S/BSL/DQ/H&HIA/004

BCL HYDRO

Breedon Trading Limited

Denbigh Quarry

Denbigh, Denbighshire

Extension to Existing Mineral Workings

Chapter 9 - Hydrological & Hydrogeological Impact Assessment

04th February 2022

BREEDON

Breedon Trading Limited
Pinnacle House, Breedon Quarry
Breedon on the Hill
Derbyshire
DE73 8AP
Tel: 08455 201 888

Breedon Trading Limited

Denbigh Quarry

Denbigh, Denbighshire

Extension to Existing Mineral Workings

Hydrological & Hydrogeological Impact Assessment

04th February 2022

Document History				
Date	Version No.	BCL Ref.	Comments	Issued to
25/11/19	01	S/BSL/DQ/H&HIA19/001	First draft for client review.	R. Hunt, Pleydell Smithyman Limited
15/01/20	02	S/BSL/DQ/H&HIA19/002	Implementation of client revisions.	R. Hunt, Pleydell Smithyman Limited
02/02/22	03	S/BSL/DQ/H&HIA19/003	Updated with additional monitoring data.	R. Hunt, Pleydell Smithyman Limited
04/02/22	04	S/BSL/DQ/H&HIA19/004	Implementation of client revisions.	R. Hunt, Pleydell Smithyman Limited

Report Prepared By	Report Checked By
Peter Simpson, B.Sc. M.Sc. FGS Senior Hydrogeologist	Henry Lister B.Sc M.Sc. Principal Hydrogeologist & Director

BCL HYDRO
BCL Consultant Hydrogeologists Limited

Technology Centre, Wolverhampton Science Park, Glashier Drive, Wolverhampton
West Midlands, WV10 9RU. Tel: 01902 824111, Fax: 01902 824112
email: info@bclhydro.co.uk, web: http://www.bclhydro.co.uk
Registered Office: 33, Wolverhampton Road, Cannock, West Midlands, WV11 1AP
Registered in England & Wales. Company Registration Number: 4043373

Contents

Page Number

Figures

Tables

Appendices

BCL CONSULTANT HYDROGEOLOGISTS' EXPERIENCE & QUALIFICATIONS

BCL is an independent consultancy specialising in all aspects of hydrogeology and hydrology as they relate to minerals extraction, waste disposal, water supply and related industries.

Peter Simpson (the author of this report) holds an honours degree (B.Sc. Environmental Science) conferred by The University of Birmingham in 2005 and a Masters Degree (M.Sc. Hydrogeology), also conferred by The University of Birmingham, in 2011.

BCL has provided specialist services, advice and reporting to the extractive, waste and related industries since 1990. During this time a collective 100+ years of experienced has been earned from involvement with wide variety of assignments. BCL's work has included:

- Installation and management of information collection systems;
- Data interpretation;
- Conceptualisation of hydrogeological systems;
- Identification of potential impacts;
- Formulation of mitigation measures;
- Management and undertaking of operational impact monitoring and impact assessment;
- Review and auditing of contingency mitigation schemes;

To reduce paper usage, this document has been formatted for digital viewing

1 INTRODUCTION

1.1 Background

1.1.1 Breedon Trading Limited (Breedon) are seeking planning permission under a consolidating planning application (The Permission) for the winning and working of limestone from a western extension (The Proposed Development) to Denbigh (Graig) Quarry, Denbigh, Denbighshire, North Wales (The Site).

1.1.2 The Site currently holds planning permission (as granted by Denbighshire County Council, DCC, in 2010, Ref: 01/2009/1424) for the winning and working of 1 million tonnes (mt) of aggregate within the existing Site footprint by 2020.

1.1.3 It is proposed that the operation of the Site be extended and expanded through working of the Proposed Development, to allow release of an additional 5.4mt of aggregate over a period of some 20 years, this being accompanied by the importation of up to 100,000 tonnes per annum (tpa) of inert infill materials to achieve a higher elevation of restoration.

1.1.4 In July 2019, Pleydell Smithyman Limited, PSL (agents of Breedon) submitted a request for a scoping opinion to DCC relating to the Proposed Development. Due to the nature, scale and setting of the Proposed Development, this included considerations with regards to assessment of potential impacts upon the water environment.

1.1.5 Requirement for such assessment was confirmed by DCC in their scoping response of August 2019, Ref: 01/2019/0573, and associated correspondence from Natural Resources Wales (NRW), dated July 2019, Ref: CAS-93101-W3L5. This also confirmed that due to the limited fluvial flood risk prevailing at the Site, a Flood Consequence Assessment (FCA) would not be required.

1.1.6 BCL Consultant Hydrogeologists Limited (BCL) have thus been instructed by PSL to undertake a Hydrogeological and Hydrological Impact Assessment (H&HIA) to assess the potential impacts of the Proposed Development upon the water environment.

1.1.7 BCL's prior involvement at the Site has included undertaking long term groundwater monitoring data collection at the Site in addition to involvement in the specification and installation of supplementary monitoring infrastructure in 2019.

2 APPROACH TO ASSESSMENT

2.1 Scope of Assessment

2.1.1 The scope of the Assessment has been informed by national and local planning policies and associated guidance which all reinforce the need to pay due regard to the likely effect of the Proposed Development upon various aspects of the water environment.

2.1.1 Policy & Guidance

2.1.1.1 Relevant current national policy documents and associated guidance that have been consulted include:

- "Minerals Planning Policy (Wales), Minerals Technical Advice Note (Wales), 1: Aggregates", Welsh Assembly Government (WAG), March 2004;
- "Planning Policy Wales, Technical Advice Note 15: Development and Flood Risk" (TAN15), WAG, July 2004,
- "Rainfall Runoff Management for Developments", Kellagher R, joint DEFRA / Environment Agency (EA) Flood and Coastal Erosion Risk Management R&D Programme, Report SC030219, October 2013;
- "The SUDS Manual v5", Construction Industry Research and Information Association (CIRIA): report no. c753, 2015, and;
- "The Environment Agency's Approach to Groundwater Protection", EA, v1.1, February 2018.
- "Hydrogeological Impact Appraisal for Dewatering Abstractions", Science Report SC040020/SR1, EA, May 2007.

2.1.2 Project Specific Guidance

2.1.2.1 Guidance specific to this assessment consulted during its composition includes:

- "Scoping Opinion of Denbighshire County Council as Local Planning Authority", Ref: 01/2019/0573, Denbighshire County Council, August 2019.

2.2 Methodology & Outcomes

2.2.1 Approach and calculation methodologies referenced as part of the Assessment are listed at *Appendix 9.1*. The Assessment process has involved:

- Baseline characterisation of the local water environment, leading to the development of a conceptual hydrogeological model (the Conceptual Model) describing the nature of (and interactions between) groundwater and surface-water systems operating within and around the Site;
- Application of the Conceptual Model to assist Impact assessment of the Proposed Development upon that environment. The assessment process is iterative; initial study aiming to identify significant potential impacts associated with early-draft project design;
- Where significant potential impacts have been identified, alterations to the project design and / or specific mitigation measures have been adopted to eliminate, reduce or compensate for those potential impacts, and;
- Consideration of cumulative and residual impacts.

2.3 Information Sources

2.3.1 Published and site-specific data sources referenced and adopted during Assessment are listed at *Appendix 9.1*.

2.4 Site Reconnaissance

2.4.1 A site reconnaissance visit was made by BCL on 10/09/2019.

3 BASELINE CONDITIONS

3.1 Site Setting and Study Area

3.1.1 Site Location

3.1.1.1 The locations of both the Site and Proposed Development are shown at *figure 1*.

3.1.1.2 The Site is located to the immediate north of the town of Denbigh, to the west of Colomendy Industrial Estate, in the County of Denbighshire, North Wales. The Site is centred upon approximately National Grid Reference (NGR) ^{3}05004 ^{3}67064.

3.1.1.3 The Proposed Development is located upon the western Site boundary, being centred upon approximately NGR: ^{3}04750 ^{3}67005.

3.1.2 The Study Area

3.1.2.1 Baseline data collection has focused upon lands within 3km of the Site boundary (The Study Area), covering an area of some 4,650 hectares (ha), as at *figure 1*.

3.1.2.2 The Study Area extends from the village of Henllan in the west to the River Clwyd in the east, and encompasses the village of Trefnant at its northern limit.

3.1.3 Topography

3.1.3.1 The western half of the Study Area occupies the upland of the Denbigh Moors, which form a series of low hills of typical summit elevations between 150 metres above Ordnance Datum (maOD) and 180maOD.

3.1.3.2 Upon the centre of the Study Area, the moors give way to the Clwyd Valley, which presents more moderate relief across the eastern half of the Study Area, with elevations falling eastwards and northwards to approximately 24maOD adjacent to the River Clwyd.

3.1.3.3 The Site is located upon the eastern limit of the Denbigh Moors, upon a hillside of maximum elevation 160maOD, and prominence of some 80m relative to the industrial estate to the east. This hillside is separated from the historic centre of Denbigh by the valley of the Henllan Brook to its south.

3.1.3.4 The Proposed Development is situated upon the hillside to the west of the Site, with ground elevations ranging from some 148.6maOD to 143maOD, falling gently southwards, towards this valley.

3.1.4 Land Use

3.1.4.1 The landuse of the Study Area is dominated by agriculture, which is prevalent across the region, with woodland and sporadic urban development also being present, the latter locally being focused upon the town of Denbigh.

3.1.4.2 The Site is located upon a heavily wooded hillside, with woodland and grassland occupying those areas not used in existing Site operations. The Proposed Development presently comprises agricultural grassland.

3.1.5 Ecological Designations

Statutorily Protected Sites of Ecological Importance

3.1.5.1 Data with regards to statutorily protected ecological sites within the Study Area has been provided by the North Wales Environmental Information Centre (Cofnod).

3.1.5.2 The identified sites are located as shown at *figure 2*, with summary detail below at *table 1*.

Table 1 Statutorily Protected Sites

Site Name	Distance* from Proposed Development (km)	Designation	Summary Description
Crest Mawr Wood	0.025	SSSI	Mixed deciduous woodland.
Graig Quarry	0.1	SSSI	Broadleaved woodland supporting rare flora.
Coedydd Ac Ogofau Elwy A Meirchion	2.98	SSSI, SAC	Woodland featuring caves.
Llwyn	3.7	SSSI	Woodland, wet woodland, swamp and springs.

*-at shortest distance from the Proposed Development

3.1.5.3 There are no such sites within the boundary of the Proposed Development. There are no wetlands of international importance (RAMSAR), Special Protection Areas (SPA) or National Nature Reserves (NNR) within the Study Area.

3.1.5.4 Graig Quarry SSSI directly abuts the southern boundary of the existing Site. Crest Mawr Woods SSSI directly abuts the western boundary of the existing Site, and is to stand off from the northern boundary of the Proposed Development by some 30m. Both these SSSIs principally constitute woodland on thin soils and are not considered to be groundwater dependent.

3.1.5.5 Coedydd Ac Ogafau Elwy A Meirchion SSSI (woods and caves of lower Elwy and Meirchion Valleys SSSI) also forms the Coedwigoedd Dyffryn Elwy (Elwy valley woods) Special Area of Conservation (SAC). This feature principally occupies the valley of the River Elwy and features groundwater dependent features (including karst features). These features fall within a separate surface water catchment to the Site and are assumed to be effectively hydraulically isolated from it.

3.1.5.6 Llwyn SSSI, which also features groundwater dependent features, is located at significant distance to the south east of the Site within the Clwyd Valley, and is considered to be effectively hydraulically isolated from the Site (being located upstream of the Site and on differing geology).

Non-Designated Sites of Ecological Importance

3.1.5.7 Data with regards to non-statutorily protected ecological sites within the Study Area has also been provided by the North Wales Environmental Information Centre (Cofnod).

3.1.5.8 The identified sites are located as shown at *figure 2*, with summary detail below at *table 2*.

3.1.5.9 There are no non statutorily protected ecological sites within or abutting the Proposed Development. There is one such site immediately abutting the existing Site to the east (Coed Parc Pierce Wildlife Site).

Table 2 Non-Statutorily Protected Sites

Site Name	Distance* from Proposed Development (km)	Designation	Summary Description
Coed Parc-Pierce	0.3	Wildlife Site	Woodland
Denbigh Golf Course	0.856	Wildlife Site	Grassland
Coed Coppy	0.978	Wildlife Site	Woodland
Coed Mawr	1.352	Wildlife Site	Woodland
King's Mill /Afon Ystrad Woods	1.689	Wildlife Site	Woodland
Bryn-y-Parc	1.966	Wildlife Site	Grassland
Pont Ystrad fields	2.119	Wildlife Site	Grassland
Rosa-fawr/Llys/Pont Ystrad Woods	2.375	Wildlife Site	Woodland
Garn	2.599	Wildlife Site	Woodland
Rectory	2.626	Wildlife Site	Grassland
The Belt	2.753	Wildlife Site	Woodland
Coed Mawr / Pandy	2.914	Wildlife Site	Woodland

*-at shortest distance from the Proposed Development

3.1.5.10 Coed Parc Pierce Wildlife Site occupies a steep, heavily wooded hillside featuring broadleaved woodland with Alder, Ash and Beech communities. This habitat is not indicated to be groundwater dependent.

3.2 Geological Setting

3.2.1 Background

3.2.1.1 Information concerning the geology of the Study Area has been obtained from:

- Published geological mapping, including British Geological Survey (BGS) 1:50,000 scale solid and drift mapping (Sheet E107, Denbigh), and 1:63,360 scale mapping (Vale of Clwyd, St. Asaph, Denbigh Lead and Copper Lodes).
- Site investigation drilling and piezometer installation logs.
- Previous geological reports for the Site.

3.2.2 Regional Geology

3.2.2.1 The geology of the Study Area is dominated by the sedimentary basin of the Vale of Clwyd. This features Silurian shales upon the high ground of the Denbigh Moors in the west of the Study area, dipping westwards towards the centre of the basin upon the Clwyd valley, and becoming overlain by successively younger Carboniferous and Triassic strata.

3.2.2.2 The western half of the Study Area thus features outcropping mudstones in the form of the Elwy Formation (EF), this giving way to a northwest-southeast oriented band of Carboniferous Limestone outcrop underlying the town of Denbigh and village of Henllan (of the Clwyd Limestone Group, CLG), before this in turn becomes overlain by Triassic strata to the east.

3.2.2.3 The eastern half of the Study Area is characterised by the low ground of the Vale of Clwyd, and the associated outcropping Triassic sandstones of the Kinnerton Formation (KSS). The outcrops of the Triassic and Carboniferous strata are delineated by a series of north-south trending fault lines, which downthrow to the east (including the Denbigh Fault to the east of the Site which downthrows the Carboniferous strata by some 300m), thus forming an escarpment upon the fringe of the Clwyd Valley, upon which the Site is located.

3.2.2.4 Across the majority of the Study Area, though excluding the areas of highest ground including those around the Site, the solid geology is obscured by drift deposits in the form of Devensian Glacial Till (GT). Further drift deposits are also present in proximity to major local surface watercourses, in the form of River Terrace Deposits (RTD) and Alluvium.

3.2.2.5 The geology of the Study Area is presented at *figure 3*, with the regional stratigraphic sequence being presented at *table 3*.

<table>
<tr><th colspan="4">Table 3 Stratigraphic Sequence</th></tr>
<tr><th>Age</th><th>Group</th><th>Formation</th><th>Lithology</th></tr>
<tr><td rowspan="3">Pleistocene & Recent</td><td colspan="2">Alluvium</td><td>Clay, silt, sand.</td></tr>
<tr><td colspan="2">River Terrace Deposits</td><td>Sands and Gravels.</td></tr>
<tr><td colspan="2">Glacial Till</td><td>Clay</td></tr>
<tr><td>Triassic</td><td>Sherwood Sandstone Group</td><td>Kinnerton Sandstone Formation</td><td>Soft, red, round-grained sandstones.</td></tr>
<tr><td rowspan="3">Carboniferous</td><td colspan="2">Warwickshire Group</td><td>Coal Measures, Red and grey mudstones and sandstones.</td></tr>
<tr><td>Carboniferous Limestone</td><td>Clwyd Limestone Group</td><td>Grey finely crystalline limestone.</td></tr>
<tr><td></td><td>Ffernant Formation</td><td>Sandstone, siltstone, mudstone conglomerate.</td></tr>
<tr><td>Silurian</td><td colspan="2">Elwy Formation</td><td>Silty and striped mudstones with subordinate sandstones.</td></tr>
</table>

3.2.3 Solid Geology

3.2.3.1 The Site and Proposed Development are entirely located upon the outcrop of the Carboniferous Limestones of the CLG, this being formed from light grey fractured limestones of estimated thickness 500m.

3.2.3.2 Exploration drilling undertaken at the Site has confirmed the presence of a north-south trending major joint of fault traversing the Proposed Development area, with intermittent clay / silt / sand filled cavities being both identified within drilling logs across the Site, and being evident within exposed quarry faces.

3.2.2 The full depth of the CLG has not been proven, though BGS mapping suggests the presence of a horizon of conglomerate upon its interface with the underlying Silurian Shales of the Elwy Formation (this featuring interbedded siltstones, mudstones and sandstones).

3.2.3 The Denbigh Fault falls to the east of Graig Road (upon which the Site entrance is located, this being upon the south eastern limit of the Site boundary). Lands to the east of the Site thus feature the outcrop of the Permo-Triassic sandstones of the KSS, which overlies the CLG across the eastern half of the Study Area. This formation is estimated to be up to 150m in thickness.

3.2.4 To the north of the Site, where the Denbigh Fault diverges from the upper limit of the CLG, overlying, younger Carboniferous strata are seen to outcrop in the form of the siltstones, sandstones and mudstones of the Warwickshire Group (WG, Barren Measures).

3.2.4 Superficial Geology

3.2.4.1 Though GT cover is entirely absent across the Site and Proposed Development areas, it is pervasive across the Study Area, with thicknesses of 7 to 30m being observed to the north east of the Site.

3.2.4.2 Areas of RTD / Alluvium are confined to the valleys of local surface watercourses and are thus absent from the immediate Site surroundings.

3.3 Hydrological Setting

3.3.1 Background

3.3.1.1 Information concerning the hydrology of the Study Area has been obtained from:

- Findings of BCLS's 2019 walkover field survey.
- The Centre for Ecology and Hydrology (CEH), National Rivers Flow Archive (NRFA) web service.
- Published data sources.

3.3.1.2 The hydrological setting of the Site is presented at *figure 4*.

3.3.2 Water Framework Directive (WFD) Catchment

3.3.2.1 The Site, in its entirety, together with the wider Study Area, falls within the Clwyd Lower Operational Catchment of the Clwyd Management Catchment, within the Western Wales River Basin Management Plan.

