Geo Consulting Engineering Ltd The Studio, Woodmanton Barns, Woodbury, Exeter EX5 1HQ
t: +44 (0) 1395 239977 e: mail@geoconsultingeng.co.uk w: www.geoconsultingeng.co.uk

geo consulting engineering ltd

Our ref: GCE01065/GS1

M J Church
Allington Transfer Station
Bristol Road
Chippenham
Wiltshire
SN14 6LZ

Fao: Ben Staff

27th November 2023

Dear Sirs

Re: Wick Quarry – Simplified Geological Summary

Introduction

South Gloucestershire Council Planning Permission P21/07554/RVC dated 27th January 2023 includes a Condition, No. 20, which requires a survey of the geological features and exposures of Wick Quarry that will be obscured by the regrading of the quarry.

This document provides a simplified geological summary of the geology of Wick Quarry, including both the Main Quarry and Truebodies voids, intended to be accessible to a wider audience. Data has been sourced from the British Geological Survey (BGS) as well as report ref: GCE01065/R1, "Phase 1 Geotechnical Assessment - Preliminary Sources Review and Walkover Survey Report" by Geo Consulting Engineering Ltd, January 2021. Relevant sections of report GCE01065/R1 are attached as Appendix A of this letter.

It should be noted that the quarry voids are presently flooded to a level of around 65mAOD, the bases being typically between 0mAOD and 5mAOD, and have therefore not been inspected recently. Geological information on the flooded sections is drawn from earlier mapping by the then operators when the voids were dewatered and will be reviewed and updated as the current planned works progress.

Wider Geological Setting

Wick Quarry is located on the eastern arm of a regional "U" shaped fold within the bedrock which has caused the layers within the bedrock to typically dip to the south-west. Faulting and further deformation events have created faults, localised folds, and boundaries between rock strata that are non-conformable meaning the rock is not necessarily present in the order in which it was formed, layers may have been removed by erosion, or moved via faults.

The attached Figures 1 & 2 provide geological maps of Main Quarry and Truebodies respectively.

Main Quarry

The Main Quarry void comprises five distinct rock units as summarised in the table below, see the attached Figure 1 for a geological map of Main Quarry:

Main Quarry			
Name	**Basic Rock Type**	**Location within Quarry Void**	**Description and Characteristics**
Clifton Down Limestone (CDL)	Limestone	Found across much of the central and western parts of the void forming the northern and southern slopes and the lower western slopes.	Strong, grey, thickly bedded (600mm - 2000mm thick) LIMESTONE. Bedding layers dip to the south-west at c.55°. Potential for karstic weathering features (rifts and voids dissolved by the movement of water).
Clifton Down Mudstone (CDM)	Muddy Limestone with Shale Layers	Eastern side of the void. Forms the eastern end of the northern and southern slopes as well as the lower sections of the eastern slope.	Strong, grey, typically very thinly to medium bedded (20mm-600mm thick) muddy LIMESTONE with occasional 200mm-500mm thick layers of thinly laminated (beds up to 6mm thick) black SHALE. Bedding dips south-west at 45-55°. Shale layers are weaker than the muddy limestone and therefore get preferentially weathered.
Gully Oolite (GUO)	Oolitic Limestone	Upper slopes on the eastern side of the void.	Strong, light cream grey, thickly bedded (600mm - 2000mm thick), oolitic LIMESTONE. Bedding layers dip at c.60° to the south-west
Cromhall Sandstone (CSA)	Sandstone	Narrow band across the mid-slopes of the western side of the void.	Strong, grey occasionally red, medium bedded (200mm-600mm thick) SANDSTONE. Layer is 4m thick (top to base, ignoring dip). Bedding dips south-west at c.45°.
Oxwich Head Limestone (OHL)	Oolitic Limestone	Middle to upper slopes of the western end of the void, above the CSA.	Area being worked at time of inspection so description limited. Noted at Truebodies as: Strong, cream grey locally stained red brown, very thinly to medium bedded (60mm - 600mm thick), fine grained oolitic LIMESTONE. Bedding dips south-west at 50°.

Joints are fractures within the rock which are typically a result of the stress history of the rock. Four main sets of joints have been identified at Main Quarry dipping to the east-north-east, south-east, south-west, and north. The interaction between existing slope faces, bedding fractures, and joint fractures is a significant part of understanding the stability hazards associated with the voids.

Faults, i.e. fractures or fracture zones within the rock across which movement has occurred, are present at the following locations in and around Main Quarry:

- Fault NE1 Runs north-east to south-west across the north side of Main Quarry.
- Fault NNW1 Runs north-north-west to south-south-east along the eastern side of Main Quarry and Truebodies Quarry. Also known as the Wick Fault.
- Fault NNW2 Runs to the east of and roughly parallel to NNW1.

Truebodies

The Truebodies void outcrops fewer rock units but is structurally more complex than Main Quarry. The following table summarises the rock units encountered, see the attached Figure 2 for a geological map of Truebodies:

Truebodies			
Name	**Basic Rock Type**	**Location within Quarry Void**	**Description and Characteristics**
Clifton Down Limestone (CDL)	Limestone	Found across the bulk of the quarry floor as well as the southern slopes, southern ends of the eastern and western slopes, and a small section at the northern end of the eastern.	Strong, light grey locally stained red brown, medium to very thickly bedded (200mm - >2m thick, beds up to 6m thick recorded), locally micritic (muddy), LIMESTONE. Bedding typically dips west. Prominent fold in the south of Truebodies, more information given below. Karstic weathering features present.
Oxwich Head Limestone (OHL)	Fossiliferous & Oolitic Limestone, localised Shale	Found at the northern end of the western slopes and across the middle and upper northern slopes.	Strong, light grey locally stained red brown, very closely to medium spaced bedding fractures (20mm - 600mm spacing), LIMESTONE. Faulting and folding create a complex arrangement of preferentially eroded shale beds, shelly limestone, and conglomerate. Bedding typically dips 60-70° to the south. Clay often found infilling fractures.
Quartzitic Sandstone Group (QSG)	Sandstone & Mudstone	Found at the northern end of the eastern slopes, in the lower northern slopes, and towards the northern end of the western slopes. Also interpreted to outcrop as a band across the north-west below the existing waterline between the outcrop on the western slopes and the outcrops along the northern slopes.	Complex sequence of interbedded quartzitic SANDSTONE and extremely weak, extremely closely to closely fractured (<20mm - 200mm spacing) MUDSTONE. Bedding typically dips west at c.70°. Faulted boundary (Faults NNW 1&2/ Wick Fault) against the older CDL.

Three joint sets have been identified at Truebodies dipping to the east-north-east, south-east, and south-west. A plunging fold (a fold within the rock that has then itself been tilted by a later phase of deformation) has been recorded on the south side of Truebodies within the Clifton Down Limestone. The fold axis plunges to the north-north-west at 65° with the beds on either side dipping to the west-north-west at 45° and north-north-east at 85°.

The main faults in and around Truebodies are as follows noting that numerous minor faults are present but would not be practical to list:

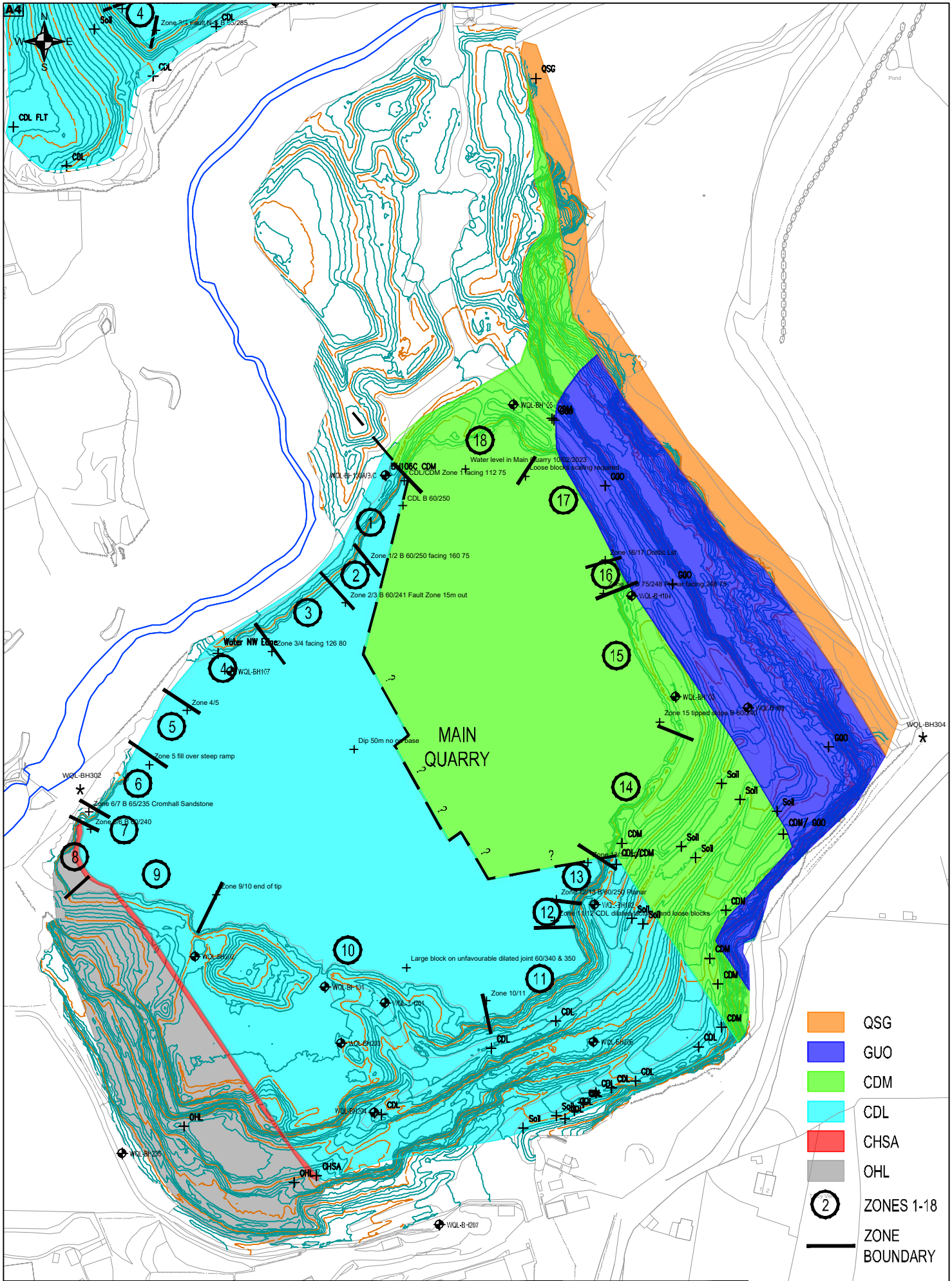
- Fault NE2 Runs north-east to south-west across the south-east of Truebodies.
- Fault NE3 Runs north-east to south-west on the eastern side of Truebodies.
- Fault EW1 Runs east to west at the north end of Truebodies.
- Fault EW2 Runs east to west just south of EW1.
- Fault NNW1 Runs north-north-west to south-south-east along the eastern side of Main Quarry and Truebodies Quarry. Also known as the Wick Fault.
- Fault NNW2 Runs to the east of and roughly parallel to NNW1.
- Fault NW1 Runs north-west to south-east in the north-west corner of Truebodies, intersects EW1.

Yours faithfully

[redacted]

Mark Harrison BSc., FGS
for and on behalf of Geo Consulting Engineering Ltd

Appendix A Relevant extracts of: *"Phase 1 Geotechnical Assessment - Preliminary Sources Review and Walkover Survey Report"* by Geo Consulting Engineering Ltd, January 2021, ref: GCE01065/R1.



