitions and methods of measurement of precision and accuracy are discussed below.

## 3.2 Precision

Precision is the measurement of the ability to obtain the same value on re-analysis of a sample (i.e., the reproducibility of the data). The closer the results of the measurements are together, the greater is the precision. Precision is not related to accuracy or the true values in the sample; instead, precision is focused upon the random errors inherent in the analysis that result from the measurement process and are compounded by the sample vagaries. Precision is measured by analysing two portions of the sample (sample and duplicate) and then comparing the results. This comparison can be expressed in terms of relative percent difference (RPD). RPD is calculated as the difference between the two measurements divided by the average of the two measurements, as follows:

$$RPD = \frac{D_1 - D_2}{(D_1 + D_2) \times 0.5} \times 100$$

where:

| | | |
|---|---|---|
| RPD | = | Relative percent difference |
| $D_1$ | = | First sample value |
| $D_2$ | = | Second sample value (duplicate) |

Acceptable RPD values for field duplicates are usually 50 % to 150 %. Field duplicates were generated for this project. One field duplicate was collected each round, totalling six for the project.

### 3.2.1 Field QA/QC Samples

The results are used to evaluate the combined reproducibility of both the laboratory analyses and field sampling.

One duplicate sample was generated per monitoring event in the field (by filling two sets of bottles from the sampling tube alternating between bottles) and sent blind to McQuillan Environmental for analysis. Table 2 (monitoring events 1, 2 & 3) and Table 3 (monitoring events 4, 5 & 6) provide the results of 52 parameters and the calculated RPD between each pair of samples. Note, where both the original and duplicate result are less than the limit of detection (LOD), the RPD is zero. Where only one value is less than the LOD, half of the LOD value is used to permit calculation of the RPD; in such cases the "0.5 X <LOD" value is indicated by grey fill. Table cells with a blue fill indicates an RPD greater than 50% but less than 150%. Yellow filled cells indicate an RPD greater than 150%.

## Table 2 Duplicate data and associated RPD (%), monitoring events 1,2 & 3

| | | Round 1 | | | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Description** | | **Kilomulty Spring** | | **% RPD** | **CCF06 (FSTC Intermediate)** | | **% RPD** | **CCF07 (F-STC-DEEP)** | | **% RPD** |
| **Lab ref** | | *077002* | *077003* | | *082086* | *082085* | | *086071* | *086073* | |
| **Date Sampled** | **Units** | *19/11/2020* | | | *25/05/2021* | | | *13/10/2021* | | |
| Alkalinity, Bicarbonate as CaCO3 | mg/l | 399 | 407 | 2.0 | 170 | 195 | 13.7 | 140 | 135 | -3.6 |
| Alkalinity, Total as $CaCO_3$ | mg/l | 404 | 410 | 1.5 | 199 | 198 | -0.5 | 148 | 138 | -7.0 |
| Aluminium (diss.filt) | ug/l | 11.3 | 5 | -77.3 | <10 | <10 | 0 | 19.1 | 18 | -5.9 |
| Ammonia as N | mg/l | 0.37 | 0.39 | 5.3 | < 0.11 | <0.11 | 0 | 0.34 | 0.055 | -144 |
| Anions | ueq/l | 9440 | 9530 | 0.9 | 5,900 | 5,900 | 0 | 4,600 | 4,340 | -5.8 |
| Arsenic (diss.filt) | ug/l | 12.8 | 12 | -6.5 | <0.5 | <0.5 | 0 | <0.5 | <0.5 | 0 |
| Barium (diss.filt) | ug/l | 267 | 252 | -5.8 | 87.3 | 86.3 | -1.2 | 27.2 | 27.1 | -0.4 |
| Boron (diss.filt) | ug/l | 18.8 | 23.8 | 23.5 | 13 | 5 | -88.9 | <10 | <10 | 0.0 |
| Bromide | mg/l | 0.207 | 0.207 | 0 | 0.202 | 0.207 | 2.4 | 0.0873 | 0.0994 | 13.0 |
| Cadmium (diss.filt) | ug/l | <0.08 | <0.08 | 0 | <0.08 | <0.08 | 0 | <0.08 | <0.08 | 0 |
| Caesium, Dissolved | ug/l | <1.0 | <1.0 | 0 | < 1.0 | <1 | 0 | < 1.0 | < 1.0 | 0 |
| Calcium (diss.filt) | mg/l | 120 | 121 | 0.4 | 49.6 | 50 | 0.8 | 13.058 | 13.788 | 5.4 |
| Cations | ueq/l | 9570 | 9580 | 0.1 | 5,600 | 5,700 | 1.8 | 4,190 | 4,300 | 2.6 |
| Cerium, Dissolved* | ug/l | <1.0 | <1.0 | 0 | < 1.0 | < 1.0 | 0.0 | - | - | - |
| Chloride as Cl | mg/l | 37 | 39.1 | 5.5 | 33.1 | 33.5 | 1.2 | 27.7 | 25.0 | -10.2 |
| Chromium (diss.filt) | ug/l | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 |
| Cobalt (diss.filt) | ug/l | <0.5 | <0.5 | 0 | <0.5 | <0.5 | 0 | <0.5 | <0.5 | 0 |
| Copper (diss.filt) | ug/l | 0.338 | 0.15 | -77.0 | <0.3 | <0.3 | 0 | <0.3 | <0.3 | 0 |
| Dissolved Organic Carbon | mg/l | 5.07 | 5.28 | 4.1 | 3.08 | 3.53 | 13.6 | < 2.0 | < 2.0 | 0 |
| Electrical Conductivity | uS/cm | 885 | 894 | 1.0 | 557 | 559 | 0.4 | 442 | 439 | -0.7 |
| Fluoride as F | mg/l | 0.45 | 0.455 | 1.1 | 0.59 | 0.58 | -1.7 | 1.67 | 1.65 | -1.2 |
| Iodide* | mg/l | <0.1 | <0.1 | 0 | <0.1 | <0.1 | 0.0 | - | - | - |
| Ionic Balance | % | 0.6 | 0.3 | -66.7 | -2.6 | -1.7 | -41.9 | -4.7 | -0.5 | -162 |
| Iron (diss.filt) | mg/l | 9.39 | 9.47 | 0.8 | 0.167 | 0.15 | -10.7 | <0.019 | <0.019 | 0 |
| Lead (diss.filt) | ug/l | <0.2 | <0.2 | 0 | <0.2 | <0.2 | 0 | <0.2 | <0.2 | 0 |
| Lithium (diss.filt) | ug/l | 7.69 | 8.04 | 4.5 | 19.8 | 19.8 | 0 | 12.4 | 12.7 | 2.4 |
| Magnesium (diss.filt) | mg/l | 22.7 | 22.6 | -0.4 | 13 | 13.4 | 3.0 | 4.17 | 4.31 | 3.3 |
| Manganese (diss.filt) | ug/l | 93.3 | 90.7 | -2.8 | 34.7 | 34.2 | -1.5 | 8.73 | 8.05 | -8.1 |
| Mercury (diss.filt) | ug/l | <0.01 | <0.01 | 0 | <0.01 | <0.01 | 0 | <0.01 | <0.01 | 0 |
| Nickel (diss.filt) | ug/l | 1.21 | 1.15 | -5.1 | <0.4 | <0.4 | 0 | <0.4 | <0.4 | 0 |
| Nitrate as N | mg/l | 0.58 | 0.04 | -174 | <0.08 | <0.08 | 0 | 0.13 | 0.09 | -36.4 |
| Nitrite as N | mg/l | <0.05 | <0.05 | 0 | < 0.05 | < 0.05 | 0 | < 0.05 | < 0.05 | 0 |
| Nitrogen, Total | mg/l | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 |
| pH | Units | 6.8 | 6.92 | 1.7 | 7.82 | 7.84 | 0.3 | 8.47 | 8.53 | 0.7 |
| Phosphate, Ortho as P | mg/l | <0.07 | <0.07 | 0.0 | < 0.07 | < 0.07 | 0.0 | <0.02 | <0.02 | 0 |

| | | Round 1 | | | Round 2 | | | Round 3 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample Description | | Kilomulty Spring | | % RPD | CCF06 (FSTC Intermediate) | | % RPD | CCF07 (F-STC-DEEP) | | % RPD |
| Lab ref | | *077002* | *077003* | | *082086* | *082085* | | *086071* | *086073* | |
| Date Sampled | Units | *19/11/2020* | | | *25/05/2021* | | | *13/10/2021* | | |
| Phosphorus (diss.filt) | ug/l | 68.4 | 34.1 | -66.9 | <10 | <10 | 0.0 | 10 | 20 | 66.7 |
| Potassium (diss.filt) | mg/l | 8.23 | 8.21 | -0.2 | 11.9 | 12 | 0.8 | 7.05 | 7.47 | 5.8 |
| Selenium (diss.filt) | ug/l | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 |
| Sodium (diss.filt) | mg/l | 21.3 | 21.2 | -0.5 | 39.8 | 40.8 | 2.5 | 68.80 | 70.50 | 2.4 |
| Strontium (diss. filt) | ug/l | 1750 | 1700 | -2.9 | 424 | 420 | -0.9 | 236 | 234 | -0.9 |
| Sulphate as SO4 | mg/l | 11.5 | 11.2 | -2.6 | 47.00 | 47.20 | 0.4 | 41.00 | 41.80 | 1.9 |
| Total Dissolved Solids | mg/l | 528 | 526 | -0.4 | 343 | 345 | 0.6 | 245 | 229 | -6.8 |
| Total Organic Carbon | mg/l | 4.14 | 4.14 | 0 | 2.43 | 2.46 | 1.2 | 1 | 0.09 | -167 |
| Total Oxidised Nitrogen as N | mg/l | 0.58 | 0.04 | -174 | < 0.08 | < 0.08 | 0 | 0.13 | 1 | 154 |
| True Colour | mg/l Pt/Co | 14.4 | 6.78 | -72.0 | <1 | <1 | 0 | <1 | <1 | 0 |
| Turbidity | ntu | 92.1 | 88.8 | -3.6 | 3.21 | 3.64 | 12.6 | 0.93 | 1.03 | 10.2 |
| Uranium (diss.filt) | ug/l | <0.5 | <0.5 | 0 | 17.9 | 18 | 0.6 | 10.9 | 10.7 | -1.9 |
| Zinc (diss.filt) | ug/l | 1.6 | 2.77 | 53.5 | 1.67 | 0.5 | -108 | 6.53 | 3.14 | -70.1 |

* Removed following absence of detections in any well

## Table 3 Duplicate data and associated RPD (%), monitoring events 4, 5 & 6

| | | Round 4 | | | Round 5 | | | Round 6 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample Description | | CCD08 (D-DIW-TRANS) | | % RPD | FPBH02 | | % RPD | RW-BH-03 | | % RPD |
| Lab ref (MCQ) | | 101359 | 101365 | | 105794 | 105796 | | 108346 | 108349 | |
| Date Sampled | Units | 10/03/2021 | | | 16/06/2022 | | | 25/08/2022 | | |
| Alkalinity, Bicarbonate as CaCO3 | mg/l | 70.6 | 90 | 24.2 | 250 | 295 | 16.5 | 133 | 84.7 | -44 |
| Alkalinity, Total | mg/l | 70.3 | 89.6 | 24.1 | 280 | 274 | -2.2 | 119 | 105 | -13 |
| Aluminium (diss.filt) | ug/l | <10 | <10 | 0 | 11.3 | 5 | -77.3 | 17.1 | 21.9 | 25 |
| Ammonia as N | mg/l | 0.055 | 0.14 | 87.2 | <0.11 | <0.11 | 0 | <0.11 | <0.11 | 0 |
| Anions | ueq/l | 2820 | 3890 | 31.9 | 6720 | 6580 | -2.1 | 3050 | 2850 | -7 |
| Arsenic (diss.filt) | ug/l | <0.5 | <0.5 | 0 | 0.674 | 0.882 | 26.7 | 1.77 | 1.8 | 2 |
| Barium (diss.filt) | ug/l | 79.9 | 77.8 | -2.7 | 163 | 163 | 0 | 25 | 24.3 | -3 |
| Boron (diss.filt) | ug/l | 18.9 | 11.5 | -48.7 | 11.6 | 10.5 | -10.0 | <10 | <10 | 0 |
| Bromide | mg/l | 0.0866 | 0.102 | 16.3 | 0.114 | 0.116 | 1.7 | 0.071 | 0.104 | 38 |
| Cadmium (diss.filt) | ug/l | 0.125 | 0.04 | -103 | <0.08 | <0.08 | 0 | <0.08 | <0.08 | 0 |
| Caesium, Dissolved | ug/l | <1.0 | <1.0 | 0 | <1.0 | <1.0 | 0 | 1 | 1 | 0 |
| Calcium (diss.filt) | mg/l | 31.7 | 41 | 25.6 | 54 | 55 | 1.8 | 27.3 | 26.4 | -3 |
| Cations | ueq/l | 2480 | 3240 | 26.6 | 6350 | 6500 | 2.3 | 2540 | 2490 | -2 |
| Cerium, Dissolved* | ug/l | - | - | - | - | - | - | - | - | - |

| | | Round 4 | | | Round 5 | | | Round 6 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample Description | | CCD08 (D-DIW-TRANS) | | % RPD | FPBH02 | | % RPD | RW-BH-03 | | % RPD |
| Lab ref (MCQ) | | 101359 | 101365 | | 105794 | 105796 | | 108346 | 108349 | |
| Date Sampled | Units | 10/03/2021 | | | 16/06/2022 | | | 25/08/2022 | | |
| Chloride as Cl | mg/l | 15.2 | 33.3 | 74.6 | 25.8 | 25.3 | -2.0 | 19.1 | 20.4 | 7 |
| Chromium (diss.filt) | ug/l | <1 | <1 | 0 | 1.05 | 1.13 | 7.3 | <1 | <1 | 0 |
| Cobalt (diss.filt) | ug/l | <0.5 | <0.5 | 0 | <0.5 | <0.5 | 0 | 3.81 | 3.83 | 1 |
| Copper (diss.filt) | ug/l | 0.388 | 1.93 | 133 | 1.93 | 2.04 | 5.5 | <0.3 | <0.3 | 0 |
| DOC | mg/l | 10 | 3.1 | -105 | 3.4 | 3.4 | 0 | 4.7 | 3.5 | -29 |
| Electrical Conductivity | uS/cm | 298 | 410 | 31.6 | 643 | 642 | -0.2 | 285 | 260 | -9 |
| Fluoride as F | mg/l | 0.0614 | 0.022 | -94.5 | 0.304 | 0.286 | -6.1 | 0.0698 | 0.764 | 167 |
| Iodide* | mg/l | - | - | - | - | - | - | - | - | - |
| Ionic Balance | % | -6.5 | -9.1 | 33.3 | -2.8 | -0.6 | -129 | -9.3 | -6.6 | -34 |
| Iron (diss.filt) | mg/l | <0.019 | <0.019 | 0 | <0.019 | <0.019 | 0 | 10.9 | 11.2 | 3 |
| Lead (diss.filt) | ug/l | 0.1 | 0.208 | 70.1 | 0.343 | 0.325 | -5.4 | <0.2 | <0.2 | 0 |
| Lithium (diss.filt) | ug/l | <1 | <1 | 0 | 26.1 | 26.1 | 0 | 1.65 | 1.78 | 8 |
| Magnesium (diss.filt) | mg/l | 5.45 | 5.91 | 8.1 | 20 | 20.5 | 2.5 | 1.82 | 1.74 | -4 |
| Manganese (diss.filt) | ug/l | 3.23 | 241 | 195 | 23.8 | 23.1 | -3.0 | 1320 | 1290 | -2 |
| Mercury (diss.filt) | ug/l | <0.01 | <0.01 | 0 | <0.01 | <0.01 | 0 | <0.01 | <0.01 | 0 |
| Nickel (diss.filt) | ug/l | 0.585 | 0.481 | -19.5 | 1.03 | 1.29 | 22.4 | 3.15 | 3.16 | 0 |
| Nitrate as N | mg/l | 9.46 | 13 | 31.5 | 0.1 | 0.1 | 0 | <0.08 | <0.08 | 0 |
| Nitrite as N | mg/l | <0.05 | <0.05 | 0 | <0.05 | <0.05 | 0 | <0.05 | <0.05 | 0 |
| Nitrogen, Total | mg/l | 9.22 | 12.5 | 30.2 | <1 | <1 | 0 | <1 | <1 | 0 |
| pH | Units | 6.22 | 6.18 | -0.6 | 7.87 | 7.87 | 0 | 6.56 | 6.47 | -1 |
| Phosphate, Ortho as P | mg/l | <0.02 | <0.02 | 0 | <0.02 | <0.02 | 0 | <0.02 | <0.02 | 0 |
| Phosphorus (diss.filt) | ug/l | 10 | 23.6 | 81.0 | <20 | <20 | 0 | 77.9 | 75.7 | -3 |
| Potassium (diss.filt) | mg/l | 0.833 | 4.8 | 141 | 23.3 | 23.8 | 2.1 | <0.87 | <0.87 | 0 |
| Selenium (diss.filt) | ug/l | <1 | <1 | 0 | <1 | <1 | 0 | <1 | <1 | 0 |
| Sodium (diss.filt) | mg/l | 9.65 | 12.9 | 28.8 | 32.5 | 33.4 | 2.7 | 8.82 | 8.74 | -1 |
| Strontium (diss. filt) | ug/l | 140 | 166 | 17.0 | 1240 | 1250 | 0.8 | 68.4 | 67.7 | -1 |
| Sulphate as SO4 | mg/l | 14.8 | 11.1 | -28.6 | 18.3 | 18.1 | -1.1 | 6.46 | 8.3 | 25 |
| TDS | mg/l | 152 | 263 | 53.5 | 367 | 374 | 1.9 | 167 | 163 | -2 |
| TOC | mg/l | 2.8 | 15 | 137 | 3.3 | 3.2 | -3.1 | 5 | 3.7 | -30 |
| TON as N | mg/l | 9.46 | 13 | 31.5 | 0.1 | 0.1 | 0 | <0.08 | <0.08 | 0 |
| True Colour | mg/l Pt/Co | 0.5 | 2.1 | 123 | 4.48 | 4.47 | -0.2 | 12.2 | 45 | 115 |
| Turbidity | ntu | 0.616 | 0.427 | -36.2 | 0.452 | 0.359 | -22.9 | 64.4 | 81.8 | 24 |
| Uranium (diss.filt) | ug/l | <0.5 | <0.5 | 0 | 46.8 | 46.7 | -0.2 | 1.03 | 1.06 | 3 |
| Zinc (diss.filt) | ug/l | 9.91 | 8.4 | -16.5 | 3.44 | 3.49 | 1.4 | 16.5 | 10.3 | -46 |