3.3.2.2 The Proposed Development falls within the Sub-catchment of the Henllan Brook (a minor tributary of the River Clwyd).

3.3.3 Surface Watercourses

Major Surface Watercourses

3.3.3.1 The hydrology of the Study Area is dominated by the River Clwyd. This watercourse rises in Clocaenog Forest, near the town of Corwen in southern Denbighshire, before flowing north to the Vale of Clwyd, passing 3km to the east of the Site at closest approach, and discharging to the Irish Sea at Rhyl.

3.3.3.2 The NRFA details flows within the River Clwyd at Pont-y-Cambwll gauging station (in the far north of the Study Area) to have a Q95 (flow rate exceeded 95% of the time) of 0.952m^3/s, and a Q50 (flow rate exceeded 50% of the time) of 3.88m^3/s.

3.3.3.3 There are two significant tributaries of the River Clwyd within the Study Area. This includes the Afon Ystrad, and Afon y Merchion.

3.3.3.4 The Afon Ystrad rises to the south of the Denbighshire village of Nantglyn, before flowing eastwards, to the south of the town of Denbigh (passing 1.6km to the south west of the Site at closest approach), and discharging to the Clwyd 2km to the east of Denbigh.

3.3.3.5 The Afon y Merchion rises near the village of Y Groes, before flowing northwards, passing to the east of the village of Henllan, and on to the River Elwy and subsequently the Clwyd to the north of the Study Area. This watercourse passes 2.8km to the northwest of the Site at closest approach.

Minor Surface Watercourses

3.3.3.6 There are a number of minor watercourses within the Study Area, all of which also ultimately drain to the River Clwyd.

3.3.3.7 This includes 2 no. minor watercourses to the south of the Site within the town of Denbigh, including the Henllan Brook and its unnamed southern tributary, the Southern Denbigh Stream (SDS), which coalesce to the east of the town before flowing to the Clwyd to the east of the Site.

3.3.3.8 The Henllan Brook rises upon a series of springs around a small hill to the west of Lodge Farm, 1.3km to the south west of the Site (this being formed from EF), before flowing eastwards to Denbigh town (underlain by CLG).

3.3.3.9 The Henllan Brook is seen to enter a manmade culvert of elevation approximately 109maOD at location WFS1, *figure 4*, with associated flow control structures and debris screens (also underlain by CLG). Flows at this location were observed to be minimal (flow backed up and near stagnant), though the sizing of the flow control structures indicated potential for high flow rates.

3.3.3.10 The Henllan Brook re-emerges at approximately 68.5maOD at location WFS2, *figure 4*, also from a manmade culvert with debris screen (underlain by KSS). Higher flow rates were observed at this location (in the region of 10 to 15l/s). The watercourse then flows eastwards to its confluence with the SDS.

3.3.3.11 Though the Henllan Brook is underlain by EF, CLG and KSS along its course, these units are obscured by GT upon which it is assumed to be based. This, combined with its probable culverted route (as indicated by flood risk mapping, as discussed at *section 3.3.6*, and the constant fall in topography along its presumed course), indicate the culvert to likely be entirely of anthropogenic construction as opposed to any formalisation of natural sub-surface flow routes (karst). Flow gains along its course are likely attributable to its use to convey urban drainage from the Denbigh conurbation. This is further confirmed by reported flood alleviation upgrades to the culvert in 2013.

3.3.3.12 The SDS rises at Pennant Farm to the south of Denbigh Castle, 1.4km to the south of the Site, before flowing north eastwards to its confluence with the Henllan Brook, and on towards the River Clwyd at Llewen Hall (3km to the north east of the Site). The SDS is underlain by GT for its entire course, this being underlain by EF upon its upper reaches, with the remaining reach being underlain by KSS.

3.3.3.13 A further unnamed tributary of the Henllan Brook is present to the immediate east of the Site, in the form of a small, typically dry ditch running eastwards along the southern limit of a now removed rail spur. This ditch becomes culverted, though is understood to ultimately flow to the Henllan Brook to the East of the Site (The Henllan Ditch). This watercourse receives discharge from the Site water management system. This ditch is entirely situated upon GT cover overlying KSS.

3.3.3.14 A further un-named minor watercourse is seen to rise upon GT overlying KSS on farmland to the northeast of the Site (The North Eastern Stream, NES). The NES passes 0.5km to the east of the Site before joining the Denbigh Streams and flowing on to the Clwyd.

3.3.3.15 The NES was observed during Water Features Survey at location WFS3, *figure 4*, to form a dry, shallow grass covered ditch of depth 0.5m and width 1.5m. This feature is assumed to convey surface waters derived from upon the GT cover.

3.3.3.16 Further watercourses of similar nature and setting to the NES are present further to the north.

3.3.4 Surface Waterbodies

3.3.4.1 The Study Area is void of any substantial surface waterbodies (excepting those within the Site itself), though numerous ponds are present throughout the region and area local to the Site. These ponds are exclusively located of areas of GT cover and are thus assumed to be hydraulically isolated from groundwaters within the CLG.

3.3.5 Springs and Seepages

3.3.5.1 There are a number of springs present to the west of Denbigh, associated with the headwaters of the Afon y Merchion (WFS4, *figure 4*) and Henllan Brook (WFS5-6, *figure 4*). These springs are all underlain by GT and EF, and are assumed hydraulically isolated from the Site.

3.3.5.2 There is a further spring located upon Alluvium / GT overlying KSS 1.8km to the east of the Site, at WFS7, *figure 4*. This is likely supplied either from the Alluvium or by upwelling groundwaters from the underlying KSS. Direct connection (karstic) to the Site is precluded by the intervening KSS.

3.3.6 Flooding

3.3.6.1 The prevailing risk of fluvial flooding across the Study Area is presented at *figure 5*.

3.3.6.2 The Site is entirely located within Flood Risk Zone 1 (FRZ1), the lowest risk class of flood risk zone, with an Annual Exceedance Probability (AEP) of 1 in 1,000 or less (chance of flooding of 0.001 or less in any given year).

3.3.6.3 The nearest areas of FRZ2 (AEP of between 1 in 100 and 1 in 1,000), and FRZ3 (AEP of 1 in 100 or more) are located upon the course of the Henllan Brook to the south of the Site, and within the streets of Denbigh town where this watercourse is culverted.

3.4 Meteorological Setting

3.4.1 Background

3.4.1.1 Information concerning the meteorology of the Study Area has been obtained from:

- Published and third party historic data sources.

3.4.2 Long Term Area Averages

3.4.2.1 Long-term monthly average data (MAFF[1]) indicate an annual average rainfall depth for the area of 786 millimetres (mm; MAFF Rainfall Area 14), as at *table 4*.

Table 4 Area Long Term Average Monthly Rainfall and Potential Transpiration

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
Area Average Rainfall	70	54	52	53	66	57	67	79	68	66	80	74	786
Potential Evaporation	3	10	30	53	80	90	90	74	46	20	5	1	502

3.4.2.2 The Standard Average Annual Rainfall for the Site area in the period 1961 to 1990 (SAAR6190) obtained from the CEH FEH13 rainfall model[2] is 797mm.

3.4.3 Local Data

3.4.3.1 Rainfall data has been provided by NRW for the closest operative rain gauge to the Site, as at *table 5*, this being located at approximately NGR: [3]07021 [3]66440.

Table 5 NRW Rain Gauge Data

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2009	70	19.6	33.6	27.8	41.6	46.8	79.4	22.6	29.6	23.4	153.4	102.2	650
2010	64.8	30	45.8	19.6	32	20.6	79.2	58.2	0.2	56.2	67.2	31.8	505.6
2011	47.2	57.8	9	16.4	30.4	48.4	53.4	55.2	0.6	50	32.6	121.2	522.2
2012	50	27.8	22.2	115	40.2	94	106.2	76	107.8	72	114.4	109.8	935.4
2013	76.8	51.2	31	15.6	78.8	55.6	61.6	36.8	57.8	104.4	73	119	761.6
2014	135.4	130.2	41.8	27.6	86.2	41.8	75.2	76.2	6	68.4	43.8	82.6	815.2
2015	78.4	26.2	52.2	32.8	79.8	30.8	37.2	3.6	0.2	23.6	112.4	143.4	620.6
2016	127.2	80.4	63.4	85.4	16	80.4	45.6	23	39	29.8	93	34.2	717.4
2017	43.6	60.2	75.2	17.4	12.2	89.6	70	55.4	105.8	40.8	83.8	97.2	751.2
2018	0	0	62.2	48.6	28.4	0.2	40.2	28.6	87.2	71	52.4	90.6	509.4
Mean	69.34	48.34	43.64	40.62	44.56	50.82	64.8	43.56	43.42	53.96	82.6	93.2	**678.86**

3.4.4 Effective Rainfall

3.4.4.1 Long-term monthly average rainfall and potential evaporation statistics (MAFF, corrected using FEH13 SAAR6190 data) have been used to derive estimates of monthly average effective rainfall[3], as at *table 6*.

3.4.4.2 Calculation has been performed to provide estimates for bare earth[4], grass cover and open water using methods described by Grindley[5] and EA R&D Handbook W6-043/HB[6].

1 "Climate & Drainage", Technical Bulletin No.34, Ministry of Agriculture Fisheries & Food (MAFF), September 1976.
2 Centre for Ecology & Hydrology Flood Estimation Handbook Web Service, FEH13 Rainfall Model (https://fehweb.ceh.ac.uk/), November 2018.
3 The proportion of rainfall available for runoff and groundwater recharge after accounting for evapotranspiration and satisfaction of soil moisture deficit.
4 Which may be taken to represent a quarried surface.
5 "The Calculation of Actual Evaporation and Soil Moisture Deficit over Specified Catchment Areas", Grindley J, November 1969, Hydrological Memorandum 38, Meteorological Office, Bracknell, UK.
6 "Estimation of Open Water Evaporation, Guidance for Environment Agency Practitioners", R&D Handbook W6-043/HB, J W Finch and R L Hall, October 2001.

Table 6 Derivation of Effective Rainfall for Differing Surfaces

Bare Earth (rc = 0mm)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rf	70	54	52	53	66	57	67	79	68	66	80	74	786
Pe	3	10	30	53	80	90	90	74	46	20	5	1	502
rf-Pe	67	44	22	0	-14	-33	-23	5	22	46	75	73	284
dPsmd	0	0	0	0	14	33	23	-5	-22	-43	0	0	
dAsmd	0	0	0	7	7	21	5	-5	-22	-13	0	0	
Asmd	0	0	0	0	14	47	70	65	43	0	0	0	239
Psmd	0	0	0	7	14	35	40	35	13	0	0	0	144
Ae	3	10	30	60	73	78	72	74	46	20	5	1	472
ERF	67	44	22	0	0	0	0	0	0	33	75	73	**314**
Permanent Grassland (rc = 75mm)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rf	70	54	52	53	66	57	67	79	68	66	80	74	786
Pe	3	10	30	53	80	90	90	74	46	20	5	1	502
rf-Pe	67	44	22	0	-14	-33	-23	5	22	46	75	73	284
dPsmd	0	0	0	0	14	33	23	-5	-22	-43	0	0	
dAsmd	0	0	0	7	7	33	23	-5	-22	-43	0	0	
Asmd	0	0	0	0	14	47	70	65	43	0	0	0	239
Psmd	0	0	0	7	14	47	70	65	43	0	0	0	246
Ae	3	10	30	60	73	90	90	74	46	20	5	1	502
ERF	67	44	22	0	0	0	0	0	0	3	75	73	**284**
Open Water													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Correction Constants	1.4	1.1	0.9	1.0	0.9	1.0	1.2	1.4	1.5	2.0	2.3	2.0	
Ae	4.3	11.4	27.6	50.4	72.8	91.8	111.6	101.4	67.6	39.8	11.5	2.0	592.0
ERF	65.7	42.6	24.4	2.7	-6.8	-34.8	-44.6	-22.4	0.4	26.2	68.6	72.1	**194.0**

rc: Root Constant, Rf: Rainfall, Pe: Potential Evaporation, Psmd: Potential Soil Moisture Deficit. Asmd: Actual Soil Moisture Deficit, Ae: Actual Evaporation, ERF: Effective Rainfall. All units other than correction constants are millimetres.
Note: Estimates of effective rainfall for bare earth and grassland cover are identical due to the preponderance of rainfall over evapotranspiratton in the area which militates against the development of significant SMD during average climatic years.

3.5 Hydrogeological Setting

3.5.1 Background

3.5.1.1 Information concerning the Hydrogeology of the Study Area has been obtained from:

- Findings of BCLS's 2019 walkover field survey.
- Published geological mapping, including British Geological Survey (BGS) 1:50,000 scale solid and drift mapping (Sheet E107, Denbigh), and 1:63,360 scale mapping (Vale of Clwyd, St. Asaph, Denbigh Lead and Copper Lodes).
- Site investigation drilling and piezometer installation logs.
- Previous geological reports for the Site.
- Site specific hydrometric monitoring data.
- Published and third party data sources

3.5.2 Aquifer Classification

3.5.2.1 The Carboniferous limestones of the CLG and the sandstones of the KSS are classified by NRW as 'Principal Aquifers', being defined as highly permeable deposits that support water supply and river baseflow on a strategic scale.

3.5.2.2 The Silurian shales of the EF are classified as a 'Secondary B' aquifer, defined as lower permeability layers storing limited amounts of groundwater only.

3.5.2.3 The drift deposits of the GT are classified as a 'Secondary Undifferentiated' aquifer, defined as deposits with varying hydraulic properties that can function either as aquifers or unproductive strata at the local scale.

3.5.3 Groundwater Flow Mechanism

Clwyd Limestone Group

3.5.3.1 The CLG form an unconfined triple porosity aquifer (The Aquifer), featuring primary (intergranular), secondary (fracture) and tertiary (dissolution enlarged conduit) porosity components.

3.5.3.2 The primary porosity component features negligible permeability, and makes limited contribution to supporting groundwater flows.

3.5.3.3 The secondary porosity component typically features diffuse laminar groundwater flow and comprises the majority of Aquifer storage, though flow rates can vary due to heterogeneous aquifer properties (being highest where fracturing is most prevalent). Such flows can be enhanced / impeded by the presence of joints, bedding planes and faulting.

3.5.3.4 Where groundwater flows are concentrated, dissolution of the rock matrix can lead to the development of tertiary porosity in the form of conduits and other karst features. Groundwater flows within such features can be rapid and turbulent, sometimes featuring perennial flow regimes and / or groundwater flow directions contrary to that within the wider distribution of the Aquifer.

3.5.3.5 Though conduit flow typically occurs at or near normal groundwater elevations, such flows can occur in the unsaturated zone where epikarst is well developed (dissolution enlarged features formed by infiltrating waters), where paleokarst is present (conduits formed historically when groundwater levels differed to present conditions), or where allogenic (sourced from outwith the distribution of the Aquifer) recharge features persist (such as sinking streams).

Kinnerton Sandstone Formation

3.5.3.6 The KSS form a double porosity aquifer (The KSS Aquifer). Groundwater flow is typically diffuse and intergranular, though flows within the secondary porosity component may also persist where fracturing / faulting has occurred.

3.5.3.7 The KSS Aquifer is typically confined across the region by the overlying drift deposits, with artesian heads being observed in some locations[7].

Elwy Formation and Warwickshire Group

3.5.3.8 The EF and Warwickshire Group predominantly feature mudstones and siltstones of negligible aquifer properties which are anticipated to function as aquitards (partial barriers to groundwater flow / infiltration).

3.5.3.9 Though typically offering limited potential for groundwater flows, the presence of interbedded sandstone horizons within these units can support limited groundwater movement, though such horizons are of varied thickness / distribution, and feature varying degrees of connectivity.

3.5.4 Aquifer Boundaries

Aquifer Vertical Boundaries

3.5.4.1 The Aquifer is unconfined at the Site location, with its upper surface thus being formed by ground level.

3.5.4.2 Though the EF and conglomerate at interface are present upon the base of the Aquifer, the thickness of the CLG at the Site location implies that the base of the Aquifer is likely to be formed by the limit of its effective porosity.

Aquifer Lateral Boundaries

3.5.4.3 To the south and west of the Site, lateral boundaries of the Aquifer are formed by the limit of its distribution.

3.5.4.4 To the north and east, the distribution of the CLG extends beyond its outcrop, though likely at depths in excess of that supporting effective porosity and thus significant groundwater flows.

3.5.4.5 It should be noted that there are no reported low permeability strata at the interface of the Aquifer and the overlying KSS to the east of the Site. As both units form principal aquifers, some hydraulic continuity between them may be expected (with the Aquifer thus providing some allogenic recharge to the KSS).

Aquifer Internal Boundaries

3.5.4.6 As discussed, hydraulic properties within the Aquifer may vary depending upon the presence and concentration of fracturing. The Aquifer is known to feature joints, faults and bedding planes, including within the Site itself, that are clay / silt filled. Such features may function as internal aquifer boundaries, though are likely to be of importance at the local scale only (due to their limited extent and varied distribution).

3.5.5 Aquifer Recharge

3.5.5.1 The presence of GT serves to impede the infiltration of recharge waters across the region, though some leakage through this deposit can be expected. Recharge to the

[7] Environment Agency / British Geological Survey, 'The Physical Properties of Major Aquifers in England and Wales', Hydrogeology Group Technical Report WD/97/34, 1997.

Aquifer is thus anticipated to principally be autogenic (sourced from within the distribution of the Aquifer), though concentrated within areas of CLG outcrop where GT cover is absent.

3.5.5.2 Aquifer recharge may be further concentrated where epikarst features are present, these being formed by infiltrating waters coalescing within pathways featuring enhanced permeability. Such features are known to be prevalent in the Aquifer unsaturated zone in the local area, and are evident within the worked faces of the Existing Site.

3.5.5.3 It should be noted that, though the presence of karst features within the Aquifer unsaturated zone may affect the rate / routeing of recharge waters, this is typically of greatest importance at the local scale, with all such waters ultimately being expected to contribute to the Aquifer saturated zone.

3.5.5.4 The topography of the Site vicinity features ground elevations falling away from the CLG outcrop, thus presenting limited scope for any allogenic recharge sources. This is with the exception of a small area to the west of Denbigh where ground elevations fall from the EF outcrop towards the CLG (at the location of the Henllan Brook).

3.5.6 Groundwater Occurrence and Levels

The Available Data

3.5.6.1 Groundwater elevations at the Site are recorded on a monthly basis by BCL at 5 no. piezometers (P1/19 to P5/19, The 2019 Series Piezometers, located as at *figure 6*).

