TETRA TECH

Watlington Quarry Landfill Environmental Permit

Hydrogeological Risk Assessment

784-A117209

MICK GEORGE

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1.0 INTRODUCTION

1.1 Report Context

1.1.1 This report presents the Hydrogeological Risk Assessment (HRA) for an Environmental Disposal Permit application of Watlington Quarry, which will be ultimately converted to an inert landfill facility. The following chapters have been prepared by Hydrogeologica Consulting Ltd in support of the Permit Application currently being compiled by Tetratech (TT) on behalf of Mick George Ltd (MGL).

1.1.2 The objectives of this document are to assess whether the proposed operations and end-use as an inert landfill, its engineered containment design and construction, monitoring network and management controls fulfil the requirements of the Groundwater Regulations 2009 and Landfill Directive 1999 and ensure that the site is in compliance with the requirements of the Environmental Permitting Regulations, 2010.

1.1.3 Please refer to the various documents (ESSD, Operating Techniques, ERA, etc.) submitted as part of this application for detailed information on other technical aspects relating to the site.

1.1.4 Due acknowledgement is made for specific background information used in this document which was obtained from TerraConsult (South) Ltd report: Watlington Quarry - Oakfield, Groundwater Protection and Hydrogeological Impacts, September 2019, Report No. 10312-R04, parts of which are repeated here for completeness.

1.2 Site Location

1.2.1 The application site forms part of the wider Watlington Quarry site in Norfolk and located approximately 1.5km north east from the village of Watlington. The site is centred at approximate National Grid Reference (NGR) TF 63427 11556. The environmental permit boundary is shown on Drawing Number MGL/A117209/PER/01.

1.2.2 Access is achieved from an access road off Watlington Road located to the north of the site. Beyond the wider quarry site, the immediate surroundings are agricultural and the nearest residential property is considered to be Oak House which is located approximately 575m north of the application site.

1.2.3 The proposed facility will cover an area of approximately 11.1ha and lies on the crest of a local mound. Spot heights using the Magic website tool are shown to be gently sloping towards the west, with elevations 13mAOD in the east to approx. 7mAOD west towards the Hobbs drain.

1.3 Brief Site History and Proposed Development

1.3.1 Watlington Quarry has been an active site for the production of sand and gravel and aggregate since the first planning permission was issued in the mid 1960s and since then a number of planning permissions for extensions to the site have been granted.

1.3.2 A detailed list of the various planning permissions issued is found in the ESSD document accompanying this application.

1.3.3 The planning permission granted by NCC (No. FUL/2021/0007) would allow the extraction of sand, gravel and clay with subsequent restoration in an area to the south of the existing quarry site (as outlined on Drawing Number MGL/A117209/PER/01).

1.3.4 As part of the restoration works, the operator seeks to utilise imported inert waste materials rather than 'virgin soils'. As such, the proposal entails the importation of inert waste to infill and progressively restore the quarry void that will be created following mineral extraction activities.

1.3.5 The proposed phasing plan is detailed in a series of drawings (Number W8/1/19/05-09 – Working Plan). As detailed in these plans, the site will comprise five phases (Phase 1, 2, 3, 4 and 5) which will progress from north to south.

1.3.6 Permitted wastes accepted at the site will be strictly inert as classified under the Landfill Directive (1999/31/EC) and Council Decision (2003/33/EC) of 19 December 2002 'Establishing criteria and procedures for the acceptance of waste landfills'.

1.3.7 Details regarding the proposed waste types including restrictions are provided in the Operating Techniques (Appendix B of the Environmental Permit Application).

1.3.8 The restoration of the site will require approximately 800,000m^3 of material to be brought on to the site. When using a bulk conversion factor of 1.6 tonnes/m3 this equates to 1,280,000 tonnes. It is proposed that approximately 250,000m^3 (or 400,000 tonnes) of material would be imported to the site per annum.

1.3.9 As detailed on the restoration scheme (Drawing Number W8/1/19/04) the site will be restored to high quality agricultural land (at pre-development levels) whilst additionally creating alternative habitats in line with the biodiversity action plan objectives.

1.4 Landfill Design Philosophy

Basal Layer and Side Slope Engineering

1.4.1 The removal of the mineral deposit layer will expose the underlaying geological bedrock defined by the Kimmeridge Clay. This lithological unit will form the geological basal layer of the installation based on its proven thickness beneath the site. However, the exposed side slopes will be lined with engineered *in situ* clay with specified minimum parameters of 1m thickness and shall have an hydraulic conductivity with an average of $1x10^{-7}$ m/s or 0.5m thick at an average of $5x10^{-8}$ m/s.

Capping

1.4.2 In accordance with the current requirements of the Landfill Directive, an engineered cap (clay or plastic) is not required. On completion of filling to final levels, the site will be capped with 1m of suitable restoration soils.

Restoration

1.4.3 The site will be restored as a low-level landform and to a combination of grassland and agriculture parcels of land as shown in the Restoration Proposals (Drawing Number W8/1/19/04).

Aftercare

1.4.4 Aftercare will be carried out for a period of 5 years following the completion of restoration of any phase and will provide for the management of the soil resources to establish a sustainable after use.

1.4.5 An annual site meeting between Mick George and Norfolk County Council will be undertaken to review the performance of the aftercare scheme for that year and agree on a detailed programme for the following year.

1.4.6 Details regarding the site's aftercare are provided in the Closure and Aftercare Plan (Appendix I of the main application).

1.5 Regulatory Context, Groundwater and Surface Water Protection

Aquifer designation

1.5.1 According to the Multi Agency Geographic Information for the Countryside (MAGIC) website, the site lies within a secondary A aquifer (formerly a minor aquifer) associated with superficial deposits. The bedrock underlying the superficial deposits is classed as non-productive.

1.5.2 With reference to the Groundwater Vulnerability Map, the site is situated within an area of Minor medium-low vulnerability but does not lie within a Groundwater Source Protection Zone (GSPZ).

Licensed and Unlicensed Abstractions

1.5.3 According to TerraConsult (2019) there are two licensed groundwater abstractions within 1km of the site. One is associated with the Watlington Quarry mineral washing activities the second licence is related to spray irrigation abstraction.

1.5.4 There is a number of surface water abstractions, the furthest located 2.3km north west of the site.

1.5.5 The search for private unlicensed abstractions yielded one point registered within a 3.5km radius of the proposed extraction area.

Water Table Conditions

1.5.6 Given the current groundwater levels distribution and seasonal fluctuation, it is expected that dewatering of the aquifer will be implemented in order to obtain safe and dry working conditions.

Hydrology

1.5.7 According to detailed information provided by TerraConsult (2019) the development lies within the catchment of the River Nar, which is located approximately 1.4km north of the site's boundary.

1.5.8 The surface water features and groundwater elevations surrounding the site are controlled by the artificial drainage channels which ultimately discharge into the Polver Drain, via the Hobbs Drain to the north. The final destination of these surface water flows is the River Great Ouse.

1.5.9 The development was subjected to an extensive flood risk assessment carried out by Amber Planning (report: Flood Risk Assessment September 2020, Extension of sand & gravel extraction area, Land at Watlington Quarry), which found the site not in a flood warning area and located in Flood Zone 1 (low risk).

Ecology

1.5.10 The MAGIC website shows the nearest Statutory Designated ecological sites to be within 1km north of the site, identified as the Setchey SSSI.

1.5.11 A habitat survey confirms that a majority of the site comprises intensely managed arable land with smaller areas of moderate ecological value and recommends further surveys to be undertaken in order to identify the presence of protected species, as appropriate.

1.5.12 The proposed project will enhance the ecological value by reflecting wider benefits to the eco-system and contributing to the establishment of resilient ecological networks consistent with the Norfolk Biodiversity Action Plan.

2.0 CONCEPTUAL HYDROGEOLOGICAL MODEL

2.1.1 The conceptual hydrogeological model for the site is based on the potential source-pathway-receptor linkages and relies on gathered geological and hydrogeological information.

2.1.2 A preliminary schematic conceptual hydrogeological model for the site is shown as cross sections in Drawing number MGL-A117209-HYD-01. This model will be updated as the site develops and more information becomes available.

2.1.3 The three linkages are defined below as:

2.1.4 **Source**: potentially-contaminating leachate that could be generated by rainfall infiltration through the emplaced inert material and any moisture inherent to the inert material itself.

2.1.5 **Pathways**: to include the void filled with inert material, a zone within the *in situ* geology, and the aquifer beneath the site in which dilution and degradation processes may occur.