*Removed following absence of detections in any well

The majority of RPD values were below 50%. In total, 26 of the 312 (i.e., 8%) of RPD > 50% but less than 150%. There were seven instances of RPD > 150%. With one exception, these exceedances/high RPDs were generally associated with low concentrations and often with one value being at the LOD (and thus 0.5 x LOD used for the calculation). For Manganese in the Round four duplicate, the recorded concentration were 3.23 ug/L and 241 ug/L. All other parameters for these two duplicates are in line with expected values for a duplicate pair. The manganese concentrations were checked with the laboratory who confirmed their accuracy and suggested the deviation was due to a contamination issue.

Overall, the duplicate %RPD data are considered satisfactory and the data useable for the intended evaluations.

## 3.3 Ionic Balance/Charge Balance

Within a water sample, the amounts of positive charges and negative charges should be equal, resulting in a charge balance or ionic balance of close to zero. Determining the ionic balance of a sample is a useful means of checking the laboratory analysis of ions have been carried out correctly and all major ions were analysed. Values of ± 10% are satisfactory for this QA/QC test.

Of the 36 values, 34 were within ± 10%, with a median value of -2.6 %. One value was close to ±10% at -10.2% (Derg Lagoons well Lab ref: MCQ101364, sampled on10/03/2022). The remaining value was within ± 15%, at 14.5% (Corgary Trout well Lab ref: MCQ101236, sampled 08/03/2022).

The laboratory checked the results for samples with elevated ionic balances and confirmed analysis were correct and data accurate.

Overall, the ionic balances were acceptable indicating good and complete analysis, with all major anions and cations analysed.

# Section 4 Data Summary & Interpretation

## 4.1 Summary Statistics

This section provides a statistical summary of the analytical results and a comparison of the analytical results against selected assessment criteria. Where the reported values were below the detection limit (<LOD), the values were substituted with a value of half the limit of detection (0.5 x <LOD). The summary statistics apply to all 36 samples collected during the six monitoring events across all wells.

The summary statistics presented are briefly described below:

- WQS: water quality standard value/threshold to which the results are compared (either IGV or GTV, as below)
- IGV: EPA Interim Guide Value (Towards Setting Guideline Values for The Protection of Groundwater in Ireland – Interim Report http://www.epa.ie/pubs/advice/water/ground/towardssettingguidelinevaluesfortheprotectionofgroundwaterinireland.html)
- GTV: Groundwater Regulations Threshold Value (S.I. No. 9 of 2010)
- Source: WQS source
- LOD: laboratory analytical limit of detection
- Min: minimum detected value above the LOD
- Mean: mean of dataset
- Maximum: maximum value detected
- Median: median value of dataset
- 97.7$^{th}$ percentile: 97.7$^{th}$ percentile of dataset
- No. of Samples: number of samples analysed for this parameter
- No. of WQS Exceedances: number of exceedances of the WQS threshold
- % Of WQS Exceedances: percentage of values above the WQS threshold
- No. of Detections: number of values above the detection limit
- % Of WQS Detections: percentage of values above the limit of detection

Summary statistics of the field physico-chemical water quality parameters along with major and minor elements are contained in Table 4. Table 5 contains the summary statistics of the trace metals (trace elements). Exceedances of the respective WQS are indicated by orange highlight of the number and percentage WQS exceedance.

There were exceedances of the respective threshold/WQS for the following field parameters, and major and minor elements (Table 4):

- Ammonia as N (exceedance no. 8, or 20 %).
- Potassium (K) (exceedance no. 6, or 17 %);
- Specific electrical conductivity (SEC) (exceedance no. 6, or 17 %); and,
- pH (exceedance no. 6, or 17 %).

There were exceedances of the respective threshold/WQS for the metals (trace elements) (Table 5):

- Manganese (Mn) (exceedance no. 22 or 61 %);
- Arsenic (As) (exceedance no. 16, or 44 %);
- Barium (Ba) (exceedance no. 12, or 33 %);
- Iron (Fe) (exceedance no. 10, or 28 %);
- Uranium (U) (exceedance no. 3, or 8 %);
- Cadmium (Cd) (exceedance no. 1, or 3%); and
- Nickel (Ni) (exceedance no. 1, or 3 %).

**Table 4: Summary statistics of field parameters, and major and minor elements**

| Test | Units | LOD | WQS | Source | Min* | Mean | Max | Median | 97.7th percentile | No. Samples | No. Detections | % Detections | No. WQS Exceedances | % WQS Exceedances |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ammonia (as N) | mg/l | <0.11 | 0.065 | GTV 2016 | 0.130 | 0.108 | 0.620 | 0.055 | 0.612 | 36 | 7 | 19.5 | 7 | 20 |
| Specific Electrical Conductivity | µS/cm | <1.00 | 800 | GTV 2016 | 298 | 549 | 914 | 492 | 907 | 36 | 36 | 100 | 6 | 17 |
| Potassium (Dissolved) | mg/l | <0.174 | 5.000 | IGV 2003 | 0.833 | 4.83 | 38.2 | 2.50 | 36.8 | 36 | 36 | 100 | 6 | 17 |
| pH (field) | | - | <6.5, >9.5 | IGV 2003 | 6.11 | 7.24 | 8.93 | 7.37 | 8.90 | 36 | - | - | 6 | 17 |
| Redox (field) | mV | - | - | - | -498 | -191 | 163 | -218 | 162 | 36 | - | - | - | - |
| Anions | ueq/l | - | - | - | 2,820 | 5,703 | 8,960 | 5,435 | 8,614 | 36 | - | - | - | - |
| Cations | ueq/l | - | - | - | 2,480 | 5,389 | 8,180 | 5,110 | 8,156 | 36 | - | - | - | - |
| Ionic Balance | % | - | - | - | -10.2 | -2.17 | 14.5 | -2.30 | 7.81 | 36 | - | - | - | - |
| Dissolved oxygen (field) | mg/l | - | - | - | 0.380 | 1.70 | 5.98 | 1.090 | 5.84 | 36 | - | - | - | - |
| Fluoride as F | mg/l | <0.02 | 1.0 | IGV 2003 | 0.023 | 0.171 | 0.343 | 0.175 | 0.324 | 36 | 35 | 97 | 0 | 0 |
| Magnesium (Dissolved) | mg/l | <0.10 | 50 | IGV 2003 | 5.25 | 13.6 | 23.0 | 15.7 | 21.9 | 36 | 36 | 100 | 0 | 0 |
| Sodium (Dissolved) | mg/l | <0.15 | 150 | GTV 2010 | 9.65 | 25.6 | 78.1 | 16.3 | 78.0 | 36 | 36 | 100 | 0 | 0 |
| Calcium (Dissolved) | mg/l | <0.10 | 200 | IGV 2003 | 10.8 | 58.3 | 105 | 55.6 | 103 | 36 | 36 | 100 | 0 | 0 |
| Chloride | mg/l | <0.35 | 187.5 | GTV 2016 | 13.4 | 42.4 | 156 | 19.4 | 150 | 36 | 36 | 100 | 0 | 0 |
| Sulphate as $SO_4$ | mg/l | <5.00 | 187.5 | GTV 2016 | 7.65 | 19.5 | 54.9 | 14.9 | 53.5 | 36 | 27 | 75 | 0 | 0 |
| Total Dissolved Solids (TDS) | mg/l | <1.5 | 1,000 | IGV 2003 | 151 | 308 | 506 | 282 | 506 | 36 | 36 | 100 | 0 | 0 |

| Test | Units | LOD | WQS | Source | Min* | Mean | Max | Median | 97.7th percentile | No. Samples | No. Detections | % Detections | No. WQS Exceedances | % WQS Exceedances |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrate (as N) | mg/l | <0.08 | 37.5 | GTV 2016 | 0.090 | 2.58 | 13.6 | 0.105 | 12.6 | 36 | 21 | 58 | 0 | 0 |
| Ortho-phosphate as P | mg/l | <0.02 or <0.07 | 0.035 | GTV 2016 | - | - | - | - | - | 36 | 0 | 0 | 0 | 0 |
| Alkalinity, Total as $CaCO_3$ | mg/l | <5.00 | NO WQS | - | 70.3 | 194 | 290 | 191 | 289 | 36 | 36 | 100 | - | - |
| Alkalinity, Bicarbonate as CaCO3 | mg/l | <5.00 | NO WQS | - | 70.6 | 194 | 290 | 200 | 287 | 36 | 36 | 100 | - | - |
| Nitrite (as N) | mg/l | <0.05 | No WQS | - | - | - | 0.360 | - | - | 36 | 1 | 3 | - | - |
| Total phosphorus | ug/l | <20 | No WQS | - | 21.1 | 54.1 | 302 | 29.0 | 284 | 24 | 12 | 50 | - | - |
| Total organic carbon | mg/l | <1/<2/ <3 | No WQS | - | 0.160 | 8.44 | 67.0 | 2.43 | 63.8 | 36 | 21 | 58 | - | - |
| Dissolved organic carbon | mg/l | <1/<2/ <3 | No WQS | - | 1.15 | 8.53 | 67.0 | 3.05 | 63.8 | 36 | 24 | 67 | - | - |
| Total oxidised Nitrogen (TON) | mg/l | <0.08 | No WQS | - | 0.09 | 2.61 | 13.6 | 0.105 | 12.6 | 36 | 22 | 61 | - | - |

*Minimum result above detection limit

**Table 5: Summary statistics of metals (trace elements)**

| Test | Units | LOD | WQS | Source | Min* | Mean | Max | Median | 97.7th percentile | No. Samples | No. Detections | % WQS Detections | No. WQS Exceedances | % WQS Exceedances |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Manganese | ug/l | <3.0 | 50 | IGV 2003 | 3.23 | 680 | 4,000 | 131 | 3,412 | 36 | 33 | 92 | 22 | 61 |
| Arsenic | ug/l | <0.50 | 7.5 | GTV 2016 | 0.556 | 11.1 | 91.1 | 1.61 | 44.8 | 36 | 26 | 72 | 16 | 44 |
| Barium | ug/l | <0.2 | 100 | IGV 2003 | 11.1 | 84.5 | 207 | 75.2 | 204 | 36 | 36 | 100 | 12 | 33 |
| Iron | mg/l | <0.019 | 0.20 | IGV 2003 | 0.024 | 1.66 | 16.8 | 0.057 | 16.2 | 36 | 21 | 58 | 10 | 28 |
| Uranium | ug/l | <0.50 | 9.0 | IGV 2003 | 0.527 | 3.23 | 10.2 | 1.50 | 9.36 | 36 | 27 | 75 | 3 | 8 |
| Cadmium | ug/l | <0.08 | 3.75 | GTV 2010 | 0.098 | 1.72 | 59.6 | 0.040 | 11.8 | 36 | 11 | 31 | 1 | 3 |
| Nickel | ug/l | <0.40 | 15.0 | GTV 2010 | 0.528 | 3.33 | 20.9 | 1.22 | 13.9 | 36 | 32 | 89 | 1 | 3 |
| Magnesium | mg/l | <0.1 | 50 | IGV 2003 | 5.25 | 13.6 | 23 | 15.7 | 21.9 | 36 | 36 | 100 | 0 | 0 |
| Zinc | ug/l | <1.00 | 75.0 | GTV 2016 | 1.00 | 4.07 | 18.7 | 2.56 | 16.8 | 36 | 31 | 86 | 0 | - |
| Aluminium | ug/l | <10.0 | 150 | GTV 2016 | 18.6 | 6.48 | 30.8 | 5.00 | 21.3 | 36 | 3 | 8 | 0 | - |
| Boron | ug/l | <10.0 | 750 | GTV 2010 | 12.4 | 7.62 | 21.9 | 5.00 | 19.5 | 36 | 9 | 25 | 0 | - |
| Bromide | ug/l | <0.06 | No WQS | No WQS | 0.071 | 0.259 | 1.00 | 0.128 | 1.00 | 36 | 31 | 86 | 0 | - |
| Lead | ug/l | <0.1 | 7.50 | GTV 2016 | 0.248 | 0.151 | 1.34 | 0.100 | 0.520 | 36 | 4 | 11 | 0 | - |
| Copper | ug/l | <0.3 | 1500 | GTV 2010 | 0.307 | 0.470 | 2.63 | 0.150 | 2.12 | 36 | 13 | 36 | 0 | - |
| Chromium | ug/l | <1 | 37.5 | GTV 2016 | - | - | 3.05 | - | - | 36 | 1 | 3 | 0 | - |

| Test | Units | LOD | WQS | Source | Min* | Mean | Max | Median | 97.7th percentile | No. Samples | No. Detections | % WQS Detections | No. WQS Exceedances | % WQS Exceedances |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Caesium | ug/l | <1 | No WQS | - | 2.40 | 0.661 | 4.40 | 0.500 | 2.79 | 36 | 2 | 6 | - | - |
| Lithium | ug/l | <1 | No WQS | - | 1.33 | 9.11 | 85.3 | 2.31 | 83.0 | 36 | 25 | 70 | - | - |
| Strontium | ug/l | <1 | No WQS | - | 17.9 | 252 | 488 | 221 | 485 | 36 | 36 | 100 | - | - |
| Selenium | ug/l | <1 | No WQS | - | - | - | - | - | - | 36 | 0 | - | - | - |
| *Cerium | ug/l | <1 | No WQS | - | - | - | - | - | - | 18 | 0 | - | - | - |

* Analysis discontinued due to non-detects across all monitoring locations in project

# Section 5 Water Physiochemical Characteristics and Water Type

This section provides analysis and interpretation of water physicochemical characteristics and the water types. For the purposes of assessing the water physicochemical characteristics and assessing the water types, the wells are divided in three groups. Each group represents two wells which are in close geographical proximity within the catchment. In each group, there is one deep and one transition well. The three groups are:

- Group 1: Derg Inlet Works (*n* = 12);
- Group 2: Corgary Trout Hatchery (*n* = 12); and
- Group 3: Derg Lagoons (*n* = 12).