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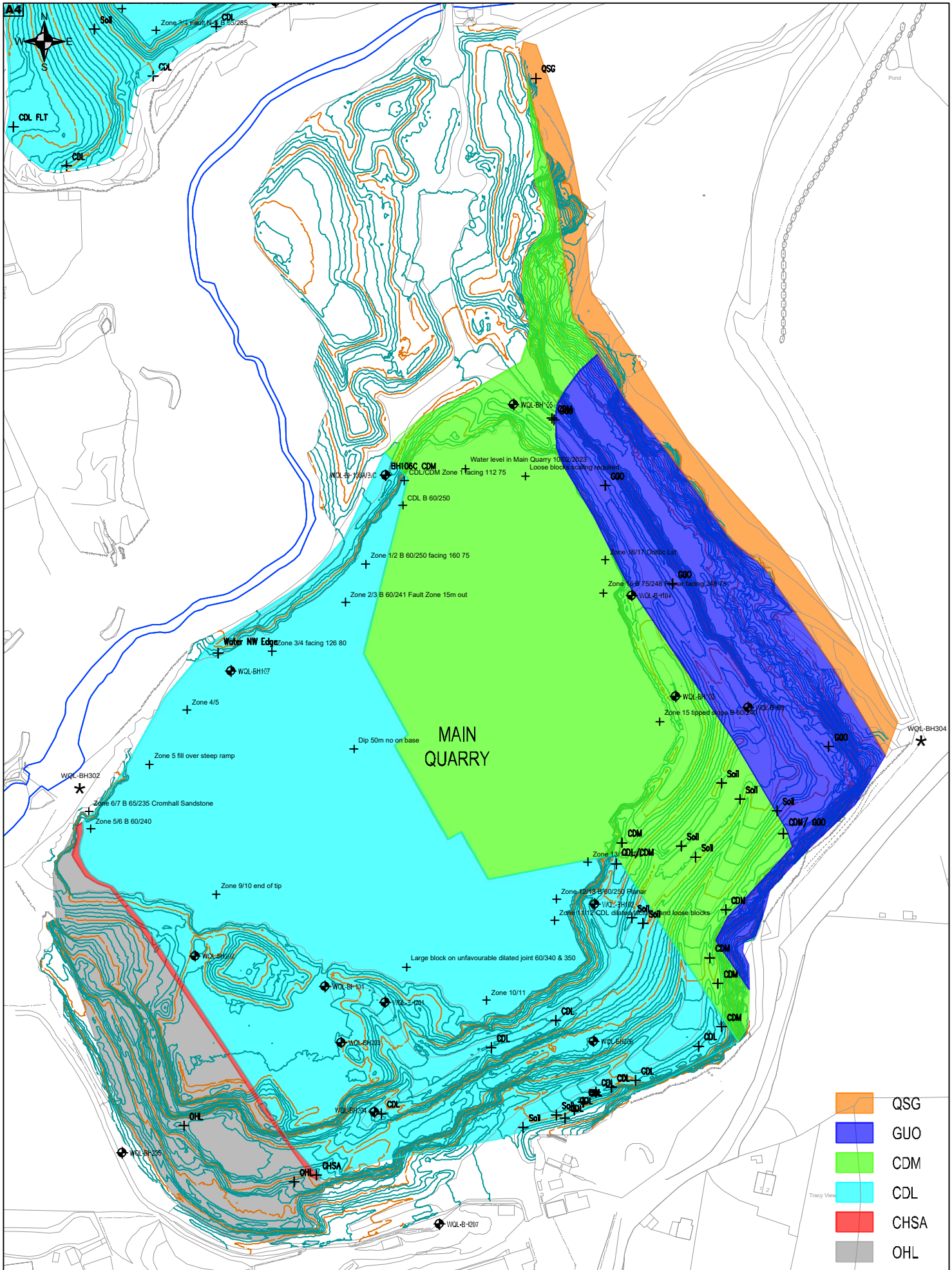
Rev	Date	Revision



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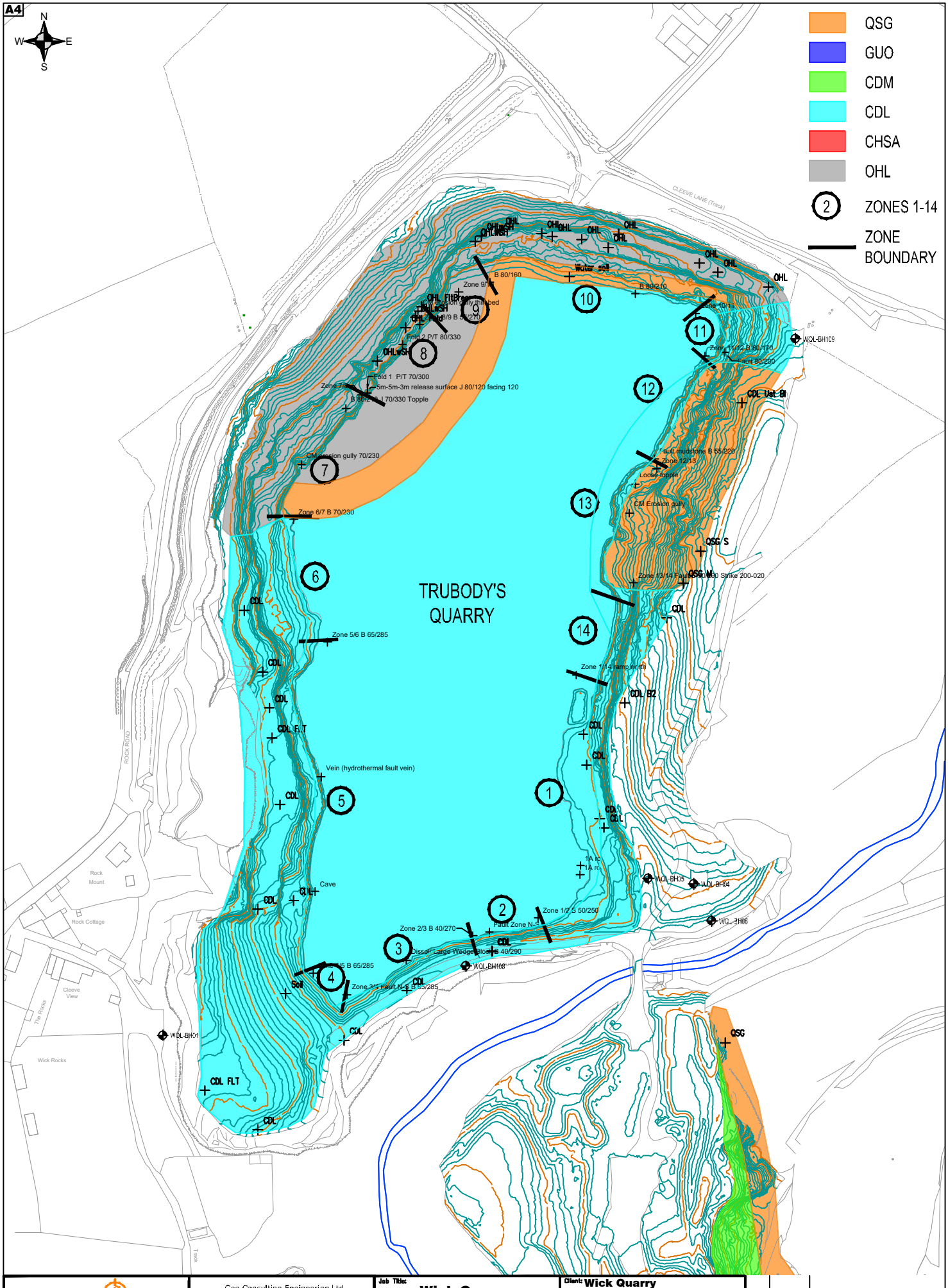

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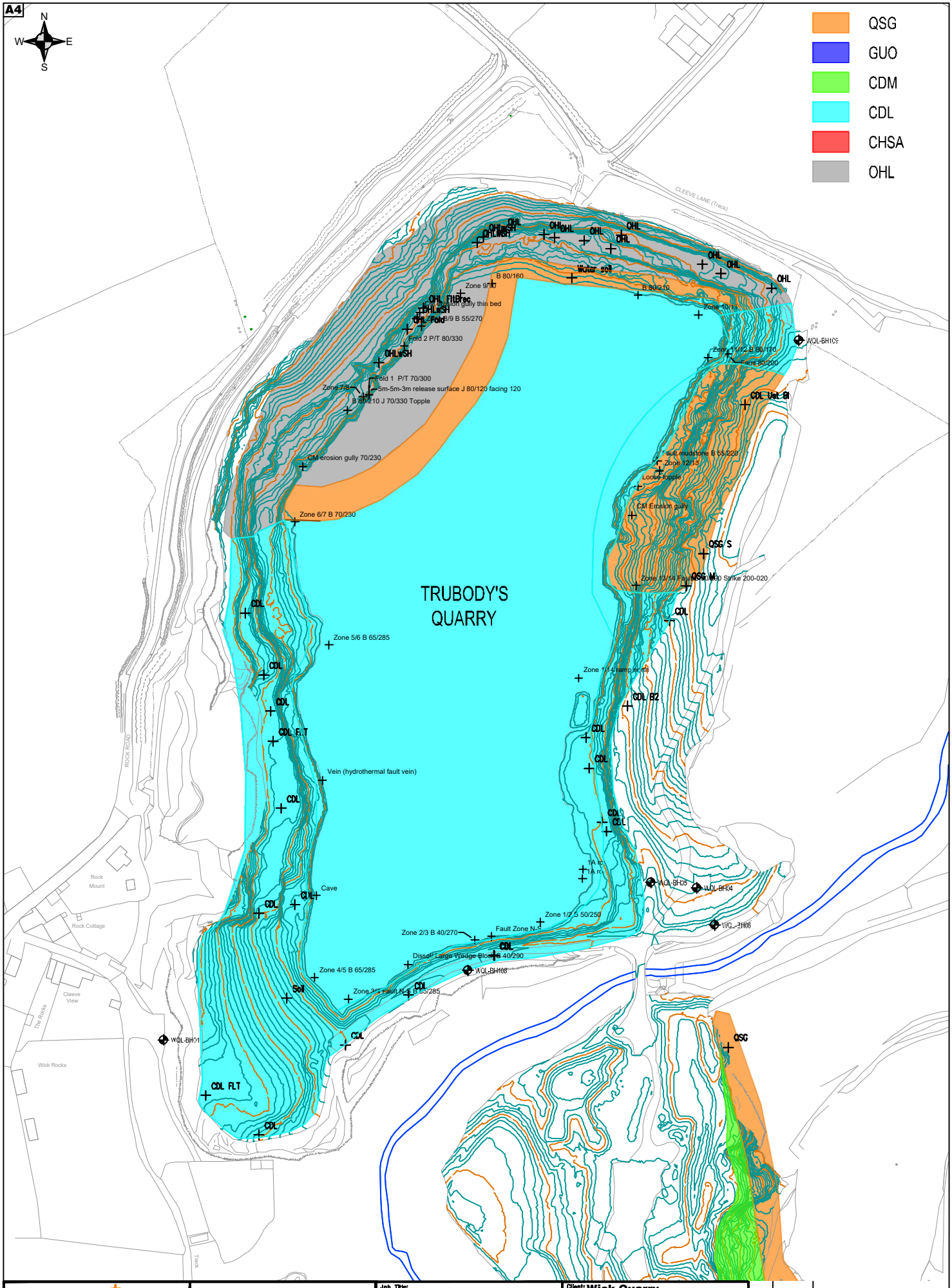

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Phase 1 Geotechnical Assessment

Preliminary Sources Review and Walkover Survey Report

Wick Quarry

Dewatering, Slope Instability, Soil Recovery and Restoration

Report: GCE01065/R1

January 2021

Report prepared for:	Horizon Consulting Engineers Suite 2 The Dairy Barn Westpoint Court Sidmouth Road Exeter EX5 1DJ
Report Number:	GCE01065/R1
Version:	1
Issue Date:	January 2021
Report Prepared by:	Philip Curtis BSc., MSc, CGeol., FGS

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Report Reviewed by: David Jackson BSc., CEng., MICE., FGS

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2.0 SITE DATA

2.1 Site Location

Wick Quarry comprise two large water filled excavations. The Main Quarry is located to the south of the River Boyd and Trubody's Quarry is located to the north of the River Boyd. The National Grid Reference for the approximate centre of the site is 371030, 173090.

A site location plan is presented in Figure 1.

2.2 Site Description

A site layout plan is presented in Figure 2. Photographs are presented in Appendix A.

Wick Quarry comprises two large and deep excavations into the limestone bedrock. The southern excavation is known as Main Quarry and the north excavation is known as Trubody's Quarry. The latter also comprises a former ARC Quarry in the south-west corner and the Gatherham Farm Extension in the north part.

The River Boyd flows generally from north-east to south-west in between the two quarries. The river bed level at the north-east end is circa 65mAOD.