2.1.6 **Receptors**: the groundwater system beneath the site is considered to be the primary receptor. There are no secondary receptors in the form of licensed/unlicensed abstractions and surface water features that are in the immediate vicinity that could be influenced by the planned activities of the development.

2.1.7 A detailed discussion of the three components of the conceptual model is given in the sections below.

3.0 CONCEPTUAL MODEL: SOURCE TEAM

3.1.1 The requirements of the Landfill Directive for the disposal of inert waste material do not necessitate the installation of a leachate management or monitoring system. Therefore, there will not be a discussion of a leachate source term component in this risk assessment process.

3.1.2 The proposal entails the importation of inert waste under a disposal permit to infill and progressively restore the quarry void that will be created following mineral extraction activities. The works will be completed in accordance with the proposed restoration scheme (Drawing W8/1/19/04) that was submitted as part of the planning application to Norfolk County Council.

3.1.3 Details regarding the proposed permitted R/D codes and waste types are provided in the Operating Techniques (Appendix B of the Environmental Permit Application).

3.1.4 A volume of 800,000m^3 of imported material (or approx. 1,300,000 tonnes using a conversion factor of 1.6m^3/tonne) would be required in order to restore the site following mineral extraction. It is proposed that approx. 400,000 tonnes of material would be imported per annum.

3.1.5 A consideration is made for the potential of waste that is not inert (e.g. potentially contaminated soil) or non-inert waste concealed within a load that appears to be inert. The likelihood of any (or both) of these types of actions is predicted to be extremely low as strict source characterisation procedures (as detailed in the Operation Techniques document) will be applied to the loads being imported and visual inspection of each load will be undertaken prior to and during disposal.

3.1.6 Any fuel tanks and oil drums used on the site and by sub-contractors will be stored in a containment bund capable of containing 110% of the total quantity of fuel present at any one time.

3.1.7 All fuel spillages from moving plant or machinery will be remediated immediately in a safe and controlled manner by ensuring spills kits are kept on site and on plant and are checked daily.

4.0 CONCEPTUAL MODEL: PATHWAYS

4.1 Geology

4.1.1 The site's geological sequence beneath the site comprises of Tottenhill Gravels (superficial deposits) overlying Kimmeridge Clay (bedrock). There is an alluvial strata to the west of the site near Spring Pit.

4.1.2 To the south and east of the site, the Tottenhill Gravels and Nar Valley Deposits give way to Diamicton (Glacial Till) to the south and the Sandringham Sand formation in the east, respectively.

4.1.3 The British Geological Survey (BGS) describes the Tottenhill Gravel Member as a complex sequence of sands and gravels, dominated by flint. There is a sharp lithological change between the Tottenhill Gravels and the Kimmeridge Clay Formation.

4.1.4 The Kimmeridge Clay Formation comprises dark brown-grey to black, organic rich, fissile mudstone with occasional hard, thin carbonate-cemented horizons.

4.1.5 A total of 5 no. boreholes were installed around the site. In addition to providing basic geological and hydrogeological information these boreholes indicated the depths of exploitable minerals and are used as the current groundwater monitoring network (Drawing C534/9).

4.1.6 According to the results from the BGS' "Geology of Britain Viewer" there is no evidence of any mine activities (subsurface pathways) beneath the site.

Groundwater Monitoring Boreholes

<u>Groundwater levels</u>

4.1.7 The available groundwater data submitted by MGL were plotted on the hydrograph of Appendix A (raw level data also in this appendix). The following comments apply to the plotted data:-

- The highest average water table levels are recorded in BH1, BH4 and BH5 in the south eastern part of the site, whereas the lowest average levels were measured in boreholes BH2 and BH3, located in the north western portion of the site. From these data the groundwater flow direction can be broadly be inferred to be south east to north west towards the River Nar, as previously interpreted by TerraConsult (2019); and

- The hydrograph shows a partial correlation with natural rainfall cycles during the year, with a clear rise in March 2017. The remaining data set is probably affected by the irregular frequency of the monitoring visits.

- The largest fluctuation in groundwater levels was noted in BH5 of around 1.2m. The limited amplitude of these fluctuations is probably due to the vertical restriction of the aquifer and its relatively high permeability.

4.1.8 The inferred groundwater flow direction has allowed for the identification of the up- and down-gradient boreholes, namely:-

- Up-gradient: BH1, BH4, and BH5; and
- Down-gradient: BH2, and BH3.

Baseline Groundwater Quality

4.1.9 Groundwater quality data were obtained from the boreholes forming the current monitoring network (Drawing C534/9) between January 2017 and December 2021.

4.1.10 The groundwater quality results for the indicator substances Ammoniacal Nitrogen (Amm. N) and chloride are chosen to identify are potential contamination arising from the landfill due to their high mobility. Sodium is also included as an additional substance since it has been identified as being associated with the host geology (TerraConsult, 2019).

4.1.11 The raw and plotted data to derive the time series chemographs are shown in Appendix B.

4.1.12 The following comments apply to these graphs and the raw data:-

Up-gradient boreholes

- The Amm. N chemograph displays a peak in values on two occasions (BH5 in May 2019, BH1 in March 2021) within all the sampled boreholes – these high values seem to be anomalous with respect of the remaining concentrations. The residual data points are in an harmonised pattern, with no discernible trends. Average concentrations are recorded between a maximum of 1.55 mg/l and a minimum of 0.41 mg/l, however the maximum value could be skewed as a result of the noted peaks.

- Chloride average concentrations are all below 200mg/l for these up-gradient boreholes. Although there is a decreasing trend after March 2020, the pattern is generally stable and linear which is reflected by the narrow range in average concentrations of between 32 mg/l and 52 mg/l

- Average sodium values are within a narrow range of between 12 mg/l and 20 mg/l. The plot of these concentrations displays a similar pattern to chloride, with relatively stable and linear trend for all the monitoring locations and slightly decreasing.

- Metal values up-gradient display similar patterns within the three monitoring boreholes, with most substances not detected in all the visits e.g. lead, cadmium. Average values for chromium and iron (consistently found in the dissolved state) are 8.4µg/l and 250µg/l respectively. The remaining metals have varying concentrations between being below the limits of detection or a narrow range of values.

Down gradient boreholes

- The Amm. N plot is also affected by the noted spurious behaviour of values as found in the same time period as the up-gradient boreholes (March 2019 and March 2021). For the remainder of the monitoring points trends are mostly linear and stable and fall within a very narrow range of values. Average concentrations range between a minimum of 1mg/l and a maximum of 2mg/l, although these values could be affected by the noted peaks in concentration.

- Average chloride concentrations are all below 100mg/l. The remaining average values fall within a range of 39 mg/l and 55 mg/l. The linear trends displayed in the chemograph by all the monitoring points reflect the narrow plotting series of these boreholes.

- Average sodium values are also within a single value for both boreholes of 18 mg/l. In BH2 the plot of its concentrations displays a rising linear trend for all the monitoring visits, whereas BH3 shows a less regular pattern with a wider variation in values and a noticeable decrease in values between Feb. and Mar. 2021 values.

- Metal values down-gradient display similar patterns to those up-gradient monitoring boreholes. Again, lead has not been detected in all the visits, however chromium has been identified with an average of around 4µg/l. Iron is consistently found in the dissolved state. The remaining metals have varying concentrations between being below the limits of detection or a narrow range of values.

4.1.13 As an overall comment, the average groundwater quality between the up-gradient and down-gradient monitoring points is generally of an identical nature, as expected to be found within a hydrogeological environment that is undeveloped.

Long Term Hydrogeological Changes

4.1.14 Hydrogeological changes are expected within the Superficial Deposits as a result of the proposed extraction activities. These impacts are predicted as localised changes to recharge characteristics and flow directions; but would not affect resources within the underlaying Chalk Formation. The impact of the proposed activity on recharge and flow direction are assessed as being minor, but long term, due to the localised nature of the development.

4.1.15 Any impacts in terms of both magnitude and duration that future climatic changes could bring about on the groundwater regime are too difficult to predict given the localised nature of the development.

5.0 CONCEPTUAL MODEL: RECEPTORS

5.1 Current licensed/exempt groundwater or surface water abstractions

5.1.1 There are no important groundwater abstractions within a 1km radius of the site.

5.1.2 Based on evidence from the MAGIC website, the site does not lie within the source protection zone (SPZ) of any public water supply.

5.1.3 Therefore, the underlying remaining geological unit(s) i.e. the Tottenthill Gravels, is considered to be the principal receptor for this assessment.