The following are assessed in this section:

- Water chemistry:
  - Major cations and anions, with box plots and interpretation in Section 5.1, and
  - Major and minor (trace) constituents, with box plots and interpretation in Section 5.2;
- Water physiochemistry, via assessment of alkalinity, oxidation reduction potential (ORP) and pH with box plots and interpretation in Section 5.3.1; and
- Water type, by piper diagram assessment of major ions in Section 5.3.2.

## 5.1 Major Cations and Anions

A summary of the concentration pattern of each of the major cations and anions is provided below.

### 5.1.1 Calcium

- Calcium (Ca) concentrations within the Derg catchment range from 10.8 mg/L at Group 2: Corgary Trout Hatchery to 105 mg/L at Group 1: Derg Inlet Works (Figure 2).
- The widest interquartile range occurs at Group 2: Corgary Trout Hatchery while Group 1: Derg Inlet Works displays the narrowest range of values.2
- The interquartile ranges overlap and median concentrations are similar across all three locations.

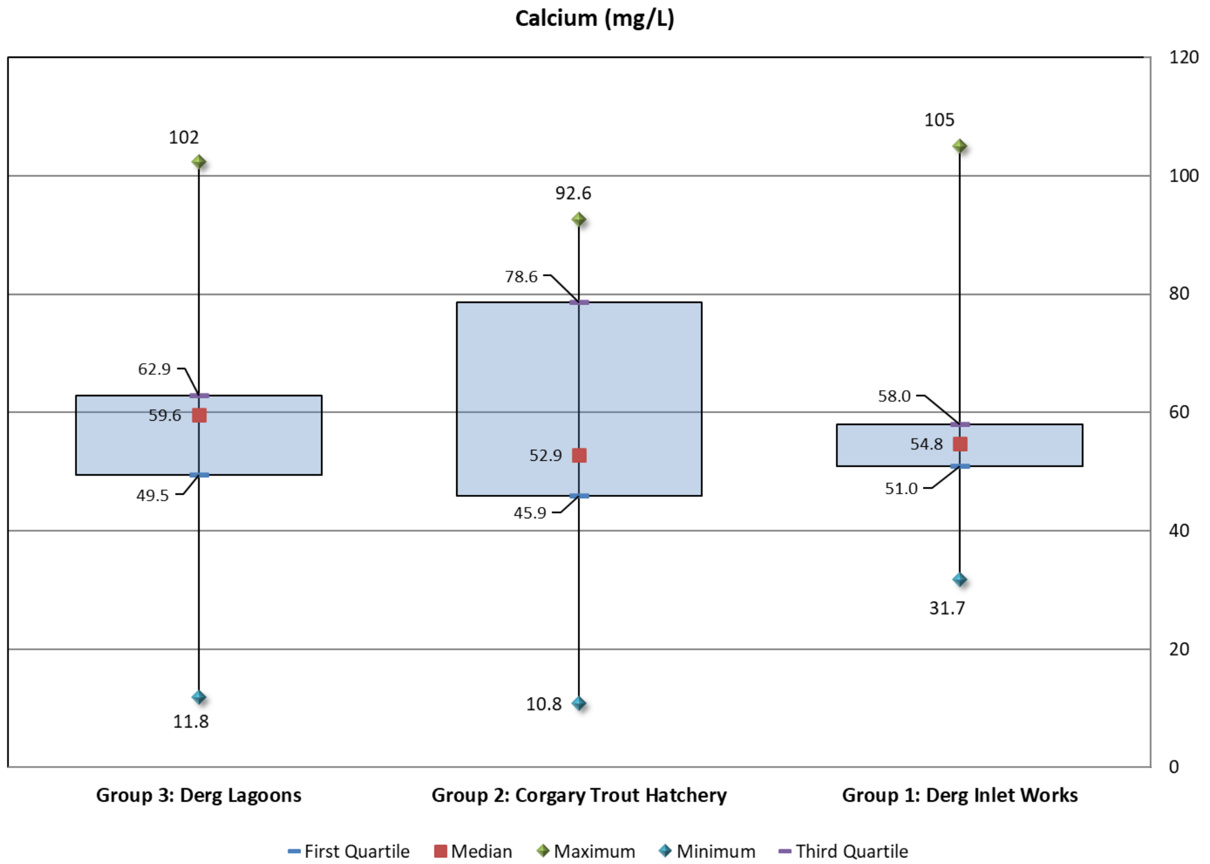


**Figure 2: Calcium (Ca) boxplot, where x-axis is the well group**

## 5.1.2 Magnesium

- Magnesium (Mg) concentrations within the Derg catchment range from 5.25 mg/L at Group 3: Derg Lagoons to 23 mg/L at Group 2: Corgary Trout Hatchery (Figure 3).
- The interquartile ranges overlap and median concentrations are similar across all three locations.

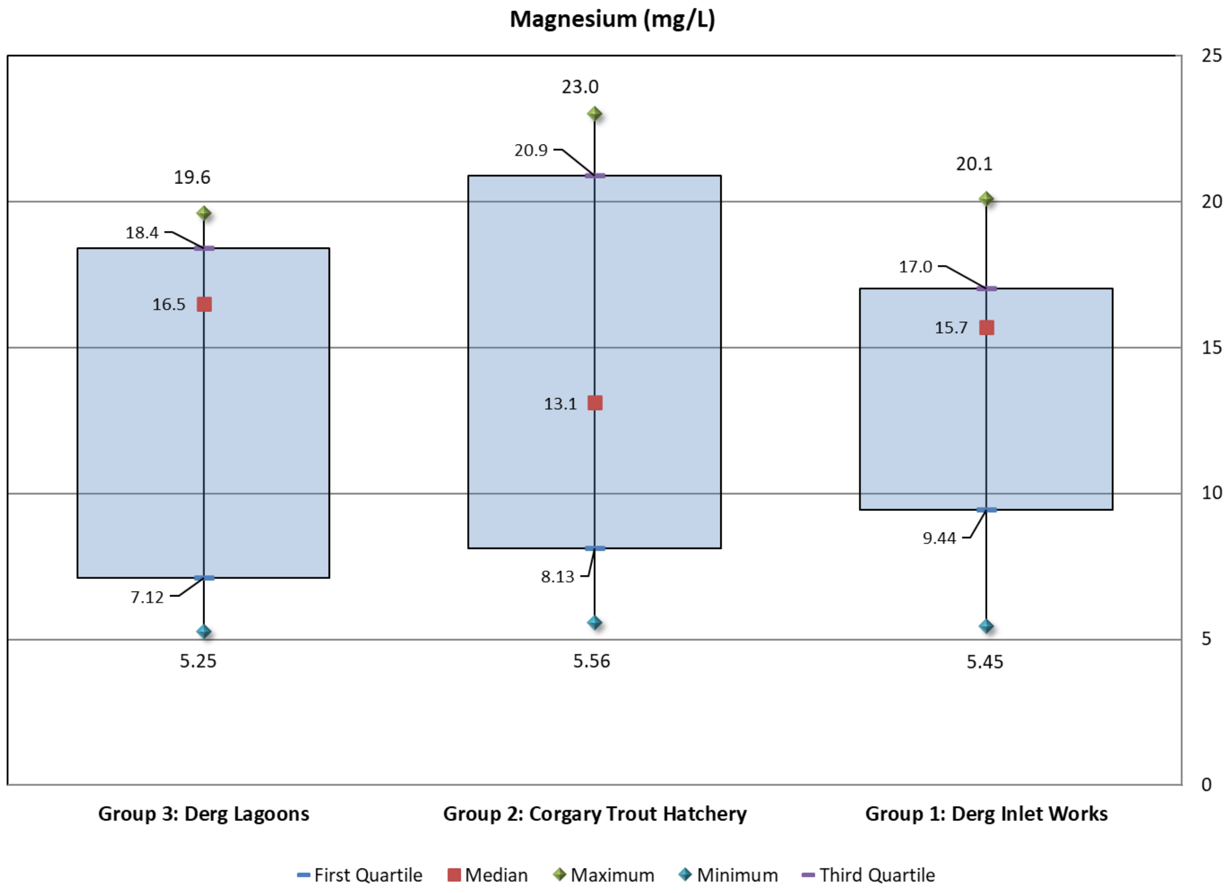


**Figure 3: Magnesium (Mg) boxplot, where x-axis is the well group**

### 5.1.3 Sodium

- Sodium (Na) concentrations within the Derg catchment range from 9.65 mg/L at Group 1: Derg Inlet Works to 78.1 mg/L at Group 3: Derg Lagoons (Figure 4).
- Group 1: Derg Inlet Works has the widest interquartile range of sodium concentrations. The interquartile ranges at the other two locations are similar and relatively narrow.
- The median sodium concentration is similar in all groups and the interquartile ranges overlap.

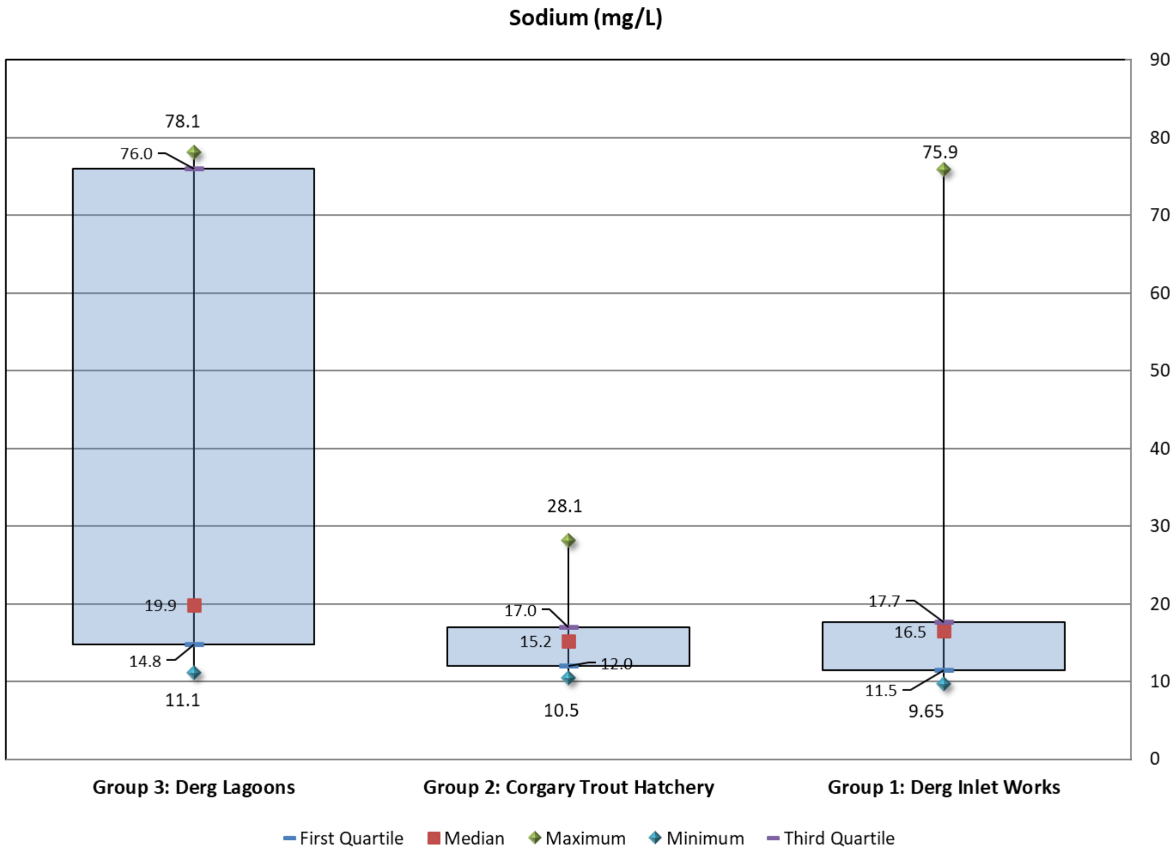


**Figure 4: Sodium (Na) boxplot, where x-axis is the well group**

### 5.1.4 Chloride

- Chloride (Cl) concentrations within the Derg catchment range from 13.4 mg/L at Group 2: Corgary Trout Hatchery to 156 mg/L at Group 1: Derg Inlet Works (Figure 5).
- The interquartile range is relatively narrow and median chloride concentration similar at Group 1: Derg Inlet Works and Group 2: Corgary Trout Hatchery. The interquartile range of chloride concentrations at Group 3: Derg Lagoons is relatively wider.
- Chloride concentrations at Group 1: Derg Inlet Works and Group 2: Corgary Trout Hatchery are similar to each other and distinct from Group 3: Derg Lagoons.

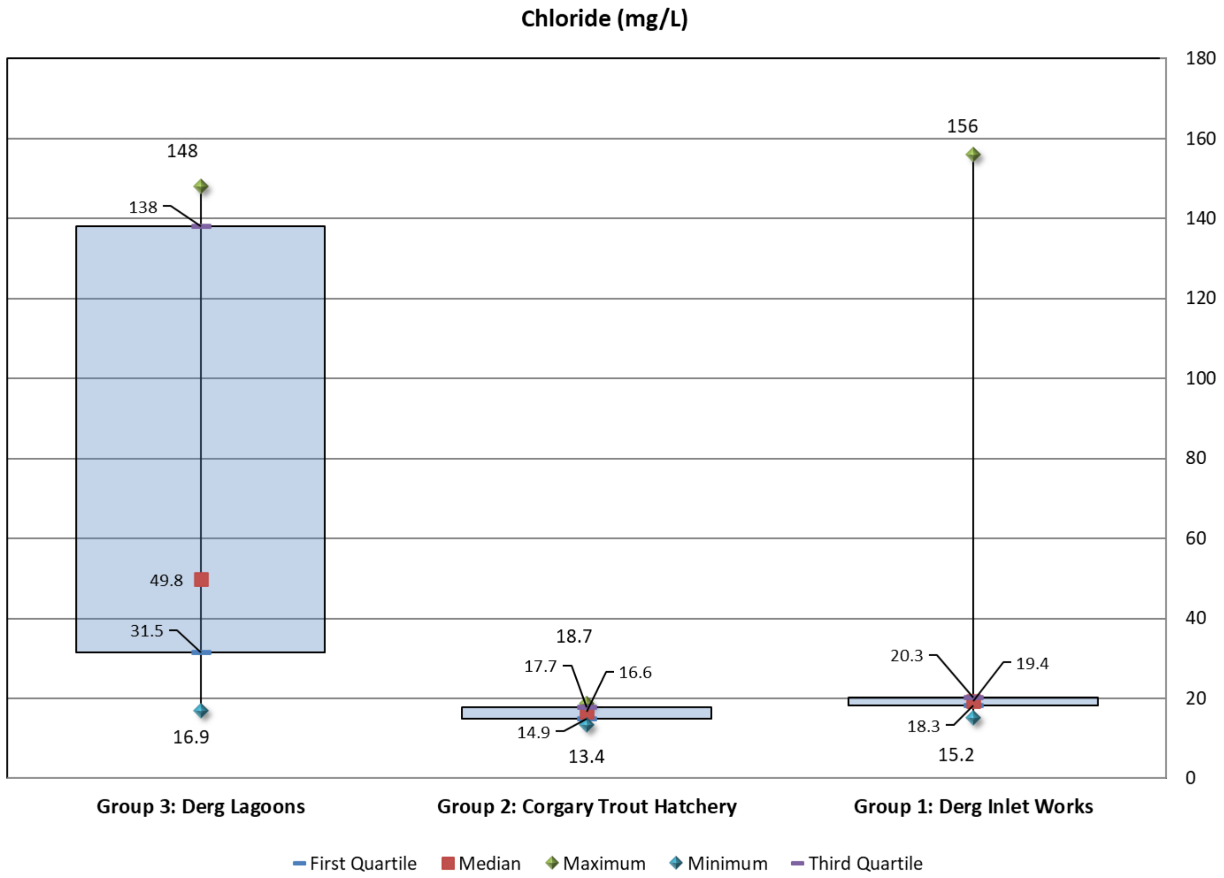


**Figure 5: Chloride (Cl) boxplot, where x-axis is the well group Potassium**

- Potassium (K) concentrations within the Derg catchment range from 0.83 mg/L at Group 1: Derg Inlet Works to 38.2 mg/L at Group 2: Corgary Trout Hatchery (Figure 6).
- The interquartile range of all three locations is distinct (not overlapping). Generally, higher concentrations of potassium are found at Group 3: Derg Lagoons and the lowest potassium concentrations are found at Group 1: Derg Inlet Works.