The quarry excavations were previously pumped during the quarry works, however, since the pumping ceased the water levels rose from a surveyed quarry base of circa 0mAOD in the Main Quarry and circa 7mAOD in Trubody's Quarry to form large water bodies. The water levels in the quarries were measured on the 26th November 2020 as follows:

- Main Quarry 62.76mAOD
- Trubody's Quarry 63.36mAOD

Main Quarry

The Main Quarry outer and upper ground level dimensions are roughly rectangular and very approximately 400m north-east to south-west and 250m north-west to south-east. The upper boundary levels of Main Quarry are circa 100mAOD. There is variation of levels around the perimeter as expected from the combination of natural topography and the placement of quarry waste tips.

The water level in the Main Quarry forms an approximate trapezoidal shape in plan view. The approximate dimensions are:

- North-west side – 315m
- South side – 240m
- South-east side 175m
- North-east side 180m.

The approximate surface area of water, based on google earth imagery is 54,000m^2. This will vary as the water levels rise and fall seasonally.

Steep quarried rock slopes form the following areas or domains:

- Main south slopes
- Main south-east slopes
- Main east slopes
- Main north-east slopes
- Main north-west slopes
- Main south-west slopes

The details of these domains will be referenced in subsequent sections of the report in terms of the geology and topography based on previous survey data.

Neighbouring land uses around Main Quarry are summarised in the table below:

Direction	Features
North-west	Quarry boundary, woodland, River Boyd, circa 17m away at closest point.
North	Quarry Tip No. 1, Main Quarry Fill Ramp, haul track to Trubody's Quarry, former Lagoon No. 9. River Boyd and Trubody's Quarry.
North-East	Tip No. 2, farmland.
South-East	Public road, farmland.
South	Wick Quarry works area.
South-West	Access track and farmland.
West	Woodland and River Boyd, with weir and former holding pond.

Trubody's Quarry

The outer and upper ground levels Trubody's Quarry are roughly irregular rectangular in plan view. The rough dimensions are:

- East side 350m long.
- South side 250m long.
- West side 380m long
- North-west side 215m long.
- North side 170m long.

Steep quarried rock slopes with soil berms form the sides of the quarry excavation down to the water level of circa 63mAOD.

The surface water area within Trubody's Quarry as measured on Google Earth imagery is 51,250m^2. This will vary as the water levels rise and fall seasonally.

The quarry has been divided into South and North Domains:

South Domain has been sub-divided into:

- South domain south slopes.
- ARC Quarry in south-west corner
- South domain west slopes.
- South domain east slopes.

North Domain has been divided into:

- North domain east slopes.
- North domain north slopes.
- North domain west slopes.

The details of these domains will be referenced in subsequent sections of the report in terms of the geology and topography based on previous survey data.

Neighbouring land uses around Trubody's Quarry are summarised in the table below:

Direction	Features
North-west	Public road, overhead cables, farmland.
North	Access road, farmland.
North-East	Buildings with access road and farmland beyond
East	Quarry access track, woodland, farmland and Tip No. 3 Lagoons 3 & 5.
South-East	Lagoon No. 7.
South	Quarry Haul track, woodland, River Boyd, Tip No. 1
South-West	Farmland, access road, residential properties including Wick Rocks, The Rocks, Rock Cottage and Rock Mount. The property boundaries are very close to the top of the rock quarry in the area of the former ARC Quarry, which contains Tip No. 7.
West	Tip No. 8 above the quarry slope. Public road and farmland.

2.3 Geology

The underlying and exposed geology is significant due to the scale and complexity and importance in assessment of the quarry excavation stability and groundwater.

The strata are interpreted to represent an 'inlier' of older Carboniferous hard rocks surrounded by younger Triassic Mercia Mudstones. The inlier is interpreted to represent the east part of a larger scale syncline, or "U" shaped fold in the geological strata, where in general, except for faulting, the conformable beds young from east to west, indicating the core of a large fold to the west.

The geological history has resulted in a number of deformation events. The end effect of this is to create a complex set of discontinuities, or breaks within the rock mass. The discontinuities provide release surfaces for rock fall and slope instability and also provide pathways for groundwater movement. It is therefore important to recognise this complexity and, as such, the following section is more detailed than a standard report, with attention being given to the faults and folds that will result in a complex intersection of joints.

Several data sources have been reviewed in the assessment of the geology.

The Landmark Geology mapping is presented in Appendix B.

2.3.1 British Geological Survey (BGS)

British Geological Survey 1:50,000 Series Sheet 265 Bath 2011 identifies a complex geology at the site:

- The Clifton Down Limestone (CDL) Formation provides the main quarry rock largely removed by excavation.
- The Naishcombe Hill Fault strikes approximately north-east to south-west and is located on the north side of the Main Quarry. The mapping suggests the downthrow is to the south and strike slip is sinistral, which means the south side has moved to the right.

The geological sequence to the west of the quarries is mapped and interpreted to young to the west:

- Middle Cromhall Sandstone Formation (CHSA) sandstone is mapped to the west of the CDL, forming a relatively thin layer. This formation is younger than the Clifton Down Limestone.
- Oxwich Head Limestone (OHL) Formation is located to the west of the CHSA. This formation is younger than the Middle Cromhall Formation.
- Cromhall Sandstone (CSHA) sandstone followed by limestone is mapped further to the west of the OHL. These strata a mapped as being younger than the OHL.

A series of faults places younger against older geological strata. For the purpose of description these are identified below on the basis of general strike orientation as follows:

a) North-east to south-west strike.
b) East-west strike.
c) North-north-west to south-south-east strike.
d) North-west to south-east strike.

a) North-east to south-west strike:
    - NE1 crosses the north side of the Main quarry.
    - NE2 is located on the east side to the south-east of Trubody's quarry south of the River Boyd.
    - NE3 is located on the east side of Trubody's quarry north of the River Boyd.

b) East-west strike:
    - EW1 is located at the north end of Trubody's and extends to the east.
    - EW2 is located south of EW1 with limestone mapped between the two sub-parallel faults.

c) North-north-west to south-south-east strike:
    - NNW1 is located along the east side of both Main and Trubody's quarries. This was mapped as Wick Fault on the 1998 RMC mapping.
    - NNW2 is located sub-parallel and east of NNW2.

d) North-west to south-east strike:
    - NW1 is located in the north-west corner of Trubody's quarry and intersects with EW1.

The geological sequence in and to the north of Trubody's quarry is mapped and interpreted to young to the north:

- Three faults are mapped at the north end of the quarry. Fault EW1 strikes east-west across much of the east side and fault EW2 is south of and sub-parallel to EW1, with Clifton Down Limestone mapped between the two faults.
- A smaller fault NW1 is mapped in the north-west corner striking north-west to south-east. This appears to provide the east boundary of a steeply dipping syncline fold located in the north-west part of Trubody's quarry.
- The sequence of mapped strata is as follows:
    - Middle Cromhall Sandstone Formation (CHSA) sandstone is mapped to the north of the CDL, forming a relatively thin layer. This formation is younger than the Clifton Down Limestone.
    - Oxwich Head Limestone (OHL) Formation is located to the north of the CHSA. This formation is younger than the Middle Cromhall Formation.
    - Cromhall Sandstone (CSHA) sandstone followed by limestone is mapped further to the north of the OHL. These strata a mapped as being younger than the OHL.

The east side of the quarries is complex and is best divided into the area south of the River Boyd and the area north of the river, where fault NE2 indicates a general strike orientation to the south of NE2 from north-north-west to south-south-east and north of NE2 to north-east to south-west becoming east-west at the northernmost end.

The geological sequence to the east side south of the River Boyd is mapped as follows, with older strata immediately to the east and a fault placing younger strata further to the east:

- Clifton Down Mudstone (CDM) Formation is mapped in and to the east of the Main Quarry. This is interpreted on the geological mapping to be older than the Clifton Down Limestone.

- Goblin Coombe Oolite (GCO) Formation is mapped to the east of the CDM. This is identified as an 8.5m thick layer and is located within the CDM.
- CDM continues to the east.
- Gully Oolite (GuO) Formation is mapped to the east of CDM. This formation is older than the CDM and an unconformity is mapped at the contact with the CDM.
- Fault NNW1 striking north-north-west to south-south-east is mapped on the east side of the GuO.
- Quartzitic Sandstone Formation (QSG) mudstone is mapped to the east of fault NNW1. This formation is interpreted to be younger than the above CDM and GuO formations.
- Cromhall Sandstone (CSHA) sandstone followed by limestone is mapped further to the east which is older than the QSG.
- Fault NNW2 is sub-parallel to NNW2 and strikes approximately north-north-west to south-south-east with a downthrow indicated on the mapping to the east.
- The south half of fault NNW2 places the younger Quartzitic Sandstone Formation adjacent to Cromhall Sandstone Formation.
- Fault NE2 striking north-east to south-west is located south of the River Boyd within the Quartzitic Sandstone Formation.

The east side of Trubody's quarry, north of the River Boyd, is mapped as follows:

- Clifton Down Limestone in mapped across the east side of the quarry.
- Fault NNW1 continues along the east side of the quarry, however, the strike alters north of the River Boyd and fault NE2 to a north-north-east to south-south-west trend and is located on the east side of the CDL.
- A continuation of fault NNW2 meanders with an east-west strike across the River Boyd before veering on a north-north-west, south-south-east strike before intersecting NNW1.
- Quartzitic Sandstone Formation (QSG) is mapped to the east of the fault NNW1 and fault NNW2. This formation is younger than the CDL. The mapping indicates a sequence of alternating units of sandstone and mudstone striking approximately east - west.

- Fault NE3 is mapped across the QSG striking approximately north-east to south-west.

2.3.2 RMC Aggregates Ltd 1998

A simplified geological map of Main Quarry and Trubody's Quarry dated June 1998 was prepared by RMC Aggregates Limited data and apparently drew upon unpublished geological mapping carried out by Dr G A Kellaway for the British Geological Survey. The following is identified for the Main Quarry south void and east slopes south of the River Boyd:

- Clifton Down Limestone (CDL) is mapped across much of the south slopes extending north-north-west across the base of the quarry and much of the north-west slopes. Inclined strata with a dip of 60 degrees and dip direction of 240 degrees are mapped towards the base of the quarry.
- Middle Cromhall Limestone (MCS) is mapped as a relatively thin band on the west side of the CDL. The is geologically younger than the CDL.
- Hotwells Limestone is mapped to the west of the MCS. This is geologically younger than the MCS and CDL.
- A fault striking north-east to south-west with a downthrow to the south is mapped west of the Main Quarry, cutting through the Hotwells Limestone and Middle Cromhall Limestone.
- Clifton Down Mudstone (CDM) is mapped across much of the south-east slopes and east slopes of the Main Quarry, striking approximately north-north-west to south-south-east.
- Gully Oolite is mapped to the east of the CDM in the far south-west corner and along the upper quarry benches. This is geologically older then the CDM
- Wick Fault striking north-north-west to south-south-east is mapped to the east of the Gully Oolite. Upper Cromhall Sandstone (UCS) is mapped immediately east of the fault, where the younger UCS has been placed against the older Gully Oolite.
- A series of three faults striking approximately north-east to south-west cut through the Wick Fault.
- The southernmost of the three faults is mapped with a downthrow to the south, with Gully Oolite placed north of and adjacent to the younger Upper Cromhall Sandstone.

An off-set continuation of the Wick Fault places Quartzitic Sandstone Group immediately east of the Gully Oolite.

- The central of the three faults is mapped with a downthrow to the north, with the Wick Fault continuing to the north and placing CDM immediately adjacent to the QSG.
- The northernmost of the three faults is mapped to the south of the River Boyd with a downthrow to the south. The CDM is not mapped to the north of this fault whilst the CDL is mapped to the north with a continuation of the Wick Fault northwards with a downthrow to the east placing younger Quartzitic Sandstone Group immediately adjacent to the Clifton Down Limestone.

2.3.3 RMC Aggregates Ltd 2002

A simplified geological map of Trubody's Quarry and Gatherham Farm Extension was prepared by RMC Aggregates (UK) Limited and dated 04/04/2002. This identified the following:

The quarry can be divided into the south domain and north domain:

- South domain is be further sub-divided into the south slopes, east slopes and west slopes.
- North domain is sub-divided into west slopes, north slopes and east slopes.