5.2 Existing natural/induced discharges (e.g. springs/wetlands)

5.2.1 Groundwater flow direction appears to be south east to north west, following the topographic gradient of the strata. There is a reported spring line emanating north of the area (TerraConsult, 2019), where the underlying Kimmeridge Clay outcrops, however this can be risked out given the reported distance (approx. 575m) from the boundary of the site.

Surface Water

5.2.2 The site lies within the River Nar catchment, approx. 3km north of the site, therefore, due to its distance is not considered to be a potential receptor as considerable dispersion of any potential contaminants would be taking place over this distance.

5.2.3 A series of four surface water bodies have been identified in the TerraConsult (2019) report, which highlights only one as being potentially a receptor affected by the dewatering operations – a pond located adjacent to the proposed extension. However, the risk of contamination generated by site activities is considered to be extremely low due to the various control and management procedures to be implemented during the development of the site.

5.2.4 The remaining potential receptors were risked out as they were assessed to be beyond the radius of influence of the dewatering cone.

5.3 Sites of Ecological or Nature Conservation Significance

5.3.1 There are no Sites of Special Scientific Interest (SSSI) within 1km of the site.

6.0 HYDROGEOLOGICAL RISK ASSESSMENT

6.1 The Nature of the Assessment

6.1.1 The proposed disposal permit application will be submitted for Watlington Quarry Landfill in order to receive inert materials.

6.1.2 In line with current legislation, inert landfills could be subject to a quantitative risk assessment process if a reduction in (1) the specification of the Landfill Directive, Annex 1 "geological barrier", would be considered and (2) the receiving environment has been identified as being particularly sensitive.

6.1.3 In the case of the geological barrier specification (1), it has been presented in the sections above that a geological basal barrier will be afforded by the present of the Kimmeridge Clay Formation and an engineered side slope system would be constructed using *in situ* materials.

6.1.4 The hydrogeological unit which could be affected by the development i.e. the Tottenhill Gravels has been described in the TerraConsult (2019) report as being poor in terms of potential water bearing zone due to the laterally and vertically limited extent of these deposits i.e. groundwater flow is restricted within a shallow saturated horizon at the base of the Tottenhill Gravels. In addition, the inert nature of the materials imported into the site has ensured that leachate will not be generated and thus has removed the first component of the Source-Pathway-Receptor linkage, therefore causing the sensitivity of the development to be considerably lowered.

6.1.5 However, essential due care will be taken during the operational phase, where the likelihood of accidents that could result in a potential negative impact are associated with the excavation and infilling activities, especially when plant and machinery are used. However, such risk is considered low and closely related to efficient site management implementation of site procedures through regular equipment and visual inspections and conscientious plant operators, as detailed in the Operating Techniques document accompanying this application.

6.2 Environmental Assessment Limits (EALs)

6.2.1 Although the site will accept inert materials, a set of EALs will still be required to form part of the Environmental Permit. These are defined as a set of values at the down gradient compliance points BH2 and BH3, calculated to be a maximum concentration allowable at that point in order to protect the identified potential principal receptor.

6.2.2 It is proposed to use the Agency's recognised statistical approach of the mean plus 2 x standard deviation for the following chosen substances: Amm. N, chloride, and sodium, using the average values at the up-gradient boreholes, and shown in Table 1. See Appendix B for their statistical derivations.

6.2.3 As a hazardous substance lead has been chosen for being a highly mobile ion, and the EAL value has been set at the corresponding limit of quantification (LoQ) as defined by the UK Technical Advisory Group (Technical report on groundwater hazardous substances, Sept. 2016).

Table 1: Priority Substances and EALs

Determinants	LoQ	Selected EALs
Hazardous substance		
Lead (µg/l)	0.2	0.2
Non-hazardous pollutants		
Amm. N (mg/l)		4.8
Chloride (mg/l)		93
Sodium (mg/l)		26

6.2.4 It is recommended these EALs be reviewed during the annual monitoring reporting procedure but also informally following each monitoring visit due to the specific environmental circumstances associated with the site once operational.

7.0 REVIEW OF TECHNICAL PRECAUTIONS

7.1 Review of Technical Precautions

7.1.1 A series of necessary technical precautions have been identified as part of this risk assessment, which will be reviewed during the life of the permit.

Capping

7.1.2 On completion of infilling to final waste levels, the installation will not require a capping system, as explained in Section 1.4.2.

Lining Design

7.1.3 The proposed development comprises the importation of inert material under a disposal permit to restore the site to agriculture as approved under planning permission FUL/2021/0007. Furthermore, as defined in section above, the site is not situated within a GSPZ and therefore the risk to soil and groundwater is defined as low. As such, it is considered that a geological basal barrier is not required for the proposed development, however an engineered side slope system will be constructed.

Leachate Head Control, Drainage and Extraction Systems

7.1.4 These operational controls will not be required as the installation is an inert landfill.

Groundwater Management

7.1.5 Given the difference in proposed basal level and current average groundwater elevations it is expected to counteract a groundwater inflow to the workings. TerraConsult (2019) have calculated a theoretical radius of influence of the dewatering system as well as a maximum abstraction yield. Any proposed CQA supervision will also ensure that any potential heave encountered during construction works will be managed and that safe working conditions will be maintained.

Surface Water Management

7.1.6 A surface water management system has not been proposed due to the low profile of the final landform and any water generated will discharge into the surrounding water features.

8.0 REQUISITE SURVEILLANCE

8.1 The Risk-Based Monitoring Scheme

Groundwater Monitoring

8.1.1 Groundwater level and chemical data are to be collected from the groundwater monitoring points shown in Drawing (C534/9).

8.1.2 The parameters to be sampled and monitoring frequency to be included in the Environmental Permit are presented in Table 2 below. These requirements are considered adequate in providing an ongoing characterisation of the groundwater conditions.

Table 2: Groundwater Determinants and Sampling Frequency

Monthly	Quarterly	Annually
Levels	pH, Chloride, Alkalinity Amm N, Sulphate, Sodium, Potassium, Iron, Manganese, Cadmium Chromium, Copper, Calcium, Nickel, Lead, Zinc, Electrical conductivity, Selenium, Magnesium	*To include quarterly suites plus:* Hazardous substances

8.2 Compliance Limits

8.2.1 Compliance limits are set for the chosen down-gradient boreholes, namely BH2, and BH3.

8.2.2 The parameters to be sampled and monitoring frequency to be included in the Environmental Permit are presented in Table 2 below. These requirements are considered adequate in providing an ongoing characterisation of the groundwater conditions.

8.2.3 These limits can be applied to the chosen down gradient boreholes, as prescribed in the regulatory requirement in Agency’s H1 guidance, Annex J3 since these down-gradient boreholes intersect the same geology.

8.2.4 For hazardous substance lead, the relevant LoQ was chosen as the compliance limit. Table 4 contains these new sets of levels, which will be included in the newly issued Permit.

Table 4: Groundwater Compliance Limits

Determinands	Compliance limits
Ammoniacal Nitrogen (mg/l)	4.8
Chloride (mg/l)	93
Sodium (mg/l)	26
Lead (µg/l)	0.2

8.3 Contingency Action Plan

8.3.1 An annual review of the proposed compliance limits should be carried out and any alterations in the compliance levels discussed and agreed with the EA.

8.3.2 Where the site monitoring programme identifies an increase in groundwater determinants that could lead to a breach, then a series of contingency actions will be required. Suggested contingency actions, which will need to be agreed with the Environment Agency, are presented in Table 5.

Table 5: Suggested Contingency Actions

Appropriate Contingency Action	Timescale
Advise Site Management	Immediately
Advise Operator's Environmental Manager	1 Week
Advise Environment Agency	1 Week
Confirm by repeat sampling and analysis	1 Month
Review existing monitoring information	1 Month
Review site management/operations, implement actions to prevent future failure of a compliance level	3 Months
Review assumptions in conceptual site model	3 Months
Review existing HRA Compliance Levels	6 Months
Consult EA about need for corrective action	6 Months

9.0 CONCLUSIONS

9.1.1 The proposed engineered containment for the proposed inert landfill at Watlington Quarry complies with the Landfill Directive.

9.1.2 Surface water runoff will not be controlled as the final landform will be low profile thus suitable to allow infiltration of any rainfall event.

9.1.3 The proposed installation will comply with current engineering design, materials, specifications and CQA protocols applicable to current landfill containment best practices.