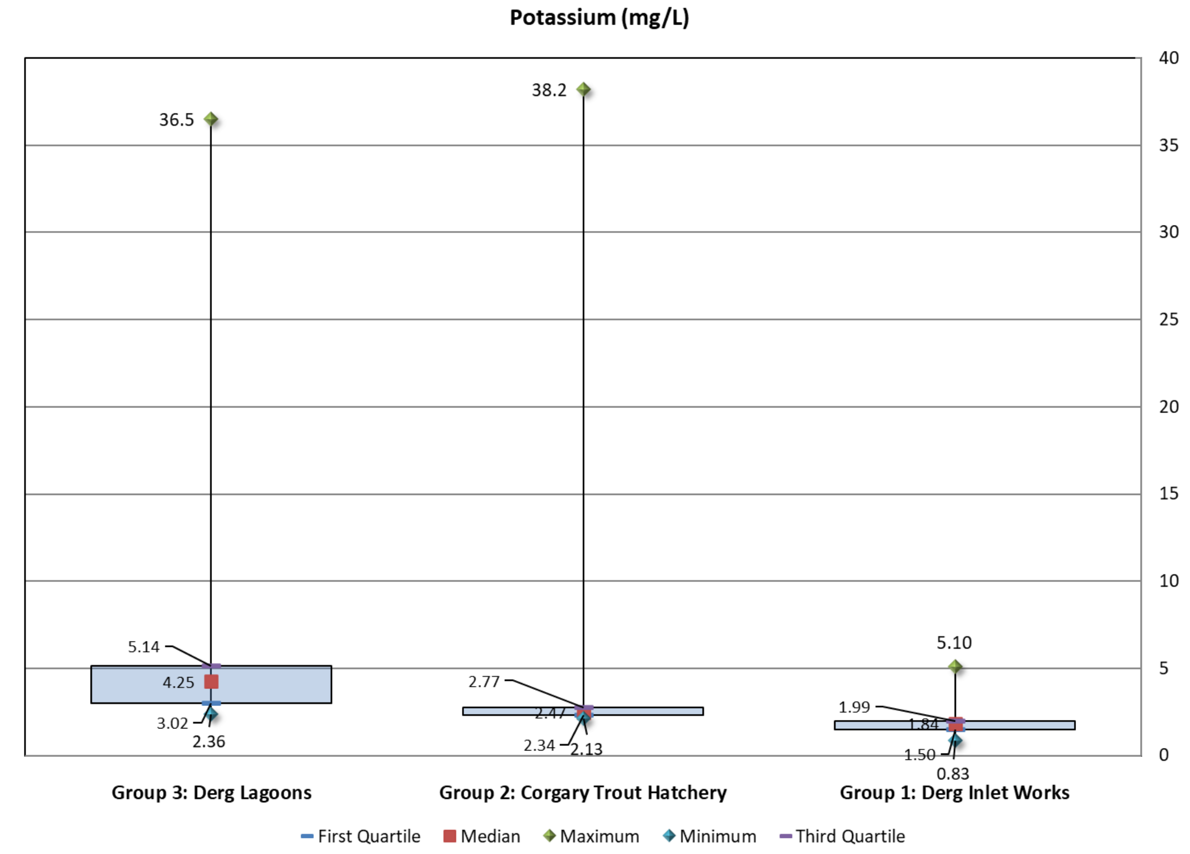


**Figure 6: Potassium (K) boxplot, where x-axis is the well group**

## 5.1.5 Sulphate

- Sulphate ($SO_4$) concentrations within the Derg catchment range from range from <LOD (5 mg/L, included in the graph as 2.5 mg/L) at Group 2: Corgary Trout Hatchery and Group 3: Derg Lagoons to 54.9 mg/L at Group 1: Derg Inlet Works (Figure 7).

- The interquartile range at Group 3: Derg Lagoons is relatively wide, while that at Group 2: Corgary Trout Hatchery is relatively narrow.

- The median concentration and interquartile range at Group 2: Corgary Trout Hatchery is distinct from the other two groups. The interquartile ranges are overlapping and median values similar at Group 1: Derg Inlet Works and Group 3: Derg Lagoons.

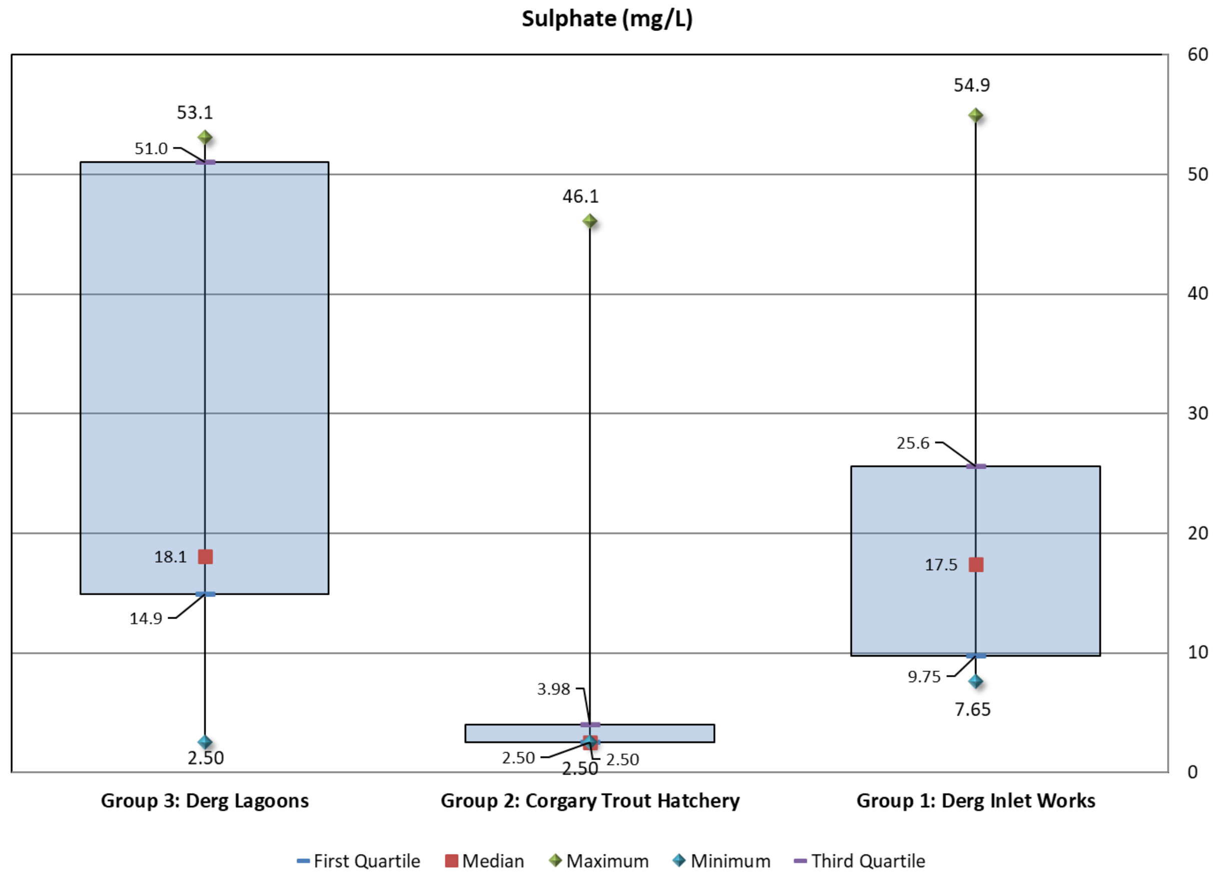


**Figure 7: Sulphate ($SO_4$) boxplot, where x-axis is the well group**

## 5.1.6 Fluoride

- Fluoride (Fl) concentrations within the Derg catchment range from <LOD (0.02 mg/L, included in the graph as 0.01 mg/L) at to 0.34 mg/L at Group 2: Corgary Trout Hatchery (Figure 8).

- The interquartile range and median fluoride concentration of Group 3: Derg Lagoons and Group 1: Derg Lagoons are similar to each other and distinct from the interquartile range and median at Group 2: Corgary Trout Hatchery.

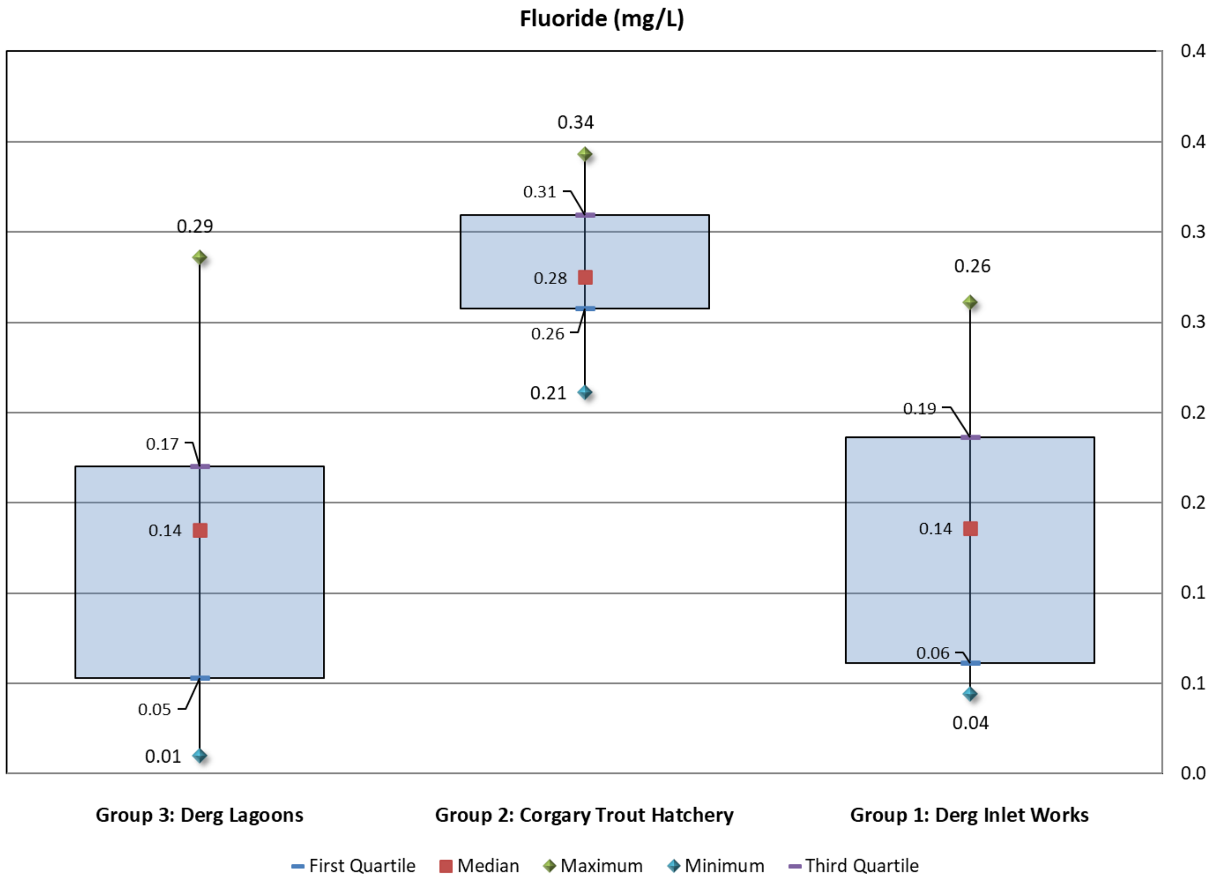


**Figure 8: Fluoride (F) boxplot, where x-axis is the well group**

## 5.1.7 Nitrate ($NO_3$ as N)

- Nitrate ($NO_3$) concentrations within the Derg catchment range from <LOD (0.08 mg/L, included in the graph as 0.04 mg/L) at all groups to 13.6 mg/L at Group 3: Derg Lagoons (Figure 9).

- Consistently low concentrations of nitrate are recorded at Group 2: Corgary Trout Hatchery (normally <LOD).

- The interquartile ranges of nitrate concentrations overlap for Group 1: Derg Inlet Works and Group 3: Derg Lagoons. Generally, higher nitrate concentrations are recorded at Group 1: Derg Inlet Works compared to Group 3: Derg Lagoons.

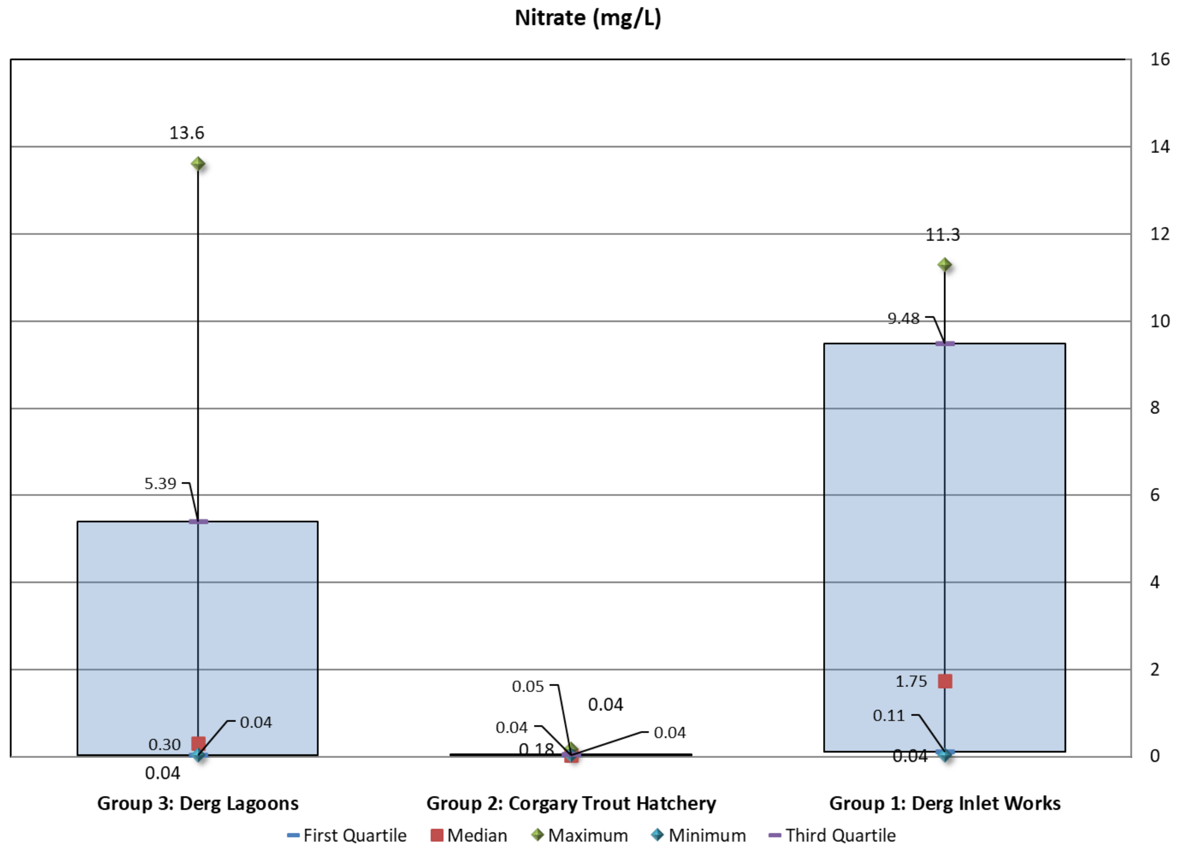


**Figure 9: Nitrate ($NO_3$ as N) boxplot, where x-axis is the well group**

## 5.2 Major and Minor (Trace) Elements

A summary of the concentration patterns of major and minor (trace) elements, for which there were at least three detections, is provided below. The data are grouped based on clusters of wells as previously discussed.