Trubody's South Domain:

- Clifton Down Limestone (CDL) extends across the majority of Trubody's Quarry.
- West side/ slopes: Middle Cromhall Sandstone (MCS) is mapped immediately west of the CDL and Hotwells Limestone (Now mapped as Oxhill Head Limestone) to the west of MCS. This indicates younger conformable strata to the west. Faults typically east-west striking are mapped on the west side, in addition a north-north-west to south-south-east fault is mapped and a north-west to south-east striking fault is mapped on the west side.
- East side/slopes: Thrust fault with downthrow to the west is shown on the east side of the quarry, where younger Quartzitic Sandstone has been placed against the Clifton Down Limestone. East-west striking faults are mapped along this zone towards the north and towards the base of the quarry.

- Inclined strata dip measurements in degrees are marked on the map. The topographic levels of these measurements are not known.
- South side/ slopes show general trend of inclined strata dips to the west at approximately 60-70 degrees. The dip angles vary in the south-west corner around 40-50 degrees. One reading is not clear possibly 80 or 88 degrees west.
- East slopes above Trubody's Fill Ramp records dips of 61-68 degrees typically to the west. Southernmost reading dips towards the north-west.
- East slopes below haul ramp, north of fault show dips 70-72 degrees to west, south of fault 70-71 degree to south-west.
- West slopes south towards the base of the excavation indicate inclined strata dips 40-60 degree typically to the west, some measurements to north-west and some to south-west. Fault is shown in the south-west corner. Three faults are shown in the north -east corner.

Trubody's north domain is characterised by a more complex geology with overturned strata indicated by faults and folds in this zone:

- North-west side is characterised by CDL, MCS and OHL from east to west. The MCS and OHL form a syncline in the north-west corner. The east side of the fold is indicated by inclined strata dipping 50-60 degrees towards the west and south-west; the west side of the fold the strata is overturned dipping towards the south at angles around 62 degrees on the outer side of the fold and steeper around 82 degrees towards the fold core. A 72 degree dip towards the north-west i.e. 315 degree is shown in the core of the fold. This indicates the fold axis (based on SRK Consulting measurements).
- The intersection of the steeply folded bedding provides release surfaces for wedge failure.
- North side/ slopes is characterised by a fault in the north-west corner and a fault on the north boundary. Inclined strata south of the fault dips 60 degree to the west and north of the fault dips 50 degrees to the north-north-west. Overturned inclined strata are mapped to the east of the fault across the north-slopes where the dips range between circa 50 and 80 degrees and dip to the south. This indicates potential for planar failure on the north-east side of the north slopes.

- North-east side/ slopes comprises a thrust placing the older CDL against the QSF. A series of five mapped east -west trending faults cut through this zone. The inclined strata dips 85 degree to the south-west at the south end with an overturned strata reading to the west of this dipping approximately south at 70 degrees. The dip of the inclined strata becomes less steep, circa 60 degrees to the north-east. A localised inclined strata dipping 44 degrees to the east is shown between two faults, with overturned inclined strata shown to the north of the fault.

2.4 Hydrogeology

The detailed hydrogeology of the site is outside the scope of this report, however, the following is relevant to dewatering and slope instability.

The Limestone is likely to be classed as a Principal Aquifer. The limestone is characterised by karstic weathering, whereby natural breaks in the rock mass have provided preferential flow paths within the dual porosity aquifer. The rainwater falling on to the land above absorbs carbon dioxide and becomes weakly acidic and over geological time dissolves the calcium carbonate and redeposits the material as Tufa. This results in an interconnected network of dissolution widened cavities of varying dimensions.

The cavities may contain a combination of air, water and soil in varying proportions. The cavities choked with clays soils are likely to be of low permeability, however, the open cavities of air and or water provide open conduits for rapid water flow. Cavities infilled with silts and sands may be prone to piping and once choked cavities may washout under a critical hydraulic gradient.

The characteristics of limestone are therefore different to most other rock types, which are largely dual porosity aquifers where fractures under high water pressure will open preferentially.

The potential for localised permeability contrasts between different rock types and at smaller scale different layers of rock such as interbedded layers of mudstone/ shale and limestone

can result in a build up of water pressure if dewatering is undertaken too quickly for equalisation within the rock mass.

The effective stress will affect the opening or closing of fractures and therefore influence the volume of water that can pass along the opening, if there is a pressure differential driving flow.

2.5 Hydrology

The River Boyd flows between Main Quarry and Trubody's Quarry. A topographic survey indicates the bed level at the outfall of the former Lagoon No. 9 at 65.05mAOD. The stream flows from north-east to south-west.

The underlying geology is mapped as Clifton Down Limestone across much of the area relevant to the two quarries. The river crosses the Cromhall Sandstone Formation and on to the Oxhill Head Limestone to the west of Main Quarry.

The potential exists for river water to flow through preferential pathways in the limestone and into the quarry voids. The water levels in the voids as measured on the 26th November and 17th December 2020 were:

	26/11/2020	17/12/2020
Main Quarry	62.76	63.37
Trubody's Quarry	63.36	63.459

The water levels in the River Boyd appear to be higher than the water levels in the voids suggesting a hydrodynamic lag between the river water and surface water. This suggests the river bed is likely to be leaky and contribute to the surface water levels in the quarries, but the flow rate is not sufficiently high for the two levels to equalise.

It is anticipated that dewatering the quarry would result in an alteration in the hydraulic gradient of the groundwater below and to the sides of the River Boyd and an increased

hydraulic gradient is likely to result in a higher flow rate into the voids and the potential for greater loss of water to the quarry.

The previous discharge point for Trubody's Quarry is up-gradient and might mitigate the loss but result in some degree of recirculation of water.

The water within the River Boyd would likely maintain a greater pressure head nearest the open quarries, west side of Main Quarry and South side of Trubody's Quarry during the continuous dewatering of the quarries and therefore present the most likely cause for groundwater pressure imbalance and slope instability.

Collection of the water from the River Boyd up-stream of Trubody's Quarry and over-ground pumping to a location down gradient of Main Quarry could mitigate this potential significant slope instability hazard.

2.6 Site History

The following table provides a brief summary of the historical mapping, where selected information is picked out from the mapping:

Mapping Date	On-site	Off-site
1886-1887 *1:10,560*	Small quarry feature in the south and small quarry feature in area of ARC Quarry and Limekiln Quarry in north in area of Tip No. 8. Road located over Trubody's Quarry.	A weir is located on the River Boyd associated with Wick Rolling Mills (Iron works company). River Boyd channel above the weir appears to be significantly wider, i.e. flooded, than the current river channel and extends to the edge of the existing water filled Main Quarry. The upper section of river appears to follow the same path as existing.
1904 *1:10;560*	Wick Rocks Quarries labelled in the south extending across Main Quarry towards the flooded river channel of the River Boyd above the weir. Two quarries labelled on the south-west part of Trubody's Quarry.	Golden Valley Ochre and Oxide Works to the west of the Weir. Flooded river channel shown above the weir. Gatherham Farm to the north and quarries labelled immediately north of Trubody's Quarry.
1923 *1:10;560*	Largely as above	Largely as above
1955 *1:10,560*	Main Quarry in the south significantly increased in area. ARC Quarry appears larger in area as does the quarry in the west part of Trubody's Quarry.	Works associated with the quarry shown to the south of Main Quarry. Weir and flooded channel of river Boyd mapped and close to north-west boundary of Main Quarry void. Reservoir shown to the east of Main Quarry on Bury Lane.
1976 *1:10,560*	Limestone Quarry labelled in area of Main Quarry. Limestone Quarry labelled in south part of Trubody's Quarry. Embankment shown on west side of River Boyd to the north of Main Quarry. Rock Road labelled to north and across Trubody's Quarry. Water filled quarry base in area of ARC Quarry.	Works associated with quarry shown to the south. River Boyd above weir appears to follow original confined river channel. Rock Road labelled to north and across Trubody's Quarry.

Mapping Date	On-site	Off-site
1999 *1:10,000*	Main Quarry area extended to edge of River Boyd, with embankment mapped on the west and south side of the river. Conveyor shown in Main Quarry. Limestone quarry confined to the south part of Trubody's Quarry with water filled void in area of ARC Quarry. Rock Road alignment mapped over north west part of Trubody's Quarry.	"Works disused" labelled in area of former Golden Valley Ochre and Oxide Works.
2006 *1:10,000*	Perimeter of Main Quarry appears similar to existing with a small central water body in the centre. Track is shown within the quarry. Lagoon No. 9 is shown to the north of Main Quarry. Perimeter of Trubody's Quarry similar to existing, with Rock Road realigned along the west and north-west boundary of the quarry. Track is shown within the quarry. No water is identified within the quarry. Lagoon No. 7 is shown. ARC Quarry no longer shown as a water body suggesting this had been infilled.	Weir shown on River Boyd, stream channel appears to be the original narrow river bed. Associated Golden Valley Ochre and Oxide Works no longer shown. Rock Road alignment shown off site and altered to the perimeter boundary of Trubody's Quarry. Works shown to the south. Wick Rocks and associated residential properties shown immediately west of ARC Quarry.
2020 *1:10,000*	Main Quarry shown as large area of water. Trubody's Quarry shown as large area of water.	As above.

3.0 INFORMATION REVIEW

3.1 Introduction

The following information has been reviewed for data regarding the quarry rock cut excavations in order to provide a preliminary assessment of the quarry slope instability and requirements for an artificial geological barrier.

The following information sources have been reviewed

- Horizon
- Wardell Armstrong
- SRK Consulting
- CEMEX
- RMC

3.2 Horizon

Six boreholes drilled by APEX Drilling late 2020 provide information on the geological strata.

- Borehole BH01 was positioned on the south-west side of Trubody's quarry in the area of residential properties above the ARC Quarry.
- Borehole BH02 was positioned to the west of Main quarry, north of the River Boyd and west of the Weir.
- Borehole BH03 was located to the east of Main quarry.
- Borehole BH04 was located to the east of Trubody's quarry.
- Borehole BH05 was located on east side of Trubody's quarry to the west of BH04.
- Borehole BH06 was located to the east of Trubody's quarry to the south of BH04 and north of the River Boyd.

A simplified summary of the strata encountered in the boreholes:

BH01 was drilled 95m vertically from 102.3mAOD to 7.3mAOD and encountered:

- Strong to very strong grey to dark grey fine to coarse grained limestone with occasional fossils. The borehole appears to be located in the Clifton Down Limestone.
- Localised karstic weathering of fractures.
- Fractures mid angle with orthogonal and intersecting fracture orientation.
- Cross cutting calcite veins throughout with occasional quartz veins.

BH02 was drilled 63m vertically from 58.53m to -4.47mAOD. The borehole record indicates:

- Limestone from 54 - 41.8mAOD.
- Mudstone from 41.8 - 31.5mAOD.
- Sandstone from 31.5 - 18.43mAOD.
- A variable sequence of limestone, sandstone and mudstone is described from 18.4 - 4.47mAOD. This sequence is mapped as the Cromhall Sandstone Formation where both sandstone and limestone are mapped.

BH03 was drilled 64.5m vertically from 71.66mAOD to 7.16mAOD:

- Backfill was recorded to 65.6mAOD.
- Limestone was described from 65.6mAOD to 25.83mAOD.
- This was described as grey to dark grey slightly weathered to unweathered extremely strong fine to coarse grained limestone. Calcite veins with near vertical joints, orthogonal fractures, localised quartz vein mineralisation. Localised karstic weathering of steeply inclined fractures.
- Mudstone was identified from 25.8 - 7.16mAOD.
- A 45 degree contact between the limestone and mudstone was observed in the core. The surface was undulate.
- The mudstone was described as dark grey very weak to weak closely to medium spaced bedding mudstone.

- Bedding is sub 45 degrees, partings are planar to undulating and smooth, locally polished, shiny and glassy.
- Locally highly to completely weathered zones of hard and soft clay layers below 14mAOD.
- Below 10mAOD fractures surfaces are smooth with vertical slickenside striations with calcite growth, with locally polished fracture surfaces.