9.1.4 An independent CQA procedure will be carried out for all aspects of the sidewall lining construction. This ensures that the liner meets the required engineering standards and thus complies with the Landfill Directive and will not have an impact on the groundwater system.

9.1.5 Compliance limits for groundwater have been derived.

9.1.6 The requirements of the Groundwater Regulations, 2016, have been satisfied by the inclusion of requisite surveillance of the groundwater quality to be carried out regularly as discussed in Section 6.

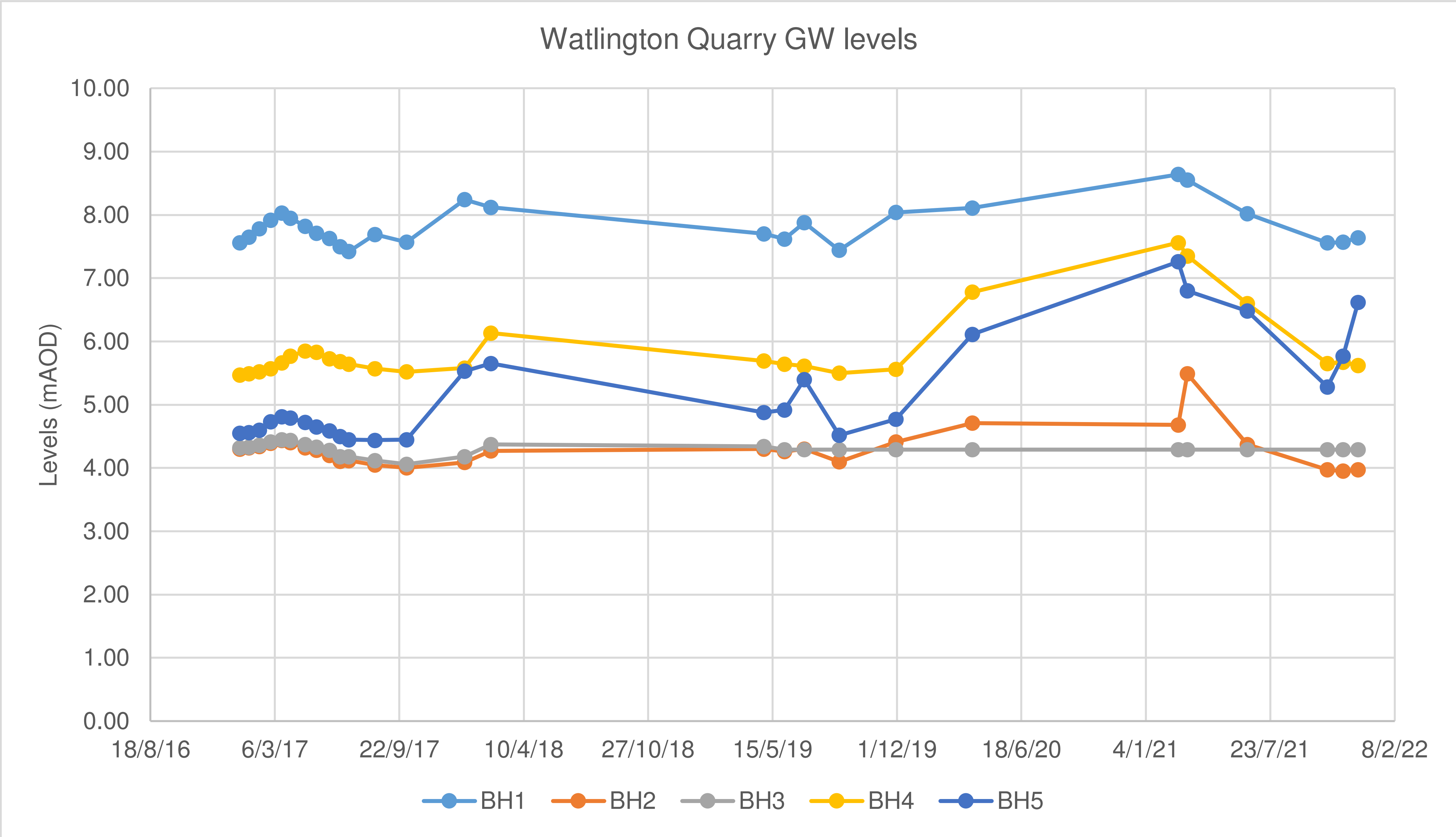
Drawings

MGL/A117209/PER/01	General site layout and permit boundary
MGL-A117209-HYD-01	Site hydrogeological conceptual model with engineering details
W8/1/19/04	Restoration scheme
W8/1/19/05-09	Working Plan
C534/9	Monitoring network and inferred groundwater flow direction

Appendix A

Groundwater Levels Data and Plot

	BH 1	BH 2	BH 3	BH 4	BH 5
9/1/17	7.56	4.30	4.32	5.47	4.55
23/1/17	7.65	4.32	4.33	5.49	4.56
9/2/17	7.78	4.34	4.36	5.52	4.60
27/2/17	7.92	4.39	4.41	5.57	4.73
17/3/17	8.03	4.44	4.45	5.66	4.81
31/3/17	7.95	4.40	4.44	5.77	4.79
24/4/17	7.82	4.32	4.37	5.85	4.72
12/5/17	7.71	4.28	4.33	5.83	4.65
2/6/17	7.63	4.20	4.28	5.73	4.59
19/6/17	7.50	4.11	4.18	5.68	4.50
3/7/17	7.42	4.12	4.18	5.64	4.45
14/8/17	7.69	4.05	4.12	5.57	4.44
4/10/17	7.57	4.00	4.06	5.52	4.45
5/1/18	8.24	4.09	4.18	5.58	5.53
16/2/18	8.12	4.27	4.37	6.13	5.65
1/5/19	7.7	4.3	4.34	5.69	4.88
3/6/19	7.62	4.26	4.29	5.64	4.92
5/7/19	7.88	4.3	4.29	5.61	5.4
30/8/19	7.44	4.10	4.29	5.50	4.52
29/11/19	8.04	4.41	4.29	5.56	4.77
31/3/20	8.11	4.71	4.29	6.78	6.11
25/2/21	8.64	4.68	4.29	7.56	7.26
12/3/21	8.55	5.49	4.29	7.35	6.80


Watlington Quarry GW levels
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Levels (mAOD)
18/8/16
6/3/17
22/9/17
10/4/18
27/10/18
15/5/19
1/12/19
18/6/20
4/1/21
23/7/21
8/2/22
BH1
BH2
BH3
BH4
BH5

Appendix B

Groundwater Quality and Plots

1/5/19

		BH 1	BH 2	BH 3	BH 4	BH 5
pH		8.3	7.8		7.5	8.0
Electrical Conductivity	µS/cm	540	730		530	700
Alkalinity (Total)	mg/l	200	120		130	350
Chloride	mg/l	9.1	47		10	23
Ammonia (Free)	mg/l	0.60	0.18		0.085	0.95
Ammoniacal Nitrogen	mg/l	4.4	4.0		4.0	15
Sulphate	mg/l	34	76		49	61
Calcium	mg/l	100	110		75	89
Potassium	mg/l	3.0	2.8		2.9	8.7
Magnesium	mg/l	5.0	4.7		3.1	5.5
Sodium	mg/l	15	16		13	19
Cadmium (Dissolved)	µg/l	< 0.080	< 0.080		< 0.080	< 0.080
Chromium (Dissolved)	µg/l	< 1.0	< 1.0		< 1.0	< 1.0
Copper (Dissolved)	µg/l	3.7	3.1		< 1.0	3.1
Iron (Dissolved)	µg/l	130	110		94	140
Manganese (Dissolved)	µg/l	< 1.0	3.4		3.5	6.8
Nickel (Dissolved)	µg/l	< 1.0	1.7		< 1.0	< 1.0
Lead (Dissolved)	µg/l	< 1.0	< 1.0		< 1.0	< 1.0
Selenium (Dissolved)	µg/l	1.9	< 1.0		< 1.0	1.0
Zinc (Dissolved)	µg/l	< 1.0	2.5		< 1.0	< 1.0
Mercury Low Level	µg/l	< 0.010	< 0.010		< 0.010	< 0.010