### 5.2.1 Dissolved Iron

- Dissolved iron (Fe) concentrations within the Derg catchment range from <LOD (0.02 mg/L, included in the graph as 0.01 mg/L) at all groups to 16.8 mg/L at Group 2: Corgary Trout Hatchery (Figure 10).
- The interquartile range at all three locations overlap.
- The interquartile range of iron concentration of Group 1: Derg Inlet Works and Group 3: Derg Lagoons are similar.
- Group 2: Corgary Trout Hatchery has the widest interquartile range and generally also the highest iron concentrations.

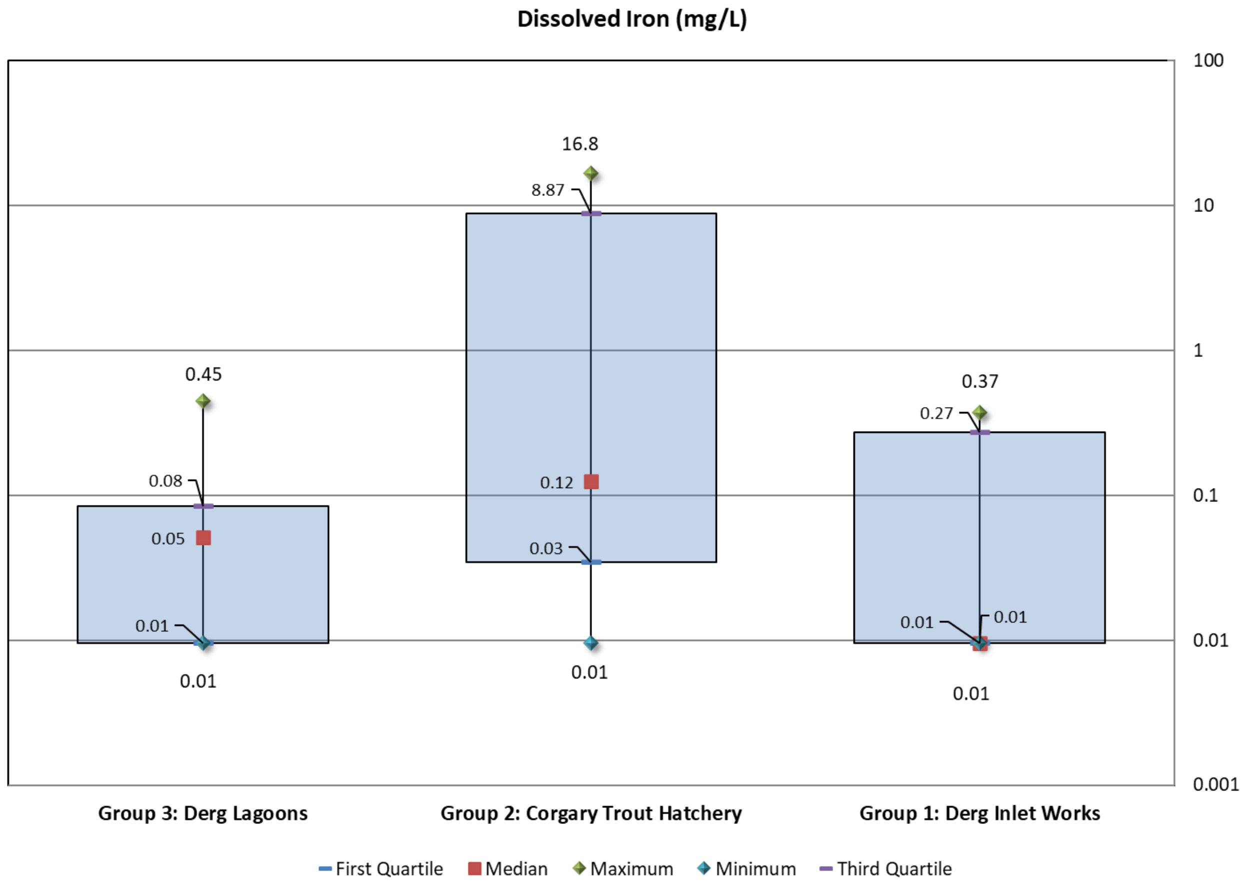


**Figure 10: Dissolved Iron (Fe) boxplot, where x-axis is the well group and log scale y-axis**

### 5.2.2 Dissolved Barium

- Dissolved barium (Ba) concentrations within the Derg catchment range from 11.1 ug/L at Group 2: Corgary Trout Hatchery to 207 ug/L at Group 1: Derg Inlet Works (Figure 11).
- The interquartile range of barium concentrations overlap for Group 1: Derg Inlet Works and Group 3: Derg Lagoons.
- The interquartile range of barium concentrations for Group 2: Corgary Trout Hatchery is distinct to the other two groups (i.e., not overlapping).
- Generally, lower barium concentrations are recorded at Group 2: Corgary Trout Hatchery relative to the other two locations.
- Similar barium concentrations are recorded at Group 1: Derg Inlet Works and Group 3: Derg Lagoons, though concentrations are somewhat higher at the former and lower at the latter.

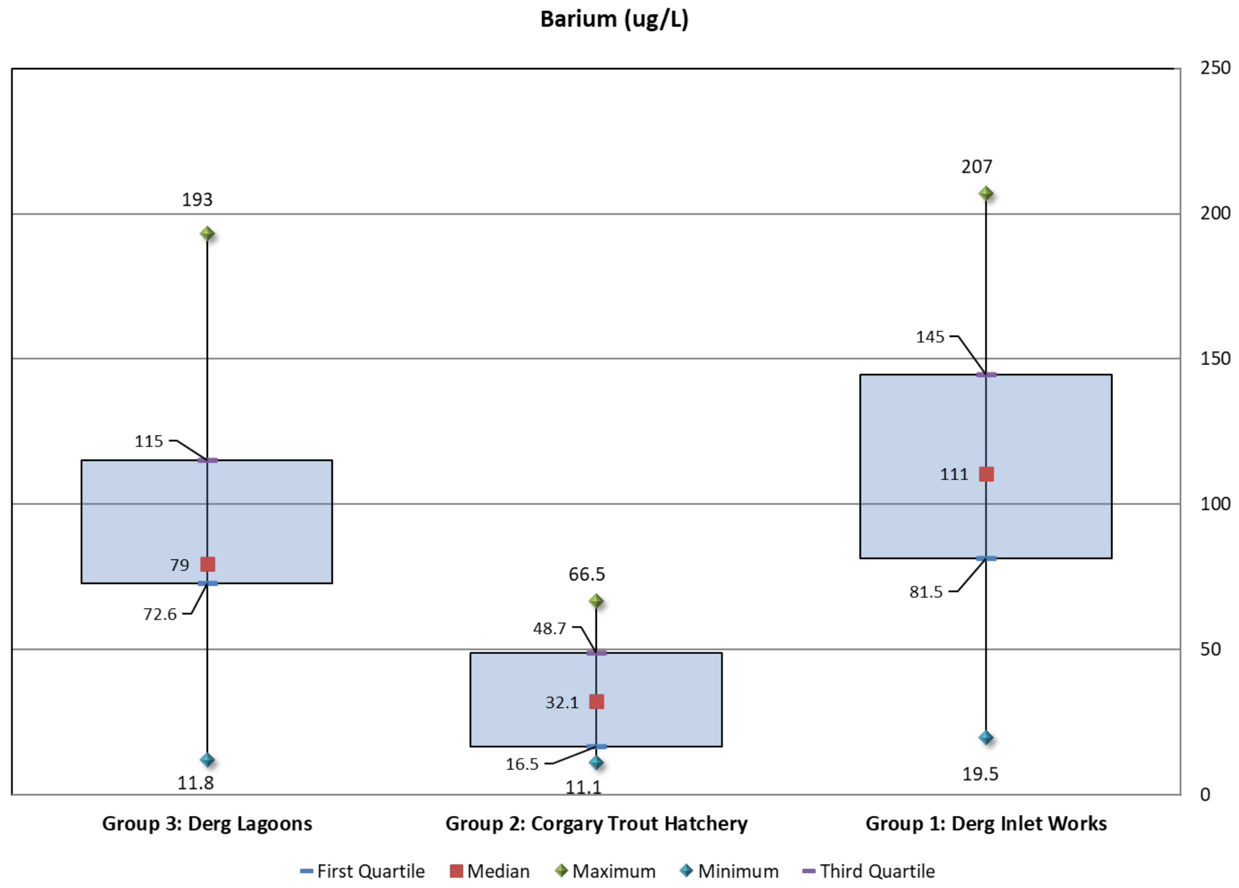


**Figure 11: Barium (Ba) boxplot, where x-axis is the well group**

### 5.2.3 Dissolved Nickel

- Dissolved nickel (Ni) concentrations within the Derg catchment range from <LOD (0.04 ug/L, included in the graph as 0.02 ug/L) at Group 2: Corgary Trout Hatchery and Group 3: Derg Lagoons to 20.9 µg/L at Group 1: Derg Lagoons (Figure 12).
- The widest interquartile range is found at Group 2: Corgary Trout Hatchery. The interquartile ranges at Group 3: Derg Lagoons and Group 1: Derg Lagoons are relatively narrow.
- The interquartile ranges and the median concentrations are distinct, with generally lower nickel concentrations at Group 1: Derg Lagoons and generally higher nickel concentrations at Group 2: Corgary Trout Hatchery.

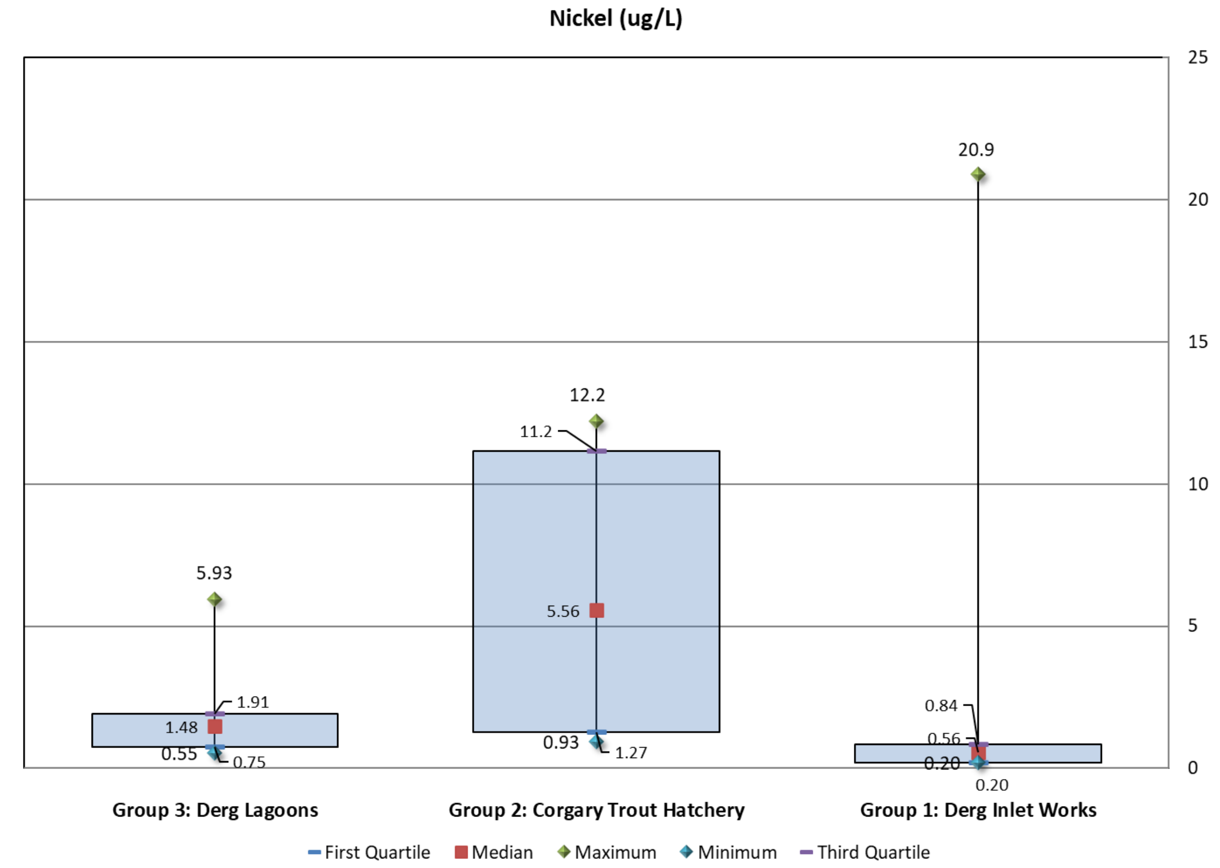


**Figure 12: Nickel (Ni) boxplot, where x-axis is the well group**

### 5.2.4 Dissolved Zinc

- Dissolved zinc (Zn) concentrations within the Derg catchment range from <LOD (1.00 ug/L, included in the graph as 0.50 ug/L) at all locations to 18.7 µg/L at Group 2: Corgary Trout Hatchery (Figure 13).

- The interquartile range of zinc concentrations at Group 2: Corgary Trout Hatchery and Group 3: Derg Lagoons are similar to each other, and both also relatively distinct from the interquartile range of Group 1: Derg Lagoons.

- Generally, higher zinc concentrations are found at Group 1: Derg Lagoons and lower concentrations found at Group 2: Corgary Trout Hatchery and Group 3: Derg Lagoons.

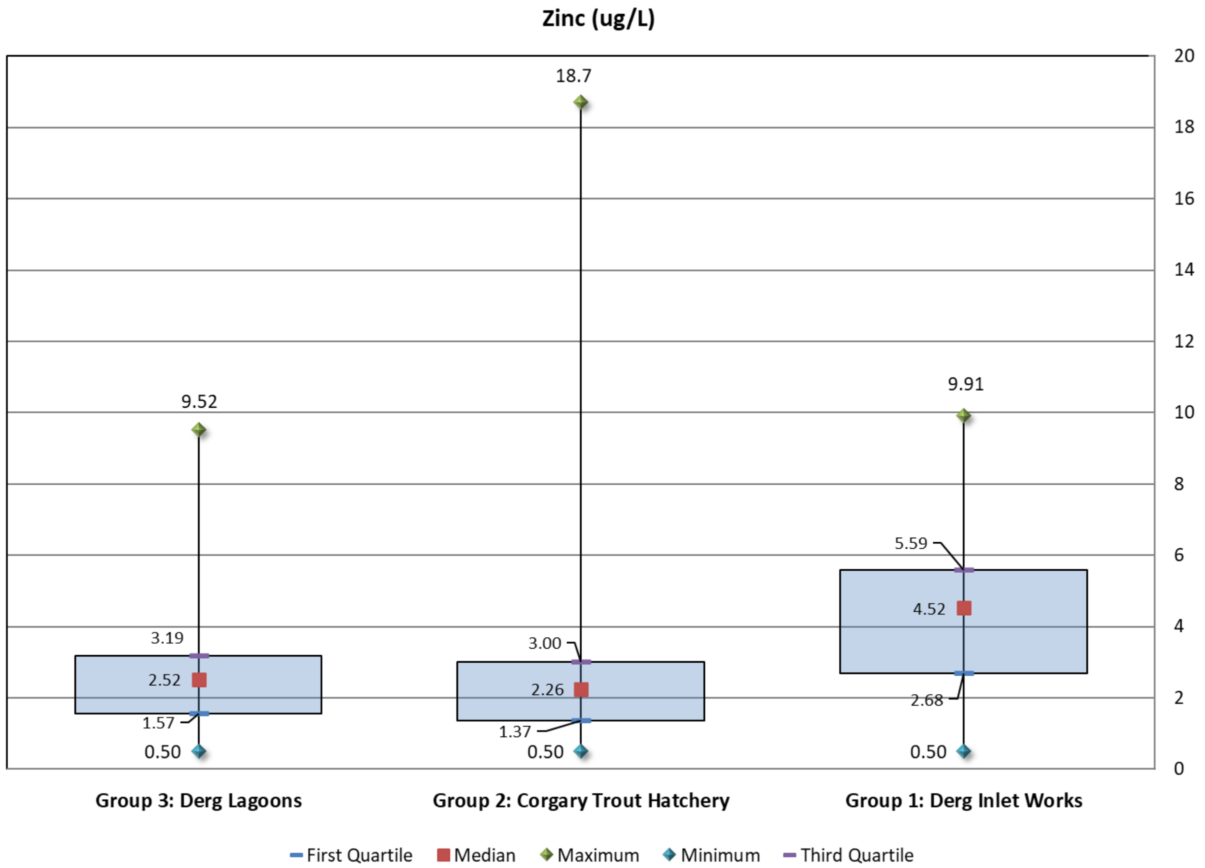


**Figure 13: Zinc (Zn) boxplot, where x-axis is the well group**

### 5.2.5 Dissolved Strontium

- Strontium (Sr) concentrations within the Derg catchment range from 17.9 ug/L at Group 1: Derg Inlet Works to 488 ug/L at Group 3: Derg Lagoons (Figure 14).
- The interquartile ranges at all three locations overlap.