3.5.6.2 Historic groundwater elevation data for the Site, recorded by previous Site operators, is available for a further 7 piezometers (DB9-89, DB11-89, Bund, Top Ramp, New Wood, DB1-01 and 2003 (The Historic Piezometers, as at *figure 6*).

3.5.6.3 Details of the available piezometers are presented below at *table 7*, with drilling / construction logs for the piezometers (where available) being presented at *appendix 9.2*.

Table 7 Details of Site Piezometers

Piezometer (*figure 6*)	Construction	Depth (m)	Data Range*	Status / Note
DB9-89	19mm ID, partially penetrating GLG.	54.77	89 - 07	Lost. Full construction not known, location approximate.
DB11-89	Unknown, assumed to partially penetrate CLG.	Unknown	93 – 00	
Bund				
Top Ramp				
New Wood			93 – 97	
DB1-01	Open hole, assumed to partially penetrate CLG.		01 – 07	Lost. Full construction not known, datum approximate.
2003	50mm ID, partially penetrating CLG.	57.50	03 – 22	Previously lost, since reactivated. Full construction not known.
P1/19	50mm ID, geotextile wrapped screen with gravel pack to full intercepted lithology, bentonite seal at surface, locking headworks. Partially penetrating CLG.	30.00	19 - 22	Active.
P2/19		60.00		
P3/19		67.00		
P4/19		78.50		
P5/19		71.00		
ID: Internal Diameter. *: typically at monthly resolution.				

3.5.6.4 Water elevation data within the quarry sump is also available, both from historic dips taken against a fixed datum and for direct levels recorded during periodic professional surveys of the Site.

3.5.7 Temporal Groundwater Level Variations

3.5.7.1 Hydrographs of the available data collected at the Historic Piezometers, 2019 Series Piezometers and a combined data set, are presented at *figures 7*, *8* and *9* respectively.

3.5.7.2 Data for the historic piezometers shows groundwater elevations at the Site to range from 80.24maOD to 119.16maOD, with the observed ranges in recorded groundwater elevations typically being high, and varying greatly between individual piezometers (observed ranges of between 6.5m to 30m).

3.5.7.3 The high observed ranges, and variation thereof, is considered characteristic of Carboniferous Limestone aquifers such as that present at the Site, due to the high variability in aquifer properties at the local scale, and limited primary porosity.

3.5.7.4 Piezometers featuring rapid responses to individual rainfall events accompanied by high ranges in heads (notably at piezometers Bund and New Wood) are indicative of the interception of areas of enhanced permeability (secondary / tertiary porosity being prevalent).

3.5.7.5 Piezometers featuring more subdued responses to individual rainfall events, and more limited ranges in heads (such as piezometer DB1/01) are considered indicative of the interception of areas where enhanced permeability is less prevalent (with groundwater movement being principally dictated by primary / secondary porosity components).

3.5.7.6 The Historic Piezometers cover a combined period of some 18 years, with the full data record being bridged by piezometer DB9-89. Data for this piezometer demonstrates no long term trend in rising / declining groundwater elevations at the Site location.

3.5.7.7 It should however be noted that minimum groundwater elevations recorded at DB9-89 are coincident with the base of the piezometer (remnant water in the base of which was likely recorded). This piezometer is therefore unlikely to have detected the full range in heads at this location (with respect to minima).

3.5.7.8 The range in observed heads at piezometer Bund is notably greater than at any other piezometer (by some 10m), primarily with respect to maximum heads. This may be a result of piezometer construction (which is unknown), though may also be attributable to conduit (tertiary porosity) interception.

3.5.7.9 The Historic Piezometer record is assumed to bridge periods within which historic dewatering operations have been undertaken at the Site. This may have had some influence on the data recorded.

3.5.7.10 Data for the 2019 Series Piezometers corroborates the trend observed within the historic data, a high range in heads being observed with rapid response to recharge. Again, more subdued response is noted in certain piezometers (P1/19).

3.5.7.11 This is confirmed where 2019 Series Piezometers are effectively acting as replacements for historic piezometers (such as Top Ramp / P2/19 and DB1-01 / P1/19). In such cases, the most recent data confirms that historically observed in terms of level, range and trend.

3.5.7.12 This is with the exception of piezometer 2003, which intervenes between P3/19 and P4/19, and features notably higher minimum heads (by 7m to 10m). Piezometer 2003 was installed to lesser depth (57.5m, as opposed to 67m and 78.5m for P3/19 and P4/19 respectively), is of unknown internal construction, and has a history of blockage. Any widespread perched groundwaters would have been intercepted by the 2019 Series Piezometers (as they were screened to their full depth) or would at least have been detected by drilling water strike. It is thus assumed that the full range in heads at piezometer 2003 (with respect to minima) was not recorded, either due to piezometer construction, blockage, or small-scale influence of intercepted strata.

Groundwater Head Distribution

2019 Series Piezometers

3.5.7.13 Groundwater elevation data for the 2019 Series Piezometers recorded in September 2019 has been used to produce an interpolated contour plot of groundwater elevations across the Site, as at *figure 10*.

3.5.7.14 Groundwater levels are shown to range across the Site by some 17.39m (90.75maOD to 73.36maOD), falling northeastwards, towards the Denbigh Fault, and in line with flows within the Clwyd Valley and general local topography, at an average gradient of 0.02, this steepening northwards and eastwards.

3.5.7.15 Groundwater flows are thus indicated to be made northwestwards. This is in general agreement with the broader accepted interpretation of the hydrogeology of the local area, which suggests that groundwaters within the Carboniferous strata upon the western side of the Vale of Clwyd (such as that present at the Site) cross-flow into the adjacent KSS Aquifer, groundwater flows within which are made towards and in line with the River Clwyd (with which they are in partial continuity), with any remaining deep flows within the CLG being made northwards to the coast[8].

Historic Piezometers

3.5.7.16 Though a longer data record is available for the Historic Piezometers that is available for the 2019 Series Piezometers, this data is subject to limitations as below:

- There is no cross over between Historic and 2019 Series datasets excepting piezometer 2003.
- There is no cross over in data recorded at all Historic Piezometers.
- The spatial distribution of the Historic and 2019 Series piezometers varies.
- Confidence in the available historic dataset is limited by estimated locations / datums, unknown construction details, and unknown external influences (such as dewatering at the Site).

8 British Geological Survey, 'Hydrogeology of Wales', 2015

- A number of the Historic Piezometers are indicated to have been affected by insufficient installation depth and / or significant local scale influence that may not be representative of groundwater elevations across the wider Site.

3.5.7.17 The principal value of the historic data is thus to confirm the range and trend observed in more recent data, and where possible, to expand upon the available spatial distribution / resolution, to better understand groundwater elevations across the Site, as below.

Combined Head Distribution

3.5.7.18 The suitability of the available piezometers for application to a combined head distribution under minimum, maximum and average expected groundwater elevations is considered below at *table 8*.

Table 8 Piezometer Suitability for Combined Head Distribution

Piezometer (*figure 6*)	Comment	Suitability		
		Minimum Conditions	Maximum Conditions	Average Conditions
DB9-89	Data suggests insufficient installation depth.	Unsuitable	Data	Unsuitable
DB11-89	Historic data record rational.	Data	Data	Data
Bund	High range, potential local scale / historic dewatering influence.	Unsuitable	Unsuitable	Unsuitable
Top Ramp	Replaced by P2/19.	Not Required	Not Required	Not Required
New Wood	Possible dewatering influence.	Unsuitable	Data	Unsuitable
DB1-01	Replaced by P1/19.	Not Required	Not Required	Not Required
2003	Potentially not recording full range, possible local scale influence and historic blockage.	Unsuitable	Data	Unsuitable
P1/19 P2/19 P3/19 P4/19 P5/19	Observed range and trend in agreement with historic sources.	Data	Data	Data

3.5.7.19 Data for the piezometers outlined above has been used to produce interpolated contour plots estimating groundwater elevations across the Site under minimum, maximum and average expected conditions, as at *figures 11, 12* and *13* respectively.

3.5.7.20 Under minimum conditions, groundwater elevations are seen to range from some 88maOD to some 70maOD, falling to the north east at a gradient of 0.03. Groundwater flow is implied to be made to the east, towards the Denbigh Fault, with a north easterly component on the northern Site boundary.

3.5.7.21 Under maximum conditions, groundwater elevations are seen to range from some 122maOD to some 86maOD, falling to the north east at a notably steeper gradient of 0.05. Groundwater flow is again implied to be made to the east, towards the Denbigh Fault, though with a south easterly component on the south eastern Site boundary. This discrepancy with that observed under minimum conditions is thought to result from the more limited range in elevations recorded at piezometer P1/19, which is not indicated to have intercepted well developed secondary / tertiary porosity features. The true groundwater flow direction (excluding this likely localised effect) is thus likely to mirror that discussed for minimum conditions.

3.5.7.22 Under average conditions, groundwater elevations are seen to range from some 97.5maOD to some 82.5maOD, falling uniformly to the east at a gradient of 0.03, groundwater flows thus being made on this vector, towards the Denbigh Fault.

Sump Elevations

3.5.7.23 Data for the elevation of waters within the quarry sump, located as at *figure 6*, with the collected data presented at *figure 9,* are available both from historic dips made from a fixed datum upon the quarry face (WL99/2) and from periodic survey data (Sump), between which there is general agreement (dewatering impact upon WL99/2 is not evident).

3.5.7.24 The available data indicates a range in sump water elevation of 5.71m (95.56maOD to 89.85maOD), relative to a sump basal elevation of 88.1maOD (water depths of 1.75m and 7.46m).

3.5.7.25 Consultation of the combined head distribution presented for the Site implies groundwater levels at the sump location of 82maOD, 106maOD and 91.5maOD for minimum, maximum and average conditions respectively.

3.5.7.26 Under average conditions, predicted groundwater elevations are in general agreement with those recorded within the sump itself.

3.5.7.27 Under maximum conditions, groundwater elevations are shown to exceed the recorded range in sump elevations, though to remain within the elevations of the sump itself (lip elevation circa 106maOD). This corroborates qualitative reports of higher water levels in the sump (at maximum freeboard), as reported by local residents (as at *section 3.5.9*).

3.5.7.28 Under minimum conditions, predicted groundwater elevations are shown to fall below the base of the sump. This observation is confirmed through the recording of concurrent sump elevation and groundwater elevation readings by BCL on 10/09/2019, at which point the water level within the sump (95.5maOD) was seen to exceed that observed across the piezometer network (90.75 to 73.36maOD, as at *figure 8*), including both up hydraulic gradient and down hydraulic gradient piezometers. Similar occurrences are evident within the historic data.

3.5.7.29 It is thus considered that whilst water elevations within the sump fall within the range of groundwater elevations expected at the Site, during periods of low groundwater elevations, the Sump level becomes perched.

3.5.7.30 Rainfall / runoff from across the Site drains to the sump, though this alone would be expected to dissipate rapidly and be of limited volume during periods of depressed groundwater elevations (which are shown to respond rapidly to rainfall events).

3.5.7.31 There is potential for perched groundwaters to sustain the sump during such periods, though as discussed, the 2019 Series Piezometers intercepted no such features, implying a highly localised influence if present.

3.5.7.32 It is therefore considered more likely that groundwater flows from the sump are vertically impaired, effectively stranding waters within it as groundwater elevations fall, with rainfall / runoff maintaining its level in the interim.

3.5.7.33 This is possibly explained by the historic, and recently continued practice, of tipping clay overburdens within the sump upon its eastern margin, which may have sealed areas of enhanced permeability on the down hydraulic gradient side of the sump from which it may have historically drained, and / or its excavation into a horizon of poorly developed secondary / tertiary porosity.

Saturated and Unsaturated Thicknesses

Aquifer Saturated Thickness

3.5.7.34 The full thickness of the Aquifer, and depth of its effective permeability are not fully understood. Aquifer saturated thickness cannot therefore be determined at this time.

Aquifer Unsaturated Thickness

3.5.7.35 Topographic survey data for the Proposed Development has been combined with estimated minimum and maximum groundwater elevations to estimate maximum and minimum unsaturated thicknesses, as at *figures 14* and *15* respectively.

3.5.7.36 Minimum unsaturated thickness is seen to typically range from 31.7m to 29.6m, being relatively consistent across the Proposed Development, excepting areas of locally altered topography (such as the quarry void and a small hill in the south eastern limit of the Proposed Development area, likely forming and old overburden tip).

3.5.7.37 Maximum unsaturated thickness is seen to typically range from 63m to 55m, generally thickening to the north and west, in line with increasing topographic elevation.

3.5.8 Aquifer Parameters

Clwyd Limestone Group

3.5.8.1 Field testing to determine hydraulic parameters for the Aquifer were undertaken by BCL in September 2019, comprising falling head testing (slug testing) of 5 no. piezometers partially penetrating the CLG (Piezometers P1/19 to P5/19, *figure 6*).

3.5.8.2 Falling head testing involves the introduction of a volume of water into the piezometer to create an artificial head differential between the section of aquifer comprising the piezometer (and its immediate vicinity) and the undisturbed rest water level within the aquifer adjacent to the piezometer. The rate and form of the return to rest groundwater level following the introduction of water to the piezometer can be diagnostic of the permeability of the strata under test.

3.5.8.3 For each piezometer, following introduction of water, the decay of induced head was recorded using an automated data-logger allied to a barometric pressure logger (Van Essen Diver) which allowed collection of accurate level and time data.

3.5.8.4 By virtue of their small scale, falling-head tests are generally considered to indicate hydraulic properties of the aquifer only in the immediate vicinity of the well under test. The results of such tests should therefore be considered as indicative of general field-conditions rather than absolute.

3.5.8.5 Accounts of the data, methodology and results of the falling head testing are presented at *appendix 9.3*, with summary results below at *table 9*.

Table 9 Results of Falling Head Testing

Piezometer (*figure 6*)	Hydraulic Conductivity (m/d)	Note
P1/19	0.008	Good decay in head recorded, assumed representative of lower end permeability (primary / secondary porosity component).
P2/19	0.4	Rapid loss of head, estimate likely to underestimate actual permeability at this location.
P3/19	0.02	Irregular decay in head recorded, assumed more representative of lower end permeability (primary / secondary porosity component).
P4/19	1.18	Rapid and irregular loss of head, estimate likely to underestimate actual permeability at this location.
P5/19	0.1	Reasonable decay in head recorded.

3.5.8.6 Slug testing identified a range in permeability of 0.008m/d to 1.18m/d, though is considered to have produced unreliable results where permeability was indicated to be elevated. The results for P1/19 and P5/19 are considered of greatest relevance, likely to local scale intergranular / fracture permeability.

3.5.8.7 The Major Aquifer Properties Handbook[7] describes typical intergranular permeability for Carboniferous Limestone aquifers in the region of 0.001m/d to 0.01m/d, with bulk permeability ranging from 0.1m/d to 9.4m/d. Data specific to the CLG are not presented.

3.5.8.8 Test pump results specific to the CLG are detailed within the Hydrology of Wales[8], reporting transmissivities of 0.15 to 1.8m^2/d.

3.5.8.9 Representative bulk permeability for the Aquifer at the Site is assumed to range from 0.1m/d to 10m/d. It should be noted that such properties are highly variable at the local scale and dependent upon the presence / absence of enhanced areas of permeability. Further, active conduits, if intercepted, may potentially convey volumes of groundwater in significant excess of these estimates.

Kinnerton Sandstone Formation

3.5.8.10 Aquifer properties for the KSS, as reported in the Major Aquifer Properties Handbook[7], indicate permeability for the KSS to range from $3*10^{-4}$m/d to 3m/d (to mean 0.21m/d), with a mean transmissivity of 130m^2/d.

3.5.9 Karst Features

Survey

3.5.9.1 Water Features Surveying undertaken by BCL in September 2019 did not identify any surface water features that were expressly identified to be dependent upon direct karst flows derived from within the CLG.

3.5.9.2 The Water Features Survey did however include inspection of the quarry faces, within which numerous karst features were identified (exclusively within the unsaturated zone). This included a number of clay filled vertical features as well as numerous open lateral features. These features were not conveying any flows at the time of survey, and are considered to form epikarst, providing pathways for the infiltration of recharge waters through the unsaturated zone of the Aquifer. The approximate locations of these features are presented at *figure 16*.

3.5.9.3 Discussions with Site staff identified a 'headland' area of unworked mineral, adjacent to which the majority of karst features were identified, which was left unworked due to the significant interception of void spaces during drilling, thus precluding the safe blasting of mineral in this area.

3.5.9.4 Discussions with a local resident resulted in reports of very high water levels within the sump of Denbigh Quarry following periods of heavy rainfall, this being associated with the occasional and short lived activation of a conduit conveying flows from within the sump to emergence within Coed Parc-Pierce to the south of Plas Clough Farm (within 200m of the Site boundary). The presence of such features could not be confirmed on the ground, and the reported emergence is not associated with any known watercourses.

Literature

3.5.9.5 The available literature describes a relative concentration of caves and associated features upon and around the Afon Merchion and River Elwy. The closest of these is located 2.2km to the north west of the Site at Plas Heaton (Plas Heaton Cave)[9].

3.5.9.6 These features are associated with the same outcrop of CLG as the Site is located upon. They are however associated with watercourses within the Elwy catchment. A groundwater flow divide is expected to be present within the CLG between the Clwyd and Elwy catchments. Though the location of this is not known, the surface water catchment divide is estimated to be located some 1.5km to the west of the Site. These features are thus effectively hydraulically isolated from the Site.

3.5.9.7 A small cave is reportedly present beneath Denbigh Castle, 0.9km to the south of the Site[10]. This feature is reportedly dry (likely paleokarst or epikarst). The presence of associated active features in this locality is not known. This cave is located cross hydraulic gradient from the Site and is separated from it by intervening lower ground (the valley of the Henllan Brook). Any direct hydraulic connection between this area and the Site is thus considered unlikely.

3.6 Water Resources Setting

3.6.1 Catchment Abstraction Management Strategy

Overview

3.6.1.1 The Study Area falls entirely within the Clwyd Catchment Abstraction Management Strategy (CAMS) area, as administered by NRW.

3.6.1.2 The Site and Proposed Development fall within the Middle / Lower Clwyd Management Catchment of the CAMS area.

9 Ford, T.D, 'Limestones and Caves of Wales', Cambridge University Press, 1989.

10 North Wales Caving Club [WWW], northwalescavingclub.org.uk

Surface Water Resource Availability Status

3.6.1.3 Surface water resource availability at the Site location is 'more water available', meaning that water availability exceeds that required to sustain existing abstractions and the needs of the environment, and that new consumptive abstractions may be licenced subject to site specific assessment, up to a renewal date of 31st March 2029.