3/6/19

		BH 1	BH 2	BH 3	BH 4	BH 5
pH		8.4	8.2		8.4	8.5
Electrical Conductivity	µS/cm	440	580		510	620
Alkalinity (Total)	mg/l	200	110		140	330
Chloride	mg/l	9.5	49		13	21
Ammonia (Free)	mg/l	0.22	0.18		0.16	0.45
Ammoniacal Nitrogen	mg/l	1.3	1.6		1.0	2.5
Sulphate	mg/l	35	79		54	60
Calcium	mg/l	90	79		81	93
Potassium	mg/l	3.1	3.0		2.8	3.4
Magnesium	mg/l	5.5	3.7		4.9	6.5
Sodium	mg/l	16	13		16	17
Cadmium (Dissolved)	µg/l	< 0.080	< 0.080		0.13	< 0.080
Chromium (Dissolved)	µg/l	5.5	4.3		4.8	< 1.0
Copper (Dissolved)	µg/l	< 1.0	< 1.0		< 1.0	< 1.0
Iron (Dissolved)	µg/l	220	110		130	170
Manganese (Dissolved)	µg/l	78	11		21	68
Nickel (Dissolved)	µg/l	< 1.0	< 1.0		3.9	< 1.0
Lead (Dissolved)	µg/l	< 1.0	< 1.0		< 1.0	< 1.0
Selenium (Dissolved)	µg/l	2.4	< 1.0		1.4	1.1
Zinc (Dissolved)	µg/l	< 1.0	< 1.0		5.3	< 1.0
Mercury Low Level	µg/l	< 0.010	< 0.010		< 0.010	< 0.010

5/7/19

		BH 1	BH 2	BH 3	BH 4	BH 5
pH		7.9	7.6		7.6	7.6
Electrical Conductivity	µS/cm	560	560		510	610
Alkalinity (Total)	mg/l	170	110		120	230
Chloride	mg/l	29	44		17	22
Ammonia (Free)	mg/l	< 0.050	< 0.050		< 0.050	< 0.050
Ammoniacal Nitrogen	mg/l	< 0.050	< 0.050		< 0.050	< 0.050
Sulphate	mg/l	37	77		49	53
Calcium	mg/l	89	94		84	110
Potassium	mg/l	4.5	3.5		3.6	3.8
Magnesium	mg/l	7.7	5.8		4.3	7.3
Sodium	mg/l	20	16		13	17
Cadmium (Dissolved)	µg/l	< 0.080	0.11		< 0.080	< 0.080
Chromium (Dissolved)	µg/l	< 1.0	< 1.0		< 1.0	1.0
Copper (Dissolved)	µg/l	3.2	< 1.0		< 1.0	< 1.0
Iron (Dissolved)	µg/l	130	150		110	150
Manganese (Dissolved)	µg/l	3.2	27		1.6	2.7
Nickel (Dissolved)	µg/l	< 1.0	3.9		< 1.0	1.1
Lead (Dissolved)	µg/l	< 1.0	< 1.0		< 1.0	< 1.0
Selenium (Dissolved)	µg/l	1.7	1.2		< 1.0	1.4
Zinc (Dissolved)	µg/l	2.4	5.8		< 1.0	< 1.0

30/8/19

		BH 1	BH 2	BH 3	BH 4	BH 5
pH		8.3			8.1	8.1
Electrical Conductivity	µS/cm	570			560	640
Alkalinity (Total)	mg/l	180			170	250
Chloride	mg/l	39			12	1200
Ammonia (Free)	mg/l	< 0.050			< 0.050	0.27
Ammoniacal Nitrogen	mg/l	0.12			0.16	3.5
Sulphate	mg/l	47			53	74
Calcium	mg/l	110			99	110
Potassium	mg/l	4.2			4.0	7.7
Magnesium	mg/l	5.0			3.1	7.4
Sodium	mg/l	19			15	21
Cadmium (Dissolved)	µg/l	< 0.080			< 0.080	< 0.080
Chromium (Dissolved)	µg/l	5.6			25	< 1.0
Copper (Dissolved)	µg/l	4.5			1.1	1.8
Iron (Dissolved)	µg/l	230			200	110
Manganese (Dissolved)	µg/l	4.3			< 1.0	17
Nickel (Dissolved)	µg/l	< 1.0			< 1.0	< 1.0
Lead (Dissolved)	µg/l	< 1.0			< 1.0	< 1.0
Selenium (Dissolved)	µg/l	3.6			1.3	1.0
Zinc (Dissolved)	µg/l	10			2.3	< 1.0

29/11/19

BH 1	BH 2	BH 3	BH 4	BH 5
8.4	8.4	8.6	8.4	8.6
950	500	690	540	880
170	110	210	150	230
93	31	29	12	75
< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
0.22	0.12	0.19	0.16	0.12
80	72	97	50	65
140	64	110	79	140
4.4	2.2	3.4	3.5	5.0
9.1	3.3	5.0	3.1	8.2
19	13	16	13	20
< 0.080	0.13	< 0.080	< 0.080	< 0.080
8.1	1.6	1.8	17	7.7
5.0	4.1	1.6	1.8	5.3
440	290	440	1000	450
3.6	44	140	11	6.0
1.1	4.1	1.4	< 1.0	1.6
< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
3.8	1.1	2.1	< 1.0	2.6
5.4	15	12	4.4	6.0

31/3/20

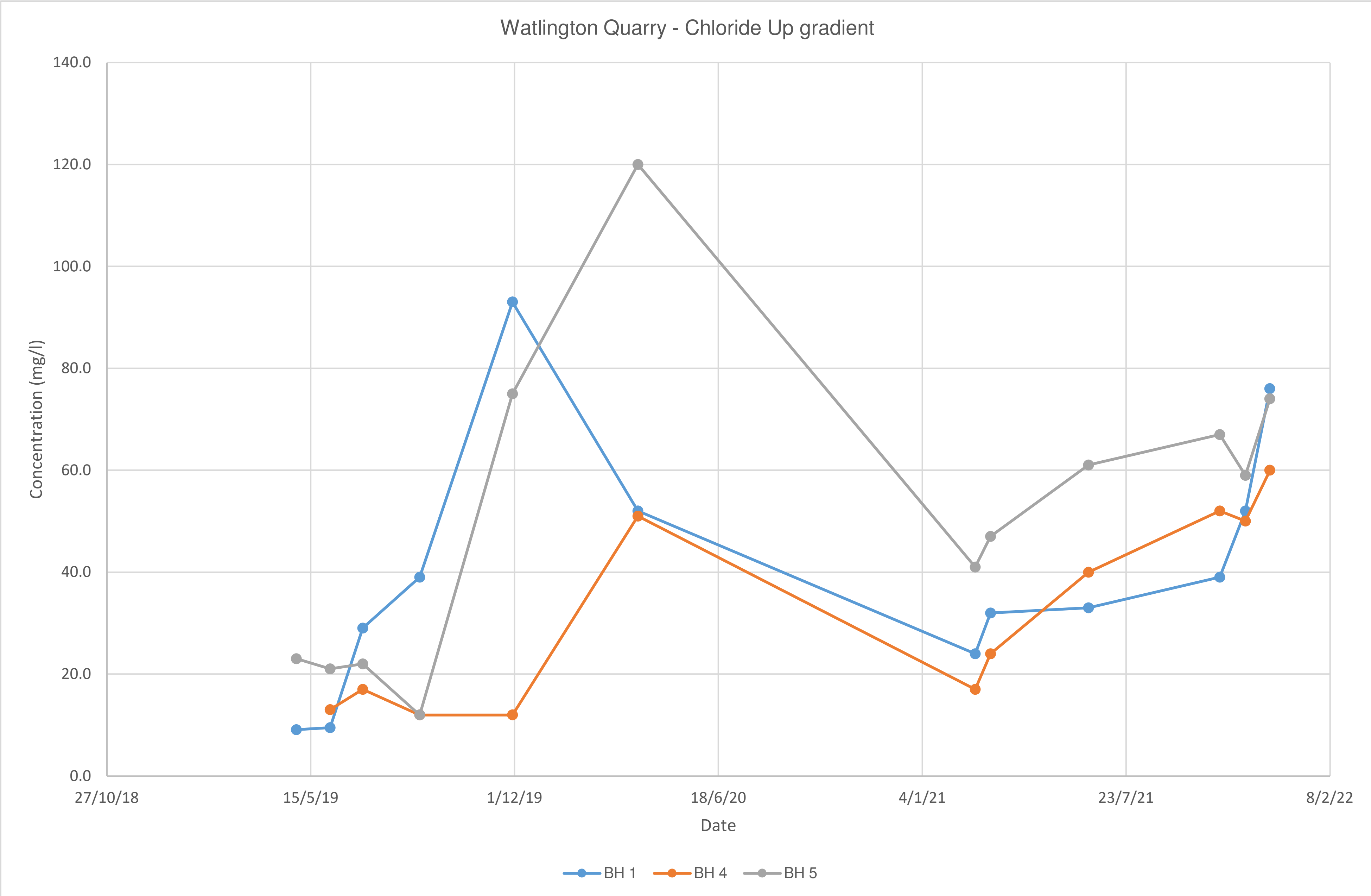
BH 1	BH 2	BH 3	BH 4	BH 5
8.5	8.4	8.5	8.0	8.5
780	630	730	400	1100
150	100	150	16	200
52	43	45	51	120
< 0.050	< 0.050	0.11	< 0.050	0.44
0.078	0.086	0.58	0.051	2.3
88	83	160	34	110
160	88	93	53	170
5.6	3.2	3.1	2.9	4.4
11	5.2	7.2	2.6	12
23	17	19	8.3	18
< 0.080	0.15	< 0.080	< 0.080	< 0.080
6.7	5.8	1.2	7.3	7.5
4.5	4.8	1.3	2.0	4.8
780	370	490	370	800
7.5	11	280	92	4.3
1.2	5.6	1.4	1.5	1.6
< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
3.4	1.7	< 1.0	1.2	2.0
3.6	14	9.5	6.0	4.3