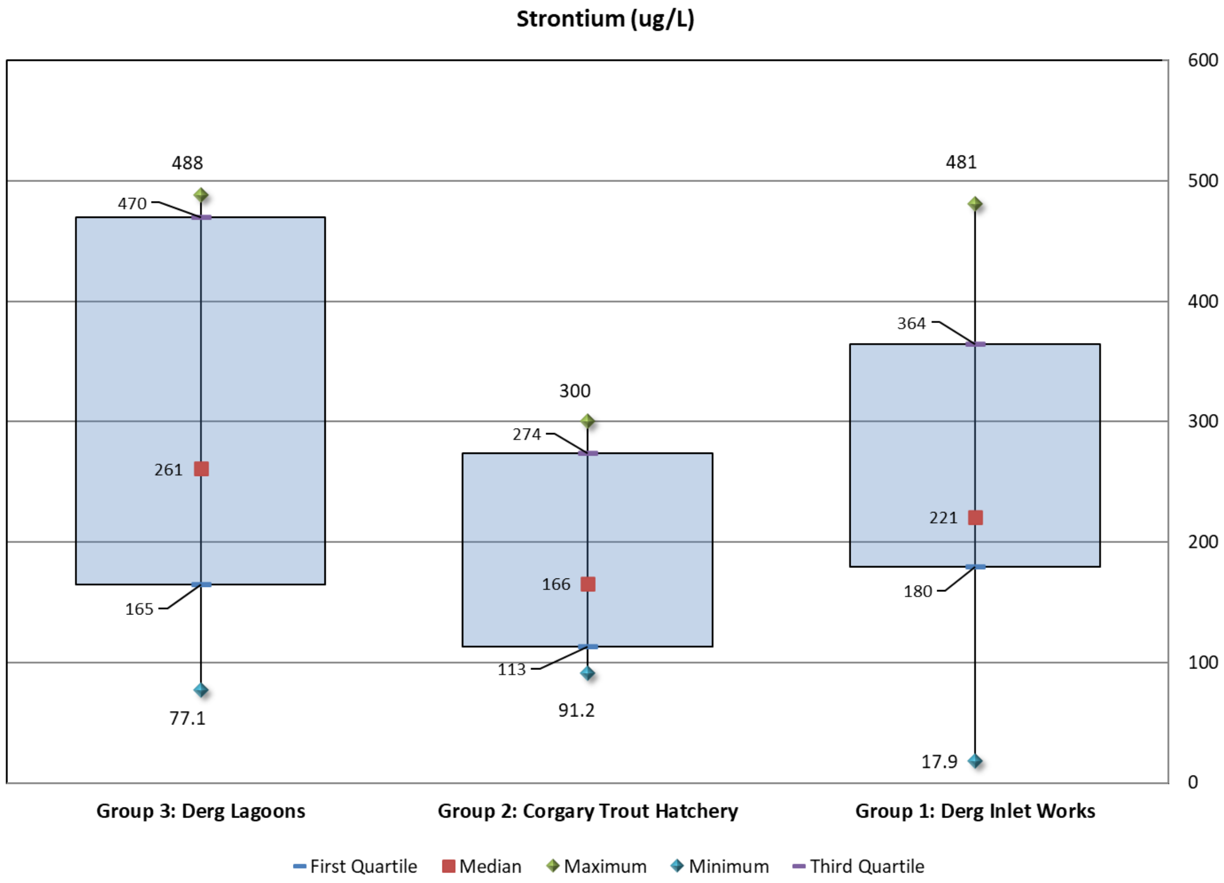


**Figure 14: Strontium (Sr) boxplot, where x-axis is the well group**

## 5.2.6 Dissolved Manganese

- Manganese (Mn) concentrations within the Derg catchment range from <LOD (3 ug/L, included in the graph as 1.5 ug/L) at Group 1: Derg Inlet Works to 4,000 µg/L at Group 2: Corgary Trout Hatchery (Figure 15).
- The interquartile ranges of all three locations are distinct (not overlapping).
- Generally, higher concentrations of dissolved manganese are recorded in samples from wells in Group 2: Corgary Trout Hatchery followed by Group 3: Derg Lagoons, and lower concentrations are recorded in samples from wells in Group 1: Derg Inlet Works.
- Samples from wells in Group 1: Derg Inlet Works had the widest range of manganese concentrations, while Group 3: Derg Lagoons had the narrowest interquartile range.

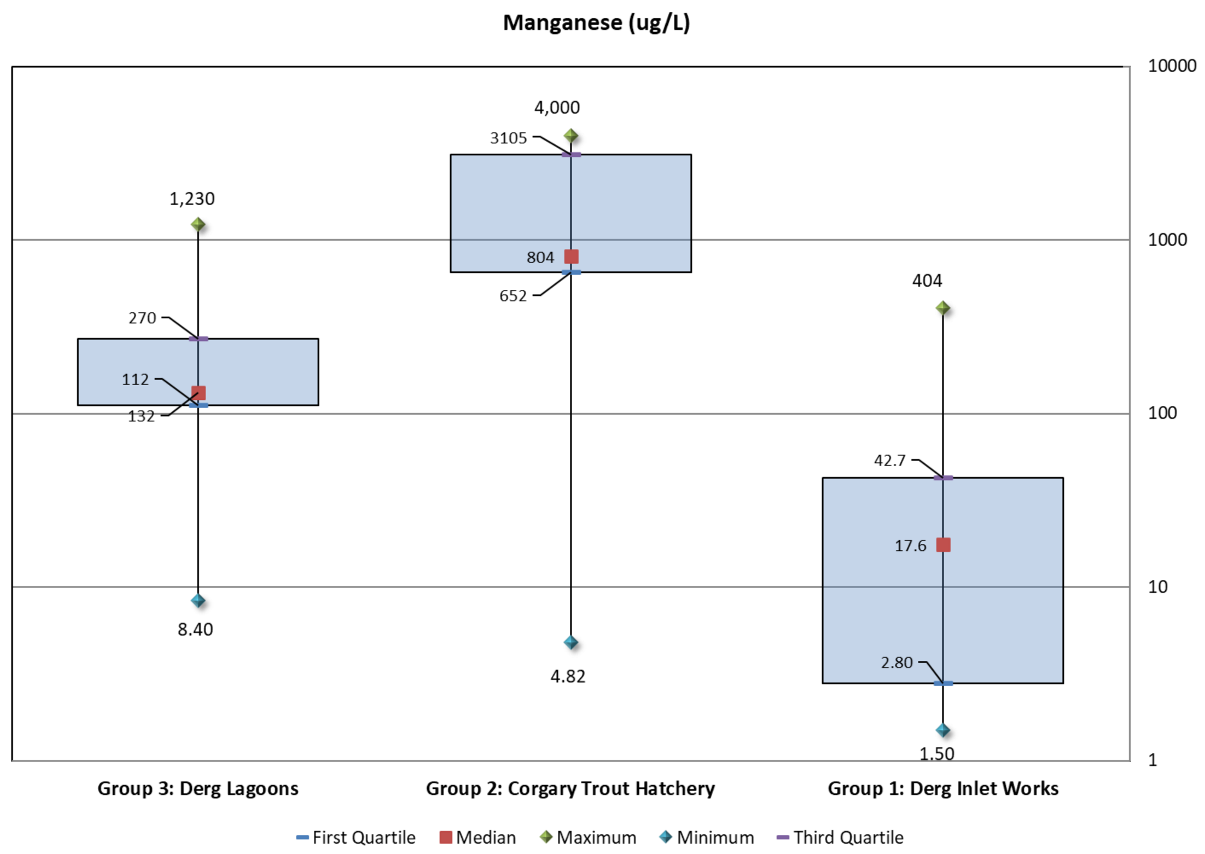


**Figure 15: Manganese (Mn) boxplot, where x-axis is the well group and y-axis is log scale**

### 5.2.7 Dissolved Lithium

- Dissolved lithium (Li) concentrations within the Derg catchment range from <LOD (1 ug/L, included in the graph as 0.50 ug/L) at all groups to 85.3 ug/L at Group 2: Corgary Trout Hatchery (Figure 16).
- The interquartile range of all three locations overlap.
- Generally, higher concentrations of dissolved lithium are recorded at Group 3: Derg Lagoons and lower concentrations at Group 2: Corgary Trout Hatchery.

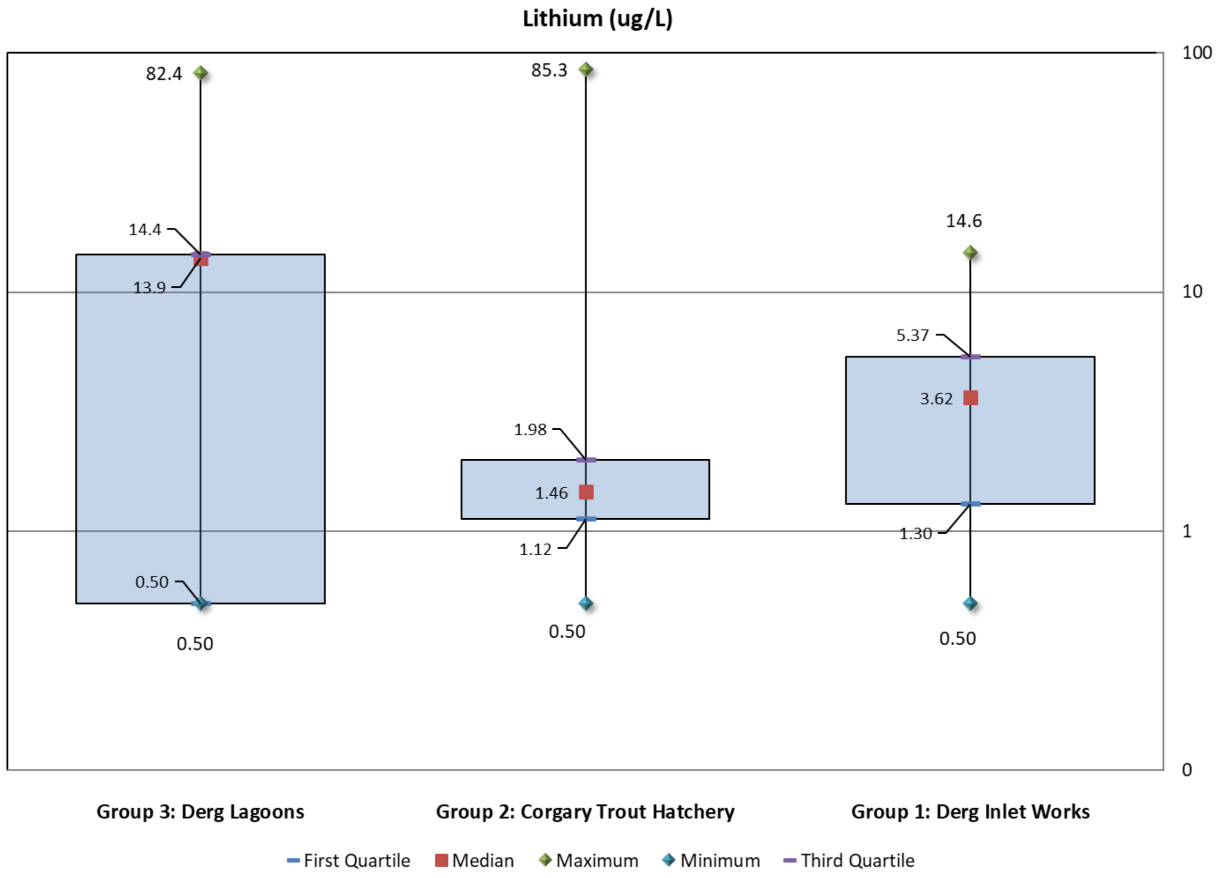


**Figure 16: Lithium (Li) boxplot, where x-axis is the well group, and log scale y-axis**

### 5.2.8 Dissolved Uranium

- Dissolved uranium (U) concentrations within the Derg catchment range from <LOD (0.50 ug/L, included in the graph as 0.25 ug/L) at all groups to 10.2 ug/L at Group 1: Derg Inlet Works (Figure 16).
- The interquartile ranges at all three locations overlap. Generally, higher uranium concentrations are found at Group 1: Derg Inlet Works and lower concentrations at Group 3: Der Lagoons.

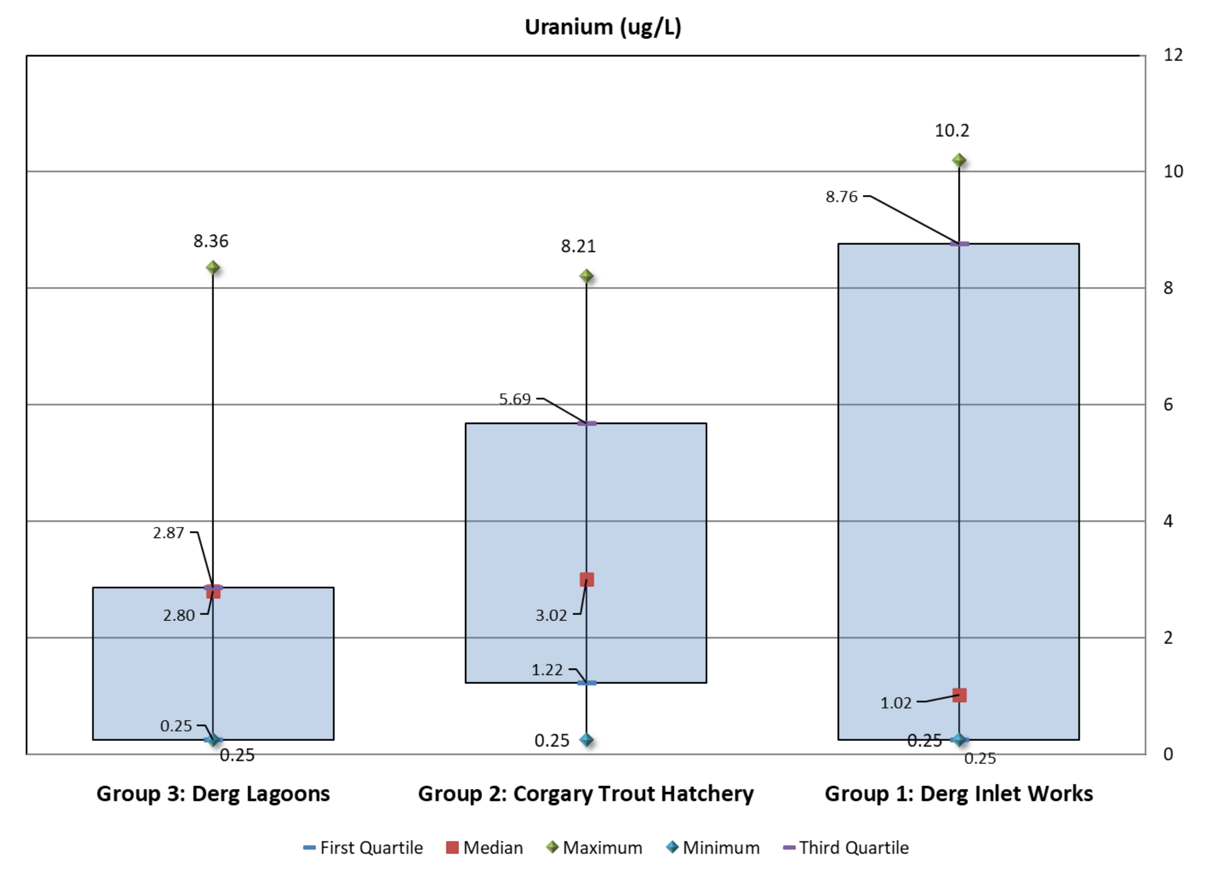


**Figure 17: Uranium (U) boxplot, where x-axis is the well group**

## 5.3 Physicochemical Characteristics and Water Types

### 5.3.1 Water physiochemistry: Alkalinity, Oxidation-Reduction Potential (ORP) & pH

A summary of water chemistry parameters alkalinity, pH and oxidation reduction potential (ORP) are presented below.