Groundwater Resource Availability Status

3.6.1.4 The CAMS area details two main groundwater resources in the form of the central and coastal blocks of the KSS.

3.6.1.5 The majority of the Study Area falls within an area detailed as exempt from licensing. It should be noted that this exemption is no longer in effect, and licencing restrictions are now applied across the region.

3.6.1.6 The CAMS document states that, where outside of these areas, groundwater abstraction from drift deposits will be licenced in line with surface water resource availability in the corresponding catchment.

3.6.1.7 The Site falls outwith both the main groundwater resources, previously exempt areas, and the distribution of any drift aquifers.

3.6.1.8 It is therefore assumed that groundwater resource availability is linked to surface water resource availability in the Middle / Lower Clwyd catchment as discussed above.

3.6.1.9 The KSS present to the east of the Site falls within the central block, and has a groundwater availability of 'no', meaning that new consumptive abstractions from this unit are unlikely to be granted (though license trading may be possible).

3.6.2 Water Framework Directive Groundwater Body Quantitative Status

3.6.2.1 The Site falls within the Clwyd Permo-Triassic Sandstone groundwater body, and has an overall status of 'good' and a quantitative status of 'good'.

3.6.3 Water Abstractions

Licenced Abstractions

3.6.3.1 Data regarding licenced abstraction within the Study area has been provided under conditional licence by NRW. Specifics as to the nature and location of the abstractions cannot therefore be presented.

3.6.3.2 There are 2 no. licenced abstractions within the Study area. One of these is made from a cluster of groundwater abstraction points, with the KSS as their source of supply. These abstractions are located some 3km from the Site boundary and are not indicated to feature any hydraulic connection to the Site.

3.6.3.3 There is 1 further abstraction, made some 0.8km from the Site, being located upon the CLG. This is a surface water impoundment, and is not indicated to feature any hydraulic connection to the Site.

De-regulated Abstractions

3.6.3.4 Locations and available details for de-regulated abstractions (private water supplies of less than 20m^3/d for which an abstraction licence is not required) within the Study Area, as provided by DCC, are presented at *figure 17* and *table 10* below.

3.6.3.5 Abstractions A, B, C and D are all made from wells drilled to the EF, and are located at distance to the southwest of the Site (2-2.5km). These abstractions are thus considered to by hydraulically isolated from the Site.

3.6.3.6 Abstractions E, F and G are all made from wells indicated to be drilled to the KSS. Abstraction H is made from a spring which is also likely fed by groundwaters from the KSS. As discussed, the KSS is potentially in receipt of allogenic recharge from the CLG, and a potential hydraulic connection thus exists between the Site and these abstractions. It should however be noted that abstractions E, G and H are in excess of 2km from the Site, abstraction F being 0.85km from the Site and 1.1km from the Proposed Development.

Table 10 De-regulated Abstractions

Map Code (*figure 17*)	DCC Reference	Type	Use	Source of supply
A	P5590175	Borehole	Domestic & dairy	EF
B	P5590173 A	Borehole	Livestock only	EF
C	P5590173 B	Borehole	Livestock only	EF
D	P5590173 C	Borehole	Livestock only	EF
E	P5590131	Borehole	Domestic & livestock	KSS
F	P550707	Borehole	Car wash	KSS
G	P550162	Borehole	Domestic & dairy	KSS
H	P5590199	Spring	Domestic	KSS
I	P550585	Borehole	Livestock only	WG / CLG
J	P5590585	Borehole	Livestock only	WG / CLG
K	P5590575	Borehole	Domestic & dairy	CLG
L	P5590172	Well	Domestic	CLG

EF: Elwy Formation, KSS: Kinnerton Sandstone, WG: Warwickshire Group, CLG: Clwyd Limestone Group

3.6.3.7 Abstractions I and J are both made from boreholes drilled to the WG, though the exact construction of these wells is not known, and potential exists for them to fully penetrate the WG and thus have the CLG as the source of supply (and thus potentially having a hydraulic connection to the Site). These abstractions are however located some 1.7km to the north of the Site, and are up hydraulic gradient.

3.6.3.8 Abstractions K and L are made from boreholes indicated to be drilled to the CLG and are thus in potential hydraulic continuity with the Site. Abstraction K is located some 2.1km to the north west and is up-hydraulic gradient. Abstraction L is however in relatively close proximity to the Site, being 0.23km to the north east of the Site and 0.5km to the north east of the Proposed Development.

3.6.3.9 DCC have identified the well at Abstraction L to be 'surface water derived'. Maximum groundwater elevations at the closest piezometer (140m to the south west of the abstraction, and up hydraulic gradient) are at approximately 82maOD, relative to ground elevations at Abstraction L of some 99maOD. If truly surface water derived, this abstraction is unlikely to be dependent upon groundwaters from the saturated zone of the CLG. Supporting perched groundwaters would be unlikely to propagate beyond the quarry itself due to its depth, which would hydraulically isolate the abstraction from the Proposed Development. In lieu of definitive detail on the well construction, it must however be assumed to gain at least some of its supply from the saturated zone of the CLG.

3.6.4 Source Protection Zones

3.6.4.1 Data with regards to the locations of groundwater Source Protection Zones (SPZs) has been provided by NRW.

3.6.4.2 The Site and Proposed Development fall entirely outwith any designated SPZ, the closest such zone being located some 1.6km to the east upon the outcrop of the KSS, as at *figure 18*.

3.7 Hydrochemical Setting

3.7.1 Background

3.7.1.1 Information concerning the water quality of the Study Area has been obtained from:

- Published and third party data sources.
- Historic Site monitoring data.

3.7.2 Groundwater Quality

Groundwater Vulnerability

3.7.2.1 Data with regards to groundwater vulnerability has been provided by NRW.

3.7.2.2 The Site location is classified as 'Principal Aquifer, Medium Vulnerability', this likely being due to the intermittent GT cover overlying the Aquifer.

Water Framework Directive Groundwater Body Chemical Status

3.7.2.3 The Site falls within the Clwyd Permo-Triassic Sandstone groundwater body, and has an overall status of 'good' and a chemical status of 'good'.

Groundwater Quality Data

3.7.2.4 Water quality data for historic discharge from the Site, which would have constituted a mixture of quarry dewatering water (groundwater) and surface runoff from across the Site, is available for a single sample point as recorded in September 1999. The available data is presented below at *table 11*.

Table 11 September 1999 Site Discharge Quality Data

Determinand	Concentration (mg/l)	Standard (mg/l)	Standard Type
Sulphate	37.3	250	Drinking Water Standard
Calcium	50.8	250	Drinking Water Standard
Magnesium	2.78	50	Drinking Water Standard
Sodium	15.3	200	Drinking Water Standard
Potassium	1.81		
Iron	0.07	0.2	Drinking Water Standard

Aluminium	0.03	0.2	Drinking Water Standard
Amoniacal Nitrogen	<0.2	0.5	Drinking Water Standard
Nitrate	1.2	50	Drinking Water Standard
Bicarbonate Alkalinity	99		
Carbonate Alkalinity	0		
Chloride	27	250	Drinking Water Standard

3.7.2.5 The available data demonstrates water quality to be within the relevant standards where applicable, featuring elevated calcium and bicarbonate alkalinity, indicative of the limestone bedrock present at the Site.

3.7.3 Surface Water Quality

WFD Classifications

3.7.3.1 The Site falls within the Clwyd Management Catchment of the Western Wales River Basin District.

3.7.3.2 The River Clwyd, Afon Y Merchion and the Denbigh Streams have an overall waterbody status of 'Moderate', with the Afon Ystrad having an overall status of Good.

3.7.4 Potential Sources of Pre-existing contamination

Landfill Sites

3.7.4.1 The locations of historic landfills within the Study area are shown at *figure 19*, with summary detail at *table 12* below.

Table 12 Summary Detail for Landfill in the Vicinity of the Site

Identification	Distance (km)*	Status	Class	Operator
Bryn Nefydd	0.69	Historic	I, C&I	Clwyd County Council
Halal Slaughterhouse	2.26	Historic	I, C&I	Halal Meat Company
Henllan Landfill	2.3	Historic	I, C&I, HH, S	Glyndwr District Council
Ty Gwyn Farm	3.3	Historic	I, L/S	Mr D E Jones
Bodfari Road	3.4	Historic	I, C&I, HH	Unknown

*At shortest distance from the Proposed Development boundary.

3.7.4.2 Bodfari Road Landfill is located upon KSS outcrop with Till cover and is at significant distance from the Site to the northeast. This landfill is not considered in potential hydraulic continuity with the Site.

3.7.4.3 Halal Slaughterhouse and Henllan landfills (on CLG outcrop) and Ty Gwyn Farm landfill (on EF) are all located within the valley of the Afon Meirchion, and are assumed to by hydraulically isolated from the Site by an expected groundwater flow divide between the Afon Meirchion and Clwyd catchments.

3.7.4.4 Bryn Nefydd landfill is indicated to be based upon the CLG (with Till cover) and is in potential hydraulic continuity with the Site, being located up hydraulic gradient. This landfill is reported to have received inert and industrial wastes, and is indicated by historic mapping to be on the site of a lime kiln (1879) and associated workings (Till cover having thus likely been removed), this having been filled in the 1990s.

3.7.4.5 It is understood that the restoration of the existing Site is to involve the importation of 100,000 tonnes of inert waste per annum, these being deposited within the northern area of the Site, being entirely deposited above groundwater elevations. This will be unaffected by the Proposed Development, and the inert nature of the wastes, as controlled by the required Environmental Permit, will obviate any significant risk to groundwater quality.

Other Potential Sources of Existing Contamination

3.7.4.6 The NRW records of pollution incidents, dated July 2019, shows no record of any such incidents within the Study Area.

3.7.4.7 Consultation of historic mapping for the Site location confirms the presence of the quarry in 1898 with no evidence of subsequent potentially contaminating industrial activities (such activities being limited to quarrying and agriculture).

4 CONCEPTUAL HYDROGEOLOGICAL MODEL

4.1 The Site is underlain by a 'Principal Aquifer' in the form of the CLG. This forms an unconfined triple porosity aquifer featuring limited intergranular permeability, with the bulk of groundwater flow occurring within the secondary (fracture) and tertiary (conduit) porosity components (which support high bulk permeability).

4.2 The Aquifer is unconfined, featuring rapid, vertical recharge, this being concentrated through preferential pathways of enhanced permeability (epikarst). Where such pathways are not present, permeability may be sufficiently low to allow the retention of infiltrating waters within the unsaturated zone, forming perched groundwaters.

4.3 The base of the Aquifer is assumed to be formed by the limit of its effective permeability (full thickness not proven). The extent of the Aquifer is limited by its distribution, this forming a 'block' delineated by faulting, giving way to the underlying Silurian mudstones and sandstones of the EF to the west, overlying mudstones and sandstones of the Warwickshire Group to the northeast, and to the unconformably overlying KSS to the east (against which it abuts at the north-south trending Denbigh Fault, and which also forms a 'Principal Aquifer').

4.4 The majority of the local area is obscured by drift deposits in the form of glacial Till (which is considered to locally act as an aquitard). This excludes the immediate Site location and the majority of the Proposed Development.

4.5 Groundwater flows within the CLG 'Block' are indicated to be made largely in line with surface topography. At distance to the east of the Site, flows are indicated to be made towards the River Elwy and its tributaries (where some evidence of active karst features is present).

4.6 The Site itself falls within the Clwyd Catchment, and is thus isolated from the Elwy catchment by an intervening groundwater flow divide. In the vicinity of the Site, groundwater flows are indicated to be made principally eastwards, towards the Denbigh Fault at which point ground elevations fall away to the Vale of Clwyd.

4.7 Groundwater level data for the Site locality suggests average levels to fall eastwards at a gradient of 0.03, groundwater flows thus predominantly being made in this direction. Groundwater elevations are characterised by a high range in heads and rapid response to recharge events. Unsaturated thickness is typically high, ranging from 30m to 63m across the Proposed Development.

4.8 Though the interface of the CLG and KSS is demarked by a series of ditches and ponds, this is indicated to be due to the presence of Till cover as opposed to the emergence of groundwaters directly from the CLG (these features being located above indicated coincident groundwater elevations and exclusively upon KSS, the CLG interface with which is near vertical).

4.9 Groundwaters from within the Site are thus assumed to cross-flow to the KSS to the immediate east of the Site (at which point any conduits would terminate), though some deeper flow within the CLG may also occur beneath the Vale of Clwyd (ultimately flowing to the coast).

4.10 Groundwaters within the KSS are assumed to flow in line with regional trends, towards and in line with the River Clwyd, with which it may be in partial hydraulic connectivity via leakage through the overlying Till (this being of substantial thickness, commonly confining the KSS and leading to artesian heads in some places).

4.11 The widespread distribution and thickness of Till within the local area offers a moderate to high degree of hydraulic isolation between surface waters and groundwaters, including areas underlain by CLG (dependent upon Till thickness). This limits the likelihood of direct connections between groundwaters within the CLG and local minor surface watercourses (such as the Henllan Brook to the south of the Site). This is demonstrated by the fact that such watercourses typically rise on areas underlain by EF, and do not sink when flowing onto CLG outcrop regardless of elevation.

4.12 The flow regimes of these watercourses are assumed to be principally supported by surface runoff from areas of Till cover, and from their upper catchments (upon EF) where infiltration rates are minimal. The relative contribution of runoff from areas of CLG where Till cover is absent is considered to be minor (due to the high infiltration rates expected in such areas).

4.13 The CLG is considered vulnerable to groundwater contamination as it is unconfined and highly permeable, and features limited potential for natural attenuation (due to the presence of preferential, solution enlarged, flow pathways). The KSS is considered of limited vulnerability due to the thickness and prevalence of Till cover.

4.14 The CLG supports limited abstraction only, with the majority of such abstraction within the Study Area being made from the KSS and associated watercourses. The CLG is not indicated to be over-abstracted, having good quantitative status and water resource availability.

5 THE SITE

5.1 The Existing Site

5.1.1 Overview

5.1.1.1 The existing Site landholding (The Existing Site) covers an area of approximately 26.5ha, of which some 16.1ha has been subject to mineral extraction.

5.1.2 Site Layout and Areas

5.1.2.1 The Site is split into two distinct areas, the Quarry Area and the Plant Area, as at *figure 20*. These are joined by a northeast to south west aligned haul road cut between existing quarry faces.

5.1.2.2 The Plant Area, which occupies the southern extent of the Site, currently houses the Site office, welfare and weighbridge facilities.

5.1.2.3 The eastern limit of the Plant Area houses a third party operated concrete batching plant, a settlement and attenuation lagoon (The Plant Area Lagoon), and the Site road access (at its eastern extent).

5.1.2.4 The Plant Area ranges from 96.7maOD to 80maOD, falling eastwards towards the road access, and is cut into steep historic quarry faces at its northern and western limits (to maximum elevation 144.4maOD).

5.1.2.5 The Quarry Area occupies the majority of the Site, with floor elevations ranging from approximately 111.0maOD to some 105maOD, falling towards the central 0.08ha inundated sump within its deepest sinking (to basal elevation 88.1maOD).

5.1.2.6 The Quarry Area is demarked by steep faces on all sides, of maximum elevations 153maOD to the west and 125maOD to the east, with a distinct bench present on the western side (131maOD). A haul road allowing access to the upper benches is present on the southern boundary.

5.1.3 Current Site Operations

5.1.3.1 Current Site operations within the Plant Area are limited to administration and sales.

5.1.3.2 Within the Quarry Area, mineral extraction is focused upon the existing, permitted, reserve within the southwestern faces, which are being progressed westwards within the existing Site boundary.

5.1.3.3 A mobile crushing plant is operated in proximity to these faces, the aggregate produced by which is loaded onto wagons by mobile plant (loading shovel) prior to transportation from the Site via the Plant Area weighbridge.

5.1.3.4 Restoration works are also periodically undertaken, this recently focusing upon the deposition of clay contaminated materials within the quarry sump upon its eastern margin.

5.1.4 Site Water Management

Overview

5.1.4.1 A drainage plan for the Site under present conditions is presented at *figure 20*, with further detail for each Site area being provided below.

Plant Area

5.1.4.2 The administrative facilities within the Plant Area are serviced by mains water, with sewerage being provided by a regularly emptied, sealed, septic tank. A mains supplied wheel wash (with water recycling facility and requiring no discharge) is also operated at this location.

5.1.4.3 Drainage from across the Plant Area is conveyed diffusely overland eastwards in line with the prevailing topography, before being captured by a slot drain and being directed to the Plant Area Lagoon.

5.1.4.4 The Plant Area Lagoon is approximately 28m long by 8.5m wide, being split into 5 no. settlement cells (estimated 3.5m depth) by dividing steel partitions. The slot drain feeds into the north eastern end of the lagoon, with waters then cascading through the cells to the south western limit, where they are discharged via a rectangular weir.

5.1.4.5 Discharge from the Plant Area Lagoon has historically been made under Environmental Permit, Water Discharge Activity, ref: CG0333601 (*appendix 9.4*), the latest available version of which permitted the discharge of trade effluent to the Henllan Ditch at a volume not exceeding 260m^3/d, at a rate not exceeding 6l/s. This was further limited to a discharge quality with respect to suspended solids of 60mg/l and a pH of between 5 and 9 pH units. Records of correspondence with the Environment Agency (EA) in 1999 (also at *appendix 4*) detail an intended increase in the permitted discharge rate to some 117l/s. Works are presently in progress to update and renew this permit.

5.1.4.6 Discharge is made through a buried pipeline which passes eastwards beneath Graig Road to the south of the Site access, and is reported to have a maximum capacity of 130l/s (based on historic Site records).

5.1.4.7 Data regarding discharge rates from the Plant Area Lagoon, as recorded from the rectangular weir on its outlet, is available for the period 2009 to 2012 (*appendix 9.5*). The data shows daily discharge rates to range from 0m^3/d to 5,749m^3/d (average 81.4m^3/d). This suggests discharge rates within the revised consent limit proposed in 1999.

5.1.4.8 It is understood that the third party operated concrete batching plant within the south eastern limit of the Plant Area undertakes some abstraction from the Plant Area Lagoon for use in concrete production. NRW hold no records of a licensed abstraction at this location.

Quarry Area

General Water Management

5.1.4.9 The Quarry Area forms a closed depression within which all incident rainfall / runoff is captured and contained. Such waters drain diffusely overland to the quarry sump, where they are attenuated and allowed to dissipate to groundwater.

5.1.4.10 Periodic dust suppression is provided as and when required by a towed 6,000l bowser. This is filled from the quarry sump at a rate not exceeding 20m^3/d (thus being exempt from requirement for an abstraction licence).

Dewatering Water Management

5.1.4.11 Dewatering operations are not presently undertaken at the Site, though this has occurred historically. It is understood that dewatering abstraction was made from the sump via electro-submersible pump, this lifting abstracted waters to the Plant Area Lagoon (for onwards surface water discharge) over the intervening quarry faces.