25/2/21

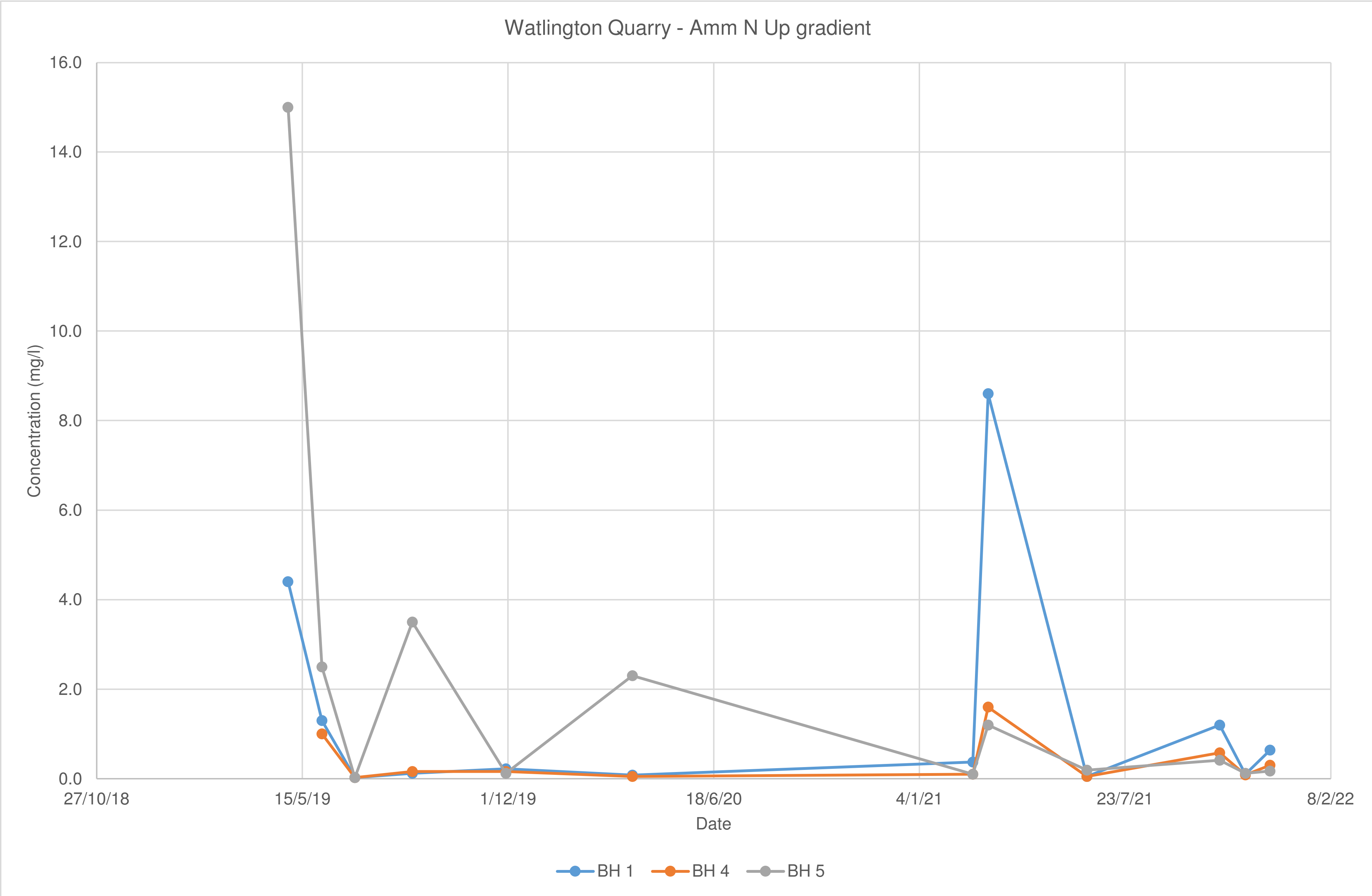
BH 1	BH 2	BH 3	BH 4	BH 5
8.2	7.6	7.2	7.7	7.8
550	700	230	190	810
170	110	27	34	310
24	59	19	17	41
< 0.050	< 0.050	< 0.050	< 0.050	< 0.050
0.37	0.21	0.12	0.10	0.10
46	77	29	27	64
76	94	18	18	120
5.5	3.8	2.4	2.6	6.7
6.6	6.1	1.3	1.3	10
16	21	7.4	7.1	17
< 0.08	0.22	0.09	0.08	< 0.08
8.5	6.5	3.7	8.5	9.1
8.6	6.6	3.7	4.8	6.8
20	16	82	50	22
12	10	43	44	3.5
1.6	7.5	2.2	2.0	1.8
< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
1.2	1.1	0.88	0.89	0.98
27	18	6.4	11	11

12/3/21

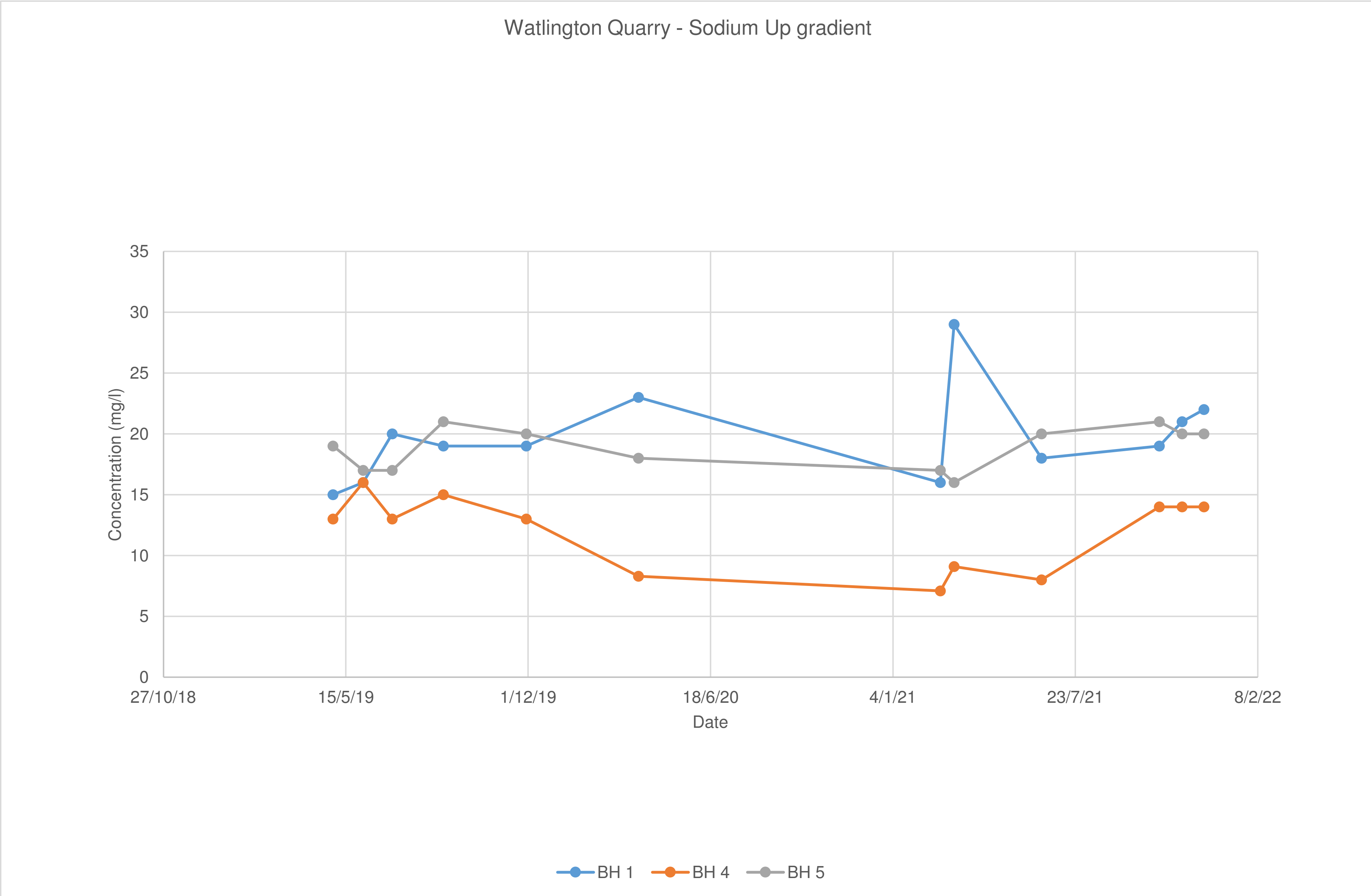
BH 1	BH 2	BH 3	BH 4	BH 5
8.0	7.8	8.1	7.0	8.0
540	700	730	220	840
220	120	180	50	480
32	55	45	24	47
0.64	0.24	0.26	< 0.050	0.083
8.6	5.8	3.1	1.6	1.2
52	86	150	30	72
76	83	99	23	120
4.7	3.2	3.4	2.5	4.8
8.3	5.3	8.0	2.2	9.3
29	19	22	9.1	16
< 0.12	0.23	< 0.12	< 0.12	< 0.12
6.1	7.0	2.0	6.5	8.5
5.8	7.0	1.7	2.7	5.7
25	94	290	46	25
5.9	4.7	220	93	2.6
0.83	6.8	1.1	1.5	1.2
< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
1.1	0.93	< 0.50	0.71	0.91
< 3.0	14	3.1	3.5	< 3.0