#### Alkalinity (Bicarbonate a $CaCO_3$)

- The alkalinity within the Derg catchment range from 70.6 mg/L at Group 1: Derg Inlet Works to 290 mg/L at Group 2: Corgary Trout Hatchery (Figure 18).
- Generally, higher alkalinities are recorded in wells at Group 2: Corgary Trout Hatchery and lower alkalinities are recorded in wells at Group 3: Derg Lagoons.
- The interquartile ranges at Group 2: Corgary Trout Hatchery and Group 3: Derg Lagoons are distinct (i.e., not overlapping). The interquartile range of Group 1: Derg Inlet Works overlaps the interquartile range of both other locations.

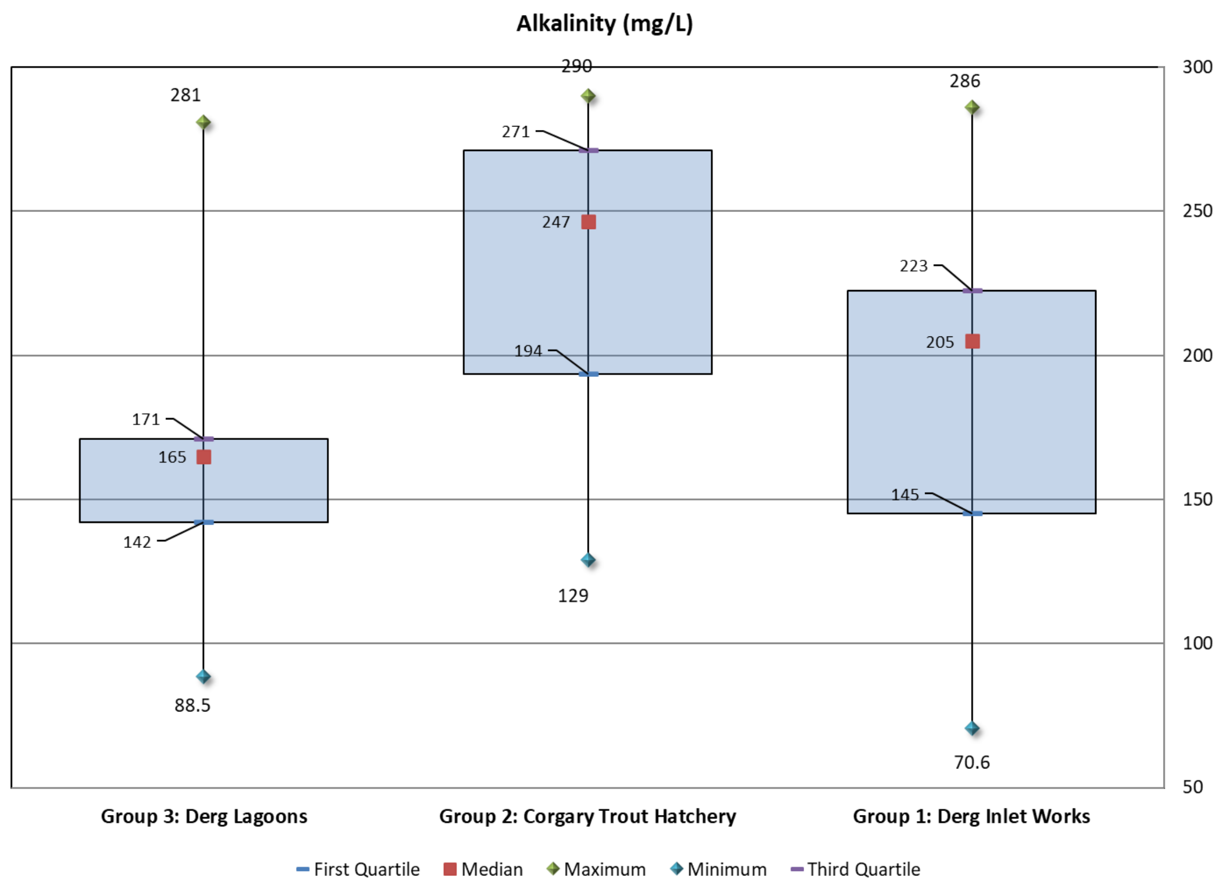


**Figure 18: Alkalinity (Bicarbonate as $CaCO_3$) boxplot, where x-axis is the well group**

## Oxidation-Reduction Potential (ORP)

- The ORP within the Derg catchment ranged from -498 mV to 164 at Group 2: Corgary Trout Hatchery (Figure 19).
- The interquartile ranges at all three locations overlap and have similar median ORP values (ranging from -202 mV at Group 3: Derg Lagoons to -268 mV at Group 1: Derg Inlet Lagoons). The interquartile ranges of at all three locations are negative. This indicates generally reducing conditions at all three locations.

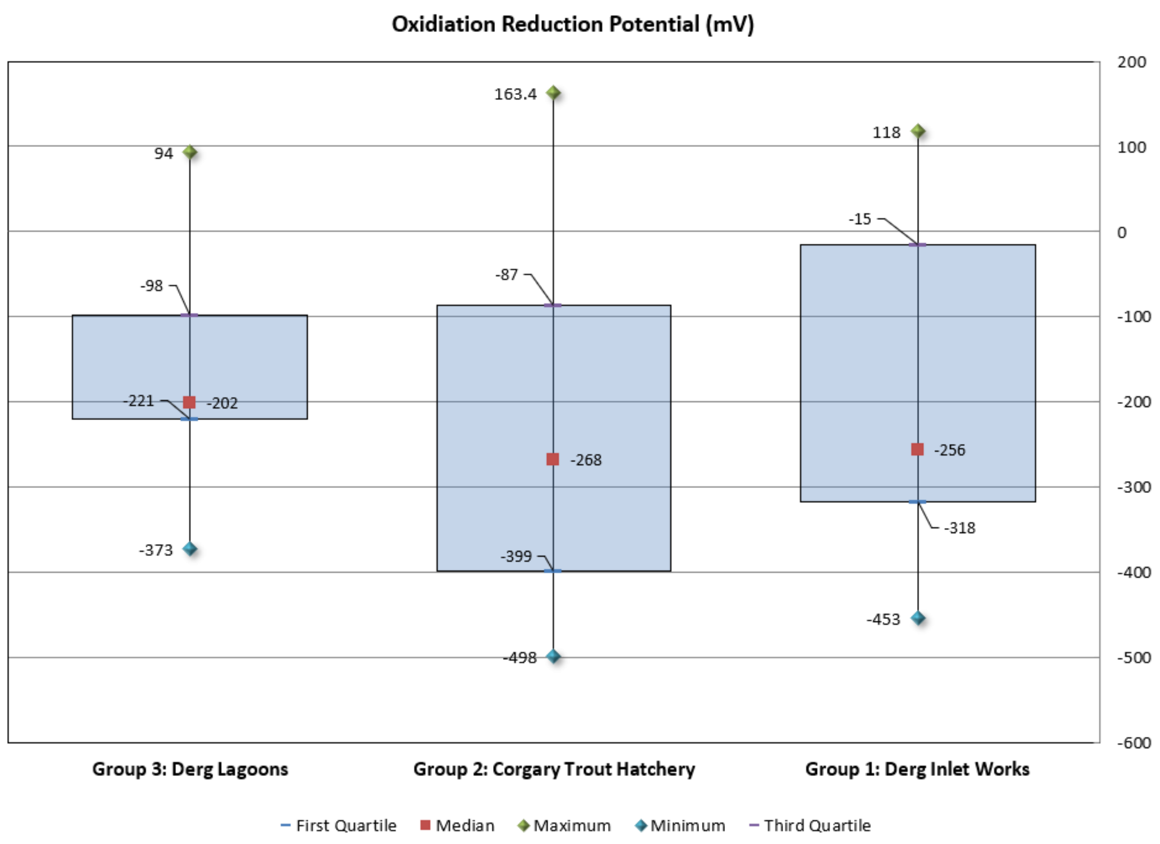


**Figure 19 Oxidation Reduction Potential (ORP) boxplot, where x-axis is the well group**

## pH

- The highest pH value is recorded at Group 2: Corgary Trout Hatchery (at 8.93) and the lowest pH is recorded at Group 3: Derg Lagoons (at 6.11) (Figure 20).
- The pH interquartile ranges overlap and are similar across all three groups.

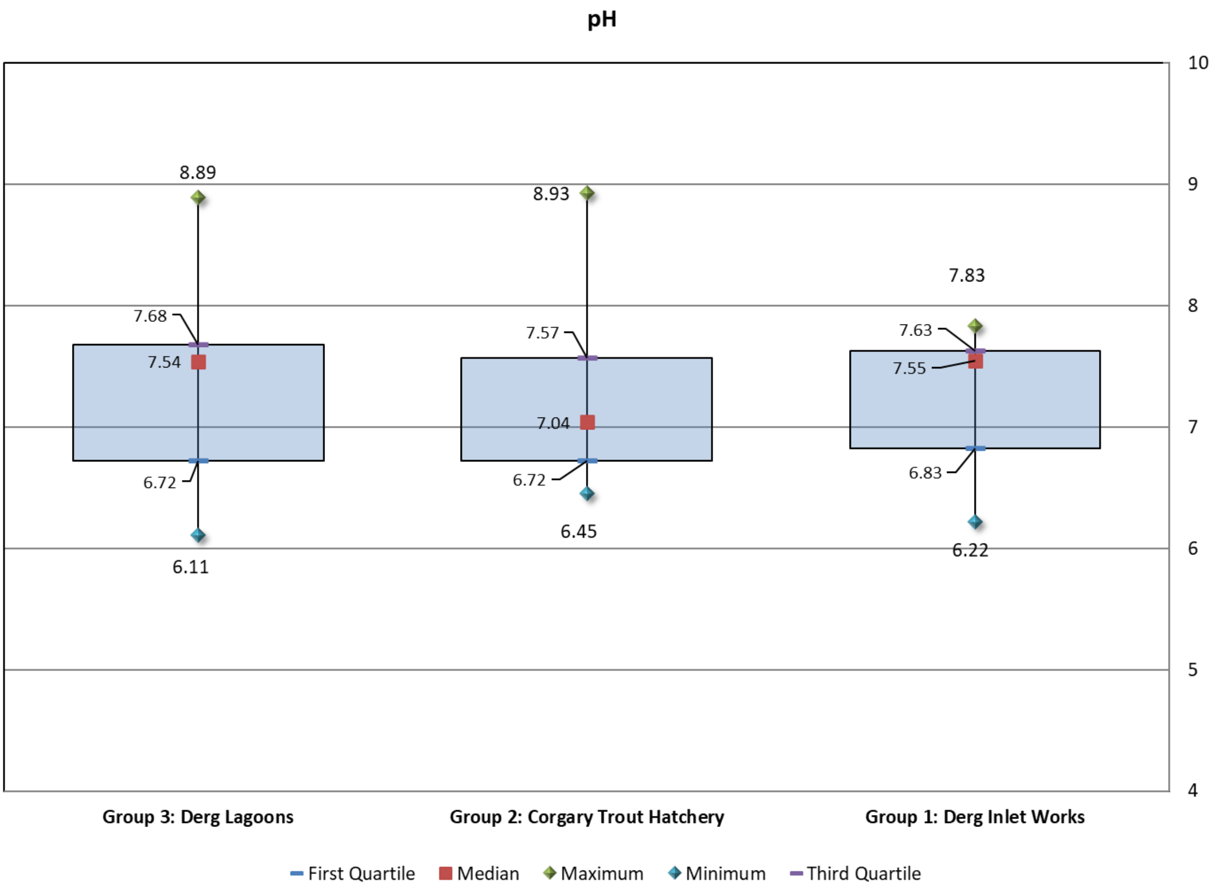


**Figure 20: pH boxplot, where x-axis is the well group**

## 5.3.2 Water Type

Piper diagrams are used to determine water type within the catchment. An illustration of the interpretation of piper diagrams is presented in Figure 21. Piper diagrams are used to determine the water type in the Derg catchment (


Figure 22) and in each cluster of wells within the catchment (

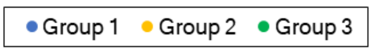


Figure 23).

The groundwater in the Derg catchment is predominantly Ca-Mg-$HCO_3$ type, with a small number of samples plotting as “mixed type” (

Figure 22).

Groundwaters at Group 1: Derg Inlet Works is Ca-Mg-$HCO_3^-$ type with a few plotting on the mixed water type. Groundwater Group 2: Corgary Trout Hatchery is largely Na-$HCO_3^-$ with a few samples plotting as mixed water type and non-dominant type. Group 3: Derg Lagoon groundwater is predominantly Ca-Mg-$HCO_3^-$ type (


Figure 23).