5.1.4.12 Historic dewatering rates are available for the period July 1999 to September 1999 *(appendix 9.5)*, demonstrating abstraction rates of up to 1,070m^3/d (to average 670.5m^3/d), of durations up to 24hrs per day at instantaneous rates of up to 12.4l/s (to average rate 9l/s). The available data indicates that water levels within the sump were lowered by 3.5m during this period (antecedent conditions are not known).

5.1.4.13 Combining historic peak discharge rates from the Plant Lagoon (1,486m^3/d), these being understood to solely be derived from drainage of the Plant Area, with peak historic dewatering discharge rates (1,070m^3/d), suggests potential for a combined discharge rate of some 1,953m^3/d (equivalent to an instantaneous rate of some 29.6l/s). This suggests discharge rates within the revised consent limit proposed in 1999.

5.1.4.14 Piezometer readings across the wider Site coincident with the period for which pumping data is available (as at and *figure 9*) is of insufficient resolution to identify any induced drawdown. The available data does however suggest the pumping to have coincided with groundwater elevations exceeding average conditions by approximately 1m. Application of the predicted average groundwater head distribution (*figure 13*) suggests a groundwater elevation of 93.5maOD immediately up-gradient of the sump location under such conditions (dewatering thus inducing an estimated 5.4m of drawdown).

5.1.4.15 Rainfall data for the period is not available, however application of long term average rainfall data, as estimated at *table 4* (average monthly total of 71.3mm), over the predicted extent of the Quarry Area at this time (11.7ha), suggests potential for daily rainfall volumes of up to 270m^3/d (effective rainfall for this period potentially being zero, as at *table 6*).

5.1.4.16 The available data is insufficient to accurately predict the full effect of historic dewatering upon the Aquifer and application of conventional methodology in this regard is of limited value within karst environs. The available data does however allow comparison of predictive methodology against observed data.

5.1.4.17 Adopting the representative range in hydraulic conductivity for the CLG (*section 3.5.8*), together with the estimated depth of dewatering (drawdown) and the areal extent of dewatering (the quarries lowest sinking at its historic maximum extent of some 1.25ha), the methodology described by CIRIA113 (incorporating the Modified Todd equation) has been applied to provide indication of the likely influence of historic dewatering upon the Aquifer.

5.1.4.18 The CIRIA/Todd methodology is described together with details of calculations at *appendix 9.6*. The results of analysis are summarised below at *table 13*.

Table 13 Predicted Dewatering Influence, Historic Workings

Drawdown (m)	Hydraulic Conductivity (m/d)	Radius of Influence, R_0 (m)	Discharge Rate, Q (m^3/d)	Discharge Rate, Q (l/s)
5.4	0.1	17.4	38	0.4
	10	174.3	691	8.0

5.1.4.19 Assessment indicates a dewatering discharge rate of 8l/s under conditions approximating those during the period for which pumping data is available, this being in general agreement with the pumping data (average rate 9l/s, higher rates potentially attributable to rainfall). The maximum predicted Radius of Influence (R_0) of 190m is thus considered a reasonable approximation of that associated with dewatering operations within the Existing Site.

5.2 The Proposed Development

5.2.1 Overview

5.2.1.1 The Proposed Development aims to extend the Quarry Area by some 5ha, over which mineral will be extracted in 4 no. benches, to a basal elevation of 88maOD, allowing release of an additional 4mt of aggregate over a period of some 20 years.

5.2.1.2 Existing working methods, as discussed at *section 5.1*, will be continued during the working of the Proposed Development.

5.2.1.3 Although the Proposed Development will not exceed the maximum working depth observed within the Existing Site, the lowest sinking (presently inundated and forming the quarry sump) will be extended westwards, this being facilitated by dewatering, allowing a safe and efficient working environment to be maintained.

5.2.1.4 Existing Site operations within the Plant Area will be unchanged from those presently undertaken.

5.2.2 Phased Development Plan

5.2.2.1 The Proposed Development is to be worked in 4 no. phases, as shown at *figures 21*, 22, *23* and *24*, this being followed by a 5th phase comprising restoration works.

5.2.2.2 Works are to commence with the stripping of soils / overburdens, and their storage within perimeter screening bunds. Phase 1 will then commence, within which the existing upper bench will be extended westwards over an area of some 1.5ha, at a floor elevation of some 132maOD. Concurrent placement of infill comprising Site derived interburden and imported inert materials will occur upon the southern and eastern Site boundaries.

5.2.2.3 On completion of Phase 1, Phase 2 will see the further westwards extension of the upper quarry bench to combined area 2.05ha, with the extension being deepened in 2 further 15m lifts to floor elevation 110maOD. Restoration works during this phase will focus upon the northern limit of the Site through placement of infill.

5.2.2.4 Phase 3 will see the upper bench expanded to the full extent of the Proposed Development, expanding mineral extraction over a 3.6ha area, with the lower benches being progressed southwards. This is to be accompanied by completion of restoration within the northern Site limit and southwards progressing infill placement within this area.

5.2.2.5 Phase 4 will then see the existing benches expanded across the Proposed Development, together with the westwards progression of the quarry's deepest sinking, completing the extension area with a basal elevation of 90maOD, this being at slight gradient to the east. Infill placement will be progressed southwards and westwards.

5.2.2.6 Phase 5 will see the continued placement of infill across the lowest quarry bench.

5.2.3 Development Water Management

Overview

5.2.3.1 A drainage plan for the Proposed Development is presented at *figure 25*, with further detail being provided below.

General Water Management

5.2.3.2 The Proposed Development will make no alteration to water management practices within the Plant Area.

5.2.3.3 The extended Quarry Area will continue to form a closed depression within which all incident rainfall / runoff will be captured and contained, with all such waters being routed diffusely overland to the quarry sump. Dust suppression measures will remain as presently undertaken.

Dewatering Water Management

Requirement for Dewatering

5.2.3.4 Comparison of expected groundwater elevations, as at *figures 11* to *13*, and development plans (*figures 21* to *24*) has been undertaken to identify the likelihood of dewatering requirements, as at *table 14*. Groundwater elevations have been estimated for each bench as the Proposed Development is worked westwards into the hydraulic gradient.

5.2.3.5 Assessment indicates that under minimum groundwater elevations, the base of works in all phases will be above that of groundwater, including the quarry sump (basal elevation 88.1maOD). Dewatering is not expected to be required under such conditions (with incident rainfall / runoff dissipating to the Aquifer via the quarry sump).

5.2.3.6 Under maximum groundwater elevations, the 3rd bench is expected to extend beneath groundwater during the working of Phase 2, with an expected depth of dewatering of some 8m. Concurrent groundwater elevations across the wider quarry are expected to be below the quarry floor, and within the maximum freeboard of the sump (106maOD).

Intercepted groundwaters are thus expected to run diffusely over the quarry floor to the sump for dissipation to the Aquifer (intermittent dewatering discharge may be required, especially following rainfall events, due to the limited freeboard expected within the sump under such conditions).

5.2.3.7 Under maximum groundwater elevations, the 4th bench is expected to extend beneath groundwater over its full extent, this occurring during Phase 4. A depth of dewatering is expected at some 24m. Dewatering discharge will be required under such conditions.

5.2.3.8 Under average groundwater elevations, groundwater interception upon the 4th bench is expected during the working of Phase 4, with a depth of dewatering of approximately 6.5m. Concurrent groundwater elevations across the wider quarry are expected to remain below the quarry floor, and within the maximum freeboard of the Sump. Intercepted groundwaters are thus expected to run diffusely over the quarry floor to the sump for dissipation to the Aquifer. Intermittent dewatering discharge may still be required, especially following rainfall events.

5.2.3.9 Dewatering at the Site is thus only expected to be routinely necessary under peak groundwater elevations. Consultation of Site hydrometric monitoring data (*section 3.5.6*) confirms such conditions to prevail only in the winter months, above average conditions, through which a degree of dewatering may be necessary, extending from autumn to spring. Intermittent dewatering may however be necessary across the year in response to severe rainfall events.

Table 14 Likelihood of Dewatering Requirements

Bench	Basal Elevation (maOD)	Groundwater Elevation, Proposed Development (maOD)	Groundwater Elevation, Sump Location (maOD)	Maximum Expected Depth of Dewatering (m)
Minimum Groundwater Elevations				
1	132	87	83	0
2	120	87	83	0
3	106	87	83	0
4	90	87	83	0
Maximum Groundwater Elevations				
1	132	114	106	0
2	120	114	106	0
3	106	114	106	8
4	90	114	106	24
Average Groundwater Elevations				
1	132	96.5	91.5	0
2	120	96.5	91.5	0
3	106	96.5	91.5	0
4	90	96.5	91.5	6.5

Management of Dewatering

5.2.3.10 Though the Site is not presently dewatering, such operations have historically occurred and are presently permitted within the Existing Site. Where required during the working of the Proposed Development, this will be operated in line with historic practices, with waters being pumped to the existing Site discharge point for onwards conveyance to the Henllan Ditch.

5.2.3.11 In order to fully dewater the lowest bench of the quarry, the existing sump, which extends beneath the proposed 90maOD base of works by some 1.9m, will be retained. Dewatering abstraction will be made from this feature (within which treatment via settlement will be provided, and episodic rainfall events will be attenuated).

Estimation of Dewatering Rates / Influence

5.2.3.12 As discussed, application of predictive techniques for quantifying dewatering impact in karst environs is of limited value, as the assumptions associated with the methodology are rarely met. Comparison of predicted / observed data for historic dewatering operations did however indicate the applied methodology to represent a reasonable approximation of historic dewatering activities.

5.2.3.13 Approximation of the potential influence of dewatering within the Proposed Development has thus been undertaken adopting the same methodology applied at *section 5.1.4*. This has been applied to the maximum expected drawdown at the maximum extent of the Proposed Development (western limit of extraction at end of Phase 4) to provide basis for conservative assessment. The results of this assessment are presented at *table 15*.

Table 15 Predicted Dewatering Influence, Proposed Development

Drawdown (m)	Hydraulic Conductivity (m/d)	Radius of Influence, R_0 (m)	Discharge Rate, Q (m^3/d)	Discharge Rate, Q (l/s)
24	0.1	77.5	387	4.5
	10	774.6	9,329	108

5.2.3.14 Assessment suggests a maximum R_0 of some 775m, with associated rates of groundwater ingress of 108l/s. This represents an increase in R_0 of some 601m, and an increase in ingress rates of some 100l/s, relative to historic dewatering operations.

5.2.3.15 Combining historic peak discharge rates from the Plant Lagoon (1,486m^3/d), these being understood to solely be derived from drainage of the Plant Area, with predicted maximum dewatering rates (9,329m^3/d), and average effective rainfall rates over the extended Quarry Area (129.3m^3/d with variation thereof attenuated within the quarry) suggests potential for a combined maximum discharge rate of some 10,944m^3/d (equivalent to an instantaneous rate of some 127l/s).

5.2.3.16 The degree of anticipated groundwater drawdown resulting from dewatering will decrease rapidly with increasing distance from the working faces of the Site, with the magnitude of impact thus being limited towards the fringes of the estimated R_0. Estimates of the magnitude of anticipated drawdown in relation to distance from the dewatered area are also shown at *appendix 9.6* and summarised at *table 16* below.

Table 16 Estimated Magnitude of Groundwater Drawdown Under Worst Case Conditions.

Distance from Face (m)	Magnitude of Groundwater Drawdown (m)	Magnitude of Groundwater Drawdown (%)	Distance from Face (m)	Magnitude of Groundwater Drawdown (m)	Magnitude of Groundwater Drawdown (%)
5	22.88	95.31	300	5.76	24.02
25	20.02	83.40	400	4.41	18.38
50	15.83	65.95	500	2.95	12.31
100	12.08	50.34	650	1.32	5.49
200	8.00	33.34	775	0.15	0.61

5.2.3.17 Due to the steepness of the prevailing hydraulic gradient, groundwater drawdown upon the eastern flank of the Site will be reduced relative to that predicted above. Examination of predicted maximum groundwater elevations (*figure 12*) and the proposed base of workings (90maOD) shows groundwater elevations to fall below the base of workings within 250m to the east of the existing sump. Propagation of dewatering drawdown beyond this point is thus not anticipated.

5.2.3.18 Further, such influence will be temporary, will be of intermittent duration, and will not depress groundwater elevations below indicated baseline minimum elevations (as natural groundwater elevations are indicated to fall below the proposed base of workings across the full extent of the Site during dry conditions).

5.2.3.19 In summary, based on the available information, and subject to the limitations of the employed methodology within the Site setting, the potential dewatering influence during the working of the Proposed Development is estimated as follows:

- No expected requirement for dewatering during the working of Phases 1 and 2.
- Potential requirement for dewatering of limited magnitude during working of Phase 3 where groundwater elevations exceed expected averages (assumed up to 50% of the time in the winter months).
- Regular requirement for dewatering of Phase 4 excluding periods where groundwater elevations fall to historic minima (assumed required spring to autumn, with intermittent year round dewatering operation in response to severe rainfall).
- Abstraction of a conservatively estimated volume of up to 9,239m^3/d of groundwaters from the CLG, with an associated estimated R_0 of up to 775m (at maximum extent of works under maximum groundwater elevations).
- No propagation of R_0 beyond point at which maximum groundwater elevations fall below the base of workings (estimated 250m to east / south east / north east of the existing sump).

5.2.4 Restoration Proposals

5.2.4.1 The restoration concept for the Site is as presented at *figure 26.*

5.2.4.2 The Plant Area is to be restored to calcareous grassland via the removal of existing infrastructure and spreading of soils and subsequent planting.

5.2.4.3 The quarry benches will be allowed to naturally regenerate, becoming populated by trees and shrubs.

5.2.4.4 The Quarry Area is to be back filled with imported inert materials, forming a closed depression sloping south-westwards with a basal elevation of some 101maOD. This landform will also be restored to calcareous grassland via the spreading of soils and subsequent planting, excepting the lowest area which will form marshy grassland with a small waterbody.

5.2.5 Restoration Water Management

Overview

5.2.5.1 A drainage plan for the restored Site is presented at *figure 27*, with further detail being provided below.

Plant Area

5.2.5.2 The restored Plant Area will gently slope to the east in line with existing topography, promoting drainage in this direction.

5.2.5.3 The proposed removal of Site infrastructure from the Plant Area (including some areas of hard standing) and re-placement of soils and vegetation, is anticipated to reduce runoff rates relative to existing conditions.

5.2.5.4 Runoff rates and runoff quality are thus expected to approximate greenfield (pre-development) conditions (negating requirement to provide attenuation / treatment via settlement within this area), though may in fact be lower due to the reduced relief of this area resulting from mineral extraction.

5.2.5.5 The Plant Area is however orientated to drain towards a public road, with the Site having been in place for a significant period of time (pre-development drainage routing thus not being plausible to reinstate).

5.2.5.6 The existing Plant Area Lagoon is thus to be replaced with an equivalent feature of more sympathetic design (the current such feature forming a shear sided concrete lined lagoon).

5.2.5.7 This feature (the Restoration Lagoon) will discharge to the existing buried pipeline serving the Plant Area Lagoon (for onwards conveyance to the Henllan Ditch), and will be provided with feeding French drains to replicate the function of the slot drains intercepting runoff and diverting it to the Plant Area Lagoon under current conditions.

5.2.5.8 Expected Greenfield Runoff Rates (GRR) for the catchment of the Restoration Lagoon have been estimated using the HR Wallingford UK SuDS Greenfield Runoff Rate Estimation Web Tool, which represents lead technical guidance in this regard, as at *appendix 9.7*.

5.2.5.9 Assessment indicates a 1 in 100 year GRR for the restored Plant Area of some 81.6l/s. This rate is within the maximum conveyance capacity of the discharge pipeline (estimated 130l/s), precluding any significant risk of flooding resulting from the Plant Area Lagoon.

5.2.5.10 It is however proposed that the Restoration Lagoon should retain at minimum an equivalent storage volume to that provided by the Plant Area Lagoon (which is proven in operation at the Site location without resulting in any reports of associated on or off Site flooding). This is estimated at some 833m^3.

Quarry Area

5.2.5.11 The restored Quarry Area will form a closed depression within which all incident rainfall / runoff will be captured and contained, this being routed diffusely overland to the lowest point (western extent of quarry), forming marshy grassland / a small waterbody (The Restoration Lake).

5.2.5.12 Restored levels at the location of the Restoration Lake are at approximately 101maOD, with adjacent groundwater elevations ranging both above and below this level (to average approximately 96.5maOD).

5.2.5.13 During periods when groundwater elevations fall below this level, the Restoration Lake will become perched upon the infill material, and will be sustained by surface runoff incident upon the Quarry Area only, thus ranging from marshy grassland during dry periods to a small waterbody following rainfall events.

5.2.5.14 During such rainfall events, incident rainfall / runoff will be attenuated within the Restoration Lake, the area of which will expand to beyond the margins of the distribution of the infill material (as at *figure 27*), allowing the infiltration of attenuated waters to the Aquifer.

5.2.5.15 In order to estimate the extent of the Restoration Lake under such conditions, point catchment descriptors for the Site location have been sourced from the Centre for Ecology & Hydrology (CEH) Flood Estimation Handbook (FEH) web service.

5.2.5.16 The resultant data has been applied to the CEH / Wallingford Hydro Solutions (WHS) Revitalized Flood Hydrograph Model (ReFH2), from which as rural Greenfield Runoff Rates (GRRs) and greenfield 6 Hour Cumulative runoff Volumes (6HCVs) for the 15.3ha catchment of the Quarry Area were derived in line with the relevant technical guidance[11].

5.2.5.17 The introduction of inert infill material following restoration has been simulated via application of the urbanisation model within ReFH2, using runoff coefficients derived from the NCB Procedure[12].

5.2.5.18 The NCB procedure (derived from the Rational Method) allows estimation of runoff coefficients from catchment slope, vegetative cover and soil type. The reduction in permeability resulting from the introduction of inert infill has been reflected via adjustment of soil type to ‘Clay’, resulting in a runoff coefficient of 0.78, as applied to the extent of the infill within the Quarry Area catchment (8.2ha).

5.2.5.19 The results of the assessment, as at *appendix 9.7*, suggest runoff volumes for a 1 in 100 year, 6hr duration storm, of some 4,514m^3.