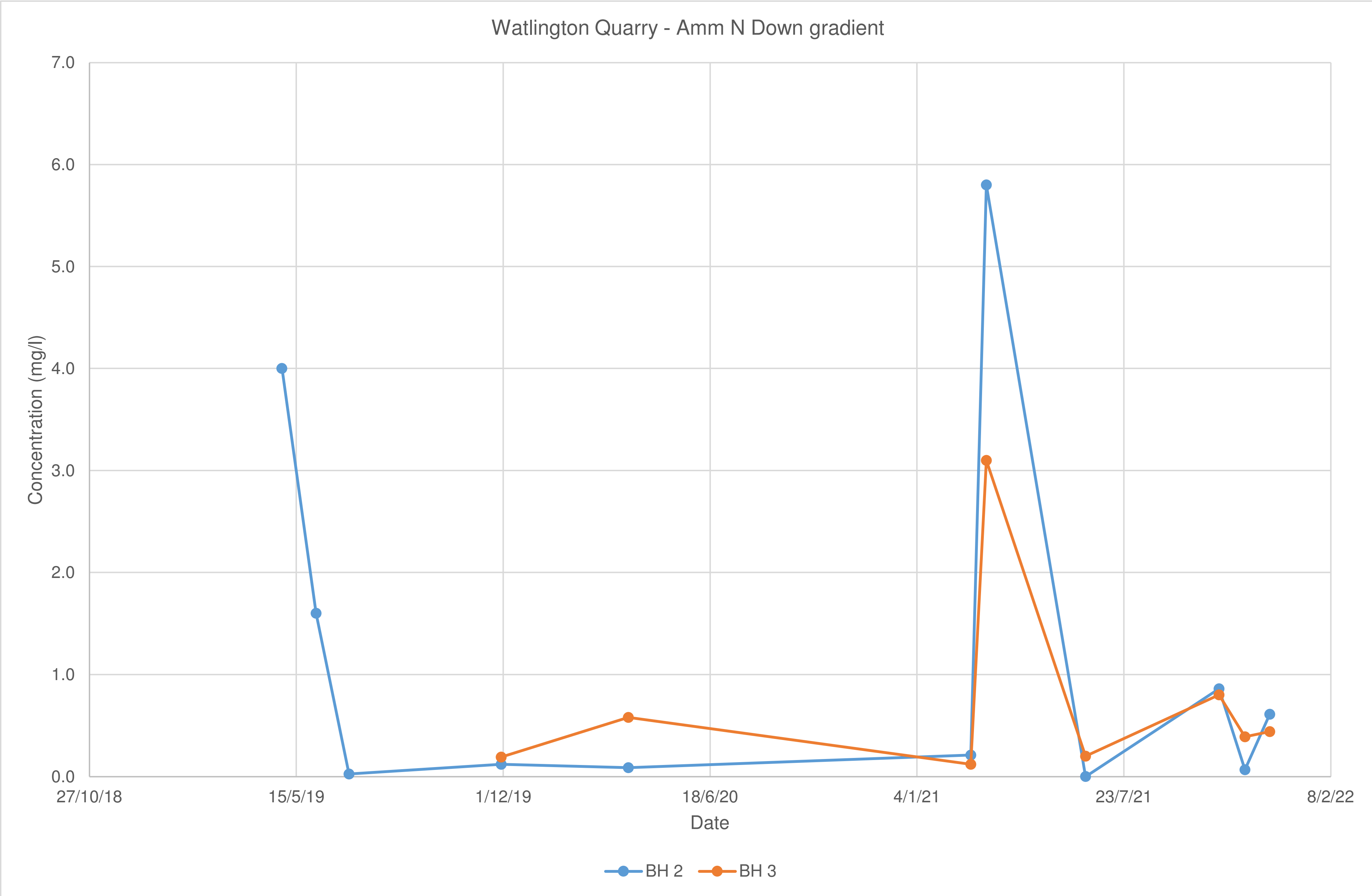
Watlington Quarry - Chloride Up gradient
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
Concentration (mg/l)
27/10/18
15/5/19
1/12/19
18/6/20
4/1/21
23/7/21
8/2/22
Date
BH 1
BH 4
BH 5