BH04 was drilled 73m vertically from 76mAOD to 3mAOD:

- Backfill was recorded to 66mAOD.
- Drillers description of broken limestone to 64.5mAOD and limestone to 63mAOD.
- Sandstone was encountered from 63m to 46mAOD.
- From 63m to 56.8mAOD was grey strong medium grained grey Sandstone. Fractures medium to wide spacing surfaces smooth to rough. Occasional white and pink staining. Occasional quartz veins. Steep orthogonal fractures along beds and joints.
- The sandstone was reddish brown to 55.6mAOD, grey to 47.1mAOD, red brown to 46mAOD.
- Mudstone was recorded from 46 - 43mAOD. This was described as dark purplish grey mottled grey green weak to medium strong Mudstone. Very dark layers of fine mudstone throughout. This zone appears to represent a possible shear zone?
- At 43mAOD a 60-70 degree contact between the mudstone and sandstone below.
- Alternating layers of red brown and grey sandstone from 43m - 29mAOD.
- A zone of low RQD (9 to 10) was encountered from 44.9 - 47.7mbgl (31.1m - 28.3mAOD) and a zone of zero RQD was encountered from 47.7 - 48.5mbgl (28.3m-27.5mAOD). The borehole was open-hole drilled from 48.5m to 51.2mbgl. This indicates a highly fractured zone from 31.1m to 24.8mAOD. The material recovered was described as grey crystalline limestone with red brown staining and clayey infill.
- Strong to extremely strong dark blueish grey Mudstone was encountered from 24.8m - 3mAOD. Occasional red brown veins recorded. Quartz mineralisation on parting at 45 degrees. Fractures generally clean.

BH05 was drilled 31m vertically from 72.76mAOD to 41.76mAOD.

- Backfill recorded to 68.26mAOD.
- Drillers description of broken limestone to 61.26mAOD.
- Sandstone was encountered from 61.26m - 50mAOD. The sandstone was described as very strong to extremely strong fine to medium grained SANDSTONE. Fractures are medium to wide spacing with pinkish brown staining.
- RQD was zero with no solid core recovery from 61.26m - 58.26mAOD and low, RQD=7 from 55.26m - 53.66mAOD.
- Total core recovery improved below 19.1m below ground level, although the range was 26-75% and the lowest was at the base of the borehole.
- Mudstone was encountered from 50mAOD to 41.76mAOD.
- The mudstone was described as very dark grey mottled grey green and red extremely strong mudstone. Bedding is close spaced. Fracture spacing is fine to medium planar and smooth with occasional white staining. Fractures steeply dipping with horizontal slickenside striations with horizontal calcite crystal growth. Localised brecciated appearance indicative of a shear zone.

BH06 was drilled 25.8m vertically from 70.58mAOD to 44.78mAOD:

- Drillers description of clay to 62.8mAOD.
- Drillers description of limestone to 60.58mAOD.
- RQD's of zero from 60.58 - 57.01mAOD. Recovered material grey strong fine to medium grained sandstone. Fractures are close to medium spaced, stepped, random and rough, with red brown staining.
- Poor recovery from 57.01 - 55.68mAOD. Described as stiff red brown mottled grey clay tending to weak mudstone.
- RQD and SCR of zero from 55.68m - 54.18mAOD.
- Sandstone recovered from 54.18m - 44.78mAOD.
- The sandstone was described as dark grey very strong to extremely strong sandstone. Fractures closely to mediumly spaced, random, stepped and rough with red brown staining and occasional clay infill. Occasional quartz veins. Occasional dark grey bedding. Occasional red brown sand infill on fractures.

- Poor recovery 21.6 - 22mbgl and 24.7 - 25.8mbgl at the base of the hole.

Approximate water levels using a Topcon GPS were measured on 26th November 2020 by GCEL. These were:

- Main Quarry 62.76mAOD
- Trubody's Quarry 63.36mAOD.

Static groundwater depths (GWD)were recorded on the borehole records by APEX. The following table summarises the initial depths and corresponding water levels (GWL):

BH	1	2	3	4	5	6
GL mAOD	102.31	58.53	71.66	76	72.76	70.58
GWD mbgl	35.3	3.3	8.4	11.1	8.9	5.25
GWL mAOD	67.01	55.23	63.26	64.9	63.86	65.33
Quarry WL 26/11/2020	63.36	62.76	62.76	63.36	63.36	63.36

Further monitoring of the groundwater levels and quarry water levels is required, together with water levels in the River Boyd.

River Boyd Bed Level north of Lagoon No. 9 was 65.05mAOD (SKR 2007 report).

The above preliminary water levels indicate the following:

- Main Quarry (MQ) water levels of BH03 (63.26)>MQ (62.75)>BH02 (55.23mAOD). This indicates a hydraulic gradient from east to west, or a permeability contrast on the west side of the quarry, or a drop in river bed level to the west.
- Trubody's Quarry east side: BH05(63.86mAOD) is just above TQ (63.26mAOD), suggesting localised connectivity. BH06 (65.33)>BH05 (64.9)>BH04 (63.86mAOD). Trubody's Quarry west side: BH01 (67.01)>TQ (63.26mAOD). This indicates groundwater flow into the quarry and a rate below evaporation rates from the open water body.

3.3 Wardell Armstrong

Wardell Armstrong - Notes of Meeting date 11/03/2020 with EA and MJC

- EA require site-specific information on the water balance for the current baseline to understand the hydrogeological area of recharge, units where flow occurs, hydrogeological controls on flow such as structures and identified discharge zones.
- Anecdotal report from an EA hydrogeologist who has previously worked on the site when it was operational and 'reports that the river leaked like a sieve when the quarry was being dewatered'. WFD status of the River Boyd is a key consideration for future assessments.

Wardell Armstrong report, "A New Authorisation" December 2019. For MJC Ltd.

Introduction:

Wick Quarry operated since late 1800's. Two voids: Trubody's (north) and Main Quarry (south), separated by the River Boyd flowing south-west direction.

Site has planning permission (Ref: PK15/1959/F) for 'restoration of a quarry to a nature reserve and outline permission for a wardens lodge (dwelling), greenhouse, poly tunnels, barns, machinery shed, workshop and office with welfare facilities, education centre and business and office units (Drawing WICK011).

Site has been operational for decades and abstracted water to allow mineral extraction up until the end of 2011. The activity of dewatering was previously an 'exempt activity' and did not require an abstraction licence. However in January 2018 new regulations came into effect which meant the activity of dewatering is no longer exempt and an abstraction licence would need to be in place for this activity to continue.

Opencast excavations extend to between 50m and 60m below the water table, resulting in slope heights in the range of 80m to 100m in Trubody's quarry and 60m to 85m in the Main Quarry.

Dewatering was required for mineral extraction however ceased in later 2011 and water was allowed to recover to its natural levels.

Geotechnical Issues

Numerous geotechnical assessments have been undertaken at the site, all of which conclude that the site has stability issues and is not safe. The stability issues include, but are not limited to: general rockfall involving frequent release of relatively small isolated blocks of rock; and planar, wedge and toppling failure involving the less frequent release of larger masses of rock.

Geotechnical actions include but are not limited to: install buttress support for the full height of slopes; scaling and bolting and meshing of benches; and pushing back of the lower exposed benches to a profile which eliminates the overhanging.

Part VI of The Quarries Regulations 1999, state that the operator shall ensure that excavations and tips are designed, constructed, operated and maintained so as to ensure the a) instability; or b) movement, which is likely to give rise to a risk to the health and safety of any person is avoided. Therefore the quarry will need to be structurally safe before restoration of the site can commence and will require dewatering of the quarry voids to achieve these safety measures.

Historically, the quarrying extended below the water table resulting in water entering the workings. During operations, water was pumped out of the voids and into the River Boyd under the provision of discharge consent licences.

One Flygt 2151 submersible pump was installed in Trubody's quarry and two Flygt 2151 submersible pumps were installed in Main quarry. All Flygt 2151 pumps pump to Stage pumps and discharge via an 8'' outlet to the River Boyd at two different locations. The site has two discharge consents. Discharge location 1 (Drawing ST17205-002) is permitted to discharge 7,500m^3/d and discharge location 2 is permitted to discharge 12,500m^3/ day. Discharge flow rate from both voids were monitored daily, records for January 2011 can be found in Appendix 2 of the WA document.

Mineral extraction and dewatering was suspended in late 2011. The water levels have since been allowed to recover to their natural level at approximately the level of River Boyd at 60mAOD.

Future dewatering

Communication with the EA (Appendix 4 of the document) identifies that the final methodology for waste disposal will need to be confirmed. If the decision is made not to dispose of waste directly into water then stabilisation works will be required to allow the quarry to be safely accessed and dewatering will be required to achieve these stabilisation works.

The restoration of the site is estimated to take approximately 25 years. During these restoration works, there will be a continued need to undertake geotechnical assessment of the voids to ensure that they are still safe to be working within. The voids will be required to be dewatered for these assessments to be completed to ensure that all areas where restoration work is occurring are safe.

Water levels within the quarry voids are currently approximately 60mAOD. The voids will need to be dewatered to approximately -5mAOD.

Appendices to the WA report:

Appendix 1 email from EA regarding abstraction licence application query.

Appendix 2 detail of pump.

Appendix 3 discharge log Jan 2011. Flow rates of 40 for Trubody's and 75 for Water Hole. Units not detailed.

Appendix 4 Wick Quarry – Geotechnical Assessments Report. SRK Consulting BROW-Wick-2010-rep-Final.doc July 2010.

Appendix 5 Discharge consent:
Outlet B max. discharge 12,500 m^3/day 144 litres/ second.
Outlet A max 7,500m^3/day, 87 litres/ second.

Appendix 6: EA 12/11/2019. Environmental Permitting – Recovery or Disposal Operation.

3.4 SRK Consulting

SRK Consulting September 2001 – Initial geotechnical assessments report – excavations, tips, stockpiles and lagoons.

- Four solid tips.
- Three liquid lagoons, one of which is silt.
- Quarry site also contains two tunnels.
- River Boyd bisects the site.

11 significant hazards identified.

SRK 2002:

Photographs:

Main Quarry –

- East slope shows base sump, below dry quarry base circa 5mAOD, with six benches and Tip No 2 at top.
- South-east slope – joint controlled cut bench dip direction approximately 315 degrees, very steep.
- South slope – Bedding with apparent dip direction approximately 250 degrees, appears less steep at base.
- South-west slope. Very steep cut slope in corner, with end tipped material bench 1 to 2. Sump at base of quarry.

Trubody's Quarry –

- Northern domain – syncline shown.
- Southern domain – Localised large planar failures apparent on the east side slope. Apparent bedding steeply dipping towards circa 250 degrees. Water seepages from south slope below River Boyd.
- West slope – Very steep cut and blast slopes. Bedding appears to dip into the slope, however, perpendicular joint set dips out of slope. This creates a bedding release and joint sliding surface for block failure. Steeply dipping beds with localised undermining

provide toppling failure potential, although a steep south dipping joint/fault set is apparent which indicates potential for wedge failure.

SRK 2003:

Figure 1 section provides dip and dip direction data. This indicates a joint set perpendicular to the bedding, so providing base failure surface, with bedding release surface discontinuities for wedge and block failure on west side of quarry.

Figure 1.2 provides illustration of geology and discontinuity mapping in Gatherham Farm extension.

SRK 2004:

Photographs (Gatherham Farm Extension):

1. North domain north-west active slopes (Gatherham Farm Extension), looking north-west from east Slope. Nose of Syncline in north-west corner at base of bench 3. Bench rollover slope in north-west corner.
2. Bench 1 rollover slope, with tension cracks.
3. Large tension cracks in Bench 1 rollover slope.
4. Folded bedding creates potential wedge release surface on north-west and west side of Trubody's Quarry.
5. Axis of syncline 85/338 dipping steeply into the cut slope. Clay/shale layer on both outer limbs of the fold.
6. Intersection of folded bedding of limestone and sandstone and unfavourable joint sets creates unstable wedge block failure mechanism.
7. North domain, north-east corner and east slope. Fault zone, potential toppling zone, bedding strike approximately east-west and due to orientation of fold limbs creates a toppling zone potential.
8. East slope looking south – South domain – slope parallel to bedding with undercutting of bedding; north domain – slope normal to bedding.

- Access tunnel and surge pile tunnel photographs. Loose mesh.
- Tip No 8 placed above East Slope of Trubody's Quarry.

- Main Quarry Fill ramp, blasting to bench 2 has created overhangs due to undercutting.
- Main quarry east slope. Unstable column of rock with recent fall.

SRK 2005:

Fig 1.1. photograph – View of north-west corner of Trubody's Quarry zone 70m to 90m, toppling block failure on clay filled joint parallel to slope striking NNE-SSW (dip direction approximately 315 degrees).