---

[11] Wallingford Hydro Solutions, *The Revitalised Flood Hydrograph Model ReFH2.2: Technical Guidance*, 2016

[12] National Coal Board, *‘Technical Management of Water in the Coal Mining Industry’*, 1982

5.2.5.20 The available attenuation volumes within the restored Quarry Area are as estimated at *table 17* below.

Table 17 Available Attenuation Volumes, Restored Quarry Area			
Elevation (maOD)	Area (m^2)	Attenuation Volume (m^3)	Area Underlain by Aquifer Material (m^2)
102	12,448	6,224	3,240
104	32,302	38,526	6,041
106	44,224	82,750	9,123
108	57,128	139,878	19,233

5.2.5.21 Assessment indicates the available storage volumes to significantly exceed expected runoff volumes, with a 1 in 100 year 6 hr storm event being estimated to result in a water feature of some 103maOD in elevation, to approximate area 22,375m^2. This feature would be in contact with some 4,641m^2 of underlying unsaturated Aquifer material through which gradual dissipation of attenuated waters would be able to occur upon abatement of storm conditions.

5.2.5.22 Continuity between the Restoration Lake and its interface with the Aquifer at times when its level is below the limit of the distribution of the infill is to be provided by an open ditch, this being excavated along the interface of the infill / in situ Aquifer material, as at *figure 27* (Ditch 1).

5.2.5.23 During periods of elevated groundwater elevations, as groundwater elevations exceed the elevation of the infill, the Restoration Lake will gain hydraulic continuity with groundwaters within the Aquifer upon its margins.

5.2.5.24 The extent of the Restoration Lake is not indicated to exceed 106maOD (area of approximately 44,224m^2 of which 9,123m^2 would be abutting in-situ Aquifer material), as peak estimated groundwater elevations on the down-gradient (eastern) side of the infill fall below the quarry floor (where comprising in-situ Aquifer material) at this elevation (waters above this level will infiltrate to ground).

5.2.5.25 In the event of a severe storm coinciding with such conditions, the previously estimated attenuation volume required for a 1 in 100 year, 6hr duration, storm event (4,514m^3) would raise the elevation of the Restoration Lake by just 0.1m, thus remaining within the available freeboard, prior to the dissipation of attenuated waters to the Aquifer upon the lake margins.

6 IMPACT ASSESSMENT & MITIGATION MEASURES

6.1 Background

6.1.1 Assessment has facilitated the conceptualisation of the extant groundwater and surface water regimes operating within and around the Site.

6.1.2 This understanding has been utilised to inform assessment of the potential impacts that may be posed by the Proposed Development upon the water environment.

6.1.3 Where significant potential for adverse impact is identified, recommendations for specific mitigation measures are proposed.

6.1.4 Both specific mitigation measures and those incorporated into the design of the Proposed Development are described.

6.2 Generic Potential Impacts

6.2.1 Direct Impacts

6.2.1.1 As is typical of the majority of operations of this type and scale, the Proposed Development has the potential to impact upon the water environment in the following direct ways:

- Potential for impact upon groundwater levels and flows;
- Potential for impact upon surface water levels and flows;
- Potential for derogation of groundwater quality;
- Potential for derogation of surface water quality, and;
- Potential for the exacerbation of extant flood risk.

6.2.2 Indirect Impacts

6.2.2.1 The direct impacts outlined above may lead, in-turn, to indirect impacts upon:

- Potential for indirect derogation of surface water flow rates and / or waterbodies;
- Potential for indirect impact upon the volume of groundwater and / or surface water available to existing abstractions;
- Potential for indirect impact upon the quality of groundwater and / or surface water available to existing abstractions;
- Potential impact upon floral and / or faunal habitats as a result of flow / quality derogation within surface water-courses / wetland areas.

6.3 Preliminary Risk Screening

6.3.1 A preliminary screening of the potential impacts of the Proposed Development upon the water environment has been undertaken to identify where such impacts are potentially significant.

6.3.2 Where potential for significant impact is identified, further assessment has been undertaken at *section 6.4* with mitigation measures / planning controls being formulated as required (summarised at *section 6.5*).

The results of preliminary risk screening are presented at *table 18* below.

Table 18Preliminary Risk Screening

Activity	Impact Class	Potential Primary Impact	Note	Potential Secondary Impacts	Requirement for Further Assessment
Alteration of surface cover / topography.	Groundwater levels and flows	Alteration of Aquifer Recharge	Majority of Proposed Development on CLG outcrop with minimal GT cover. Majority of incident rainfall expected to form Aquifer recharge. No significant impact anticipated.	No significant primary impact.	No.
	Surface water levels and flows	Alteration of runoff routes / rates.	Runoff routeing to be altered within Proposed Development, from catchment of Hennlan Brook to within closed depression formed by quarry void.	Potential derogation of water availability to abstractors / ecology.	Yes
	Groundwater quality	Alteration of groundwater vulnerability	Proposed Development on unconfined CLG outcrop with minimal GT cover. Negligible impact upon groundwater vulnerability thus anticipated.	No significant primary impact.	No.
	Flood Risk	Alteration of runoff routes / rates	Runoff routeing to be altered within Proposed Development, from catchment of Hennlan Brook to within closed depression formed by quarry void. No expected increases in surface water flow rates.	No significant primary impact.	No.
Removal of Aquifer Material from Unsaturated Zone	Groundwater levels and flows	Interception of perched groundwaters.	Epikarst prevalent at Site providing preferential infiltration pathways and storage of waters in unsaturated zone.	Potential derogation of water availability to abstractors / ecology.	Yes.
	Surface water levels and flows	Interception of perched groundwaters.	Epikarst has potential to support surface water features, though no such features have been identified by baseline assessment which are in hydraulic continuity with / in meaningful proximity to, the Site.	Potential derogation of water availability to abstractors / ecology.	No
	Groundwater quality	Alteration of groundwater vulnerability.	Existing Site operations will not be significantly changed. Recharge rapid and concentrated within primary / secondary porosity components. Minimal natural attenuation offered by unsaturated zone.	No significant primary impact.	No.
Removal of Aquifer Material from Saturated Zone	Groundwater levels and flows	Conduit interception.	Presence of active karst conduits within Aquifer saturated zone likely.	Potential derogation of water availability to abstractors / ecology.	Yes.
	Surface water levels and flows		Active karst conduits may support surface water features.	Potential derogation of water availability to abstractors / ecology.	Yes.
	Flood Risk	Conduit interception.	Interception of active karst conduits may increase groundwater ingress to the works.	None.	Yes.
		Increase in groundwater flood risk posed to the Site.	Works will be maintained dry by dewatering abstraction.	None.	No.
Operation of Dewatering Abstraction	Groundwater levels and flows	Alteration of groundwater levels and flows.	Dewatering abstraction will lower groundwater levels in proximity to the Site and induce groundwater flows towards the works.	Potential derogation of water availability to abstractors / ecology. Potential impact on land stability.	Yes.

	Surface water levels and flows		Surface watercourses in proximity to the Site which may depend upon a degree of groundwater baseflow.	Potential derogation of water availability to abstractors / ecology.	Yes.
	Groundwater quality	Interception of pre-existing sources of groundwater contamination.	Historic landfill in potential hydraulic continuity with the Site.	Potential derogation of water quality available to abstractors / ecology.	Yes.
		Accidental spillage / long term leakage of potentially contaminating substances.	Though the Proposed Development will not alter this risk relative to existing Site operations, consideration of mitigating procedures is considered prudent.	Potential derogation of water quality available to abstractors / ecology.	Yes.
	Surface water quality	Derogation of groundwater quality.	Identified risks to groundwater quality may also impact upon surface water quality where such features are in groundwater continuity.	Potential derogation of water quality available to abstractors / ecology.	Yes.
		Discharge of dewatering waters to surface waters.	Dewatering waters will be discharged from the Site with potential to impact upon water quality within the receiving watercourse.	Potential derogation of water quality available to abstractors / ecology.	Yes.
	Flood Risk	Increase in surface water flow rates	Dewatering waters will be discharged from the Site with potential to impact upon flood risk.	None.	Yes.
Restoration	Groundwater levels and flows	Alteration of groundwater levels / flows.	Inert infill will be of lower permeability than Aquifer material it will replace.	Potential derogation of water availability to abstractors / ecology.	Yes
		Increase in surface water area.	Potential increase in evaporative losses.	Potential derogation of water availability to abstractors / ecology.	Yes
		Alteration of surface cover.	Infill materials will impede Aquifer recharge. Quarry area to be drained to groundwater. Recharge volumes thus unchanged.	None.	No
	Surface water levels and flows	Alteration of groundwater levels / flows.	Surface watercourses in proximity to the Site which may depend upon a degree of groundwater baseflow.	Potential derogation of water availability to abstractors / ecology.	Yes
		Drainage of Plant Area to surface waters.	Discharge rates will approximate greenfield conditions. Attenuation provision retained within Restoration Lagoon.	None.	No.
	Groundwater quality	Use of inert infill in Site restoration.	Imported inert infill may potentially impact upon groundwater quality.	Potential derogation of water quality available to abstractors / ecology.	Yes.
	Surface water quality	Derogation of groundwater quality.	Identified risks to groundwater quality may also impact upon surface water quality where such features are in groundwater continuity.	Potential derogation of water quality available to abstractors / ecology.	Yes.
		Drainage of Plant Area to surface waters.	Vegetated ground cover to be re-instated and settlement provision retained within Restoration Lagoon.	None.	No.
	Flood Risk	Drainage of Plant Area to surface waters.	Discharge rates will approximate greenfield conditions. Attenuation provision retained within Restoration Lagoon.	None	No.
		Use of inert infill in Site restoration.	Restoration infill will be of lower permeability than Aquifer material it will replace.	None	Yes.

6.4 Further Assessment of Potential Impacts

6.4.1 Groundwater Levels and Flows

Background

6.4.1.1 The Proposed Development as described herein is considered to have the potential to impact upon groundwater levels and flows in the following ways:

- Potential for interception of perched groundwaters;
- Potential for interception of active karst conduits;
- Potential for the alteration of groundwater levels and flows via dewatering abstraction;
- Potential for alteration of groundwater levels and flows via Site restoration, and;
- Increase in surface water area following restoration.

Potential for Interception of Perched Groundwaters

6.4.1.2 Baseline assessment has identified the presence of epikarst features within the Aquifer unsaturated zone at the Site location, with the available groundwater level data indicating potential for perched groundwaters to be sustained by such features and / or local variations in vertical Aquifer permeability.

6.4.1.3 The removal of the Aquifer unsaturated zone within the Proposed Development has the potential to intercept such perched groundwaters, with associated potential to impact upon groundwater levels and flow rates.

6.4.1.4 The presence, elevations, volume and extent of such perched groundwaters is indicated to be highly variable at the local scale, with all such waters ultimately draining to the Aquifer saturated zone via preferential infiltration pathways. The ultimate destination of such waters will thus be unchanged.

6.4.1.5 The removal of Aquifer unsaturated zone will however increase the rate of Aquifer recharge within the Proposed Development area, as the associated Aquifer storage, which serves to retard infiltration rates, will be lost.

6.4.1.6 The associated loss of storage has been estimated in line with prevailing guidance[13], at *table 19*, assuming a 1% specific yield for the Aquifer of which 50% is attributable to vadose storage, and that the full volume of material to be removed from the Proposed Development is unsaturated (based on minimum groundwater elevations).

6.4.1.7 The existing sump has an area of approximately 1ha, within which an available freeboard of just 0.6m is required to provide an equivalent volume of storage to that predicted to be lost from the unsaturated zone as at *table 19*. Further, this sump has historically demonstrated that it provides the storage of waters within the unsaturated zone during dry conditions.

6.4.1.8 It is thus considered that the quarry sump is suitable for compensating any Aquifer storage loss resulting from the removal of unsaturated zone within the Proposed

[13] Environment Agency, 'Hydrogeological Impact Appraisal for Dewatering Abstractions', Science Report SC040020/SR`, 2007

Development, which is therefore unlikely to result in any significant impact upon groundwater levels and flows.

6.4.1.9 It should be noted that the storage provided upon restoration, as at *section 5.2.5*, will also exceed that lost as at *table 19*.

Table 19 Estimation of Unsaturated Zone Storage Loss

Bench (Descending)	Bench Height (m)	Bench Area (m)	Bench Volume (m^3)	Storage Provided (m^3)
1	8	33,712	269,696	1,348.5
2	12	31,640	379,680	1,898.4
3	14	23,596	330,344	1,651.7
4	16	15,533	248,528	1,242.6
			Total:	6,141.2

Potential for Associated Secondary Impacts

6.4.1.10 The interception of perched groundwaters during the working of the Proposed Development has the potential to result in associated secondary impacts upon ecology / abstractors where such features are dependent upon groundwaters sourced from the unsaturated zone.

6.4.1.11 As discussed, the presence of such groundwaters is expected to be highly variable at the local scale with all such waters ultimately draining to the Aquifer saturated zone (significant primary impacts upon which are not anticipated in this regard).

6.4.1.12 Further, baseline assessment has not identified any features indicated to be directly or indirectly supported by perched groundwaters in the vicinity of the Site, that support ecological interest, abstraction or otherwise.

6.4.1.13 Significant secondary impacts associated with the removal of unsaturated zone at the Site are thus not anticipated as a result of the Proposed Development.

Potential for Interception of Active Karst Conduits

6.4.1.14 The removal of Aquifer material from the saturated zone during the working of the Proposed Development has the potential to intercept active karst conduits, with associated potential to impact upon groundwater levels / flows.

6.4.1.15 There are no known active karst features in hydraulic continuity with the Site excepting the qualitative reports of karstic drainage of the quarry sump to the east coincident with exceptionally high water elevations within the sump.

6.4.1.16 This connection, if present, is intermittent and rarely active, and will not be disturbed outside of periods of active dewatering (which will be temporary only). Impacts upon this connection are thus not anticipated to be significant, as the associated flow regime is already rare and therefore not vulnerable to derogation. Further, any such impacts will not exceed those associated with existing, consented Site operations (with the exception of prolonging any derogation induced by dewatering).

6.4.1.17 Potential however remains for the interception of active karst conduits that are not yet identified. Such conduits are likely to generally follow the regional groundwater flow direction (easterly), towards the interface of the CLG and KSS, at which point any cross flow will become diffuse (as tertiary permeability does not typically develop within sandstone aquifers). Significant associated impacts upon the KSS are thus not anticipated.

6.4.1.18 The interception of such conduits does however have the potential to both increase the influence of the Site upon groundwater levels and flows outside of that which may be expected in association with dewatering activities, and to increase required dewatering volumes.

6.4.1.19 As baseline groundwater elevations across the Site are shown to fall below the proposed base of workings during dry periods, it is unlikely that any conduits that may be intercepted are permanently saturated (likely activating only when groundwater elevations are sufficiently elevated). This may limit the magnitude of any associated impact.

6.4.1.20 The likelihood and magnitude of any such impact cannot however be definitively quantified. It is thus considered prudent that hydrometric monitoring be continued / supplemented at the Site, so that any interception of active karst features can be identified and quantified, with associated mitigation measures being formulated and implemented as required.

Potential for Associated Secondary Impacts

6.4.1.21 Any primary impact upon groundwater levels and flows associated with the interception of active karst conduits during the working of the Proposed Development has the potential to result in secondary impacts upon groundwater dependent abstractors and / or ecology.

6.4.1.22 As discussed, the possible karstic connection between the quarry sump and woodland to the east (the non-statutorily designated dry woodland of Coed Parc-Pierce local wildlife site) is rarely active, and thus unlikely to support any water dependent ecology. There are no known surface water features within this woodland to support downstream abstraction.

6.4.1.23 Baseline assessment has not identified any groundwater dependent sites of ecological importance (designated or otherwise) indicated to be in hydraulic continuity with the Site. Secondary impacts upon such features associated with the interception of active karst conduits are thus not anticipated.

6.4.1.24 Baseline assessment has not identified any licenced groundwater abstractions in hydraulic continuity with the Site. Significant impacts upon such features are thus not anticipated in this regard.

6.4.1.25 Baseline assessment has identified 1 no. deregulated abstraction (Abstraction L, *figure 17*) that is potentially in hydraulic continuity with the Site and is in meaningful proximity to it. The degree to which this abstraction's supply is dependent upon conduit flows is not known, though the potential for derogation of this abstraction via conduit interception cannot be excluded.

6.4.1.26 It should however be noted that the vulnerability of this abstraction to such impact is expected to be low, as any connecting conduits that may be intercepted are unlikely to be permanently saturated (minimum groundwater elevations at the abstraction would not be impacted).

6.4.1.27 It is however considered prudent that the proposed hydrometric monitoring be extended both to include and where necessary, mitigate, any impact upon this abstraction (subject to consent of its operator).

6.4.1.28 This should include discussions between the operator of the abstraction to agree access to it for assessment / monitoring / provisional contingency mitigation formulation.

Potential for the Alteration of Groundwater Levels and Flows via Dewatering Abstraction

6.4.1.29 The dewatering of the Proposed Development will create a cone of depression around the Site within which groundwater levels will be lowered, with groundwater flows being induced towards the sump.

6.4.1.30 As discussed at *section 5.2.3*, dewatering operations, under worst case conditions, are estimated to result in the removal of 9,329m^3/d from the Aquifer, with an associated R_0 of up to 775m, which will not propagate beyond the point at which groundwater elevations fall below the base of workings of 90maOD, as occurs at maximum 250m to the east, north east and south east of the Site. Groundwater flows within this R_0 will be altered to be made towards the quarry sump, with associated groundwater levels being reduced by up to 24m (this reducing with increasing distance from the dewatered faces).

6.4.1.31 Dewatering of this magnitude will not be required at all times due to the high range in heads observed across the Site, which are known to fall beneath the proposed base of workings across the full Site area during dry periods. Dewatering impact will therefore not lower groundwater elevations below their minimum baseline elevations, or increase unsaturated thicknesses (which are naturally high at 30m to 40m across the proposed Development) beyond that naturally occurring (though the full natural range in groundwater elevations will be suppressed during dewatering).

6.4.1.32 Even under maximum conditions, groundwater elevations fall below the base of workings to the east of the Denbigh Fault, at which point groundwaters are expected to cross flow to the adjacent KSS aquifer. Ground elevations upon the fault (of some 80maOD) are also below the base of workings. Dewatering impact is thus not expected to be observed outside of the distribution of the CLG.

6.4.1.33 The removal of up to 9,329m^3/d (108l/s) of groundwaters from the Aquifer will however reduce groundwater cross flow volumes to the KSS by up to the same amount (up to 100l/s greater than associated with the Existing Site). This volume is considered minor relative to the wider distribution of the KSS, which, along with the CLG, is of good quantitative status with respect to the Water Framework Directive (WFD). Further, the discharge of dewatering waters (abstraction of which will be non-consumptive), will be made to the catchment of the River Clwyd, which is understood to be in partial hydraulic connectivity with the KSS (there will be no change in the volumes of water contributed to the Clwyd catchment, though the Proposed Development will transfer some groundwater cross flow to surface water flow).