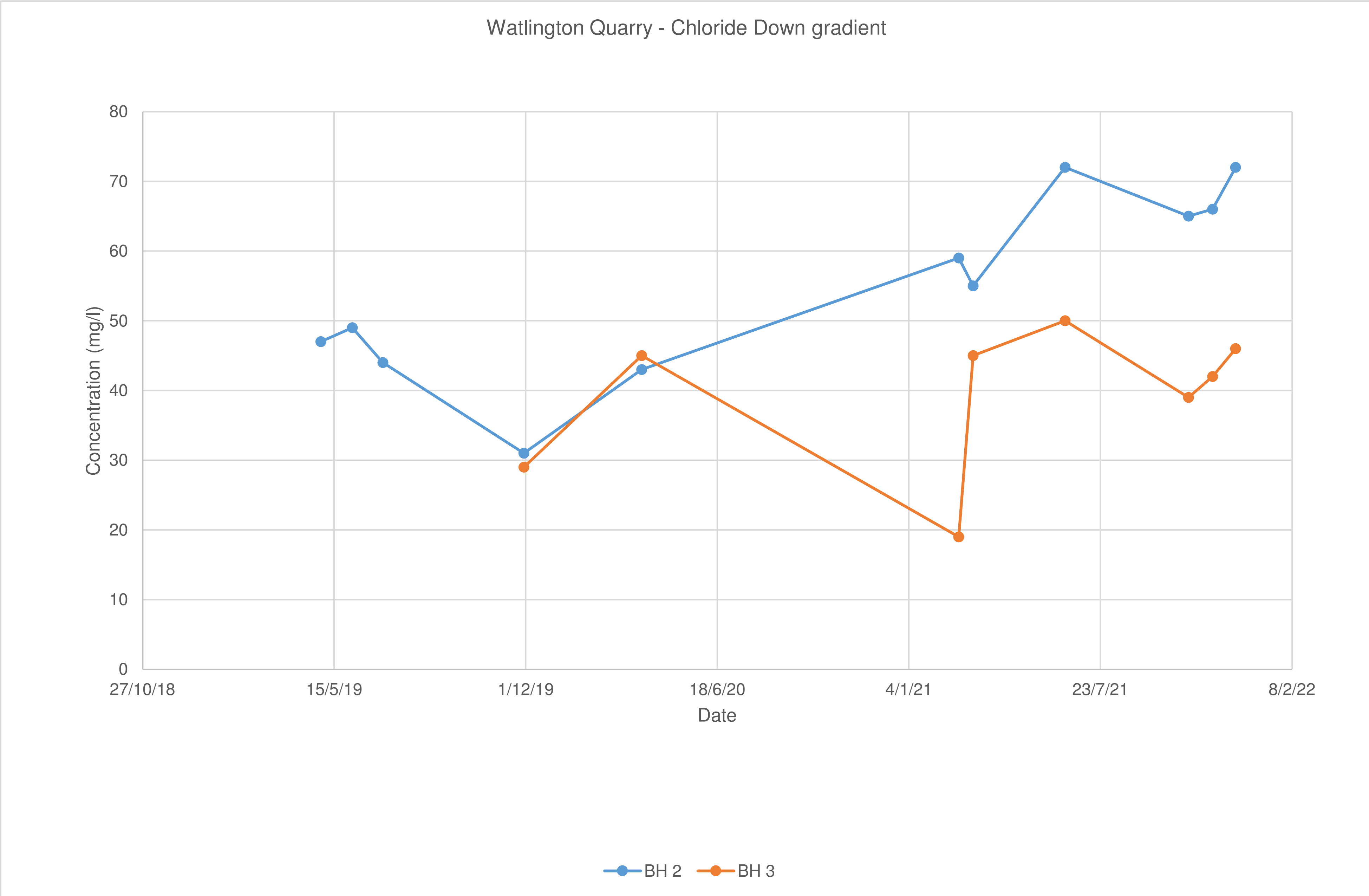


Watlington Quarry - Amm N Up gradient
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Concentration (mg/l)
27/10/18
15/5/19
1/12/19
18/6/20
4/1/21
23/7/21
8/2/22
Date
BH 1
BH 4
BH 5

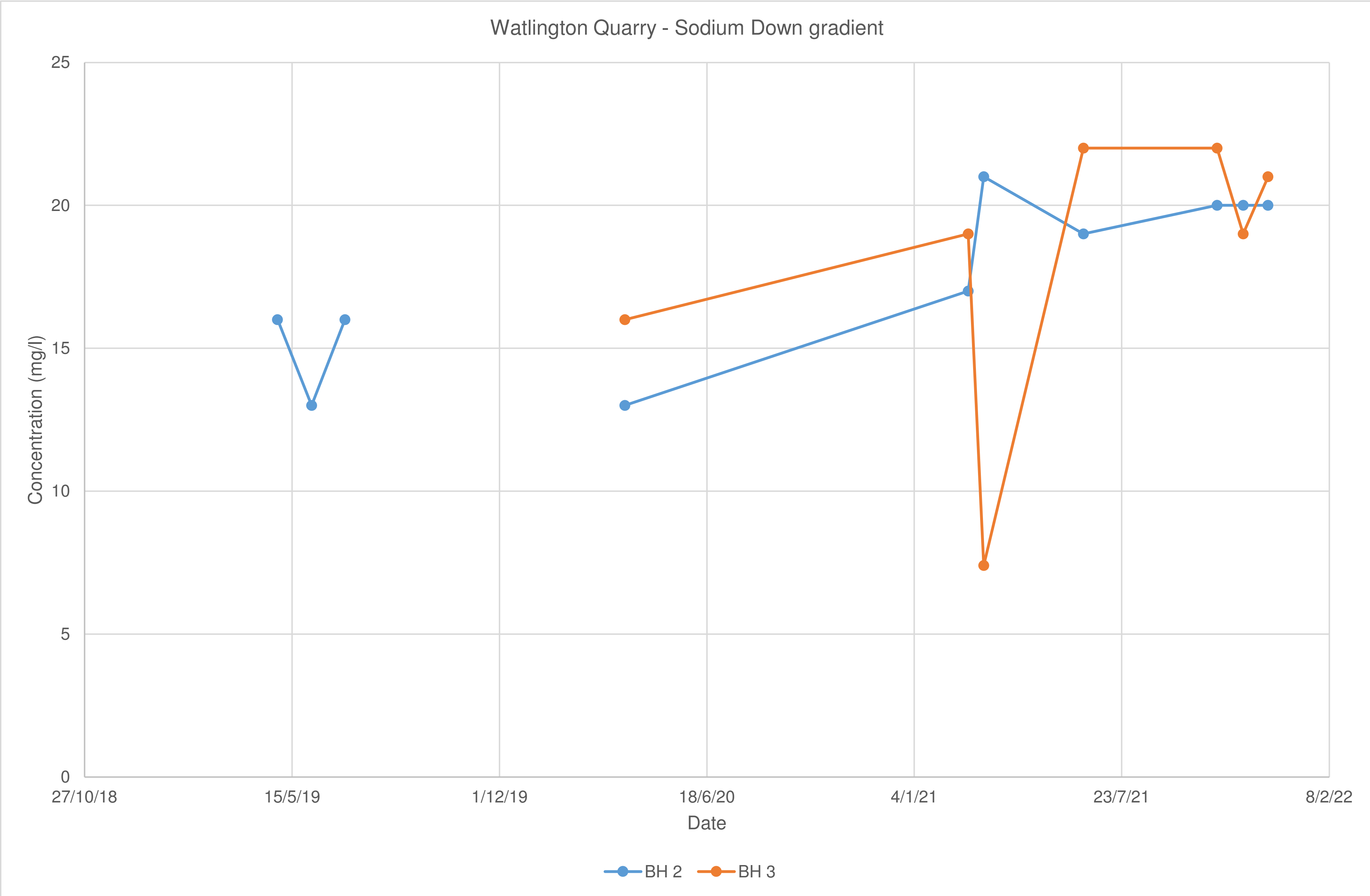


Watlington Quarry - Sodium Up gradient
Concentration (mg/l)
35
30
25
20
15
10
5
0
27/10/18
15/5/19
1/12/19
18/6/20
4/1/21
23/7/21
8/2/22
Date
BH 1
BH 4
BH 5


Watlington Quarry - Amm N Down gradient
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Concentration (mg/l)
27/10/18
15/5/19
1/12/19
18/6/20
4/1/21
23/7/21
8/2/22
Date
BH 2
BH 3



Watlington Quarry - Chloride Down gradient
Concentration (mg/l)
80
70
60
50
40
30
20
10
0
27/10/18
15/5/19
1/12/19
18/6/20
4/1/21
23/7/21
8/2/22
Date
BH 2
BH 3


Watlington Quarry - Sodium Down gradient
Concentration (mg/l)
25
20
15
10
5
0
27/10/18
15/5/19
1/12/19
18/6/20
4/1/21
23/7/21
8/2/22
Date
BH 2
BH 3

Outlier calculations using Grubb's test or ESD method (Extreme Studentised Deviate)

		BH 1	BH 4	BH 5	BH 1	BH 4	BH 5	BH 1	BH 4	BH 5	BH 1	BH 4	BH 5	BH 1	BH 4	BH 5	BH 1	BH 4	BH 5
Ammoniacal Nitrogen	mg/l	4.4	4.0		1.3	1.0	2.5	0.025	0.025	0.025	0.12	0.16	3.5	0.22	0.16	0.12	0.078	0.051	2.3
Chloride	mg/l	9.1	10	23	9.5	13	21	29	17	22	39	12	12	93	12	75	52	51	120
Sodium	mg/l	15	13	19	16	16	17	20	13	17	19	15	21	19	13	20	23	8.3	18

Ammoniacal Nitrogen	mg/l	BH 1	BH 4	BH 5	BH 1	BH 4	BH 5	BH 1	BH 4	BH 5	BH 1	BH 4	BH 5	BH 1	BH 4	BH 5	BH 1	BH 4	BH 5	Ave	Std Dev	pliance limits
Chloride	mg/l	0.37	0.10	0.10	8.6	1.6	1.2	0.05	0.05	0.19	1.20	0.58	0.41	0.10	0.09	0.12	0.64	0.30	0.17	1.12	1.82	4.8
Sodium	mg/l	24	17	41	32	24	47	33	40	61	39	52	67	52	50	59	76	60	74	41	26	93
		16	7.1	17	29	9.1	16	18	8.0	20	19	14	21	21	14	20	22	14	20	17	5	26

Value removed because considered to be an outlier