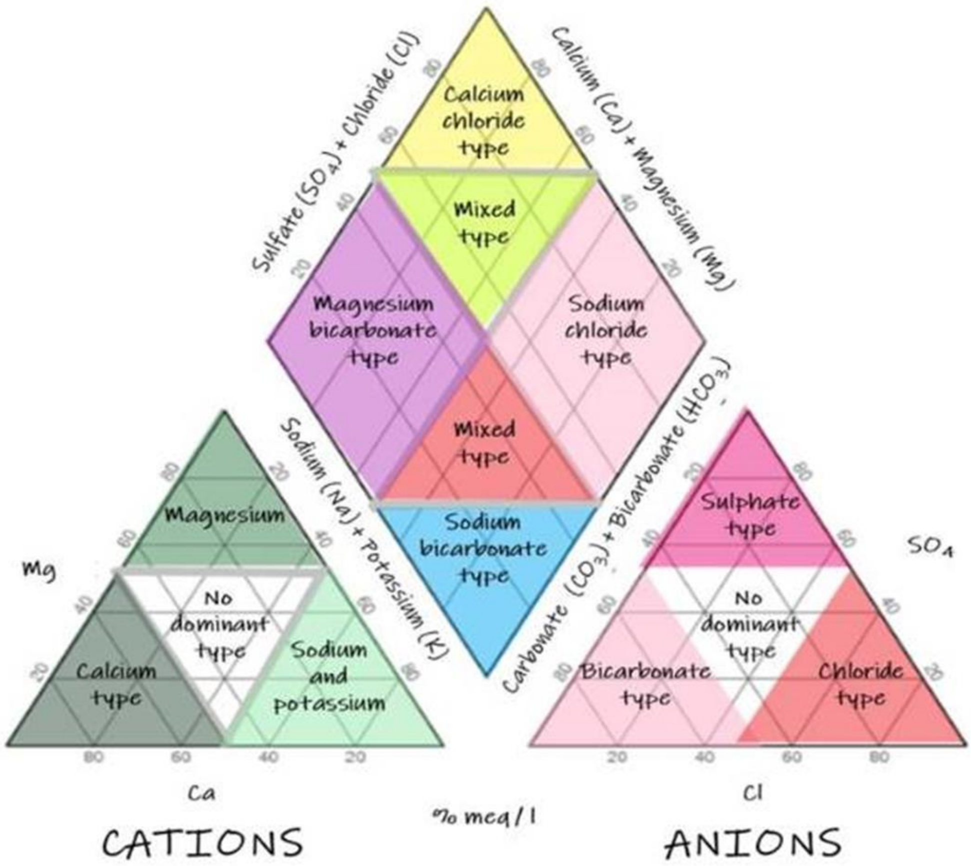


**Figure 21 Piper Diagram Interpretation**

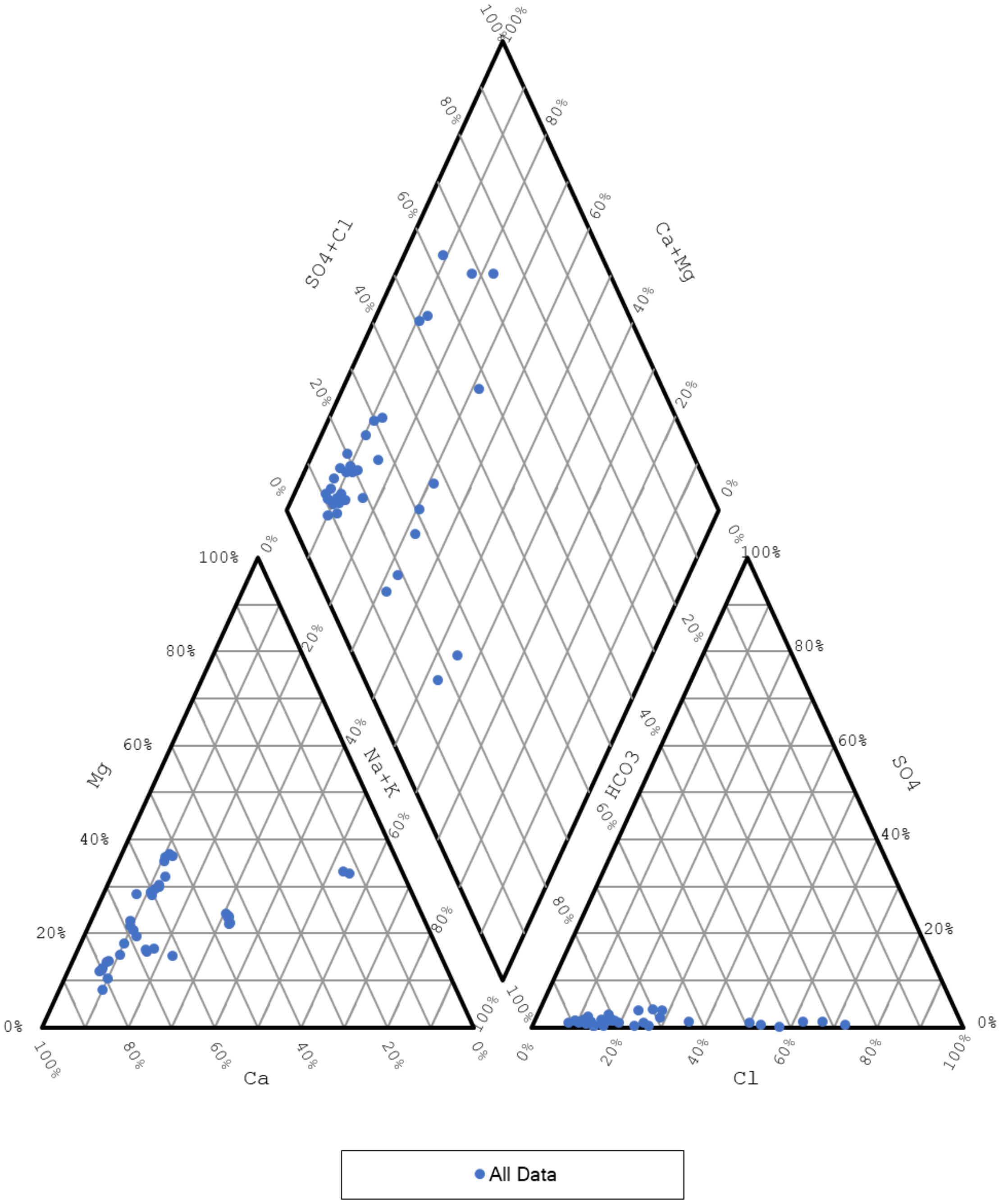


**Figure 22: Piper diagram of all samples**

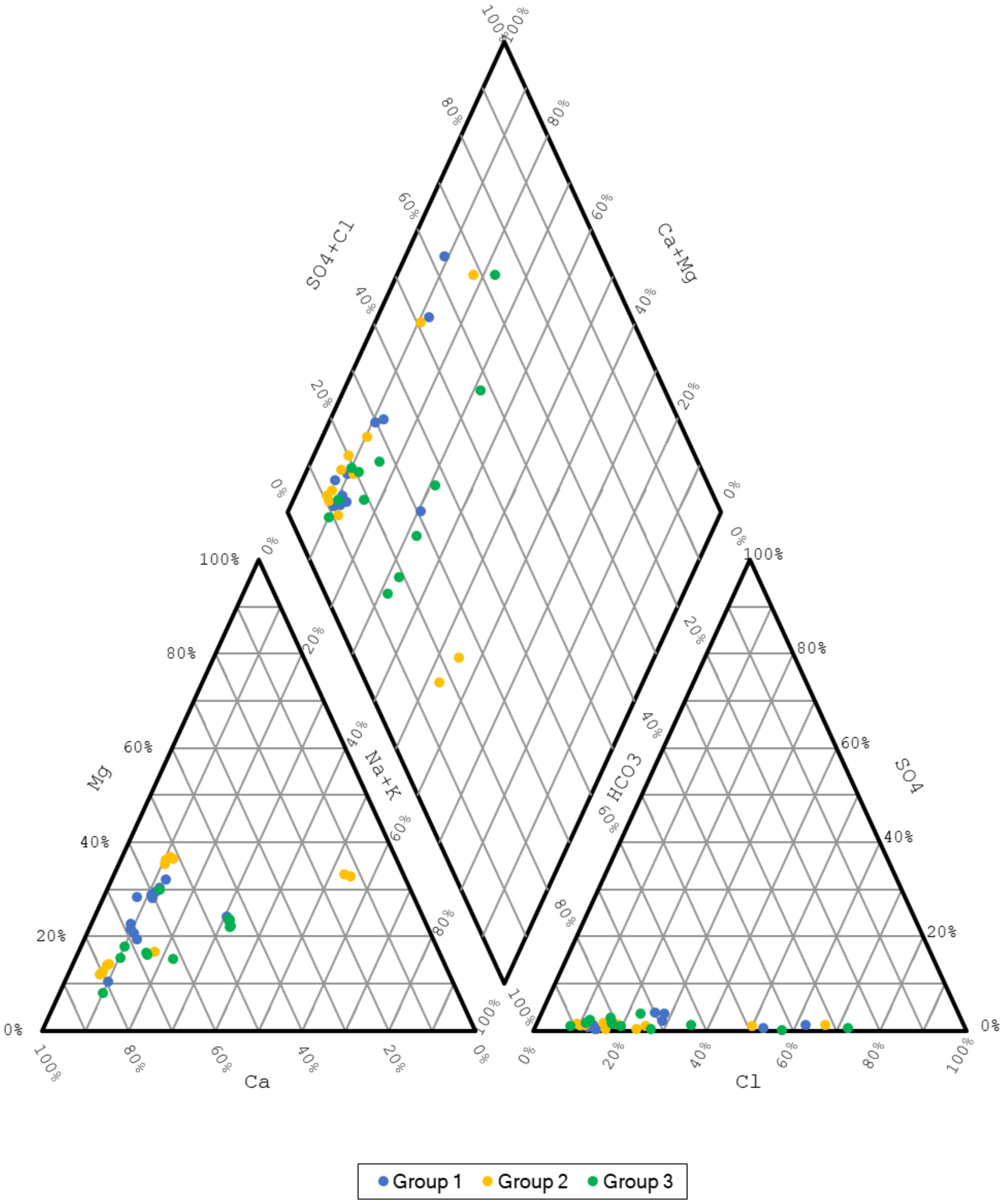


**Figure 23: Piper diagram for the grouped wells, where Group 1: Derg Inlet Works, Group 2: Corgary Trout Hatchery & Group 3: Derg Lagoon**

## 5.4 Organic and Microbial Parameters

A number of organic parameters and microbial parameters were monitored as pollution indicator parameters. These included pesticides and herbicides.

### 5.4.1 Organic parameters

Organic parameters were monitored at all six wells during Round 1 (November 2020). The wells were monitored for 81 organic parameters, including pesticides and insecticides, including MCPA (at LOD <0.1 µg/l). There were no detections of any organic parameter at any well.

### 5.4.2 Microbial parameters

Microbial parameters (total coliforms, *E. Coli* and *Clostridium perfringens*) were monitored during Round 6 (August 2022) in the three transition wells in the catchment;

- CCD08 (Derg Inlet Work - Transition);
- CCD05 (Derg Lagoons - Transition); and
- CCD03 (Corgary Trout Hatch - Transition).

Microbial parameters were not detected at CCD08 (Derg Inlet Work - Transition).

Total coliforms and *E. coli* were detected at CCD05 (Derg Lagoons – Transition) (>80 cfu/100ml and 36 cfu/100ml, respectively) and CCD03 (Corgary Trout Hatch - Transition) (69 cfu/100ml and 39 cfu/100ml), respectively. This indicates domestic wastewater treatment systems (human waste) or agricultural practices (animal waste) may be a pressure on transition groundwater at these locations. *Clostridium perfringens* was not detected in either well.

# Section 6 Summary and Recommendations

## 6.1 Water Type

The groundwater in the Derg catchment is predominantly Ca-Mg-$HCO_3$ type, with a small number of samples plotting as “mixed type” (


Figure 22).

Groundwaters at Group 1: Derg Inlet Works is Ca-Mg-$HCO_3^-$ type with a few plotting on the mixed water type. Groundwater Group 2: Corgary Trout Hatchery is largely Na-$HCO_3^-$ with a few samples plotting as mixed water type and non-dominant type. Group 3: Derg Lagoon groundwater is predominantly Ca-Mg-$HCO_3^-$ type (


Figure 23).

## 6.2 Exceedances, Pressures & Pollution Indicators

Landuse in the east of the catchment is principally agricultural pastures, with some areas of natural vegetation and some discontinuous urban fabrics (Corine Landcover 2018). Peat bogs, coniferous forest and mixed forests become prevalent to the west of the catchment.

There were exceedances of the respective WQS threshold for the physicochemical parameters, and major and minor elements:

- Ammonia as N (exceedance no. 8, or 20 %);
- Potassium (K) (exceedance no. 6, or 17 %);
- Specific electrical conductivity (SEC) (exceedance no. 6, or 17 %); and,
- pH (exceedance no. 6, or 17 %).

There were exceedances of the respective WQS thresholds for the metals (trace elements):

- Manganese (Mn) (exceedance no. 22 or 61 %);
- Arsenic (As) (exceedance no. 16, or 44 %);
- Barium (Ba) (exceedance no. 12, or 33 %);
- Iron (Fe) (exceedance no. 10, or 28 %);

- Uranium (U) (exceedance no. 3, or 8 %);
- Cadmium (Cd) (exceedance no. 1, or 3%); and
- Nickel (Ni) (exceedance no. 1, or 3 %).

The locations of the exceedances of WQS thresholds are outlined in Table 6. Yellow fill indicates only one exceedance of the relative threshold and orange fill indicates more than one exceedance.

Some of these elevated concentrations may relate to aquifer hydrochemistry (e.g., barium) and others may relate to catchment land use practices (e.g., ammonia).

Potassium, iron and barium bearing minerals are common in the bedrock geology across the catchment (

Table 1). Potassium is also be found in synthetic fertilizer.

The elevated uranium and nickel at Group 1: Derg Inlet Lagoons, cadmium at Group 3: Derg Lagoons and elevated arsenic and low pH values across all locations may be due to the presence of sedimentary rock and graphitic minerals.

The elevated specific electrical conductivity at Group 1: Derg Inlet Works and Group 3: Derg Lagoons may be an artifact of recent construction or may be due to an anthropogenic pressure.

Manganese is mobilized from minerals under reducing conditions. The oxidation-reduction potential indicates generally reducing conditions at all locations.

Elevated ammonia (a nutrient pollution parameter) was recorded at Group 2: Corgary Trout Hatchery and Group 3: Derg Lagoons. Given the predominantly agricultural landuse, this may be derived from agricultural practices, as well as bog leachate.

**Table 6 Exceedances of WQS parameters relative to well group/well location**

| Parameter | Manganese | pH | Arsenic | Iron | Potassium | Barium | Ammonia as N | Specific EC | Uranium | Cadmium | Nickel |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Group 1: Derg Inlet Works | | | | | | | | | | | |
| Group 2: Corgary Trout Hatchery | | | | | | | | | | | |
| Group 3: Derg Lagoons | | | | | | | | | | | |

There were no detections of any organic parameter at any location (including MCPA analysed at LOD < 0.01 µg/l).

Total coliforms and *E. coli* were detected in the transition well at Group 2: Corgary Trout Hatchery and Group 3: Derg Lagoons when monitored during Round 6 (August 2022). Microbial parameters were not detected in the shallow well at Group 1: Derg Inlet Works. This indicates human or animal waste may be a pressure on shallow groundwater in this catchment.

The data indicate that anthropogenic pressure(s) may be impacting the groundwater, particularly at Group 2: Corgary Trout Hatchery and Group 3: Derg Lagoons. Given the landuse and the data, agricultural practices and/or domestic waste water treatment systems may be (among) the pressures.

It should be noted that these conclusions are based on a relatively small dataset. Additional monitoring should take place to carry out further assessments and determine/confirm any pressures on the groundwater bodies.

## 6.3 Recommendations

It is recommended that monitoring is continued to develop a robust baseline dataset and to assess and characterize the pressures on the groundwater bodies, where they exist, particularly at locations Corgary Trout Hatchery and Derg Lagoons. This programme should be guided by the results of this project and include at a minimum the parameters that indicate anthropogenic pressures for which there were exceedances/detections.

It is recommended that analysis of microbial parameters be continued and extended at Corgary Trout Hatchery and Derg Lagoons to determine the extent, source and pattern of microbial inputs.

It is recommended that further assessments be carried out to provide insight on the potential sources of anthropogenic contamination (i.e., pressures). This might include assessments of phosphorus and nitrogen species (ammonia, nitrate, nitrite) concentrations relative to background values to assess the impact of agricultural practices. Other assessments might consider further the total organic carbon and total dissolved solids, as well as the ratios of chloride to bicarbonate, sodium to calcium and sulfate to bicarbonate.

Further work might include better definitions of individual wells and probability plots or other statistical methods to develop background values when a larger dataset is available.

# Section 7 References

*Corine Landcover 2018.* Available at: https://land.copernicus.eu/pan-european/corine-land-cover/clc2018 (Accessed: February 7, 2023).

*EPAMaps*. Available at: https://gis.epa.ie/EPAMaps/(Accessed: February 7, 2023).

*GSI Map Viewer.* Available at: https://dcenr.maps.arcgis.com/apps/MapSeries/index.html?appid=a30af518e87a4c0ab2fbde2aaac3c228 (Accessed: February 7, 2023).

*GSNI GeoIndex*. Available at: https://mapapps2.bgs.ac.uk/GSNI_Geoindex/home.html (Accessed: February 7, 2023).

*UK Soil Observatory.* Available at: https://mapapps2.bgs.ac.uk/ukso/home.html?layer=AFBIWRB (Accessed: February 7, 2023).