6.4.1.34 As discussed, there is some uncertainty in the expected magnitude of dewatering impact as inherent to karst environments. The proposed continuation of hydrometric monitoring at the Site should therefore be continued and be regularly reviewed to allow identification of any impact in excess of that predicted herein.

6.4.1.35 It should be noted that no dewatering can be undertaken at the Site until such time as a water abstraction (transfer) license is in place. Historic pumping at the Site precedes the deadline for transitional applications (following revocation of dewatering exemption), the application window for which has now closed. A 'day job' (non-transitional) application to NRW for such a license is thus required to be made. The potential impacts of the proposed dewatering abstraction will be further assessed at this stage (to a greater degree than is applied to transitional applications), with potential for the license to be conditioned further to planning requirements (offering additional prevention of significant impact occurrence).

6.4.1.36 As discussed at *section 3.6*, the groundwater resource availability for the Site is indicated to be 'more water available', and Site dewatering will be non-consumptive. Further, the Aquifer is of good quantitative status. Though the adjacent KSS aquifer has a poorer resource availability, significant impacts upon this aquifer are not anticipated. It is thus considered that Site abstraction requirements should be licensable, subject to assessment of local impact (as considered herein), and without need for imposition of any Hands Of Flow (HOF) conditions.

Potential for Associated Secondary Impacts

6.4.1.37 There are no groundwater dependent ecological sites within the expected maximum R_0 of dewatering. Ecological sites that do fall within the radius, such as Crest Mawr Wood SSSI, Craig Quarry SSSI and Coed Parc-Pierce Local Wildlife Site not considered groundwater dependent and are underlain by significant unsaturated thicknesses. Significant associated impacts on these features are not anticipated.

6.4.1.38 There are no licenced or documented deregulated groundwater abstractions within the predicted R_0 of quarry dewatering that are considered vulnerable to dewatering induced impact.

6.4.1.39 There is 1 no. licensed abstraction at the limit of the maximum predicted R_0 of Site dewatering, though this is in the form of a surface water impoundment underlain by Till, and is thus hydraulically isolated from the Site. Impacts on this feature are not anticipated.

6.4.1.40 Although Abstraction L, *table 10*, is within the maximum predicted R_0, it is located to the north east of the Site, where propagation of dewatering influence is limited to some 250m by prevailing maximum groundwater elevations falling below the proposed base of workings of 90maOD. This abstraction is located some 400m from the quarry sump, and is not considered at significant risk of impact in this regard. As discussed, monitoring of this abstraction is however recommended due to its proximity to the Site (subject to agreement of its operator).

6.4.1.41 The third party operated concrete plant abstraction, as made from the Plant Area Lagoon, is made from a lined, perched waterbody sustained by surface runoff from the Plant Area (which will be unaffected by the Proposed Development). The status of this abstraction with regards to licensing requirements may however be altered by the Proposed Development, as the Plant Lagoon is 'on-line' with the proposed routeing of dewatering discharge. An abstraction license application (full) may thus be required for this operation.

6.4.1.42 Further potential for associated secondary impacts exists in relation to ground subsidence, due to the risk of collapse of saturated void space within the Aquifer once drained. As discussed, the dewatering of the Site will not lower groundwater elevations below historic minima, and no permanently saturated void spaces are anticipated to be drained. Significant impacts are thus not anticipated in this regard.

Potential for the Alteration of Groundwater Levels and Flows via Site Restoration

6.4.1.43 The restoration of the Site will involve the sub-watertable placement of infill materials comprising on-Site clay contaminated interburdens and imported inert infill materials. This infill is anticipated to be of lower permeability that the Aquifer material it will replace, and may therefore form a barrier to groundwater movement, with associated potential to impact upon groundwater levels and flows.

6.4.1.44 The reduced aquifer flow field created by the proposed infilling implies that hydraulic gradients will increase in order to accommodate the rate of groundwater flow (which will remain materially unchanged by the Proposed Development).

6.4.1.45 Increase of the hydraulic gradient dictates that groundwater levels will be raised upon the up-gradient (western) side of the restored Site, with a corresponding shadow of reduced groundwater levels on the down gradient (eastern) side. Any such impact is likely to be highly localised though would be permanent.

6.4.1.46 The Aquifer is readily permeable and the infill will not extend to the full thickness of the Aquifer (basal elevation 92maOD on up-gradient side), allowing groundwater flow beneath it to occur, thus minimising the obstruction presented. This implies that only a minor increase in head gradient would be required to induce the required flow rates within the reduced aquifer flow field (this within an Aquifer featuring high unsaturated thickness).

6.4.1.47 Minimum groundwater elevations are estimated at 87.3maOD on the western Side of the infill, and at 77.3maOD on the eastern side, relative to corresponding basal infill elevations of 92maOD and 88maOD respectively.

6.4.1.48 Under such conditions, the infill material will present only a minor obstruction at the top of the Aquifer saturated zone, with heads falling beneath the base of infill within its distribution. Any associated impacts on groundwater levels / flows are thus anticipated to be highly localised on of minor magnitude.

6.4.1.49 Maximum groundwater elevations are estimated at 114maOD on the western Side of the Site, and at 103maOD on the eastern side, relative to corresponding basal infill elevations of 92maOD and 88maOD respectively.

6.4.1.50 Under such conditions, up gradient heads will exceed the corresponding upper infill elevation (101maOD), forming a waterbody draining back to groundwater on the margins of the infill (as at *section 5.2.5*). Any impact upon groundwater levels / flows under such conditions induced by the infill will be largely mitigated by the levelling effect of this waterbody (which would serve to lower groundwater elevation on the up-gradient, western, side of the infill and raise groundwater elevations on the down gradient, eastern side). It should be noted that this effect, and any associated impact, would be of significantly smaller magnitude than that induced by dewatering during quarry operations as already assessed.

6.4.1.51 Average groundwater elevations are estimated at 97maOD on the western Side of the Site, and at 89maOD on the eastern side, relative to corresponding basal infill elevations of 92maOD and 88maOD respectively.

6.4.1.52 Under such conditions the infill material will present a minor obstruction at the top of the Aquifer saturated zone, though to the full thickness of the infill material on the up-gradient side (10m) and across its full distribution. Any impacts associated with this effect would thus be of greatest magnitude under groundwater elevations approximating average conditions.

6.4.1.53 It should however be noted that natural background variations in groundwater elevations are estimated to exceed average levels by some 9m on the up-gradient side of the infill, and to subceed them by some 8m on the down-gradient side. Any associated impacts on groundwater levels and flows are thus highly unlikely to alter groundwater elevations beyond pre-development conditions.

6.4.1.54 Although significant potential for impact in this regard is not anticipated, it is considered that the proposed continuation of hydrometric monitoring at the Site will allow identification of any impact in excess of that estimated above, with mitigation measures being formulated and implemented if identified to be required.

Potential for Associated Secondary Impacts

6.4.1.55 As primary impacts upon groundwater levels and flows of significant magnitude associated with the placement of infill materials during Site restoration are not anticipated, significant secondary impacts in this regard are not expected.

Increase in Surface Water Area Following Restoration

6.4.1.56 The establishment of the Restoration Lake will increase the area of open water within the Site from approximately 1 ha to an estimated maximum of 4.42ha under expected maximum groundwater elevations, with which additional evaporative losses may be associated. This has the potential to result in the loss of waters from the Aquifer with associated potential to result in impact upon groundwater levels / flows.

6.4.1.57 As presented at *table 6*, effective rainfall is estimated at 284mm/a for the existing landuse of the Site, and at 194mm/a for open water (a reduction of 90mm/a). Applying this to the increased open water area proposed during restoration indicates evaporative losses in the order of 3,080m^3/a, equivalent to an instantaneous rate of just 0.1l/s. This rate of loss is not considered significant at the scale of interest and is not considered likely to result in any significant impact upon groundwater levels or flows.

Potential for Associated Secondary Impacts

6.4.1.58 As primary impacts upon groundwater levels and flows of significant magnitude associated with an increase in open water area following Site restoration are not anticipated, significant secondary impacts in this regard are not expected.

Requirement for Mitigation / Planning Controls

6.4.1.59 A Hydrometric Monitoring Scheme (HMS) specific to the Proposed Development (though incorporating existing infrastructure) should be drafted, approved and implemented, including provision for minimum monthly groundwater level monitoring throughout the life of operations and continuing to a minimum 1 year post completion of works. This should be complemented by the collection of dewatering volumes, discharge volumes and rainfall volumes.

6.4.1.60 Periodic review and interpretation of the data collected under the HMS, at minimum annual frequency, should be undertaken to determine:

- Any requirement for monitoring infrastructure maintenance / replacement.
- Identification of any significant impact upon groundwater levels and flows in excess of that estimated above.
- Identification of potential active conduit interception.
- Assessment of any impact upon Abstraction L, *table 10*.
- The formulation and implementation of mitigation measures required should significant impact be identified.
- Review of HMS requirements.

6.4.1.61 No dewatering should take place prior to the application for, and subsequent issue of, a water transfer license (dewatering) for the Site. Application should include consideration of the licensing implications upon the third party operated concrete plant abstracting from the Plant Area Lagoon (further application to regularise this should be made if required).

6.4.2 Surface Water Levels and Flows

Background

6.4.2.1 The Proposed Development as described herein is considered to have the potential to impact upon surface water levels and flows in the following ways:

- Alteration of runoff routes / rates.
- Potential for interception of active karst conduits, and;
- Potential for the alteration of groundwater levels and flows.

Alteration of Runoff Routes / Rates

6.4.2.2 The Proposed Development will involve the alteration of ground elevations over an area of some 4.4ha, runoff from which will be modified to be made to the closed depression formed by the quarry void. This has the potential to result in the derogation of surface water levels / flows within the catchment to which runoff is presently routed (The Henllan Brook).

6.4.2.3 During dewatering operations, this same volume of water will be discharged to the Henllan Brook, thus minimising any impact in this regard, though discharge will be made downstream of the Site, will not be undertaken constantly, and will be temporary only. Outside of dewatering operations, such volumes will be dissipated to groundwater within the CLG via the quarry sump (with which the Henllan Brook is not in hydraulic continuity, though partial connectivity between such groundwaters and downstream watercourses can be expected).

6.4.2.4 Applying average annual effective rainfall for the current landuse of the Proposed Development (*table 6*) to the area over which ground elevations will be altered (4.4ha), indicates effective rainfall volumes of some 12,435m^3/a to be available for runoff / infiltration within the Proposed Development, equivalent to an instantaneous rate of just 0.4l/s.

6.4.2.5 The Proposed Development is located upon unconfined CLG outcrop with minimal GT cover, featuring rapid, vertical infiltration to the Sub-surface. Runoff is thus expected to account for a minor component of this volume / rate (which is in itself minor relative to the wider catchment of the Henllan Brook). Associated impacts upon the Henllan Brook are thus not anticipated to be significant.

Potential for Associated Secondary Impacts

6.4.2.6 In lieu of identification of potentially significant primary impacts upon surface water levels / flow rates associated with the alteration of runoff routes / rates during the working of the Proposed Development, significant secondary impacts in this regard are not anticipated.

6.4.2.7 It should however be noted that the Henllan Brook is not known to support any licenced or deregulated abstraction, and does not pass through any designated or non-designated ecological sites.

Potential for Interception of Active Karst Conduits

6.4.2.8 The removal of Aquifer material from the saturated zone during the working of the Proposed Development has the potential to intercept active karst conduits, with associated potential to impact upon surface water levels / flows.

6.4.2.9 As discussed, there are no known active karst features in hydraulic continuity with the Site excepting the qualitative reports of karstic drainage of the quarry sump to the east, with which there are no known associated surface water features.

6.4.2.10 Potential however remains for the interception of active karst conduits that are not yet identified, these likely following the regional groundwater flow direction (easterly), to termination at the CLG / KSS interface. Interception of such features may potentially derogate any surface water features these conduits may support.

6.4.2.11 Baseline assessment has not identified any surface water features indicated to be in hydraulic continuity with the Site, these being dependent upon karstic flows or otherwise. This is largely attributable to the high unsaturated thickness prevailing across the CLG, the proximity of the KSS to the Site, and the prevalence of GT cover across the area.

6.4.2.12 It should however be noted that the Henllan Brook, though indicated to be underlain by GT and culverted across the majority of its passage over the CLG, does pass in proximity to the Site, is of sufficiently low elevation that comparable groundwater elevations are feasible, and does gain flow along its course (though this is likely urban drainage). This, combined with uncertainty as to the construction of its culverted sections, means that potential karst connections between the Proposed Development and the Henllan Brook (potentially upwelling through the GT cover) cannot be definitively excluded (though this risk is considered low).

6.4.2.13 It is therefore considered prudent that the proposed HMS be extended to record surface water levels within the Henllan Brook downstream of the Site, allowing identification of any impact on this feature that may be attributable to Site operations, with mitigation measures being formulated and implemented as required, this being prompted by periodic review of the monitoring data.

Potential for Associated Secondary Impacts

6.4.2.14 Mitigation measures formulated with regards to potential primary impacts upon surface water levels and flows are considered sufficient to additionally address any potential secondary impacts in this regard.

6.4.2.15 It should however be noted that the Henllan Brook is not known to support any licenced or deregulated abstraction, and does not pass through any designated or non-designated ecological sites.

Potential for the Alteration of Groundwater Levels and Flows

6.4.2.16 Assessment has identified potential for the proposed dewatering of the Site to impact upon groundwater levels and flows. Associated potential therefore exists for such impact to additionally affect surface water levels / flows where supported by groundwater baseflow.

6.4.2.17 As previously stated, there are no surface water features indicated to be in hydraulic continuity with the Site due to the high unsaturated thickness prevailing across the CLG, the proximity of the KSS to the Site, and the prevalence of GT cover across the area.

6.4.2.18 As discussed, though this also applies to the Henllan Brook, potential for a limited degree of groundwater baseflow to this feature from the CLG cannot be completely excluded.

6.4.2.19 Though this watercourse does pass within the maximum predicted R_0 of quarry dewatering (775m), this occurs entirely where the watercourse holds an elevation of less than 90maOD (the proposed base of quarry workings), below which groundwater elevations will not be impacted.

6.4.2.20 Assessment has further identified potential for the proposed restoration of the Site to impact upon groundwater levels and flows. Associated potential therefore exists for such impact to additionally affect surface water levels / flows where supported by groundwater baseflow.

6.4.2.21 As discussed, the magnitude of such impact is minor relative to that associated with the working phases of Site development.

6.4.2.22 Significant impacts upon surface water levels and flows resulting from the alteration of groundwater levels and flows are thus not anticipated to result from the Proposed Development.

Potential for Associated Secondary Impacts

6.4.2.23 In lieu of identification of significant primary impacts on surface water levels and flows, secondary impacts in this regard are not anticipated to occur as a result of the Proposed Development.

Requirement for Mitigation / Planning Controls

6.4.2.24 The proposed HMS should be extended to include minimum monthly collection of surface water level data for the Henllan Brook, upstream and downstream of the Site, with periodic data review additionally identifying any impacts on this feature that may have resulted from the Proposed Development (with mitigation measures being formulated and implemented as required).

6.4.3 Groundwater Quality

Background

6.4.3.1 The Proposed Development as described herein is considered to have the potential to impact upon groundwater quality in the following ways:

- Interception of pre-existing sources of groundwater contamination, and;
- Accidental spillage / long term leakage of potentially contaminating substances.
- Use of inert infill materials in Site restoration.

Interception of Pre-Existing Sources of Groundwater Contamination

Introduction

6.4.3.2 As the Proposed Development involves sub-watertable working with identified potential for impact upon groundwater levels / flows, potential exists for any pre-existing contamination of the Aquifer to be exacerbated by the Proposed Development.

6.4.3.3 As a result of the above, a preliminary contamination assessment has been undertaken below, utilising the Source, Pathway, Receptor (SPR) methodology, including the following elements:

- Establishment of Conceptual Site Model (CSM);
- Estimation of risk posed by identified hazards;
- Evaluation of risk posed to identified hazards, and;
- Recommendations.

Conceptual Site Model

I: Hazard Identification

6.4.3.4 Baseline assessment has identified 1 no. potential source of pre-existing groundwater contamination in the form of the Bryn Nefydd historic landfill (BNHL).

6.4.3.5 BNHL is located 0.69km to the west of the Site, as at *figure 19*, and is thus located up hydraulic gradient from the Site and upon the same underlying bedrock (CLG).

II: Potential Contaminant Source

6.4.3.6 As discussed at *section 3.7.4*, BNHL is known to have received inert and industrial wastes, these being deposited on the site of a lime kiln and associated workings in the 1990s by Clwyd County Council.

6.4.3.7 The nature of the infill material implies minimal risk to groundwater quality, though the exact nature of the industrial waste element, and method of construction of the landfill, are not known. To form basis for conservative assessment, it must thus be assumed that potentially contaminating substances may have been deposited, with the landfill having been completed on a dilute and disperse basis (without engineered containment).

6.4.3.8 Prevailing unsaturated thickness however dictate that any deposited wastes are highly unlikely to have been placed within the CLG saturated zone.

III: Potential Contaminant Pathway

6.4.3.9 Although BNHL is indicated to be underlain by GT cover, the historic presence of a lime kiln at this location implies that the GT may have been historically removed with the underlying CLG being extracted and exposed.

6.4.3.10 Any contaminants released from this landfill are thus expected to be transmitted vertically through the Aquifer unsaturated zone, prior to lateral transmission through the Aquifer saturated zone, and on to the KSS aquifer, via groundwater flow.

6.4.3.11 During transmission through the CLG, this may occur within rapid flowing conduits which offer minimal potential for natural attenuation, though within which significant dilution would be expected, limiting contaminant concentrations. Resultant contaminant concentrations may however be episodic (due to varying flow rates in such features depending upon antecedent conditions).

6.4.3.12 The combined pathway via groundwater flow within the CLG and KSS, within which minimal potential for transmission to surface waters is expected, is of substantial length. The natural attenuation potential of this pathway is considered likely to be sufficient to mitigate any existing contamination.

IV: Potential Contaminant Receptor

6.4.3.13 As discussed, there is considered to be limited potential for any contamination resulting from BNHL to be transmitted beyond the groundwater flow pathway. The principal receptor must therefore be considered to be the water resource provided by groundwaters along this pathway.

Risk Estimation

I: Risk at Source

6.4.3.14 As discussed, BNHL is likely to be of composition obviating any significant risk to groundwater quality, though receipt of potentially contaminating industrial wastes cannot be excluded. There is no primary data available on the risk this may pose.