Fig 1.2 View of north-west corner of Trubody's Quarry with bench levels of 70m, 63m and 57m. Fold apparent in north-east corner.

Fig 3.1 Gatherham Farm Extension north end of excavation. New rollover slope shown. Folded bedding orientation varies, normal to cut on west side, parallel to cut on north side circa dip direction 180 degrees, dip circa 80 degrees. Undercutting evident on north side, planar failure potential B3.

Fig 3.2 Southern end of rollover slope, showing restoration of slips in upper part of slope.

Hazard Plan with Cross Sections of Trubody's Quarry.

Drawings include:

Hazard Plan:

Trubody's area indicates Moderate Hazard at:

- North Domain Gatherham Farm Extension. Bedding at north end 80/163, 80/155, 90/190.
- North Domain East Slope
- South Domain East Slope
- South Domain South Slope.

Low Hazard identified at:

- South Domain West Slope
- Tip No. 7
- Tip No. 8
- Trubody's Fill Ramp

Main Quarry area indicates Moderate Hazard at:

- Main South Slope.

- Main East Slope.

Low Hazard is shown at:

- Main north-west slope
- Main south-west slope
- Tip No. 1
- Tip No. 2
- Red corner stockpiles
- Dust
- MOT type 1 Stockpile
- Surge Stockpile
- Top Rock & Scalping Stockpile
- Main Quarry Fill Ramp.

Site Development Plan

Cross Sections through Trudbody's

SRK 2006:

Significant hazards:

- Trubody's Quarry (including Gatherham Farm Extension)
- Main Quarry

Non-significant hazards:

- Access and surge pile tunnels.

Water levels in base of quarries:

- Trubody's 7.96mAOD 09/08/2006.
- Main Quarry 3.89mAOD 26/05/2005.

Hazard Plan:

Identifies inadequate berm width on north-west slope of North Domain Gatherham Farm Extension.

SRK 2007:

Existing Quarry Elements:

Significant risk:

- Trubody's Quarry (including Gatherham Farm Extension)
- Main Quarry.

Non-significant hazards:

- Access and surge tunnels.

Tips:

None of the tips are classified as Significant Hazards at Wick Quarry.

Non-significant hazards:

- Tip No. 1
- Tip No. 2
- Tip No. 5
- Tip No. 7
- Tip No. 8
- Main Quarry Fill Ramp
- Trubody's Fill Ramp

Section 1.5 details the Location.

- River Boyd flows between Trubody's and Main Quarries at elevations of 67mAOD to 53mAOD.
- The river is 17m from Main Quarry at its closest.
- The river is 10m from Trubody's quarry at its closest.
- Trubody's incorporates a smaller excavation the 'ARC Quarry' on its south-western side.
- Residential areas are located on the southern boundary of Main quarry (Wick) and to the west of Trubody's quarry (Wick Rocks). The closest being within 6m of the quarry.

River Boyd Bed Level north of Lagoon No. 9 was 65.05mAOD.

Excavations:

Trubody's Quarry (including Gatherham Farm Extension)

North domain:

- Majority of production has taken place.
- Another lift taken out of the quarry floor circa 24mAOD.
- Benches 5 and 6 have been the primary excavation benches and are not in their final positions.
- Final slopes of the northern, north- western and western slopes have been re-designed to incorporate a 5m stand-off from the toe of the slopes that run adjacent to the main haul road into working area to the 24mAOD level.
- The slope geometries have generally been developed in line with the re-design in the fact that they have left a wide access ramp in place.
- It was noted, however, during the site visit, that the 5m standoff had not been developed or maintained.

Northern Slopes:

- *With the exception of the newly formed bench below the haul road (Bench 6) there have been no changes to the benches within the northern slopes of Trubody's Excavation.*
- *The benches have been excavated beyond their final design limits and minimal berm widths have been left, which, in addition to the effects of the break-back, has resulted in final berm widths which are ineffective in containing rockfall.*

Fig 3-1. Photograph shows Benches 1, 1a, 2, 3, 4, 5, 6 and excavation at 22mAOD level. Proposed 5m standoff on Bench 5 haul road yet to be developed.

North-western Slopes:

- *Excavation taking working level down to 24mAOD.*

- *The overall slope is approximately 55 degrees and despite the non-compliance with the original final design, it has not had any adverse affects on the overall slope stability and is unlikely to do so.*
- *In the area of the syncline axis bedding plane strike steeply obliquely and normal to the slopes which is favourable to stability though there is some ravelling of weaker materials on the benches which has lead to some rugged slopes and rock fall.*
- *The berm that has been left at the toe of Bench 5 is in places less than 1m width. This may be a result of over quarrying or break back along joint sub-parallel to the slope but the end effect will likely increase the risk of rockfall reaching the working level.*

Eastern Slopes:

- *Excavation to 24mAOD with two additional benches on the eastern slopes. The benches are both lower than 12m height. The slopes remain stable and there are no geotechnical concerns.*

Western Slopes:

- *Excavation has lowered the toe of the western slopes to 22m AOD, with benches 5 and 6 in their final positions.*
- *Poor rock quality and break back have lead to the loss of berms in the upper benches.*
- *Again, narrow berm widths that have been left enhance the risk of rockfall though the final design incorporates the 5m stand-off at the toe of these slopes.*
- *With the blocky nature of the rock in this area it is imperative that the stand-off is developed and maintained.*

Figure 3-2 Photograph Northern Slopes shows new haul road. This is around Bench 5 dropping down to Bench 6.

Figure 3-3 Photograph Eastern Slopes shows north domain and south domain.

Figure 3-4 Photograph North Western Slopes. Shows Benches B1a, 1b, 2, 3, 4, 5 and 6. Steeply dipping fold axis visible from bench 2 to 6.

Figure 3-5 Photograph Western Slopes. Bench levels:

- B1a 90mAOD. Top of slope 96mAOD.
- B1b 80 - 84mAOD
- B2 70mAOD. Grass covered berm 70mAOD at north end
- B3 57mAOD. Grass covered berm 63 - 70mAOD at south end
- B4 46mAOD. Blocky poor-quality rock at south end.
- B5 38mAOD. Blocky poor-quality rock at south end. Undercutting
- B6 22mAOD. Blocky poor-quality rock at south end. Undercutting

SRK 2010 (WA Report Appendix 4)

A geotechnical assessment of the quarry was undertaken on 27th July 2010.

This identifies the excavations of Trubody's and Main Quarry as Significant Hazards. The report identifies that previously worked areas are no longer accessed, which reduces the hazard provided there is no entry.

Water level in Main Quarry 15.1mAOD. The report identifies rock slope protection measures above the narrow haul road on the east side of Main Quarry. Photographs show the now submerged benches on the east and north-east sides. The bench width appears narrow, with little edge protection for falling debris. The excavation cut slopes appear parallel to the bedding. Hydrophilic vegetation is evident on the slopes towards the base and on the benches and in the south-east corner.

Water level in Trubody's Quarry at 48mAOD. Photograph shows water inflow on the east slope in the area of the former pumping pipework.

3.5 CEMEX

CEMEX 20th June 2008 Includes Memorandum from David Roberts to Brian Mills:

From the attached plan you will see that along the north-western boundary of the old quarry (red boundary adjacent to River Boyd) that we have already worked slightly outside the permitted boundary, although it appears to have been a long time ago. The limit of the current working in this area therefore defines the full extent of the quarry. I have spoken to Shaun Denny (Western Development Planner) who confirms that the presence of the haul road outside this area is not a problem.

At the western end of the site, the consented (blue) boundary for most of its length coincides with the edge of the stockpile area but extends into the old quarry. The quarry in the extreme north-west has developed slightly beyond this boundary, but given the nature of the land surface in that area, I don't think anyone will notice. Again though, the extent of the existing quarry is as far as we can go.

Plan showing permitted areas at Wick Quarry.

Drawing: CEMEX UK Material Limited – Wick Quarry – Planning Boundaries – Old Quarry 20-06-2008.

3.6 RMC

Wick Quarry – Gatherham Farm Extension Site (Wick Quarry) Geological, hydrogeological and hydrogeological assessment. December 1997.

- Three boreholes drilled October 1988. BH1 - BH3
- Seven trial pits 1992.
- Eleven boreholes drilled March 1993.
- Three boreholes October 1997 BH1/97, BH2/97, BH3/97.
- The boreholes drilled in 1993 geophysically logged for natural gamma and density sondes.
- Standpipe piezometers were installed in BH4, BH7 and BH3/97.

The Wick Quarry floor at 31mAOD was approximately 10m lower than the groundwater levels measured at Gatherham Farm. Water maintained in the quarry floor sump at 30mAOD.

Archive information indicates a consistent water level of 65mAOD, approximately coincident with the River Boyd.

- Quarry inflow is estimated at 264m^3/year.

Borehole water depths and levels for BH/3 and BH/4. Groundwater levels 1997:

- BH/3: July 41.09m, Nov 42.47mAOD,
- BH/4: Oct 36.6m, Dec 43.1mAOD.

5.0 PRELIMINARY GEOTECHNICAL WALKOVER & DISCONTINUITY SURVEY

5.1 Introduction

A walkover survey was undertaken on the 17th December 2020. The purpose of the survey was to observe the characteristics of the mapped geology and measure the discontinuities (breaks in the rock mass) in order to assess the geotechnical characteristics and instability of the quarry excavations in view of the proposed dewatering process.

The survey included the following:

- Walking the haul roads above water level of circa 63.3mAOD.
- Recording each location with GPS easting, northing and level.
- Description of the rock type and comparison with the geological mapping.
- Discontinuity measurements of dip, dip direction and interpreted discontinuity type.
- Observations of faults and folds.

Cross Sections for Main Quarry are presented in Appendix C. Cross Sections for Trubody's Quarry are presented in Appendix D.

5.2 Main Quarry Geology

The walkover survey of Main Quarry identified the following geological formations:

- Clifton Down Limestone (CDL)
- Clifton Down Mudstone (CDM)
- Gully Oolite (GuO)
- Cromhall Sandstone (CHSA)
- Oxhill Head Limestone (OHL)

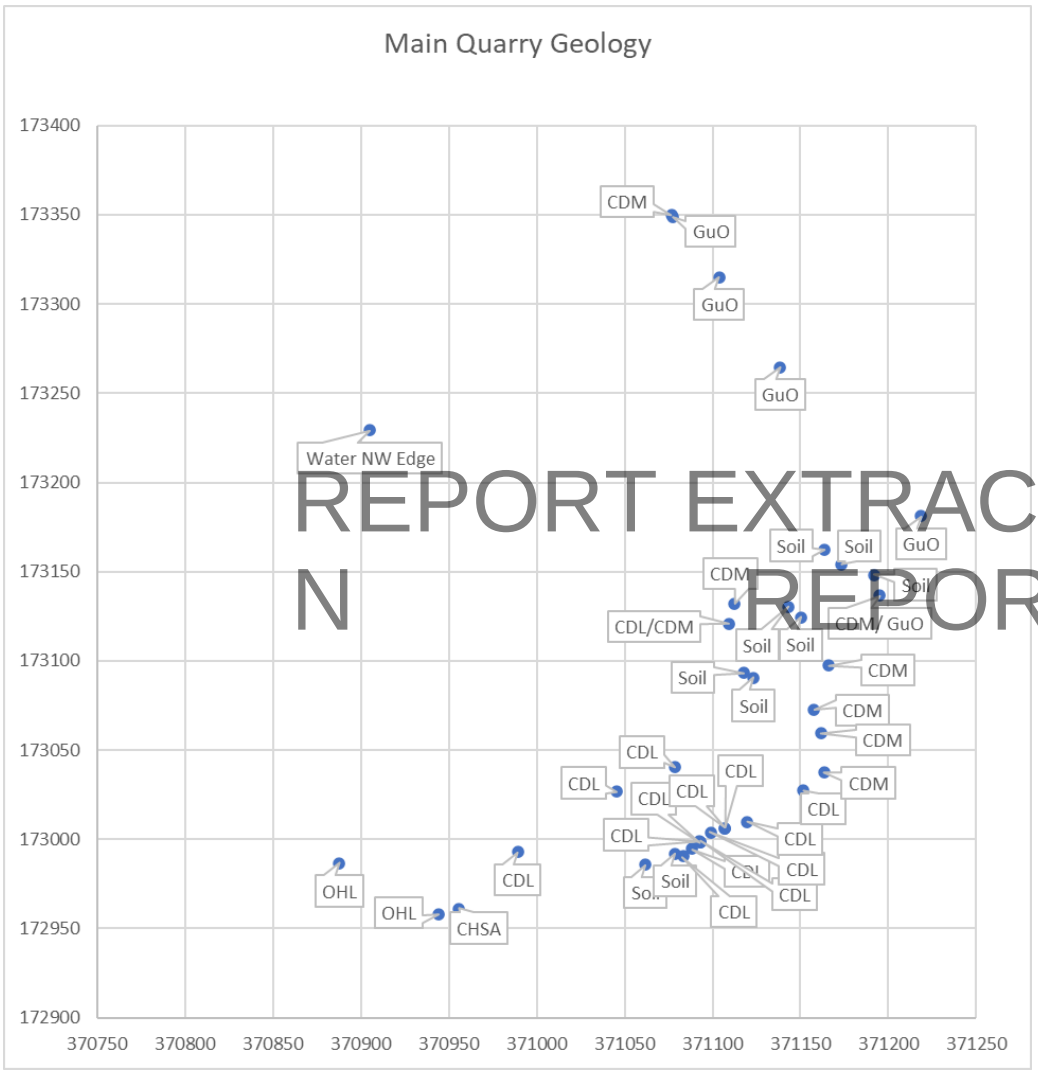
Locations 100-138 were recorded using the GPS to provide eastings, northings and levels.

The following table indicates the geology at each location:

Point	Easting	Northing	Level	Quarry	Geology	Point	Easting	Northing	Level	Quarry	Geology
100	371061.873	172985.783	95.665	MQ	Soil						
101	371078.825	172992.105	94.338	MQ	Soil	120	371163.618	173162.405	73.731	MQ	Soil
102	371088.008	172994.588	94.861	MQ	CDL	121	371150.386	173124.473	74.126	MQ	Soil
103	371083.176	172990.558	96.126	MQ	CDL	122	371143.033	173130.102	74.086	MQ	Soil
104	371092.414	172998.819	92.997	MQ	CDL	123	371123.342	173090.461	73.835	MQ	Soil
105	371092.845	172998.608	93.087	MQ	CDL	124	371117.641	173093.254	74.024	MQ	Soil
106	371092.853	172998.608	93.079	MQ	CDL	125	371078.544	173040.656	71.296	MQ	CDL
107	371099.082	173003.768	91.457	MQ	CDL	126	371045.42	173026.724	71.24	MQ	CDL
108	371107.1	173006.298	90.647	MQ	CDL	127	370989.091	172992.797	75.549	MQ	CDL
109	371107.161	173006.241	90.66	MQ	CDL	128	370955.889	172961.254	80.967	MQ	CHSA
110	371119.544	173009.892	88.897	MQ	CDL	129	370944.262	172957.817	83.379	MQ	OHL
111	371151.797	173027.423	89.508	MQ	CDL	130	370887.658	172986.541	81.331	MQ	OHL
112	371163.616	173037.375	87.337	MQ	CDM	131	371109.59	173121.002	68.419	MQ	CDL/CDM
113	371157.623	173072.823	83.795	MQ	CDM	132	371112.596	173131.874	67.335	MQ	CDM
114	371161.835	173059.539	85.412	MQ	CDM	133	371138.402	173264.718	68.234	MQ	GuO
115	371165.779	173097.392	80.892	MQ	CDM	134	371103.888	173315.169	67.061	MQ	GuO
116	371192.064	173148.286	77.294	MQ	CDM/GuO	135	371077.621	173348.787	67.555	MQ	GuO
117	371195.239	173136.581	78.4	MQ	GuO	136	371076.666	173349.705	67.576	MQ	CDM
118	371218.685	173181.191	81.256	MQ	GuO	137	370905.224	173229.268	63.337	MQ	Water
119	371173.145	173154.162	73.82	MQ	Soil	138	371068.359	173524.067	77.746	MQ	QSG

Note water level 63.337mAOD on 17th December 2020, compared to 62.76mAOD on 26th November 2020.

The following plot of points based on eastings and northings shows the identified geological formation at each location:



The above plot combined with the walkover survey observations provides the following:

- South Slope characterised by Clifton Down Limestone. A 4m bed of Cromhall Sandstone was encountered on the west boundary of the CDL and Oxhill Head Limestone to the west of the CHSA. Soil filled berms and haul roads present.

- Boundary between Clifton Down Limestone and Clifton Down Mudstone confirmed at boundary between south slope and south-east slope.
- South-east Slope characterised by Clifton Down Mudstone with soil filled berms and haul roads.
- East slope characterised by Gully Oolite exposure on the east side above the main haul road, with Clifton Down Mudstone at the north end, in alignment with the geological mapping indicating Clifton Down Mudstone below and to the west of the main haul road and forming the submerged east side quarry cut slopes.
- North-west slope submerged with no visible outcrop, except to the north-west of the River Boyd. Soil berms and former submerged haul road located on west side.
- Quartzitic Sandstone Group was identified to the east of the former Lagoon No. 9.

Clifton Down Limestone:

The following table provides descriptions of the rock mass:

Points	Rock Mass
104-106	Strong brown and grey, closely, medium, widely spaced bedding locally massive LIMESTONE. Calcite veins. Joint set discontinuities measured.
107	Strong grey massive to widely spaced bedded LIMESTONE. Bed of fault breccia. Fault above strike 100-280 degrees, rock cream grey on south side, bedding near horizontal above fault. Bed 50/230. Joint set discontinuities measured.
108-109	Strong grey and brown massive to thickly bedded LIMESTONE. Bedding dips to west 55/240. Joints dip to north. Preferred orientation of calcite veins strike east-west. Joint set discontinuities measured.
110	Tunnel: Strong grey and brown thickly bedded LIMESTONE. Beds dipping to west. Joints striking east-west, with near vertical dip that varies in direction from north to south. This indicates a release surface for block slides on lower angled joints dipping to the north.
111	Limestone massive beds dipping to west. Joints strike east-west, with near vertical dip that varies in direction from north to south.
125	Bedding 55/250. Joint set discontinuities measured.
126	Joint dip/ dip direction 40/010 is unfavourable and provides a sliding surface for block failure.
127	Bedding 55/235. Joint 65/020 provides an unfavourable release surface, when combined with the joint at 126.

The joint set orientations are likely to dominate the stability characteristics of the rock mass on the south slope.

The above indicates bedding with intersecting joint sets combined with the likely karstic weathering of the limestone will allow release of water from south to north.

The presence of steep joints dipping to the north provides a probable release surface and this would act as a tension crack with water pressure. The greater the water pressure the greater the

destabilising force. The combination of bedding and orthogonal joints is likely to provide wedge base surfaces for block sliding with uplift water pressure, subject to the rate of surface water pumping and equalisation of groundwater pressures.

A groundwater monitoring borehole is recommended on the south side of the quarry within the Clifton Down Limestone.

Clifton Down Mudstone:

The following table provides descriptions of the rock mass:

Points	Rock Mass
112	West dipping bed forming quarry slope face. Exposure: Very strong dark grey, purple, paleo-bed, fine-grained thinly laminated to varved muddy LIMESTONE. Bed 55/255. Joint set discontinuities measured.
112-113	Quarry slope faces west. Very strong dark grey micritic to muddy LIMESTONE. Bedding thickness alternates from thin becoming medium spaced bedding to the east, with beds of black lime/mud/shale, altered to preferentially eroded light grey shale/ lime beds 200-500mm with very strong muddy limestone beds. Bed 45/245. Joint set discontinuities measured.
114	Bed 45/245. Joint set discontinuities measured.
115	Lime/shale bed 1.2m thick dipping steeply to the west 52/230. This bed is preferentially weathered and eroded compared to the stronger limestone/ lime/mud beds including some very strong banded and glassy to vitreous limestone beds.
116-117	Transition zone from CDM to Gully Oolite.
136	Transition from Gully Oolite to CDM at north end of east slope. Exposure of Strong limestone with beds of shale and a breccia/ conglomerate horizon.

A bedded rock mass will normally display anisotropic behaviour, where the horizontal hydraulic conductivity along the beds is often greater than across the beds.

The presence of westerly dipping steep beds of muddy limestone/ calcareous shale interbedded with the very strong limestone beds is significant in terms of the horizontal hydraulic conductivity of the strata. This alters a favourable anisotropic hydraulic conductivity to an unfavourable condition, where the steeply dipping beds of calcareous shale form a permeability contrast which is likely to slow the groundwater equalisation on the east side of the quarry as dewatering takes place. This is likely to result in an imbalance of water pressures and a rapid-draw-down condition.

The shaly limestone beds are likely to provide zone of preferential weakness and therefore likely failure surfaces, particularly when combined with an imbalance of water pressures.

A groundwater monitoring borehole is recommended on the south side of the quarry within the Clifton Down Mudstone.

Gully Oolite

The following table provides descriptions of the rock mass:

Points	Rock Mass
117	Strong light cream grey stained red, massive to widely spaced bedding, fine grained to ooidal, Oolitic LIMESTONE.
118	Strong light cream grey stained pink fine grained to ooidal Oolitic LIMESTONE. Massive bed 60/245 indicates possible release surface. Joint 32/270 indicates possible sliding surface. Karstic weathering evident.
133-135	Strong light cream grey massive to widely spaced bedding fractures, fine-grained ooidal Oolitic LIMESTONE. Bed 62/ 235.
134-135	Rock slope protection netting.
136	Transition from Gully Oolite to Clifton Down Limestone at north end of east slope.

Cromhall Sandstone

The following table provides descriptions of the rock mass:

Points	Rock Mass
128	Strong grey, occasional red mediumly spaced bedding fracture SANDSTONE. Beds 45/240, layer approximately 4m thickness perpendicular to top and bottom of bed. Some beds .03m-0.4m thickness. A shaly limestone was observed at the contact to the east of the sandstone.

Oxhill Head Limestone

The following table provides descriptions of the rock mass:

Points	Rock Mass
129-130	Limestone with unfavourable joint set 40/010. Beds 50/220. Unfavourable release fracture 62/320. Joints 55/060, 40/140.

This area is currently being worked and requires further assessment. The dip of the beds to the west creates overhangs where stronger and thicker beds are undermined by weaker thinner layers. An joint set orthogonal to the bedding creates a sliding/ release surface for block failure and or topple failure.

The anisotropic hydraulic conductivity of the bedding is likely to create less favourable conditions on the west side of the site, particularly combined with the bedding and joint set orientations which are likely to have resulted in a number of over-steep overhangs of rock.