II: Evidence of Contamination

6.4.3.15 As discussed at *section 3.7*, groundwater quality data for the Site does not indicate any significant groundwater contamination to be present (being within the relevant quality standards for all tested determinands). It should however be noted that is based on the analysis of one sample only, likely being recorded during infilling at BNHL.

III: Potential for Proposed Development to Impact Upon Source

6.4.3.16 BNHL is located 0.69km from the Site and will not be physically disturbed by the Proposed Development in any way. There is thus negligible potential for impact upon the potential contaminant source.

IV: Potential for Proposed Development to Impact Upon Pathway

6.4.3.17 BNHL is located within the predicted maximum R_0 of quarry dewatering, though is located up hydraulic gradient from the Site, and at significant distance. Drawdown at this location predicted under worst case conditions is just 1.3m, as at *table 16*, this being of minor magnitude relative to prevailing unsaturated thicknesses (*figure 15*). There is thus potential for associated contamination to be present at the Site, though negligible potential for this to be significantly exacerbated by the Proposed Development (migration pathway will be effectively unaltered).

V: Potential for Proposed Development to Impact Upon Receptor

6.4.3.18 The dewatering of the Proposed Development has potential to intercept any groundwater contamination that may have resulted from BNHL, with the intercepted waters being discharged from the Site to the Henllan Ditch. This has the potential to 'short circuit' the natural attenuation of any such contamination (via shortening the pathway), and transmit such contamination to local surface watercourses (forming a new receptor previously isolated from such contamination).

Risk Evaluation

6.4.3.19 Assessment indicates that the risk of pre-existing groundwater contamination resulting from BNHL is inherently low, with there being no evidence of any such contamination being present.

6.4.3.20 Further, any potential for the Proposed Development to exacerbate the impact of any such contamination is not considered significant, as contaminant migration pathways will be unaltered (BNHL already being up-gradient of the Site and underlain by significant unsaturated thickness). It is thus considered that the Proposed Development has negligible potential to result in the derogation of water quality via the interception of pre-existing groundwater contamination.

Recommendations

6.4.3.21 In lieu of any significant risk of impact upon groundwater quality specific to the Proposed Development resulting from the interception of pre-existing groundwater contamination, recommendations in this regard are not considered necessary.

Potential for Associated Secondary Impacts

6.4.3.22 As significant primary impacts in this regard are not anticipated to occur, associated secondary impacts are not anticipated.

Accidental Spillage / Long-Term Leakage of Potentially Contaminating Substances

6.4.3.23 The working of the Proposed Development will require the operation of mobile plant and the associated use and storage of potentially contaminating fuels / oils / solvents.

6.4.3.24 It is important to recognise that the likelihood or consequences of the accidental spillage / long term of such substances is considered no greater than currently prevail for the agricultural machinery working the Proposed Development under its current land use.

6.4.3.25 It should be recognised that quarrying is a historical activity at the Site location and that workings within the Proposed Development will be carried out in an equivalent manner to that already undertaken, and within the same hydrostratigraphic environment. Therefore, neither the potential scale, nor likelihood of occurrence, of derogation of groundwater quality will significantly increase as a result of the Proposed Development.

6.4.3.26 Notwithstanding the foregoing, in recognition of the potential for impact, measures to minimise the likelihood of occurrence during working of the Proposed Development have been formulated. These measures, which comply with EA guidelines (the Oil Care Code), are advanced below.

- Fuel-oil powered mobile plant shall be restricted to that necessary to undertake mineral extraction, remedial measures and subsequent restoration of the Site.
- A code of practice should be developed for the refuelling and maintenance of machinery. This code should be incorporated into a formal Environmental Management System (EMS, or similar) that should be incorporated into the overall Site management system. Such work should be carried out only by trained personnel and take place within a surfaced area equipped with fluid interceptors.
- Any oil storage tanks to be located within the Proposed Development should be sited upon impermeable bases enclosed by oil-tight walls. The enclosure should remain at a volume of at least 110% of the capacity of the oil tank and maintained free of accumulations of rainwater. Any mobile storage tanks should be double skinned and well maintained.
- All fill and draw pipes emanating from oil storage tanks should be provided with locking mechanisms and be contained within the impermeable enclosure.
- No refuelling or maintenance should be carried out in areas of mineral working.
- Operators should check their vehicles on a daily basis before starting work to confirm the absence of leakages. A reporting system should be implemented to ensure that repairs are undertaken to that vehicle before it enters the working area.
- Sufficient oil sorbent material should be available on Site to cope with a loss equal to the total fluid content of the largest item of plant. Following the use of such oil sorbent material, any contaminated materials should be disposed of from Site in accordance with current waste disposal legislation.
- Hydraulic & fuel oil lines on all plant operated within the extraction areas shall be renewed at the manufacturers recommended service intervals to minimise the potential for contamination relating to failure of hoses or lines.

6.4.3.27 The foregoing measures have been incorporated into a preferred fluids handling protocol presented here at *appendix 9.8*.

Potential for Associated Secondary Impacts

6.4.3.28 Mitigation measures formulated for prevention of primary impacts on groundwater quality resulting from the accidental spillage / long term leakage of potentially contaminating substances is considered sufficient to additionally prevent against any secondary impact in this regard.

Use of Inert Infill in Site Restoration

6.4.3.29 The restoration of the Site is to require the placement of interburden materials native to the Site and imported inert materials, some of which will be placed beneath the water table. This has the potential to impact upon groundwater quality.

6.4.3.30 It is proposed that the Site will accept inert materials only, this being subject to strict Waste Acceptance Criteria (WAC) and Waste Acceptance Procedure (WAP). Inert materials in terms of waste are defined by the Landfill Directive (1999/31/EC), article 2(e) as: '*waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health. The total leachability and pollutant content of the waste and the ecotoxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and / or groundwater*'.

6.4.3.31 Section 2.1.1 of the 2002 Council Decision*, 'Establishing Criteria and Procedures for the Acceptance of Waste at Landfills Pursuant to Article 16 of and Annex II to Directive 1999/31/EC' (the Landfill Directive)*, lists a number of waste types that are considered inert without need for testing (subject to being single stream of a single waste type or combination of types).

6.4.3.32 Other waste types are also classified as inert provided that they meet the leaching limit values (determined by testing) outlined at section 2.1.2.1 of the Council Decision.

6.4.3.33 The inert waste types intended to be accepted at the Site will meet with the above criteria, and any accepted wastes that are not listed at Section 2.1.1 of the Council decision will be tested to ensure compliance with section 2.1.2.1 of that decision.

6.4.3.34 The foregoing notwithstanding, an Environmental Permit application will be required for the proposed infill operation, which will require inclusion of appropriate controls / monitoring, to ensure protection of groundwater within the wider Aquifer, this being assessed within a Hydrogeological Risk Assessment (HRA).

Potential for Associated Secondary Impacts

6.4.3.35 Mitigation measures with regards to the prevention of primary impact upon groundwater quality resulting from the use of inert infill materials during Site restoration are considered adequate to additionally protect against any secondary impacts in this regard.

Requirement for Mitigation / Planning Controls

6.4.3.36 The above measures designed to limit the risk of groundwater quality degradation via the accidental spillage / leakage of fuels / oils / solvents should be implemented in full and continued throughout the operation of the Site to the completion of restoration works.

6.4.3.37 Application should be made for an Environmental Permit consenting the deposition of inert wastes within Site restoration prior to commencement of any such works.

6.4.4 Surface Water Quality

Background

6.4.4.1 The Proposed Development as described herein is considered to have the potential to impact upon surface water quality in the following ways:

- Derogation of Groundwater Quality;
- Discharge of dewatering waters to surface waters.

Derogation of Groundwater Quality

6.4.4.2 Where potential for impacts upon groundwater quality is indicated, potential exists for associated impacts upon surface water quality where in groundwater continuity or otherwise connected.

6.4.4.3 Where potential impacts upon groundwater quality have been identified, associated mitigation measures are considered sufficient to additionally prevent against any impacts upon surface water quality.

Potential for Associated Secondary Impacts

6.4.4.4 As significant primary impacts in this regard are not anticipated to occur, associated secondary impacts are not anticipated.

Discharge of Dewatering Waters to Surface Waters

6.4.4.5 The dewatering of the Proposed Development will require the discharge of abstracted waters to the Henllan Ditch. This has potential to derogate the water quality within this feature, and downstream watercourses (such as the Henllan Brook).

6.4.4.6 It should be noted that this risk is largely unchanged from that posed by existing, consented Site operations (which permit both dewatering and discharge), though the discharge volumes will be increased.

6.4.4.7 All dewatering waters will be collected in the quarry sump prior to dewatering abstraction, within which treatment via settlement will be allowed to occur. Such waters will again be treated via settlement within the Plant Area Lagoon prior to discharge.

6.4.4.8 As discussed at *section 5.1.4*, the Site historically held an Environmental Permit, Water Discharge Activity (*appendix 9.4*), consenting the discharge of such waters from the Site, this containing conditions relating to the quality of discharged waters intended to mitigate any associated risk to surface water quality (renewal of which is currently in progress).

6.4.4.9 Issue of the renewed permit, and adherence to any conditions it may apply, is considered to offer adequate and enforceable protection against derogation of water quality in this regard, without need for further mitigation.

6.4.4.10 It should be noted that application for such a permit is an absolute requirement of the Proposed Development. Duplication of such requirement at the planning stage is therefore unnecessary.

Potential for Associated Secondary Impacts

6.4.4.11 Mitigation measures formulated for prevention of primary impacts on surface water quality resulting from the discharge of waters from the Site is considered sufficient to additionally prevent against any secondary impact in this regard.

Requirement for Mitigation / Planning Controls

6.4.4.12 Works are already in progress to renew the Site discharge permit, this allowing for the requirements of the Proposed Development. Specific planning controls in this regard are thus not warranted.

6.4.5 Flood Risk

Background

6.4.5.1 The Proposed Development as described herein is considered to have the potential to impact upon flood risk in the following ways:

- Potential for interception of active karst conduits.
- Potential to increase surface water flow rates.
- Use of inert infill materials in Site restoration.

Potential for Interception of Active Karst Conduits

6.4.5.2 As discussed, the Proposed Development has the potential to intercept previously unknown active karst conduits. Such features may convey significant volumes of groundwater, with associated potential to increase the groundwater flood risk posed to the Site.

6.4.5.3 It should be noted that interception of any such conduits within the unsaturated zone is unlikely (this risk thus being limited to the working of Phases 3 and 4 of the Proposed Development). Further, any such risk would be unlikely to prevail during dry periods (as the base of works will not proceed below minimum groundwater elevations).

6.4.5.4 In the event of active conduit interception, resultant groundwaters would be discharged from the Site via the dewatering abstraction. Residual groundwater flood risk remains where the volumes of such groundwater may exceed the capacity of the dewatering pump or abstraction / discharge permit limits (the risk of which is considered low).

6.4.5.5 In such event, additional pumps could be brought in at short notice to increase abstraction / discharge rates, with associated temporary arrangements for the removal of flood waters being agreed with NRW, ahead of application for more permanent arrangements (if required).

6.4.5.6 Regardless of the above, groundwater flood levels would be unlikely to exceed those observed under maximum historic groundwater elevations (as at *figure 11*). Such flood waters would thus be entirely contained within the lower benches of the quarry, within which no permanent plant, equipment, personnel, or flood vulnerable infrastructure of any type will be located.

Potential to Increase Surface Water Flow Rates

6.4.5.7 As detailed at *section 5.2.3*, the dewatering of the Proposed Development is expected to increase the required discharge rates from the Site to the Henllan Ditch to a predicted peak rate of 127l/s, with associated potential to impact upon extant flood risk. This increase is solely due to dewatering operations, Plant Area drainage discharge rates being entirely unchanged from present conditions.

6.4.5.8 As detailed at *appendix 9.4*, prior correspondence with the Environment Agency (EA) has demonstrated acceptance of flow rates of up to 117l/s within the Henllan Ditch. Discharge rates associated with the Proposed Development are however predicted to marginally exceed this.

6.4.5.9 Field observations confirm the Hennlan Ditch to have an approximately 1m^2 cross section, conveying minimal flows. Channel dimensions and gradient have been applied to establish channel flow capacity using Manning's equation, as at *table 20* below.

Table 20 Assessment of Channel Capacity, Hennlan Ditch

Variable (units)	Value	Justification
Width (m)	1	Field Observation
Depth (m)	1	Field Observation
Slope ()	0.045	Average gradient on ditch course.
Construction	Excavated earth channel with short grass on banks.	
Flow Capacity (l/s)	3,776.56	Mannings Equation

6.4.5.10 Assessment demonstrates the flow conveyance capacity of the Hennlan Ditch to significantly exceed required peak discharge rates.

6.4.5.11 As detailed at *section 5.1.4*, the Site discharge pipeline has a maximum flow capacity of some 130l/s. The existing infrastructure is thus indicated to be sufficient to accommodate expected discharge rates without forming a source of on-Site flooding.

6.4.5.12 Significant impacts upon flood risk are thus not anticipated as a result of the discharge of waters from the Site.

Use of Infill Materials in Site Restoration

6.4.5.13 The use of imported inert infill materials within Site restoration will introduce material of lower permeability than the Aquifer material it replaces, with associated potential to increase runoff rates and impede infiltration, thus potentially impacting upon flood risk.

6.4.5.14 As discussed at *section 5.2.5*, the infilled areas will be within the closed depression of the Quarry Area, within which all incident rainfall / runoff will be captured and contained, prior to gradual dissipation to the Aquifer upon the margins of the infill (and thus its interface with in-situ Aquifer material).

6.4.5.15 The maximum expected elevation of the Restoration Lake formed within the restored Quarry Area, as at s*ection 5.2.5*, is 106maOD (occurring periodically under expected peak groundwater elevations), well within the available freeboard within the Site (108maOD). Associated off-Site flooding is thus not anticipated to occur.

6.4.5.16 It should however be noted that under such conditions, a significant part of the Quarry Area would be temporarily inundated (44,224m^2). This area would however contain no flood vulnerable infrastructure or personnel, being completed to a flood compatible afteruse (marshy grassland) dependent upon periodic inundation to maintain its ecological function.

6.4.5.17 It is however recommended that the proposed HMS should incorporate monitoring of the level of the Restoration Lake upon its formation, to allow characterisation of its hydrological regime, and thus to inform completion of Site restoration / drainage measures.

Requirement for Mitigation / Planning Controls

6.4.5.18 It is recommended that the proposed HMS incorporate requirement for the monitoring of the elevation of the Restoration Lake upon its completion.

6.5 Summary Impact & Mitigation Schedule

6.5.1.1 The measures and procedures incorporated into the design of the Proposed Development, together with additional specific measures and planning condition requirements recommended for the minimisation of impact upon the water environment are summarised overleaf at *table 21*.

Table 21 Summary Schedule of Potential Impacts & Mitigation Measures

Impact Class	Mitigation by Design	Mitigation by Procedure	Contingency Action
Groundwater Levels and Flows	Quarry sump to replicate storage function of removed Aquifer material. Maximum working depth not to proceed below minimum groundwater elevations.	Drafting and implementation of Hydrometric Monitoring Scheme (HMS) with periodic data review, designed to monitor dewatering impact, potential conduit interception and any impacts upon abstraction L, *table 10*. Application for water abstraction license (transfer(prior to dewatering commencement.	Implementation of any recommendations (including further mitigation where required) made by periodic review of monitoring data.
Surface Water Levels and Flows	Maximum working depth not to proceed below minimum groundwater elevations.	Extension of HMS to include collection and periodic review of surface water level data from the Henllan Brook, *figure 4,* upstream and downstream of the Site.	Implementation of any recommendations (including further mitigation where required) made by periodic review of monitoring data.
Groundwater Quality	Infill materials to be inert only.	Implementation of measures to minimise likelihood of accidental spillage / long-term leakage of potentially contaminating substances (fuels / oils / solvents), as at *section 6.4.3* and *appendix 9.8*. Application for, and adherence to, an Environmental Permit consenting the deposition of inert wastes at the Site.	Containment / removal of spillages, notification of regulator where required (NRW).
Surface Water Quality	Discharge to be made under existing arrangements following settlement in quarry sump and Site lagoon.	Renewal of, and adherence to conditions of, Site Environmental Permit, Water Discharge Activity.	Temporary cessation of dewatering discharge.
Flood Risk	Site entirely located with Flood Risk Zone 1 (FRZ1), the lowest risk class of Flood Risk Zone. Discharge to be made under Environmental Permit, Water Discharge Activity. Flood compatible landuse on restoration of base of Quarry Area.	No permanent plant, personnel or flood vulnerable infrastructure to be placed within dewatered area (lowest bench). Extension of HMS to include collection and periodic review of surface water level data from the Restoration Lake, *figure 27,* upon its formation.	Removal of flood waters under temporary supplemental discharge arrangements. Alteration of restoration drainage proposals.

7 CUMULATIVE & RESIDUAL IMPACT

7.1 Cumulative Impact

7.1 Consideration of other pending planning permissions in the area local to the Site, and their potential to result in cumulative impacts when considered along site the Proposed Development, is presented at *table 22* below.

Table 22 Assessment of Potential Cumulative Impact

Reference	Name	Potential Cumulative Impacts	Note	Requirement for Further Assessment
01/2019/0743	Plot 1 - DCC Waste Depot	Flood Risk, Water Quality	Application of SuDS and requirement for Environmental Permit will negate any risk of cumulative impact.	None
01/2019/0773	Plot 2 - Yard Space Wales	Flood Risk	Application of SuDS will negate any risk of cumulative impact.	
01/2019/0774	Plot 3 - Henllan Bread			
01/2019/0775	Plot 4 - Lock Stock			
01/2019/0776	Plot 5 - Emyr Davies			

SuDS: Sustainable Urban Drainage Systems

7.2 Assessment indicates that the potential for cumulative impacts associated with the above planning applications is low, and that no further assessment or mitigation in this regard is required.

7.3 Assessment has further considered a number of proposed housing developments in the local area. Developments of this nature are also not expected to result in any cumulative impacts subject to implementation of SuDS.

7.2 Residual Impact

7.1 Subject to implementation of the recommendations included herein, significant residual impacts are not anticipated in association with the Proposed Development.

8 CONCLUSIONS

8.1 In view of the findings of assessment and the planned approach to the Proposed Development, which includes specific measures for the protection of the water environment, there are considered to be no over-riding hydrogeologically or hydrologically based reasons why the planned development should not proceed in the manner described by the Application.

8.2 This conclusion assumes that any permission, if granted, should be conditioned by implementation and adherence to any relevant recommendations advanced within this report and other such conditions that may be reasonably imposed by the Planning Authority.

Peter Simpson, BSc, MSc,FGS
Principal Hydrogeologist

<u>BCL Consultant Hydrogeologists Limited</u>
04th February 2022