5.3 Trubody's Quarry Geology

The walkover survey of Trubody's Quarry identified the following geological formations:

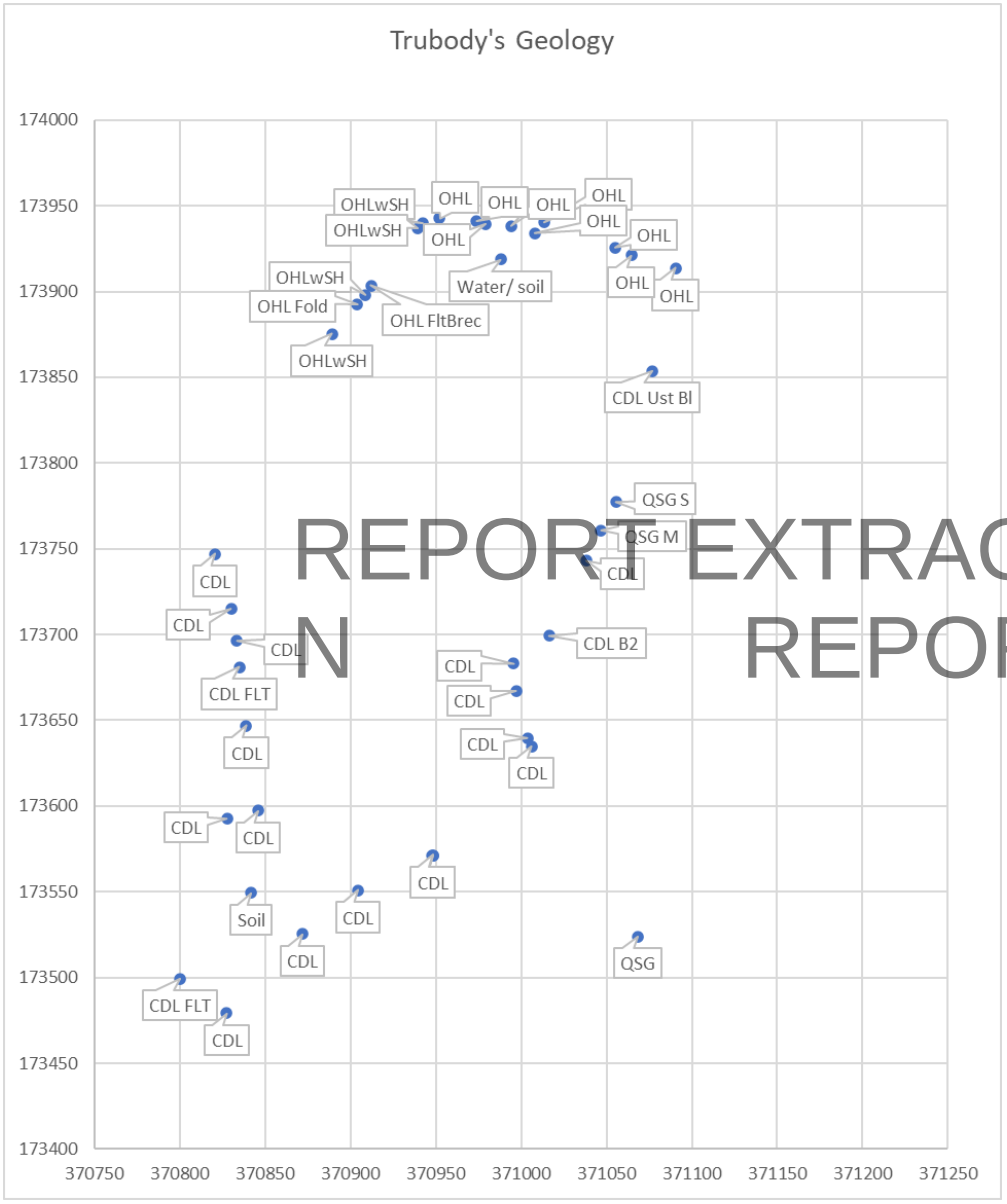
- Clifton Down Limestone (CDL). Soil berms on east and west sides.
- Cromhall Sandstone (CHSA)
- Oxhill Head Limestone (OHL). Soil berms on north, north-west and west sides.
- Quartzitic Sandstone Group (QSG) located to the east of CDL and the Wick Fault.

Location 139 to 178 were recorded using the GPS to provide easting, northing and levels.

Point	Easting	Northing	Level	Quarry	Geology	Point	Easting	Northing	Level	Quarry	Geology
139	370948.362	173571.119	68.102	TBQ	CDL	159	371090.575	173913.637	85.899	TBQ	OHL
140	370948.217	173571.217	68.111	TBQ	CDL	160	371064.665	173921.057	81.718	TBQ	OHL
141	370948.015	173571.247	68.102	TBQ	CDL	161	371055.014	173925.755	80.517	TBQ	OHL
142	370904.345	173550.866	67.805	TBQ	CDL	162	371013.367	173940.775	79.782	TBQ	OHL
143	370871.947	173525.337	69.316	TBQ	CDL	163	371007.97	173933.917	73.001	TBQ	OHL
144	370827.451	173479.234	76.735	TBQ	CDL	164	370994.379	173938.089	71.624	TBQ	OHL
145	370800.192	173499.422	77.531	TBQ	CDL FLT	165	370979.231	173939.422	71.141	TBQ	OHL
146	370841.848	173549.414	73.086	TBQ	Soil	166	370973.753	173941.077	71.276	TBQ	OHL
147	370846.016	173597.281	66.519	TBQ	CDL	167	370952.287	173942.813	71.766	TBQ	OHL
148	370827.551	173592.876	75.163	TBQ	CDL	168	370942.623	173939.856	70.892	TBQ	OHL SH
149	370838.907	173646.73	78.648	TBQ	CDL	169	370939.533	173937.015	69.813	TBQ	OHL SH
150	370834.764	173681.086	79.217	TBQ	CDL FLT	170	370911.929	173903.332	71.276	TBQ	OHL FB
151	370829.922	173715.175	82.737	TBQ	CDL	171	370908.626	173897.85	70.381	TBQ	OHL SH
152	370820.554	173746.966	84.404	TBQ	CDL	172	370903.745	173892.628	70.539	TBQ	OHL Fold
153	370833.343	173696.566	79.802	TBQ	CDL	173	370889.152	173875.346	70.753	TBQ	OHL SH
154	371016.514	173699.188	80.263	TBQ	CDL B2	174	370987.959	173918.779	63.459	TBQ	Water soil
155	371038.138	173742.991	90.21	TBQ	CDL	175	371005.992	173634.952	65.425	TBQ	CDL
156	371046.692	173760.771	92.108	TBQ	QSG M	176	371003.573	173639.622	64.971	TBQ	CDL
157	371055.562	173777.264	97.038	TBQ	QSG S	177	370996.94	173667.308	64.407	TBQ	CDL
158	371076.91	173853.802	94.933	TBQ	CDL Ust Bl	178	370995.242	173682.972	64.027	TBQ	CDL

Note: water level 63.459mAOD on 17th December 2020, compared to 63.336mAOD on 26th November 2020.

The following plot shows the identified geological formation at each point:



The above plot combined with walkover survey observations provides the following:

- Clifton Down Limestone on the south, south-west and south-east quarry slopes above water level. A large soil berm is located on the south-west side extending up into the

former ARC Quarry. The former soil berm forming haul road is located on the east side, which becomes submerged to the north.

- Quartzitic Sandstone Group of sandstone identified to the south of the River Boyd east of CDL and on the north-east side of the quarry with layers of mudstone on the north-east side. This is located to the east of the CDL and the Wick Fault.
- Oxhill Head Limestone on the north and north-west of the quarry. Soil filled berms are located on the cut benches above and below water. Not possible to access the north domain west side of the quarry.

REPORT EXTRACTION REPORT

Clifton Down Limestone:

The following table provides descriptions of the rock mass:

Points	Rock Mass
139-141	Fold axis trend 65/355, provides an unfavourable slide surface for wedge failure. Beds either side of fold axis 45/300 and 85/015.
142	Strong light grey, some red brown and brown grey medium to widely spaced bedding fractures. Bed 50/280 degrees. Beds range from 0.1m to 1m thickness. Wedge failure potential.
143	Prominent fracture 55/346 is unfavourable.
144	Limestone is massive bedding 1m to 6m wide.
145	Fault vertical striking east west. Bedding dips to west. A perpendicular joint set dips to the east, forming an unfavourable sliding surface for the west cut slopes.
146	Stockpile of soil across the south-west corner.
147	South domain west slope: Limestone. Bed 55/285. Four joint sets measured. Fault strikes east to west near vertical varies in dip direction from north to south.
148	Strong light grey massive limestone, bedding 1m to 6m. Bed 45/275 with horizontal striations orientated north-south. Two unfavourable joint sets dipping 35/125 and 60/125 forming slide and release surfaces respectively. Joint 45/095 unfavourable for west side.
149	Limestone beds 50/285. Joint sets measured.
150	Fault striking east-west, near vertical with dip direction varying from north to south.
151	Limestone with unfavourable joint 75/095.
152	Limestone bed 55/255. Seepages on joints 55/105 and 75/185. Fossils visible in the limestone beds. Striations on bedding running north-south.
153	Fault/ joint strike 125-305 dip/ dip direction 70/220. Infilled with orange brown clay.
154	South domain east slope. Possible bench 2.
155	Limestone is micritic.
175-176	Strong massive fractured limestone with no obvious bedding. Joints near vertical. Striations near horizontal north to south on joint surfaces.
177	Limestone bedding 60/285.
178	Limestone paleo surface on bedding. Bed 65/285 into the water.

The following observations are summarised below.

- The Clifton Down Limestone is located across the south domain.
- The bedding dips more towards west and west-north-west in the area of Trubody's Quarry.
- This creates a potential unfavourable anisotropic hydraulic conductivity orientation on the east and west sides.
- A fold structure is evident on the south side with an unfavourable axis dipping to the north.
- Karstic weathering features are evident.
- Joint sets provide unfavourable release and sliding surfaces.
- Water seepages are evident on the west side above the quarry water level.

A groundwater monitoring borehole is recommended on the south side between the River Boyd and the water filled quarry void. This should target the area of the fold.

Quartzitic Sandstone Group:

The following table provides descriptions of the rock mass:

Points	Rock Mass
138	Quartzitic Sandstone. Bedding 70/260. South of River Boyd.
156	Extremely weak, extremely closely to closely fractured red brown Mudstone/Shale.
157	Sandstone outcrop on edge of rock, not able to closely inspect.

The Quartzitic Sandstone Group was encountered on the east side of the site and to the east of the Clifton Down Limestone and the Wick Fault. An unstable block of limestone (Lst Ust Bl) was noted on the fault line to the east of location 158, the actual location being unsafe to access.

Oxhill Head Limestone:

The following table provides descriptions of the rock mass:

Points	Rock Mass
159	Strong very closely to medium fractured limestone. Fracture spacing 0.05m to 0.3m creating an angular gravel to cobble like material rather than a competent rock mass.
160	Closely fractured with possible cambering.
161	Strong cream grey stained red brown closely to medium fractured fine grained ooidal Oolitic limestone. Fracture surfaces rough. Seepage from base of fracture 5m from top of slope. Fault on main fracture with gravelly clay infill, which is not calcareous. Main discontinuity probable bedding dip and dip direction 65/185. This forms the main cut face on the north domain north slope.
162	Strong light grey closely to medium spaced bedding fractures fine grained LIMESTONE. Beds 0.1-0.3m wide. Probable bedding 70/185. Joint sets measured.
163	Below 162 on ramp. Limestone. Discontinuities measured.
164	Limestone. Predominant fracture probable bedding 70/180. Discontinuities measured.
165	Fault/ vertical fracture striking north-south with 0.1m yellow brown clay infill.
166	Strong grey with red brown staining, fossil rich limestone. Bivalve shells and Brachiopods. Red clay infilling fractures.
167	Limestone bed 80/170 with paleo surface and rounded nodules. Bedding 60/175, 62/175, 75/170.
168	Calcareous shale bed. Fracture spacing 0.1-0.2m joints open or infilled with red clay 0.05-0.1m and parallel to bedding.
169	Limestone with numerous fossils.
170	Strong limestone with beds up to 2m thick. Shale layers 0.5-0.6m thick. Strong fossil rich limestone with 0.05-0.2m thick beds and paleo surface dripping with water. Fault breccia evident.
171	Calcareous shale layer and a conglomerate layer 0.8m thickness.
172	Scree slope from eroded shale bed above. Folded bedding 75/345.
173	Folded beds fold access 70/315. Fossil rich limestone beds with calcareous shale bed 0.3m thick. Fault 85/180.
174	Water level 63.459mAOD on soil berm.

The north domain and north-west domain comprise Oxhill Head Limestone. The presence of faults and significant fold structures creates a complex arrangement of preferentially eroded calcareous shale beds adjacent folded beds of shelly limestone and conglomeratic beds of limestone. These are large scale features that dominate the north-west domain and prevented safe access to the north domain west slope.

The dip direction of the beds in the north part define the steep cut slopes and the closely fractured nature of the material creates a gravel/ cobble like behaviour rather than a competent rock mass at the top of the slope with bench failure evident above the water level.

The dip and dip direction of the bed creates an unfavourable anisotropic orientation in terms of hydraulic conductivity. The presence of red clay infilling fractures combined with the calcareous shales in this area indicates the requirement for a groundwater monitoring borehole on the north side.

5.4 Discontinuity Survey and Data Plotting

A total of 148 discontinuities were recorded during the two visits, (11) 26th November 2020 and (137) 17th December 2020. The dip and dip directions are recorded in degrees. The dip is recorded in degrees below horizontal and the dip direction is measure in degrees on a compass.

The data has been converted from polar coordinates to cartesian coordinates in order to provide a plot showing dip vectors similar to a stereonet.

The following example shows points at every six degrees to provide the outer circle. The dip vectors for the bedding are plotted as dip and dip direction. A 70 degree east cut slope represented by the curved line from north-south and an inner circle that represents a friction angle of 35 degrees in the Clifton Down Mudstone :